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A NEW NODOSAURID DINOSAUR FOSSIL FROM THE CRETACEOUS PERIOD OF
RUYANG, HENAN

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Content summary: According to new material, a new nodosaurid armor dinosaur is named from the Luoyang area south of Yellow River, *Zhongyuanosaurus luoyangensis* gen et sp. nov. Its skull shape and the tail vertebra characteristically demonstrated that this specimen belongs to the nodosaurid group of armored dinosaurs. It is different in the skull length and breadth is 1.4:1, the skull parietal bone area is approximately flat, the posterior edge of the skull and lateral edge of the orbit is straight [in dorsal view]; the widths of the distal end of the humerus and the proximal end are nearly equal, the attachment scar for the *M. latissimus dorsi* with *M. terres major* on the posterior surface of the proximal end of the humerus is hollow [i.e., concave], and the ischium shaft is straight. These characteristics distinguish it from other nodosaurid armored dinosaurs.

Key word: early Late Cretaceous; nodosaurid armored dinosaur; Luoyang area south of Yellow River; Ruyang County; Henan Province.

The Ankylosauria are odd quadrupedal, herbivorous dinosaurs, covered over the back and sides of the body by longitudinally arranged rows of osteoderms, and with characteristically small-toothed, unique skull; they are found on all continents (Vickaryous et al., 2004). In comparison with other dinosaur fossil, for instance the sauropod, hadrosaur and small theropods, ankylosaur fossil discoveries in our country are few. Previous main ankylosaur discoveries in our country at Ningxia Hui Autonomous Region (Young, 1935), Xinjiang Uygur Autonomous Region (Dong Zhiming, 1993), Inner Mongolia Autonomous Region (Godefroit et al., 1999; Vickaryous et al., 2001); Shanxi Province (Pang Qiqing and Cheng Zhengwu, 1998); Shandong Province (Buffetaut, 1995), Liaoning Province (Dong Zhiming, 2002; Xu et al., 2001) and Zhejiang Province (Lü et al., 2007, in press). But these armored dinosaur fossils, except the Liaoxi province Liaoning dinosaur (Xu et al., 2001) and the Zhejiang specimen, belong outside the nodosaurid group of armored dinosaurs (Lü et al., 2007, in press), the classification position of these other two ankylosaurs is not yet decided.

Traditionally, the Ankylosauria includes two groups, a group with skull wide skulls and a tail hammer growth, but another group has a skull longer than wide and the end of the tail centrum is visible, the nodosaurids (Coombs, 1978). What this article records is the discovery in Henan Province, Ruyang County, Liu Dianxiang (Figure 1), a new early Late Cretaceous nodosaurid armored dinosaur. The fossil preserves the basic parts, especially the vital parts for identification, for instance the skull and the terminal part of the tail, which are all very well preserved. In the Henan Ruyang's armor dinosaur fossil, the skull is not wide and the terminal part of the tail is not formed into a characteristic tail hammer, demonstrating that this specimen is without doubt a nodosaurid armored dinosaur. The discovery of this nodosaurid armored

dinosaur, regarding studies of our country's Ankylosauria, is of vital significance for their ancient geographic distribution and evolution.

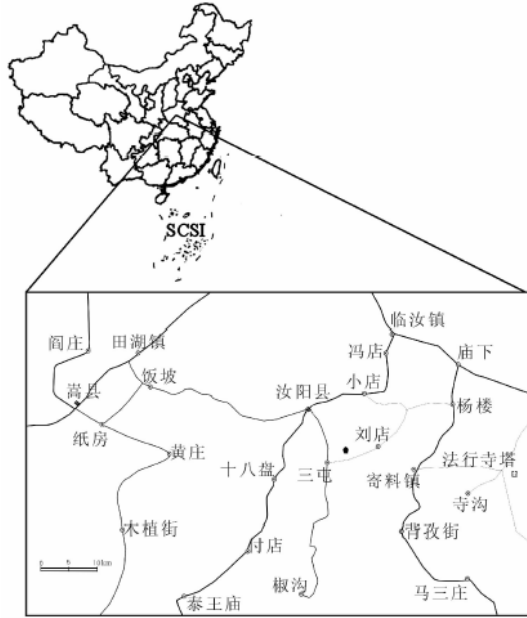


Figure 1. Map of the Luoyang area south of Yellow River showing the dinosaur fossil site (solid shape represents the fossil site).

1. System paleontology

Thyreophora Nopsca, 1915

Euryopoda Sereno, 1986

Order Ankylosauria Osborn 1923

Family Nodosauridae Marsh 1890

Zhongyuangosaurus gen. nov. (Plate I, II)

Etymology: For the area south of Yellow River area, Henan Province.

Diagnosis: Same as for the species.

Zhongyuangosaurus luoyangensis sp. nov.

Etymology: Luoyang, refers to the fossil site, Ruyang County, the administrative regionalization of the Luoyang area.

Specimen: Nearly complete skull and small fragment of the lower jaws, 3 dorsal neural arches, 1 damaged neural spine from a cervical vertebra, 1 nearly complete dorsal, 2 dorsal centra, 7 anterior caudal centra, 3 posterior caudal centra, and 7 fused distal caudal vertebrae, complete left humerus, two ischia, and a pubis, and several different scutes, ribs, and other fragments. Specimen housed in the Henan Province Geological Museum (41HIII-0002).

Locality and stratigraphic position: Henan Province, Ruyang County, Liu Dianxiang, Sichuan group (Lu et al, 2006).

Diagnosis: A large-sized nodosaurid armored dinosaur, the skull length greater than width, its ratio is approximately 1.4; the parietal bone area is flat; rear margin of skull and the edge lateral to the orbit is straight. Premaxilla without teeth, maxillary tooth row straight, has 18 teeth. The ventrally placed occipital condyle is semicircular, with a concave dorsal surface. The secondary bone blocks [osteoderms] are not fused to the skull surface. The width of the distal end of the humerus and the proximal end are nearly equal; on the posterior surface of the proximal end of the humerus, the scar for the *M latissimus dorsi* with *M. teres major* is concave; the ischium shaft is straight, different from other nodosaurids.

2 Specimen Description

2.1 Skull (Plate 1)

The skull is dorso-ventrally distorted, and the right front maxilla is partially damaged, but otherwise preserves the basic integrity. The skull length from the occipital condyle to the front edge of the premaxilla is 37.5cm; the maximum width is 26cm, and has a maximum width across the outer edge of the orbit of 24.4cm. No orbital horn is present. From the front of the orbit the front part of the skull gradually constricts forward. The tip of snout is straight, the premaxillary is concave ventrally. At the back of the skull, most of the suture lines are not visible, the area of the frontal and parietal bones is smooth, the rest of the surface is rough, especially above orbit and right side of the nasal bone. The maxilla dentition preserves two teeth and 16 alveoli, therefore the maxilla altogether has 18 teeth, half that in *Ankylosaurus magneventris* (Carpenter, 2004). The premaxillary plate is smooth and concave on the palatal side and the external side bulges out. The anterior part approaches the medial plane, and a trough extends from the front edge and terminates at the front of the [palatal] vacuity. Externally, the premaxillae form a keel between the external nares. Another vertical keel is present inside the nares forming two cavities, the inner one being the larger than the outer. The two premaxillae are not fused, but are separated by a big V-shaped crevice (premaxillary incisure). There is a large air hole in the premaxilla placed close to the median line. In ventral view, the maxilla dentition is straight. The vomer bone plate has a longitudinal groove between the two vomer bones.

2.2 Braincase

Because of crushing, the supraoccipital bone is a little distorted, but a keel is still distinct above the foramen magnum. After the supraoccipital bone and its common ossification with the exoccipital, their contact relation is not clear. The exoccipital forms the sides of the foramen magnum, and its smooth paroccipital process extends outwards. The paroccipital extends nearly to the sides of the skull and fuses with the quadrate. *Pawpawsaurus* (Lee 1996) is different with its distal ends completely free, not fused to the osteoderms or quadrate. The basioccipital bone has the obvious contact with the basisphenoid bone anteriorly, and posteriorly forms the hemispheroid occipital condyle. The basioccipital bone forms the ventral part of the foramen magnum, which is distorted. In ventral view, the anterior part of the basioccipital bone is V-shape, which extend down and locks onto the basisphenoid bone posteriorly. Ventrally, anterior body of the basioccipital bone has a weak median ridge, which extends backwards to the middle where it vanishes. The middle of the occipital condyle, on the ventral side, is concave. On the left side of the basioccipital bone and the basisphenoid bone cranial nerve foramina are clear. The length of the basisphenoid bone is less by far than that of the basioccipital bone. The parasphenoid bone suture line is not clear, the pterygoid is widely expanded, and extending ventrally, its base and the basipterygoid bone are fused completely.

2.3 lower jaws

The left lower jaw is damaged, preserving on the posterior portion of the mandible. The preserved portion has nine alveoli. The outer part of the alveolar border is higher than the inner border. On the [inner] side of the tooth row, there is a circular [nutrient] foramen at the position corresponding with the base of the tooth root; the distance between neighboring foramina is equivalent to three alveoli. On the medial side of the jaw, the broad posterior part narrows to the articular, which should form a wedge beneath the lamina of bone [surangular]?

2.4 Possible Angled Nasal Bone Osteoderm

During repair of the fossil, a thickened bone was discovered in the region of the nasal (22.5cm long, proximally 11cm). This bone shape is special with a pointed end, because although distorted, as a whole it remains arrow-shaped. The other end is wide and also has an articular surface, which fits well with the middle of a concave region of the nasal bone. The pointed end faces anteriorly, and has a rough, pitted surface rough sculpture. Posteriorly, the other end is narrow. The base of the osteoderm and skull surface is concave, but this osteoderm is not fused with the nasal bone. In shape, this bone horn is different than seen in any other specimens. Therefore, we infer this bone horn homologous to other scutes, differing only in shape; it may have projected from the nasal bone on an angle. Never has such an angled osteoderm been reported in ankylosaurs. This osteoderm possibly functioned in defense and attack.

2.5 Postcrania Skeleton

The cervical vertebra has a damaged neural spine and neural arch. The centrum is nearly horizontal, the ends angled slightly. The neural canal is nearly rectangular. The neural arch contacts the centrum on both sides. Comparisons with the dorsal neural arch show that it was short, and that the cervical vertebra centrum was much shorter than the dorsal centrum.

2.6 Dorsal Vertebra

A nearly complete dorsal centrum is known. The centrum has flat articular faces, smooth, constricted sides, and ventrally, a weak medial ridge. The centrum is long, with a nearly circular, wide neural canal. The neural arch and the centrum suture line is not obvious, the posterior articular face of the centrum is located beneath the neural arch.

The front part of the neural spine is damaged; the anterior articular face is nearly vertical and the edge of the centrum is expanded laterally. The neural spine extends past the centrum length. The transverse process extends from the centrum, forming an angle of approximately 40° to the neural spine. The centrum has a longitudinal groove and at the front of the base of the neural arch base is a big circular concavity for the dorsal rib. The posterior articular face of the centrum is not expanded laterally. Looking from the back, the neural canal is small and narrow. The top of the neural spine is expanded, forming a platform for the armor.

2.7 Mid-Caudal Vertebra

The articular face of the centrum is concave, and the ventral surface has a groove. The length and anterior width of the centrum are nearly equal; laterally, the centrum has a weak longitudinal keel; the neural arch is not fused to the centrum.

2.8 Posterior Caudal Vertebrae

The posterior centra are a little distorted from crushing. The articular faces are concave, ventral surface is grooved. The neural spine decreases in size and disappears, and the zygapophyses fused. The more anterior centra are longest; the prezygapophyses form a V-shape. The centra join into an immovable structure. The centrum width is more than the centrum height.

2.9 Posterior-most Caudal Vertebrae

The posterior most seven vertebrae are fused; the prezygapophysis is half the centrum length. The preceding vertebra is wedged between the prezygapophyses of its succeeding neighbor, forming an immovable joint. The entire coossified posterior vertebrae become plate-like to the termination. The terminal caudal vertebrae did not form a tail club (Plate IID), as is characteristic of nodosaurids. The anterior prezygapophyses are the longest; the anterior centrum has a weak longitudinal keel, and ventrally a groove. The neural arches are not fused to the centra.

2.10 Humeri

The humerus is sturdy, and has a very well developed deltopectoral crest, which is about 43% the humerus length. At the lower ventral end of the deltopectoral crest is a large scar which should be for the insertion of the *M. pectoralis*. The proximal end of the humerus (above the deltopectoral crest), the anterior face is concave, but in the middle has two smaller connected concave surfaces. From their positions, they should be for the insertion of the *M. latissimus dorsi* and *M. teres major*. Between the distal ends of the humerus is slightly concave. The distal end width (15cm) is slightly less than the proximal end width (16cm). Posteriorly, the proximal end has a longitudinal groove. The medial tubercle on the proximal end is not developed.

2.11 Claw

A complete claw is preserved; it is flat, similar with other ankylosaurs.

2.12 Ischia (Plate IIA,B)

Two complete ischia are preserved (length 47cm, shaft width 5.5cm, proximal width 19cm). The shaft is plate-like, and does not taper distally. The outer surface of the proximal end is concave, and internal surface slightly bulged. Distally, there is a shallow longitudinal groove. Distal to the groove on the medial side is a small prominence of tubercle for a muscle. The posterior edge of the shaft is slightly curved, and the front edge also makes the corresponding curve; this is different that the front edge is nearly straight in other ankylosaur ischia (Vickaryous et al 2004), and is also different from that seen in other nodosaurid armor dinosaurs. For instance, the *Edmontonia* ischium shaft curves forward about 1/3 from the distal end (Carpenter 1990). Thus, the ischium of *Zhongyuangosaurus luoyangensis* under consideration is intermediate between the ischia of ankylosaurids and nodosaurids.

2.13 Pubis

Most of the left pubis is preserved, and is only a little damaged at the terminal and proximal ends. The preserved portion is 12cm long, and is estimated to have been 15cm long. The medial side has a pubic skirt.

2.14 Armor (Fig 2C).

Because the armor was scattered, their position on the skeleton is not certain. They may be divided into eight types based on size and shape:

(1) big, thin, irregular quadrangle: dorsal surface is flat or slightly bulged, has a jagged sculpture along the edges, the ventral surface is hollow. Ventrally, the front part extends downwards and forms a deep concavity, and the outer surface is rough. This kind of armor is possibly located on the front portion of the back, similar to the situation in *Edmontonia* (Carpenter 1990).

(2) big, thick, irregular quadrangle: except for its thickness, the surface is flat and the front edge extends considerably downward, forming a deeply concavity on the outer surface, otherwise is similar to Type 1.

(3) circular: smaller than Type 1 and Type 2. The outer surface has a off centered, keel; ventrally, the keel is deeply concave. The outer surface and edge have a short rugose sculpture.

(4) circular: not much smaller than Type 1 and Type 2. The outer surface has a well developed keel, which extends along the major axis, not along the middle, therefore, it is asymmetrical.

(5) circular: small, shape similar to Type 4, but the posterior surface has irregular grooves, no ridges. Ventrally, there is a medially placed longitudinal ditch.

(6) hollow cone: diameter of the cone base 10cm, the edge has incised sculpture. The outside surface has the irregular grooved sculpture.

(7) kidney shape: middle of the outer surface hollow, with the side folded upwards, one edge is thick, the other edge is thin. Surface is a pit shape structure, ventrally it is a pointed structure.

(8) ridge shape: preservation is incomplete, the inside open, bone wall thin 2.3mm. The outside surface has irregular grooved sculpture. Height at least 7cm, length at least 16cm.

2.15 Rib

A complete right dorsal, side rib is preserved; it is 1 m long and has a proximal width of 6 cm. The rib bone does not expand, the double heads for articulation with the centrum is rugose and the articular face of the tubercle is circular. Rib shaft thickens along the outer edge, whereas the inner edge is thin.

3. Comparisons and Discussions

Zhongyuangosaurus luoyangensis has characteristics of the nodosaurid armored dinosaurs: The buccal shelf is restricted to the maxilla, the occipital condyle is semicircular and has a neck. The deltopectoral crest length is less than half the shaft length and so on (Carpenter 2001). In addition, the skull surface is rough across its width, the terminal caudal vertebrae do not have a tail club. The tip of the snout tapers, which is characteristic of nodosaurid armored dinosaurs (Kilbourne and Carpenter 2005).

In top view, the nodosaurid skull is long, pear-shaped, has a narrow, pointed snout, and the skull length always surpasses the extreme breadth (Coombs 1978), whereas in ankylosaurids, the skull width is less than length or are equal (Brown 1908, Maryanska, 1977; Coombs 1978). The skull from south of the Yellow River can be compared with those of other nodosaurid ankylosaurs, especially in the parietal bone area. It is flat, but in *Pawpawsaurus* (Lee 1996) and *Silvisaurus* (Eaton 1960), the parietal area is bulged into an arch shape; in *Sauropelta* (Ostrom 1970) and *Panoplosaurus* (Lambe 1919), the parietal area is moderately bulged; but in *Edmontonia* (Sternberg 1928), the parietal area is only slightly bulged. The postorbital angle [horn] is similar to that of *Sauropelta*, *Edmontonia*, *Silvisaurus*, and *Panoplosaurus*; the postorbital angle [horn] is slightly developed in *Animantarx* (Carpenter et al 1999). It is well developed in *Pawpawsaurus*. The nodosaurid from south of the Yellow River has a slightly curved ischial shaft; it does not taper distally, like *Struthiosaurus languedocensis*, but is different than the terminal thinning of *Edmontonia rugosidens* and *Edmontonia longiceps* (Garcia and Pereda Suberbiola 2003). The ischial shaft is straight, differing from the typical curve seen in nodosaurids (Coombs 1979). Its shape is situated between the ankylosaurid and nodosaurids.

4. Conclusions

The dinosaur from the area south of Yellow River has a complete skull and complete terminal tail vertebrae indicate the presence of the nodosaurid dinosaurs in our country. Its skull and tail vertebra structure indicate a nodosaurid, but the structure of its ischium is not typically nodosaurid. The discovery of this specimen is of vital significance to the study of ankylosaur evolution, in particular the origins of the nodosaurids, their paleogeographic distribution and their evolution.

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