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The First Stegosaur (Dinosauria, Ornithischia) from the Upper Jurassic Shishugou Formation of Xinjiang, China

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Abstract: A new stegosaur species, *Jiangjunosaurus junggarensis*, gen. et sp. nov., is erected based on a specimen collected from the Upper Jurassic upper section of the Shishugou Formation in the Junggar Basin, Xinjiang, China. It represents the first stegosaur from the Jurassic of Xinjiang and increases the diversity of the dinosaur fauna in the Shishugou Formation. The new genus is characterized by symmetrical and proportionally wide tooth crowns, a sub-rectangular axial neural spine seen in lateral view, and large openings on the lateral surfaces of the cervical centra. A preliminary character analysis suggests that this new taxon is more derived than the Middle Jurassic stegosaur *Huayangosaurus* but more primitive than most other known stegosaur species.

Key words: Dinosauria, Stegosauria, Upper Jurassic, Shishugou Formation, Xinjiang

1 Introduction

The Middle-Late Jurassic Shishugou Formation of the Junggar Basin, Xinjiang, China has yielded many dinosaur specimens derived from several clades (Eberth et al., 2001). Since 2000, we have been prospecting and excavating in this formation and have discovered several new vertebrate taxa (Clark et al., 2004; Xu et al., 2006a, b). Here we report a new stegosaur, based on a specimen collected in 2002 at the Jiangjunmiao locality that represents the first specimen of this clade from Jurassic deposits of the Junggar Basin.

The aim of the present paper is to name the taxon based on the key specimen. The description of other preserved skeletal elements is omitted for lacking evident diagnosis. A full description will be given elsewhere, together with several other specimens collected later from the same formation.

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2 Systematic Paleontology

Dinosauria Owen, 1842
Ornithischia Seeley, 1887
Stegosauria Marsh, 1877
Stegosauridae Marsh, 1880
Jiangjunosaurus junggarensis, gen. et sp. nov.

Etymology: "*Jiangjun*", Chinese, "general", and "*saurus*", Greek, "lizard"; the generic name is derived from the deserted town of Jiangjunmiao near the holotype locality, named for an ancient general who died nearby. The specific name is derived from the Junggar Basin, the large geographical area that includes the type locality.

Holotype: IVPP V 14724 (Institute of Vertebrate Paleontology and Paleoanthropology, Beijing), a partial articulated skeleton, including partial skull, an almost complete mandible, 11 articulated cervical vertebrae , some ribs and two dermal plates (Figs. 1a and 2a). The cranial sutures and other skeletal morphologies are tight

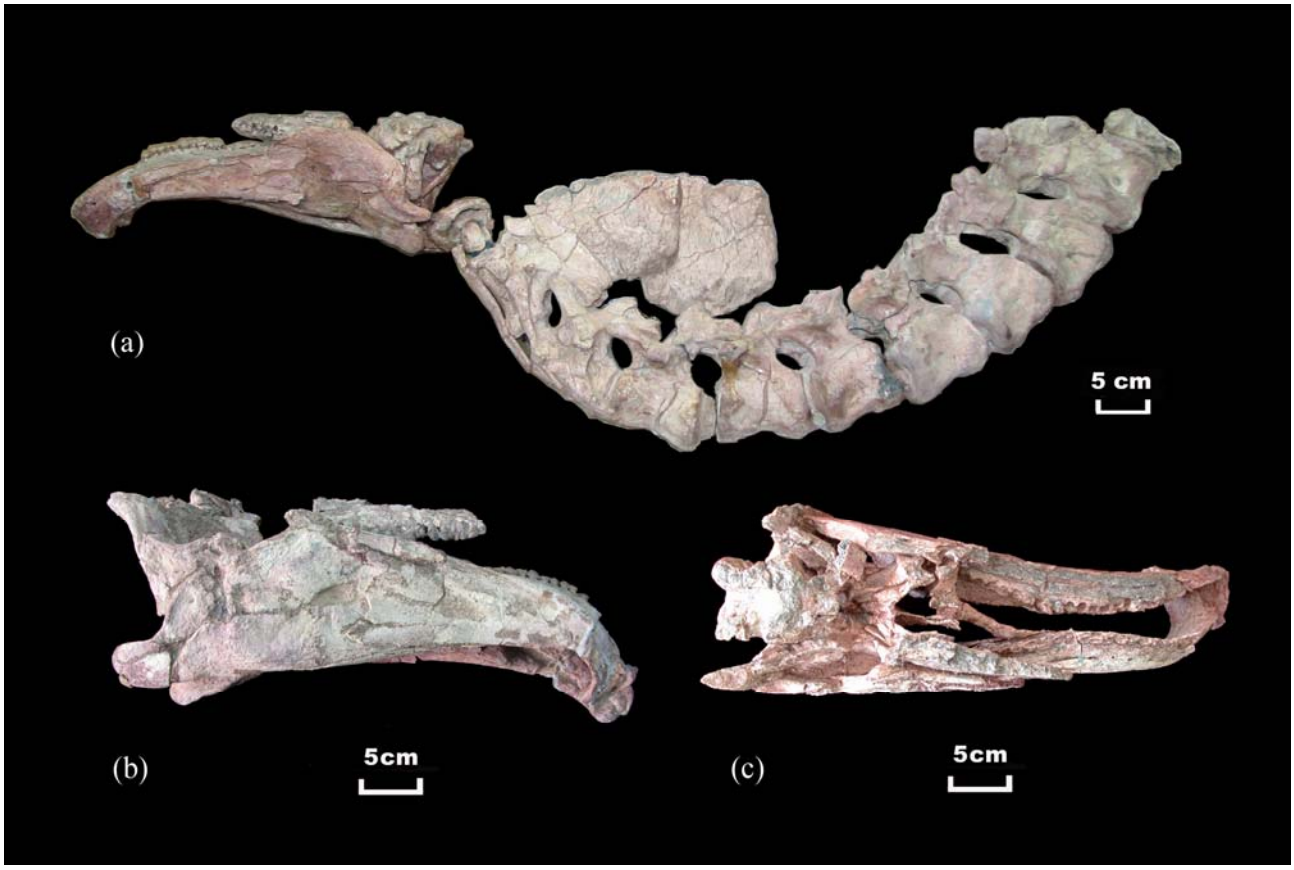

Fig. 1. *Jiangjunosaurus junggarensis* gen.et sp. nov. (IVPP V 14724, holotype): photograph of (a) skeleton in left lateral view; skull and lower jaw in right lateral view (b) and dorsal view (c).

but not closed or fused. Fusion is also incomplete between the odontoid process and axial centrum, between the atlantal neural arches and centrum, and the scapula and coracoid. Yet, the interpterygoid vacuity is not present on the palate and neurocentral sutures of all other cervical vertebrae are closed. These features suggest that the holotype is a sub-adult individual.

Type locality and horizon: Jiangjunmiao Junggar Basin, Xinjiang, China; upper section of the Shishugou Formation; Oxfodian, early Late Jurassic.

Diagnosis: A stegosaur different from other species in the following features: tooth crowns symmetrical and proportionally wide mesiodistally; a sub-rectangular axial neural spine; and large openings on the lateral surface of the posterior cervical centra.

3 Description

The cranial skeleton in IVPP V14724 preserves a partial right maxilla, an incomplete right jugal, a right quadratojugal, nearly complete right quadrate, the ventral half of the braincase, partial left and right pterygoids, and a nearly complete mandible (Figs. 1b and 2b). The skull is proportionally long relative to its width, the maximum post-orbital region being about 35% of the basal skull length. The cranial sutures are tight but not fully closed. An interpterygoid vacuity is not present on the palate.

The quadratojugal is a tri-radial bone with a robust anterior process, a distinct ventral process that covers the ventral end of the quadrate, and a slender and low dorsal process that partially covers the quadrate shaft and dorsally extends to about mid-height on the quadrate (Fig. 2b). The anterior process is nearly horizontally oriented. The quadrate slopes posterodorsally. A large ventral quadratojugal facet extends to the posterior surface of the quadrate. There seems to be a fossa on the pterygoid ramus of the quadrate. A paraquadrate foramen is absent. The pterygoids are broadly in contact with each other anteriorly, are lacking a distinct posterior tab and without a distinct interpterygoid vacuity.

A small external mandibular fenestra is present (Fig. 2b). The predentary has a small main body, a distinct, long ventral process, and two long and slender lateral processes (Fig. 2c). The anterior end of the dentary is downturned and curves medially to form ventrally a U-shaped mandibular symphyseal region. A distinct flange supports the lateral process of the predentary. Anteriorly, the diastema between the predentary and the tooth-boring

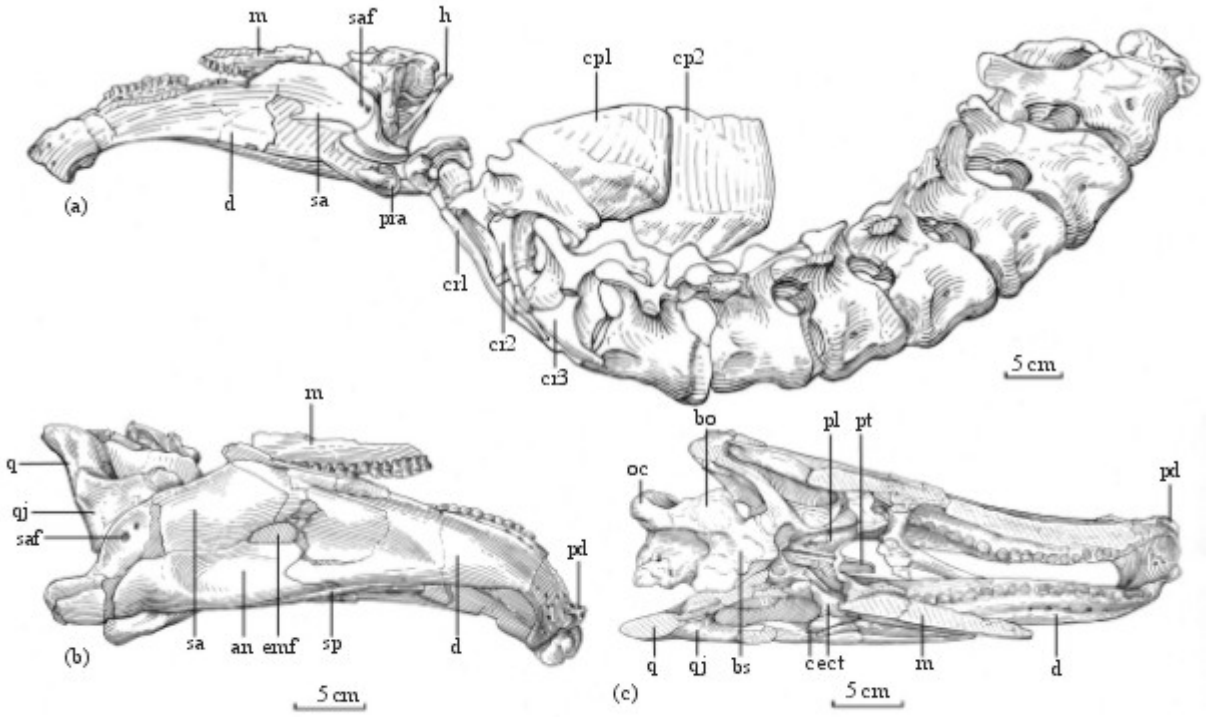

Fig. 2. *Jiangjunosaurus junggarensis* gen. et sp. nov. (IVPP V 14724, holotype): line drawing of (a) skeleton in left lateral view; skull and lower jaw in right lateral view (b) and dorsal view (c).
Abbreviations: an – angular; bo – basisoccipital; bs – basisphenoid; c – coronoid; cp – cervical plate; cr – cervical rib; d – dentary; ect – ectopterygoid; emf – external mandibular foramen; h – hyoid; m – maxillary; oc – occipital condyle; pd – predentary; pl – palatine; pra – prearticular; pt – pterygoid; q – quadrate; qj – quadratojugal; sa – surangular; saf – surangular foramen; sp – splenial.

portion of the dentary is long, occupying about four tooth positions. This part of the dentary is strongly compressed and sharp dorsally. A dentary shelf is developed along the whole tooth row and there is a prominent lamina extending dorsally from the dorsolateral margin of the posterior half of the dentary, which obscures the dentary teeth from lateral view (Fig. 2b). The lamina increases in depth posteriorly and forms a distinct, peaked coronoid eminence posteriorly that overhangs the surangular. The medial part of this projection is formed by the posterior end of the L-shaped coronoid bone, the anterior ramus of which runs along the alveolar margin of the dentary and terminates about the mid-length of the dentary tooth row (Fig. 2c).

There are 14 maxillary and 21 dentary teeth, which are generally similar except that the maxillary teeth are slightly smaller than those on the dentary. As in other stegosaurs, the cheek teeth have enamel on both sides, and each tooth bears a prominent ring-shaped cingulum. The tooth crowns are symmetrical, sub-triangular in lingual and buccal view, with seven denticles on both mesio and distal margins. The tooth crowns are wide, with a basal-apical length subequal to a mediodistal width. The tooth crowns are convex mesiodistally. Minor ridges are weakly developed except on the mesiomost and distalomost teeth.

The postcranial skeleton preserves the first 11 articulated cervical vertebrae, some ribs, and two dermal plates (Figs. 1a and 2a). The identification of cervical vertebrae is based on the associated cervical ribs, which are dramatically different from the dorsal ribs, and the relatively low position of the parapophyses located below the neurocentral suture. The axis has a long and moderately tall neural spine, which is sub-rectangular in lateral view due to its tall anterior margin. The postaxial cervical centra are amphicoelous with a slightly concave anterior articular surface and a more concave posterior one. The cervicals are subequal in anteroposterior length, but become taller down the series. The first four centra are rounded ventrally. From the fifth cervical on, they bear distinct large fossae on the lateral surfaces of the centra and are flat ventrally. Nutrient foramina are present within the lateral fossae, and from cervical 8 on the foramina are significantly enlarged. The foramen on the tenth cervical is 11 mm in anteroposterior diameter compared to a 73 mm-long centrum. The transverse processes are longer in the posterior cervical vertebrae and oriented

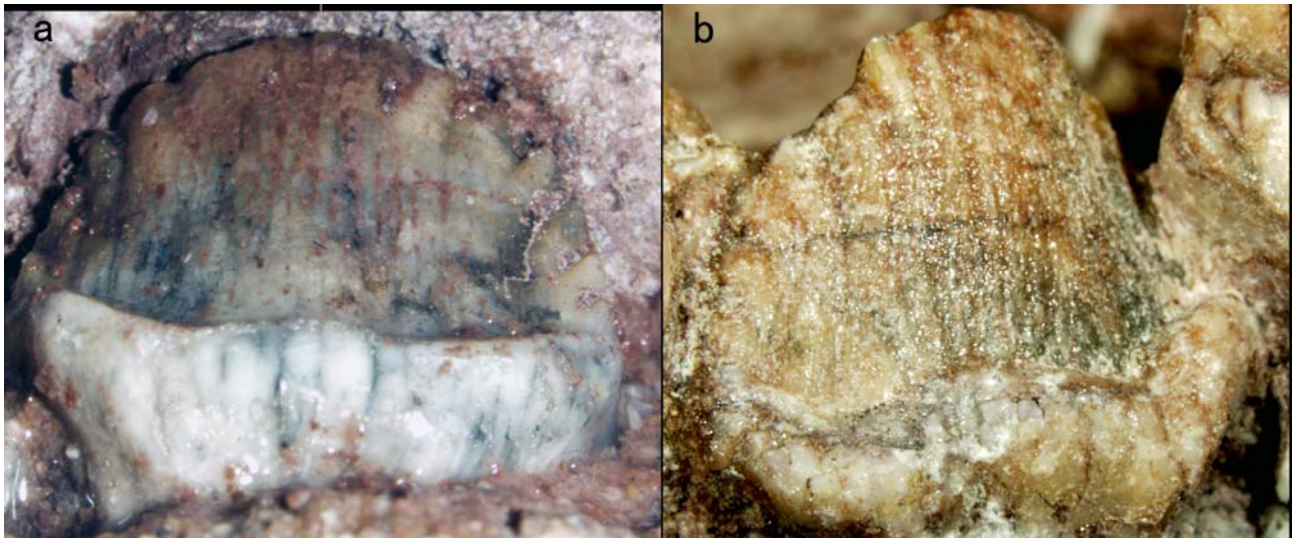

Fig. 3. *Jiangjunosaurus junggarensis* gen. et sp. nov. (IVPP V 14724, holotype): photograph of a posterior maxillary tooth in lingular view (a) and a middle dentary tooth in lingular view (b). 比例尺？

dorsolaterally, whereas they are shorter and extend ventrolaterally in the anterior cervicals.

All cervical ribs are double-headed except for that of the atlas and their total anteroposterior length is slightly longer than the respective central length. Several fragmentary anterior dorsal ribs are preserved, one of which bears a short, crescent-shaped flange near the distal end. The odontoid process and axial centrum are not fused. Fusion is incomplete between the atlantal neural arches and centrum, and neurocentral sutures of all other cervical vertebrae are closed.

A partial scapula and coracoid are preserved; they are unfused. The proximal end of the scapula is thick and massive, and wider than that of the coracoid, though both are not complete.

Two small cervical dermal plates are present (Figs. 1a and 2a). One is positioned above the axis and the other above the third cervical vertebra. They overlap each other slightly. The cervical plates are subcircular in outline, taller than axially long, transversely much thinner along the outer margin than at the base, and bear minute radiating grooves along the outer margin.

4 Comparison

There are several significant differences between the new taxon and other stegosaurs especially in dental morphology. The tooth crowns are symmetrical, sub-triangular in lingual or buccal view, bearing few (about seven) denticles on the mesial and distal margins. The tooth crowns are proportionally wide, with their basaloapical length less than mesiodistal width. No primary ridge is present, though the tooth crowns are convex mesiodistally. Secondary ridges are also extremely weakly developed, except for those on the mesiomost and distalmost teeth.

Within the skull, the external mandibular fenestra is proportionally similar in size to that in *Huayangosaurus* (Dong et al., 1982; Zhou, 1983, 1984; Sereno, 1986; Dong, 1990; Sereno and Dong, 1992). The anterior process of the quadratojugal is oriented nearly horizontal unlike the anterodorsally oriented one in *Hesperosaurus* (Carpenter et al., 2001), *Tuojiangosaurus* (Dong et al., 1977, 1983; Dong, 1990) and *Huayangosaurus* (Dong et al., 1982; Zhou, 1983, 1984; Sereno, 1986; Dong, 1990; Sereno and Dong, 1992). The posterodorsal slope of the quadrate is unlike that in *Huayangosaurus* but like most other stegosaurs. As in *Huayangosaurus* and *Regnosaurus* (Berman and McIntosh, 1986), a dentary shelf is developed along the whole tooth row. As in stegosaurs more derived than *Huayangosaurus*, a prominent lamina on the dorsolateral margin of the back of the dentary obscures the dentary teeth.

As in most stegosaurs except *Huayangosaurus* (Dong et al., 1982; Zhou, 1983, 1984; Sereno, 1986; Dong, 1990; Sereno and Dong, 1992) and *Kentrosaurus* (Hennig, 1924, 1936; Galton, 1988), a paraquadrate foramen is absent. The pterygoids lack a distinct posterior tab and a distinct interpterygoid vacuity.

Dorsal ribs bear a short, distal crescent-shaped flange as in *Huayangosaurus* (Dong et al., 1982; Zhou, 1983, 1984; Sereno, 1986; Dong, 1990; Sereno and Dong, 1992).

The cervical plates resemble those in *Dravidosaurus* (Yadagiri and Ayyasami, 1979).

5 Discussion and Conclusions

Jiangjunosaurus junggarensis is clearly a stegosaur based on its general morphology and the following stegosaur autopomorphies (Galton, 1990; Galton and Upchurch, 2004): fossa or fenestra present on the pterygoid flange of the quadrate, the proximal scapular plate with a larger surface area than the coracoid, and parasagittal rows of large cervical plates. Several salient features suggest that *Jiangjunosaurus junggarensis* is a new taxon. The cheek tooth crowns are symmetrical in lingual and buccal view, are mesiodistally wider than basaloapically, and bear no primary ridge and distinct but weak secondary ridges. These dental features are not known in other stegosaur taxa.

Other diagnostic features include a sub-rectangular axial neural spine seen in lateral view and the nutrient foramina significantly enlarged in posterior cervical vertebrae. In other stegosaur species, the neural spine of the axis is triangular in lateral view, with a low anterior margin. Particularly interesting is the presence of enlarged nutrient foramina, which are superficially similar to the pneumatic openings in saurischian dinosaurs. However, based on unpublished CT (Computerized Tomography) data, they are not of pneumatic origin as they do not lead to expanded chambers.

Jiangjunosaurus junggarensis is more derived than *Huayangosaurus* in having a large ventral process and a horizontally oriented anterior quadratojugal process, a posteriorly located dentary tooth row, a prominent lamina hiding the posterior half of the dentary tooth row from view, and, in ventral view, a U-shaped mandibular symphysis at the anterior end of the dentary. These derived character states are present in other stegosaur species besides *Huayangosaurus* (Dong et al., 1982; Zhou, 1983, 1984; Sereno, 1986; Dong, 1990; Sereno and Dong, 1992). Several similarties to *Stegosaurus* (Gilmore, 1914, 1918; Ostrom and McIntosh, 1966) also indicate a relatively derived position for *Jiangjunosaurus*. For example, a distinct posterior tab is absent on the pterygoids, the ascending process of the quadratojugal covers less than half of the posterior border of the lateral fenestra, the sub-occipital portion of the basioccipital is wider than long, and the dentary has a low tooth count (21 dentary teeth in *Jiangjunosaurus*; 20–23 in *Stegosaurus* compared to 27 in *Huayangosaurus* and 25 in *Tuojiangosaurus*). However, *Jiangjunosaurus* appears to be more basal than most other stegosaurs as it lacks the following derived characters of the Stegosauria: long and robust ascending process of the quadratojugal, and anterior part of the dentary tooth row not inset from the lateral surface of the dentary. It is interesting that *Jiangjunosaurus junggarensis* appears to share several derived features with *Huayangosaurus*: prominent and peaked coronoid eminence; a small external mandibular fenestra; and dorsal ribs bearing a short, crescent-shaped flange near the distal end. The precise systematic position for *Jiangjunosaurus junggarensis* has to be determined by a numerical phylogenetic analysis, but which will be done elsewhere.

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