A new iguanodontid (*Jinzhousaurus yangi* gen. et sp. nov.) from the Yixian Formation of western Liaoning, China

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Abstract **A new iguanodontid, *Jinzhousaurus yangi* gen. et sp. nov., is erected based on the cranial and dental morphology of a specimen from the Yixian Formation of western Liaoning. Although a few primitive characteristics remain, *Jinzhousaurus yangi* display a number of characteristics similar to those seen in derived iguanodontids. Other interesting characteristics include the absence of antorbital fenestra and the frontal excluded from the participation in orbit, which are closer to the condition in hadrosaurids. The unusual combination of the characteristics provides important data for assessing morphological evolution toward hadrosaurs. The new discovery also represents the first reported large-sized dinosaur from Jehol fauna in western Liaoning, and increases the diversity of this famous fauna. Furthermore, the discovery of a derived iguanodontid from the Yixian Formation provides further evidence supporting a Cretaceous age of the Jehol fauna, which is consistent with an isotopic age.**

Keywords: Western Liaoning, Lower Cretaceous, Yixian Formation, Jehol Biota, Iguanodontid

Iguanodontids represent a paraphyletic group, including taxa ranging between hypsilophodontids and hadrosaurs[1—4]. They are also among the earliest named and described dinosaur taxa[5], and their fossil record ranges from Late Jurassic through Late Cretaceous deposits of all continents except Antarctic and is richest in Early Cretaceous Europe[4].

Recently a completely preserved iguanodontid skeleton was collected from the lacustrine deposits of the middle Yixian Formation in the Fuxin-Yixian Basin of western Liaoning. The fossil site is located at Baicaigou, Toutai, Yixian County. Associated fauna includes *Hyphalosaurus*, pterodactyloidea and enantiornithes. This discovery represents the first large-sized dinosaur from the Jehol fauna in western Liaoning, and increases the diversity of the biota. The present note will describe preliminarily the cranial morphology of the new taxon and a detailed description on the postcranial will be given later after the specimen is fully prepared.

1 Systematic Paleontology

Order Ornithischia Seeley, 1888
Suborder Ornithopoda Marsh, 1881
Family Incertae sedis
Genus *Jinzhousaurus* gen. nov.[1)]
Species *Jinzhousaurus yangi* gen. et sp. nov.[1)]

Diagnosis. Large-sized Iguanodontid dinosaur, about 7 m in total length. The skull is about 500 mm in length and 280 mm in height. The antorbital portion is long, accounting for 64% the skull length. The maxilla is triangular in lateral view and has a long, narrow rostral extension. The antorbital fenestra is absent. The frontals are fused into one element. The frontals extend quite anteriorly, close to the anterior border of the orbit and do not contribute to the formation of the orbit. The quadrate has a curved shaft. The supratemporal foramen is pointed forward outsides. The quadtatojugal is large. The ventral process of the predentary is very weakly bifurcated. The dorsal and ventral margins of the dentary are straight. There are more than 16 dentary teeth that become larger posteriorly.

Etymology. The genus name Jinzhou refers to the larger geographic area that includes the type locality; the species name is in horner of Yang Zhongjian who is the founder of the vertebrate paleontology in China.

Holotype. A nearly complete skeleton with a complete skull. Institute of Vertebrate Paleontology and Paleoanthropology (IVPP) specimen number: IVPP V12691 (figs. 1 and 2)

Locality and horizon. Baicaigou, Toutai, Yixian County, Liaoning; Dakangpu member, the middle part of the Yixian Formation (comparable to Dawangzhangzi Bed); Huaterivian, Early Cretaceous (based on a 135 Ma J/K boundary) or Barremian, Early Cretaceous (a 144 Ma J/K boundary)

Description. A nearly complete skeleton, about 7 m in total length. The skull exposes its left and dorsal sides and visible elements include premaxilla, maxilla, nasal, lacrymal, prefrontal, frontal, postorbital, palpebral, parietal, jugal, qudratojugal, angular, surangular, quadrate, paraoccipital process, hyoid, predentary, dentary, and teeth.

Skull. The skull is about 500 mm in length (from the tip of the snout to the posterior margin of the parietal), about 280 mm in height. The antorbital portion is long, accounting for 64% the skull length. The dorsal margin of the snout mildly raised, describing a weak arch, and the skull roof is relatively flat. The orbit is relatively small, about 100 mm in anteroposterior diameter.

The most occipital elements are obscured by the squamosals and parietals, with the exception that the left paraoccipital process is exposed in the left supratemporal

1) Genus and species were named in the same paper of *Chinese Science Bullerin* (in Chinese), 2001, 46(5): 419.

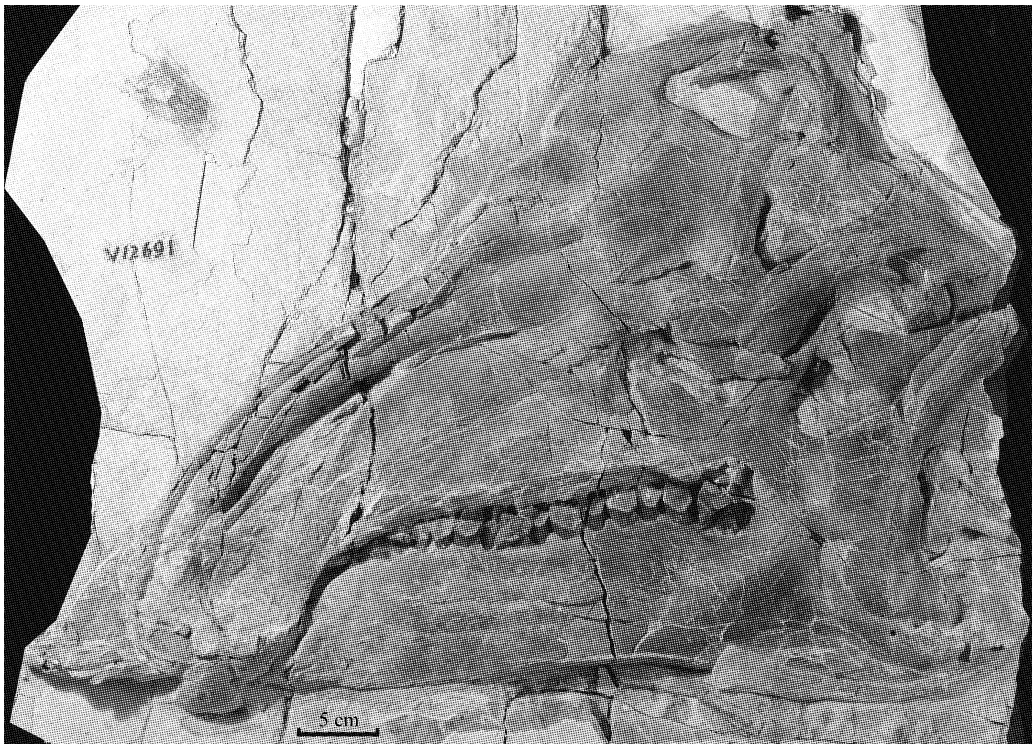

Fig. 1. The skull of *Jinzhousaurus yangi* gen. et sp. nov. (IVPP V12691, holotype).

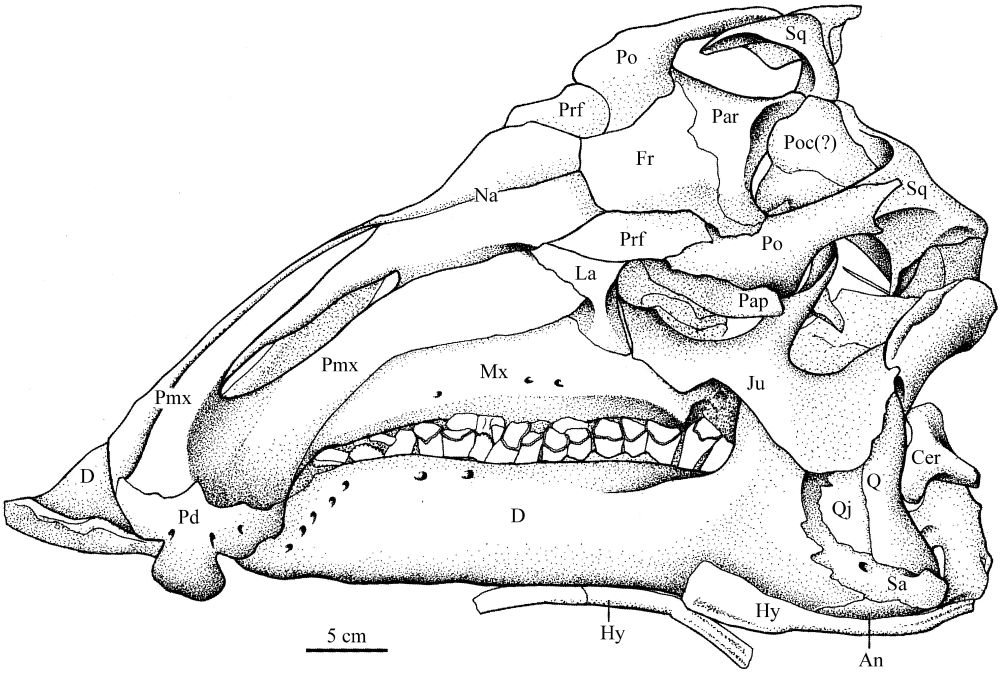

Fig. 2. The outline of the skull of *Jinzhousaurus yangi* gen. et sp. nov. (IVPP V12691, holotype). An, Angular; Cer, cervical; D, dentary; Fr, Frontal; Hy, hyoid; Ju, jugal; La, lacrimal; Mx, maxilla; Na, nasal; Pap, palpebral; Par, parietal; Pd, prodentary; Pmx, premaxilla; Po, postorbital; Poc, paroccipital; Prf, prefrontal; Q, quadrate; Oj, quadtatojugal; Sa, surangular; Sq, squamosal.

Fenestra. The left and right parietals are fused along the middle, the maximum transverse width of which is about 130 mm and anteroposterior length about 75 mm. It is significantly wider than in other iguanodontids. Posteriorly a saggital crest is present. The supratemporal fenestra is oval in outline, narrower anteriorly and wider posteriorly. The maximum length of the fenestra is about 90 mm and the maximum width is about half the anteroposterior length. The long axis of the fenestra is oriented anterolaterally as in *Ouranosaurus*[4,7] but different from *Ig-*

uanodon in which it is directed anteriorly or anteromedially [4,8,9]. The infratemporal fenestra is elliptical in outline.

The frontals are fused into one element. Anteriorly it contacts the nasal through a straight suture; laterally it contacts the prefrontal and postorbital; and posteriorly it contacts the parietal through sinuous suture, more similar to the condition in *Iguanodon*[4] but different from the straight one in *Ouranosaurus* and *Camptosaurus*[4, 10]. The frontals extend quite anteriorly, close to the anterior border of the orbit. Different from other iguanodontids, the frontal does not contribute to the formation of the orbit. The nasal is wide posteriorly and narrow anteriorly. A shallow groove is present along the midline of the nasals and a fossa is present on the dorsal surface of the posterior nasals, but this is probably due to the preservation. The nasal extends anteriorly close to the anterior margin of the external naris and posteriorly to contact the prefrontal and frontal at the level of the anterior border of the orbit. The external naris is large, about 210 mm in length. The subnarial fossa is well developed.

The prefrontal is large, about 300 mm long, accounting for about 60% the length of the skull. The rostral portion of the skull is expanded as in other iguanodontids. The maxillary process of the premaxilla is enlarged posteriorly, contacting the maxilla ventrally and the nasal dorsally. Its posterior end contacts the lacrymal. The main body of the premaxilla is enlarged, extending ventrally off to the ventral margin of the maxilla. The maxilla is comparatively small, triangular in outline. It is about 170 mm long and 80 mm in maximum height. A few large nutrient foramina are visible on the lateral surface of the maxilla. Unlike other iguanodontids, the antorbital fenestra is absent as in hadrosaurids. Among other iguanodontids, *Iguanodon lakotaensis* has a large antorbital fenestra[11] and others have a relatively small one.

The jugal forms the ventral margin of the orbit. Its maxillary process appears to insert into a groove on the posterior lacrymal, and its postorbital process is oriented posterodorsally, contacting the ventral process of the postorbital. Posteriorly the jugal is large, sheet-like, forming the ventral and possibly part of the posterior margins of the infratemporal fenestra. The qudratojugal appears to be excluded from the posterior margin of the infratemporal fenestra. The lacrymal is large, and rough laterally. The rod-like palpebral is preserved and restricts its contaction with the only prefrontal. The prefrontal contacts the frontal, nasal, and lacrymal, forming the anterodorsal border of the orbit. The postorbital has a robust ventral process.

The squamosal contributes to the formation of the posterior and posterolateral margins of the supratemporal fenestra, and the postodorsal margin of the infratemporal fenestra. The left and right squamosal contacts each other, separating the parietals from the occipital region in dorsal view. The quadrate has a curved shaft as in *Iguanodon atherfieldensis*[9], *Camptosaurus*[10], and *Ouranosaurus*[7]. In *Iguanodon bernissartensis*[8] and *Probactrosaurus*[12], it is straight.

Mandible. The mandible exposes the predentary, dentary, angular and surangular.

The predentary is denticulate anteriorly. Its ventral process is very weakly bifurcated. The dentary is about 350 mm long and about 90 mm in the maximum height. The dorsal and ventral margins of the dentary are straight as in *Camptosaurus* and *Ouranosaurus*[4]. In *Iguanodon* and *Probactrosaurus* the anterior end of the dentary is downturned. The first dentary tooth is positioned relative to the predentary by a distance of two-tooth position as in other iguanodontids[4]. Seven nutrient foramina are present on the anterior dentary in lateral view. The relatively large surangular foramen is present, and the angular exposes a small portion laterally.

Dentition. The maxillary teeth are smaller than the dentary ones in size. Generally the primary ridge on the lateral surface of the maxillary tooth crown is well developed, and positioned slightly posteriorly. A weakly- developed secondary ridge is present between the primary ridge and well-developed the anterior shelf of the crown. The posterior shelf of the crown is weakly developed. There are more than 16 dentary teeth that become larger posteriorly. The crowns are heavily weared and the wear facets face dorsolaterally. The first and second dentary teeth are at their erupted position, with well-developed serrations. The sixth alveolus contains a functional as well as a replacement tooth.

2 Comparison and discussion

Jinzhousaurus yangi is apparently an iguanodontid ornithopod based on its cranial and dental morphology. Comparable iguanodontids includes relatively primitive *Camptosaurus,* and comparatively derived *Iguanodon, Ouranosaurus, Muttaburasaurus* [13], *Probactrosaurus* and *Nanyangosaurus*[1,4, 14].

Jinzhousaurus yangi can be differed from other iguanodontids based on both pleisomorphic and apomorphic characters. The pleisomorphic characteristics include relatively small number of the dentary tooth, very weakly bifurcated ventral process of the predentary (more like uni-lobed). The derived characteristics include anteriorly extended frontal (close to the anterior margin of the orbit), frontal excluded from the participation of the orbital border, and antorbital fenestra absent, which are not known in other iguanodontids but similar to the condition in hadrosaurs[2,15]. The unusual combination of characters in *Jinzhousaurus yangi* provides data important for assessing the morphological transition towards hadrosaurid dinosaurs.

Jinzhousaurus yangi shares some similarities with *Iguanodon*, for example, long and tall snout, the pre-orbital portion more than half the length of the skull, triangular maxilla with shallow and long anterior process, completely fused frontals, and palpebral exclusively contacting the prefrontal etc. It differs from *Iguanodon* in straight ventral margin of the dentary and lateroanteriorly directed supratemporal fenestra.

Jinzhousaurus yangi shows some striking similarities with *Probactrosaurus*, i.e. the left and right squamosals contacting each other and the well-developed primary ridge on the lateral surface of the maxillary tooth crown. It is different from the latter in the morphology of the quadrate and dentary. The dental morphology of *Probactrosaurus* is more similar to hadrosaurs than that of *Jinzhousaurus yangi*[4,14,15].

The similarities shared by *Jinzhousaurus yangi* and *Camptosaurus* and *Ouranosaurus* include the straight ventral margin of the dentary, recurved quadrate shaft, and the oval supratemporal fenestra with its long axis anterolaterally directed, but differs in general cranial morphology[4].

The above comparisons suggest that the new specimen is different from all known iguanodontids and represent a new iguanodontid.

So far, two genera and four species of iguanodontid taxa have been reported from the Lower Cretaceous of northern China, including *Probactrosaurus gobiensis* and *P. alashanicus* from Dashuigou Formation of Inner Mongolia[12], *P. mazongshanensis* from Xinmingpu Group of Gansu[16], and *Nanyangosaurus zhugeii* from the Sanping Formation[14]. The known Chinese iguanodontid material is either lacking of cranial elements or preserves only partially, and thus a detailed comparison is not available currently. The reported ornithischian taxa from western Liaoning include ceratopsian *Psittacosaurus*[17] and primitive ornithopod *Jeholosaurus*[18], both being small-sized animals. *Jinzhousaurus yangi* represent the first large- sized ornithischian dinosaur found from the Jehol fauna in western Liaoning, and its holotype also represents the most complete iguanodontid specimen from Asia reported to date.

The iguanodontid fossils are widely distributed in the Lower Cretaceous of Europe, North America, Asia, Africa and Australia. *Iguanodon* occurrences are from Valanginian-Albian of England, Belgium, Spain and Germany[4], and Barremian of America[11]. Asian iguanodontid fossil records are mainly from the Lower Cretaceous of northern China and Mongolia, and *Ouranosaurus* and *Muttaburrasaurus* from Aptian-Albian of Africa and Australia[4, 7, 13].

The holotype of *Jinzhousaurus yangi* is from the Dakangpu Bed[19], Yixian Formation, which is slightly higher in horizon to the Jianshangou Bed that has produced spectacular fossil remains particularly at Sihetun locality. The Dakangpu Bed is the same as the Dawangzhangzi Bed of the middle Yixian Formation[20]. The associated fauna include *Hyphalosaurus*, pterodactyloidea and enantiornithes. The preliminary study on cranial morphology of *Jinzhousaurus yangi* suggests that this animal is as derived as *Iguanodon* and *Probactrosaurus* and probably lived in Early Cretaceous, which is consistent with the isotopic age of the fossil-bearing bed.

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