Dinosaurs from the Jurassic of Sichuan

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Abbreviations for figures

Cranial abbreviations

Ant.f.-Antorbital fenestra

Ang.-Angular

Art.-Articular

Ax.c.-Axis contact

Boc.-Basioccipital

Bo.tbr.-Basioccipital tuberosity

Bpt.-Basipterygoid

Bpt.pr.-Basipterygoid process

Bs.-Basisphenoid

C.-Coronoid

D.-dentary

Ec.-Ectopterygoid

Exoc.-Exoccipital

Ext.nar.-Exteranl nares

Ep.-Epipterygoid

Lat.temp.f.-Lateral temporal fenestra

F.-Frontal

F.m.-Foramen magnum

Ex.m.f.-External mandibular fenestra

F2.-Second antorbital fenestra

Gl.-Glenoid

In.n.- Internal nares

Ju.-Jugal

La.-Lacrymal

Lat.temp.fen.-Lateral temporal fenestra

Mx.-Maxilla

Md.-Mandible

N.-Nasal

O.-Orbital

Orb.rug.-Orbital rugosity

Pa.-Parietal

Par.-Prearticular

Pd.-Predentary

Pf.-Postfrontal

Pl.-Palatine

Po.-Postorbital

Po.p.-Postorbital process

Poc.-Paroccipital

Prf.-Prefrontal

Prm.-Premaxilla

Prm.n.p.-Nasal process of premaxillary

Pro.-Prootic

Ps.-Parasphenoid

Pt.-Pterygoid

Ptd.-M. Pterygoideus

Q.-Quadrate

Qj.-Quadratojugal

Sa.-Surangular

Soc.-Supraoccipital

S.f.-Supratemporal fenestra

Sor.-Supraorbital

Spl.-Splenial

Sq.-Squamosal

Axial abbreviations

A.-Atlas

Ax.-Axis

Ax.s.-Axis articular surface

C.-Capitulum

Cv.-Cervical

Cd.-Caudal

Di.-Diapophysis

Do.-Dorsal

Ca.-Capitulum

Di.-Diapophysis

Hypn.-Hypantrum

Hyps.-Hyposphene

Id.l-Infradiapophyseal lamina

In.-Intercentrum

Ipoz.l.-Infrapostzygapophyseal lamina

Iprz.l.-Infraprezygapophyseal lamina

K.-Keel

N.a.-Neural arch

Oc.c.-Occipital contact

Oc.s.-Occipital articular surface

Od.-Odontoid process

Pl.-Pleurocoel

Prdi.L.-Prediapophyseal lamina

Prz.-Prezygapophysis

Poz.-Postzygapophysis

Pp.-Parapophysis

Pl.-Pleurocoel

R.-Rib

S.l.-Supradiapophyseal lamina

Sp.-Spine

Sprz.l.-Supraprezygapophyseal lamina

T.-Tuberculum

Apendicular abbreviations

Shoulder girdle and forelimb

Cl.-Clavicle

Co.-Corocoid

Co.f.-Corocoid fenestra

Hu.-Humerus

He.-Humeral head

D.c.-Deltopectoral crest

Ol.-Olecranon

R.-Radius

R.c.-Radial condyle

Sc.-Scapula

U.-Ulna

U.c.-Ulnar condyle

Pelvic girdle and hind limb

Ac.-Acetabulum

As.-Astragalus

As.p.-Astragalar process

Ca.-Calcaneum

C.cr.-Cnemial crest

D.s.-Distal sacral

F.-Fibula

Fe.-Femur

F.h.-Femoral head

F.tr.-Fourth trochanter

Il.-Ilium

Il.tib.-mm.-Iliotibialis contact

Is.-Ischium

Is.p..-Ischiac peduncle

L.co.-Lateral condyle

L.tr.-Lesser trochanter

M.co.-Medial condyle

Ob.-Obturator foramen

Pb.-Pubis

Pb.p.-Punic peduncle

Pr.c.-Preacetabular crest

Po.c.-Postacetabular crest

Po.k.-Posterior keel

S.di.-Sacral diapophyses

T.-Tibia

Abstract

Mesozoic continental sediments in the Sichuan Basin are extremely thick with abundant dinosaur data produced from the Jurassic portion of these sediments. Over fifty years of world renowned research has been conducted in the basin, initiating with the seminal work of Professor C. C. Young and continuing through to recent years, with large amounts of new dinosaurian data revealed. This monograph is the result of the study of this new data. Accompanying descriptions in this text are discussions, supplementary descriptions, revisions, and taxonomic assignments. Two orders of Jurassic dinosaurs are described: the Saurischia (including Prosauropoda, Sauropoda, and Theropoda) and the Ornithischia (including the Ornithopoda and Stegosauria), among which are 12 genera (including four new genera) and 19 species (including six new species). In addition, the text discusses stratigraphic problems of the dinosaur bearing sediments in addition to phylogenetic and evolutionary questions. 103 figures and 44 plates accompany the text.

Foreword

Expansive exposures of continuous Mesozoic terrestrial sediments in the Sichuan Basin have produced abundant fossil vertebrates. This is particularly characteristic of dinosaur localities which are numerous, widely dispersed, and taxonomically diverse. Thes data are extremely significant toward stratigraphic subdivision and correlation in addition to dinosaur biogeography and phylogenetics.

Although research into the dinosaurs of the Sichuan Basin began relatively early, difficulties have been confronted due to the long-standing restricted nature of more recent data, the vague stratigraphic position of fossiliferous sediments, and a confusion in taxonomic nomenclature. Recently, however, systematic collection and stratigraphic verification has provided a basis for revision, synthesis, applied research, and publication.

Appreciation is hereby expressed[*] to those who provided data and additional information from 1974-1979 toward collection and verification of specimens from the Sichuan Basin. This work occurred with the support and assistance of the Sichuan Provincial Office of Geology, the Synthetic Research Corps, the Aerial Survey and Mobilization Corps, and the 107th Geological Corps. Further guidance and enthusiastic solicitude in support of completion of this work were provided by local Party members and capital officials.

This volume was completed through the laborious and diligent support of the Chungking[**] Natural History Museum, the Zigong Museum of the Salt Industry, and the Institute of Vertebrate Paleontology and Paleoanthropology, Academia Sinica (IVPP). Particular appreciation is expressed to the Chungking Natural History Museum, which has provided extensive guidance and public education during the collection and excavation of Sichuan Basin dinosaurs. Further appreciation is expressed to Mr. Xuanmin Li for his extensive and diligent efforts during the excavation of the Wujaiba Dam specimen. We also hereby cherish the memory of the deceased dinosaur excavator Mr. Dongyao Lan.

The crystallization of this text is the result of efforts from the Chungking Natural History Museum and IVPP. The authors hereby acknowledge the efforts of colleagues Qiren Fang, Cunyi Wang, Xiaozhang Fang, Xinglong Xiang, Youshu Cao, Youling Su, Dianwu Liu, Lianhai Hou, Zhilu Tang, Guobin Zhang, Zhongyi Zhao, and several others who will not be forgotten. Text figures were drawn by IVPP personnel Zhixiang Ceng, Wenlong Shen, Zeng Liu, and Xiaoping Xu. Photographic plates were taken by Zhefu Wang and Yanwan Gong.

The authors also wish to thank Dr. A. Charig of the British Museum (Natural History), and H. Osmólska from the Polish Institute of Paleontology for providing reference material.

Theropod descriptions were written by Yihong Zhang and Zhiming Dong, sauropod and ornithopod descriptions were written by Zhiming Dong, stegosaur descriptions were written by Shiwu Zhou, and final compilation and manuscript revision was undertaken by Zhiming Dong.

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[*] The translator expresses his appreciation to the Jurassic Foundation for providing partial financial support and to Matt Carrano, State University of New York at Stony Brook for reading the manuscript.

[**] Translator's note: Although Pinyin romanization now spells this city Zhongqing, this translation will retain the conventional and more familiar Wade-Giles romanization of Chungking.

During the composition of the manuscripts the authors deeply cherished the memory or our forerunner and mentor, professor C. C. Young. Approaching the first year anniversary of his passing, the authors sincerely wish to dedicate this volume to him.

I Synopsis of the Sichuan Basin

Sichuan Province reflects a typical basin structure, being circumscribed by mountains with a low and flat center. In outline it is rhomboid, slightly broader to the east and west, and compressed from north to south. In area it encompasses nearly 580,000 square kilometers and is infilled with Mesozoic terrestrial red sediments that may reach two thousand meters in thickness. Its most distinguishing character is its structural simplicity, from which the prevalent name "Sichuan Basin" is derived.

The northern margin of the Sichuan basin is bounded by the Qinling, Micang, and Dabashan mountain ranges, with elevations of two to three thousand meters. The Qinling range extends east-west to delineate the provinces of Sichuan and Shaanxi and composes a natural barrier protecting the basin from the cold climatic conditions to the northwest. In the west-central region of the basin, at the middle and lower reaches of the Minjiang River, lies an alluvial plain called the Chengdu Plain that is intimately related to the orogeny of the Longchuanshan Mountains. Within the Longchuanshan Mountains is a northeast-southwest trending orogenic belt confining the hydrolics of the Minjiang and Tuojiang rivers to a southward drainage pattern. The orogeny and obliquity of the Minshan and Qiongxia mountains to the northwest provided the source rock for the abundant sediments which were impounded by the obstruction of the Longchuanshan Mountains and hence the genesis of the Chengdu Plain.

The Chengdu Plain is a vast expanse of fertile land that has benefited by the Dujiang levy and irrigation system for millennia. Furthermore, the climate of four annual temperate and mesic seasons are favorable for long periods of crop growth. Therefore, since antiquity the Sichuan Basin has been referred to as "Kingdom of the Celestial Prefecture."

The Chengdu Plain predominantly constitutes the central and western region of Sichuan Province, while the eastern region is referred to as the Chuandong (eastern Sichuan) fold belt, which is composed of six northeast-southwest trending parallel folded mountain ranges structurally referred to as the Chuandong arc complex. The central basin is characterized by flat-topped low and gentle undulating hills with heights of merely several tens of meters. Gravels are frequently observed at the top of these low red mounds which are attributed to the Pleistocene "Yaan Stage."

The river system of the Sichuan Basin is derived from the four mountain ranges surrounding the region and takes the form of a convergent radiating system which ultimately flows southward into the Yangzi River. In the southwest portion of the basin the Yangzi is referred to as the Chuanjiang River, then downstream it converges with the Minjiang, Tuojiang, Jialing rivers in addition to the Wujiang River which descends off the Sichuan-Guizhou Plateau. This Yangzi then winds southeastwards to truncate Wushan Mt., exit through the Three Gorges, and enter the Jianghan Plain. Because the basin is the location of the confluence of four major rivers, the region has derived its name "Sichuan" (four rivers).[**]

II Sedimentology of the dinosaur beds in the Sichuan Basin

On a large structural scale the Sichuan Basin is located on the northern portion of the Guizhou-Hunan platform which is bounded by the She and Xikang-Yunnan terrains, the Longmenshan parageosyncline, and the Jiangnan terrain, and as such the basin predominantly exhibits characters reflecting a paraplatform. Relatively stable basin sedimentation was initiated in the Late Paleozoic.

[**] "Encyclopedia of Sichuan": Northern Song Dynasty, fourth year of the Xianping Reign (996 AD).

Deposition in the Sichuan Basin is structurally controlled and as such facies in the north differ slightly from those in the south. The late Middle Triassic witnessed a marine regression and by the Late Triassic a majority of the basin underwent relatively stable terrestrial deposition with the exception of the west and northwestern regions, which were still subjected to marine sedimentation. During this period the region represented a littoral basin where the climate was temperate and mesic with a flourishing perennial flora, or an environment which favored carbonization, and was the source of the Shunjiahe Fm. This formation is extremely thick in the east but gradually attenuates toward the west. In the southwest the basin had yet to be enclosed such that the region of deposition penetrated central Yunnan Province through the eastern Yunnan fold belt, as was the circumstance at the southern margins of the lacustrine basin that extended past the Qijiang River, Tongzi Co., and further into northern Guizhou Province. In central Yunnan, sediments equivalent to the Shunjiahe Fm. are recognized as the Yipinglang Fm. while in northern Yunnan and southwestern Sichuan they are referred to the Baiguowan Fm. During this period the fluvial systems in these three provinces were confluent and resulted in similar Late Triassic lithologies.

In the Early to Middle Jurassic, marine regression was complete and deposition was nearly completely lacustrine. Lacustrine depth to the northeast was relatively shallow, as reflected by coarse grain size. To the north in the Guangyuan Co. region, this period is represented by the coal-bearing Baitianba Fm. Lacustrine depth gradually increases to the southwest, reflected by finer grained sediments including marls and limestones. There are two fresh-water limestone events recorded, although this set of deposits is still predominantly red or variegated clastics, which to the east and south are designated the Ziliujing Group while to the west they are designated the Baitienba and Qianfoya formations.

After the Middle Jurassic, deposition was predominantly represented by fluviolacustrine red clastics which to the north were formerly referred to as the Guangyuan Group while to the south and east were known as the Chungking Group. Sedimentary thicknesses reach immense proportions and constitute the most extensive and prolific vertebrate-producing Mesozoic exposures in the basin.

Research in these Mesozoic red beds began relatively early although there was a long hiatus between discoveries of new paleontological data and there was controversy among paleontologists regarding precise ages. The earliest workers such as Grabau (1923), Louderback (1935), Heim (1929), Zhao and Huang (1929), and Tan and Li (1933) followed the analysis of Lipu Ge who provided a Cretaceous age for the sediments. But Camp (1935) restudied material initially diagnosed as Megalosauridae indet. by Louderback (1915) from the Bailiujing (now designated Daanzhai) Limestone of Rongxian Co. and believed it represented a Jurassic age. In 1941 C. C. Young published “New discoveries of Mesozoic reptiles from Sichuan,” in which he stated that from a perspective of the vertebrates, the age of the red beds in Sichuan, at least the lower section, was just as probably Jurassic as Cretaceous. That same year he correlated the red beds in the southern Weiyuan region to the northern Guangyuan region, providing them both with a Jurassic age. While C. C. Young was studying the Sichuan vertebrates, he predicted that ultimately the Sichuan Basin would be a prolific and an ideal location for the study of fossil vertebrates.

The Zhenzhuchong Formation

The Zhenzhuchong Fm. was formerly a member of the Ziliujing “Group”. Initially Heim (1929) erected the nomenclature the “Ziliujing Series” in the Zigong Co. region. Further study by Tan and Li (1933) redesignated the sediments the Ziliujing “beds” and subdivided them into the Zhenzhuchong clays, Dongyuemiao limestones, Fenbao clays, Guojiaao sandstones, Maanshan clays, Daanzhai limestones and Lianggaoshan sandstones. Jiang (1946) published “Conceptions on the boundaries of the Ziliujing beds in Sichuan” where he recognized a conglomerate overlying the Ziliujing limestone in southern Sichuan that he designated the boundary with the Chungking

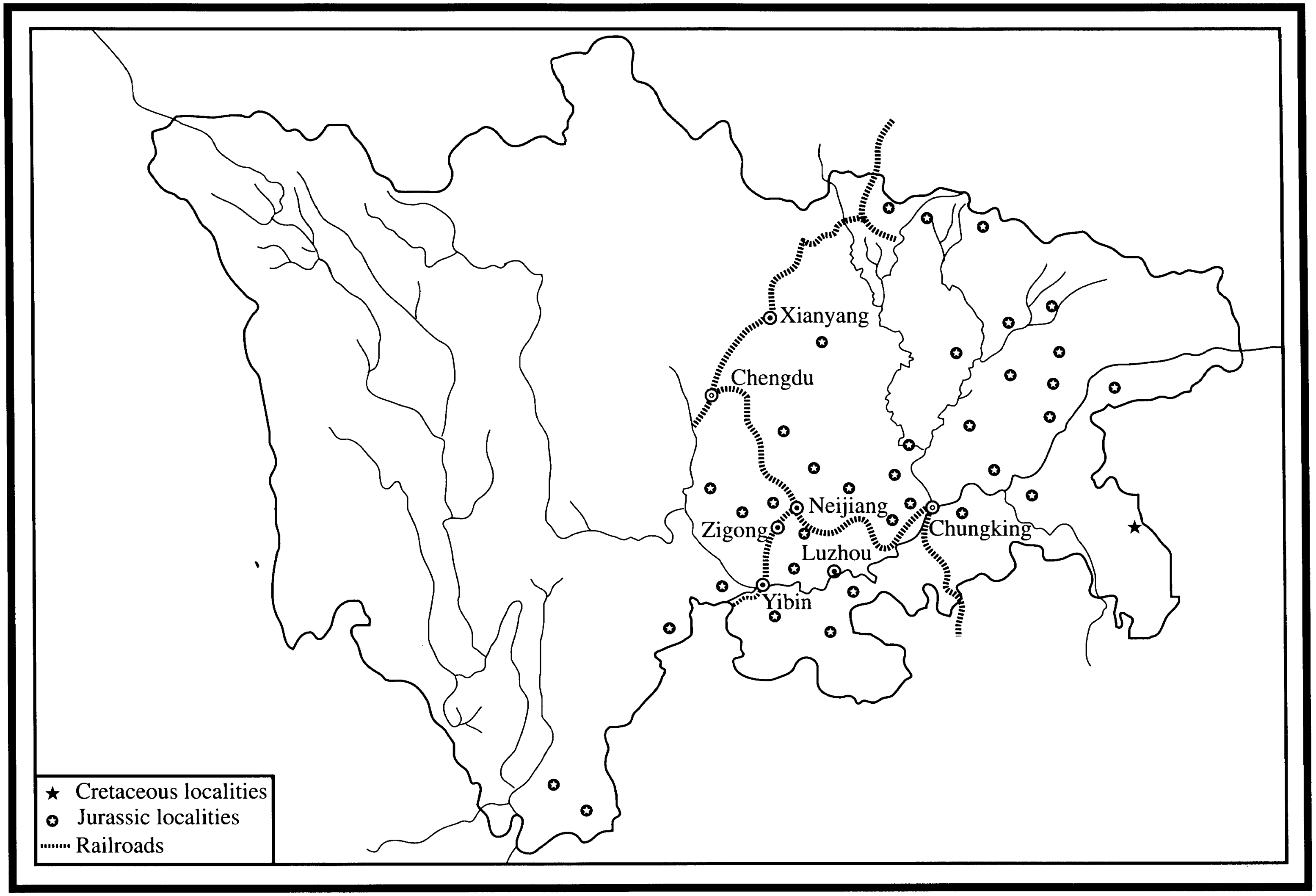

Figure 1. Distribution of vertebrate localities in Sichuan Province.

Fm. Where this conglomerate was absent he recognized the boundary at either the highest limestone or at shales that produced the pelecypod *Cyrena*. Yi (1958) noted the clear distinction between the Ziliujing and Chungking groups in eastern Sichuan, and proposed a synthesis of the Ziliujing Group restricting it to the Zhenzhuchong, Dongyuemiao, Maanshan, Daanzhai limestone, and the Lianggaoshan sandstone members.

The First National Stratigraphic Congress in 1959 witnessed the identification of a Jurassic age for the Ziliujing Group based upon bivalve biostratigraphy conducted by Zhiwei Gu, a diagnosis that has remained relatively stable. In 1972 field surveys and mapping were conducted in the Yunnan, Guizhou, Sichuan vicinity by the Tri-provincial Geologic Department. Subsequently, in 1974 the 108 Corps of the Guizhou Department of Geology made the first discovery of a Lufeng Fauna in the Zhenzhuchong Mem. in Dafang Co., which was a breakthrough for further discoveries of vertebrates and reidentified the basal age of the Ziliujing Group.

In 1978 a Symposium on the Mesozoic Stratigraphy of Sichuan addressed the problems of the Zhenzhuchong Mem. from the aspects of fossil macro plants, palynology, vertebrate paleontology (particularly dinosaur data) and lithologic character. There was agreement that this unit should be provided formational status with an age of Early Jurassic.

The Zhenzhuchong vertebrate collection made by the 108 Corps of the Guizhou Department of Geology in the Xinchang Basin, Dafang Co., was diagnosed by Chengzhi Hu of the Geological Museum as containing the prosauropod *Gyposaurus sinensis,*[*] and the poposaur *Sinosaurus* sp. In 1977 Zhengwu Cheng from the Chinese Academy of Geology collected a plateosaurid prosauropod from this formation at the Huangshiban cross-section in Weiyuan Co. In 1978 further prospecting was conduced in the Ziliujing Fm. at Hulin, Weiyuan Co. where an ungual phalanx was recovered with a size and morphology attributable to *Lufengosaurus*. This data confirms that the Zhenzhucheng Fm. produces an Early Jurassic (Rhaeto-Liassic) Lufeng Fauna.

Pollen studies undertaken by Yuanhong Bai identify a *Cyathidites undulatisportes* zone which he identified as at Early Jurassic. Fossil macro plants are dominated by the fern *Coniopteris* which is also regarded Early Jurassic.

The Lufeng Saurischian Fauna is the most celebrated dinosaur fauna in China, with its Type locality in the Lufeng Basin of Yunnan Province. Prior to his demise, C. C. Young believed that it could be correlated to the Late Triassic *Plateosaurus*-bearing Upper Keuper Fm. of southern Germany in addition to the Stormberg Group in South Africa. But most recently Xijin Zhao of IVPP has reported the occurrence of a primitive true sauropod allegedly from sediments equivalent to the Lower Lufeng Fm. in the Zhonghe Basin, Yongren Co., Yunnan. This would contradict the general assumption that true sauropods do not appear until later in the Jurassic.

Galton (1976) conducted a study of the prosauropods from the North American Newark Fm. and concluded that the Plateosauridae extend into the Jurassic. Combined with the macro-plants and pollen data in addition to the fact that the Liassic taxon *Bishanopliosaurus*[**] is derived from the overlying Dongyuemiao Mem. of the Ziliujing Fm., the Zhenzhuchong fauna is confidently recognized as Early Jurassic, or Rhaeto-Liassic.

The Ziliujing Formation

The Ziliujing Fm. currently encompasses the Dongyuemiao, Maanshan, and Daanzhai members of the former Ziliujing beds.

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[*] Galton (1976) synonymized this genus with *Anchisaurus*.
[**] In 1979 B. Halstead regarded this a synonym of *Rhomaleosaurus*.

Dongyuemiao member: This unit consists of gray, dark gray, and yellow-gray clays and silty sands interbedded with multistoried fresh-water bivalve limestones that vary in thickness from 15 to 58 meters. Bivalves are dominated by the genus *Pseudocardinia.* The plesiosaur *Bishanopliosaurus youngi* is recovered from this unit and bears a strong resemblance to the European upper Liassic *Rhomaleosaurus*. A turtle found by the Second Unit of the Sichuan Aerial Survey Corps at Hulukou in Weiyuan Co. is currently the earliest record in China for the order.

The Maanshan Member consists of gray-yellow, red, and purple mudstones interbedded with yellow-gray siltstones, sandstones, and massive sandstones with a relatively diverse fauna. Recorded are:

Sanpasaurus yaoi Young
Coeluridae indet.
Cetiosaurinae indet.
Peipehsuchus teleorhinus Young
Sinopliosaurus weiyuanensis Young
Ceratodus szechuanensis Young
Chelonia indet.

This fauna is conspicuously more derived than the underlying Lufeng Fauna from the Zhenzhuchong Fm., as it is dominated by large but primitive cetiosaurine sauropods which occur in the Early to Middle Jurassic of Europe, Australia, India, and Argentina. Late Triassic to Earliest Jurassic prosauropods are undocumented from this unit. *Peibehsuchus teleorhinus* resembles the European Early Jurassic *Teleosaurus*. Tarol (1962) studied the Chinese *Sinopliosaurus* and concluded it should be synonymized with the extensively distributed European Late Jurassic *Pliosaurus*. It is possible that this fauna is correlative to the upper dark red-beds of the Lower Lufeng Fm. based upon the aforementioned correlations and the presence of *Lepidotes* in the overlying Daanzhai Mem., which is commonly found in the Early to Middle Jurassic. The age of this unit therefore is provisionally regarded as Early Jurassic pending future confirmation. A unit of equivalent age requires documentation in the Wuding Basin of Yunnan.

Daanzhai Member: The lithologic character of this unit is laterally consistent and frequently displays an upper erosional contact at the basin margins. It consists of gray and dark gray calcareous mudstones and massive limestones bearing abundant bivalves, but occurrences of vertebrates are rare, recording only Plesiosauria indet., *Lepidotes chungkingensis* Liu and Wang, and *L. luchowensis* Wang. In 1978, Yihong Zhang collected a series of large vertebrae and a scapulae from the upper limestones at the Shejiaju coal mine, Rongjing Co. Preliminary analysis diagnoses the specimens as a moderate-sized carnosaur.

Lepidotes is globally distributed in the Jurassic. Wang (1974), who has studied this taxon extensively, believes the Chinese forms approach Early Jurassic European taxa. *Lepidotes* from the Indian Kota Fm. is found in sediments with a lithologic character resembling the Ziliujing Fm., or a potentially Early Jurassic fresh-water limestone.

The age of the Ziliujing Fm. is currently rather controversial, as bivalve and conchostracan workers recognize the age as Middle Jurassic (Gu, 1974; Deng, 1975; Zhang et al., 1976). But the vertebrates indicate a transitional nature as they are more derived than the Lufeng Fauna but more primitive than the *Shunosaurus* Fauna. The crocodiles and fish are Early Jurassic elements but the dinosaurs more closely resemble a stratigraphically higher fauna. This text provisionally regards the Ziliujing Fm. as Early to Middle Jurassic predominantly based upon the bivalve data, although in 1979 a prosauropod mandible was recovered from the Daanzhai Type section in Zigong Co., suggesting an Early Jurassic age.

In northern Sichuan, vertebrate fossils are absent from the Baitianba Fm., although the overlying Qianfoya Fm. produces a *Shunosuarus* fauna. Therefore, from the perspective of the dinosaur data it may be inferred that the Baitianba correlates to the Zhenzhuchong, the Qianfoya correlates to the Ziliujing, and that the Qianfoya encompasses the Xintiangou Fm.

The Middle Jurassic Xintiangou and Lower Shaximiao* Formations

The Xintiangou Fm. was erected in 1978 by the Synthetic Research Corps. of the Sichuan Department of Geology to replace the conceptually vague “Lianggaoshan Fm.” The nomenclature was derived from the locale of Xintiangou, Bixia, Huchuan Co. Lithology consists of predominantly yellow or gray-yellow massive sandstones interbedded with purple-red mudstones and sandy mudstones. Either a disconformable or conformable contact is noted with the underlying Daanzhai Mem. of the Ziliujing Fm., while its upper boundary is defined by the contact with the massive conglomerates in the Guankou sandstone unit of the Lower Shaximiao Fm. Vertebrate occurrences are not numerous in the Xintiangou Fm., as they consist merely of Plesiosauria indet., Cetiosaurinae indet., and Carnosauria, which conform to a *Shunosaurus* Fauna.

Formational status for the Lower Shaximiao evolved from bed status in the Chungking Group. The nomenclature was derived from the town of Shaximiao on the bank of the Jialing River, Huchuan Co. The upper boundary of the formation is recognized as the highest dark purple shale producing black conchostracans. The lower boundary is the base of the Guankou Sandstone which is composed of a massive gray-green arkosic sand. Faunal complexes within the Upper and Lower formations are completely distinct. Sheng (1962) assigned a Middle Jurassic Age to the Lower formation, correlating it to the Upper Lufeng and Zaoyutian formations in Yunnan.

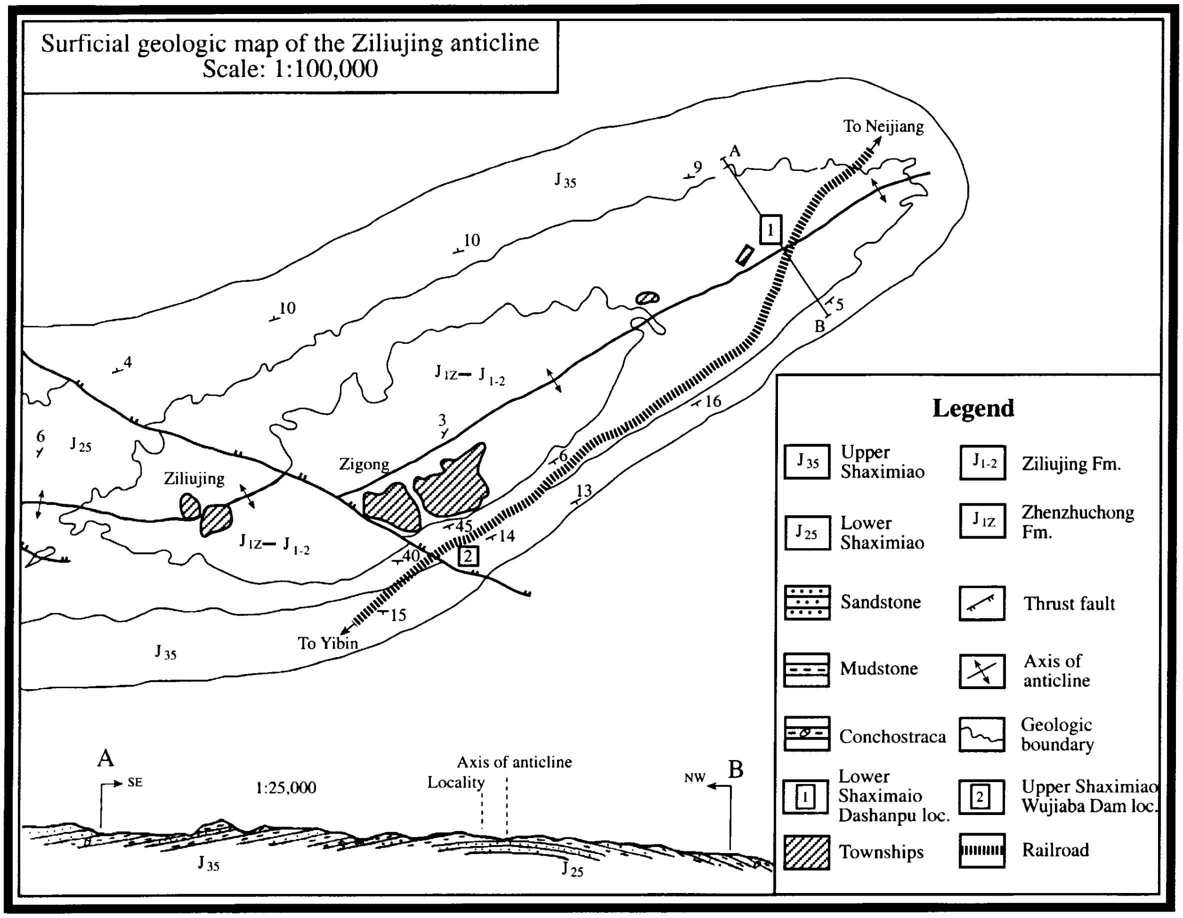
The Lower Shaximiao produces numerous dinosaur localities although currently systematic excavations are insufficient and further work is required.** Current localities include Jinji Commune, Jiangxian Co.; Luoquankai, Zizhong Co.; and Dashanpu, Zigong Co. Additionally, a tritylodontid skull resembling the genus *Bienotherium* from Yunnan was recovered by the 107th Corps of the Sichuan Department of Geology at Qilixia, Xuanhan Co. The taxonomic list from the Lower Shaximiao is as follows:

Sauropoda
    Shunosaurus lii gen. et sp. nov.
Carnosauria indet
    Coeluridae indet.
Stegosauridae
    Huayangasaurus taibaii
Ornithopoda
    Xiaosaurus dashanpuensis

Although the taxonomic record is still very incomplete, the current data suggests a unique fauna that is more primitive than the *Mamenchisaurus* Fauna and more derived than the Lufeng Fauna, although the large sauropod *Shunosaurus* retains numerous primitive characters. This fauna is hereby recognized as the Middle Jurassic *Shunosaurus* fauna.

* In some translations referred to as Xiashaximiao Fm. - wd.

** Approximately 14 tons of data were recorded from Dashanpu, Zigong Co., including sauropods, carnosaurs, stegosaurs, and turtles.



Upper Shaximiao* Formation

Exposures of the Upper Shaximiao Fm. are thicker and more extensive than the Lower formation, representing typical fluviolacustrine sedimentation with brown-yellow and purple-red mudstones intertongueing with gray and gray-white massive to moderately massive sandstones and capped by calcareous sandy mudstones. Thicknesses range from 767-2,200 m. The well-known *Mamenchisaurus* Fauna is derived from this formation and includes the following taxa:

Sauropoda
- *Omeisaurus junghsiensis* Young
- *O. changshouensis* Young
- *Mamenchisaurus hochuanensis* Young
- *M. constructus* Young

Carnosauria
- *Yangchuanosaurus shangyouensis* Dong, Chang, Li and Zhow
- *Y. magnus* sp. nov.
- *Szechuanosaurus campi* Young
- *Sinocoelurus fragilis* Young

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* In some translations spelled Shangshaximiao Fm.-wd.

Ornithopoda
Gongbusaurus shiyii gen et sp. nov.
Stegosauria
Chialingosaurus kuani Young
Tuojiangosaurus multispinus Dong, Zhow, Li, and Chang
Chungkingosaurus jiangbeiensis gen. et sp. nov.
Chelonia
Tienfuchelys tzuyangensis Young
Plesiochelys radiplicatus Young and Chow
Chengyuchelys baenoides Young and Chow
Sinospideretes wimani Young and Chow
Plesiochelys tatsuensis Yeh
Crocodillia
Hsisosuchus chungkingensis Young and Chow
Pisces
Yuchoulepis szechuanensis Su
Chungkingichthys tachuensis Su

The large sauropods *Mamenchisaurus* and *Omeisaurus* are the principle components of this fauna, which resembles the North American Morrison Fm. Fauna that produces *Diplodocus* and *Camarasaurus.* The large carnosaurs *Yangchuanosuarus* and *Szechuanosaurus* resemble the European *Megalosaurus* and North American *Allosaurus*. The well preserved *Tuojiangosaurus* and *Chialingosaurus* resemble *Kentrosaurus* from Tendaguru, East Africa. A large amount of *Plesiochelys* is produced from the Upper Shaximiao, which is also a common taxon in the Late Jurassic of Europe. The reptile fauna indicates a Late Jurassic age for the formation although paleoichthyologist Su (1974) states that the ptycholepid *Yuchoulepis* suggests a Middle Jurassic age as does its accociated bivalve assemblage. In 1965 a tritylodont skull was recovered from the Wanxian Co. region but its precise stratigraphic position was unclear. According to Kangling Deng's field observations, the specimen should have been derived from the upper portion of the Shaximiao, although some believe that it was derived from the Lower formation. If Deng is correct, then it is possible that a Middle Jurassic age may be assigned to the Upper Shaximiao *Mamenchisaurus* Fauna. This text retains the viewpoint that the fauna is early Late Jurassic.

The Suining and Penglaizhen formations

The Suining Fm. is relatively monotonous in lithology, being a set of lacustrine tan-red mudstones interbedded with thinly laminated gypsiferous siltstones. At the time of deposition the lacustrine body was relatively stable, expressing varved stratification with consistent coloration. Thicknesses range from 300-600 meters. Vertebrate fossils are currently absent in this unit with the exception of a single black caudal vertebra, which was found by Baolin Tian from the Sichuan Academy of Mines.

The Penglaizhen Fm. consists of purple red mudstones intertongueing with gray-purple and light yellow sandstones, which in some regions reach a thickness of several tens of meters. These massive sand bodies are well indurated with calcareous cement and occasionally are utilized for the production of grinding stones, millstones, or as templates for inscriptions. Exposures of this unit are less extensive than the Upper Shaximiao but in the northeast are relatively thick and often cliff forming.

Dinosaur data from this unit is extremely sparse. A small fragmentary collection was made by Xingqi Xu of the Southwestern Institute of Geology that was diagnosed by Xijing Zhao of IVPP as possibly representing the family Hypsilophodontidae. In 1978, the Chungking Natural History Museum made a collection of eight large sauropod caudal vertebrae from Santai Co. Although diagnosis is difficult due to the fragmentary nature of the specimens, and chronological

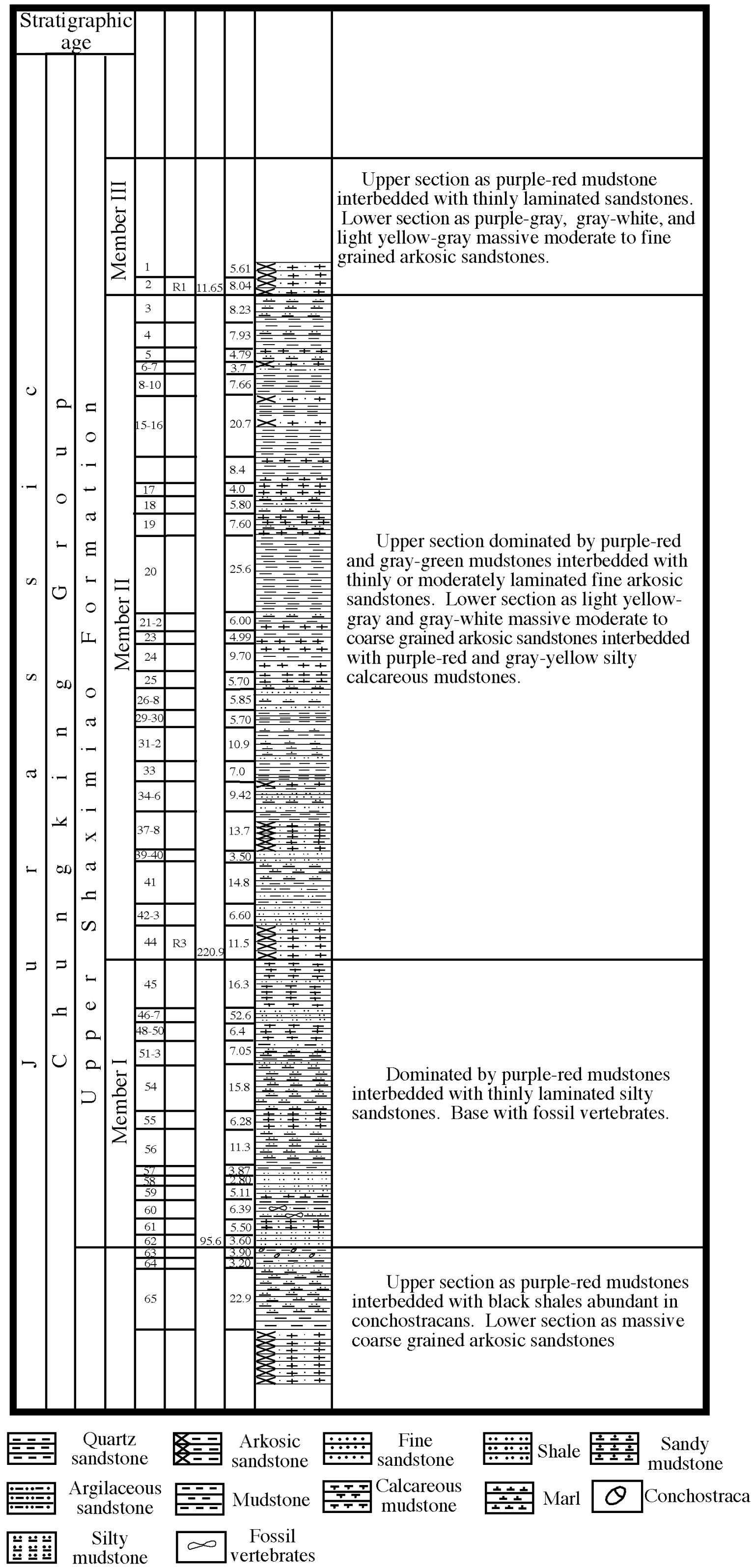

Figure 3. Generalized stratigraphic collumn representing the Upper Shaximiao Fm. at Zigong Co.

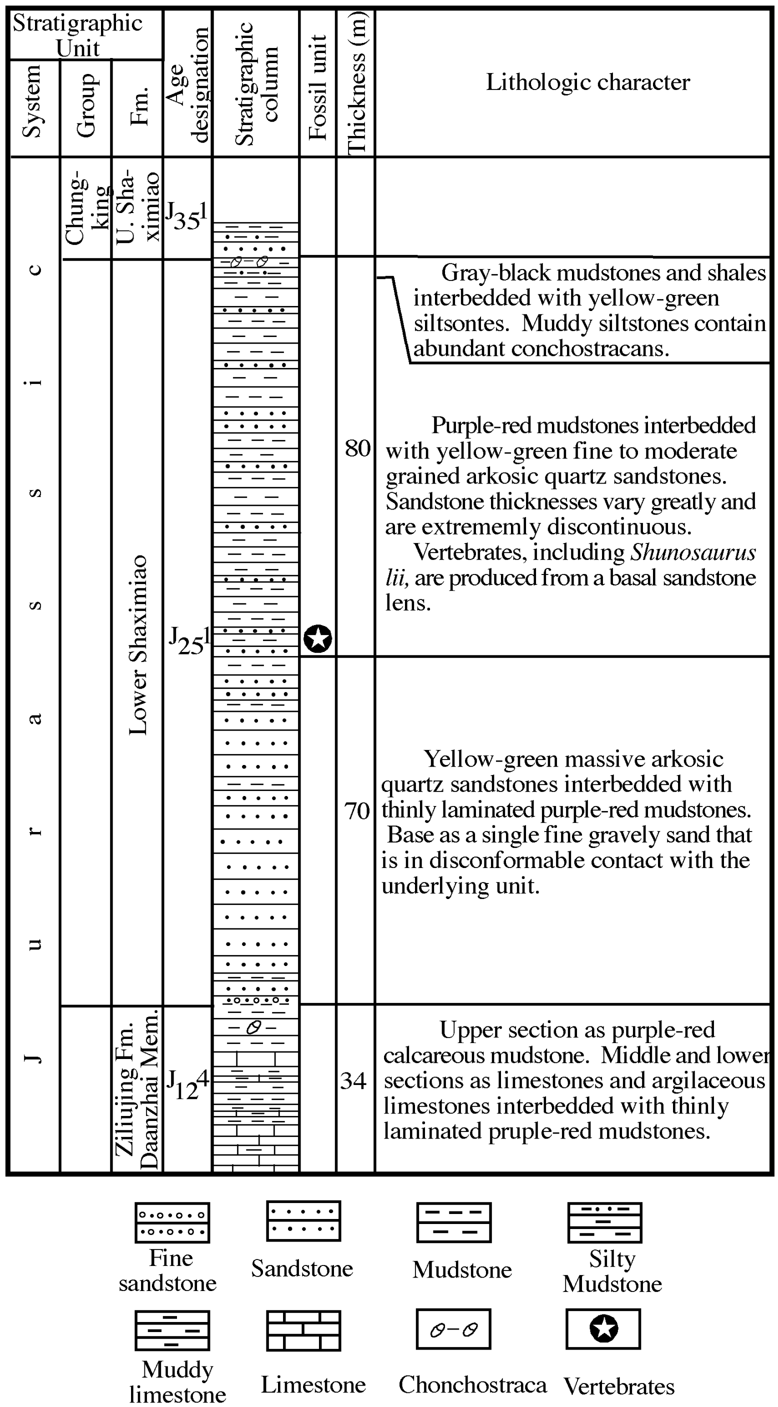

Figure 4. Stratigraphic column representing the Lower Shaximaio Fm. at Dashanpu, Zigong Co.

assessments also remain vague, the position in the stratigraphic sequence and general characteristics of the fossil data suggest a Late Jurassic age.

Synopsis

Mesozoic terrestrial sedimentation in the Sichuan basin is continuous except in several regional locations. It begins with the carbonaceous Shunjiahe Fm. and continues through the Zhenzhuchong, Ziliujing, Xintiangou, Lower Shaximiao, and Upper Shaximiao formations, with distinct stratigraphic superposition. The Late Triassic through Jurassic here is such a complete succession that it is possible to observe the phylogenetic progress of Triassic and Jurassic tetrapods and particularly the Dinosauria. Three faunas are recognized based upon the most conspicuous elements, the sauropods:

The Early Jurassic (Rhaeto-Liassic) *Lufengosaurus* Fauna in the Zhenzhuchong Fm.

The Middle Jurassic *Shunosaurus* Fauna in the Xintiangou and Lower Shaximiao fms.

The early Late Jurassic *Mamenchisaurus* Fauna in the Upper Shaximiao Fm..

Evolutionary relationships are discussed in Chapter 5.

Table 1. Stratigraphic positions of the dinosaur faunas of the Sichuan Basin.

Stratigraphic system			Weiyuan-Zigong		North Sichuan	East Sichuan	
Jurassic	Upper	J_3	Penglaizhen Fm.		Lianhuakou Fm.	Penglaizhen Fm.	Sauropoda indet.
			Suining Fm.		Suining Fm.	Suining Fm.	
			U. Shaximiao Fm.		U. Shaximiao Fm.	U. Shaximiao Fm.	*Mamenchisaurus* Fauna
	Middle	J_2	L. Shaximiao Fm.		L. Shaximiao Fm.	L. Shaximiao Fm.	*Shunosaurus* Fauna
			Xintiangou Fm.		Qianfoya Fm.	Xintiankou Mem.	
	Lower	J_{1-2}	Ziliujing Fm.	Daanzhai Mem.		Daanzhai Mem.	Cetiosauridae indet *Sanposaurus yaoi* *Bashanpliosaurus youngi* *Sinopliosaurus weiyuanensis* *Peipehsuchus teleorhinus*
				Maanshan Mem.		Maanshan Mem.	
				Dongyuemiao Mem.	Baitianba Fm.	Dongyue miao M.	
		J_1	Zhenzhuchong Fm.			Zhenzhuchong Fm.	*Lufengosaurus* Fauna
Tr.		T_3	Shunjiahe Fm.		Shunjiahe Fm.	Shunjiahe Fm.	

III History of dinosaur research in the Sichuan Basin

Historical records dating back to antiquity note the discovery of dinosaur bones in the Sichuan Basin,* although most accounts such as these are legendary and spread among local inhabitants.

The earliest documented paleontological records are recorded by the American geologist E.D. Louderback (1935) who conducted a reconnaissance in approximately 1915 in the Rongxian and Weiyuan regions where he collected a dinosaur tooth and fragmentary femur from atop a sandstone cliff southeast of the city of Rongxian (perhaps six km according to his personal estimation). The fossil locality is recorded as Guandaopang in the Ziliujing vicinity. Specimens were collected and sent to the Museum of Paleontology, University of California, Berkeley, where they were studied by C.L. Camp (1935), who diagnosed both specimens as belonging to a single individual of carnosaur. His cursory observation further led him to identify the femur as belonging to the Megalisauridae and as such, he diagnosed the age of the sediments to be Jurassic. He further called attention to the profession that the specimens were an extremely significant find as the Sichuan Basin, in the hinterlands of Southeast China, was the site of extensively distributed productive Mesozoic red-beds that contained large tetrapods and dinosaurs.

Concurrently, C. C. Young reported several reptile teeth and fragmentary bones from the Beibei region of Chungking. Wenhao Weng provided stratigraphic information on the fossil locality and confirmed that it was derived from the Ziliujing Group. A detailed analysis was not conducted by Young due to the fragmentary nature of the specimens, although it was sufficient to confirm the presence of dinosaurs.

In 1936 both Young and Camp pooled resources for an expedition where they noted several fragmentary bones atop the small mound called Xiguashan at Dongmenwai (outside of the east gate), Rongxian Co., and after a preliminary excavation they determined that it was a relatively complete skeleton of a sauropod. Subsequently, a systematic excavation was undertaken and in its published description was erected as *Omeisaurus junghsiensis* (Young, 1939).

Between 1939-1940 Professor Xixin Yue conducted geological investigations in regions including Rongxian and Weiyuan counties, where he made a collection of fossil vertebrates from the Changling region north of the village of Puziwan which itself is approximately 4 km northeast of Weiyuan. This collection was initially studied and described by C. C. Young, but during transportation to his laboratory the labels from the Yue collection were mixed with those from a locality called Xindianzi which lay between the Changling and Puziwan localities. As a result Young (1941) described a primitive ornithischian *Sanpasaurus yaoi* which was the first description of a Jurassic ornithischian in Asia.

In 1941 C. C. Young, Meinian Bien, and Hengtai Mi conducted research on the Mesozoic stratigraphy of northern Sichuan, during which they made a collection of vertebrates. Young (1942) published upon this collection from the Guangyuan region and correlated sediments to the Weiyuan region based upon the vertebrates, suggesting that the sediments from the northern and southern regions of the Basin were completely correlative. His taxonomic lists are as follows:

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* Annals of the Kingdom of Huayang (347 AD) records the presence of "dragon bones" during the Han Dynasty (206 BC-220AD) in the current Santai region of northern Sichuan.

Guangyuan	**Weiyuan-Rongxian**
Hybodus sp.	-------------
Ceratodus szechuanensis	*Ceratodus* cf. *szechuanensis*
Ganoid indet.	*Lepidotus minor* Ag.
Sinocoelurus fragilis	Coeluridae indet.
Chienkosaurus ceratosauroides	?
cf. *Omeisaurus junghsiensis*	*Omeisaurus junghsiensis*
Szechuanosaurus campi	*Szechuanosaurus campi*
-------------	*Sinopliosaurus weiyuanensis*
Chelonia indet.	Chelonia indet.

The three paleontologists published their findings (Young et al., 1943) whereupon they addressed the problems of the Mesozoic red beds in northern Sichuan and suggested that they were predominantly Jurassic in age or correlative to the Donghe Group on the northern flanks of the Qinling (formerly Tsinling) Mts. and in Gansu Province.

During the over thirty year period from 1915 to the eve of the establishment of the People's Republic, stringent paleontological work had been conducted in the Sichuan Basin but results were meager. Under the traditional Chinese feudal system the concept of paleontology, and particularly the existence of dinosaurs, was kept an enigma among the populace. Moreover, the basin lies in the hinterlands of the country and communication and transportation systems were primitive such that it was essentially cut off from the outside world. The local populace was ignorant to the scientific value of dinosaurs and specimens exposed on the ground were frequently referred to as "dragon bones," only to became pulverized and sold to local pharmacies. The climate was generally not conducive to scientific methodology. During this period only five dinosaur taxa were known from the Sichuan Basin:

Omeisaurus junghsiensis Young
Szechuanosaurus campi Young
Chienkosaurus ceratosauroides Young
Sinocoelurus fragilis Young
Sanpasaurus yaoi Young

Diagnoses of these taxa were based upon single or several isolated teeth, with the exception of *Omeisaurus.* This deficiency of data was cause for difficulties and error in the past. For instance, the most recent reevaluation of *Chienkosaurus* indicates that three of the four dental specimens actually belong to *Hsisosuchus* while the fourth tooth is a premaxillary tooth of a carnosaur.

One year after the establishment of the People's Republic, a new era began for the population of Sichuan with an upsurge in large-scale construction projects. During the repair and rebuilding of the communications network around Chungking, there were numerous workers both in railroad and highway construction who discovered fossil vertebrates that eventually were accessioned for diagnosis by the Chungking Municipal Academy of Natural Sciences (the forerunner to the Chungking Natural History Museum). This institute was later merged with the Cenozoic Research Laboratory, Academia Sinica (the forerunner to the Institute of Vertebrate Paleontology and Paleoanthropology). The fossil collection during this period included very good specimens of Chelonia, Crocodilia, and dinosaurs (Young, 1953).

In 1953 road construction began in the Mamenxi region along the bank of the Yangzi River, during which time a large sauropod was discovered. The specimen was collected by the

Yibin Municipal Cultural Office and subsequently shipped overland and by waterway to Beijing. This was the Type specimen of *Mamenchisaurus constructus*, its nomenclature commemorating the construction project that unearthed the specimen (Young, 1954).

In 1955 Xuanmin Li and others collected several large sauropod vertebrae and limb elements from around the headquarters of the Shizitan Reservoir, Changshou Co. The following year IVPP dispatched Youling Su to conduct an excavation at the site but he was only able to make cursory collections as the filling of the reservoir had already commenced. This collection thereby represents the Type specimen of *Omeisaurus changshouensis* (Young, 1958).

In 1956 the Sichuan Petroleum Exploration corps discovered the locality for *Mamenchisaurus hochuanensis* on Guloushan Mt., by Taihezhen Village on the bank of the Fujiang River in Hechuan Co. The Sichuan Museum of Natural History was informed and it subsequently dispatched Dakang Zhu to conduct a legitimate and detailed excavation along with Xuanmin Li and Yanwan Gong from the Chungking Museum of Natural History. It took three months to collect what is now the largest and most complete sauropod skeleton in China. The specimen was relocated to the Chengdu Academy of Geology, then in 1964 to the IVPP preparation labs for preparation and mounting. Currently, this specimen is on exhibit at the Chengdu Academy of Geology.

The first stegosaur recovered from the Sichuan Basin was *Chialingosaurus kuani* (Young, 1959) which was collected by Yuewu Gan at Pinganxiang, Quxian Co. It is a genuinely valuable diagnostic taxon for the entire Asian region.

The continuous discoveries of dinosaurs in the Sichuan Basin attracted paleontological attention both locally and globally as localities increased annually. Currently there are over 40 sites (Fig. 1) covering nearly the entire basin. With such an abundance of localities it has become impossible to conduct systematic excavations, and thus, comprehensive data and sufficient time for development of the sites are lacking.

In 1974 the Chungking Natural History Museum, with the assistance of personnel from the Zigong Museum of the Salt Industry and others from the municipality of Zigong, conducted a systematic excavation in the region of Wujiaba Dam, Zigong Co. The quarry is confirmed to lie at the base of the Upper Shaximiao Fm. approximately 15 m above a conchostracan-bearing shale (Figs. 2 & 4) and consists of a concentration of well-preserved animals of various orders that currently represents the most abundant Jurassic dinosaur producing locality in China in addition to being world renowned. To date, the quarry records twelve individuals of large sauropods with elements sufficient for two composite semi-complete mounts, two stegosaurs representing *Tuojiangosaurus multispinus* mounted for exhibit, a carnosaur mounted for exhibit, and a number of fragmentary enigmatic specimens. The quarry has yet to be exhausted and specimen descriptions are a major objective of this text.

Carnosauria are not well preserved among the Dinosauria such that the description of a complete skull is a major professional objective. In June of 1977 a carnosaur was discovered by Sinung Chen, the leader of the Daba Reconstruction Public Works Corps during the process of renovating the Daba Dam at the Shanyou Reservoir, Youngchuan Co. A relatively complete specimen was collected by Yihong Zhang of the Chungking Natural History Museum and later described as *Yangchuanosaurus shangyouensis* Dong, Chang, and Zhow.

Former Sichaun Basin dinosaur localities were noted from the Upper Shaximiao Fm. and the Maanshan Mem. of the Ziliujing Group. with relatively little data known from the Lower Xiaximiao Fm. It is only recently that new material has come to light. In 1969 Changji Tang from Jinji Commune, Jiangxian Co., mailed a package of fossils to IVPP that consisted of a sauropod caudal vertebra and a spoon-shaped tooth which was later confirmed to be derived from the Lower

Xiaximiao Fm. This locality is a significant contribution to the *Shunosaurus* Fauna and has been subsequently excavated by Xinlu He and Daizong Yao from the Chengdu Academy of Geology, but to date the specimen is undescribed, although this text believes it should be assigned to the cetiosaurine sauropods.

In 1977 a Sichuan Provincial Paleontological and Archeological Preservation Training class, hosted by the Zigong Museum of the Salt Industry, collected a large sauropod from a road cut at Dashanpu (Fig. 4). Mr. Peijie Zhuang from the Seventh Survey corps of the National Geologic Office provided a cross section of the locality (Fig. 4). This specimen became the Type for *Shunosaurus.*

Currently, there are 20 dinosaur taxa recorded from the Sichuan Basin spanning the Early to Late Jurassic and representing nearly all the orders of Jurassic dinosaurs. Geographically the localities are extremely widespread and occur at over 40 sites suggesting bountiful prospects for future work in the Jurassic of the Sichuan Basin.

Specimens described in this text are housed in the following institutions:

The Institute of Vertebrate Paleontology and Paleoanthropology, Academia Sinica (IVPP)

The Chungking Natural History Museum (CV)

The Zigong Museum of the Salt Industry (ZV)

IV Descriptions

The Zhenzhuchong Fm. in the Sichuan Basin produces a Lufeng Saurischian Fauna, the principle element of which is the Prosauropoda. In 1978, an ungual phalanx assigned to this order was collected by the Hulin Production Brigade of Huangshiban Commune, Weiyuan Co. A concise description is provided below:

Saurischia Seeley, 1888

Sauropodomorpha Huene, 1932

Prosauropoda Huene, 1920

Plateosauridae indet.

(Plate III, Fig. 1; Text Fig. 5)

Diagnosis: 5.4 cm of a typical prosauropod ungual is preserved.

Specimen: An incomplete right posterior ungual phalanx from digit II (IVPP V9069).

Locality and stratigraphic position: Early Jurassic (Rhaeto-Liassic) Zhenzhuchong Fm. at Hulin, Huangshiban Commune, Weiyuan Co.

Description: A typical 5.4 cm prosauropod ungual is missing its distal end which perhaps was lost prior to preservation. The element has a a groove running laterally along the gentle curvature of each side. Posteriorly, two smooth concave articular facets are present which are of equivalent depth and are separated by an extremely small medial ridge. The element is relatively thick, robust, and differs distinctly from the laterally compressed unguals of theropods.

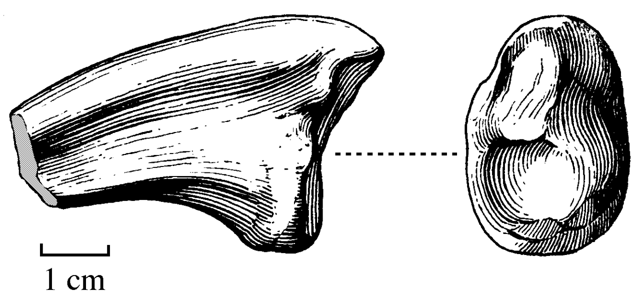

Figure 5. Palteosaurid ungual from the Zhenzhuchong Fm. of Huangshiban, Weiyuan Co.

Discussion: The two lateral grooves on specimen V9069 are asymmetrical, the lateral side is relatively convex with a gentle curvature, and the element is basically thick and robust, easily distinguishing it from the laterally compressed unguals of theropods. Although the terminal end is missing, its cross-section suggests it was a rounded apex which also distinguishes it from the laterally compressed ornithischian morph and later true sauropods. The shallow asymmetrical lateral grooves indicate it is from the second right digit. Its morphology and size are extremely close to *Lufengosaurus.*

Prosauropod taxonomy has recently undergone relatively serious revisions. Galton (1976) reevaluated North American prosauropod data and recognized two groups: the slender-footed Anchisauridae, which includes a number of rather small genera, and the broad-footed forms, which are relatively large, cumbersome, and dominated by the family Plateosauridae. As the Weiyuan specimen is relatively robust, it is diagnosed as representing the broad-footed category with a morphology resembling *Lufengosaurus.* Due to the limited nature of the data, however, diagnosis to a higher rank is impossible and it is provisionally referred to Plateosauridae indet.

Sauropoda Marsh, 1878

Camarasauridae Cope, 1877

Cetiosaurinae indet.

(Plate III, Figs. 2-6)

Diagnosis: A moderate sized sauropod with opisthocoelous cervical vertebrae, amphiplatyan dorsal vertebrae, and solid anterior sacral centra or lacking an interior honeycombed structure. Cervical centra are one and a half times the length of the dorsal centra.

Material: A dorsal and caudal vertebra, femur, and phalanx (V9070.1-4).

Locality and stratigraphic position: Early Jurassic Maanshan Mem., Ziliujing Fm. at Shiziling Tiefo, Zizhong Co. and Hulukou, Huangshiban Commune, Weiyuan Co.

Description: Specimen V9070.1 from Weiyuan Co. is a typical amphiplatyan sauropod dorsal vertebra with very slightly concave ends that lacks pleurocoels. In cross-section the centrum does not exhibit the honeycombed structure of presacral centra observed on later sauropods. Both neural arch and spine are not preserved, and centrum height and length are equivalent, which differs from the proportionally longer dorsal centra on prosauropods.

Specimens 9070.2 are three amphicoelous anterior caudal vertebrae that may belong to the same individual as 9070.1 based upon degree of mineralization and coloration. Centra are proportionally higher than long with diapophyses extending dorsolaterally from the dorsal centra.

The mineralization and coloration of the femur (V9070.3) resemble the caudal vertebrae such that it is regarded as undoubtedly from the same individual. The shaft is straight and oval in cross-section, with a proximal head that is generally well developed but lacks a femoral neck. The lesser trochanter is located laterally and relatively low, the fourth trochanter is a crest that is situated posterodorsomedially one-third down the shaft, and the two distal condyles are equivalent in size with a relatively deep notch between them.

The single phalanx (V9070.4) is relatively long and flattened with coarsened proximal and distal articular surfaces. It should represent an anterior limb element based upon the curvature of the shaft.

Discussion: These specimens from the Maanshan Mem. of the Ziliujing Fm. exhibit some prosauropod characters. A detailed comparison indicates symplesiomorphies such as unhoneycombed centra with simple morphology, and amphiplatyan dorsal centra lacking pleurocoels. However, dorsal vertebrae height/length proportions are equivalent, caudal centra are amphiplatyan and oval, and femur is straight, rather than curved, with a compressed shaft, which clearly differs from the prosauropods and more closely resembles the Sauropoda. Early cetiosaurine sauropods possess unhoneycombed presacral centra lacking pleurocoels and straight femora with an undeveloped femoral head. These characters are also shared with *Shunosaurus* from the Middle Jurassic Lower Shaximiao Fm. Consequently the aforementioned specimens are regarded as belonging to a true cetiosaurine sauropod. Currently this family is restricted to the Early to Middle Jurassic, although data is rather fragmentary. As the Maanshan Mem. specimens are also depauperate, a further diagnosis to higher rank is not possible here. Further discoveries are required for supplemental work.

Cetiosaurinae Janensch, 1929

***Zizhongosaurus* gen. nov.**

Genus diagnosis: As for species.

***Zishongosaurus chuanchengensis* gen. and sp. nov.**

(Text Figure 6)

Etymology: "Zizhong," Pinyin romanization for the county that produced the specimen and "saur", Greek for reptile. "Chuancheng," Pinyin romanization for the name of a local town (translated as "Boat City") which is on a small mountain named Yuezhongloushan that resembles a boat, and as such the people of the municipality of Zizhong refer to it as Chuancheng.

Diagnosis: A small primitive sauropod with relatively long anterior limbs, humerus with a straight and rounded shaft and dorsal vertebrae with a high neural spine with an apex as an expanded plate that descends slightly anteriorly and is concave posteriorly. Lateral spine surface is ornamented with dorsally radiating vertical striations and the diapophyses are well developed to form a right angle with the neural spine at the neural arch. A hyposhpene is present.

Specimens: A complete dorsal neural spine, a right humerus, a pubis, and several other fragments (V9067.1-3).

Locality and stratigraphic position: From a purple-red mudstone (Xintiangou Fm.?) approximately 15-20 m above the Daanzhai Limestone Mem. at Luochuanjing, Zizhong Co.

Description: V9067.1 is a relatively well preserved long piece of dorsal spine that broadens gradually from the neural arch to its apex where it reaches its maximum breadth. This spine lacks laminae and is simple in morphology, with a flat anterior margin and an apex that is slightly higher at its midpoint and a posterior margin that is concave. Vertically radiating striations ornament the lateral surface. This is an extremely characteristic neural spine and unlike the plate-shaped spines on prosauropods or sauropods. A relatively robust right diapophysis is completely preserved and extends perpendicularly from the base of the spine to terminate as a spoon shaped expansion.

V9067.2 is a partial shaft of a right humerus with its proximal end from the same individual. The shaft is straight and round with a weak triangular ridge on its proximolateral side that resembles a flattened triangular winged process. This resembles the prosauropod condition and differs only in its straight shaft.

V9067.3 is an incomplete piece of pubis that it is relatively thin and flat and resembles the true sauropod condition.

Discussion: Although specimen V9067 is extremely fragmentary, the characteristic dorsal spine and humerus lead the authors to believe this is a derived taxon, for the dorsal spine is high, wide, and there is a right angle with the diapophyses. This is clearly distinct from a prosauropod, the laminar theropod morphology, or ornithischian morph, and more closely approaches a high-spined sauropod. Dorsal spine morphology in derived sauropod taxa is complex, with individual variation spread between each vertebra. However, derived spines are all supported by several specific buttresses and are clearly distinct from V9067. Prosauropod anterior dorsal spines are expanded and rod-shaped while the posterior spines are high longitudinal plates, both of which are distinct from V9067. Although this specimen does maintain a relatively primitive humerus with a straight shaft that is round in cross-section, its compressed pubis is typical of a true sauropod.

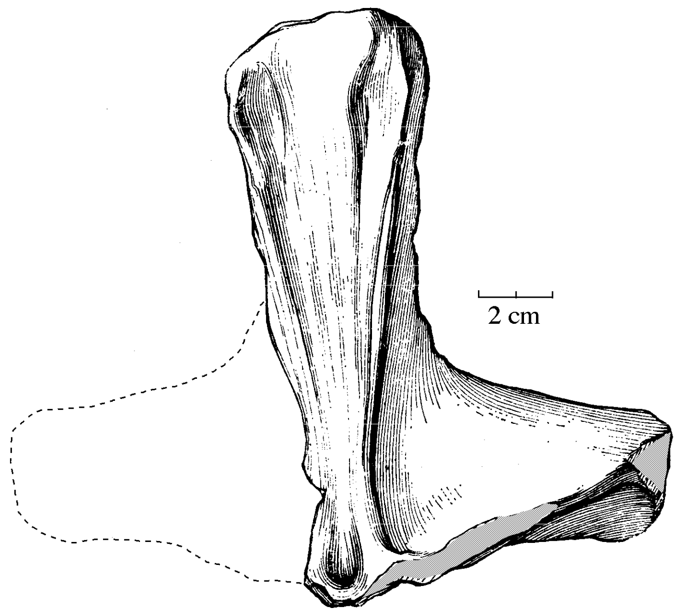

Figure 6. Dorsal spine of *Zizhongosaurus chuanchengensis* gen. and sp. nov. (x 1/2).

Consequently, a combination of the primitive humerus and derived dorsal spine influences the authors to erect the new taxon *Zizhongosaurus chuanchengensis* gen. and sp. nov., which is provisionally regarded a cetiosaurine. Although supplementary data is required for a more thorough understanding of the genus, its primitive characters imply an Early Jurassic chronology and hence the purple sediments overlying the Daanzhai Limestone are reasonably assigned this age.

Shunosaurus gen. nov.

Diagnosis: As for species.

Shunosaurus lii gen. and sp. nov.

(Plates IV-VI, Text Figs. 7-12)

Etymology: “Shu,” Pinyin romanization for the ancient abbreviation of Sichuan Province and “saur,” Greek for reptile. Species etymology: Pinyin romanization for the surname Li, in commemoration of the hydrologist Bing Li, the magistrate who governed what is now Sichuan Province (256-251 BC) for the state of Qin during the Warring States Period. He was particularly celebrated for his flood control measures along the Minjiang River which included the construction of the famed Dujiang dike and irrigation system that are still functioning today.

Diagnosis: A moderate-sized primitive sauropod, with a body length that may attain 11 m, and a skull that is moderately high with spoon-shaped teeth. Cervical and dorsal vertebra are solid and anterior sacral centra are also unhoneycombed. The neck is short with shallowly opisthocoelous vertebrae and weak anterior condyles. The cervical centra maintain a long pleurocoel which shallows anteroposteriorly. Neural arches are low and lack laminae, while neural spines are simple in morphology and gradually increase in height and length posteriorly. The apices of the last several neural spines are incised with a deep groove suggesting incipient bifurcation.

Dorsal vertebrae are weakly amphicoelous although the last several centra are nearly opisthocoelous. Neural spines are high while neural arches lack any laminar support. Anteroposteriorly, the spines gradually become elongated but neural arch morphology remains simple. Anteriorly, the spines are rod-shaped while posteriorly they become plate-shaped. Robust diapophyses are positioned on the neural arch at the base of the spine, are triangular, and extend slightly dorsally. A hyposphene is present.

The pelvic girdle is robust with a high and long ilium that has a well developed pubic peduncle. There are four fused sacral vertebrae with sacral ribs fused to the diapophyses to compose a yoke-shaped contact with the large ilium. The pubis has a large enclosed obturator foramen and, like the ischium, is straight and compressed.

The anterior limbs are relatively long with a straight radius and ulna. The femur is straight with a shaft that is elliptical in cross-section and all of the trochanters are generally relatively well developed. The tibia is thick with a well developed calcaneal process. The fibula is straight with a round shaft. Digits are robust with five complete and well developed metatarsals. Cervical to dorsal centra proportions are 1 1/2 - 1 2/3. Tibia length is two-thirds that of the femur. Vertebral count is cervical 12-13, dorsal 13, and sacral 4.

Specimens: An incomplete skeleton is composed of five cervical vertebrae, 13 articulated dorsal vertebrae, a fragmentary sacral centrum, and two caudal vertebrae. The anterior limbs only preserve a left radius, ulna and a single carpal. The ilium, ischium, and pubis are present although weathered and fragmentary. The left hind limb preserves complete femur, tibia, fibula, astragalus and complete metatarsals although all but several phalanges are absent (V9065.1-23).

Locality and stratigraphic position: Middle Jurassic Lower Shaximiao Fm., at Dashanpu, in the vicinity of Zigong (Fig. 2).

Description: Specimen V9065 lacks a skull and the axial skeleton is incomplete such that an accurate count of cervical and sacral vertebrae is not possible. However, its several symplesiomorphies shared with the Prosauropoda, such as the simple structure of cervical centra, implies that the neck was not long. Consequently, this underived form is estimated to share a cervical count approaching the prosauropods of 12-13. Sauropods generally maintain a count of 25 presacral vertebrae such that if the presumed cervical estimate is accurate, the preserved 13 articulated vertebrae should represent the complete dorsal series. Four sacral vertebrae are undoubtedly present on the basis of the articular nodes on the medial ilium.[*]

Five cervical vertebrae are preserved, among which specimens V9065.2 (Fig. 7) and V9065.3 are relatively well preserved. The remaining cervical specimens only preserve fragmentary centra. The centra are shallowly opisthocoelous (Pl. 4, Figs. 1-3) with a rather undeveloped anterior condyle. The centrum is solid and gradually lengthens along the column anteroposteriorly to reach a maximum length at the midpoint of the series before beginning to

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[*] A later 1979 excavation confirmed the presence of four fused sacral vertebrae in addition to a count of 42±3 caudal vertebrae with bifurcated haemal arches in its medial section.

undeveloped anterior condyle. The centrum is solid and gradually lengthens along the column anteroposteriorly to reach a maximum length at the midpoint of the series before beginning to gradually shorten and increase in height. This trend is common in all sauropods. In the extremely long neck of *Mamenchisaurus* the largest cervical is number Cv11, on *Omeisauris* the largest is Cv9 or Cv10, and on V9065 after comparison of the preserved cervicals and consideration of the inferred cervical count, specimen V9065-3 is the largest vertebra and hereby believed to represent CV7.

A cervical ventral keel is present that is well developed anteriorly but diminishes posteriorly to become nearly lost, while a long and deep pleurocoel is present laterally that is simpler in morphology than in *Omeisaurus* as it totally lacks laminae. Its distinct presence indicates that strong accessory musculature was present which further implies that the cranium of *Shunosuarus* was relatively heavy and that it should belong to the high-skulled forms. The presence of spoon-shaped teeth also confirms this hypothesis.

Specimen V9065.2 preserves a complete cervical centrum and neural arch although the dorsal spine is missing. It is extremely shallowly opisthocoelous with an undeveloped anterior condyle which lacks a demarkation line between it and the centrum. This character distinguishes it from *Euhelopus* which displays a semi-spherical anterior condyle, and *Mamenchisaurus* and *Omeisaurus,* which maintain distinct demarcations between their anterior condyles and centra. The centrum is medioventrally constricted with a slight saddle-shaped dorsal curvature. A long and deep pleurocoel nearly penetrates the lateral wall to create a ventral ridge which runs parallel to the ventral keel, both of which form two laminar planes separated by an approximately 45° angle. The ventral keel and lateral laminar ridge are also characteristic of prosauropods and may be regarded as plesiomorphic. Both *Omeisaurus* and *Mamenchisaurus* lack a keel and have planar ventral cervical centra.

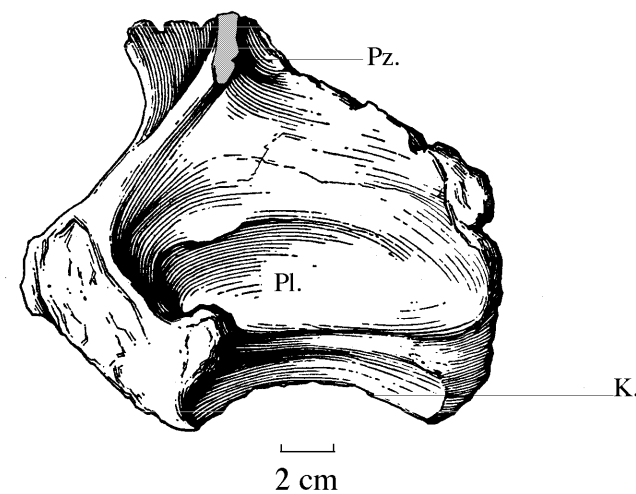

Figure 7. Cervical vertebra V9065.2 of *Shunosaurus lii* gen. et sp. nov.

Parapophyses are present anteroventrally as rounded articular nodes and the neural arch is low with a relatively simple morphology. With the exception of a small anteroventral prezygapophyseal ridge there are no other notable laminae (Fig. 7). The prezygapophyses extend directly anteriorly to reach the longitudinal plane of the anterior condyle. The neural spine is assumed to have been long, low, and of a simple morphology, deduced from what is preserved of its base as there are no supporting buttresses or laminae as in later sauropods

Specimen V9065.3 is preserved more completely than V9065.2, with a pieces of cervical rib still attached and the neural arch and spine relatively well preserved. Its morphology resembles the vertebra previously described, though the former is more robust and the latter has a weaker ventral keel and pleurocoels. Centrum length is 23 cm, being the largest among the five specimens, and as such probably represents Cv7. The anteroventral half of the neural spine is preserved indicating a long element with a deep groove running along the dorsal neural canal which gradually opens posteriorly and subsequently determines the separation of the postzygapophyses. This groove is a clear indication that the posterior cervical vertebrae of *Shunosaurus* and primitive sauropods have an incipient tendency to become bifurcated, a character that was previously unreported in primitive cetiosaurine sauropods. The attached ribs are fragmentary but their proximal ends are well preserved with a triangular shaft, symmetrical capitulum and tuberculum, and a short lancelet anterior processes.

Although several of the anterior elements are damaged due to weathering, a string of 13 articulated dorsal vertebrae are present which should represent the entire series because no dislocation is observed. The most posterior vertebra is in contact with the pelvic girdle. From a perspective of the entire series, distinctions between the cervical and dorsal morphology are conspicuous. The dorsal vertebrae are amphicoelous, short, and high with a tall neural arch and spine, and lack pleurocoels or a ventral keel (Pl. 5, Figs. 1,2). Morphologic variation is conspicuous along the vertebral sequence, but the column may basically be divided into an anterior and posterior series. The anterior series includes the thoracic dorsals which are amphicoelous with relatively small and compressed centra. Although ventrally there are no laminae, the ventral margin is relatively thick and well defined. Posteriorly along the column, the neural spines increase in height into the form of a rod and are anteriorly projected, posteriorly embayed, and have an acute apex. The centra increase in size anteroposteriorly with D12 and D13 being the largest and becoming nearly opisthocoelous, accompanied by neural spines that differ from the anterior series by being more elongated, including their apices. Selected vertebrae will be described below:

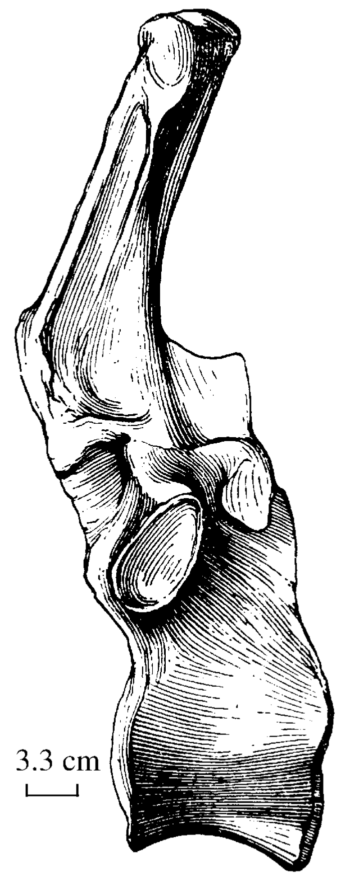

Figure 8. Dorsal vertebra of *Shunosaurus lii* gen. and sp. nov.

The nearly completely preserved specimen V9065.10 is recognized as D5 with an amphicoelous centrum lacks any internal honeycombed structure. The centrum is laterally compressed and lacks pleurocoels but possesses a depression dorsolaterally. The neural arch is high and fused tightly to the centrum. Weak laminar ridges are present on the plate-shaped arch. A laminar ridge is also present ventral to and connects with the parapophysis, which is located anterodorsally as a large elliptical articular node. The dorsal spine is high and rod-shaped, being anteriorly convex with a lateral laminar ridge on each side. At its midpoint is a thick projection with a rough surface from which small radiating laminae extend to a constricted and relatively acute apex. Posteriorly, this vertebrae has a deep concavity with two thinly laminated winged margins that open spaciously. Robust triangular diapophyses are located on the dorsal neural arch. The anterior edge of the diapophysis is convergent with the ventral side of the prezygapophysis, the ventral edge is convergent with the ventral lamina of the postzygapophysis, and the posterior edge is convergent with the dorsal lamina of the postzygapophysis. The distal end is thick with a smooth and glossy articular surface for the rib. A shallow depression lies dorsally on the lower lamina.

V6095.15 is recognized as D10. It is larger than the previously described vertebra, nearly opisthocoelous with a round centrum, and is not laterally compressed. The morphology of the neural arch resembles that of V6095.10 and only differs in the height and length of its spine. The anterior spine is convex with an anteroposteriorly expanded apex. A deep posterior reentrant extends dorsally to the expanded apex. The prezygapophyses are large and flat with dorsally directed articular surfaces. The postzygapophyses are proximal to each other, triangularly shaped, and extend posteriorly beyond the centrum body. Parapophyses are present ventrally. Diapophyses resemble those of V6095.10 and are slightly different from those on *Omeisaurus* and *Mamenchisaurus* which are extended horizontally but on this specimen they are slightly dorsally oblique.

No complete dorsal ribs are preserved. A thick spherical tuberculum is present with a wide angle separating it from the compressed capitulum. The rib shaft is triangular in cross-section and the distal end is thin and flat, resembling the typical sauropod condition.

The articular nodes on the ilium indicate the presence of four sacral vertebrae, but only the first sacral vertebra is preserved (V6095.19), with its right side tightly fused to the preacetabular process of the ilium. The sacral centrum is incomplete and its morphology is vague. Furthermore, the neural arch cannot be described as it is obscured by the massive yoke-shaped process consisting of the fused diapophysis and sacral rib which are in firm contact with the medial ilium.

Two amphicoelous caudal vertebrae are present which resemble the typical sauropod condition.

None of the pectoral girdle is preserved and the forelimb only preserves the right ulna, radius, and a weathered carpal. The radius and ulna are parallel and nearly equivalent in thickness and length. The ulna is straight and in outline resembles that of the North African *Cetiosaurus magrebiensis* with a thick and large proximal end and an inconspicuous olecranon process. A deep pocket lies medially to facilitate articulation with the thin flat radial process. Dorsally the shaft is trilateral and extends as such distally, but this triangular morphology becomes lost at the distal end which is slightly inflated with a convex articular surface. Ulna length is 77.2 cm.

The radius is relatively simple in morphology, does not differ greatly from those of more derived sauropods, is slightly shorter than the ulna at 70.2 cm, and has a straight shaft. It is relatively robust with slightly expanded proximal and distal ends that become flat and thick. The proximal end is quadrate, and the shaft is nearly circular in cross-section.

All the margins of the carpal (V6095.23) have been weathered away leaving a flatly rounded element that nearly resembles its counterpart on *Diplodocus*, as the margins are relatively thin with a slightly concave dorsal surface for articulation with the radius. Ventrally it is slightly convex. This element should represent a left forelimb element.

The pelvic girdle preserves only the left preacetabular process and pubic peduncle of the ilium (Pl. 6, Fig. 1), a relatively well preserved pubis, and a piece of ischium. The elements are typically sauropod, being composed of three robust elements that are relatively compressed and which morphologically resemble *Barapasaurus* from the Kota Fm. of India (Fig. 10). The robusticity and firm fusion reflects a strong hindlimb.

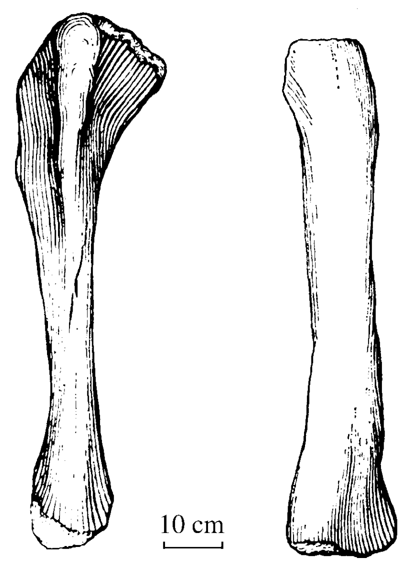

Figure 9. Ulna and radius of *Shunosaurus lii* gen. and sp. nov.

The relationship of the ilium to sacral vertebrae has already been discussed in the vertebral section. The relatively thin ilium is rather high and anteroposteriorly elongated, with a well developed plate-shaped preacetabular process with an elongated mediolateral depressioin. The well developed, robust pubic peduncle maintains a longitudinal, semi-spherical, ventromedial channel that runs along an arc to the dorsal margin of the acetabulum where it disappears at the medioventral side of the ilium. The acetabulum is large and located centrally. The ischial peduncle is not preserved but from determination of the three elements present it was probably not well developed.

Both pubes are present but have corroded proximal ends. The 55 cm long element is robust and rather compressed with an expanded and thickened sympysis that is not boot-shaped. The shaft is flattened on one side making it crescentic in cross-section, which differs from *Omeisaurus* and *Mamenchisaurus.* The proximomedial margin is round and smooth representing a large obturator foramen which is presumably enclosed. This end is thickened with a coarsened surface for contact with the pubic peduncle. The posterior margin for contact with the ischium is thin.

Both the proximal and distal ends of the ischium are present, although a portion of the shaft is missing. Its restored length is based upon the corresponding length of the pubis. This is a robust element, relatively straight, and is also not boot-shaped. The proximal end is expanded and the distal end is thick and slightly expanded with a coarsened texture resembling that on *Barapasaurus* from India.

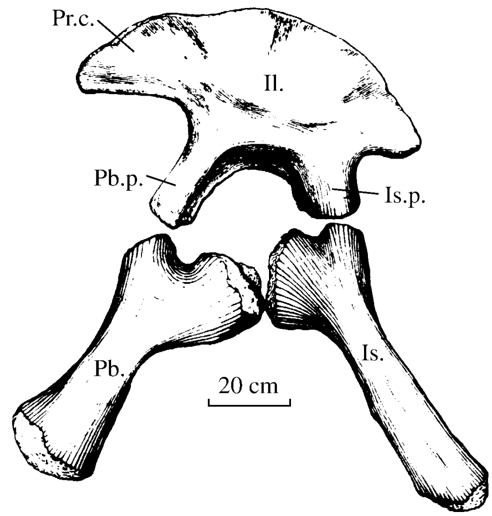

Figure 10. Pelvic girdle of *Shunosaurus lii* gen. and sp. nov.

The right hindlimb preserves only the fibula, but the left hind limb is relatively completely preserved in its natural configuration and includes the femur, tibia, fibula, and metatarsals. The five complete metacarpals express plesiomorphic characters. These limbs are strong and robust with a tibia two-thirds the length of the femur.

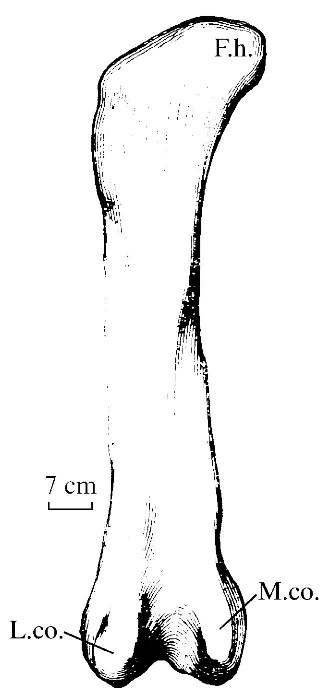

Figure 11. Femur of *Shunosaurus lii* gen. and sp. nov.

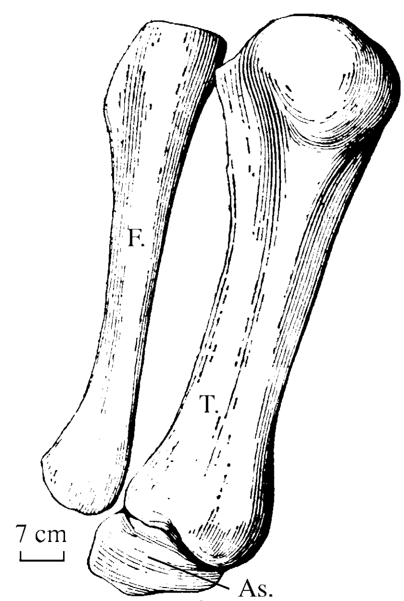

Figure 12. Tibia, fibula, and astragalus of *Shunosaurus lii* gen et sp. nov.

The femur is straight with a shaft that is elliptical in cross-section and a morphology resembling *Rhoetosaurus* from Australia. Proximally, the femur head projects dorsomedially lacks a distinct neck and has a coarsened articular surface. The lesser trochanter is absent and the fourth trochanter is located at mid-shaft posteromedially in the form of a long conspicuous ridge for attachment to strong caudifemoral musculature. Two well developed condyles lie distally, with the medial condyle larger than the lateral. A longitudinal cavity lies on the lateral side of the lateral condyle. whereas a deep intercondylar notch lies between the two condyles with a shallow anterior trochlea dorsal to it. The element is 125 cm in length (Pl. 6, Fig. 6 and Text Fig. 11).

Both the 80 cm long tibia and fibula are simple in morphology. The tibia is robust and straight with an expanded proximal end, the shaft is triangular in cross section, and the cnemial crest projects anterolaterally. The distal end is expanded and becomes coarsened with a weak, square calcaneal process.

The fibula has a straight shaft and is slightly expanded at both ends. The proximal end becomes thin and flattened with a convex surface on its medial side for abutment with the cnemial crest. The distal end is slightly rounded with a convex articular surface.

The completely preserved astragalus is a large and robust element that resembles that of *Mamenchisaurus* by being nearly rectangular with a proximal articulation consisting of a laterally oblique depression that gradually attenuates. Laterally, there is a process that is the counterpart to the medial depression on the tibial process. Ventrally the astragalus is slightly inflated to a semi-spherical articular surface for articulation with the metatarsals. This is a massive and cumbersome element with all its articular surfaces coarsened indicating a ponderous gait for the animal.

A semi-complete left hindfoot was excavated but suffered some damage during collection due to weathering. Four metatarsals had their proximal ends in tight association preserving their sequential position. Their shafts are round with coarsened proximal and distal ends. The heavy and flat marginal surfaces are spread in an equivalent arrangement. MtI is relatively short, while the morphologies of MtII, III, IV, and V do not differ much from the general sauropod condition. All the distal ends are robust with smooth and glossy articular surfaces, have a slightly concave medial section, and both lateral sides lack depressions for ligament attachment. The proximal ends are relatively large with those on MtIII and IV laterally compressed.

The phalangeal count is unknown as there are only three flattened and coarse elements preserved, which are short and thick with smooth articular surfaces and a slightly non-symmetrical saddle-shaped medial depression. A shallow depression also lies distally, bounded by two condylar processes which also lack ligament depressions and resemble *Omeisaurus* in morphology.

Discussion: Characters attributing specimen V9065 to the Sauropoda and not Prosauropoda include opisthocoelous centra; high neural arch; rod-shaped neural spines anteriorly and elongated plate-shaped spines posteriorly; robust pelvic girdle with thick but compressed ilium, ischium, and pubis; ilium high with a well developed preacetabular process and pubic peduncle; reduced ischial peduncle; and four sacral vertebrae.

The presacral vertebrae of the Zigong specimen contrast those of later sauropods by lacking internal honeycombed structure, dorsals are amphicoelous and lack pleurocoels, and cervicals have a ventral keel with a ventrolateral ridge, all of which indicate a relationship to the prosauropods.

However, the aforementioned characters are also plesiomorphies recognized in the Cetiosaurinae. This subfamily is considered relatively primitive for the order and is regarded as a basic stem group which is generally found in the Early to Middle Jurassic, though some genera such as *Dystrophaeus* and *Elosaurus* extend into the Late Jurassic. Cetiosaurine crania are extremely rare but their dorsal vertebral structure is solid, cervical spines are unbifurcated, neck is comparatively short with 13 opisthocoelous cervicals at the most, cervical to dorsal centrum ratio is 1 1/2 - 2 dorsal centra are slightly opisthocoelous, ilium is high, anterior limb is 2/3-4/5 the length of posterior limb, radius is nearly 3/4 the length of humerus, and tibia is two-thirds the length of the femur.

There are currently nine genera within the family Cetiosauridae, which are predominantly produced from Europe, North Africa, Australia, and South America. The genus *Cetiosaurus* itself was erected by the reknowned English paleontologist Sir Richard Owen (1841). Subsequent discoveries of large forms of up to 15 m in length were made predominantly from Early to Middle Jurassic sediments of Portugal and Morocco. Longman (1927) described the large *Rhoetosaurus* from the Walloon Series* based upon fragmentary material including some limb bones and vertebrae. The V9065 femur particularly resembles this specimen. Cabrera (1947) described *Amygdalodon* from the Middle Jurassic Pamna Group of Argentina which lacks genuine pleurocoels and has a sacral vertebral count of five to six. In 1964 a collection was made in central India from the Kota Fm. and later published by Jain (1975) as *Barapasaurus tagorei.*** Its stratigraphic position is confirmed as Early Jurassic with a coexisting fauna including the Liassic fish *Lepidotes*. The pelvic girdle of the Chinese specimen very closely resembles this taxon. The remaining cetiosaurid taxa are extremely fragmentary such that further comparisons are not possible here.

The Sichuan specimen is comparable to the taxa mentioned above despite their possession of a number of derived characters. Furthermore, the Sichuan specimen displays its own autapomorphies such as the incipient bifurcation its cervical spine, a ventral cervical keel, and a ventrolateral lamina. The lengths of the radius and tibia being nearly equivalent and the tibia two-thirds the length of the femur are also autapomorphic characters and are not noted on other members of the cetiosaurine subfamily. These consequently justify the erection of a new genus.

Discussion is required regarding the age of *Shunosaurus* as its morphology is primitive and approaches *Barapasaurus*, *Patagosaurus*, *Rhoetosaurus*, and *Volkheimeria* from the Early to Middle Jurassic. The question remains whether or not *Shunosaurus* is Early Jurassic. The current distribution of the genus is restricted to the Lower Shaximiao Fm. in the Sichuan basin. Stratigraphically, this overlies the Ziliujing Fm. which is undoubtedly Early Jurassic as it produces the typically Liassic fish *Lepidotes* and the pliosaur *Bishanopliosaurus*. However, pelecypod and conchostracan workers assign Ziliujing invertebrate faunas to Middle Jurassic, and hence the overlying Lower Shaximiao sediments are appropriately recognized as Middle Jurassic.

Among the three faunas produced from the Sichuan Basin, characteristics of the *Shunosaurus* Fauna are more derived than the *Lufengosaurus* Fauna but more primitive than the *Manenchisaurus-Omeisaurus* Fauna. Although *Shunosuarus* possesses numerous plesiomorphies it is derived by being a large sauropod with a derived pelvic girdle more closely resembling true sauropods. This is further justification for a Middle Jurassic age.

Euhelopodinae Romer 1956

Family diagnosis: Skull is moderate in size with a well developed rostrum, quadrate is slightly anteriorly oblique, and supratemporal fenestra is large. Presacral series is long, with 17-19 opisthocoelous cervicals with relatively shallow pleurocoels, low neural spines, and bifid

* Colbert (1975) suggested this specimen was Middle Jurassic.
** Genus etymology: Sanscrit for "big foot."

spines on the posterior cervicals. Cervical centra are 2 1/3 times the length of the dorsals. There are 12-14 opisthocoelous dorsals with generally well developed prezygapophyses. Three to four sacral vertebrae are present with the anterior three fused. Anterior caudals are procoelous, tibia is three-fifths the length of femur, and dentition is spoon-shaped.

The euhelopodine sauropods predominantly include large Late Jurassic to Early Cretaceous sauropods such as *Euhelopus, Tienshanosaurus, Asiatosaurus, Mamenchisaurus, Chiayusaurus,* and *Omeisaurus.*

Omeisaurus **Young, 1939**

1939 *Omeisaurus junghsiensis* Young, *Bull. Geol. Soc. China,* Vol. **19**, No. 3; *Bull Geol. Soc. China*, Vol. **24**, No. 3-4.
1958 *Omeisaurus changshouensis* Young, *Vertebrata PalAsiatica*, Vol. **1**, No. 1.
1976 *Zigongosaurus fuxiensis* Hue, *Vertebrata PalAsiatica,* Vol. **14**, No. 4.

Genus diagnosis: As for species.

Omeisaurus junghsiensis **Young, 1939**

(Text figures 13-35)

Original diagnosis: (includes *Zigongosaurus*) A moderate to large sauropod with a relatively high skull, short rostrum, maxillary foramina are absent, and an anteroventral process is present on the anterior maxilla dorsal to the dentition which contacts the premaxilla. The maxilla contains 12-14 teeth and is relatively thin with a laterally compressed trilaminar ascending process. The antorbital fenestra is large, the prefrontal is a principal component of the orbit, the postfrontal is particularly thickened and may attain 18 mm, and the supratemporal fenestra is elliptical. The mandible contains 15-17 teeth with a relatively thin ramus that is higher anteriorly, has a posteriorly oblique anterior end, and a rostrum that projects ventrally at its anterior end. Its lateral surface is coarsely textured with nutrient foramina present. Medially it is flat and smooth, the ventral margin is very slightly crescentic, and there is a groove upon it that extends to the symphyseal region.

Dentition is spoon-shaped and slightly posteriorly oblique. Premaxillary teeth are largest with long acute crowns and denticles present laterally with small tuberosities at both sides of the apex. Both maxillary and dentary dentition are labially convex and lingually concave which becomes more pronounced posteriorly. A lingual medial ridge is conspicuous, and anterior and posterior margins are symmetrical with denticles anteriorly. Base of the crown is lingually constricted and is then inflated as a root with a medial longitudinal groove. Dentition gradually diminishes in size posteriorly.

Vertebral column is composed of 17 cervical, 12-13 dorsal, and four sacral vertebrae. Posterior centra are opisthocoelous, relatively short, and have well developed pleurocoels. Anterior cervical neural spines are low, and laminar structure is well developed. Posterior cervicals have relatively low spines and possess a well developed pseudospinous process, posterior cervical and anterior dorsal spines are bifid, the anterior process on cervical ribs is asymmetrical, and caudal centra are relatively long and laterally compressed. The first several anterior caudals are procoelous with fan-shaped caudal ribs. The diapophyses on the first caudal attach to the first caudal rib to compose a thin flat element.

The scapula is broad with an expansive depressed surface and a terminus that differs from the distinctly expanded morphology of typical sauropods. The perforated coracoid is short, elliptical, and fuses with the scapula with a straight suture line. Breadth at the proximal end is equivalent to or exceeds its length. The sternum is elliptical. The ilium is generally short and high with a medially but slightly anteriorly positioned pubic peduncle. The pubis is broad with expanded anterior and posterior termini and a spaciously open obturator foramen. A horizontal notch lies on the ventral surface of the pubic symphysis. The proximal ischium is thick and expanded, whereas its shaft is flattened, and the distal end is not expanded. The four limbs of *Omeisaurus* are relatively long. Both ends of the humerus are of equivalent breadth, and are triangular in morphology with the proximomedial angle occasionally projected as a palm shaped expansion. The femoral shaft is elliptical in cross-section with the fourth trochanter lying dorsal to the midpoint of the shaft, and the femoral head is distinctly separate. The tibia is equivalent to or longer than three-fifths the length of the femur, and fibula is slightly shorter than the tibia.

Supplemental diagnosis: The skull is high, rostrum short, maxilla robust, occipital broad, and supraoccipital is large and laminar-shaped. Mandible is thick with a conspicuous mandibular angle with a relatively small dentition. Dental formula: Premaxilla-4, maxilla-12-13, dentary 14.

This is a moderate-sized sauropod approximately 10-15 m in length, being a member of the high-skulled forms with a short rostrum and greatest breadth of skull is posterior to the orbit. Medial nasal ridge is not projected, and bifurcates the large nares which are situated laterally and anterior to the antorbital fenestra. Supratemporal fenestra are large and dorsally situated, and orbits are large, triangular, and laterally situated. Quadrate is straight and teeth are spoon-shaped. Premaxillary teeth differ in morphology from maxillary dentition.

There are 14-17 cervicals, 12-13 dorsals, and four fused sacrals with the anterior three fusing their spines. Presacral vertebrae have honeycombed structure but caudals do not. Ventral axis is keeled. Cervical centra are opisthocoelous with well developed pneumatocoels, a flat ventral surface, but with a longitudinal ridge on each side providing the centrum with a rectangular morphology in ventral perspective. Neural spines are low, not conspicuously bifurcated, but may be said to have a plate-shaped pseudospinous process. Posterior cervicals are weakly bifid and cervical centra are two and a half times the length of the dorsals.

Thirteen opisthocoelous dorsal vertebrae are recognized with generally well-developed anterior condyles and pleurocoels located anterodorsally. Neural arches are high, diapophyses and neural spines form a right angle to each other, dorsal spines on the anterior sequence are elongated, posterior dorsal spines have elongated apices, prezygapophyseal articular facets are convex and postzygapophyseal facets are concave. Membranes facilitating musculature attachment on the spine were well developed.

Four sacral vertebrae are present but are not completely fused, although the three anterior sacral dorsal spines are completely fused to compose a uniform longitudinal plate, and the sacral ribs and diapophyses are fused into yoke-shaped plates, but the dorsal spines may be separated at their apices. The spine on S4 is completely isolated and rod-shaped, approaching the morphology of the anterior caudals.

The precise count of the caudals is unclear but is generally 35 (±5). The first caudal is amphiplatyan with slightly concave ends. Caudal ribs are fused to diapophyses and are flattened. Caudals 2-7 are procoelous, medial caudals 8-21 are amphicoelous, and terminal caudals are amphiplatyan.

Forelimbs are four-fifths the length of the hindlimbs. Scapula is straight with a large elliptical corocoid. A long, flat, and relatively straight blade-shaped clavicle is present with a lanceolate distal end and two small condyles on the proximal ends, and sternal plates are round and thin. Radius and ulna are four-fifths the length of the humerus. The ilium is high with a weak postacetabular process and a slightly stronger preacetabular process, the pubic peduncle is a large club-shaped process, distal pubis is boot-shaped, proximal pubis is thick and large, and ischium is straight, and relatively flat, with ligament attachments distally. The femur is straight with a relatively elliptical shaft and a large but undefined head. The fourth trochanter is situated posteromedially at a point one-third down the shaft, and two well developed condyles lie distally with the medial condyle larger than the lateral condyle. The tibia is robust with a distal astragalar process. The astragalus is large and flatly elongate with a simple morphology. Five robust digits are present with digit V reduced.

History of research: The type for this genus was an incomplete skeleton collected in 1936 by C. C. Young and C. L. Camp at the foot of Mt. Xiguashan, Dongmenwai (outside the east gate), Rongxian Co. Much later, in 1974, the Chungking Natural History Museum excavated a vast quantity of sauropod material from the Wujaiba dam site in Zigong Co. During the course of excavation and preparation a portion of this material, consisting of the more exceptional specimens, were hastily selected for preparation, study, and display resulting in 1976 short report published in *Vertebrata PalAsiatica* (Vol. 4). Time constraints prohibited analysis of all the data, such that based upon the limited specimens (including a piece of premaxilla, maxilla, dentary, and several limb bones) the material was recognized as distinct from *Mamenchisaurus*, *Omeisaurus*, and *Tienshanosaurus* and subsequently erected as the new genus and species *Zigongosaurus fuxiensis.*

Type specimen: The type consisted of four cervical, three presacral (including dorsal and sacral centra), and 13 articulated caudals, a complete left humerus, two incomplete ilia, two ischia, one left pubis, one complete left tibia and several fragmentary ribs, scapula, and femur.

Supplemental specimens: Two skeletons produced from the Wujiaba Dam quarry, a large amount of cranial data, limbs and vertebrae (Table 2).

Locality and stratigraphic position: Young's original description provided only the most abbreviated description by stating that the type was produced from a gray-green sandy mudstone 200 m above a Ziliujing limestone (now recognized as the Daanzhai Mem.). In 1974 additional specimens were derived from the base of the early Late Jurassic Upper Shaximiao Fm. at Zitongqiao, Dongmenwai, Rongxian Co. and Wujiaba Dam, Zigong Co.

Textual criticism: Site verification was initiated by the authors in 1978 in the Rongxian region above the Daanzhai Limestone in sediments which were formerly recognized as the "Jinggaoshan Mem." The type locality is currently under the administration of the Fudong Commune, Dongmenwai, next to the Zitong Bridge where the original fossil quarry is still evident in a dark purple sandy mudstone beneath a second set of yellow-red sandstones which underlies a massive sandstone upon which the Rongxian Buddhist inscription is engraved. This is stratigraphically equivalent to the Wujiaba Dam site in Zigong Co. An auxillary team of the Sichuan Aerial Survey Corps places the stratigraphic boundary with the Upper Shaximiao Fm. at the top of the massive sand body with the inscription. From a paleontological perspective this boundary should be shifted to below the *Omeisaurus* site. However, the site documentation process was brief and the conchostracan-bearing sediments usually applied to delineate the Upper and Lower Shaximiao were not documented.

Young's sauropod publication also described two teeth that were collected ten km northeast of Rongxian from a locality he designated Chen Chia (Chenxi). These teeth were attributed to *Omeisaurus* but it is believed here that they were produced from the Lower Shaximiao Fm. Later, in 1942 Young described four isolated teeth from the Guangyuan Group and assigned them to *Omeisaurus.*

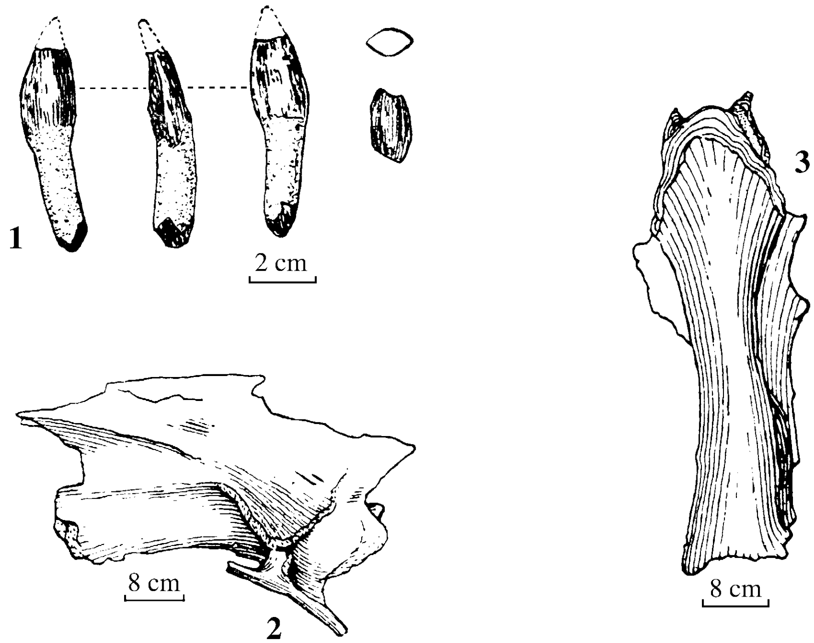

Figure 13. Type of *Omeisaurus junghsiensis* (from Young, 1939)
1. Isolated teeth. 2. Lateral view of cervical vertebra. 3. Ventral view of cervical vertebrae.

Included species: *Zigongosaurus fuxiensis.*

Justification for synonymy: After analysis of all the sauropod data from Wujiaba, with the exception of a single maxilla, all the specimens were reidentified as belonging to *Omeisaurus* with a large portion of the material diagnosed to the species *junghsiensis*. Whether or not all this data is conspecific is the basis for the current research on *Omeisaurus.* Rationale is provided below:

Stratigraphic position: The type was derived from what is now recognized as the base of the Upper Shaximiao Fm. which is stratigraphically equivalent to the Wujiaba quarry. It was collected from the municipality of Rongxian, which is less than 60 km from Zigong. The chronologic interval producing *Omeisaurus* was under the same environment at both locales, where large species of sauropods are frequently encountered.

Morphology: With the exception of several isolated teeth, the type lacked cranial material, prohibiting adequate comparison. But included in the original material was an extremely well-preserved cervical vertebra (Fig. 14) which is completely consistent with the Wujiaba material. The isolated teeth were spoon-shaped with conical roots which also correspond to premaxillary teeth in the Wujiaba collection. The limbs are also identical by being thin and flat, and elements of the pelvic girdle are identical as are measurement ratios.

The type of *Omeisaurus* was extremely fragmentary, which prohibited the recognition of a number of characters, and a majority of the data was lost in transport during World War II. Consequently, a neotype is hereby selected and a more complete description is conducted below. The Wujiaba data consists of 13 to 16 individuals of varying ontogeny and sexual dimorphism which has created difficulties in disposition. But from the perspective of the entire collection, two quite distinct taxa are recognized.

Table 2. Cranial elements of *Omeisaurus*.

Specimen Number	Specimen	Condition of preservation	Remarks
001	Occiput, cranium, frontal, and parietal	Uncompressed	Neotype (Fig. 16)
002	Occiput and cranium	Slightly compressed, right supratemporal fenestra compressed	
0003	Basioccipital and basisphenoid	Uncompressed and well-preserved	
004	Basioccipital region with exoccipital	Compressed	
005	Basioccipital with portion of basisphenoid	Well-preserved	Used for *O. fuxiensis*
006	Basioccipital with portion of basisphenoid	Compressed occipital condyle	
007	Basioccipital	Compressed occipital condyle	
008	Basioccipital region with left quadrate		
009	Basioccipital	Compressed occipital condyle	
010	Basioccipital and basisphenoid	Occipital condyle lost	
011	Basioccipital and basisphenoid	Occipital condyle lost	
012-1	Right parietal and frontal	Preserved naturally	
013-1	Supraoccipital	Completely preserved	Same individual as 013-3
014	Right parietal and left frontal	Left frontal incomplete	
015	Frontal, parietal, and left prefrontal	Left prefrontal incomplete	
016	Supraoccipital, right parietal, left frontal, and ectopterygoid	Ectopterygoid fragmentary	
017	Left frontal		
018	Supraoccipital		
019	Left prefrontal	Fragmentary	
020	Left premaxilla	First tooth fragmentary	
021	Right premaxilla	First large tooth fragmentary	
022	Left maxilla and postorbital		
023	Left maxilla	Three complete teeth	
024	Left mandible	Only the dentary	

Disposition of data: The complete collection of suaropod specimens from the Wujiaba quarry underwent five years of preparation and comprehensive study before two complete composite skeletons were mounted for exhibit. One is exhibited at the Chungking Museum of Natural History (CV 226) and one is erected at the Zigong Museum of the Salt Industry (ZMSI 001). These two skeletons have been selected as hypodigms for *Omeisaurus junghsiensis* Young, representing a large and high-skulled sauropod.

Another smaller species is recognized from the Wujiaba quarry with a skull that is lower andwith a thinner mandible which is designated *Omeisaurus fuxiensis* sp. nov. bringing the total species count to three, including *O. junghsiensis* Young and *O. changshouensis* Young.

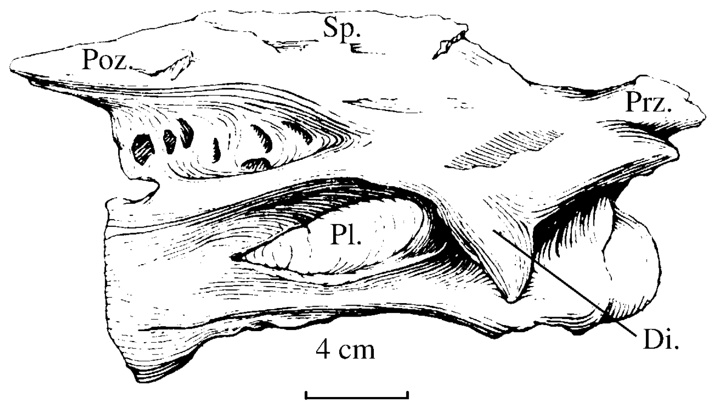

Figure 14. Cervical vertebra of *Omeisaurus.*

Within the process of collection and preparation of specimens from the Wujiaba quarry, unsuitable and damaged specimens were discarded but a large amount of cranial data was preserved providing a relatively comprehensive understanding of the cranial structure. Table 2 documents the cranial specimens and condition of preservation. The number of individuals are estimated as 13 based upon the basioccipitals represented in the collection.

Skull: Specimen number CV-001 is the most complete cranial element produced from the Wujiaba quarry and is selected as the neotype (Fig. 16). Specimen number CV-002 has suffered compressional distortion, is slightly deformed, and is recognized as the paratype (Text Fig. 17, and Pl. 7). Throughout the procedure of restoration and study, plaster casts were made of selected cranial elements. Each isolated cranial element was then compiled to form a complete skull (measurements in Table 3). The cranial length was reconstructed based upon general proportions of sauropod skulls to the three anterior cervical vertebrae,.

Description: In dorsal perspective the skull is an isosceles triangle and planar, with its greatest breadth anterior to the orbits. From this point anteriorly, the skull becomes reduced and curves anteroventrally at the nasals to become most narrow at the rostrum where it is ventrally projected. Height and breadth are equivalent and in lateral perspective, at first glance, it resembles a pseudosuchian. Five pairs of large fenestrae lie on the skull. The nasals are paired ellipses, and anterolaterally situated with a medial ridge that is flat, smooth, and curves ventrally, unlike that of *Camarasaurus* which is dorsally projected. Posterior to the nasals are a pair of large triangular antorbital fenestrae with elongated ventral margins and anterior and posterior margins of equivalent lengths which form an isosceles triangle. The orbits lie laterally and are dorsally broadened to become triangular in shape. The supratemporal fenestra are small, elliptical, and lay laterally on the parietals. The lateral temporal fenestrae are large and elliptical. The spacious extent of the fenestrae create a lightly constructed skull that is not easily completely preserved and conforms to a large and long neck.

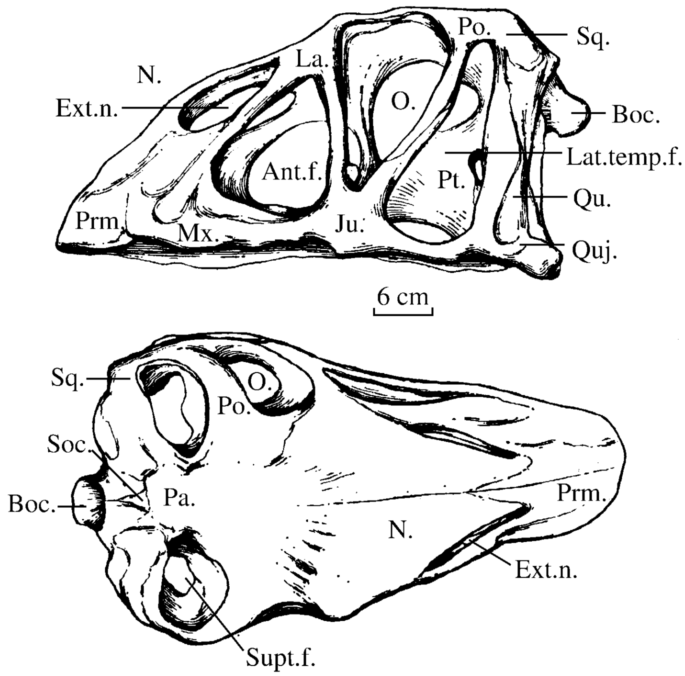

Figure 15. Reconstructed skull of *Omeisaurus junghsiensis.*
1. Dorsal view (x1/2). 2. Lateral view (x1/2).

Table 3. Cranial measurements of *Omeisaurus junghsiensis* (cm).

Cranial length	42.0
Cranial height	19.5
Cranial breadth	21.2
Rostrum length from orbit	26.0

The occipital region is composed of the supraoccipital, exoccipital, basioccipital and paroccipital processes, and is posteroventrally oblique with an approximately 45° angle between the occipital plane and the occipital condyle.

The supraoccipital constitutes the predominant element in this region of the cranium, is shaped as an isosceles triangle, located medially on the cranium, and has an inflated medial crest that expands ventrolaterally to form a circular projection. At the midpoint of the crest there are two butterfly-winged processes that contact the exoccipitals (Pl. X, Fig. 6). From a medial perspective, both sides of the element have a shallow crescentic process providing the entire outline to be butterfly-shaped (Fig. 16). The *Omeisaurus* supraoccipital is larger than on both *Diplodocus* and *Camarasaurus.* Its predominance in the occipital region also differs from these taxa and *Nemegtosaurus* which have small supraoccipitals located just dorsal to the foramen magnum. Three additional specimens maintaining supraoccipitals are present (013, 014, and 015) among which specimen 013 is complete (Pl. X, Fig. 6). The medial supraoccipital is a deep and smooth saddle-shaped depression which forms the posterior wall of the braincase. The dorsal margin of the supraoccipital penetrates the posterior parietal, its dorsolateral margins contact the squamosals, and its ventral margin contacts the exoccipitals.

The basioccipital is the most posterior element of the skull with a slightly transversely elongated hemispherical occipital condyle as its terminus. The articular surface of the condyle is posteriorly oblique at an approximate 45° angle (Pl. X, Fig. 1), and its lateral margin constitutes a laminar ridge circumventing the condyle but does not connect to form an enclosed circle and disappears at the ventral margin of the foramen magnum. This character resembles that on *Nemegtosaurus.* The condyle has a relatively long neck with a shallow dorsomedial groove on it. At the anterior end of this groove is a small circular depression anterior to which are two basiocciptal tuberosities which are also circular and have a deep fissure between them representing the carotid foramen. Their dorsal surface has coarsened tuberosities for attachment of strong cervical musculature. The basisphenoid lies anterior to the basioccipital tuberosities with a distinct suture line between it and the basioccipital. Ventrally, this suture is conspicuously crenulated.

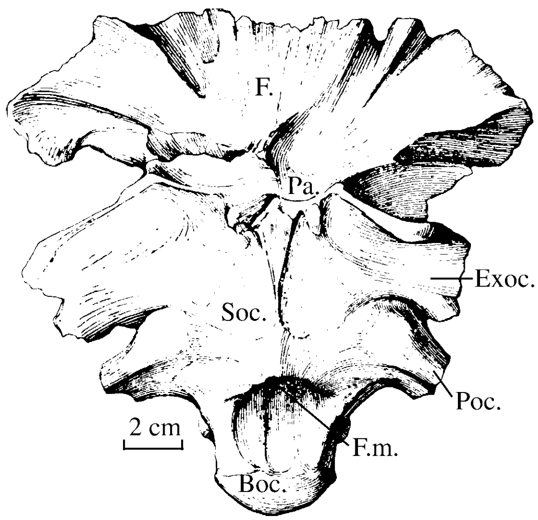

Figure 16. *Omeisaurus junghsiensis* basicranium (neotype specimen 001).

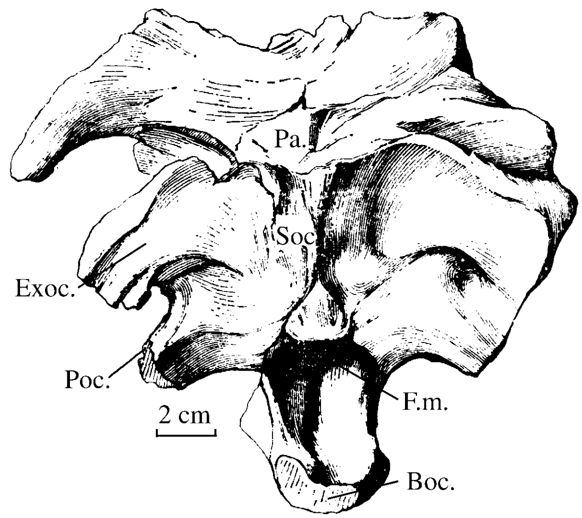

Figure 17. Occipital of *Omeisaurus junghsienis* (neoparatype).

The exoccipitals are medially constricted to form a yoke-shaped morphology and lie ventral to the supraoccipital, with their lower margin constituting the dorsal margin of the foramen magnum. On *Diplodocus, Camarasaurus,* and *Nemegtosaurus* the exoccipitals are larger than the supraoccipital, whereas here they are smaller. The paroccipital processes lie ventrolaterally as relatively small elements in the Sauropoda and are unlike the robust forms in the Pseudosuchia or Theropoda. On specimen 001 they have been damaged but still indicate an extremely thin distal end. The dorsal margin forms the ventral aspect of the lateral temporal fenestra.

The basicranium resembles that of *Diplodocus* and is composed of the basisphenoid and parasphenoid, and is bounded by the alisphenoid, opisthotic, and prootic.

The basisphenoid lies anterior to the basioccipital with two ventrally projected angular processes deemed the basipterygoid processes of the basisphenoid and which are generally not present in ornithischians. At the anterior end of the basisphenoid a small anteriorly extended crest is present which constitutes the parasphenoid, with the alisphenoid at its lateral side (Pl. X, Fig. 2).

The parasphenoid lies between the pair of alisphenoids as a thin, crested, foliate element that is not readily subject to preservation. There is an inflated crest at the anteromedial contact of these elements with a foramen lying anterior to this representing the foramen for the optic nerve. In *Omeisaurus* the two optic nerve foramina are extremely close and appear to have a tendency to fuse into a single unit, but in *Camarasaurus* and *Diplodocus* they are distinctly separated. At the anterior parasphenoid, on the ventral surface of the frontal, there is a large V-shaped fissure with an open mouth anteriorly, representing the olfactory foramen. Two symmetrical laminar crests extend laterally at 45° angles from this foramen directly to the margins of the optic foramina.

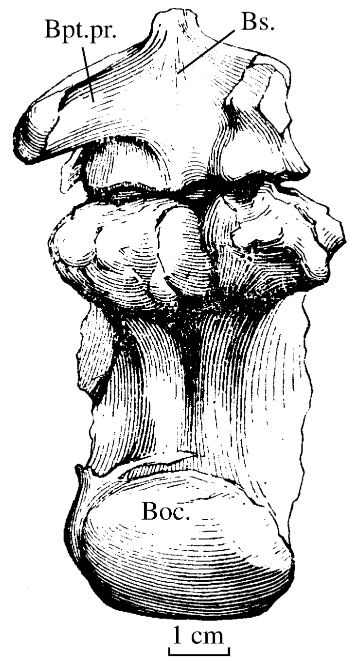

Figure 18. Basioccipital of *Omeisaurus junghsiensis.*

On the neotype, the alisphenoid is relatively well preserved lateral to the parasphenoid as two butterfly-shaped elements, with posterior ends that overlap the basipterygoid process of the basisphenoid, anterior ends that contact the frontal, and lateral margins that constitute the anteromedial wall of the supratemporal fenestra. A fissure lies at the midpoint of the lateral margin which represents the posterior branch of the ophthalmic nerve. At the posterior side of the branch is the attachment point for the M. rectus.

The prootic is a small elliptical element that forms the lateral wall of the braincase, lies anterior to the paroccipital process, and dorsal to the basisphenoid. Laterally it forms the dorsal margin of the lateral temporal fenestra, and its ventral margin is a trilateral rod-shaped crest that contacts the paroccipital process at the foramen for the trochlear, trigeminal and abducens cranial nerves.

The pterygoid is not preserved on the neotype, though an isolated spoon-shaped element was recovered from the Wujiaba quarry with anterior and posterior branches with a curvature of 60°. The anterior branch is broad, thin and wing-shaped. The posterior branch is relatively thick and rod shaped.

The parietal region is relatively flat, and from an occipital perspective sits dorsal to the supraoccipital, with two small inflated processes that project laterally as wings at both sides of the inflated medial crest of the supraoccipital. The ventrolateral side of this process forms the dorsal margin of the lateral temporal fenestra. Holland's (1906) description of *Diplodocus* identifies this wing-shaped process as the squamosal, although Gilmore's (1925) description of *Camarasaurus* specimen No. 11-338 identifies it as the parietal. The parietal of *Omeisaurus* has distinct suture lines confirming Gilmore's interpretation. The parietal forms the posterolateral margins of the supratemporal fenestra. From a dorsal perspective it maintains a shallow medial depression following the median suture line but there is no accompanying pineal eye as is present in *Diplodocus* and *Apatosaurus* and described by Osborn and Holland as the sauropod condition. It is therefore deduced that the shallow median depression on *Omeisaurus* is the vestigial remnant of this feature. The anterolateral parietal projects as a process to form the medial margin of the supratemporal fenestra. On specimen 013-1 the ventral characters of the parietal are exposed to reveal a relatively large and smooth ventromedial depression to undoubtedly house the cerebrum.

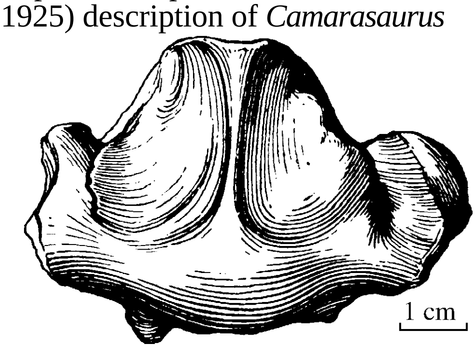

Figure 19. Supraoccipital of *Omeisaurus junghsiensis.*

The frontals consist of a pair of plates anterior to the parietal, with a slightly elevated medial suture that initiates at the margin of the supratemporal fenestra and spreads anterolaterally to form the dorsal margin of the orbits and then gradually attenuate anteriorly. At the anterior orbital margin there are two folded depressions with the lateral one housing the branch for the prefrontal contact and the medial one in contact with the nasal. The posterior frontal contacts the parietal with a straight boundary. Where it penetrates the supratemporal fenestra the contact becomes an oblique line extending anteriorly to form a "U"-shaped branch. At the posterior margin of the orbit on the frontal there is an oblique surface that contacts the postorbital. The dorsal orbit is ornamented with coarse crenulations, making them easily distinguishable from theropod cranial elements from the Wujiaba quarry. The frontal lies anterior to the parasphenoid with a ventral "V"-shaped crest. The apex of this crest lies at the midpoint of the parasphenoid and then extends laterally to the anterior margin of the orbit. A foramen representing the olfactory nerve lies between the midpoint of the crest and the parasphenoid.

The only prefrontal preserved is on specimen 015 where it is a small, fragmentary, but relatively thick triangular element anterior to the frontal. Its posterior margin is a process that penetrates the anteromedial orbital fold. Its lateral margin constitutes the anterodorsal margin of the orbit, and its medial margin is in contact with the nasal. It is approximately 1 cm thick at its contact with the orbit.

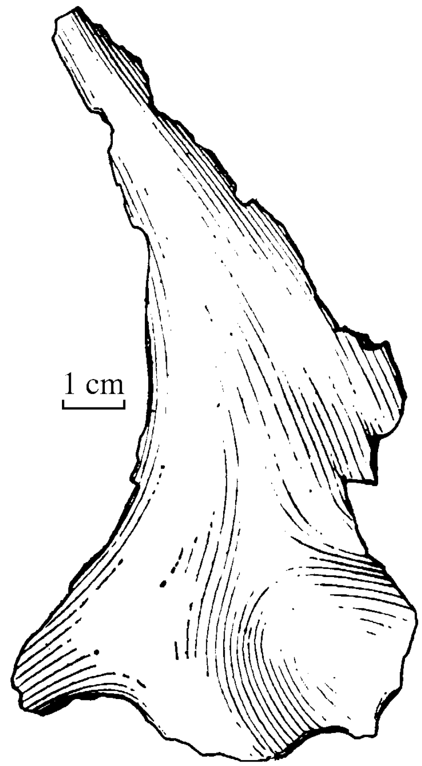

Figure 20. Nasal of *Omeisaurus junghsiensis.*

The nasals are only represented by a single incomplete specimen which is relatively long and thin and has suffered compressional distortion. It is narrow anteriorly, broadened posteriorly, and triangular in outline, resembling the morphology of *Camarasaurus* but without an ascending medial crest. Its posterior margin contacts the frontal and prefrontal whereas the anterior end is in contact with the premaxillary process, which penetrates the nasals medially. The two nasals contact each other to compose a medial septum. The external nares are situated laterally (Pl. X, Fig. 3 and Text Fig. 20).

The premaxilla (Fig. 21) is subtriangular in outline with a narrow, and long posterodorsal premaxillary process which extends posteriorly and then gradually attenuates while penetrating the medial nasals and together they compose the nasal septum. The posteroventral premaxillary process is triangular and contacts the maxilla. Four alveolae are present.

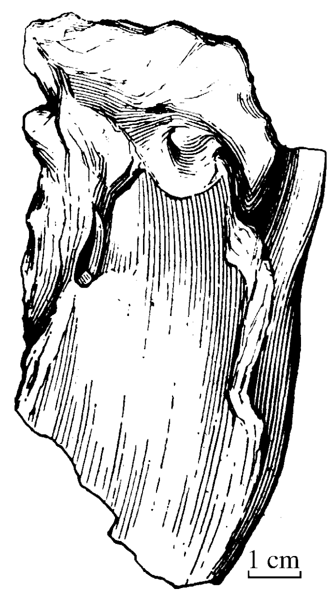

Figure 21. Premaxilla of *Omeisaurus junghsiensis.*

Five maxilla were recovered from the quarry, the best preserved of which is specimen 022 which is a size that corresponds to the neotype. This is the largest and most robust of the cranial elements (Fig. 22) being laterally flat and in outline resembles a scalene triangle. Anteriorly, it has a ventral process that contacts the premaxilla. A laterally compressed, trilateral dorsal process is also present that extends obliquely posterodorsally to contact the anterior process of the prefrontal and compose the border of both the nasal and antorbital fenestra. Anterior on this ascending process lies a depression which probably represents the vestiges of the maxillary foramen. The postmaxillary process is plate-shaped with a relatively high anterior margin that gradually decreases posteriorly to contact the jugal. Its dorsal margin forms the ventral boundary for the extremely large antorbital fenestra and there is a relatively narrow lamina that runs along the process posteriorly to contact the jugal. A series of nutrient foramina lie ventrally. The lingual aspect of the maxilla is uneven due to the eruption of replacement teeth. The functional tooth count is 14-15.

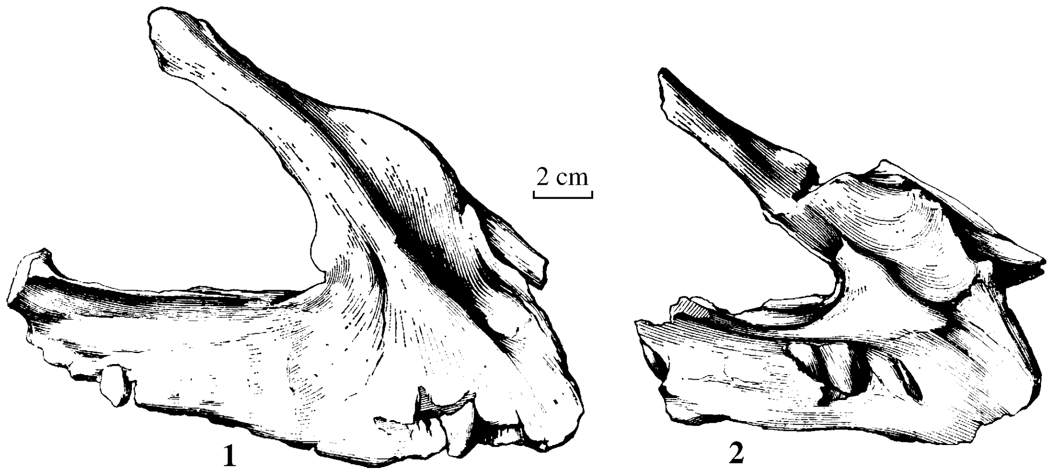

Figure 22. Maxilla of *Omeisaurus junghsiensis.*
1. Lateral view. 2. Medial view.

The lacrimal is a rod-shaped element on sauropods and is only represented by one relatively well preserved specimen from the Wujiaba quarry, which in cross-section is triangular with a relatively broad ventral end that penetrates the jugal and posterior maxilla and a dorsal end that contacts the prefrontal. This element resembles *Camarasaurus* in morphology by being a reversed T-shape element forming the boundary between the orbit and antorbital fenestra.

The jugal resembles *Camarasurus* by being a U-shaped element at the ventral margin of the orbit which contacts the lacrimal and maxilla. Posteriorly, it fuses with the ascending process of the quadratojugal (Pl. X, Fig. 4 and Text Fig. 23-2).

The quadratojugal is only represented by a single L-shaped element, resembling the theropod condition. Anteriorly, its short arm contacts the posterior process of the jugal whereas posteriorly its long arm is in contact with the quadrate.

The squamosal is presumed to be represented by only a single small crescentic element which resembles the pseudosuchian condition. It would have been located at the posterior margin of the supratemporal fenestra, in contact posteriorly with the exoccipital and parietal, and anteriorly with the postorbital to form the boundary between the supratemporal and lateral temporal fenestras. This element is thinner than on *Camarasaurus.*

Seven postorbitals are preserved from Wujiaba as cruciform elements with a relatively broad and thick anterior process which is tightly fused to the frontal (Fig. 23). The ventral process is rather gracile, thin, and extends obliquely anteriorly to contact the dorsal process of the jugal and compose the boundary between the orbit and lateral temporal fenestra. The posterior process contacts the squamosal and a small, rather coarsened tubercle is present on its lateral surface.

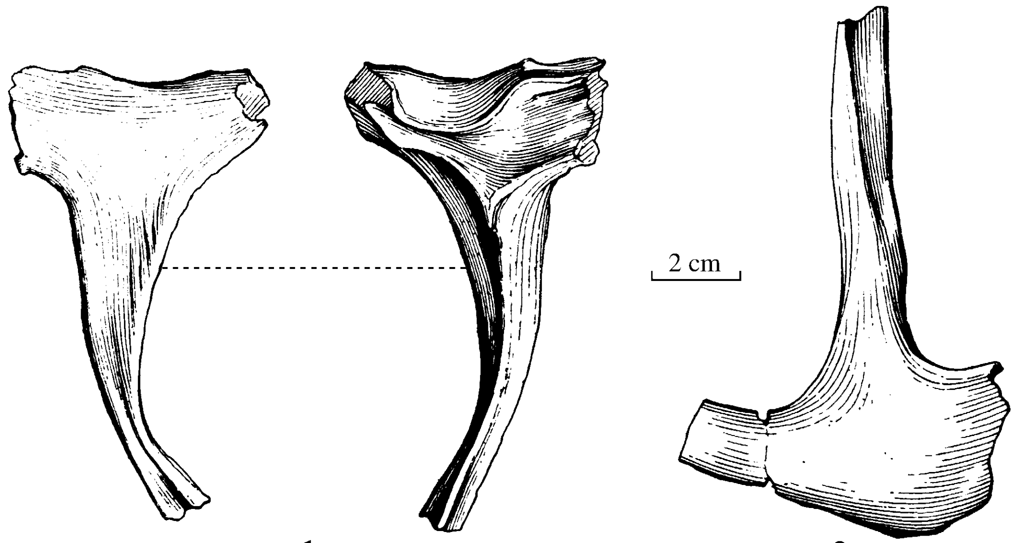

Figure 23. Postorbital and jugal of *Omeisaurus junghsiensis.*
1. Postorbital: A. Lateral view. B. Medial view. 2. Medial view of jugal.

Five quadrates were collected, the most complete specimen being 028. Its morphology resembles the typical sauropod condition with a broad dorsal end and a transversely expanded condyle for articulation with the mandible (Fig. 24). The condylar surface is slightly oblique, causing it to be subdivided into medial and lateral elements with the lateral side slightly lower. The quadrate shaft is compressed, foliate, and represents a longitudinal lamina with two wings separated by a wide angle. The anterior wing contacts the quadratojugal whereas the posterior wing is fused to the paroccipital process. Its linear morphology resembles *Camarasaurus.*

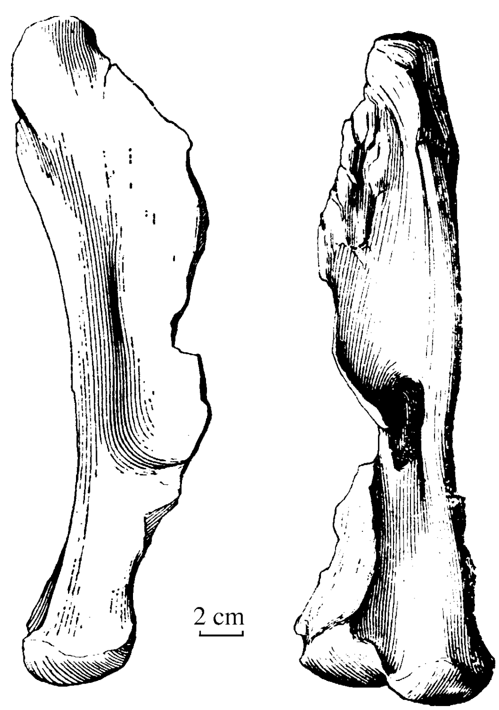

Figure 24. Quadrate of *Omeisaurus junghsiensis.*
1. Lateral view. 2. Medial view.

There are no complete mandibles recovered from the quarry and those specimens that are represented (Table 2) predominantly consist of anterior ends. Two morphologies are recognized: a high, thick morph with alternating large and small dentition, and a thin, weak morph with predominantly small dentition. Analysis of the data causes the authors to select the moderately well preserved specimen 024 to correspond to the neotype as its proportions are more consistent. The anterior mandible of *Omeisaurus* is rather robust and represents the highest point of the element. Posteriorly it gradually reduces in height, lacks curvature, and attenuates posteriorly. The dentary is thick with a smooth and glossy lateral surface, the dorsal margin has an arrangement of small nutrient foramina, and the anterior end is expanded to form a broad mandibular angle. The anteromedial side has a straight but oblique surface with a coarse laminar ridge upon it for attachment of mandibular ligaments and musculature (Pl. 15, Figs. 1, 2; Text Fig. 25). At the midpoint of the ventral margin the dentary becomes constricted and curved, and the ventromedial margin becomes thin with a Meckelian groove that broadens posteriorly and is assumed to be partially overlain by the splenial. 14-15 alveolae are present.

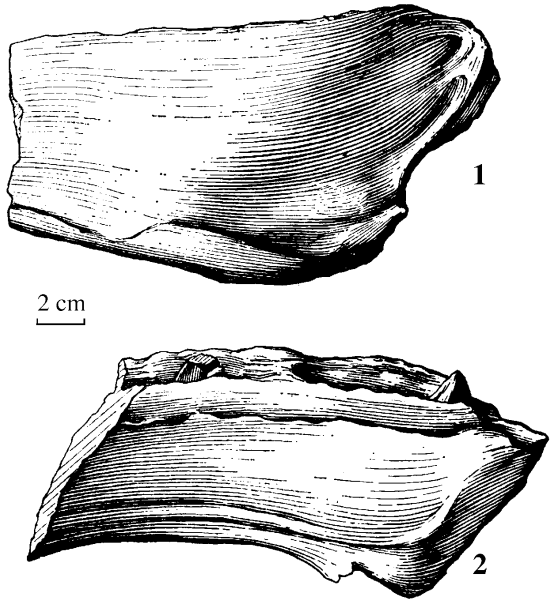

Figure 25. Dentary of *Omeisaurus junghsiensis.* 1. Lateral view. 2. Medial view.

Specimen 026 retains a fragment of the surangular that overlaps the dentary, forms the posteroventral margin, and extends anteroventrally to the most posterior tooth on the mandible. The anteroventral margin is incompletely preserved but displays an embayment which may represent the posterior margin of a reduced mandibular fenestra. The presence of a mandibular fenestra indicates the fragility of the posterior maxilla and its reason for the difficulty of preservation. The preserved portion of the surangular suggests that a coronoid process was not a distinct element.

Gilmore (1925) described a trilateral hyoid on *Camarasaurus* associated with the pharyngeal region of the mandible. Two small yoke-shaped elements 27 cm in length were collected from the Wujiaba quarry (029 and 030), which have one end that is laterally compressed and one end that is rounded and connected by a smooth and glossy shaft. This element is undoubtedly a branchial cornua (Pl. XIV, Figs. 2,3, Text Fig.26).

Dentition is one of the most useful characters for determining sauropod taxonomy. One hundred complete but isolated teeth were collected from the Wujiaba quarry of Zigong Co. Evidence from maxillary and mandibular characters, in addition to isolated teeth (Pl. VIII, Figs. 3-4) and cranial specimens consistently confirm the presence of two species of sauropods in the quarry. Isolated teeth are abundantly produced with elaborate variation within mandibular and maxillary dentition which provides excellent data for determining the function, mode of wear, and replacement regime of this sauropod dentition.

The*Omeisaurus* dental formula is Prm.-4, Mx.-14, D.-14-17. The *O. junghsiensis* dentary contains 14 teeth while the *O. fuxiensis* dentary contains 17 teeth.

All the preserved premaxillae indicate the presence of four functional teeth which are high crowned, lanceolate, nearly symmetrical, labially convex, lingually shallowly concave, and tooth roots, long, and conical. These premaxillary teeth are easily distinguishable from the low-crowned asymmetrical maxillary dentition. Consequently, the specimen described by C. C. Young (1939) from Chenxi, Rongxian Co. represents a premaxillary tooth.

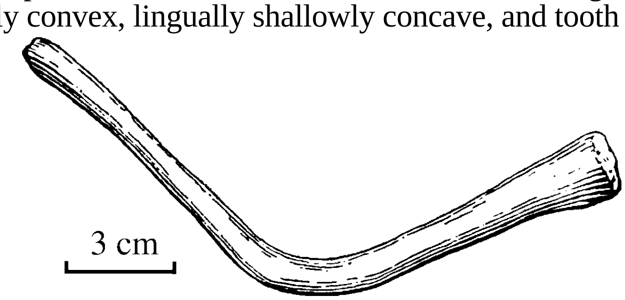

Figure 26. Hyoid of *Omeisaurus junghsiensis.*

The range of variation within *Omeisaurus* maxillary tooth-count varies between 13-15 as some specimens have 14 alveolae and some 15, which may be due to ontogenetic factors, although White (1958) described a camarasaur with eight teeth on its left maxilla and nine teeth on its right, and hence, the *Omeisaurus* dental discrepancies may be due to individual variation. Maxillary dentition is more low-crowned than premaxillary dentition in addition to being asymmetrical, more concave lingually and convex labially, thin enamel lingually and labially, denticulated margins, a gradual reduction in size posteriorly, and conical tooth roots.

The mandibular dentition morphologically approaches the premaxillary condition as anteriorly the teeth are large, high crowned, symmetrical, but reduce in size posteriorly and gradually become compressed. The anterior dental margin is posteriorly curved and denticulated. Lingually the surface is shallowly concave with an inflated medial ridge that runs along the posterior curvature to the top of the crown where it becomes the tooth's apex. The labial surface is convex. Thin enamel coats both sides, and roots are conical. Variation in mandibular tooth count varies between 14-17, with 14 on *O. junghsiensis.*

The dietary nature of sauropods is determined from their herbivorous dentition. Its primary function is attributed to the cropping and mastication of plant material, although some workers have deduced a more varied diet for some taxa within riparion regions, such as ingestion of invertebrates. However, from the curvature of the wear patterns on all portions of the *Omeisaurus* dentition, it appears as if the primary function involves cropping. The maxillary rostral dentition is acute and projected, whereas the anterior mandibular morphology and dentition is large and broad with a "chin," implying well developed rostral musculature with apparent cheek morphology, which would greatly facilitate the drawing in of food during feeding, after which the high-crowned lanceolate teeth would crop prior to ingestion. Premaxillary dental wear is longitudinal with anterior and posterior margins used for shearing. Maxillary tooth wear is generally apical with curved striations upon the facet suggesting a slight but not intense grinding function. The implications of sauropod feeding suggest a strong digestive system which may have included a massive caecum. The presence of a well developed hyoid apparatus is also an indication of tongue function.

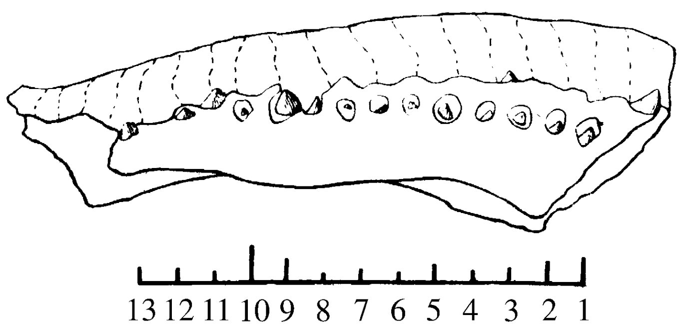

Figure 27. *Omeisaurus junghsiensis* tooth replacement sequence.

Tooth replacement in *Omeisaurus* appears to be systematic. Sauropod tooth replacement was studied by Edmund (1969) and White (1958), the latter of which believed the process to occur in a "replacement wave" which consisted of a single replacement. This has been noted by a majority of workers who have documented only two sets of teeth on any specimen, with one set representing functional teeth, one set as replacement teeth, and each set representing an interlocking mechanism. Each tooth in the dental battery represents a distinct position and roots of the replaced teeth are resorbed by the ramus.

Axial skeleton: Several hundred isolated vertebrae were collected, including over 90 cervicals, but with the exception of the four sacral vertebrae, the precise count of the remaining series is unclear regardless of the abundant new data and original type specimen. The Wujiaba quarry produced rather damaged specimens and a single articulated column of caudals. Comparisons were conducted between *Omeisaurus* elements and those from other closely related taxa to attempt to determine an accurate vertebral count. Following is a table of closely related sauropod vertebral counts.

Table 4. Comparison of sauropod vertebral sequences.

Taxon	Cervical	Dorsal	Sacral	Caudal
Diplodocus carnegii	15	10	5	73
Camarasaurus lentus	12	12	5	53
Apatosaurus louisae	12	10	5	82
Mamenchisaurus hochuanensis	19	12	4	31±?
Haplocanthosaurus priscus	¾	14	5	¾
Euhelopus zdanskyi	17	15	3-4	¾
Opisthocoelicaudia skarzynskii	¾	11	5	35±?

With their high and large dorsal spines, *Omeisaurus* vertebrae resemble those of *Mamenchisaurus* and *Euhelopus.* Bialynicka (1977) suggested that these exaggerated spines facilitated the strengthening of dorsal musculature for support of an extremely extended neck and tail such as in *Diplodocus* and *Apatasaurus*, contratry to the short spined and short necked and tailed *Camarasaurus.* The Asian taxa mentioned above, in addition to the relatively phylogenetically close *Omeisaurus,* maintain high spines and long necks and are assigned to the subfamily Euhelopidinae based upon these characters. Arrangement of the *Omeisaurus* vertebral sequence was based upon morphology, size, and reference to the characters expressed in *Mamenchisaurus,* which is regarded as both nearly contemporaneous and geographically proximal. *Omeisaurus* is hereby determined to possess 17 cervicals, 13 dorsals, four fused sacrals, and 40±5 caudals.

C. C. Young provided the following description of the cervical series: “There are at least four centra which may be accurately identified as cervicals, among which is one specimen that is nearly complete but the other three are damaged (Figs. 3 and 4). The best specimen (A) (Fig. 2) has suffered some slight damage but is still in relatively good condition, probably represents the seventh or eighth in the sequence, and compares to *Euhelopus* in having a long and complexly constructed neck. Its directly dorsally extended pseudospinous process differs from those on *Euhelopus zdanskyi* and *Camarasaurus supremus* which are instead gradually warped dorsally. The centrum is complete and opisthocoelous with distinct pleurocoels that have yet to become well divided. The ventral pleurocoel appears to have a distinct acute and oblique ridge traversing it. Pre- and postzygapophyses are complete with horizontal articular facets.”

Young’s identification of this relatively complete cervical to Cv7 or Cv8 is consitent with those identified as the same elements in this paper.

Supplemental cervical description: The long and laterally compressed centrum is opisthocoelous with centra becoming more elongated posteriorly. The longest in the series is Cv9 or Cv10 posterior to which the centra become shortened and correspondingly increase in height. Anterior and posterior cervical morphology is recognized in two morphologies: from the axis to Cv11 the centra are long with low neural spines, while from Cv12 to Cv17 the centra are short with high and broad neural spines.

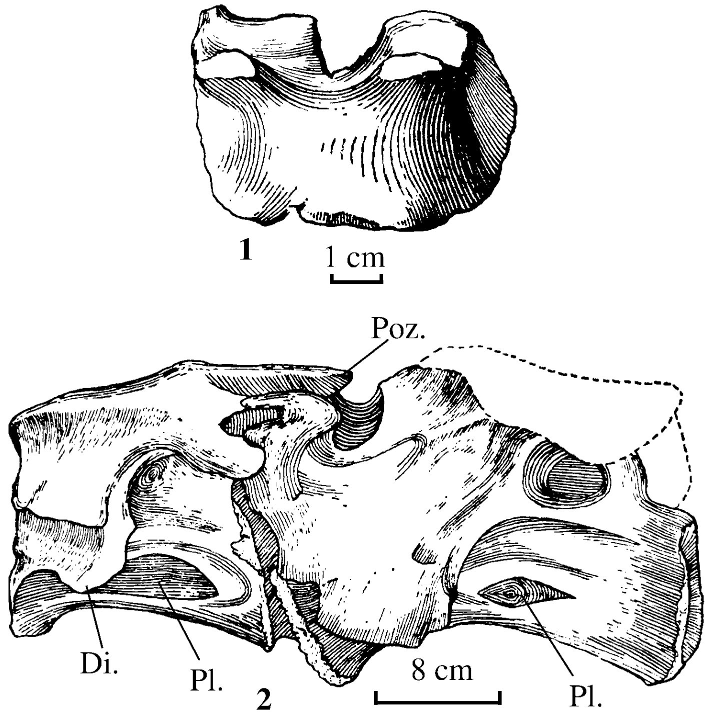

Figure 28. *Omeisaurus junghsiensis* vertebrae.
1. Atlas. 2.Axis and Cv3.

Only the intercentrum of the atlas is preserved, which is horseshoe-shaped with a rounded smooth and glossy cup-shaped depression anteriorly to facilitate the occipital condyle. Ventrally, the element is relatively flat and lacks a process such as noted on *Tuojiangosaurus.*[*]

The axis resembles that of *Mamenchisaurus* and is preserved in articulation with Cv3 (Fig. 28). The centrum is opisthocoelous with a relatively flat anterior condyle and an acute ventromedial ridge. A thick laminar ridge bounds two relatively flat ventral surfaces creating a rectangular outline. A deep pleurocoel lies laterally with a septum lying obliquely, which creates deep anterior and posterior cavities. The neural spine is low and expands anteroposteriorly as an oblique eave-shaped ridge. Prezyogapophyses are located on the anterior neural arch as small dorsally directed tuberosities, diapophyses lie anterolaterally on the spine, and parapophyses lie anteroventrally as elliptical tuberosities.

The morphologies of cervicals Cv3-Cv11 are basically consistent, resemble those of *Mamenchisaurus,* and differ only in size, which is consistent with the description made by Young (1939). Centra are opisthocoelous, maintain prominant prezygapophyses, and have distinct suture lines resembling *Mamenchisaurus* and *Nemegtosaurus.* Ventrally, the centra are flat with lateral ridges creating a rectangular outline; anteriorly, there are two expanded and winged parapophyses, the centrum expands anteroposteriorly with the posterior end larger than the anterior end, and a long pleurocoel lies laterally, containing one or two septa and numerous small cavities for facilitating musculature. The neural arch is low.

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[*] Translators note: This comparison must be a typographical error as this genus is a stegosaur and no intercentrum belonging to it is described in the literature.

Initiating with Cv11, the cervical centra become reduced in length and increase in height with a broadening of their ventral surface, while pleurocoels become shorter and deeper. The lateral ventral ridges gradually become lost while centra gradually transform from quadrate to circular, or approaching a dorsal morphology. Accordingly, neural arches gradually increase in height, pre- and postzygapophyses become constricted and short, and neural spines become transversely expanded. The presence of a posteromedial cleft at the apex of the spine initiates at Cv14. The two laminar crests on the neural arch alter from being oblique to vertical and begin to completely support the large and robust diapophyses.

No complete dorsal vertebrae were present in the type, resulting in an extremely simplified description: "Two damaged opisthocoelous centra may represent posterior dorsals. The first specimen is well preserved, but the second has been dorsoventrally compressed and laterally distorted. The dorsals are laterally compressed appropriately tall, and lack vestiges of parapophyses which is consistent with Wiman's description of *Euhelopus zdanskyi*. From the 22nd vertebra onward, parapophyses do not ascend from the centrum but are positioned higher."

Omeisaurus dorsals are extremely close to those of *Mamenchisaurus* and are only differentiated by neural spine morphology as is the condition with the majority of sauropod genera.

Supplementary description of dorsal vertebrae: The dorsals are all opithocoelus with generally equivalently deep centra, prezygapophyses are rather pronounced, and pleurocoels are located dorsally. The neural arches are tall with relatively prominant laminae which also support the trilaterally shaped, horizontally extended, diapopyses. The neural spines are large and high and vary greatly in morphology along the column.

Neural spines on D1-D4 are elongated with a relatively flat apex and a medial internal fold on each side. The spines gradually constrict to becomes narrow. Beginning with D5, the spines begin a paired curvature morphology with the anterior side convex and posterior side concave, and are associated with wing-shaped laminae. The last of the dorsal spines are rectangular with only vestigial laminae and their apices are slightly expanded with a shallow depression. These spinous transformations facilitate determination of their precise position in the vertebral sequence.

Table 4. Vertebral measurements of *Omeisaurus junghsiensis* (cm).

Sequence	Centrum length	Centrum height	Posterior breadth	Total height
2 (axis)	10.1	6.1	5.6	12.8
3	15.0	6.9	4.2	15.1
4	19.1	7.2	5.3	16.6
5	22.5	8.1	6.6	19.2
6	27.6	8.7	6.0	20.1
7	28.0	10.6	5.8	20.4
8	28.4	10.8	7.6	23.0
9	28.4	9.4	6.0	25.6
10	35.0	10.1	6.0	26.1
11	37.3	14.3	6.2	27.8
12	27.8	11.6	9.5	25.2
13	30.0	12.1	8.6	26.8
14	26.1	12.1	18.6	¾
15	23.0	8.5	16.0	¾

The dorsal verterbrae diapophyses lie upon the neural arch, are large, robust, triangular in cross-section, and are supported by three laminae. Designations for these laminae are provided in Osborn (1899): the first supports the ventral diapophysis by extending from the anterolateral side of the neural arch to the ventral side of the prezygapophysis and is designated the infraprezygapophysial lamina; the second ventral lamina extends dorsally from the lateral neural arch to compose the ventral margin of the diapophysis and is termed the infradiapophysial lamina; the third lamina extends from the posterior neural arch to support the posterodorsal margin of the diapophysis by extending dorsally from beneath the postzygapophysis and is called the infrapostzygapophysial lamina. These laminae are distinct on *Omeisaurus* and particularly resemble those on *Camarasaurus* (Fig. 29).

The articular surfaces of the centra on dorsals 1-3 of the neotype are slightly anteroposteriorly askew due to compressional distortion, which prohibits a precise description. Posterior to D4, the centra are preserved in normal condition with merely a single centrum suffering compression, although neural arches and spines have required a slight amount of reconstruction. Figure 29 illustrates a relatively complete specimen selected for the description above.

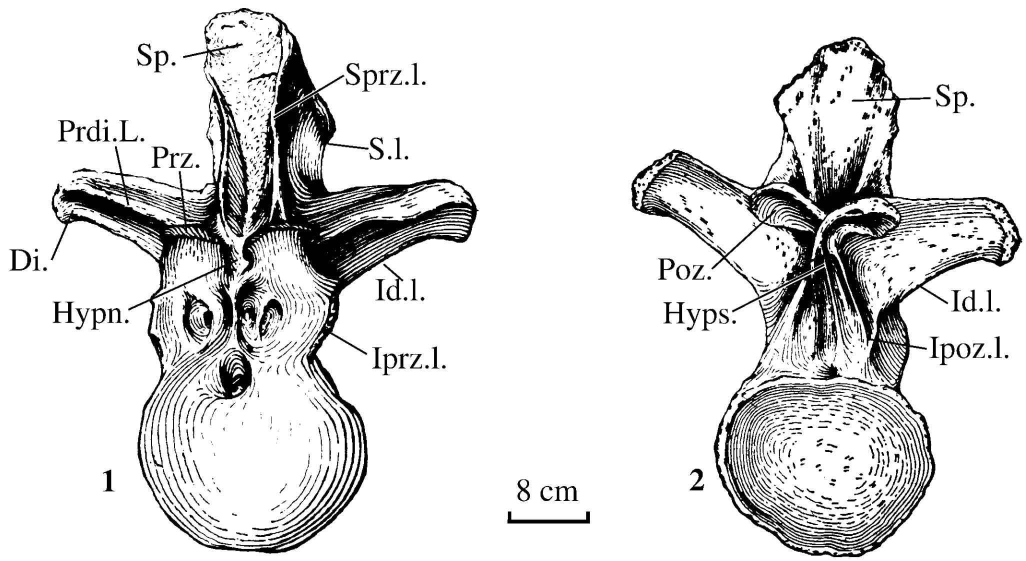

Figure 29. Dorsal vertebra 10 of the neotype for *Omeisaurus junghsiensis.* 1. Anterior view. 2. Posterior view.

Three sacrals were preserved on the type which C. C. Young noted as resembling *Camarasaurus* as described by Osborn and Mook (1921). But Figure 6 of the original text illustrates a sacral region that appears to be missing one element. Young's text states: "Sacral centra are slightly weaker than dorsal centra, are reduced, and platycoelous. The sacrocostal lobe is unpreserved although the presence of three ventral nodes for ribs confims its presence. Dorsal nodes are incomplete with the exception of the two most posterior. These two series of sacral rib plates are well preserved on the left side and are well developed to form plate-shaped crests for articulation. On the right side, only the bases of these structures are preserved and many are damaged. These sacral lamellae are slightly concave anteriorly and because of their fragmentary preservation, their precise range is difficult to ascertain. They perhaps resemble *Camarasaurus* with three fused spines and a firmly yoked articulation."

A complete sacrum was not recovered from the Wujiaba quarry, although there was a single string of four sacral neural arches and spines which indicate an affinity to the majority of genera in the subfamily Euhelopodinae. In this subfamily, the sacrals are platycoelous with S4 as slightly opisthocoelous for articulation with the prolcoelous first anterior caudal. Sacral spines are high with the anterior three fused into a plate, although the fourth sacral spine is isolated, simple in morphology, and rod-shaped, or resembling a caudal spine.

Nine anterior articulated caudals were represented on the type. The most characteristic element in this series was Cd1, which was described by C. C. Young as follows: “Among these nine vertebrae, the first (Fig. 7) may be regarded as a caudo-sacral which is extrememly distinct from those observed on other sauropods (as is noted on *Camarasaurus*). Firstly, its articulation is loose and sluggish, confirming that it was not fused to the previous three. Further, it is procoelous and like the several posterior centra is relatively short with strong fan-shaped caudal ribs. An additional distinct character is the presence of two isolated wing-shaped elements on each side of the base of the neural spine which extend with a concave ventral surface transversely dorsal to the caudal ribs. These distinctive elements in all probability are related to the pre- and postzygapophyses and correspond to the supracostal osteological partition of the sacral rib described by Osborn and Mook (1921). Most of the neural spines are incomplete but would appear to berelatively short.”

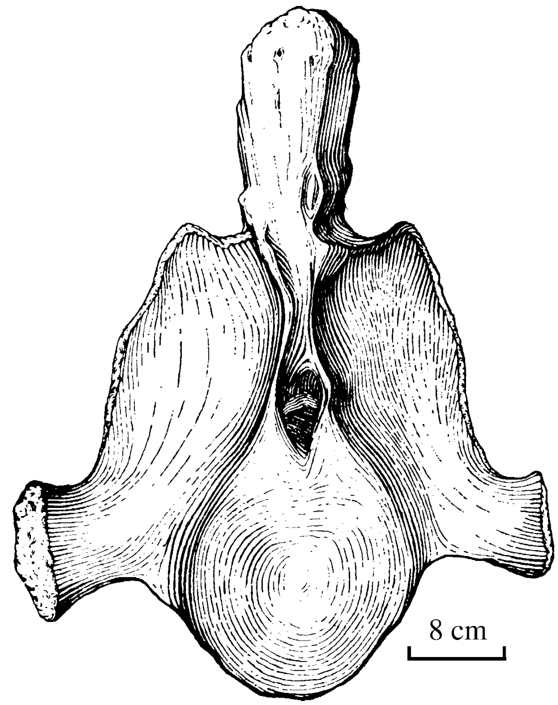

Figure 30. First caudal vertebra of *Omeisaurus junghsiensis* (slightly restored).

The neotype from Wujiaba preserves 22 articulated caudal vertebrae with morphologies and size that distinctly resemble the type (Pl. XVII, Fig. 1). The first caudal centrum adheres to the type by being shallowly procoelous with caudal ribs that fuse to diapophyses, partially contact the neural arch, and are expanded into a fan-shape. The seven anterior caudals are procoelous with a sulcus that gradually shallows anteroposteriorly. Posterior centra become amphyplatyan with Cd14 maintaining a rod-shaped neural spine, and posterior to this position the spines become low elongated plates. Prezygapophyses are extended anterodorsally on the neural arch with slightly dorsally inclined articular facets. Postzygapophyses become located on the posterior neural spine and are in tight articulation with succeeding vertebrae.

Not many ribs were preserved on the type forcing an extremely simplified description by C. C. Young. The Wujiaba site, however, produced relatively numerous specimens, but due to inappropriate excavation techniques, complete specimens are rare and only descriptions from a portion of the column are presented here.

Cervical ribs are tricapitate with a nearly symmetrical capitulum and tuberculum and an anteriorly extended anterior process. The elements are conical with an elongated trough upon them. They gradually lengthen and thicken anteroposteriorly. At the midsection of the series their shafts initiate as triangular, then thin distally, and become oval in cross-section. The several ribs at the end of the series possess a tricapitate proximal end with nearly equivalently lengthed spikes, while the shaft is trilateral and attenuates to being thin and flat.

Dorsal ribs are relatively simple in morphology and resemble the typical sauropod condition. Eight incomplete specimens were preserved on the type which were described as resembling *Camarasaurus.*

All the sauropod haemal arches excavated from the Wujiaba quarry are not forked except for a single specimen. Hence, it is assumed that on *Omeisaurus* all the arches were not forked, butconstructed in the simplified condition (Pl. XIV, Fig. 8). With reference to the positions on *Mamenchisaurus* and *Camarasaurus,* it would appear that the arches first appear on *Omeisaurus* on Cd4 or Cd6. These elements are relatively robust but gradually reduce in size anteroposteriorly. Articular surfaces proximally are transversely broadened and slightly oblique anteriorly. The haemal canal is large, oval, and posteriorly gradually becomes triangular. At the distal end the arches become laterally compressed.

Apendicular skeleton: The type specimen preserved only a fragmentary piece of scapulae and a relatively complete coracoid which Young compared to *Tienshanosaurus,* but neglected to conduct a precise description. He did, however, attempt a reconstruction of the scapula. The Wujiaba specimens confirm the basic accuracy of his reconstruction. A total of five scapulae were collected from Wujiaba which accurately resemble *Tienshanosaurus*. The glenoid fossa is massively concave within a large proximal end that is as wide as or slightly larger than the length of the shaft. A straight suture line fuses the coracoid (Pl. XIII, Fig. 1). An oblique depression, or "diagonal area," lies between the suture and the shaft, and the distal end is expanded with a depressed fan-shaped surface which facilitates the attachment for the anterior scapulohumeralis.

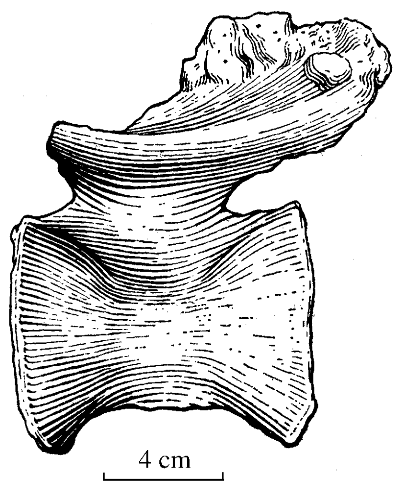

Figure 31. Caudal vertebra of *Omeisaurus junghsiensis*

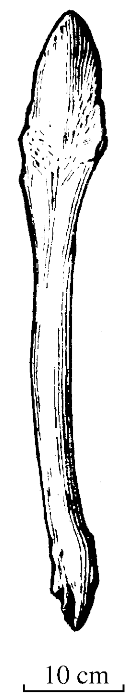

Figure 32. Clavicle of *Omeisaurus junghsiensis*

On the type, the coracoid was in tight association with the scapula, being elliptical in shape with a rounded and thin distal margin that thickens toward the glenoid fossa, was medially concave, laterally convex, and possessed a large foramen at its anterodorsal margin (Pl. XIV, Fig. 6).

Osborn (1899) described a pair of sauropod clavicles pertaining to *Diplodocus* which he placed anterolaterally on the skeleton as long, compressed, lanceolate elements. The Wujiaba quarry produced three well preserved, flattened, slightly curved, and elogated elements with a proximal end that is lancelate, a shaft that distally gradually becomes rounded, and two small tubercles distally that have a small notch between them. That these elements represent clavicles of *Omeisaurus* are undisputed (Pl. IV, Fig. 5). Similar elements were excavated from Dujia Commune, Rongxian Co. belonging to a massive *Mamenchisaurus* specimen that predominantly represented a single individual. This data confirms that the Euhelopodinae genera *Omeisaurus* and *Mamenchisaurus* possessed lanceolate clavicles.

No sternum was preserved on the type specimen, but the Wujiaba data contains a single thin, elliptical, relatively flat, element diagnosed as such (Pl. XIV, Fig. 4). Its length is greater than its breadth, it is slightly thicker medially with smooth and glossy margins, and displays ligament attachments at the midline between it and its counterpart. Its thin and flat nature prohibits it from being readily preserved.

The type preserved a left humerus described by Young as "nearly complete with only the distal end suffering damage and compressional distortion. The proximal end is extremely expanded with a deltopectoral crest and a depression to facilitate the anterodorsal musculature. The shaft is appropriately robust with relatively straight and thin margins, and distally becomes gradually expanded. At the distal end this specimen differs from *Tienshanosaurus* and more closely approaches *Euhelopus,* although the morphology of a euhelopid shaft is stronger with a distinct amount of curvature. Although the distal condylar notch is damaged, its remaining features indicate that it was not extrememely pronounced. Moreover, there are several vacuities at the midshaft. In size it is slightly smaller than *Euhelopus* and larger than *Tienshanosaurus."*

Seven humeri are preserved from Wujiaba, among which five resemble the type. The humerus on the neotype is complete with characters matching the description of Young. Supplemental characters include a slightly expanded distal end with two indistinct distal condyles maintaining a small triangular condylar notch between them, and a thin and flat shaft.

The type did not preserve an ulna or radius, but on the neotype the ulna is straight with an expanded proximal end but weak olecranon process. It is elliptical in cross-section, has a constricted distal end, and at a point one-third from the distal end is more slender than the radius. The radius is slightly shorter than the ulna with a straight shaft that is slighly constricted, is elliptical in cross section, and both ends are slightly expanded to the same degree. A depressed surface lies proximolaterally for articulation with the ulna, and the distal end is slightly rounded with a convex articular surface.

The precise manus digit formula is currently unknown. In general, sauropod forearms, metacarpals, and digits display different degrees of modification. However, as *Omeisaurus* and *Euhelopus* share a relatively close relationship, to the point of the former possibly being ancestral to the latter, forearm reduction should be minor. Therefore, with reference to *Euhelopus* and *Mamenchisaurus,* the phalangeal formula of *Omeisaurus* is estimated as 1. 2. 3. 3. 1. Individual metacarpals collected are more slender and gracile than the metatarsals, more simple in morphology, rod-shaped with slightly inflated ends; the proximal end is broad, flat, and triangular in cross-section, the midshaft is constricted where it becomes elliptical, the distal end is slightly inflated with a smooth and glossy articular surface that is slightly concave at its midsection, and there are two small condylar processes laterally.

The phalanges are short and robust, with the most notable character being the curved proximal end with its articular surface dorsoventrally elongated and slightly oblique, an irregularly surfaced shaft, a thickened medial side, and slightly oblique and relatively thinner lateral side.

Distal ligament sulci are absent. The unguals are relatively thick with asymmetrical margins, slightly curved, and generally resemble the typical sauropod condition. Digit I has the largest and slightly laterally compressed ungual.

The ilium, ischium, and pubis were all preserved on the type although they were damaged. C. C. Young expended the greatest efforts to attempt a proper reconstruction of these elements through line drawings, which are confirmed by the Wujiaba data as basically accurate. The only discrepancies lie in the postions of the postacetabular process and ischial peduncle. The neotype preserves two relatively complete and undistorted left ilia that maintain a thin iliac crest with a rather large portion of it laterally concave to facilitate the attachment of the iliofemoralis. The preacetabular process is strong with a wide angle between it and the pubic peduncle, but it is not as thickened as in *Camarasaurus.* The pubic peduncle is strong and robust with a convex anterior end, the medial acetabular surface has a crescentic depression that runs directly along the midshaft dorsally to the center of the iliac body where the groove disappears, and constitutes the dorsal margin of the acetabulum. The dorsal acetabulum maintans a twisted angle rotating it medially. The ischial peduncle is weak and is only present as a large tubercle. Four relatively distinct and crescentically arranged nodes are present on the medial ilium which represent the attachments for the sacral diapophyses and ribs.

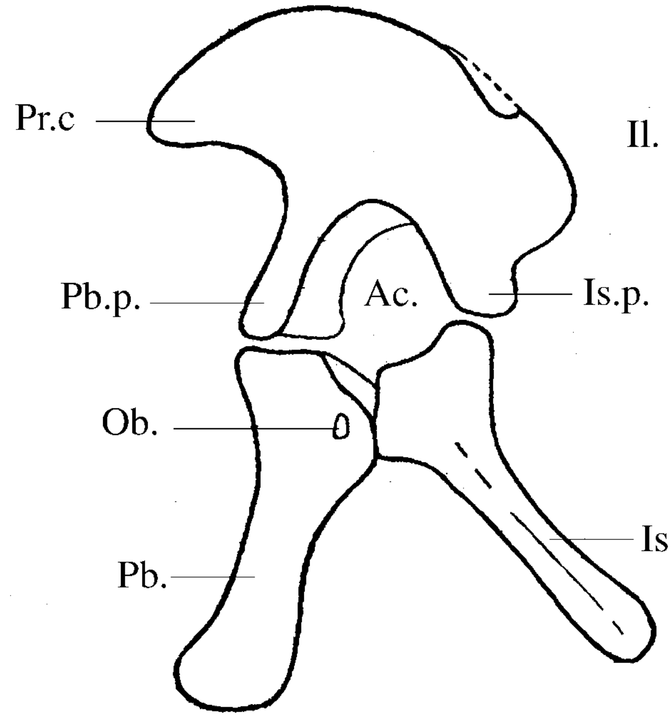

Figure 33. Restoration of the pelvic girdle for *Omeisaurus.*

C. C. Young's Figure 15 illustrates an ischium and pubis that conform in size and morphology to the specimens preserved at Wujiaba. Young conducted a detailed description of the morphologically simple plate-shaped ischium with an unexpanded distal end but expanded and flattened proximal region. He stated that "the two ischia are nearly complete with damage only to the dorsal margin. The shaft's right side is relatively more narrow, robust, and rounded than the left side. From a total perspective the element is relatively robust and differs from *Camarasaurus* but approaches *Euhelopus* and *Tienshanosaurus.* The distal end is distincly expanded as on *Tienshanosaurus* but smaller than on *Euhelopus.*"

The pubis on the type only preserved the left side with Young's description and text figures basically accurately corresponding to neotype specimens. The pubis is longer and thicker than the ischuim with a greatly expanded proximal end and a large obturator foramen near its posterior margin. The distal end is curved anteriorly and thickened with a coarsened articular surface at the symphisis for ligament attachment. This morphology resembles *Camarasaurus.*

The femur was so poorly preserved on the type that Young did not describe it, but seven specimens were recovered from Wujiaba. It is straight with an anteroposteriorly compressed shaft and a head that extends dorsomedially with a large elliptical articular surface and an inconspicuous neck. The lesser trochanter is rather weak and situated laterally, the fourth trochanter is a crest that is located approximately one-third of the way down the medial side of the shaft, and the two distal condyles are moderately developed with the medial condyle larger than the lateral condyle. On the

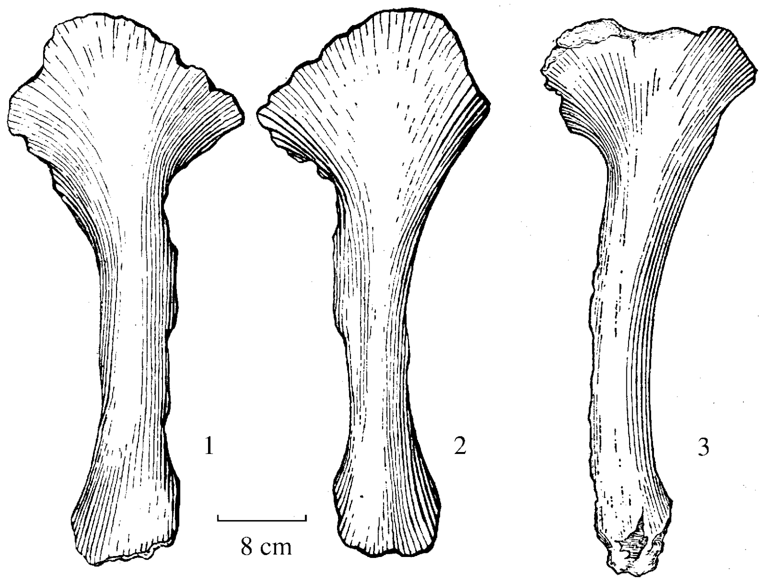

Figure 34. Ischia of *Omeisaurus junghsiensis.*
1 and 2. From Young, 1939. 3. Right ischium of neotype.

lateral side of the lateral condyle there is a shallow longitudinal groove to facilitate musculature associated with the tibia. The intercondylar notch is deep while the trochlea is shallow, smooth, and glossy.

The tibia is straight with a relatively flat shaft and is more robust than the fibula. Its proximal end is expanded with a wing-shaped anterior process that articulates with the V-shaped fovea on the opposing fibula. The tibia gradually attenuates distally but at its distal end expands transversely with a medial process on its articular surface to facilitate articulation with the astragalus (Pl. XIII, Fig. 6).

The fibial shaft is thin, flat, straight, elliptical in cross section, and anteroposteriorly expanded at both ends. The proximal end is relatively flat with a concave medial surface termed the fovea-ligamentosa. The distal end is thick, slightly flattened anterioposteriorly, and has a coarsened articular surface (Pl. XIII, Fig. 7).

The astragalus resembles that of *Mamenchisaurus,* being a massive element that is triangular in shape in posterior perspective and wedge-shaped in lateral perspective. A depression lies dorsally for articulation with the astragalar process of the tibia which is deeper than on the primitive *Shunosaurus.* Its lateral side, where it articulates with the fibula, is precipitous, while its medial side gradually attenuates to become thin (Pl. XII, Fig. 4).

The hind limb of *Omeisaurus* is is not completely preserved such that the precise structure of the foot is still unknown, but the metatarsals are more robust than the metacarpals. Comparisons were made with *Camarasaurus* and *Euhelopus* to facilitate pedal reconstruction, although it is also acknowledged that *Omeisaurus* predates these two genera in addition to *Mamenchisaurus.* It is known, however, that digit V is present due to the pressure facet present on the proximolateral side of digit IV. The first metatarsal is thick and short with a curved proximal end and a morphology that resembles *Apatasaurus louisae.* Among those preserved Mt3 is the longest, while Mt1 and Mt2 are the most robust. The proximal end of Mt3 is thick and laterally flattened and its shaft in cross-section is nearly circular. The distal end is tranversely flattened with a slightly concave articular facet. Ligament sulci are absent on both sides. An Mt5 collected and presumed to belong to *Omenisaurus* is small with a circular distal end and a very slightly coarsened articular facet suggesting the presence of an functional digit.

As *Omeisaurus* is considered more primitive than *Camarasaurus, Mamenchisaurus,* and *Euhelopus,* its phalangeal formula was reconstructed as 1-2-3-2-1 with thick but flattened digits, or resembling the standard sauropod condition.

Unguals are large, thick, laterally compressed with asymmetrical sides, and medially curved. The large first ungual is a flattened triangle with a medially curved apex, has a relatively shallow lateral groove, and is ventrally flat. This morphology undoubtedly adds breadth to the pes such that it would facilitate stability during ambulation. The unguals of digits II and III are more symmetrical than the previous in addition to being more circular with a slight curvature and a general morphology resembling other sauropods.

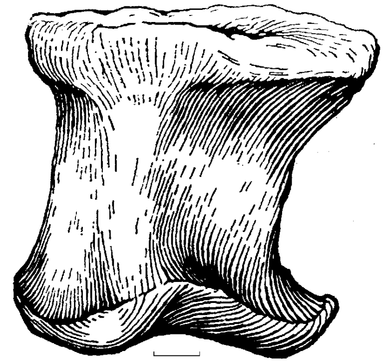

Figure 35. Metatarsal 1 of *Omeisaurus junghsiensis.*

Although material from the quarry has been prolific, there have still been no complete skeletons recovered. Excavation records indicate the elements were subjected to fluvial transport prior to deposition creating difficulties in the study and disposition of the data and particularly toward the reconstruction of a skeleton. With regard to estimation of vertebral count and determination of sequence, the only recourse was to refer to the closest taxon and consequently the comparable *Mamenchisaurus* was used. Taxonomy of the Wujiaba data was based upon morphological characters which led to the selection of the skeletal elements representing the species. Based upon the size of the type, comparison of Cv8, and acknowledging the type as a single individual, the selection of the vertebral column was further facilitated. After the vertebrae were selected, the four limbs of the neotype were constructed based upon the size of the type. The final composite skeleton is 14 meters in length.

Omeisaurus changshounsis Young, 1958

Original diagnosis: Slightly larger than *O. junghsiensis* with relatively flattened and thinned limbs. Femur and tibia are relatively long and tibia appears to exceed the length of femur.*

History of research: C. C. Young described the species in his 1958 work “Sauropods of China.” The type was derived from the early Late Jurassic Upper Shaximiao Fm. at Shizitan Reservoir, Changshou Co., Sichuan Province.

Type: Eleven disarticulated cervical and dorsal vertebrae, distal scapula, coracoid, a fragmentary left humerus, a portion of the pelvic girdle, left femur, nearly complete left tibia, fibula, and astragalus (#V930).

Description: Renovation and reconstruction of the Shizitan Reservoir, Changshou Co. unearthed the specimen and created the damage inflicted upon all of the specimens. Consequently, C. C. Young’s description is brief and to the point. Upon the study of the dinosaurs from the Sichuan Basin here, a reevaluation of the specimens were undertaken in order to facilitate

* This character is inconsistent with ratios known for the Sauropoda. Steel (1969) believed the specimens possibly represented two individuals, but a reevaluation of the data suggests it is indeed a single individual but that the femur was reconstructed in error.

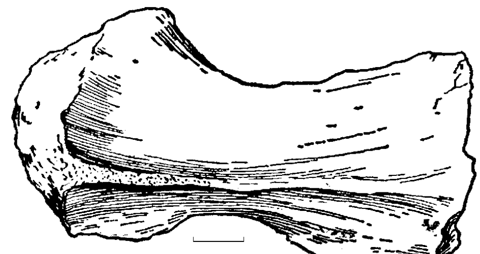

Figure 36. Cervical vertebrae of *Omeisaurus changshouenis* (from Young, 1958).

comparison with other species and corroborate the observations, taxonomy, and descriptions made by Young.

In size and general character morphology the assemblage is more or less consistent with *O. junghsiensis*, with the only distinctions lying in the cervical vertebrae and a portion of the limb bones being more compressed.

Three cervical vertebrae are present, among which two are nearly complete. The most complete specimen possesses relatively strong prezygapophyses, may represent Cv7 or Cv8, and is 46 cm in length. The remaining two cervicals are determined to be posterior elements based upon the constriction of the centra. Size and morphology are extremely close to *O. junghsiensis* but the external surface is smoother and glossier. The lack of a neural arch prohibits further description.

Eight additional vertebrae are extremely fragmentary and consist only of the centra. Six appear to represent anterior dorsals among which is a smaller specimen that may be a posterior dorsal. Pleurocoels are well developed and parapophyses are absent. Young identified the two posterior vertebrae of the other eight as possibly representing Cd1 and Cd2 as they are short with weak prezygapophyses and are opisthocoelous. One specimen still retains the base of its diapophyses. These characters differ slightly from the procoelous caudals of *O. junghsiensis* and *Mamenchisaurus.*

The right scapula is too fragmentary to attempt a description although a coracoid is present with a straight suture for fusion with the scapula and is short and broad with a large foramen equivalent in diameter to *O. junghsiensis.* The foramen's greatest diameter is 4.6 cm and glenoid fossae is 9.2 cm.

The left humerus is incomplete with the condyles unattached to the shaft, and as such Young (1958) clearly stated in his description that as the distal end is also damaged his restoration was a bit subjective, and comparisons were difficult. Its most notable character is being flat and thin. The deltopectoral crest is more reduced than in *O. junghsiensis,* and a distinct crest lies posterodorsally that runs directly ventral to the condyles. Although the crest is broken it is still distinct in outline. These characters clearly distinguish it from other species of *Omeisaurus.*

Two articulated mani are present, the most well preserved representing the right Mc1-3. Mc1 has been very slightly shifted in position but is still in articulation with a single carpal. Mc4 is laterally concave and has a pressure facet indicating the presence of Mc5 which is not preserved. The distal ends of Mc2 and 3 are damaged but from a general perspective they would be small and gracile, corresponding to the other bones of the manus.

An ilium is absent, although there are two fragmentary ischia, and a nearly complete pubis, but their precise lengths are unknown. Their characters resemble *O. junghsiensis* with the exception of having thinner and flatter shafts and the pubis is extraordinarily expanded dorsal to the ischium.

A left femur preserves only 10.7 cm of the extremely compressed shaft and damaged distal end. Because the shaft only thickens at its contact with the condyles it is presumed that the femur has a weak contact with the pelvic girdle. The tibia and fibula are nearly complete and appear relatively long in relation to the femur. The tibia is relatively gracile, weak, and has a thin and flat shaft. A left astragalus is present, resembling *Mamenchisaurus,* but is slightly smaller.

The vast majority of this data belongs to a single individual. C. C. Young concluded that "it is currently controversial whether this data is distinct from *O. junghsiensis,* as its distinguishing characters lie in its relatively large size, thin and flat long bones, and tibia-femur ratio being relatively long. Whether the specimens represent a single species is not verifiable, though clearly they belong to the same genus, and hence they are erected as *Omeisaurus changshouensis.*"

This data is currently housed in the collections of IVPP. After reevaluation of the material it is believed that errors were conducted in restoration of the tibia and fibula lengths. Vertebral centra approach both *Omeisaurus* and *Mamenchisaurus* and as the data is still very fragmentary, Young's diagnosis is maintained and the species is retained.

The stratigraphic position of *O. changshouensis* is higher than the type locality for the genus and should more closely approach the level producing *Mamenchisaurus.*

Omeisaurus fuxiensis **sp. nov.**
(Plate XV, Figs. 3,4)

Diagnosis: A relatively small sauropod with a skull not as high as *O. junghsiensis,* a narrow occiput, a weakly projected occipital condyle, long rostrum that is narrow at its terminus, an inconspicuous mandibular angle, more numerous, smaller, and brachydont dentition with a dental formula of premaxilla-4, maxilla-14, and dentary 17-19. Cervical vertebrae are long and ventral axis lacks a keel.

Material: A basioccipital, a maxilla bearing dentition, left dentary, and axis (specimen #CV00267).

Locality and stratigraphic position: Early Late Jurassic, Upper Shaximiao (Shangshaximiao) Fm. Wujiaba, Zigong Co.

During the course of disposition of the Wujiaba sauropod data, one particularly characteristic basioccipital was noted with a basisphenoid still fused to its anterior aspect (Pl. XVI, Fig. 1). Its morphology is basically consistent with *O. junghsiensis* although the occipital condyle and condylar neck are quite distinct. *O. junghsiensis* has a hemispherical, smooth, and glossy condyle, whereas CV00267 is not hemispherical, but its terminus is a pronounced but gently pointed process creating a gentle laminar morphology. The condylar neck is relatively long with a relatively deep longitudinal ventral groove upon it.

A maxilla with three complete teeth is also represented in the Wujiaba collection which was selected as the paratype for *Zigongosaurus fuxiensis.* At the time of its description it was believed to possibly represent a juvenile as it differed quite distinctly from the type with its small dentition, thin ramus, and asymmetrical posteriorly curved tooth crowns with distinctly denticulated anterior margins.

A piece of left mandible is predominantly represented by a dentary (Pl. XV, Figs. 3,4) although there is a piece of splenial lying ventromedially. This specimen is more slender and gracile than on *O. junghsiensis,* in addition to having an undeveloped mandibular angle. It is estimated that this individual had a relatively long rostrum and a low skull. The dentary has a relatively complete and tightly packed dental sequence of rather small and relatively shallow spoon-shaped teeth. The functional edge of the mandible has corroded off leaving the 17 alveolae with three erupting teeth.

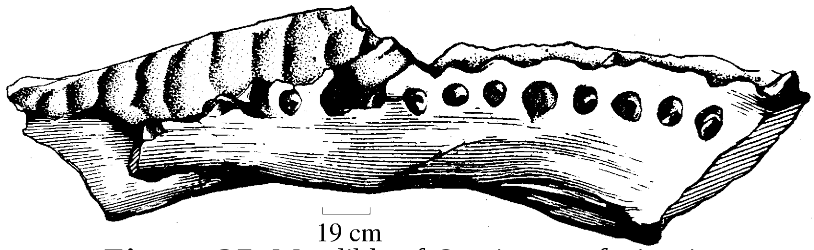

Figure 37. Mandible of *Omeisaurus fuxiensis.*

Among the specimens from the Wujiaba quarry, two sauropod species are recognized based upon axes specimens. One species, represented by two specimens (Pl. XVI, Fig. 2) is a relatively small individual with a slender and gracile axis morphology. Although its morphology is fundamentally consistent with *O. junghsiensis,* it differs in its flat ventral surface which lacks a medial crest. The presence of a strong crest undoubtedly facilitates the anterior cervical musculature, and thus, the absence of this crest indicates a species with a cranium that is more lightly constructed. It is with this justification that the aforementioned low and long mandible is associated with this axis.

Comparison and discussion: The basioccipital, maxilla, mandible, and axis described above were all derived from the Wujiaba quarry in Zigong Co. All represent autapomorphic specimens that cannot be attributed to *Omeisaurus junghsiensis* and are recognized as belonging to a distinct member of the Sauropoda. Taxonomic diversity from within a single quarry as at Wujaiba is also noted in the East African locality of Tendaguru which produces *Brachiosaurus brancai, Torniera robusta, Barosaurus africanus,* and *Dicraeosaurus.* In North America this diversity is noted at Dinosaur National Monument which produces the Late Jurassic *Diplodocus, Apatosaurus, Barosaurus, Camarasaurus,* and *Astrodon.* Some of these genera contain a variety of species and hence, it is not unusual to note a variety of species in the Wujiaba quarry.

Specimen CV00267 represents a relatively small individual with characters that basically resemble those for the genus *Omeisaurus.* But whether the morphological distinctions noted here are a result of interspecific, intraspecific, or ontogenetic variation is still a matter to be considered and is currently too difficult to determine. But throughout the entire process of diagnosis, reflection of the data and the results of analysis suggest here that the morphological distinctions are due to specific variation. Justification is as follows:

The entire collection of sauropod data from the Wujiaba quarry can be divided into two distinct species morphologies with the vast majority of specimens belonging to *O. junghsiensis.* A reconstruction was produced based upon the proportional scale of *Omeisaurus.* A continuous vertebral column is still unknown, but the collection suggests that the age of the vast majority of specimens approach the same, and that they perhaps represent a herd that met with a disastrous flood prior to burial. The several characteristic specimens indicate a small species within the herd.

The erection of these taxa is predominantly based on morphological characters. Sauropod maxillae and mandibles among different individuals of the same species may display differences in tooth count. Moreover, tooth count may vary within opposite sides of the jaws within the same individual, as exemplified by *Camarasaurus supremus* which has a left dentition that outnumbers its right dentition but only with a range of variation of one to two. CV00267 is comparable to *O. junghsiensis* except the mandible houses three more teeth. Dental morphology varies with degree of wear and position in the dental arcade although morphology in the same position is consistent. The maxilla differs greatly from *O. junghsiensis* with spoon-shaped dentition being more brachydont, teeth are comparatively smaller and thinner, and mandibular dentition is increased.

The absence of the ventral keel on the axis indicates that CV00267 was a smaller species than *O. junghsiensis* and had a more lightly constructed head. Furthermore, the mandibular angle is weak and the rostrum longer justifying the erection of the species *Omeisaurus fuxiensis* sp. nov.

Mamenchisaurus **Young, 1954**

1954 A new sauropod from Yibin, Sichuan. *Acta Pal. Sin.* **2**(4) (in Chinese).
1958 New Sauropoda from China. *Vert. PalAs.* **11**(1).
1972 *Mamenchisaurus hochuanensis.* IVPP Mon. Ser. I, No. 8 (in Chinese).

Revised genus diagnosis: A large sauropod with a large elongated neck. Cervicals may attain 19 in number with elongated cervical ribs. Dorsal and caudal series are relatively short. Dorsal laminar structure is weak, anterior dorsals are bifid, anterior caudals are procoelous, haemal arches on the mid-series of the caudals are bifurcated, pubic peduncle is moderate, tibia and fibula are compressed and long, and dentition is spoon-shaped (?). The genus includes two species: *M. constructus* Young, and *M. hochuanensis* Young and Chao.

Mamenchisaurus constructus **Young, 1954**
(Pl. XVII, Fig. 2)

Species diagnosis: A moderate-sized sauropod approximately 13 m in length. Cervical and dorsal pleurocoels are particularly large and centra are opisthocoelous. Cervical vertebrae are extremely large, dorsal spines are relatively flat and straight, and cervical ribs are distinctly grooved with wide and thin termini. Dorsal vertebrae are relatively laterally concave. The first six to seven caudals are deeply procoelous, but in the mid-series and posterior series are amphiplatyan. The caudal mid-series haemal arches are bifurcated but not large and have fused dorsal margins, unlike the opened morphology of *Diplodocus.* Hindlimbs are relatively thin and small.

Type specimens: The type is an incomplete composite skeleton that consists of 14 cervicals, 5 dorsals, 30 caudals, several fragmentary, cervical vertebrae, cervical ribs, and haemal arches. The pelvic girdle consists of a damaged ilium, the distal end of either a pubis or ischium, two small pieces of a right femur, a complete right tibia, fibula, astragalus, and several foot bones.

Locality and stratigraphic position: Early Late Jurassic Upper Shaximiao Fm. at Mamenxi Ferry which borders the municipality of Yibin.

Original description: Despite the fragmentary nature of the cervical vertebrae, the following characters are clearly distinguished: 1) they represent the general sauropod opisthocoelous condition; 2) principle characters are shared with the cervicals of *Omeisaurus,* only the dorsal margin of the pseudospinous process is more straight, lacks a projected section, and ascends rather highly; 3) the cervicals preserved are nearly equivalent in size to the well preserved specimens of *Omeisaurus* in which the seventh or eighth cervical is 45-46 cm while the two longest vertebrae from Yibin (the sixth and seventh) are 42 and 45 cm.

Only five dorsals are preserved, among which only two are articulated with relatively complete centra but no neural arches or other diagnostic features are present, and they appear to have no features that distinguish them from other sauropods. A total of 30 caudal vertebrae are represented which are reconstructed in the figure based upon size. The anterior six caudals have suffered compressional distortion. Caudals one through ten are distinctly procoelous but become more shallow posteriorly such that caudals eleven through fifteen are amphiplatyan. Haemal arches are of extreme interest, with eleven incompletely preserved elements that are nearly impossible to match to their opposing vertebrae. The several anterior arches are indistinguishable in morphology and size from other sauropods including *Tienshanosaurus* and *Omeisaurus.* However, there are at least four arches that are ventrally bifurcated, which is a morphology only observed in *Diplodocus*, though they are distinct from the latter as the dorsal margin at the contact with the centra is still fused, which constitutes an autapomorphy. These specimens undoubtedly represent the mid-portion of the tail and perhaps may reflect its phylogeny. Posterior haemal arches are more numerous with several composed in alignment, slightly recurved, and basically resemble other sauropods in being anteroposteriorly extended and parallel to the axis of the vertebrae.

In general, the hindlimb of the Yibin specimen differs from *Euhelopus* and more closely resembles *Brontosaurus*, though it is distinguished from the latter in its fibula length exceeding that of the tibia and the fibula possesses a patella shaped curvature more distinct than *Brontosaurus* but less so than *Euhelopus.*

Discussion: C. C. Young (1958) discussed additional sauropod data from Haishiwan, Yongdeng Co., Gansu, which consisted of specimens V945-V948. He assumed that this data represented three individuals, as each set of data contained caudal vertebrae, though none of the vertebrae was duplicated and some were well articulated with the anterior caudals procoelous, resembling *Mamenchisaurus.* The specimens were thereby assigned to this genus. But in his discussion he stated that "basically, several anterior caudals resemble *M. constructus* particularly. To make a more advanced diagnosis would require the haemal arches from the mid-portion of the tail to document whether they are bifurcated. Furthermore, the Haishiwan specimens are larger than the type for *Mamenchisaurus.*"

Young and Chao (1972) revised the diagnosis of the Haishiwan data and synonymized it in their description of *M. hochuanensis,* establishing the Gansu specimens as the paratype with supplemental descriptions. The type for *M. constructus* shares numerous characters with *Omeisaurus* such as the morphology of the cervical and caudal vertebrae. Currently, after comparisons with the neotype of *Omeisaurus,* there still are some characters that require confirmation such as the mid-portion of the tail which differs in the haemal arches. Whether these characters represent intergeneric or interspecific variation is still unknown and until this can be resolved the viewpoints of Young will be retained.

In 1979 the authors conducted a documentation of the *M. constructus* type locality which lay approximately 300 m from Mamenchi Ferry, on the right bank of the Jinshajiang (upper Yangzi) River in southeast Yibin Co. which lies stratigraphically in the middle of the Upper Shaximiao Fm. This documents *M. constructus* as stratigraphically lower than *M. hochuanensis.*

Mamenchisaurus hochuanensis Young and Chao, 1954

Diagnosis: Vertebral count is cervical: 19, dorsal: 12, sacral: 4, and caudal: 35+?. Cervical count exceeds any other species of sauropod and their length constitutes nearly one-half the length of the entire body with centra that are extremely weakly opisthocoelous while centra in the sacral region are distinctly opisthocoelous. The 16 anterior caudals are procoelous, but posterior to this they become amphiplatyan. Cervical neural spines are low and planar, the four anterior dorsal spines are bifid, the three anterior sacral spines are fused, while the fourth sacral spine and anterior caudal spines are spoon-shaped (anteriorly convex and posteriorly concave). Haemal arches initiate bifurcation at the ninth caudal. The ilium is robust with a pubic peduncle located beneath the center of the blade, and the ischial peduncle is slender and gracile. Tibia and fibula are thin and flat, nearly equivalent in length, and the proximal tibia is well developed. The astragalus is relatively well developed with a deep depression and an extremely high medial process for articulation with the tibia and fibula. Metatarsals are relatively short and small, and the ungual on digit I is extremely robust.

Specimens: A skeleton estimated to have a relatively complete vertebral column but lacking the skull. Haemal arches are basically complete, cervical and dorsal ribs are incompletely preserved, few limb elements are preserved, but the ilium ischium and portion of the pubis is present. Tibia and fibula are complete but only the distal end of the right femur is preserved. A pair of calcanea are represented but only a portion of the pes is preserved. The forelimb and pectoral girdle preserves only the proximal end of a right humerus and fragments of the sternum.

Locality and stratigraphic position: Early Late Jurassic Upper Shaximiao Fm. on the side of Guloushan Mt. on the bank of the Fujiang River approximately 35 km from the village of Taihezhen, northwest Hechuan Co.

Description: Reiteration of the lengthy description is not required here and as such the reader is referred to the detailed description, text figures, and plates provided by Young and Chao (1972).

Supplementary specimens: Since the description of *Mamenchisaurus hochuanensis,* quite a few sauropod specimens have been recovered from the Upper Shaximiao Fm. in the Sichuan Basin, although their mostly fragmentary nature prohibits an accurate taxonomic diagnosis. Two recent collections, however, are notable and should be referred to this species:

1. In 1977, during the course of their work, the Second Brigade of the Regional Geological and Aerial Survey Corp. from the Sichuan Department of Geology discovered a large sauropod at Dujia Commune in Rongxian Co. The specimen was then collected by Yihong Zhang and Fanmo Zeng of the Chungking Natural History Museum, where they recorded partial limbs associated with cervical and dorsal vertebrae. The morphology of the vertebrae corresponds completely with the type for *M. hochuanensis.* In addition, a complete humerus was preserved which is described as follows:

The humerus is distinctly robust with a noticeably expanded head and a ridge-shaped deltopectoral crest. In lateral perspective the dorsal margin of this crest displays a medial folded lamina for the m. pectoralis. The depression for the m. coracobrachialis brevis is transversely deep. Humeral shaft is straight with an expanded distal end and radial and ulnar condyles that are much more well developed than on *Omeisaurus.* This robust humerus indicates a massively strong forelimb to facilitate an erect posture.

2. In 1978 a worker at the Zhongxian Co. grain distribution center sent a photograph to the Chinese Academy of Sciences that illustrated a string of 19 completely preserved tail vertebrae which were later collected by Xinglong Yang and Xuanmin Li of the Chungking Natural History Museum. This mid-portion of the tail matches *M. hochuanensis* in both morphology and size and possesses bufurcated but fused haemal arches. The wide-spread range of this morphology in the basin reflects the presence of *Mamenchisaurus.*

Discussion: Currently, *Mamenchisaurus* is predominantly recovered from the Upper Shaximiao Fm. in the Sichuan Basin, in addition to the Hengtang Fm. at Haishiwan in the Minhe Basin of eastern Gansu. When C. C. Young erected the genus he stated that “there is an intimate relationship with *Omeisaurus* in the general morphology of the cervicals in addition to the proximity of the localities of Yibin and Rongxian which produced the type of *O. junghsiensis*. Provisionally, however, the two genera may not be synonymized because of two distinguishing characters, which consist of the procoelous nature of the anterior caudals and the bifurcation of the haemal arches on the medial caudals. It is unfortunate that these characters are currently unknown on *Omeisaurus,* and in order to avoid future unforeseen complications, the Yibin specimen is erected as a new genus and species. If in the future these two characters are confirmed on *Omeisaurus,* then a synonymy to a single genus or perhaps to the species level would then be appropriate with a revised diagnoses provided to the former nomenclature.”

The discovery of *M. hochuanensis* confirmed the stability of these two characters which clearly distinguishes it from *Omeisaurus* with its 16 anterior caudals all being procoelous and its immensely long cervical series. Young and Chao (1972) erected a new species and appropriately revised the characters for the genus which was permitted under the scope of nomenclatural codes due to the loss of a specimen. This data expresses that two large sauropods coexisted in the early Late Jurassic of the Sichuan Basin. Their relationships is as follows.

Omeisaurus was erected, and confirmed by other workers in the field, to be attributed to the spoon-shaped subfamily Euhelopodinae. *Mamenchisaurus* was compared to *Diplodocus* due to its bifurcated haemal arches and procoelous anterior caudals but was placed in the newly erected family the Mamenchisauridae, with a family diagnosis including an exceptionally long cervical series (19); dorsal, sacral (four), and caudals being short and small; extremely long cervical ribs; simplified pleurocoel morphology; bifid anterior dorsal spines; bifurcated haemal arches on the mid caudal series; procoelous anterior caudals; moderately developed pubic peduncle; and thin, flat, and equivalently lengthened tibia and fibula.

C. C. Young believed *Mamenchisaurus* to be related to the Homalosauropodidae indicating that it should have a long skull resembling *Diplodocus* with pedicilate teeth. But the current data from Sichuan contradicts this, as among the two primary characters defining the genus, one of them, procoelous anterior caudals, is confirmed on *Omeisaurus* with its high skull and spoon-shaped dentition. Also, the cervicals, dorsals, and sacrals of *Mamenchisaurus* are generally acknowledged to be fundamentally consistent with *Omeisaurus.* The most distinctive character in the latter genus lies in the bifurcation of haemal arches, and the very slightly bifid anterior dorsal spines. To date, amidst all the Jurassic sauropod dentition data collected from the Sichuan basin, not a single pedicillate sauropod tooth has been recovered. Furthermore, inquiries were made to Xuanmin Li who participated in the collection of *M. hochuanensis* and has stated that indeed spoon-shaped teeth were present in the excavation but that the specimens were lost in transit. Current data therefore suggests that the two genera are extremely closely related and that both possessed a spoon-shaped dentition.

The characteristically Asian Euhelopodinae appear to relate to the North American Camarasaurinae but the former encompasses several Asian long-necked genera with spoon-shaped genera including *Omeisaurus, Mamenchisaurus, Euhelopus, Asiatosaurus, Chiayusaurus,* and *Tienshanosaurus.*

Theropoda Marsh, 1881

The following theropod taxa are recorded from the Sichuan Basin:

Coelurosauria Huene, 1914

Coeluridae Marsh, 1881

Sinocoelurus Young, 1942

Sinocoelurus fragilis Young, 1942

1942 Young, *Bull. Geol. Soc. China,* Vol. **22**, No. 3-4.

Diagnosis: Laterally compressed, gracile, and long dentition with thin enamel and sharp anterior and posterior carinae that lack denticles.

Specimens: Four isolated teeth (V232, V233, V234, V235).

Locality and stratigraphic position: Late Jurassic (?) Chungking (Guangyuan) Group from Guangyuan Co., Sichuan.

Original description:

The entire collection was made within a period of three days from an ostracod-rich horizon at the top of the Guangyuan Group. The teeth are extremely long, thin, weak, slightly laterally compressed, and recurved. Three of the specimens maintain conspicuous anterior and posterior carinae with the posterior carina more distinct. The fourth specimen (V233) has sustained some damage. On the best preserved specimen, the anterior carina curves slightly laterally. No denticles are present on any of these thinly enameled specimens. Precise lengths of the teeth and extension of the enamel are vague as the basal portions and apices are missing on all the specimens. Lengths and widths are 9.0x4.5, 8.5x6.0, 7.5x5.0, and 8.0x5.2 mm.

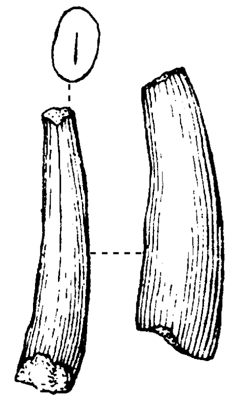

Figure 38. Isolated tooth (V232) of *Sinocoelurus fragilis* Young, 1942.

Discussion: Fig. 38 illustrates V232 as an extremely characteristic specimen that, to date, is incomparable to anything recorded from the Sichuan Basin. Steel (1970) attributed this dentition to the Coeluridae although Rozhdestvesky (1975) proposed a crocodilian affinity. Young's original description stated that because *Sinocoelurus* was derived from the ostracod-rich beds at the top of the Guangyuan System, the specimens should be recognized as being derived from the Qianfoya Fm. which overlies the Baitianba Fm. in the region of the Xujiahe and Qianfoya cross-sections in Guangyuan Co. Overlying the Qianfoya Fm. are the red beds of the Chungking (Guangyuan) Group. If this interpretation is accurate, it is very possible that these specimens are Early to Middle Jurassic and not Late Jurassic, as formerly interpreted.

Carnosauria Huene, 1920

Megalosauridae indet.

Camp 1935 *Bull. Depart. Geol. Soc. Uni. Calf.,* Vol. **23.**

Specimens: An incomplete tooth and portion of femur housed at the Museum of Paleontology, University of California, Berkeley.

Locality and stratigraphic position: Early Late Jurassic Upper Shaximiao Fm. six km southeast of the municipality of Rongxian, Sichuan.

Original description: From 1913-1915 the American geologist G.D. Louderback conducted geological research and collected several dinosaur specimens from the Rongxian and Weiyuan regions. These specimens were transported to the Museum of Paleontology, University of California, Berkeley. Later, in 1935, C. L. Camp briefly described the specimens. The dentition consists of a single large carnosaur tooth resembling *Tyrannosaurus,* but only cross-section observations were made upon the fragmentary femur from Rongxian suggesting that the microstructure was comparable to the family Megalosauridae, gen. indet.

Discussion: This Rongxian specimen is the first record of the Dinosauria from the Sichuan Basin. Camp's description and the dentition size suggests it may be assignable to *Yangchuanosaurus* from the Upper Shaximiao Fm. Camp (1935) further determined that the presence of this form indicated a Jurassic and not Cretaceous age for the Red Beds of the Sichuan Basin, an assessment that, to date, is still accurate.

Szechuanosaurus Young, 1942

Young, 1942, *Bull. Geol. Soc. China* Vol. **22**, No. 3-4
Young, 1958, *Palaeontologia Sinica*, New Series C, No. 16.
Young and Sun, 1959, *Vertebrata PalAsiatica*, Vol. **2**, No. 2

Szechuanosaurus campi Young, 1942

(Plates XVIII-XXI)

Diagnosis: Dentition typically megalosaurid, being trenchant, posteriorly recurved, and distinctly laterally compressed with anterior and posterior carinae maintaining small picketed denticles.

Original specimens: Four isolated teeth (V235, V236, V238, V239).

Locality and stratigraphic position: Late Jurassic Chungking (Guangyuan) Group from the vicinity of the municipality of Guangyuan, Sichuan Province.

Original Description: Specimens V235 and V236 are similar in both morphology and size with the latter specimen being a rather well preserved half-crown from the right side of the skull. All specimens are laterally compressed. Anterior carina is more distinctly denticulated than posterior carina with small picketed denticles that gradually diminish toward the base of the tooth. Dentition is conspicuously megalosaurid.

Discussion: In the same publication as the description of *S. campi*, C. C. Young erected the taxon *Chienkosaurus ceratosauroides* based upon four isolated teeth (V237). His diagnosis: a massive and trenchant dentition with small picketed anterior and posterior denticles, the anterior of which run lingually and obliquely toward the base of the tooth. Antero-posterior diameter slightly exceeds lingual-labial diameter. In his description Young admitted that the erection of the new genus was based upon three of the four teeth being immature.

Later, Rozhdestvensky (1964) proposed that the four teeth of *Chienkosaurus* could possibly belong to the Crocodilia. Subsequently, during the editing of “The Handbook of Chinese Fossil Vertebrates,” Zhiming Dong conducted a review of these four specimens and formally confirmed that the best preserved tooth among the V237 collection was a premaxillary tooth of a carnosaurian dinosaur, but that the remaining three teeth were assignable to the crocodile *Hsisosuchus*. Because “*Chienkosaurus*” and *Szechuanosaurus* are derived from the same stratigraphic position, the Guangyuan Group, and from the same region of Guangyuan, the V237 premaxillary tooth was compared to specimens from the Wujiaba quarry at Zigong where it is confirmed that the differences among carnosaur dentitions are due only to being in a different position in the dentition. The genus *Chienkosaurus* is now excluded and the specimen is synonymized with *Szechuanosaurus*.

Neotype: a relatively complete set of premaxillary and maxillary teeth, an incomplete skeleton including a string of seven articulated cervicals, eight disarticulated dorsals, two sacrals, and several caudal vertebrae. Pectoral and pelvic girdle are incomplete but fore and hindlimbs are relatively complete (Chungking Museum of Natural History # CV00214).

Locality and stratigraphic position: Late Jurassic, lower portion of the Upper Shaximiao Fm., Wujiaba, Zigong Co.

***Szechuanosaurus* revised diagnosis:** Detailed cranial descriptions are not possible here as theropod cranial data is rare within the collections of the Wujiaba quarry. But during disposition of the Wujiaba data, a large quantity of isolated carnosaur teeth were recognized. Although there are morphological and size discrepancies within the collection, two morphotypes are generally recognized. One set of teeth is relatively massive with asymmetrical anterior and posterior carinae which may represent premaxillary teeth. A second set is more abundant with laterally compressed crowns, asymmetrical carinae, and small picketed denticles anteriorly and posteriorly. The teeth are moderately recurved and resemble *Szechuanosaurus* in morphology. At the Wujiaba quarry there was only a single carnosaur skeleton lacking a skull associated with these sets of teeth. This skeleton (Pl. XVIII, Fig. 6) is currently mounted and on exhibit at the Chungking Natural History Museum.

Revised genus diagnosis: A moderate-sized megalosaur with laterally compressed megalosaurid style dentition maintaining small picketed anterior and posterior denticles. Premaxillary dentition is relatively thick, incipiently “incisiform” with asymmetrical anterior and posterior carinae, and lingually curved crowns. Maxillary dentition is relatively laterally compressed and moderately posteriorly recurved with parallel and symmetrical anterior and posterior carinae.

Vertebral column consists of 9 cervicals, 13 dorsals, five fused sacrals, and 45±3 caudals. Centra are typically megalosaurian. Cervical centra lack a ventral keel, and dorsal neural spines are plate-shaped with a coarsely textured dorsal tuberosity. Pelvic girdle resembles that of *Allosaurus* with a low ilium that displays a large and broad preacetabular crest that is shorter than the postacetabular crest. Distal pubes and ischia are fused and distal pubis has a weak “boot.” The four limbs are stout, pheumatized, have smooth and glossy articular ends, and strong trochanteric crests. Femur is longer than tibia, metatarsals II, III, and IV are unfused, and digits I and V are reduced. Forelimb is shorter than the hindlimb with a ratio of 1:2.2. Ungual phalanges are laterally compressed.

Neotype description: Dentition characters resemble the type specimen V236, being laterally compressed with small picketed anterior and posterior denticles. Tooth crowns are slightly posteriorly curved with thin enamel that has a smooth and glossy black sheen. A dental pulp cavity is present. Tooth root is longer than the crown, resembles a compressed cone, is exposed, and replaced by a carbonate matrix. Premaxillary and maxillary teeth are readily distinguishable, but mandibular dentition is not readily distinguishable from maxillary dentition.

Premaxillary teeth have thick tooth crowns, labial side is convexly rounded, and lingual side is relatively more flattened such that in cross-section the crown is nearly triangular. Anterior and posterior carinae are asymmetrical with the anterior carina oblique toward the lingual side and extending half-way down the crown before terminating. The posterior carina initiates at the apex and runs lingually directly to the base of the crown. These teeth are insipiently incisiform.

Maxillary dentition is inconsistent in size as traditionally the Carnosauria have larger anterior teeth than posterior teeth. A further reason for size disparity is that the dentition erupts with a multiple, continuous, and diachronous replacement of functional teeth. Consequently, functional teeth within the dental battery are not uniform and are expressed in different sizes and at different stages of wear. Generally speaking, the maxillary dentition is typically megalosaurian, being laterally compressed with small picketed anterior and posterior denticles on the carinae. Denticles are in tight alignment with a count of 24 per centimeter. Anterior and posterior carinae are symmetrical with the anterior carina short and which does not reach the base of the crown. Tooth enamel is thin, the tooth root is longer than the crown, is exposed, and elliptical (Pl. XVIII, Figs. 1-5).

It is not possible to provide a concise description of the mandibular dentition due its strong resemblance to the maxillary dentition.

In his original description, C. C. Young indicatedthat *Szechuanosaurus* resembles the North American *Allosaurus* and East African *Elaphrosaurus* in morphology. The discovery of specimen CV 00214 at Wujiaba, Zigong, confirms Young's observations. The skeleton is strongly built, all of the limb elements are pheumatized, articular surfaces are smooth and glossy, represent dexterous mobility, and are typically carnosaurian.

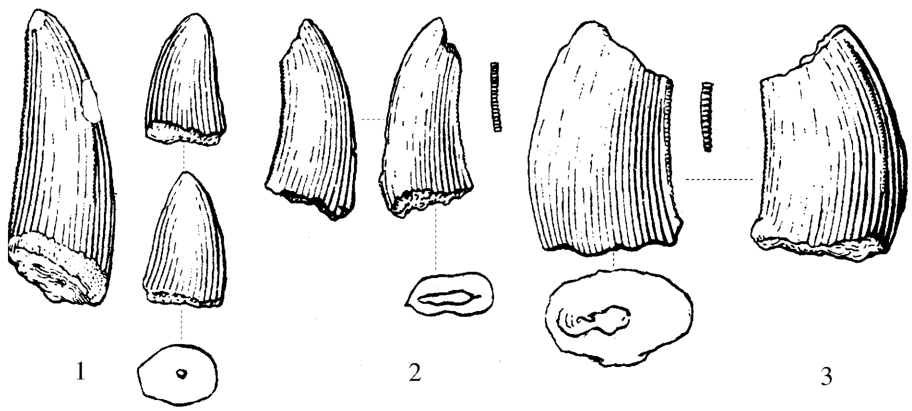

Figure 39. Isolated teeth of *Szechuanosaurus campi* (from Young, 1942, Type).
1. V235; 2. V236; 3. V238

Based upon the typical carnosaurian formula, *Szechuanosaurus* should possess 9-10 cervicals, 13 dorsals, 5 sacrals, and 45±2 caudals.

The atlas is incomplete, but initiating with the axis, there are eight articulated cervical vertebrae, thereby indicating that the cervical series of this specimen is completely represented (Pl. XIX, Figs. 1-4). The atlas resembles that on *Deinonychus* with a saucer, or horseshoe shaped centrum, a circular anterior condylar facet, and relatively flat ventral surface.

Although damage was sustained during preparation, the odontoid fusion to the axis is quite evident, indicating that the specimen was fully mature. The axis is relatively well preserved with damage only to the posterior neural spine and resembles that on *Allosaurus* and *Yangchuanosaurus.* The centrum is amphiplatyan and laterally compressed with well developed pleurocoels. Anteriorly the centrum is circular and narrow with a spherical otontoid process, broadens posteriorly, and is ventrally flat, unlike the well keeled centrum on *Ceratosaruus.* Medially, the centrum is constricted, providing it with a saddle-shaped configuration. Resembling the general theropod condition, the ventral surface is slightly oblique. The posterior articular surface is slightly concave but also slightly posteriorly oblique.

The neural arch of the axis is moderately high, with a spine that extends posteriorly from the anterior margin of the arch and composes a ridge that expands rapidly laterally. The posterior end of this ridge is spaceously broad and tri-laminar in morphology. This is a character shared with both *Allosaurus* and *Yangchuanosaurus.* Prezygapophyses lie laterally on the neural arch as small lingoid processes. Diapophyseal surfaces are coarsened and supported by three small laminae, the relationships of which are illustrated in text Figure 40. At the base of the diapophyses are three subtriangular cavities composed of the three small diapophyseal laminae. Parapophyses are located on the centrum anteroventral to the neural arch as two small laterally directed elliptical facets. Postzygaphyses are thicker than prezygapophyses and extend from the posterodorsal portion of the neural spine ventral to the triangular laminae. Their articular surfaces are elliptical and situated slightly ventrally oblique.

Table 5. Vertebral measurements for *Szechuanosaurus campi* (mm).

Sequence	Centrum length	Centrum post. ht.	Centrum post. wth.	Complete height
2	55	40	45	103
3	60	40	50	100
4	65	40	52	102
5	55	42	56	112
6	65	50	40	120
7	70	60	40	110
8	62	60	50	120
9				
10				
11	60	60	50	
12	60	70	60	
13	74	50	60	180
14	60	70	75	190
15				
16				
17	65	74	65	210
18	62	64	55	210
19	62	72	70	218

Cervical vertebrae three through nine are in articulation and display some slight variation due to compressional distortion, however their centra are relatively consistent morphologically and vary only in size. Centra are opisthocoelous with flat oblique ventral surfaces that lack a keel. At their center they are constricted, or saddle-shaped, are laterally compressed with well developed pneumatocoels, and increase in size and height posteriorly. Initiating with CV3, neural spines progressively increase in height and gradually become plate shaped. Spines that are posteriorly oblique also gradually become vertical. Parapophyses at the anterior centrum become progressively elevated while, pre- and postzygapophyses become constricted and situated dorsal to the neural arch.

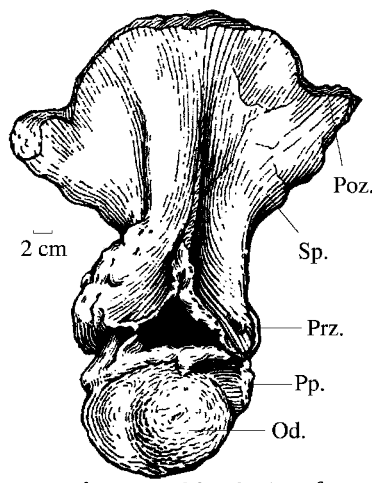

Figure 40. Axis of *Szechuanosaurus campi.*

When specimen CV00214 was excavated no articulated dorsal vertebrae were noted, though eight specimens were collected. Based upon centrum size, and morphology of parapophyses and diapophyses, they were determined to represent dorsals 1-4, 7-9, and 10. The specimens are typically megalosaurian in morphology being amphiplatyan but with a very slightly depressed posterior end, lack pneumatocoels, and are constricted in the center creating a robust circle out of the anterior and posterior ends. The two articular surfaces are nearly equivalent in size. Dorsal spines are plate-shaped and vertical with an expanded and coarsely textured apex. Initiating at the neural arch, a longitudinal groove runs along the anterior surface of the spine but disappears at it approaches the apex. Pre- and postzygapophyses lie nearly along the same plane and the prezygapophyseal articular surfaces are lingoid in shape. Postzygapophyses are coalesced with triangular articular facets. Anterior diapophyses are relatively narrow but posteriorly progressively broaden and become horizontal. They lie dorsal to the neural arch and are supported by three extremely well developed laminae that intersect ventral to the diapophyses. These elements also alter in elevation while progressively become situated more posteriorly. Parapophyses lie anterodorsally as small circular depressions.

Only a single sacral centrum is represented which lacks its neural arch and spine. It is amphiplatyan, rounded ventrally and is not constricted medially.

There are 18 disarticulated caudal vertebra represented. Sequential order was determined by centrum size and length of neural spine. Their morphology is relatively simple and resembles the general condition of the Theropoda. Centra are shallowly amphicoelous, and rather laterally compressed with a high neural arch. Anterior caudals still retain diapophyses which finally atrophy at number 13 or 14. Neural spines are plate shaped and posteriorly gradually incline and lengthen anteroposteriorly corresponding with the centra bodies. Small oblique articular facets appear posteroventrally to facilitate the heamal arch. Pre- and postzygapophyses also lengthen along the column posteriorly.

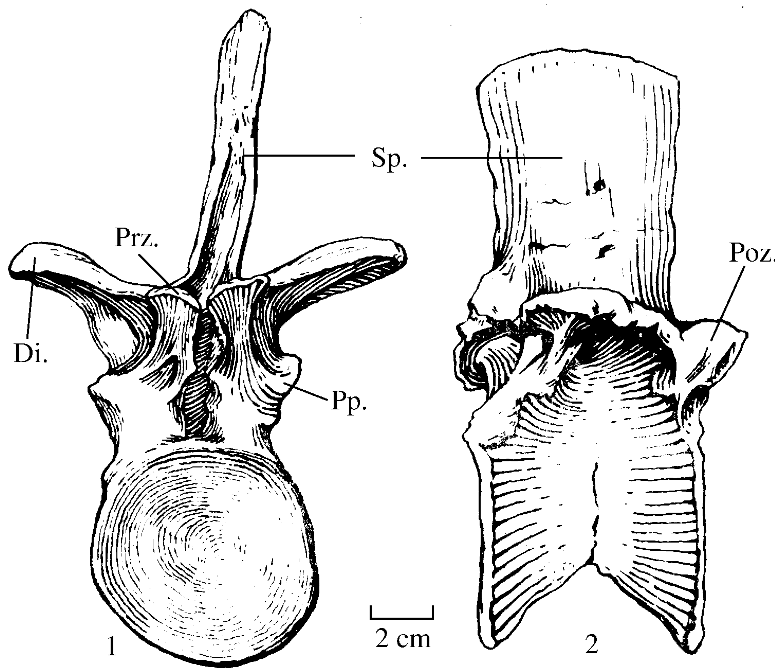

Figure 41. Dorsal vertebra of *Szechuanosaurus campi*. 1. Anterior view. 2. Lateral view.

The pectoral girdle is incomplete, being represented only by a fragmentary scapula and coracoid. Its restoration indicates a massive scapula-coracoid suture. The scapular blade is long, narrow, and simple in morphology with a relatively thick shaft that has expanded ends. The proximal end is thick and together with the coracoid composes a shallow glenoid fossa. The coracoid is rectangularly round in morphology, relatively thick, medially concave, and has a conspicuous foramen. The length of the scapula is 50 cm, distal breadth is 11 cm, and medial breadth of shaft is 7 cm.

The forelimb of specimen CV00214 is relatively well preserved, representing a relatively light and nimble element that obviously reflects the loss of functional ambulation. In addition to the retention of prey, it may have assisted in some functional movements such as support when lifting off the ground

Both left and right humeri are nearly complete. The shaft is slightly curved but not as intensely as on *Allosaurus*. The proximal end is much more expanded than the distal end with a medial femoral head that is shaped as a broad trochlea that lies at a 150° angle to the shaft. The deltopectoral crest protrudes laterally with a slightly laterally curled margin. The medial shaft is laterally compressed due to compressional distortion but in cross-section it may be noted that as with the other limb bones, it is pneumaticized. Three distinct condyles are present distally: there is a single large condyle laterally with a rounded crest medially causing the ulnar condyle to be

Table 6. Humerus measurements for *Szechuanosaurus campi* (cm).

	Left	Right
Length	27	26.5
Proximal breadth	8	9
Distal breadth	7	3 (compressed)
Smallest diameter of shaft	3	3.5

separated into two articular surfaces to facilitate large excursion for the ulna and also suggesting the ability for anteroposterior twisting. The radial condyle is relatively small and distinctly separate from the ulnar condyle. A medial condyle lies more dorsal than the other two and is larger than the radial condyle with an oblique articular surface. Two intercondylar depressions are present. This distal morphology more closely resembles *Deinonychus* than *Allosaurus.*

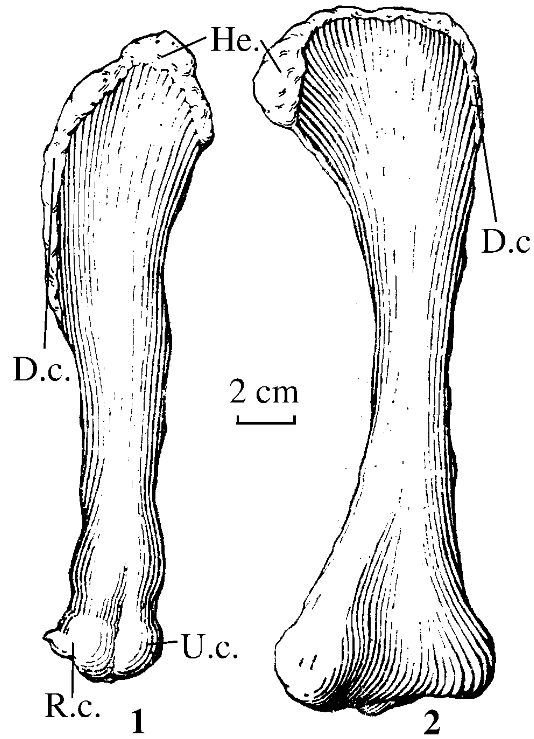

Figure 42. Humerus of *Szechuanosaurus campi.* 1. Lateral view. 2. Anterior view.

Both ulnae and radii are relatively well preserved. The elements are straight with the ulna longer than the radius but shorter than the humerus. The ulna is thicker proximally than distally, the articular fossa is relatively shallow, with a generally well developed olecranon process which is situated laterally and projects dorsally. A small ridge lies at its ventral margin which attenuates at the midshaft. A small oblique cavity lies in the posteromedial side of this ridge for facilitating ulnar-humeral musculature. From its proximal end the ulna gradually becomes constricted to be thin distally, the shaft is nearly circular in cross-section, and the distal end is slightly expanded with a rounded articular surface with a small depression for contact with the radius on its medial side.

The left radius is flattened due to compressional distortion and the right radius has been damaged. It is shorter than the ulna with a relatively constricted morphology that differs from *Allosaurus*. Both termini are slightly expanded and relatively consistent in diamter. The shaft is slightly curved.

Two irregularly-shaped small carpals are present. One, diagnosed as the radiale, is disc-shaped and crescentic in outline with two dorsal articular facets. Ventrally there is an inverted v-shaped ridge that divides the two facets, one of which facilitates the intermedium and the other the metacarpus. It is 5.2 cm in diameter and 1.8 cm thick. The other carpal element is small and circular with a small depression ventrally and may represent the intermedium.

Metacarpals I, II, and III are preserved on the left side, but only III is preserved on the right side. They resemble those of *Allosaurus* in morphology with McI short, thick, and 5 cm in length. Its proximal end is relatively broad with a small medial ridge on its articular surface which separates two different facets. The distal end is broad and flat with an oblique articular surface that is asymmetrically concave and rotated medially. This morphology provides a large angle of excursion for the first digit, suggesting the facility for grasping. Metacarpal II is longer and thicker than I with a 9 cm length. Its proximal end is particularly expanded, the shaft is nearly quadrate, and gradually attenuates distally. The articular surface is trapezoid. As on McI it also possesses a small ridge dividing it into two articular surfaces for articulation with the intermedium. The distal end is expanded with a deep articular sulcus. Metacarpal III is much weaker than the other two and has relatively shallow articular facets, but it is longer than McI.

Digits of the forelimb differ from the hindlimbs as they are gracile and long with shallow proximal articular facets. Manus formula is referred to *Allosaurus* as McI-2, McII-3, and McIII-4. Unguals consist of extremely laterally compressed large claws with the powerfully recurved first ungual being the largest. Longitudinal medial and lateral grooves run along the curvature of the claws. Ungual II is smaller than the previous with less curvature. Ungual III is small and sharp with weak curvature.

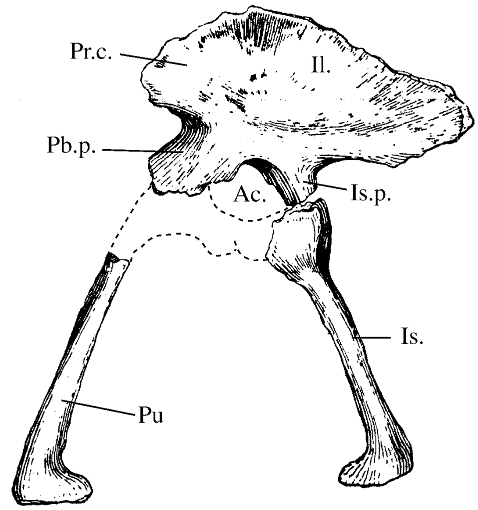

Figure 43. Pelvic girdle of *Szechuanosaurus campi.*

The pelvic girdle is incompletely preserved as the right ilium and portion of the pubis is missing, although the left side is completely preserved with an anteroposteriorly elongated element. The medial axis of the ilium is a vertical line dorsal to the acetabulum. In lateral perspective the ilium is fan-shaped with a broad preacetabular crest that is shorter than the postacetabular crest. The angle between the preacetabular crest and the pubic peduncle is larger than on both *Allosaurus* and *Ceratosaurus.* The pubic peduncle is short, stout, and thickens at the acetabulum. A crescentic ridge runs along the anterodorsal margin of the acetabulum, which is a character shared with *Yangchuanosaurus*. An expansive groove is present on the ventral margin of the postacetabular crest posterior to the ischial peduncle, which is a character shared with *Tyrannosaurus.*

The ischium is relatively completely preserved with an slightly expanded proximal end for contact with the expanded distal surface of the ischial peduncle. A portion of the shafts of the ischia are completely fused. The shaft is triangular in cross-section, the distal end has a booted process that is nearly triangular in lateral morphology, and it differs from *Ceratosaurus* by being straight.

A pair of pubes are present with damaged proximal ends, the distal shafts are fused, and a pubic boot is not well developed, a character indicating that it predates taxa with well developed pubic boots including *Allosaurus, Ceratosaurus,* and *Kelmayisaurus.* The proximal end of the pubis is diverged such that from an anterior perspective it is wing-shaped. At the ventral margin of the proximal end there is a ventrally embayed process that has a damaged ventral border and which may represent an obturator foramen.

Table 7. Pubis and ischium measurements for *Szechuanosaurus campi* (cm).

Ischium length	42
Ischium prox. breadth	12
Ischium dist. breadth	12
Ischium shaft diameter	3.5
Approx. pubis length	46
Shaft length	29
Boot length	9.5

The left and right hindlimbs are nearly completely preserved although the right femur is missing. The femur is long (58.5 cm), stout with little curvature, and has a shaft that is slightly elliptical in cross-section. The head is projected dorsomedially at nearly a 90° angle with a round and smooth articular surface. The lesser trochanter is located anterolaterally as a projected ridge. At the medial side of the ridge there is a deep groove separating it from the shaft. The fourth trochanter is a long ridge situated posterodorsomedially at a point one-third down the shaft. At the ventral end of the trochanter is a long depression to facilitate musculature. The two distal condyles are relatively conspicuous, the intercondylar notch is deep and long, but the trochlea is relatively shallow. The limb is pheumatized with relatively thick walls.

The left and right tibia are relatively completely preserved, are shorter than the femur, more robust than the fibulae, and have a well developed cnemial crest. The proximal end is triangular due to the anteriorly projected wing of the cnemial crest. The shaft is relatively straight and compressed. The distal end is laterally compressed with a distinct medially situated, angularly shaped, astragalar facet, though the facet is not inset to the degree as on *Allosaurus* or *Tyrannosaurus*. Tibia length is 58 cm.

The fibula is long and gracile with a laterally expanded, medially concave proximal end. The shaft is very slightly laterally curved and at a point one-third of the way down the shaft there is a small ridge that projects laterally. The distal end is very slightly expanded anteroposteriorly with a rounded and smooth articular surface for contact with the calcaneum. With a 56 cm length, the fibula is slightly shorter than the tibia.

Left and right astragali are complete and in articulation with the calcanea. Their morphology is typical of the Theropoda as a small elliptical element with a folded depression. In anterior perspective it is trapezoid, while in lateral perspective it is L-shaped. The ascending process of the element penetrates the astragalar facet of the tibia, is shorter than that on *Allosaurus,* and is triangular. It also differs from *Yangchuanosaurus* in which the astragalus is fused to the tibia.

The left calcaneum is preserved as a small irregularly shaped element that is rather broad anteroposteriorly, laterally compressed, and is somewhat semicircular in lateral perspective. Ventrally, it has a gently rounded articular surface whereas dorsally there lies a deep sulcus to facilitate the fibula. Its morphology is typical of the Theropoda.

Metatarsals are relatively complete with MtI and II reduced and MtIII unreduced. They are also unfused which differs from other Late Jurassic megalosaurs. MtI is 5.6 cm, or one-quarter the length of the longest metatarsal, which is MtIII, and has lost its functionality. Its proximal end is laterally compressed to form a flattened cone. Distally the shaft becomes thickened with the standard articulation for a single ungual.

MtII, III and IV are relatively long and robust with MtII and IV of equivalent lengths. They are neither fused nor reduced. These three elements are generally similar in morphology with proximal ends thicker than distal ends, and slightly concave proximal articular surfaces that are laterally compressed, and triangular. The distal ends are slightly expanded with smooth rectangular articular surfaces and lateral depressions for ligament attachments. Shafts are pneumaticized.

The digits are incompletely preserved and are restored according to the formula of *Allosaurus*. The pes differs from the manus in having relatively thicker and shorter phalanges with round and concave proximal articular surfaces. The proximal ends are thicker and larger than distal ends, and dorsally there is a triangular protrusion extending posteriorly to coincide with its articulating counterpart. The distal articular facet is deep and a small condyle is present on each side with a lateral depression upon it.

Unguals are subrounded, not laterally compressed as on the manus, and have very little curvature. The first ungual is large and trenchant. Remaining unguals are morphologically similar.

Ribs are incomplete and represent the general theropod condition. *Szechuanosaurus* possessed gastralia that resembled *Allosaurus,* as recognized during excavation of the specimen.

Discussion: The dentition of Zigong specimen CV00214 corresponds to both the type and to other specimens identified as *Szechuanosaurus campi*. After the erection of the type, *S.* cf. *campi* was described by Young and Sun (1957) based upon a partial left mandible from the Late Jurassic of Turpan, Xinjiang. Their diagnosis was based upon dental characters which, for the familial rank and higher, are reliable criteria but not as stable when applied to the genus and species level. Obviously, when faced with unsatisfactory conditions of fragmentary data, the erection of new taxonomic nomenclature is allowable, though one must be prudent. Currently, a consistent hypothesis among paleontological workers is that dinosaur teeth are continuously erupting and being replaced. Dental size and morphology not only differ within the position in the maxilla and mandible, but moreover differ due to function and time of eruption. The type of *Szechuanosaurus* was based upon several incomplete isolated teeth, such that it is difficult to conduct more comprehensive comparisons. However, the character analysis of the abundant carnosaurian dental data from the Wujiaba quarry at Zigong, resulted in the conclusion that despite a large discrepancy in dental size and morphology the range in morphology and size variation were not excessive. The quarry produced only a single relatively well preserved theropod skeleton and teeth (CV00214) confidently diagnosed to the genus *Szechuanosaurus*. The type provides no cranial or postcranial elements for comparison, but the quarry produced dental specimens reliably diagnosed to the single species *Szechuanosaurus campi* Young.

Abundant characters are represented in the skeleton: Cervical and dorsal vertebrae are typically theropod. Characters assigning it to a member of the Megalosauridae include loose sacral fusion, low anteroposteriorly extended ilium, pubic and ischial shafts are fused, and the pubic boot is not well formed. The rank of the Megalosauridae within in the Carnosauria is a complex subject as they principally include primitive taxa from the Early Jurassic to the Early Cretaceous. Currently, the family is recorded on all the continents with the exception of Oceania although definitive data is rare. Previously the best represented genera were derived from the North American Morrison Fm. as *Allosaurus* (*Antrodemus*) and *Ceratosaurus.* In contrast the current specimens of *Szechuanosaurus* and *Yangchuanosaurus* described below are the best representatives of the Megalosauridae from the Jurassic of Asia and share numerous characters with their North American counterparts.

Szechuanosaurus retains numerous plesiomorphic characters compared to later megalosaurs such as the weak pubic boot and unfused metatarsals. Its opisthocoelous cervical vertebrae that lack a ventral keel isolate it from other members in the family.

Yangchuanosaurus Dong, Chang, Li, and Zhow, 1978

1978 Science Bulletin; No. 17, Vol. 5.

Genus diagnosis: A relatively large megalosaurid that may exceed eight meters in length. Skull is robust with a moderate height-length ratio and with six pairs of fenestrae. Maxilla possesses one or two depressions. Prefrontal is robust and represents a strong supraorbital ridge. Parietal process is high, well developed, and projected dorsally. Frontal and parietal are fused while the quadrate is straight. Maxillary and mandibular dentition are robust, laterally compressed, and slightly posteriorly recurved. Premaxillary dentition is subrounded in cross-section and incipiently incisiform. Anterior and posterior carinae bear small picketed denticles. These teeth are basically megalosaurian in nature. Dentition formula is Premaxilla: 4, Maxilla: 10-14, Dentary 14-15.

There are five sacral and 23 presacral vertebrae comprising 10 cervicals and 13 dorsals. Cervicals are opisthocoelous, and ventrally oblique with a weak ventral keel. Dorsal vertebrae are amphiplatyan with plate-shaped neural spines. The five sacral vertebrae are fused as are the first four anterior spines which form a single plate. Caudal vertebrae are amphicoelous with high neural spines. The pelvic girdle is robust with a low ilium that is anteroposteriorly elongated. The preacetabular process is broad, pubic and ischial shafts are fused, there is a generally well formed pubic boot, and an obturator foramen is large and circular. The femur is curved and slightly longer than the tibia.

The genus includes two species: *Y. shangyuensis* (sic: *shangyouensis*) Dong, Chang, Li and Zhow and *Y. magnus* sp. nov.

Yangchuanosaurus shangyuensis Dong, Chang, Li, and Zhow, 1978

(Plates XXII-XXVI)

1978 *Science Bulletin*, No. 17, Vol. 5

Diagnosis: Body length is approximately seven meters, cranial height and length are moderate with a ratio of 1:1.6, maxilla is deeply concave and not perforated, five sacral centra are fused but lack any additional buttressing, ilium is low with a preacetabular process that is broad, flatly expanded anteriorly, and lacks ventral curvature. Ventral keels on the cervical vertebrae are absent.

Specimen: A nearly complete skeleton with an exceptionally well preserved skull. Complete cervical and dorsal series are represented, but only 12 caudals are present. Forelimbs have been lost but hindlimb preserves a femur, tibia, fibula, astragalus, and several phalanges. Specimen is on display at the Chungking Museum of Natural History (specimen #CV00215).

Locality and stratigraphic position: Late Jurassic Upper Shaximiao Fm. 350 m from the base of the dam at Shangyou Reservoir, Yongchuan Co.*

Description: The skull of CV00215 is complete although there is some slight distortion due to lateral compression. Some slight damage was sustained to the dentition and jugal on the right side due to the impact from explosives which exposed the specimen. The specimen has been restored to its initial perfect condition. Skull length is 78 cm, maximum height at the medial orbit is approximately 50 cm (Pl. XXIII).

Yangchuanosaurus has a moderate cranial height and length ratio of 1.6:1.0 and a slightly extended oral and facial region. In addition to the six pairs of fenestrae, the nasals and maxillae bear pitting ornamentation. Rugosities are present on the nasal and premaxilla providing the face and cranium with a distinct robusticity. The maxillae and mandibles are tightly fused, which

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* The specimen was discovered in July of 1976 by excavation laborers during the initial rennovation of the Shangyou Reservior, Yongchuan Co. Upon its discovery the reservoir authorities recognized its significance, provided it protection, and notified the Chungking Museum of Natural History. The museum then dispatched Yihong Zhang and Fanmo Ceng to the site where, under the leadership of the Party Committee and with a large amount of support from the regional cultural office, they organized a manual excavation. Subsequently, the administration and paleontologists of the Chungking Museum enlisted the assistance of the Chungking Academy of Geology, IVPP, and the Southwest Institute of Geology to study the taphonomy and geology associated with the specimen. It was due to the multilateral efforts of this group that the excavation was successfully completed.

presented certain difficulties in attempting to analyze and describe the internal structures of the skull.

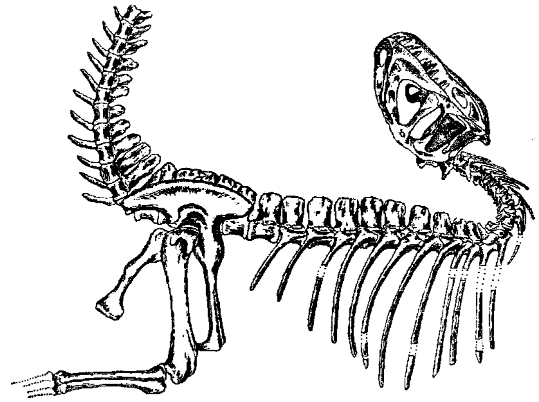

Figure 44. Schematic diagram of the *Yangchuanosaurus* specimen.

The premaxilla is divided into left and right elements that are fused at a midline. Each is triangular and slightly arched, which approaches *Allosaurus* in morphology. It has a maximum anteroposterior length of 12 cm. A long and gracile rod-shaped process extends posterodorsally from the anterodorsal region to penetrate the nasals, and together compose the anterodorsal margin of the external nares. Distance from the anterior margin of the nares to the tooth row is 8.5 cm. The posterior premaxilla penetrates the anteromedial portion of the maxilla. The premaxilla-maxilla suture line has been deformed due to compressional distortion and as such is pinched together with the maxilla-nasal suture line to compose a single ridge. Surface texture of the premaxilla is rather coarsened with numerous folds and several small nutrient foramina. Four well preserved premaxillary teeth are exposed. A small immature, or not fully erupted, tooth lies between two fully erupted teeth near the anterior margin. The basic morphology of this element resembles the general theropod condition.

The maxilla, representing the largest element on the skull, is triangular in shape with a maximum anteroposterior length of 50 cm. Its contact with the premaxilla is relatively precipitous and posteriorly it attenuates to become gracile and long to contact the jugal. Anteriorly, there is a posteriorly extended ascending process that has an anterior margin that contacts the lateral nasal, and dorsally contacts the anterior branch of the lacrimal to compose the anterior margin of the first antorbital fenestra. There is a deep elliptical depression on the anterodorsal maxilla located between the first and second antorbital fenestrae. This depression differs from that on *Tyrannosaurus* as it does not perforate the maxilla. A small, nearly triangular-shaped foramen with an anteroposterior diameter of nearly 4 cm lies ventrally on the maxillary depression and constitutes the second antorbital fenestra (Fig. 45). Its function is unclear although it may reduce cranial weight or perhaps facilitate facial musculature.

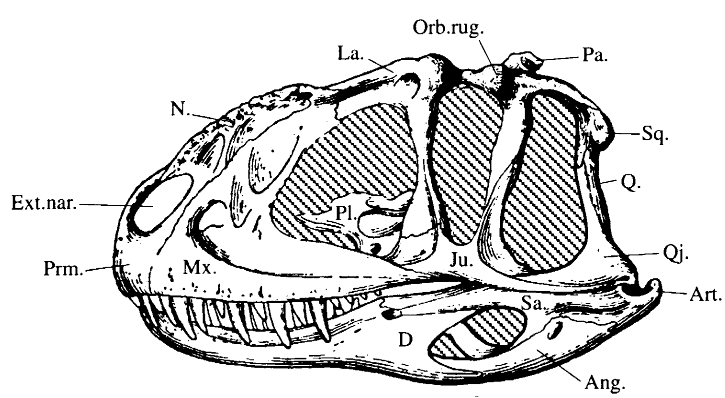

Figure 45. Lateral view of the skull of *Yangchuanosaurus shangyuensis.*

In addition to the two distinct fenestrae on the maxilla, there are numerous additional small cavities and pits. There are 14-15 teeth present. On the right side, the apices of the ninth, tenth, and eleventh teeth are missing due to damage during excavation. Numerous small nutrient foramina generally aligned along two rows lie on maxilla. The ventral series is composed of approximately 18 foramina that are parallel to the tooth row. The dorsal series is composed of approximately 12 foramina that initiate at the posterior end of the maxilla and runs along the anterodorsal curvature to terminate at the anterior end of the second antorbital fenestra. In addition, there are seven to eight small additional nutrient foramina that are irregularly distributed between the aforementioned linear series.

The nasal is 36.5 cm in length and is narrower than on *Allosaurus* and *Ceratosaurus.* Its surface texture anteriorly is smooth and glossy but posterolaterally becomes coarsened. At the anterior end there is a round and smooth bifurcation of the medial suture which facilitates the penetration of the premaxilla and composes the elliptical anterior margin of the nasal. The lateral side of the nasal fuses with the anterior ascending process of the maxilla with an extremely deep depressed suture line. The nasals' suture line itself is linear and extends to contact the midline of the frontals. Posteriorly, the nasals are bifurcated with the majority of the elements contacting the frontal, although there is a small lateral branch that contacts the anterior lacrimal. These elements are relatively flat and distinctly not elevated as on *Allosaurus*, nor is there a "horn" as on *Ceratosaurus.* Rugosities ornament the nasal surface suggesting the presence of an extremely thick keratinaceous sheath covering the nose.

The prefrontal is slightly deformed due to compressional distortion and is strongly crescentically shaped. A coarse process lies at the base of this element which facilitates contact with the lateral frontal process. The dorsal branch of the prefrontal runs anteriorly along the dorsal process of the lacrimal to contact the dorsal process of the maxilla. The ventral process of the prefrontal runs ventrally to contact the lacrimal. These two processes intersect dorsal to the first antorbital fenestra with a deep depression. This is an autapomorphy not observed on any other megalosaur.

The frontals are relatively long elements with a medially depressed dorsal groove which may be due to compressional distortion. A ridge to facilitate musculature lies posteriorly and runs medially directly to the nasal. This ridge is distinctly narrower than on *Allosaurus* in addition to being slightly longer and higher. The frontal contacts the nasal with a coarsened and sinuous suture line, while laterally the contact with the prefrontal is composed of a small vertical ridge. The frontal and parietal are in tight association, unlike many taxa in the Megalosauridae which display a more kinetic contact.

The postorbital is undamaged, form a cruciform cranial element resembling the general theropod condition, and composes the posterodorsal margin of the orbit. The robust frontal process composes a large "brow ridge" but is not as exaggerated as on *Allosaurus.* Its jugal process is longer than the other two processes with a length of 27 cm. An overlapping contact with the dorsal process of the jugal composes the boundary between the orbit and the lateral temporal fenestras. The posterior squamosal process contacts the squamosal to compose the dorsal margin of the lateral and supratemporal fenestrae.

The parietal is more elevated than on *Allosaurus* and constitutes the highest point on the skull. This character is probably related to support of the massive cranium. Its maximum length is 11 cm and width is 16 cm. A pair of cornual processes extend laterally from the midline of the two parietals directly to the mediolateral margin of the squamosal. From an occipital perspective, a longitudinal crest lies posteromedially with vertical grooves on each side of the crest that extend from the dorsal apex to the occiput. The lateral margins of these grooves diverge and expand to form cornual processes. This structure is also observed on *Allosaurus* and *Tyrannosaurus* to facilitate increased cranial musculature.

The squamosal is a cruciform element that sits lateral to the parietal as the posterodorsolateral cranial element. Its anterior process contacts the postorbital to form the dorsal boundary of the lateral and supratemporal fenestras. Its ventral branch extends to contact the quadrate. The short anterior margin of the posterior branch contacts the parietal while its posterior margin contacts the quadrate. This element resembles that of *Ceratosaurus* with an unornamented or relatively smooth and glossy external surface. A small laminar ridge is present at the intersection of the anterior and ventral processes.

The quadratojugal sits posterolaterally as an L-shaped element with a posterior margin that fuses with the quadrate, extends dorsally to invade the medial side of the ventral squamosal process, and possesses a jugal process that extends anteriorly to contact the jugal. The extremely gracile linear squamosal process is typical morphology for the Theropoda.

The quadrate is a relatively long element at the lateral side of the occiput with a laterally expanded ventral margin with a spherical articular surface. Its dorsal margin becomes thinned and transversely broadened with a longitudinal lamina at its center, causing both lateral laminae to form a nearly 90° angle. The anterior lamina penetrates the medial quadratojugal to contact the pterygoid while dorsally it penetrates the ventromedial lobe of the squamosal to contact the exoccipital. This element is relatively linear with an articular condyle that resembles *Chilantaisaurus.*

The left jugal is perfectly preserved but the right is incomplete due to the explosion that reveiled the specimen. It is reversely cruciform with an ascending process as an acute "spine" that contacts the ventral process of the postorbital. An inflated ridgelies at its base. The lower margin of the jugal attenuates as it extends posteriorly to penetrate the quadratojugal. The anterior process thins but broadens to become plate-shaped and appressed against the maxilla and lacrimal.

The lacrimal is a nail-shaped element with an anterior process that extends to contact the nasal and ascending process of the maxilla and compose the dorsal margin of the first antorbital fenestra. Its ventral process extends to contact the anterior end of the jugal. The intersection of these two processes lies at the dorsal angle of the first antorbital fenestra with a distinct deep depression. This depression is unrecorded on any other genus in the megalosaur family and should represent a facilitation for the strengthening of the facial musculature.

Detailed descriptions of the palate and basicranium are impossible due to the complete fusion of the maxilla and mandible. However, a lateral excavation through the first antorbital fenestra reveals an ear-shaped element that has been laterally compressed. Its dorsal margin is extremely thin and gradually thickens toward its base where there is a thick laminar ridge that extends anteroventrally. Anteriorly, there is a smooth rounded concave margin, which should represent the massive posterior margin of the internal nares. Additionally, there is a posterolateral depression that represents the anterior margin of the ectopterygoid fenestra. The preservation of the palatine indicates that *Yangchuanosaurus* had a well-developed secondary palate, indicating that the megalosaurs were capable of functional respiration during food ingestion.

Excavation of the lateral temporal fenestra reveals a pterygoid in contact with a portion of the ectopterygoid. The posterior process of the pterygoid is relatively thick and extends to contact the basal region of the quadrate. The plate-shaped ectopterygoid is vague as it has suffered compressional distortion appressing it against the lateral cranium.

A majority of the occiput is obscured by the atlas-axis complex but the supraoccipital, exoccipital, and opisthotic are distinguishable. This region resembles the condition of the Pseudosuchia and Theropoda in being narrow and high with relatively laterally expanded paroccipital processes. The supraoccipitals lie posterolaterally to the parietals as relatively narrow elements and constitute the dorsomedial features in the occipital region. Their dorsal margin is fused with the parietal, laterally they contact the exoccipitals, but their contact ventrally is obscured by the atlas-axis complex. The exoccipitals extend laterally as a cornual plates and then extend ventrally at a 45° angle with isolated distal ends. The opisthotic is extremely similar to that of the Pseudosuchia.

The left mandible is perfectly preserved but the right mandible has sustained some damage to the anterior end of the angular and dorsal margin of the mandibular fenestra. The distance between mandibles has become conspicuously narrowed due to compressional distortion but the quadrate articular relationship has neither been deformed nor shifted. The mandible is comparable to that of all other large carnivorous dinosaurs, particularly in lateral morphology, but it is distinctly narrower and longer. The anterior oral region has shifted in place revealing a ligament suture attachment at the midline. This region is relatively rounded in structure (or lacks a chin). Maximum length of the mandible is 78 cm and maximum height at the midline of the mandibular fenestra is 10.2 cm.

Maximum length of the dentary is 48 cm, or over half the total length of the mandible. The left dentary contains 15 teeth of varying sizes, while the right side contains 14. The midsection of the dentary is relatively broad, has a maximum diameter in cross-section of 1.6 cm, and bears a rather robust dentition. A vague small longitudinal groove lies on the dorsolateral margin. At the anterior end of the groove, and within its vicinity, lie several small round nutrient foramina furnishing each of the alveolae. At the posterolateral end of the dentary there is an irregularly shaped, extremely thinly bounded orifice which forms a portion of the large elliptical mandibular fenestra. This portion of the fenestra is composed of two acute posteriorly extended processes both dorsal and ventrally which overlap the angular and surangular respectively. The posterodorsal process of the dentary penetrates the medial side of the angular. There is another intersection of two acute processes at the region of the mandible where the dentition terminates. At this intersection there is an extremely regular, elliptical, and deep depression which represents an autapomorphic character for the Theropoda. In this region of the mandible on *Tyrannosaurus,* its analog is a fissure to facilitate ligament contact, resembling the mode of bite in extant varanid lizards.

The angular is perfectly preserved on the left side but is slightly damaged on the right. In lateral view its surface is relatively smooth, it constitutes a relatively complex element on the posterior mandible, and extends anteriorly to gradually elongate and become an extremely thin and acute plate which contacts the posterior dentary, and with it forms the basal margin of the mandible. Its dorsal margin contacts the surangular. From a ventral perspective it rotates radically lateromedially to contact the ventral prearticular. Compared to *Allosaurus* and *Ceratosaurus,* it is distinctly smoother in texture and more delicately constructed.

Posterodorsally, the surangular is present as a relatively long element that, in lateral perspective, appears relatively broad. From its dorsal margin to the ventral mandible, it rotates medially at a right-angle to form a thick osteological element. Anteriorly, it gradually tapers to compose a thin plate which contacts and overlaps the posterior dentary process, and together they thereby compose the dorsal branch of the mandibular fenestra. Posteriorly, it contacts the articular and composes a portion of the articular facet for the quadrate. Its surface is ornamented with relatively abundant pitting and a small surangular foramen lies near the posterior angular.

The most posterior element, the articular, is extremely irregular with a well developed articular facet that contains two extremely deep transverse depressions between which lies an anteriorly oblique ridge. Both articular facets articulate precisely with the opposing condyles of the quadrate. A retroarticular process lies posterior to the facets which projects obliquely anterodorsally.

A prearticular is present posteromedially as a long and recurved plate. It is visible at the ventromedial margin of the mandibular fenestra and expands anterodorsally. Further description is not possible due to obscurity.

Splenials are noted ventromedially on both mandibles as long, oblique, blade-shaped plates. Compressional distortion has detached the right element allowing measurements of 30 cm in length and approximately 0.8 cm in width.

The external nares are elliptical. Internally the medial septum is composed of the nasals, ascending process of the premaxillae, and the nasal processes. These are extremely unlike the exaggerated and anteroposteriorly elongated nares on *Allosaurus*, nor do they resemble the anteriorly narrow and posteriorly broadened morphology on *Ceratosaurus,* and are instead oval as anteriorly broad and posteriorly narrow.

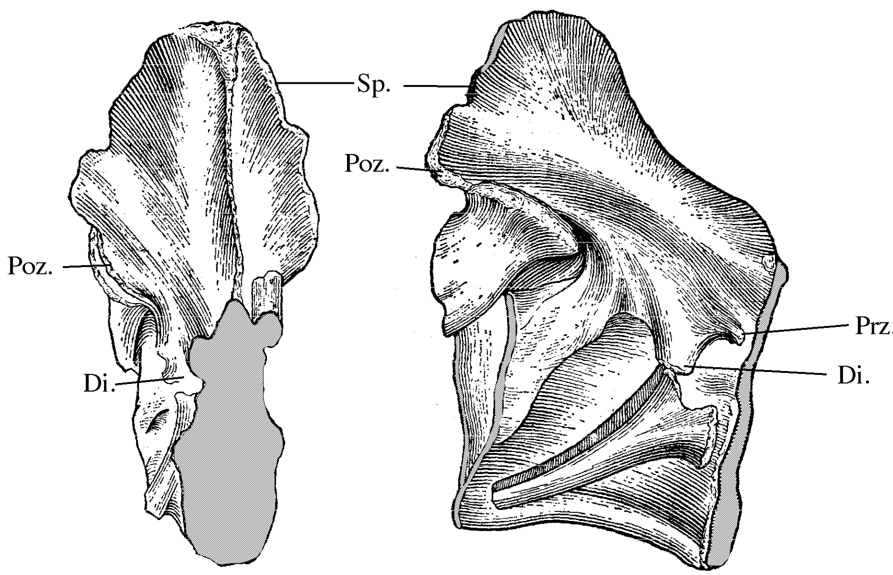

Figure 46. Anterior and lateral view of *Yangchuanosaurus shangyuensis* axis.

The second antorbital fenestra is small, triangularly shaped, and located at the anterior base of the maxilla. Many workers believe it and the first antorbital fenestra serve the same functions, which is to lighten the cranial load and increase the facility for muscularization. Others hypothesize that they serve a function for gland secretion.

The first antorbital fenestra is the largest of the fenestrae and is situated laterally. It is principally bounded by the maxilla and lacrimal and is relatively regular in form as a triangle. Its maximum anteroposterior length is 18 cm and dorsoventral length is 22 cm.

The orbit is laterally situated with its dorsal margin composed of the postorbital and the prefrontal. The anterior and ventral margins are composed of the lacrimal, jugal, and postorbital. Its outline is dorsally broad and ventrally narrow resembling a ventrally extended trapezoid. Dorsoventrally it is 21 cm and anteroposteriorly it is 11 cm.

The anterodorsal margin of the lateral temporal fenestra is composed of the postorbital, squamosal, and jugal, while the quadrate composes its posterior margin. It is nearly elliptical in morphology, being dorsally narrow, and ventrally broad. Dorsoventrally it is 26 cm.

The supratemporal fenestra is relatively small, circular, and separated from the lateral temporal fenestra by the postorbital. It is posteriorly-positioned with a dorsally-directed aperture.

Yangchuanosaurus displays megalosaurid dental characters, being long, robust, trenchant, and uniserial on lateral maxillae and mandibles, with each tooth differing somewhat in morphology. Dental formula is PM4; M14-15; D14-15. The dentition on the left side of the skull is complete. The dentition on the right side is well preserved with the exception of numbers 2, 3, 5, 6, and 10, which suffered damage during excavation. The first premaxillary tooth is relatively small and conical, with a 2.5 cm long crown that is circular in cross-section with a 1 cm diameter. The second and third premaxillary teeth are relatively large with a 3.3 cm length, slightly posteriorly curved, slightly elliptical in cross-section, and have a maximum 1.2 cm cross-section. The fourth premaxillary tooth is relatively small with an approximate 2 cm length and is 0.9 cm in lateral cross-section. It may be newly erupted.

On the left maxilla, teeth numbered 2, 5, 7, and 9 are the largest, dagger-shaped, rather laterally compressed, and are serrated on the anterior and posterior margins with 24 denticles per centimeter. The crowns are 5.6 cm in height, posteriorly curved, and are elliptical in cross-section with an approximate 2.1 cm diameter. Teeth one and three are relatively small at 3.5 cm in height. Teeth 11-15 are thin, small, and laterally compressed, with the longest being 2 cm. Numbers 4 and 6 are perhaps newly erupted as there is an erupting tooth between 3 and 4.

A portion of the mandibular teeth are obscured due to the tight fusion of the maxilla and mandible prohibiting accurate measurement and description, but from lateral perspective there appears to be 14 to 15 teeth in each mandible. They are laterally compressed and very slightly posteriorly curved. The first anterior three teeth are relatively small, numbers four through seven are relatively large and thick, and from number eight posteriorly they gradually diminish in size.

Yangchuanosaurus was preserved in complete articulation. The ten cervicals have a length of 110 cm, the 13 dorsals have a length of 148 cm, the 5 sacrals have a length of 76 cm, but only the first 12 caudals are preserved with a length of 130 cm. Comparison to the general carnosaur caudal series indicates that nearly 30 vertebrae should be missing.

Due to its obscurity by the axis and its direct contact with the occipital condyle, the atlas cannot be described. The axis is completely preserved as opisthocoelous with a relatively laterally compressed centrum and with well developed pneumatocoels. Anteriorly, it is rather expanded and then constricts in the center to a minimum width of 0.8 cm. It is extremely distinct from the ventrally flat centrum on *Allosaurus,* as it is from *Ceratosaurus* which possesses a conspicuous medial ventral keel. The posterior articular facet lies at a 60° angle to the ventral plane of the centrum. The ventral surface is 6.4 cm in length, posterior breadth is 3.9 cm, parapophyses are distinctly anteriorly situated, and diapophyses are moderately developed. The anterior neural spine is thin, blade-shaped, divergent, and gradually increases in height posteriorly. This spine resembles that of *Szechuanosaurus campi.*

Other cervicals are similar in morphology, being opisthocoelous, lacking a ventral keel, and having an oblique ventral surface and a condylar anterior articular facet. The medial centrum is constricted, the ventral surface is rather laterally compressed, pneumatocoels are well developed, and parapophyses are very well developed lateral to the anterior condyle. A laminar ridge extends posteriorly from the parapophyses to facilitate increased musculature. A neural arch is well developed although a spine is not prominent, being weaker than on *Allosaurus, Ceratosaurus,* and *Szechuanosaurus.* The first several anterior spines are small, plate-shaped, and just slightly higher than the postzygapophyses. Posteriorly, the spines gradually increase in height, broaden, and are slightly posteriorly oblique. The neural arch is well developed and spacious. Prezygapophyses are short, stout, and slightly elevated. Postzygapophyses are long and extend posterolaterally. Articular surfaces of all zygapophyses lie nearly along the same plane, a morphology that facilitates agility in neck movement. Diapophyses along the entire series are relatively well developed. Anterior diapophyses are situated medially on the centrum and extend ventrally. Posteriorly they gradually elevate to become horizontal and parallel to the dorsal diapophyses.

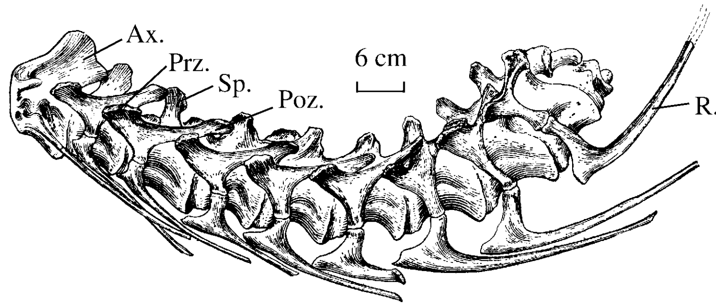

Figure 47. Cervical vertebrae of *Yangchuanosaurus shangyuensis.*

Dorsal vertebrae of *Yangchuanosaurus* are completely preserved, in articulation, and undisturbed with the exception of some damage sustained on the apex of neural spines 11, 12, and 13. Although it is difficult to determine the point of transition from posterior cervical to anterior dorsal based upon centrum morphology, the presence of cervical ribs allows the determination of 10 cervical vertebrae.

The specimen possesses 13 dorsal vertebrae with the first two dorsals similar in morphology to the last two cervicals and centra that are extremely gently opisthocoelous. The remaining dorsals are amphiplatyan and relatively flat laterally. Centra anterior and posterior articular surfaces are circular and nearly equivalent in diameter. Medially, the centra are constricted, ventrally they are saddle-shaped, and lack a ventral keel. Morphologically, they resemble the generalized carnosaurian mode. Neural arches are moderately developed with extremely well developed and robust diapophyses located dorsal to the arch, are slightly posteriorly oblique and are supported by four laminae. Of the two ventral laminae, one arises from the parapophysis while the other initiates from the posterior centrum. Of the two dorsal laminae, one initiates from the prezygapophysis, while the other initiates from the postzygapophysis and extends to the posterior margin of the diapophysis. In this manner the diapophysis composes a laterally-oblique process. Ventral to the diapophysis lie three deep subtriangular depressions. Pre- and postzygapophyses gradually diminish in intensity anteroposteriorly as they progressively become spaced closer together. The first and second dorsal spines resemble the cervical spines but become broadened posteriorly.

Dorsal vertebrae 3-5 have elongated centra, reduced prezygapophyses, and a shallowed posterior articular sulcus. The articular facets are coarsened, lateral sides are relatively smooth, pneumatocoels have become lost, and neural arches ascend rapidly. Neural spines are relatively flat and smooth, expand from being nearly columnar to become rectangular with a relatively coarsened apex, and maintain a small longitudinal ridge. Their anterior margins are slightly anteriorly projected, and the posterior margin bears a small longitudinal groove.

Dorsals 6-8 represent the apex of the sequence with a maximum length of 13 cm. They are more laterally compressed, have become very shallowly amphiplatyan with elliptical articular surfaces, and still maintain relatively coarsened margins. Laminae supporting the diapophyses dorsal to the neural arches are conspicuous and represent the greatest breadth in the series with a planar surface uniting the pre- and post zygapophyses to form a platform. From a dorsal perspective the diapophyses resemble two corneal processes. Neural spines have developed into rectangular plates with dorsal 8 being the largest. Maximum vertebral height is 36 cm with a neural spine height of 18 cm.

Dorsals 9-11 do not differ greatly in morphology from D6-8 but are laterally compressed with a centrum that is medially constricted, and there is a deep dorsal septum. Centra become more amphicoelous and initiating with D9, diapophyses reduce, weaken, and descend in position. Diapophyseal buttressing also becomes weakened posteriorly, while parapophyses ascend in height, and neural spines become completely rectangular.

The centrum of dorsal 13 again displays circular anterior and posterior articular facets while being fused posteriorly to the sacrum. Diapophyses are extremely weak, the neural spine is nearly fused with the sacral neural spine but this element is still recognized as a dorsal vertebra due to the presence of a vestigial dorsal rib.

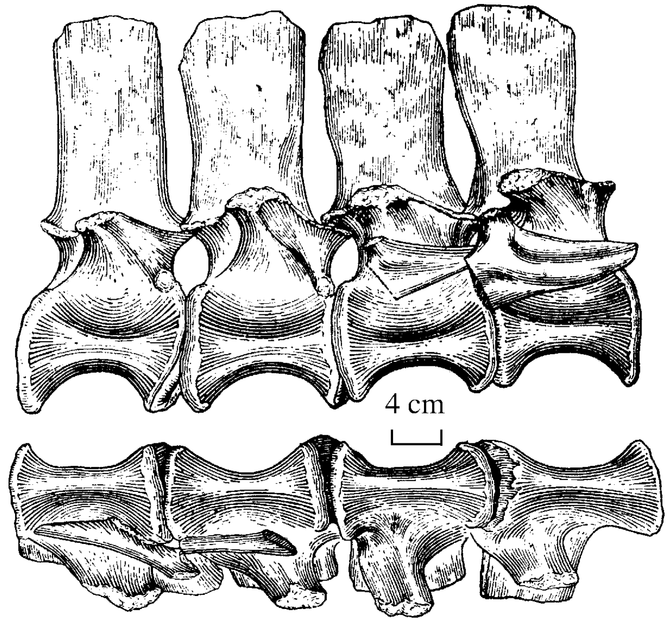

Figure 48. Dorsal sequence of *Yangchuanosaurus shangyuensis.*

The sacrum of *Yangchuanosaurus* is relatively well preserved as five fused elements. From a ventral perspective the centra boundaries have been obliterated due to their fusion, centra lengths differ with the first and fifth being relatively long (13 cm and 10.5 cm respectively), and the medial three being relatively short. Sacral ribs link the sacrum to the ilia, which obscures the relationship of the ribs to their medial sides (Pl. XXV, Figs. 1, 2). With the exception of the last spine, which is isolated, the neural spines are all rectangular and fused into a single plate. Sacral spine 5 resembles a caudal morphology, being relatively high and anteroposteriorly narrowed. These spines differ from the short spines on *Allosaurus*, the apices of which are parallel to the dorsal crest of the ilium; they differ from *Tyrannosaurus* which has spines that are not fused to the ilia; and they also differ from *Ceratosaurus*, the spines of which greatly exceed the height of the iliac crest and are posteriorly oblique. *Yangchuanosaurus* displays sacral spines that are moderate in height compared to the iliac crest.

Only 12 anterior caudal vertebrae are preserved but they are complete. The remaining were probably lost prior to deposition. The articulated haemal arches and spines are preserved in sequential order (Fig. 44). Caudals 1-5 are distinctly heavy and robust but have been subjected to lateral compressional distortion. Centra are amphicoelous, have a height greater than length and medial pleurocoels are intense (Table 8). The neural arch is moderately well developed, diapophyses are broad and thin with nearly square termini, extend horizontally, and are slightly posteriorly inclined. Neural spines are straight, high, and in lateral perspective are tongue-shaped. Maximum height of the spines attains 22.6 cm, anteroposterior breadth is approximately 8 cm, and thickness is 1.4 cm.

Caudals 6-12 gradually diminish in height as centra become elongated, lateral compression becomes less noticeable, and they become more tubular in morphology. Articular surfaces become more shallow, and posteriorly the oblique surface for fusion with the haemal arch increases in size. Diapophyses progressively become more delicate, posteriorly directed, and gradually disappear completely. Pre-and postzygapophyses progressively become elongated, neural spines gradually diminish in height and breadth, and become posteriorly inclined. (Fig. 49).

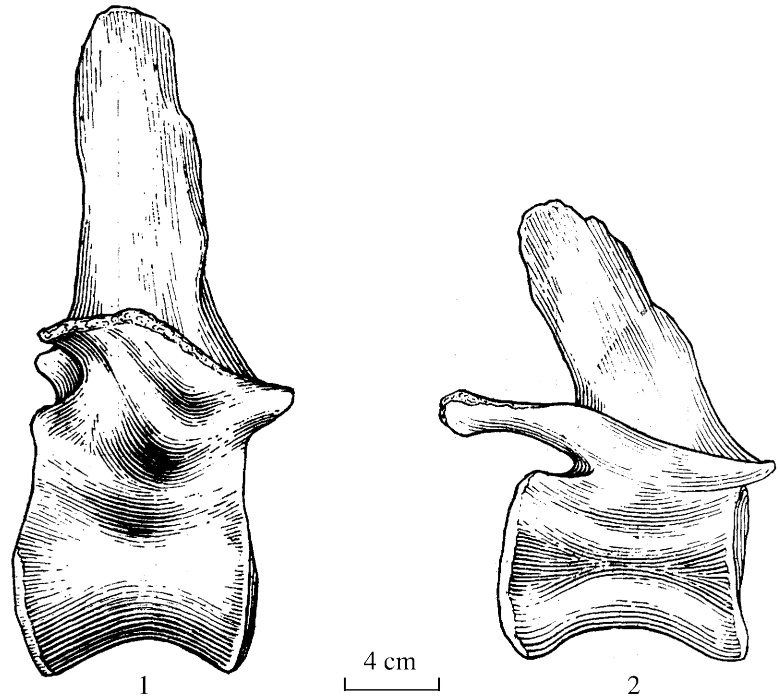

Figure 49. Caudal vertebrae of *Yangchuanosaurus shangyuensis.*
1. Caudal 5; 2. Caudal 8.

On the left side the entire series of gracile and long cervical ribs is preserved but on the right side only the ribs posterior to Cv6 are present as the remainder were exposed to weathering. Exemplified by the eighth rib, field measurements taken during excavation document a maximum length of 50 cm, such that the shaft extends beyond the posterior centrum of Cv10. Maximum breadth at the diapophyses is approximately 4 cm. The ribs are tricapitate with a short, thin, but robust anterior process. Capitulum is longer and more robust than tuberculum and articulates tightly with the vertebra. A transverse bony plate contacts the rib between the capitulum and tuberculum dividing it into anterior and posterior portions. The anterior portion of the rib is spoon-shaped while the shaft constricts posteriorly to become rod-shaped. A thin and long longitudinal groove lies on the anteromedial half of the shaft which gradually disappears posteriorly. Cervical ribs gradually lengthen from the axis to Cv8, but at Cv9 and Cv10 become slightly reduced with the spoon-shaped anterior process on rib 10 nearly completely lost as it transforms into a dorsal morphology.

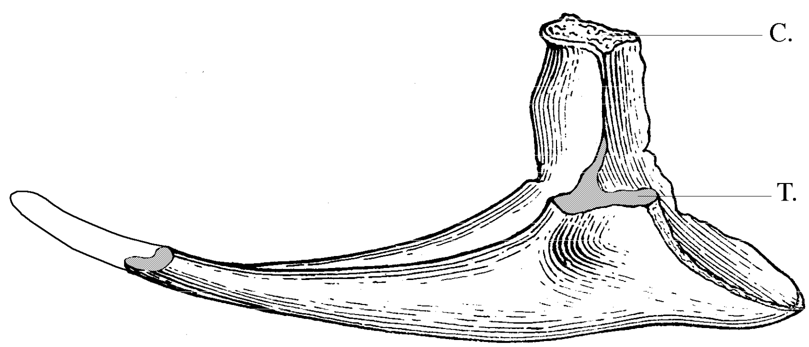

Figure 50. Cervical rib of *Yangchuanosaurus shangyuensis.*

Damage has been sustained to the dorsal ribs on the right side but on the left side are nearly complete and basically aligned in their original position, with only a few being displaced. Dorsal ribs gradually increase in length anteroposteriorly, with the fifth reaching a maximum length of 108

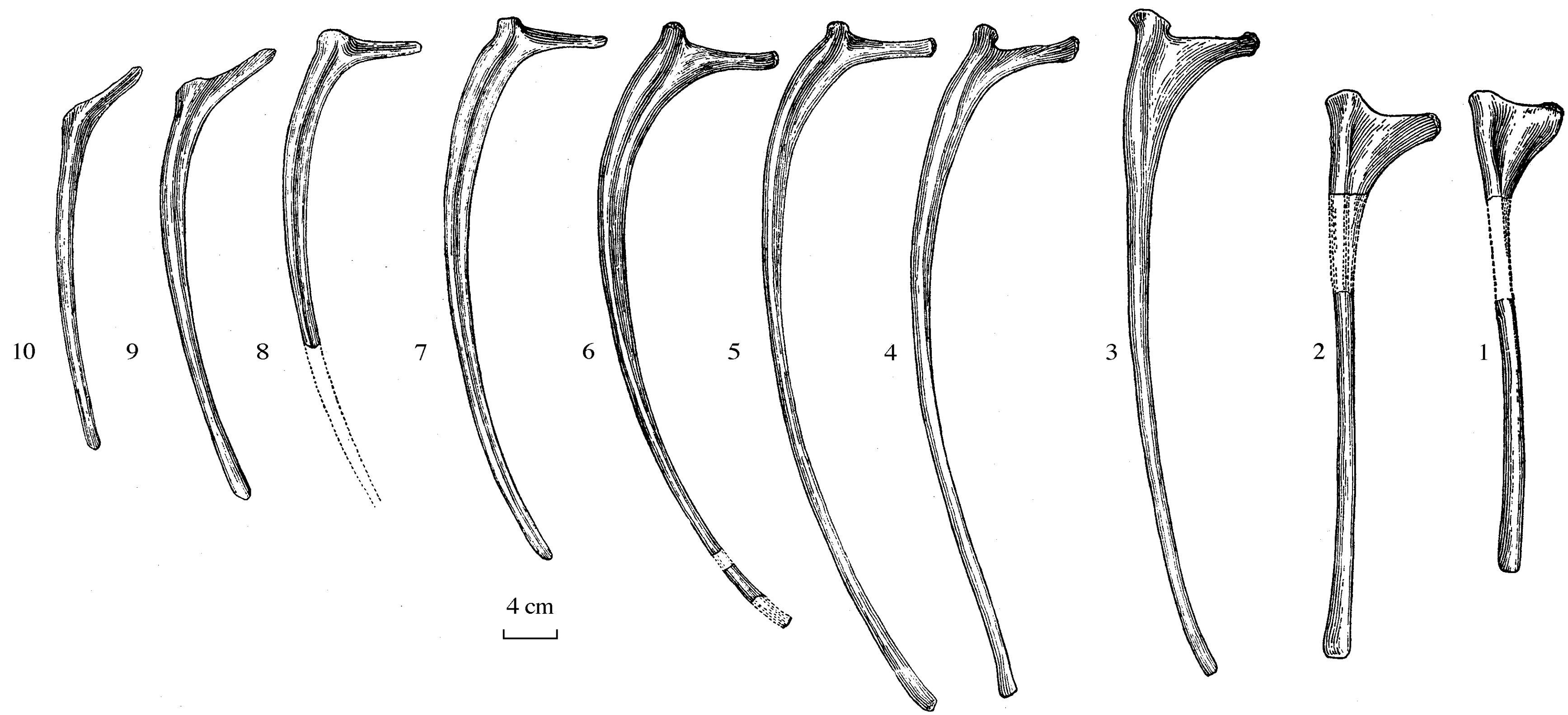

Figure 51. Dorsal ribs of *Yangchuanosaurus shangyuensis*.

cm and twelfth attaining the minimum length of 10 cm. Dorsals one, two, and three are relatively flat and straight with a robust shaft. Capitulum and tuberculum do not differ greatly in morphology and are closely spaced. A laminar ridge along the shaft is undeveloped and the distal end is relatively thin and flat. The fourth and fifth dorsal ribs are the longest with an extremely well developed capitulum and tuberculum generally spaced 14 cm apart at an approximate angle of 70°. The most proximal shaft has a curvature of approximately 150°, bears a laminar ridge, and from its mid-point distally gradually thins to become cylindrical. Dorsal ribs six through nine reduce in length, with capitulum and tuberculum gradually thinning and becoming more closely spaced. A laminar ridge on the shaft becomes increasingly pronounced, medial curvature is increased, and the distal end becomes rod-shaped. The tenth to twelfth dorsal ribs progressively reduce further in length, breadth, and distance between capitulum and tuberculum. The shaft has very little curvature and the laminar ridge becomes undeveloped.

Twelve relatively complete haemal arches are present on the second to twelfth caudal vertebrae. The first arch, which is the broadest at 4.9 cm, is shorter than the second arch which appears to be the longest at 19.9 cm. Posteriorly, they become progressively reduced with the entire arch becoming thin, flat, and smooth. From a lateral perspective the dorsal and ventral ends are broadened with a slight posterior curvature distally. From an anterior perspective the dorsal end is in tight contact with the last dorsal vertebra. There is a ventral curvature at the dorsal haemal canal between the contact surfaces of the centrum and the lateral sides of the canal which are angled dorsally. The proximal end of the haemal arch at the centrum contact is Y-shaped.

The pectoral girdle and forelimbs on the left side may have been lost prior to burial while the right forelimb was destroyed during the explosive construction work that exposed the specimen, such that all that remains is the distal end of the right scapula, which is expanded anteroposteriorly, conspicuously thick, and inflated laterally at its contact for the coracoid. Dorsally this inflation thins rapidly. The glenoid is very slightly laterally oblique with a distinct inward curvature at its midpoint. A fragmentary humerus shaft is relatively flat, thickened at its midpoint, and relatively thin at its lateral margins.

The pelvic girdle is relatively well preserved with left and right ilia, ischia, and pubes preserved in their original configuration (Pl. XXV, Figs. 1,2; Pl. XXVI, Figs. 1,2). The paired ilia are solidly attached to the lateral sacrum. The assemblage resembles both *Allosaurus* and *Ceratosaurus* in morphology, displaying a low iliac rim with elongated pre- and postacetabular crests, acetabulum situated medially, and nearly fan-shaped in outline in lateral perspective. A wide angle is present between the pubic peduncle and preacetabular crest. The expansive preacetabular crest differs from that on *Ceratosaurus* as it is not ventrally embayed. The ischial peduncle is relatively narrow with a distal end that attenuates to an acuity, and a longitudinal groove is present ventrally. The pubic peduncle is more prominent than the ischial peduncle both of which are thick, robust, and tightly fused to their counterparts. The acetabular articular surface is circular, smooth, and overlain by a broadened projected crescentic lateral margin. Articulation with the femoral head is at a 90° angle providing ample application for bipedality. Compressional distortion has caused the ilia to be appressed against the sacrum.

In anterior perspective the left and right pubes diverge dorsally to form a “Y” configuration with broad, thick proximal ends that are fused to the pubic peduncle. Combined with the sacrum these elements compose a large fenestra in the configuration of an open basket. Ventrally, the pubes become fused and constricted. Further ventrally they again expand and possess a groove at the medial suture line. Both posteromedial sides are obliquely inclined. In cross-section the fused pubes are triangular with the base of the triangle located anteriorly. Halfway down the suture line the shaft begins to become anteriorly projected to compose a 14 cm long dorsoventral laminar ridge which disappears down the shaft and where it then curves posteriorly. The distal end becomes expanded with a shallow depression. In lateral perspective the pubis is booted, dorsally it is anteroposteriorly expanded with its posterior margin in contact with the ischium. An extremely well developed obturator foramen (9.2 cm diameter) is present and enclosed ventrally by an extremely thin bony plate (Pl. XXVI, Fig. 2). The pubic shaft is relatively narrow, constricts ventrally, and then at its distal end expands to form a typical boot with an anteroposterior length of 23.5 cm. The entire element is surficially relatively smooth until the distal end where it becomes coarsened. This element conforms to other known members of the Carnosauria but maintains two autapomorphies, one being the well developed obturator foramen, and the other lying in the extremely small anterior process of the boot with the anterior shaft nearly at a right angle to the posterior extension. This differs from the anteroposteriorly expanded boots on *Allosaurus, Ceratosaurus, Tarbosaurus,* and *Tyrannosaurus.*

From a posterior perspective the two ischia are dorsally open and fused with the ischial peduncles. The ischial shafts fuse at their midpoints and a posterodorsally projected laminar ridge initiates at the dorsal margin of the suture line. The shaft is relatively thin and terminates with a slightly anteroposteriorly expanded node. Both sides are relatively flat and form a weak boot. The surface texture of the the ischia are relatively smooth, however, the distal end is rather coarsened to facilitate muscular attachment.

The left hindlimb is nearly complete, and the right limb preserves the femur, tibia, fibula and astragalus. Metatarsals and phalanges are absent (Pl. XXVI, Figs. 4-7).

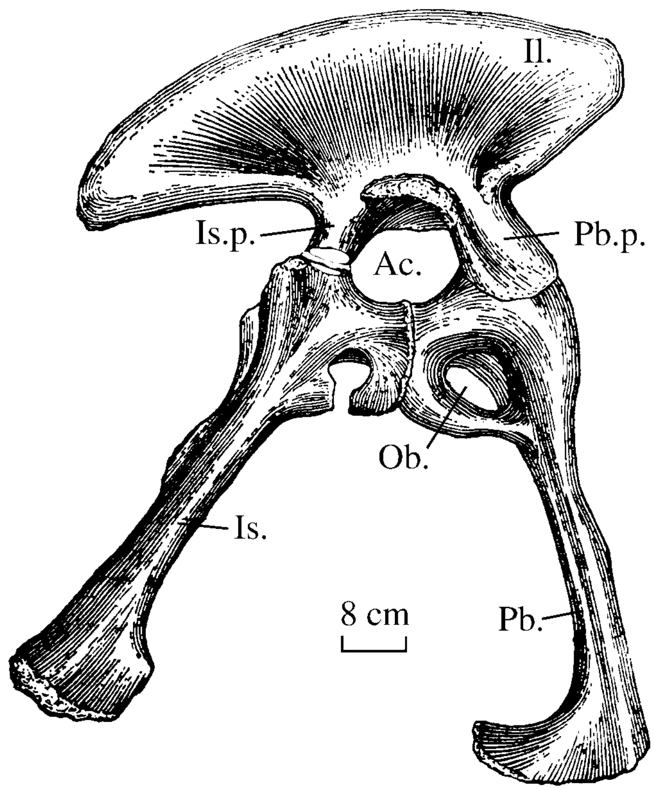

Figure 52. Pelvic girdle of *Yangchuanosaurus shangyuensis.*

The right femur has been subjected to lateral compressional distortion causing it to be elliptical in cross-section. The limb is robustly strengthened with a very slight anterior curvature. At its proximal end the head has also undergone compressional distortion and at its lateral side there projects a well developed flattened spur which represents the lesser trochanter that is isolated from the head by an extremely deep groove, and represents the typical condition of theropods. The fourth trochanter is well developed as a blade-shaped crest on the dorsomedial half of the shaft. The surfaces of the trochanters are relatively thick with laminar ridges to facilitate the attachment of massive musculature. Distally, there are two conspicuous condyles with a relatively deep intercondylar recess. The trochlea is circular and smooth, indicating the presence of soft connective tissue. Femur length is 85 cm.

The tibia is robust, has a length of 75.5 cm, and is slightly longer than the fibula. Its proximal end is laterally compressed with an expansive cnemial crest and a crescentically shaped, medially oblique articular facet for the femur that is 14 cm in length anteroposteriorly. Its lateral shaft is relatively flat and composes a straight lamina. At the lower region of the cnemial crest there is ridge that is projected toward the fibula. Both sides of this ridge are relatively thin, its apex has a coarsened texture while ventrally it travels directly and nearly evenly to the distal end. The shaft accommodates tight association with the fibula. The distal end of the tibia is thin and flat, slightly laterally expanded, and has a posteriorly oblique medial surface. At its center is a depression to facilitate the ascending process of the astragalus, which is in tight fusion with the tibia. The shaft is triangular in cross-section, and is pneumaticized with relatively thick walls.

The fibula is gracile with a slightly anteroposteriorly expanded proximal end that, like the tibia, is distinctly crescentic and medially oblique with a coarsened articular surface. The lateral shaft is relatively flat and smooth and there is a crest on the upper half of the dorsomedial side that projects to become a conspicuous ventral laminar ridge. Ventral to this ridge the tibial and fibular shafts are in extremely close proximity and a separated only by a thin seam of calcareous matrix. The distal end is coarse and irregular in morphology, slightly anteroposteriorly expanded, and displays a medial side that has a laterally oblique anteroposterior curvature, and is tightly fused to the calcaneum.

The astragalus is an extremely irregularly shaped object that is fused to the tibia. At its fusion point its sutures are obscured, infilled with matrix, and are slightly deformed as the result of compressional distortion, providing difficulty in the precise description of its morphology. In anterior perspective it is nearly rectangular with an acute, thin, triangular astragalar process, and is medially fused to the calcaneum. From a ventral perspective it is coarsely textured, nearly rectangular in outline, narrows slightly as it approaches the calcaneum, is slightly projected anteroposteriorly, and maintains a transverse depression at its center. Conforming to its lateral sides, it is very slightly anteriorly projected. Its ventral margin is distally arched and dorsally its articular surface is an oblique v-shaped depression to facilitate fusion with the anterodistal end of the tibia (Fig. 53).

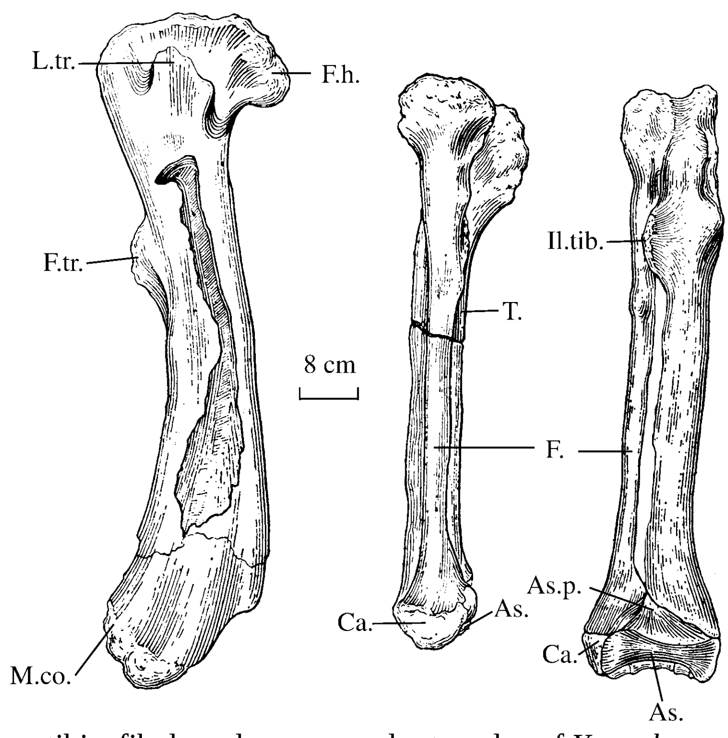

Figure 53. Femur, tibia, fibula, calcaneum and astragalus of *Yangchuanosaurus shangyuensis.*

The calcaneum is a small nearly regularly shaped object that is slightly anteroposteriorly larger than the astragalus although in total perspective it is narrower. Medially it is in tight association with the tibia and astragalus. From anterior perspective it is relatively broad dorsally and extremely narrow ventrally with a coarse surficial texture. From a lateral perspective it contacts the fibula dorsally with an anteroposterior depression such that the entire lateral side is semicircular with a coarsened surface and a small fossa at its center (Fig. 53).

Diagnosis and discussion: *Yangchuanosaurus* is a moderate sized carnosaur with an enormous cranium that is moderate in height-length proportions. Maxillary and mandibular dentitions are robust, laterally compressed, and typically megalosaurian. The neck is relatively short with opisthocoelous centra, dorsals are amphiplatyan, there are five fused sacrals with the anterior four spines fused. The scapula is relatively narrow and small, ilium is low and anteroposteriorly elongated, pubic and ischial shafts are fused, distal ends are booted, and there is a well developed obturator foramen. Hindlimbs are long with a robust femur that has an anteroposterior curvature. A well developed astragalar process is present. These characters justify the nomenclature of the genus and species *Yangchuanosaurus shangyuensis* which was initially erected in a 1978 short report and assigned to the family Megalosauridae.

Table 9. Cranial character comparison between *Ceratosaurus*, *Allosaurus*, and *Yangchuanosaurus*.

Ceratosaurus	*Allosaurus*	*Yangchuanosaurus*
1. Nasal horn present	Nasal horn absent	Nasal horn absent
2. Nasals smooth and rounded	Nasals coarse and precipitous	Nasals smooth and gently rounded
3. Skull narrow dorsoventrally	Skull broadened dorsoventrally	Skull narrow dorsoventrally
4. Quadrate long	Quadrate relatively short	Quadrate relatively short
5. Three teeth in premaxilla	Five teeth in premaxilla	Four teeth in premaxilla
6. 18 maxillary teeth	20-22 maxillary teeth	14-15 maxillary teeth
7. Second antorbital fenestra absent	Second antorbital fenestra present	Second antorbital fenestra present
8. Lateral temporal fenestra large with greatest length ventrally	Lateral temporal fenestra relatively small with greatest length high in the lower half	Lateral temporal fenestra moderate with greatest length ventrally
9. External nares circular	External nares elongated	External nares oval
10. Posteromedial nasals with fossa	Posteromedial nasals lack fossa	Posteromedial nasals lack fossa
11. Posterior nasals to external nares expansive	Posterior nasals to external nares gradually narrow	Nasals gradually narrow
12. Parietal-frontal contact not kinetic	Parietal-frontal contact kinetic	Parietal-frontal contact not kinetic
13. Mandibular fenestra moderate	Mandibular fenestra small	Mandibular fenestra large
14. Angular foramen absent	Angular foramen absent	Angular foramen present

The family Megalosauridae contains several moderate-sized Jurassic carnosaurs and several enigmatic Cretaceous carnosaurs. *Yangchuanosaurus* is appropriately placed within the Megalosauridae which is diagnosed as being moderate to large with a robust body, large and moderately high cranium, ventral process of squamosal oblique, quadrate posteriorly oblique, postorbital thin and rod shaped, mandible long and fenestrated, dentition large and laterally compressed, 9-10 cervicals, 13-14 dorsals, five fused sacrals, ilium low, pubis with a gracile and long shaft that is booted at its terminus, forelimb shorter than hindlimb, and digits I and V reduced.

The Megalosauridae is currently recorded from Late Jurassic sediments on every continent, with the exception of Antarctica. *Yangchuanosaurus* itself approaches the genus *Megalosaurus* which also maintains a maxillary depression, similar dental formula, and is produced from Late Jurassic sediments of Europe and East Africa. *Megalosaurus* differs in the presence of a single antorbital fenestra and comparatively smaller mandibular fenestra. Specimens of this genus are rather fragmentary although records for the genus in Europe are relatively numerous. Numerous fragmentary records of the family are also recorded from Asia such as *Szechuanosaurus* and *Chilantaisaurus*, although the former is a smaller and a more delicately constructed form while the latter is represented by a fragmentary skull and forelimb and displays a kinetic contact between the parietal and frontal. Both do not compare well with *Yangchuanosaurus.* However, the North American *Allosaurus* and *Ceratosaurus* are comparable as illustrated in Table 9:

With regard to vertebrae, *Yangchuanosaurus* has laterally compressed centra, particularly the anteroposteriorly elongated dorsals which are particularly embayed and typically amphiplatyan. Particularly worthy of note are the distinct morphologies of the dorsal spines on the three genera. On *Allosaurus* the dorsal spines are low with thin anterior and posterior edges but thickened at the center and display an apex that is expanded to resemble a mushroom cap. Compared to both *Allosaurus* and *Yangchuanosaurus*, *Ceratosaurus* has cervical spines that project perpendicularly at a height that lies between the other two genera, are laterally compressed, anteroposteriorly elongated and lack an inflation at the apex. Dorsal and sacral spines are most typical as they compose a linear and long rectangular "plate" situated high upon the neural arch. This character is also noted on the vertebrae of several other fragmentary carnosaurs.

Mounting of the skeleton: Taphonomic conditions of the skeleton are expressed by its lying on its side with head and tail upturned. Furthermore the maxillae and mandibles are tightly fused, and the hindlimb was posteriorly extended in a death throe. This preservation of a life-like position is rarely encountered. The articulation of the elements is also distinctly undisturbed and will provide valuable evidence toward the study of other carnosaurs. The specimen was subsequently mounted in free relief for the benefit of the local populace.

During the restoration process one aspect concentrated on the preservation of original material while a second aspect concentrated on authenticity in posture. Consequently, the damage sustained to the right forelimb during excavation was reconstructed on the basis of *Szechuanosaurus* with reference to the remaining distal right scapula for size. Restoration of the pes was also based upon *Szechuanosaurus* but with the proportions adequate for the rest of the limb. The posterior tail was not reconstructed due to its unimportance toward the total mount.

***Yangchuanosaurus magnus* sp. nov.**

(Pl. XXVII-XXXI, Text Figs. 54-63)

Diagnosis: An extremely large megalosaur with a massive skull that displays two maxillary depressions, one of which penetrates the maxilla. Four of the five sacral spines are fused with the anterior sacral centrum more robust than the other centra.

Specimens: An incomplete skeleton including a partial skull, four cervical vertebrae, six dorsal vertebrae, complete sacral vertebrae, four articulated anterior caudals, four medial caudals, pectoral girdle is absent, pelvic girdle preserves an ilium and ischium, and hindlimb preserves only a right femur and two fragmentary phalanges (Chungking Museum of Natural History #CV00216).

Locality and stratigraphic position: Early Late Jurassic Upper Shaximiao Fm. from the Hongjiang Machine Factory* in the vicinity of the municipality of Yongchuan.

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* In September of 1973 excavation for the foundation of the Hongjiang Machine Factory uncovered this specimen, attracting the attention of the workers and leadership who provided protection to the specimen at the site and informed the Chungking Museum of Natural History of its presence. The museum dispatched Xuanmin Li, Shiwu Zhou, and Dongyao Lan to investigate and excavate the specimen. With the assistance and support of the personnel from the Hongjiang factory the specimen was successfully collected. The authors hereby express their gratitude to those who assisted in this project.

Description: The skull had already been subjected to weathering prior to the specimen's discovery with damage to the parietal and occipital regions. Posterior cranial reconstruction was therefore based upon *Y. shangyuensis* due to its close affinity (Pl. XXVII). Skull length is 111 cm and height is 65 cm providing a ratio of 1:1.67, or approaching that of *Y. shangyuensis*. The morphology of the cranial elements and relationship of the sutures also resemble the smaller species, its only major distinction being that one of the two maxillary depressions perforates the maxilla. Isolated internal cranial elements, identified as an ectopterygoid and palatine, were discovered during preparation of the specimen which compare to analogs on other carnosaurs. These elements were not described on *Y. shangyuensis* due to their obscurity by the mandible, and hence, supplemental description is now provided for the genus.

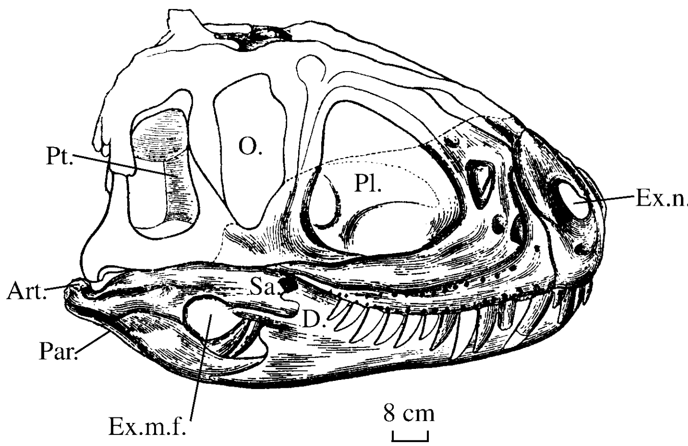


Figure 54. Skull and mandible of *Yangchuanosaurus magnus.*

The ectopterygoid is an irregularly-shaped element that is bifurcated posteriorly as a u-shaped projection (Fig. 55) with a medial branch as a thin acute plate approximately 20 cm long and its lateral branch as being rather robust, while extending and expanding ventral to the jugal. The surficial texture of this element is relatively smooth and glossy, and morphologically it resembles *Megalosaurus.*

The palatine is a long, linear plate with a posteriorly embayed semicircular margin which may represent the anterior margin of the internal nares. The element is relatively thick with its lateral side contacting the medial maxilla, and posteriorly it bifurcates to reach the medial side of the jugal.

Both left and right mandibles are well preserved, although compressional distortion has slightly appressed the anterior end into the medial side of the maxilla, and although the right mandible is hardly deformed the left side has undergone compressional distortion and weathering such that a portion of it is only preserved in outline. The mandible is relatively robust, 117 cm in length, and possesses a large mandibular fenestra, at the midpoint of which is the broadest point of the mandible. The dentary is massive, 56 cm in length, and constitutes more than one-half the entire mandible. The two mandibles fuse with a ligament suture line at a precipitous angle. On *Y. shangyuensis* there is an additional small foramen at the posterior end of the mandible, but this foramen is absent on *Y. magnus*. Morphologically the mandible shares the same characters and suture configurations as *Y. shangyuensis* such that this element differs only in its massive size.

Maxillary and mandibular teeth are extremely large and distinctly megalosaurian in character. They are laterally compressed and slightly posteriorly recurved with serrated anterior and posterior carinae. The dental formula is exactly the same as on *Y. shangyuensis* as Pm-4, M14, D-14-15.

Both the left and right premaxillae bear four teeth with those positioned at the midline small with thin crowns, trenchant, 5 cm long, sub-circular in cross-section, and with a 1.5 cm diameter. The third premaxillary tooth is rather robust and circular in cross-section. The fourth tooth is relatively small, being 4 cm in length, but is intensely trenchant. Anterior and posterior carinae are all serrated but not completely symmetrical and therefore, these teeth are quite distinct from the maxillary dentition.

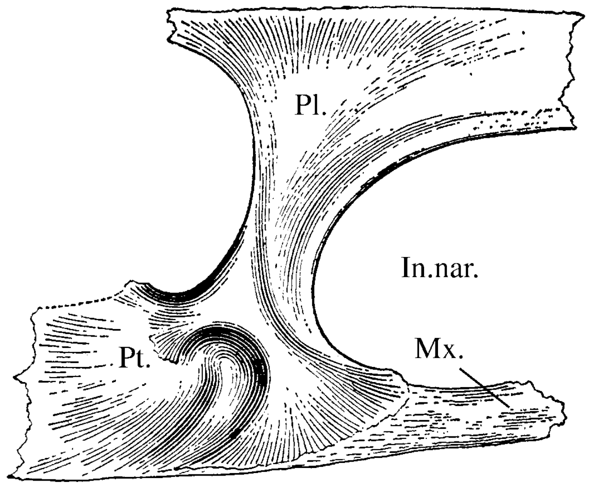


Figure 55. Right palatine and ectopterygoid of *Yangchuanosaurus magnus.*

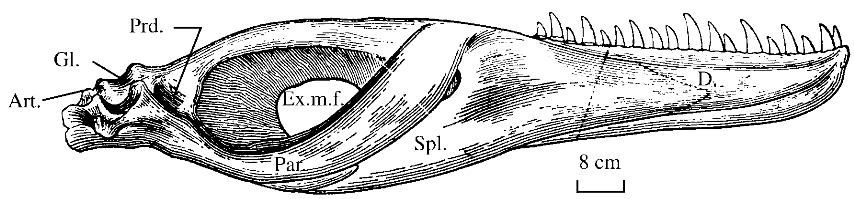


Figure 56. Medial view of mandible of *Yangchuanosaurus magnus.*

The anterior maxillary teeth are well preserved but posterior teeth have been lost or damaged due to weathering. The right maxilla preserves three anterior teeth, posterior to which are seven teeth that only preserve the base of their crowns. These teeth are all robust, and from the eighth tooth posteriorly begin to diminish in size. This is a sequence of characters typical of carnosaurian dinosaurs. The anterior left maxilla is well preserved but its posterior portion was also subjected to weathering and thereby lost. Seven teeth are preserved but are not uniform in size. Tooth number seven is complete and robust with a 7.5 cm crown and an exceedingly long root of 10.3 cm. Dental characters resemble those of *Y. shangyuensis*.

Vertebrae from all sections of the sequence are represented, and it is presumed that this species possessed 23 presacral vertebrae based upon comparisons to *Y. shangyuensis*. Size and morphology identifies the axis; cervicals 3, 5, 6, 8, 10; five dorsals, five sacrals, and eight caudals.

The atlas is not preserved but those cervicals that are represented are typically carnosaurian in morphology, being opisthocoelous with plate-shaped neural spines that progressively increase in size and height posteriorly. The axis is perfectly preserved and completely undistorted (Pl. XXVIII Figs. 1-4, Text Fig. 57) with well developed pleurocoels that are slightly posteriorly inclined. The anterior centrum is inflated and in tight fusion with the intercentrum of the atlas. The neural arch is low, robust, and resembles *Y. shangyuensis* in morphology. From its most anterior end the spine rapidly inflates posteriorly to form a spacious medial ridge. A semicircular odontoid process lies anterodorsally, ventral to which is a saddle-shaped process which represents the atlas intercentrum, which, in lateral perspective, is triangular in morphology, and anterolaterally possesses a labial-shaped margin. This morphology is also typical of carnosaurs. The fusion of the intercentrum indicates that *Y. magnus* is a fully mature individual.

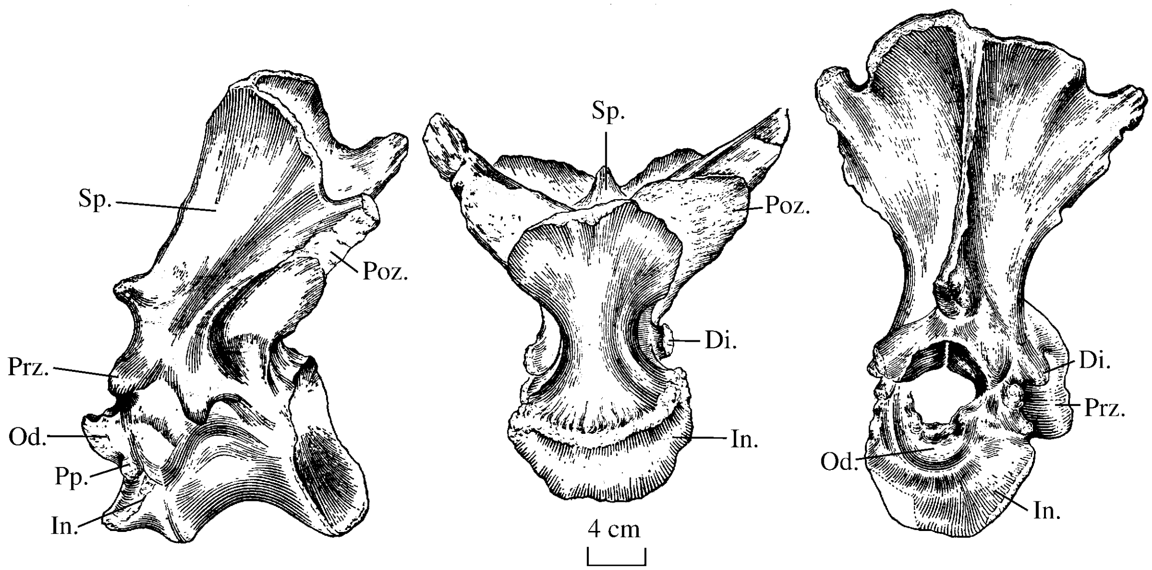


Figure 57. Lateral, ventral, and anterior view of *Yangchuanosaurus magnus* axis.

Table 10. Axis measurements of *Yangchuanosaurus magnus* (cm).

Length (including intercentrum)	11.5
Height (including neural spine)	24.0
Anterior width	8.3
Posterior width	8.5
Medial minimum breadth	2.4

The third cervical vertebra has a short centrum with a thick and large hemispherical anterior condyle. Ventrally it is relatively flat, medially constricted, and expands rapidly posteriorly. Pleurocoels are well developed, slightly posteriorly inclined, and neural arch is moderately high. The height of the spine and arch in combination with the positions of the pre- and postzygapophyses determines this to be the third cervical. Prezygapophyses are robust, situated anterior on the neural arch and are projected laterally. Their articular surfaces are dorsomedially oblique to articulate tightly with the postzygapophyses of the axis, expressing a mode of articulation that increases the range of mobility. The postzygapophyses are, in contrast, short with large articular facets that are ventrolaterally directed. Diapophyses are ventral to the neural arch with small, ventrally-directed articular facets and are in close proximity to the parapophyses. Parapophyses are projected laterally extremely weakly with coarsely-textured and circular articular facets. The neural spine expands posteriorly, has a relatively thin anterior margin, and gradually inflates dorsally to a coarsely textured and rounded apex.

Identifications of the other cervicals are determined by their height of neural arch and spine in addition to position of pre- and post zygapophyses. Although they are relatively close in morphology, they are identified as CV 5, 6, 7, 8, and 10. CV 10 is perfectly preserved with a thick and short opisthocoelous centrum. Ventrally the centrum is narrow with a well developed blade-shaped keel. The hemispherical anterior condyle is gently and smoothly rounded with a coarse surface texture. The base of the neural arch sits relatively high on the centrum, the neural spine is high and vertical, and diapophyses are nearly parallel to the neural arch with small circular and coarsened articular facets. This element is in a transitional phase from cervical to dorsal morphology but is recognized as a cervical due to its opisthocoelous centrum.

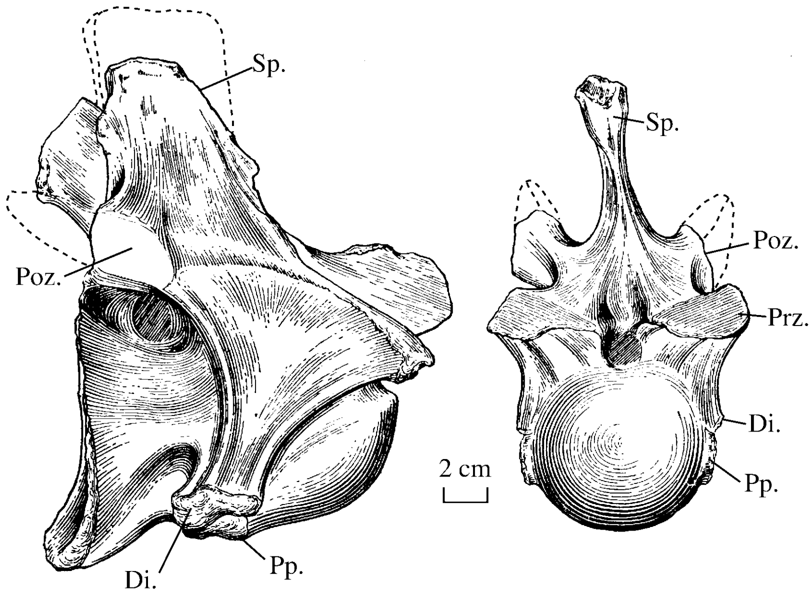


Figure 58. Lateral and proximal view of *Yangchuanosaurus magnus* third cervical vertebra.

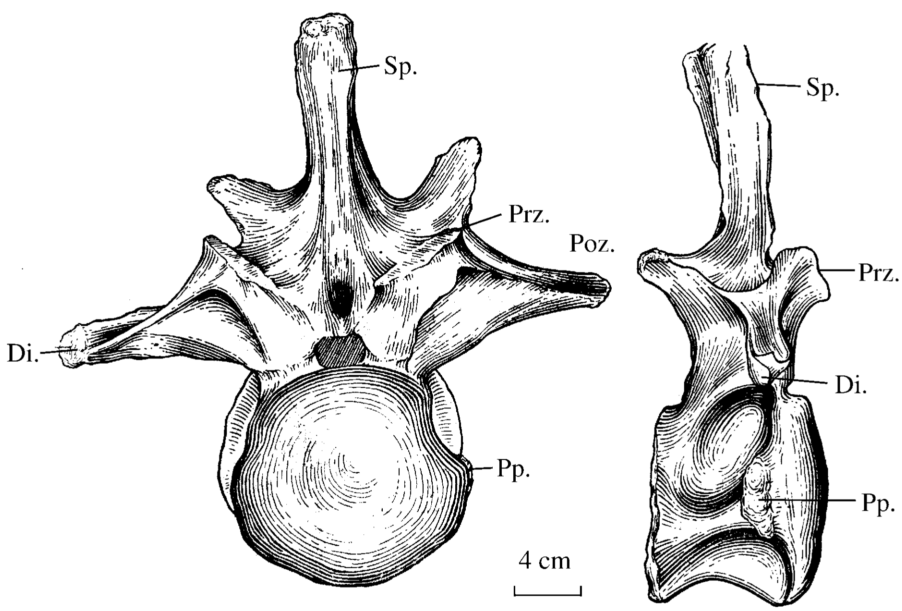


Figure 59. Proximal and lateral view of *Yangchuanosaurus magnus* tenth cervical vertebra.

Y. magnus is determined to have 13 dorsal vertebrae based on a comparison to *Y. shangyuensis*. Only six dorsals are preserved and morphologically compare to

Y. shangyuensis as dorsals 1, 2, 6, 8, 10, and 12 among which 2, 6, 10, and 12 are well preserved. Dorsal centrum 2 is flatly opisthocoelous, anteroposteriorly shortened, ventrally relatively narrow, and maintains a ventral keel that has been laterally flattened due to compressional distortion. Pleurocoels are absent, neural arch is high, neural spine is anteroposteriorly narrowed nearly quadrate, and slightly posteriorly oblique. Prezygapophyses are foliate and dorsally directed with conspicuous laminae and small articular facets (Text Fig. 60), while postzygapophyses are weak. Robust diapophyses with strong articular facets extend parallel to the neural arch and are supported by four laminae. Anterior laminae extend from the prezygaphyses, posterior laminae extend from the postzygapophyses to the posterior margin of the diapophyses, and two laminae extend ventrally from the diapophyses, one to the posterodorsal parapophyses and one to the neural arch.

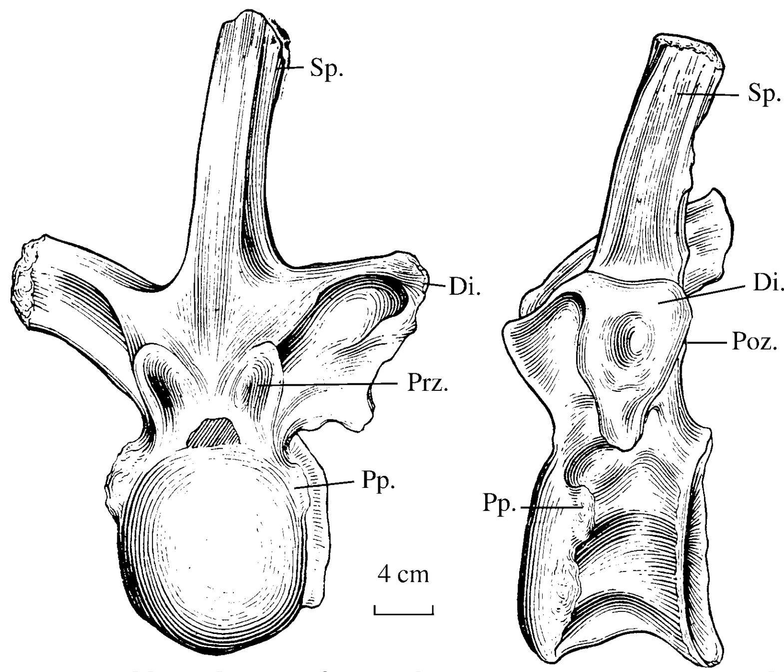


Figure 60. Anterior and lateral view of *Yangchuanosaurus magnus* second dorsal vertebra.

Dorsal 6 is amphiplatyan, relatively flat ventrally, lacks a ventral keel, neural arch is high, and spine has suffered compressional distortion, but is determined to have been plate-shaped. Dorsals 10 and 12 are amphiplatyan, nearly circular, ventrally flat, slightly constricted medially, and neural arch is high with a well developed plate-shaped neural spine.

The sacrum is composed of five tightly fused vertebrae with the posterior four neural spines fused into a single plate, but the first neural spine is isolated. The first vertebra is located between the ilium and pubic peduncle with a morphology resembling the posterior dorsals. Anterior centrum margin is thick, ventral margin is slightly anteriorly projected, and prezygapophyses are large, distinctly circular, and expanded. Diapophyses are short and robust, while the isolated neural spine is high and anteroposteriorly narrow. The four posterior sacrals are tightly fused with vague centrum boundaries. Ventrally the centra are relatively thin and smooth sacral processes (or diapophyes) are short, robust, and progressively increase in strength anteroposteriorly while descending in position along the neural arches and contact surfaces with the ilium progressively increase in size (Text Fig. 61). Laminae supporting the diapophyses progressively migrate anterodorsally on the neural arch and become posteriorly inclined. The first neural spine differs from those on sacrals 2-5 which are extremely more robust, spacious, and unite to form a single plate. The fifth sacral differs slightly by its posterior reduction, flat articular surface, and well developed anterodorsal neural arch.

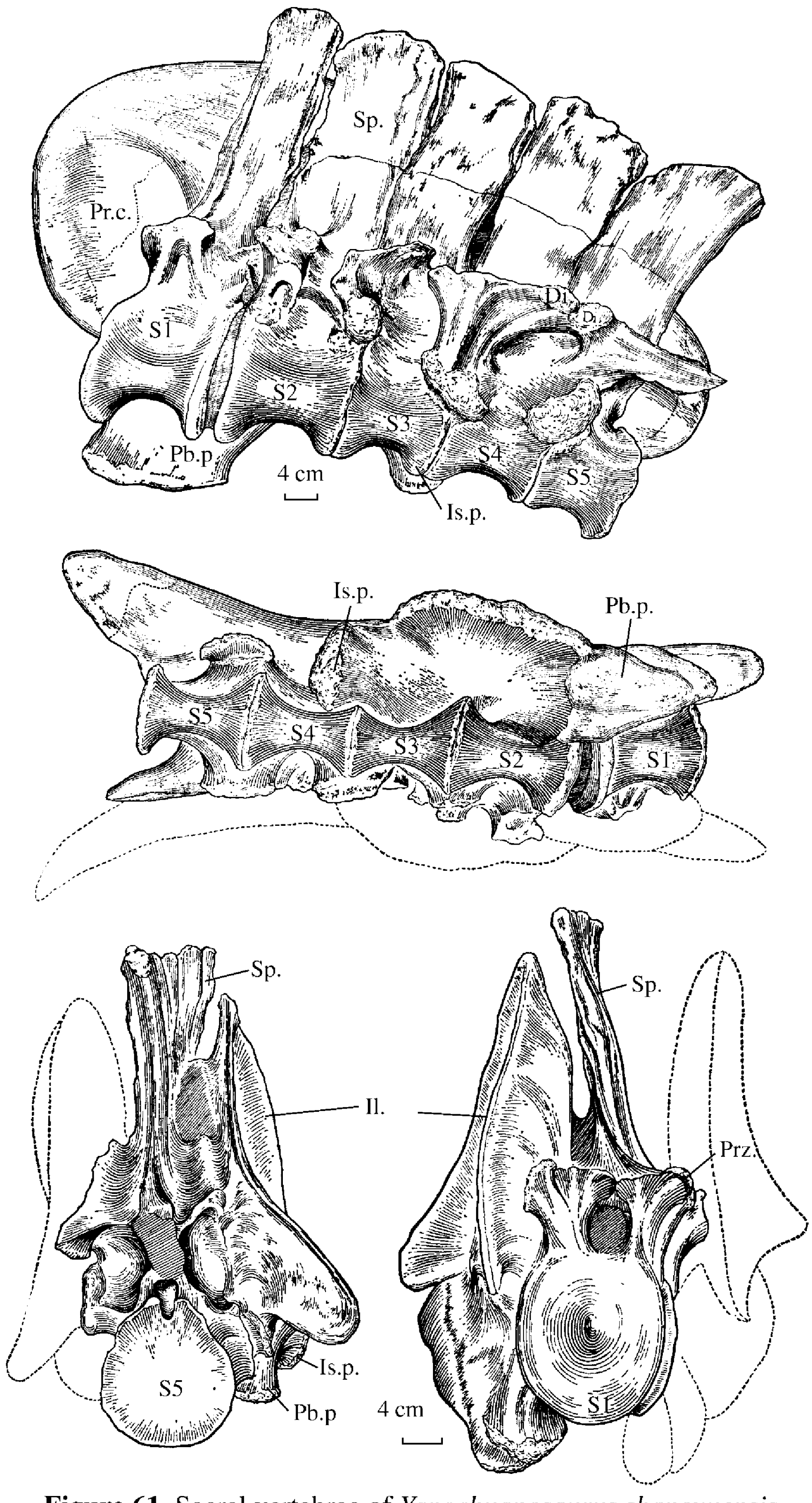


Figure 61. Sacral vertebrae of *Yangchuanosaurus shangyuensis*.
Top: lateral view. Middle: ventral view. Bottom left: posterior view. Bottom right: anterior view.

Table 11. Sacral measurements of *Yangchuanosaurus magnus* (cm).

Sequence	Centrum length	Vert. height	Spine height	Spine width	Centrum post. breadth
1	14.5	54.0	30.5	7.8	14.0
2	13.5	52.0	29.0	11.0	13.0
3	12.0	50.0	26.5	10.5	10.0
4	11.1	48.0	25.0	12.0	13.0
5	12.0	47.5	24.5	11.5	12.0

Only eight caudals are preserved with four anterior caudals in articulation and four represented as medial caudals. Caudal 1 displays numerous sacral characters such as a relatively small anterior end with the centrum gradually expanding to a large circular posterior end. A haemal arch is absent ventrally, neural spine is high, pre- and postzygapophyses are weak although diapophyses resemble those on the fifth sacral with relatively well developed laminar buttressing on the lateral neural arch. This may be regarded a sacrocaudal vertebrae because the elongation of the postacetabular process promotes a functional use of this vertebra in the sacrum. The remaining caudals are amphiplatyan, very slightly medially constricted with distinct posteroventral contact points for the haemal arches; neural arches progressively descend in association with thier neural spines, which also thin and become posteriorly inclined; pre- and postzygapophyses become elongate, and centra also elongate, becoming lower, and laterally compressed.

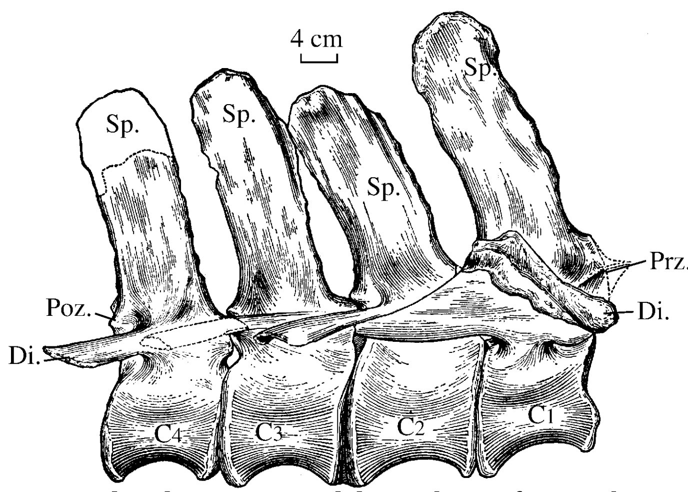


Figure 62. Four articulated anterior caudal vertebrae of *Yangchuanosaurus magnus.*

Table 12. Measurements of four articulated anterior caudal vertebrae of *Yangchuanosaurus magnus* (cm).

Sequence	Centrum length without zygapophyses	Centrum post. breadth	Centrum post. height	Centrum medial minimum breadth	Height of caudal	Spine height
1	13.0	15.0	13.0	7.8	47.0	29.0
2	12.5	15.0	14.0	9.0	45.0	26.0
3	12.5	14.5	14.0	9.5	50.0	27.0
4	12.0	13.5	13.5	9.0	46.0	

The pectoral girdle and forelimb are absent and the pelvic girdle only preserves a right ilium and ischium. Characters of the ilium resemble those on *Y. shangyuensis,* only it is much larger. Pre- and postacetabular crests are rather elongated with a length-height ratio of 2:1. The pubic peduncle is relatively robust with a coarsened articular surface, while the ischial peduncle is weak. The dorsal margin of the acetabulum is composed of an oblique ridge projecting off the ilium, which causes the acetabular sulcus to be laterally directed and the femur to articulate at its ventral margin. This morphology differs radically from quadropedal forms. A longitudinal groove runs ventrally along the postacetabular process to facilitate femoral musculature, a character which is also present on *Szechuanosaurus* (Pl. XXX, Figs. 1-3).

The ischium is incompletely preserved as its distal end has been lost, although the 56 cm length that is preserved resembles *Y. shangyuensis* in morphology. Its proximal end is robust, 15 cm in diameter and shafts become fused distally.

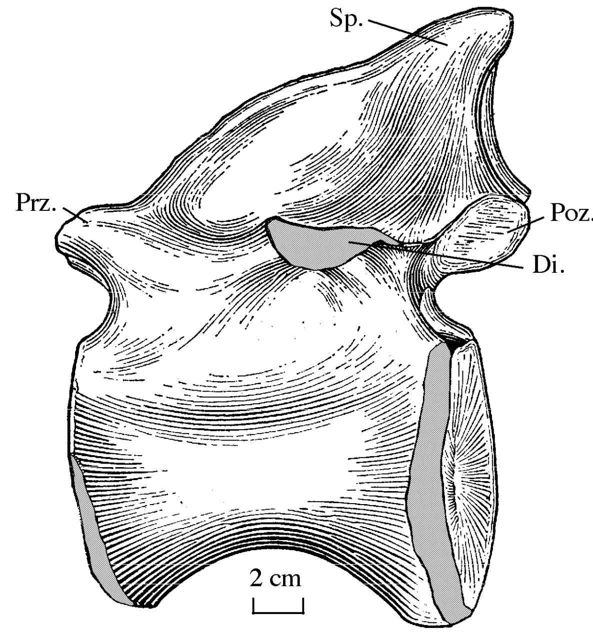


Figure 63. Medial caudal vertebrae of *Yangchuanosaurus magnus.*

Of the hindlimb, only the right femur, in addition to fragments of the second and third digits, are preserved. The femur is strong and robust with a 95 cm length, slightly anteriorly curved, subcircular in cross-section, and is pneumaticized with thickened walls. The femoral head is distinct with gently rounded articular surfaces. A lesser trochanter is well developed, isolated from the head by a deep depression, rather broad anteroposteriorly, laterally flattened, and bears crenulated ridges for facilitating musculature attachment. The fourth trochanter is an inflated ridge that is situated on the proximal third of the shaft, the distal end displays a deep intercondylar recess, and the trochlea is a depression that constitutes the surface inside the medial and lateral condylar processes. The medial condylar process is relatively broad anteroposteriorly but with narrow sides and an articular surface projecting anteriorly. The lateral condyle is large and circular with a coarsened surficial texture.

Only two pieces of strong, robust phalanges are represented from the right hindlimb, representing the first and third proximal phalanges. One is large, broad, and displays a slightly distally concave facet for articulation with the metatarsals Width exceeds height. The distal end resembles the generalized theropod condition with a smooth articular surface and lateral ligament depressions.

Diagnosis and Discussion: Specimen CV00216 has an enormous skull with maxillae and mandibles expressing its distinct affinity with the Carnosauria. Although its ilia and sacrum are solidly fused, it is not as consolidated as on the later tyrannosaurids and the ilia do not contact the neural spines. The specimen is undoubtedly assigned to the Megalosauridae based upon characters of the ilia and large skull. Although the skull of this specimen is large, its height-length ratio approaches that of *Y. shangyuensis* at 1:1.67 and it shares numerous other characters such as dentition, pelvic morphology, and biochronology, indicating its assignment to the genus *Yangchuanosaurus.* Although there are numerous shared characters between CV00216 and *Y. shangyuensis,* there are also several distinctions, such as one of the maxillary depressions

Table 8. Vertebral measurements of *Yangchuanosaurus shanguensis* (mm).

	Series	Centrum length	Post. centrum height	Post. centrum width	Spine ht., wth. thickness	Vertebral height
Cervical	1					
	2	64	75	39		166
	3	78	77	50	40x40x8	125
	4	95	78	60	50x30x15	148
	5	115	88	60	45x50x12	155
	6	118	90	80	50x40x12	175
	7	120	90	80	45x30x13	189
	8	138	90	90	45x23x19	195
	9	114	90	90	60x25x26	195
	10	95	90	70	73x25x26	205
Dorsal	11	120	84	75	100x30x21	250
	12	120	85	60	125x33x22	270
	13	120	86	60	131x40x18	330
	14	120	87	50	145x65x15	340
	15	125	88	50	155x80x15	350
	16	130	90	60	165x100x15	360
	17	130	90	60	170x100x15	350
	18	128	90	75	180x110x20	360
	19	130	110	82	185x110x18	355
	20	130	110	85	205x100x19	350
	21	135	110	90	200x95x15	350
	22	132	116	90	200x100x14	340
	23	133	105	90	—	—
Sacral	24	130	110	90	—x90x15	390
	25	110	110	—	220x100x15	390
	26	91	91	—	220x100x14	387
	27	100	103	—	210x100x14	385
	28	105	105	113	208x70x15	380
Caudal	29	98	110	80	226x7015	360
	30	102	110	70	225x85x14	365
	31	100	100	90	220x82x16	360
	32	96	116	90	119x80x10	350
	33	106	115	90	170x70x11	300
	34	118	106	90	160x70x12	290
	35	108	96	85	150x67x10	280
	36	107	95	85	100x70x7	280(?)
	37	115	88	60	100x70x7	280(?)
	38	110	70	60	140x33x7	230(?)
	39	110	65	65	130x34x6	205
	40	110	65	60	80x35x6	160

perforating the maxilla and the absence of a small depressed foramen on the posterior mandible. The pelvic girdle of CV00216 is incomplete but the ilia and sacrum are readily distinguishable from *Y. shangyuensis*. This is the largest carnosaur currently known from the early Late Jurassic, and as such is erected as *Yangchuanosurus magnus* sp. nov.

Produced from the Upper Shaximiao Fm. of the Sichuan Basin, this taxon is recognized as being derived in its enormous size and solidly fused sacral region. Its presence confirms the age of the Upper Shaximiao *Mamenchisaurus* fauna to be early Late Jurassic.

Ornithischia Seeley 1888

The first documentation of the Ornithichia in the Sichuan Basin was C. C. Young's description of *Sanpasaurus yaoi* (1944) which was collected from the Maanshan Mem. of the Ziliujing Fm. in the Weiyuan Co. region. Its description is summarized as follows:

Ornithopoda Marsh 1871

Iguanodontidae Cope 1869

Sanpasaurus Young 1944

Genus diagnosis: As for species.

Sanpasaurus yaoi Young 1944

1944 Young. *Bull. Geol. Soc. China,* Vol. **24**, No. 3-4.

Specimen: There are 20 vertebrae, a forelimb, and portion of hindlimb (IVPP # V156).

Diagnosis: A member of the Camptosauridae within the Iguanodontia. Dorsal vertebrae are heavy, sacral vertebrae are unfused, forelimb relatively long, distal end of scapula relatively thin, radius and ulna long and gracile with the ulna slightly longer than the radius, the radial and ulnar articular facets on the humerus are indistinct, femur and tibia are relatively small, and the ungual phalanges are flat and curved.

Discussion: Specimens representing *Sanpasaurus yaoi* are relatively poor, the original description extremely terse, and they are poorly illustrated. It is extremely difficult to determine whether or not the specimens described belong to the same individual, as the original description notes the possibility of there being two individuals. Hence, its final taxonomic assignment is subject to several considerations. Rozhdestvensky (1975) suggested the specimens represented a small sauropod after his comparison to a collection of specimens made by C. C. in 1953 from Datienwan, Chungking, which is currently housed in the Chungking Museum of Natural History. After study by the current authors it was determined that erroneous interpretations had definitely been made, for the caudal vertebrae and limbs are typical of a sauropod. However, the dorsal vertebrae of the type of *Sanpasaurus* are typically ornithopod.

The type locality for *Sanpasaurus* has been verified as being in the Maanshan Mem. of the Ziliujing Fm. In 1978, the authors of this paper visited Huangshiban Commune in Weiyuan Co. where they collected two small typically ornithopod vertebrae (Plate I, Fig. 7) and a single flattened ungual phalanx from purple mudstones of the Maanshan Mem., which confirms the presence of a moderate sized ornithopod in this member and, for this reason, it is believed the erection of the genus is justified, although supplementary diagnosis and descriptions are required from collections in the future.

Fabrosauridae Galton 1972

Gongbusaurus gen. nov.

Genus diagnosis: As for species.

Gongbusaurus shiyii gen. et sp. nov.

(Plate 43, figs. 6-8)

Etymology: Gongbu - Pinyin romanization for "The Ministry of Works in feudal China." The famous Tang Dynasty poet Dufu was an adjunct member in this ministry, and it was thereby commonly referred to as the "Du Ministry of works." "Shiyi" is Pinyin romanization for an official post during the Tang Dynasty with the responsibility to counsel the emperor upon potential error, a post that was also held by the poet Minister Dufu. As these specimens were found among a mixed assemblage of material in Sichuan, or were seemingly lost and then recovered to rectify the error, the acknowledgement of Dufu through this double entendre commemorates the great poet of the Tang Dynasty, by the erection of *Gongbusaurus shiyii* gen. et sp. nov.

Diagnosis: A small primitive ornithopod with a rounded premaxillary tooth crown and asymmetrical serrations on the anterior and posterior carinae. The teeth are flat with the lingual side possessing a thin layer of enamel, the center of the crown possesses a small swollen ridge, and the lingual and labial sides are swollen to form a symmetrical crown that maintains small picketed denticles on the anterior and posterior carinae.

Locality and Stratigraphic Position: Behind Huangtong Elementary School, Duxin Commune, Rongxian Co., Sichuan; early Late Jurassic Upper Xiaximiao Formation (Field No.: Rong H6-2). Collected by the Second Unit of the Sichuan Aerial Survey. IVPP specimen # V9069.

Description: Specimen V9069-1 is a complete isolated left premaxillary tooth lacking its root. The tooth crown is sharp, slightly curved posteriorly, oval, asymmetrical, and laterally convex. The root is subcircular in cross-section. A laminar ridge occurs on both the anterior and posterior margins, upon which are very small, tightly packed denticles. The lingual side of the crown is ornamented with folded laminae that become compressed from the root to the top of the crown. This morphology resembles *Fabrosaurus* (Fig. 64).

V9069-2 is a single laterally compressed cheek tooth with basically symmetrical sides that are both enamel covered, and there is a medial inflated ridge that extends directly to the apex of the tooth to form a sharp medial cusp. The anterior and posterior carinae maintain small folded denticles (Plate XLIII, Figs. 6-8). The anterior carina maintains seven denticles while the posterior carina maintains six denticles. There is neither a cingulum nor longitudinal laminae on the crown, which clearly differentiates it from both the Stegosauria and Ankylosauria, but is comparable to *Echinodon*.

Comparison and Discussion: The two foliate-shaped teeth from Rongxian County are characteristically ornithischian. They differ from the Stegosauria which possess cingula, and are easily distinguished from the Ankylosauria which have pronounced longitudinal laminae. The dentition of the Ceratopsia generally displays only unilateral enamel due to the formation of wear facets. Therefore, these two foliate teeth are undoubtedly assigned to the Ornithopoda.

Among the ornithopods, there are three families that possess premaxillary teeth: the Heterodontosauridae, Hypsilophodontidae, and Fabrosauridae. The former family contains several small and morphologically primitive Late Triassic to Jurassic taxa that possess caniniform teeth. The Hypsilophodontidae contain several small Late Jurassic to Cretaceous ornithopod species that Galton (1970) believed to be derived, with flattened tooth crowns and unilateral enamel. Consequently, the Rongxian specimens are excluded from the two former families.

The Rongxian County specimens morphologically resemble *Echinodon*, which was initially classified as a squamate by Owen (1864). Later, both Huene and Steely assigned it to the Stegosauria. In 1972, Galton assigned it to the family Fabrosauridae within the suborder Ornithopoda. When *Fabrosaurus* was erected by Ginsburg (1964) he assigned the genus to the Scelidosaurinae. Subsequently, Thulborn (1970, 1971) reassigned this genus to the Hypsilophodontidae. Galton (1978), in his discussions on the evolution of the ornithopods, elevated it to family status, containing the two genera *Fabrosaurus* and *Echinodon*. The Rongxian specimens are morphologically very similar to these two genera, which are relatively small individuals. Because the type specimens are principally represented by mandibles, it is impossible to compare the Rongxian County specimens to them. The Rongxian premaxillary tooth is similar to *Fabrosaurus*, but the maxillary tooth differs from that of *Fabrosaurus* by possessing a relatively distinct medial ridge. Despite the sparsity of the Sichuan data, it nevertheless reflects the presence of a small species of fabrosaur in the upper Shaximiao Formation. However, due to the aforementioned distinctions, the specimens are erected here as *Gongbusaurus shiyii* gen. et sp. nov. Its discovery among the extremely diverse *Mamenchisaurus* Fauna increases the correlative data that indicate the Upper Shaximiao Formation not only shares large sauropod and theropod affinities with the East African Tendagaru Formation and the North American Morrison Formation, but now also shares the presence of small ornithopods.

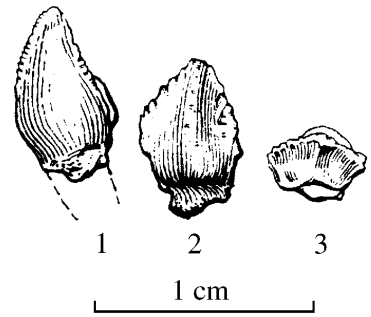


Figure 64. Isolated teeth of *Gongbusaurus shiyii* gen. et sp. nov. 1. Anterior maxillary tooth; 2. Cheek tooth; 3. Cheek tooth in occlusal view

Stegosauria Marsh, 1877

The first record of the suborder in the Sichuan Basin is *Chialingosaurus kuani* Young 1959.

Stegosauridae Marsh 1880

Stegosaurinae Nopcsa 1917

Chialingosaurus Young 1959

1959 *Vertebrata PalAsiatica* Vol. **1**, No. 1.

Original genus diagnosis: Skeleton rather delicate in construction with relatively small dorsal armor, rather long forelimb, with humerus femur ratio at 1.62, which lies between the North American *Stegosaurus* and East African *Kentrosaurus*, but is closer to the latter genus. Humerus has a relatively conspicuous shaft, and femur is thin, linear, long, and lacks a fourth trochanter.

History of research: The specimens were collected in 1957 by Yaowu Guan of the Sichuan Regional Petroleum Exploration Office from Taipingzhai in the village of Pinganxiang, Yongxing District, Quxian Co. In 1959, C. C. Young diagnosed the specimens and erected the nomenclature *Chialingosaurus kuani* Young.

Type specimens: Six fragmentary vertebrae, three dorsal spines, a pair of coracoids, a pair of humeri, a left femur, right radius, shaft of a left scapula and three phalanges (IVPP # V2300).

Locality and stratigraphic position: Pingan Commune, Quxian Co.; early Late Jurassic Upper Shaximiao Fm., Chungking Group.

Supplementary specimens: In November of 1978, Angui Wang from the Quxian County Hydroelectric Office noted numerous occurrences of fossil bone at the locality that produced *Chialingosaurus.* Re-excavation was thereby undertaken by a consortium including Shiwu Zhou from the Chunking Natural History Museum, Xingyao Li from the Quxian County Cultural Office, and Shengquan Xu of the Hydroelectric Office. The following supplemental specimens were collected from the type quarry:

Skull: Anterior end of right mandible, right pterygoid, a pair of quadrates, left squamosal, prefrontal, left jugal, and occipital elements.

Axial skeleton: Three fragmentary cervicals, four dorsals (two of which are relatively complete), and four caudals (one of which is complete).

Apendicular skeleton: Right scapula, ulna, radius, tibia, fibula, astragalus, and calcaneum (specimen #CV00202).

Approximately 100 meters west of the *Chialingosaurus* quarry, additional specimens were recovered that are now considered as the paratype (specimen # CV00203). These include two fragmentary cervical vertebrae, six incomplete dorsal vertebrae, five caudal vertebrae lacking their spines, a postacetabular process of a left ilium, and left femur.

Revised genus diagnosis: As for revised species diagnosis.

***Chialingosaurus kuani* Young 1959**

(Plates XXXII-XXXIV)

Original species diagnosis: As for genus.

Revised species diagnosis: A moderate sized stegosaur with a slim and graceful body typical of the suborder. Mandible is thick, posterior cranium is high, and quadrate lies vertically. Dentition is few and lacks superimposed replacement teeth. Cervical and dorsal vertebrae are nearly amphicoelous with large and circular neural arches. Caudals are flatly opisthocoelous with the first and second caudals displaying diapophyses that are extremely expanded at their bases. Olecranon process of ulna is not developed. Femur is thin, straight, and lacks a fourth trochanter, and humerus to femur ratio is 1.62 whle maintaining weak articular surfaces. Postacetabular process of ilium is narrow, acetabulum is shallow and flat, iliac plate is light, thin, spinous, and has an anterodorsal margin that lies at a 55° angel from the ventral margin.

Description: The occipital region is relatively well preserved with an elliptical foramen magnum, relatively large occipital condyle composed of the basioccipital and exoccipital, and a basioccipital shaft that is medially constricted. A vague longitudinal ridge lies near the ventromedial surface of the occipital condyle, a basioccipital process is not developed, and the ventral surface of the basioccipital shaft is relatively flat, or unlike that on *Tuojiangosaurus* which bears three longitudinal grooves (Pl. XXXII, Figs. 1,2).

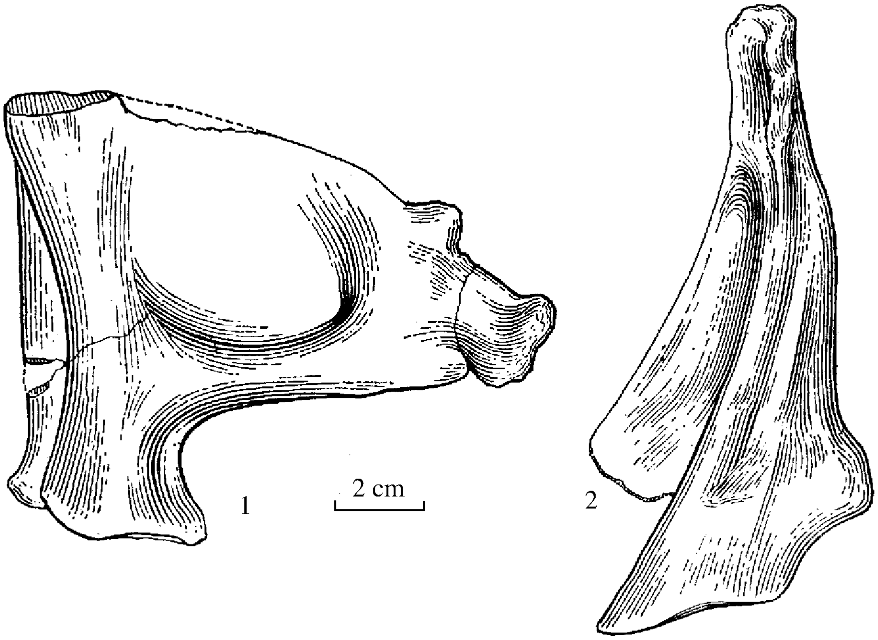


Figure 65: Left and right quadrate of *Chialingosaurus kuani*.
1. Medial view of left quadrate. 2. Posterior view of right quadrate.

The left quadrate is nearly complete but right quadrate is missing its dorsal end. The complete quadrate is 14 cm in length with a relatively robust shaft which becomes slightly inflated and expanded both dorsally and ventrally. The dorsal margin is arched, laterally inflated, and medially depressed. The ventral margin is slightly anteriorly convex with an oblique articular facet that is 4.2 cm in width. A shallow longitudinal groove lies posteromedially on the shaft. Anteriorly on the shaft there is a triangular corneal projection that represents an exceptionally well developed quadrate process which contacts the posterior process of the pterygoid. Because the shaft is vertical and moderately lengthened, it is presumed that the cranium of *Chialingosaurus* is rather high (Pl. XXXII, Fig. 7).

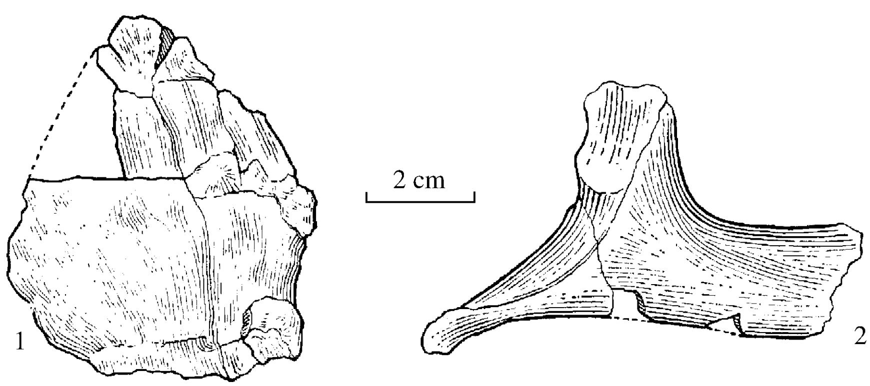


Figure 66: *Chialingosaurus kuani.*
1. Dorsal view of prefrontal. 2. Left jugal.

A right squamosal is well preserved, being triangular in outline with precipitous sides, a dorsal margin that composes a laminar ridge, and a deep depression ventrally to facilitate the dorsal end of the quadrate. The 7.9 cm long precipitous medial side constitutes the posterior margin of the supratemporal fenestra, which is interpreted as being relatively large (Pl. XXXII, Fig.5).

Only one of the two extremely thin prefrontals is preserved as a slightly oval element with rough surficial texture (Fig. 66-1).

In lateral perspective, the pterygoid in the Stegosauria is saddle-shaped. Specimen CV00202 preserves a complete right pterygoid with four processes and which does not differ markedly from the general condition, as illustrated in Fig. 67. Laterally, the posterior and the pterygoid processes extend anteriorly and posteriorly respectively, with termini that are 10.3 cm apart. The anterior process contacts the palatine while the lateral side of the posterior process contacts the quadrate. Two relatively short processes lie on the medial side of the pterygoid with the ventromedial process being the smallest among the four and contacting the basisphenoid. The dorsomedial process contacts the posterolateral side of the palatine. The configuration of the pterygoid between the two medial processes is a smoothly rounded concave surface.

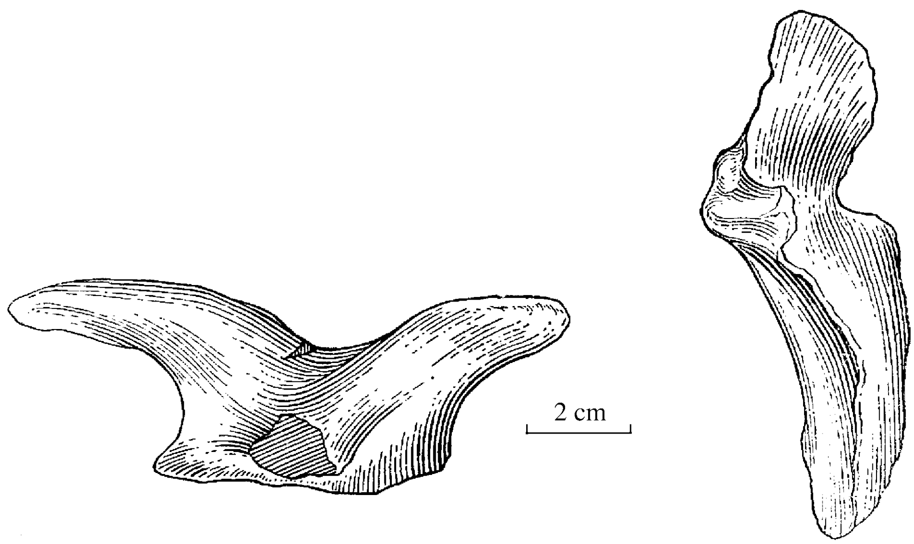


Figure 67: Right pterygoid and left squamosal of *Chialingosaurus kuani.*

A 12.3 cm long, 2.7 cm wide, and 1.6 cm thick piece of the left anterior dentary is preserved (dentary thickness on *Tuojiangosuarus* is .9 cm). This element is thick with a relatively large medial curvature and bears very few teeth, with those represented widely spaced. The largest diastema is 14 mm while the smallest is 7 mm, and dentition spacing gradually constricts anteroposteriorly. Five damaged teeth are present with nearly completely destroyed crowns. Enamel appears to be moderately developed with vertical laminae, carinae possess small denticles, and dentition gradually increases in height posteriorly (Fig. 68)

C. C. Young's original description of the vertebrae is as follows: Of the six vertebrae represented, only one preserves a portion of the neural arch and has also suffered compressional distortion. The other cervical, two dorsals and two caudals are only represented by partial or complete centra. Generally speaking, they resemble the general condition of the Stegosauria in morphology, with cervicals being shallowly amphicoelous and caudals being amphiplatyan, while dorsals are intensely laterally compressed and extended dorsoventrally.

Only four additional incomplete cervicals which belong to the medial portion of the series were recovered during the re-excavation of the *Chialingosaurus* quarry. Specimen CV00202 and CV00203 medial cervicals are all amphicoelous with a deep anterior articular depression and shallow posterior articular depression. Three of the centra are complete with lengths of 6.8, 7.1 and 7.3 cm respectively. Centra are medially constricted, a ventral keel is present on a relatively flat surface that is expanded transversely to compose an x-shape, and represents a morphology that differs distinctly from *Tuojiangosaurus.* Centrum width exceeds height, exemplified by one of the specimens with a breadth of 7.7 cm and height of 4.8 cm. The neural arch is relatively low but contains an extremely well developed, large, and tubular neural canal with a diameter of 3.1 cm. Parapophyses are located anterodorsally and are only recognized vestigially due to being weathered.

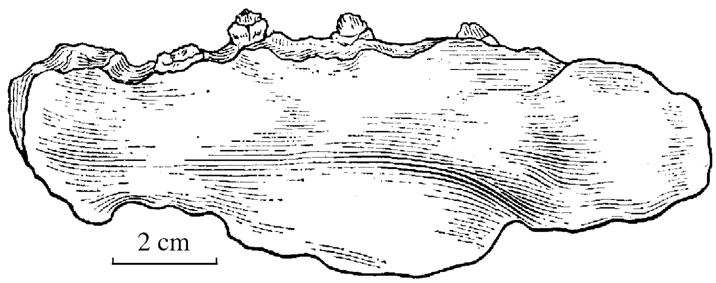


Figure 68: Left dentary of *Chialingosaurus kuani*.

Eight dorsal vertebrae are represented on CV00202 and CV00203, which are amphicoelous with a shallow anterior articular facet but deep posterior facet. Centra are slightly anteroposteriorly expanded, medially constricted, and a distinct ventral keel is present. Neural arches on the anterior dorsals are relatively low, and dorsally constrict rapidly with a smaller canal than on the cervicals. Dorsolaterally extended diapophyses are tongue-shaped with a relatively long shaft that is triangular in cross-section, has a constricted proximal end, and expanded distal end. There is a 45° angle between diapophyses and the neural spine. Parapophyses lie directly laterally at the base of the diapophyses and project slightly laterally with a shallowly depressed elliptical articular surface. Pre- and postzygapophyses are well developed with prezygapophyses maintaining broad and deep articular facets which lie conspicuously lower than postzygapophyses. Postzygapophyses are expansive, large, dorsally broad, and ventrally narrow with flat and smooth articular facets. Neural spine is slightly posteriorly directed and resembles a long, thin rectangular plate with a base that is broader than the apex.

Six caudal vertebrae representing the anterior, medial, and posterior series are represented with the nearly complete specimen CV00202. The remaining caudals are represented only by centra. Three anterior caudals are present, one of which is complete and may represent the first caudal. The centrum is opisthocoelous, short, and elliptical with a 3.7 cm length and 9.0 cm posterior breadth. Caudal ribs are fused to diapophyses and compose a thin and flat plate that extends dorsolaterally as a corneal digit with a slightly anteriorly curved shaft that lies at a 60° angle to the perpendicular axis of the vertebra. The neural canal is extremely large with prezygapophyses located on its dorsal margin which extend anterodorsally with flat elliptical articular surfaces. Medially there is a longitudinal groove which bifurcates the prezygapophyses. The neural spine is high, rod shaped, and is flat at its basal and medial section but is slightly transversely expanded dorsally with a depressed fold posterodorsally. The other two anterior caudals have elongated amphiplatyan centra with ventrolaterally curved diapophyses that are robust at their bases and acute at their distal ends to be nail-shaped in morphology. Portions of two amphiplatyan medial caudals are preserved with centra that are are hexagonal, very slightly medially constricted, maintain distinct ventral articular facets for the haemal arch, and have diapophyses that are relatively short with mastoid shaped articular nodes. Two posterior caudals are present, but one only preserves the centrum while the other has lost a small portion of its neural spine. The centra are amphiplatyan with a vague ventral longitudinal groove and a neural spine that is anteroposteriorly elongated.

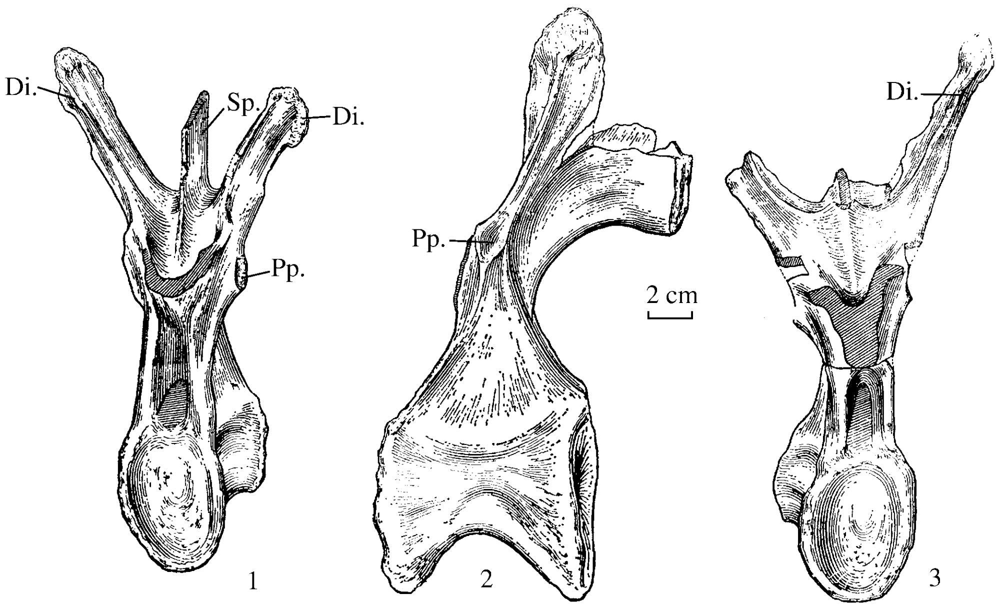


Figure 69. Anterior (1), lateral (2), and posterior (3) views of dorsal vertebrae of *Chialingosaurus kuani.*

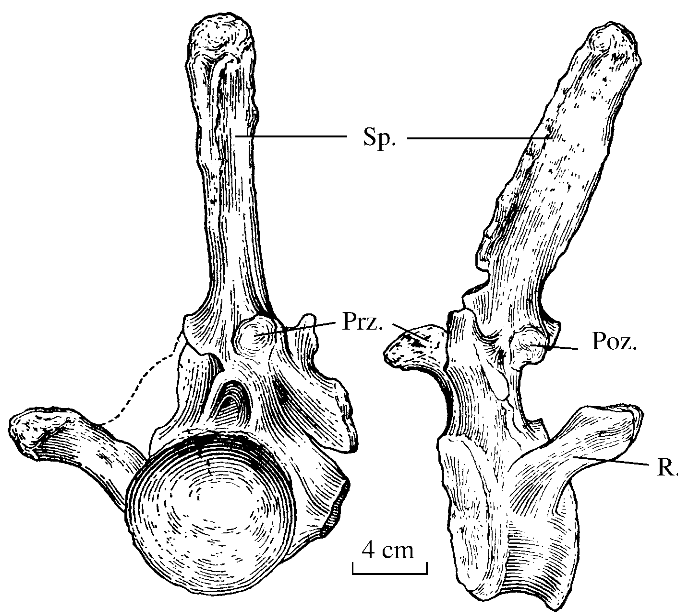


Figure 70. Posterior and lateral view of first caudal vertebra of *Chialingosaurus kuani.*

Type specimen V2300 preserves only a fragmentary scapular shaft with a damaged distal end although the lateral laminar process is complete. C. C. Young identified it as a right element, noting a distal breadth of 7.7 cm, and a morphology resembling *Kentrosaurus*. During re-excavation of the quarry a proximal end of a right scapula was recovered to complete the entire element and provide a length of 35.7 cm with a maximum proximal breadth of 22.0 cm. Morphological resemblance to *Kentrosaurus* and *Tuojiangosaurus* is confirmed although this specimen has a lateral laminar ridge that runs extremely close to the ventral margin and there is also an extremely conspicuous scapular column. The proximal end is flat, spacious, nearly semicircular, but constricts radically at the shaft to compose a 7.4 cm diameter scapular column. A swollen spheroid with a coarse surficial texture consisting of small tuberosities lies proximolaterally, which clearly facilitates musculature for strengthening the pectoral girdle. A depression representing the glenoid fossa lies at the medial side of the spheroid but is not as well developed as on *Tuojiangosaurus*. This also suggests that the corresponding articular facet on the humerus is not well developed. The fusion point for the coracoid lies at the proximoanteromedial portion with a nearly linear contact.

A majority of the right coracoid is preserved, being extremely close in morphology to *Kentrosaurus* with a relatively large foramen that, from a lateral perspective, appears to lie rather distant from the scapula

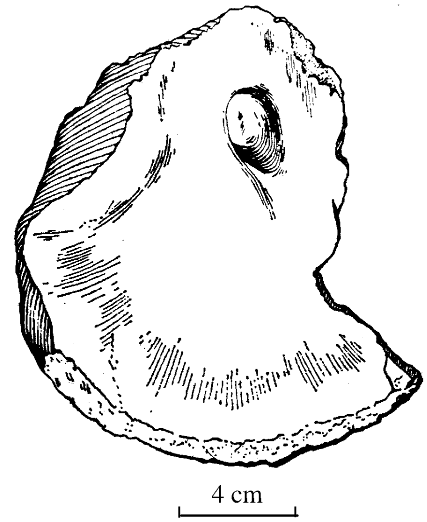


Figure 71. Lateral view of right coracoid of *Chialingosaurus kuani* (from Young, 1959).

Of the forelimb, both humeri are well preserved on type specimen V2300, but only the proximal end of the radius was present until the re-excavation recovered its distal end, completing the element in association with the right ulna.

In Young's description of the humeri, he noted its most distinctive character as the proportional length of 1.62, which exceeded those on all other members of the Stegosauria, or lying between the ratios of *Kentrosaurus* and the primitive *Scelidosaurus*, and differing greatly from the North American forms. Its conspicuous shaft is also noteworthy.

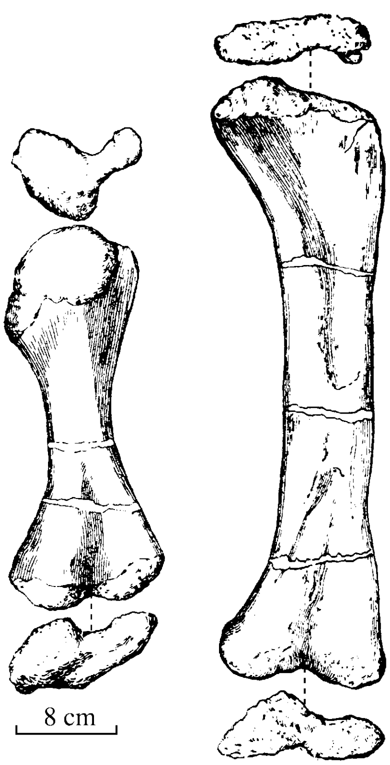


Figure 72. Humerus and femur of *Chialingosaurus kuani.*

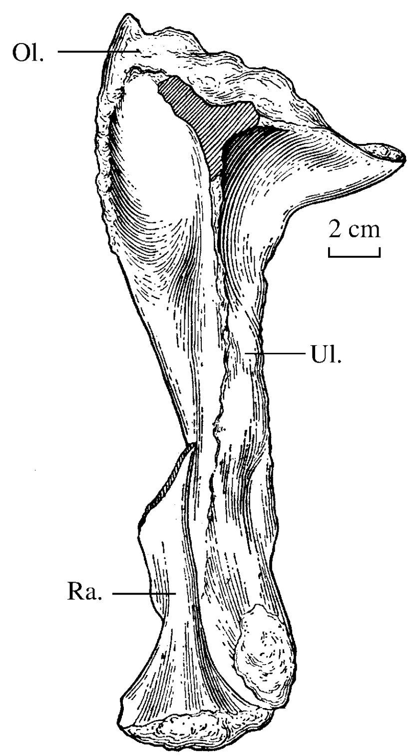
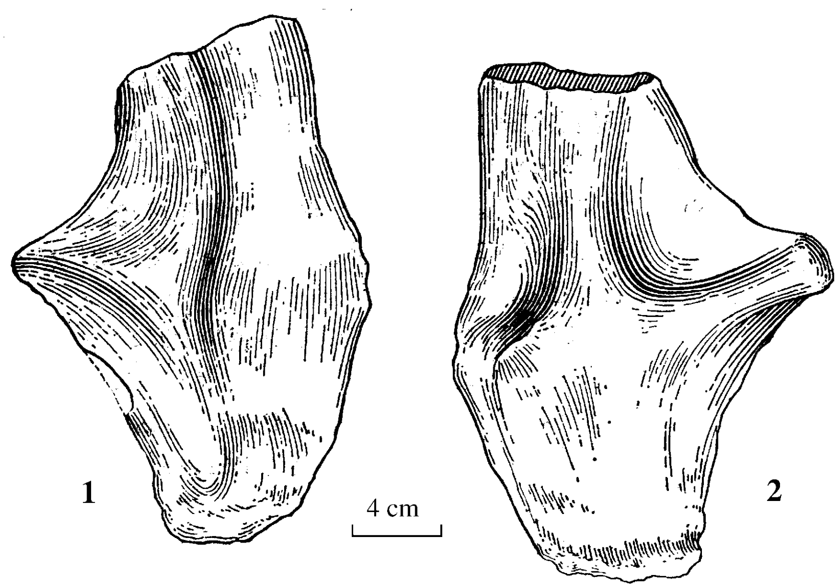


Figure 73. Lateral view of radius and ulna of *Chialingosaurus kuani*

The ulna is 23.5 cm in length with its distal end fused to the distal end of the radius such that both elements appear to be unified. Its proximal end is expanded with a coarse surficial texture, while distally it gradually thins and terminates with a rounded articular facet. From a dorsal perspective the proximal end is triangular with an extremely weak posterolateral olecranon process that only very slightly extends above the articular surface of the humerus and represents a configuration that differs greatly from *Stegosaurus*. Among the three sides of the proximal end, the anterior side is deeply concave to facilitate the proximal head of the radius. From a posterior perspective the radial head completely conceals the ulna. The lateral side has a depressed surface approximately the same size as the anterior surface and terminates approximately halfway down the shaft where there is a coarsely textured arc which circles posterolaterally and facilitates the contact for the triceps brachii. Although the distal ends of the ulna and radius are fused, they do not lie upon the same plane as the distal radius exceeds the ulna. On specimen CV00202 the radius and ulna are nearly equivalent lengths, which is an indication of maturity.

None of the pelvic girdle was preserved on the original specimen but supplementary specimen CV00203 preserves a left ilial postacetabular process and a large portion of the acetabulum. The fragment is 21.2 cm in length and differs distinctly from the general stegosaurian condition by being short and tightly constricted to compose a narrow trianglar element that becomes particularly thin. A dorsomedial longitudinal groove bifurcates the postacetabular process, but this may be a result of compressional distortion. A triangular spur projects laterally off the left side and then very slightly curves ventrally with an arced anterior and posterior margin. A lateral ridge lies ventromedially, while a projected ridge also lies ventromedial on the postacetabular process representing the ischial peduncle. The anterior portion of the peduncle constitutes the acetabulum, which is not well developed and is very slightly depressed posteriorly while its anterior half is rather flattened.

1



2

Figure 74. Left ilium of *Chialingosaurus kuani* .
1. Dorsal view. 2. Ventral view.

A left femur was represented with the type specimen and a supplementary specimen is preserved on CV00203. C. C. Young described it as 69 cm in length thin, flat, long, straight, lacking a fourth trochanter, and bearing extremely indistinct articular surfaces.

A complete tibia is preserved in articulation with the fibula on specimen CV00202, with a shaft that is slender and weak while anterior and posterior ends are differentially expanded and slightly curved. The lateral shaft bears a rounded and smooth symmetrically angled ridge that extends and expands along the length of the tibia. The proximal fibula is fused to the left side of the tibia while its distal end is fused to the right side, with distal ends of both the tibia and fibula lying upon the same plane. The tibia's articular surface for the femur is medially inclined and ornamented with a reticulated folds. A ridge projects from the left side of the proximal end, where, between it and the shaft, there is a longitudinal groove to facilitate the proximal end of the fibula. Anterior to this groove is another depression to facilitate contact for the flexor digitorum longus. Tibia-femur ratio is 1:1.53 (Pl. XXXIV, Fig. 3).

Table 13. Tibia and fibula measurements for *Chialingosaurus kuani* (cm).

Length	45.0	45.0
Proximal breadth	17.6	5.6
Distal breadth	14.3	5.2
Smallest diameter of shaft	6.6	2.6
Proximal transverse measurement	8.5	3.1

The astragalus and calcaneum are tightly fused to the tibia and fibula prohibiting a precise description of their morphology. The calcaneum is saddle shaped and the astragalus is small, or approximately one-third the size of the calcaneum. The posterior astragalus and calcaneum are also fused to compose the medial and lateral surfaces of this limb. The medial surface is depressed, the lateral surface is relatively flat, and the ventral margin is a laminar ridge for articulation with the metatarsals. The posterior tibia and fibula penetrate a fossa on the astragalus concealing their posteromedial and lateral ends.

Table 14. Calcaneum and astragalus measurements for *Chialingosaurus kuani* (cm).

	Calcaneum	Astragalus
Breadth	7.4	8.0
Length	10.0	3.1
Dorsal breadth	6.9	5.6

Discussion: The two stegosaur collections V2300 and CV00202 from Quxian Co. are believed to represent a single individual for the following reasons:

The field records of Yaowu Guan indicate that specimen V2300 was excavated from the same locality as CV00202, coloration of the fossil bone is identical, CV00202 and V2300 are comparable in vertebral and limb morphology, elements from both collections are not duplicated, and a perfect contact was made between the proximal radius of CV00202 and the distal radius of V2300.

In 1959 C. C. Young suggested that *Chialingosaurus* shared an an intimate relationship with the two subfamilies Scelidosaurinae and Stegosurinae, and that it should be more appropriately assigned to the latter family. The Quxian Co. *Chialingosaurus* is typically stegosaurine in its 1.62 fore-hindlimb ratio, in addition to the morphology of its vertebrae and armor. This genus most closely resembles *Kentrosaurus.*

Chialingosaurus is a relatively small stegosaur which Young believed lay between *Stegosaurus* and *Kentrosaurus*, and he further suggested that it may represent the most primitive member of the subfamily. He admitted that its age could be regarded Late Jurassic but that an earlier age of Early or Middle Jurassic could not be completely rejected. Steel (1969) believed that its primitive nature suggested *Chialingosaurus* was ancestral to all stegosaurs.

When C. C. Young studied his collection of this taxon, his specimens were limited and he neglected to provide adequate illustrations. Consequently, Rozhdestvensky (1975) expressed skepticism regarding the genus, although the new data from CV00202 confirms the primitive nature of this genus, as reiterated below.

1. The skeleton is relatively small and delicately built.

2. Skull is high and narrow.

3. The jugal is relatively robust.

4. The forelimb is long, humerus possesses a distinct shaft, and is not curved.

5. The femur is straight, thin, and lacks a fourth trochanter.

6. Metatarsals are long.

7. The ilium is narrow with an open sacral region.

8. Armor is spinous, small, and thin.

9. Dentition count is few and in spacious alignment.

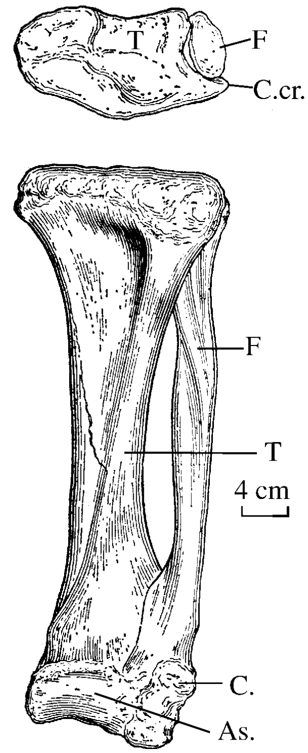


Figure 75. Tibia, fibula, calcaneum, and astragalus of *Chialingosaurus kuani*.

The Stegosauria is generally recognized to have been derived from the Late Triassic *Scelidosaurus.* Steel (1969), during his discussion of stegosaur evolutionary trends, determined tendencies toward an increase in body size, a reduction of the coracoid and jugal, sacral region thickened and strengthened, limbs become strengthened and robust, supraorbital becomes more well developed, calcaneum is reduced in length, and armor is increased in size. A number of the aforementioned characters may be noted in *Chialingosaurus* which express its primitive nature compared to more derived stegosaurs.

Few teeth are contained in the mandibular dentition and they are widely spaced, indicating a derived character for this herbivore, as does the absence of a fourth trochanter, which is also a derived character. A mosaic of primitive and derived features are frequently expressed in taxa that are in a transitional state, and in *Chialingosaurus* are distinctly significant toward the evolution of the Stegosauria. Young was inclined to determine a Middle Jurassic age for the sediments producing *Chialingosaurus.* Current stratigraphic data correlate the sediments to the middle and Upper Shaximiao Fm. which produces *Mamenchisaurus* and is currently regarded as early Late Jurassic.

Tuojiangosaurus **Dong, Zhow, Li and Chang, 1977**

1977 *Vertebrata PalAsiatica* Vol. **15**, No. 4.

Genus diagnosis: As for species.

Tuojiangosaurus multispinus **Dong, Zhow, Li and Chang, 1977**

(Plates XXXV-XXXIX)

Etymology: This stegosaur from Zigong Co. has 17 pairs of plated armor, which constitutes the most heavily armored genus in the subfamily. The specimen was collected from the Tuojiang river valley, which is a tributary to the Sidajianghe River. Hence, its nomenclature *Tuojiangosaurus multispinus.*

Species diagnosis: A large stegosaur with a skull typical for the subfamily. Zygomatic arch is not developed, two to three supraorbitals are present with coarse tubercular nodes ornamenting their surfaces. Numerous tightly packed mandibular and maxillary teeth are present with maxillary teeth being superimposed, or tiled. Four sacral vertebrae are present, pelvic girdle is spaceously broad, sacral ribs and diapophyses are not completely fused, and as such, the dorsal spines are not completely fused. Armor is represented in a variety of morphologies: in the cervical region the armor is circular, in the dorsal regions it is triangular, whereas in the sacral and caudal regions it is conically compressed. A conspicuous fourth trochanter is present on the femur, the femur-humerus ratio is 1.57, and the ventral scapula is not strongly expanded.

Specimen: Two individuals are represented, one being relatively complete and is selected as the type (CV00209), while the other specimen is recognized as the paratype (CV00210).

Locality and stratigraphic position: Wujiaba, Zigong Co., early Late Jurassic, base of the Upper Shaximiao Fm., Chungking Group.

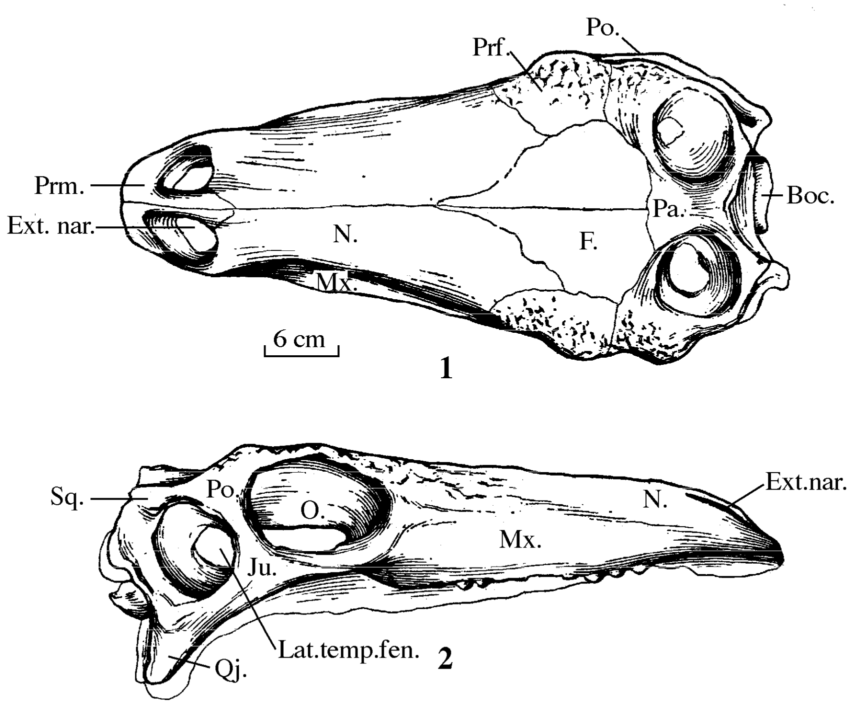


Figure 76. Restoration of the skull of *Tuojiangosaurus multispinus.*
1. Dorsal view. 2. Lateral view.

Description: Although the skulls are incompletely preserved, referral to both the type and the paratype allows a synthetic approach to reconstruct a relatively complete skull (Pl. XXXV, Figs. 1-3; Text Fig. 76.). In lateral perspective the skull is low, narrow, and long resembling a wedge. The facial region is particularly long with a muzzle that projects beyond the mandible. The external nares are long, large, and anterolaterally situated. Orbits are also large, situated laterally, and constitute approximately one-fifth the length of the skull. The lateral temporal fenestra is small, being widest at its midsection, and maintains margins that are conspicuously laterally projected. The direct distance from the ventral margin of the orbit to the ventral margin of the mandible is approximately one-half the height of the skull. From a dorsal perspective the skull is triangular, anteriorly acute, and posteriorly broad. The parietal is the highest point on the skull and borders an elliptical supratemporal fenestra. From a posterior perspective, the occipital region is nearly square in outline.

The ventrally situated basioccipital is represented by the occipital condyle and its associated condylar shaft. The occipital condyle lies posteriorly, is appropriately wider than the shaft, and terminates in a smooth and elliptical condyle. Ventrally, the condyle is constricted, inclined anteriorly, and forms a wide angle for articulation with the atlas. Surficially there is a broad shallow groove that together with the exoccipitals form the large foramen magnum. The condylar shaft is constricted, anteriorly inclined, and possesses small longitudinal grooves. The basioccipital process is a tongue-shaped element that is located anteromedially on the basioccipital shaft. At its contacts with the basisphenoid, there is a relatively deep longitudinal groove which becomes conspicuously bifurcated. CV00209 does not exhibit a strong basioccipital process but instead displays characters resembling *Camptosaurus.*

The exoccipitals are large lateral elements of the occipital region that flank the foramen magnum. Ventrally, they unite with the posterior basioccipital to compose the occipital condyle. The exoccipitals extend posterolaterally to form an approximate 45° angle with the medial axis of the cranium. Two small foramina lie anteriorly and posteriorly upon these elements, the posterior of which represents the canal for the hypoglossal and the anterior of which facilitates passage for the vagus and accessory. These foramina are separated by a thin bony wall that arises from the anterior region of the foramen magnum.

The general concensus is that the supraoccipital in the Stegosauria resembles the general condition on other dinosaurs by composing the dorsal margin of the foramen magnum. However, on specimen CV00209 the dorsal margin of the foramen magnum is in actuality constructed from the unified exoccipitals and not the supraoccipital, which is a configuration that more closely resembles the extant *Alligator*. From a posterior perspective, the supraoccipital is relatively complete and in contact with the parietals whereas ventrally and laterally it contacts the exoccipitals. In fully mature individuals these three elements become completely fused, and on CV00209 the suture lines for these elements are not visible. Posteromedially on the supraoccipital there is a distinctly inflated ridge with symmetrical lateral grooves at each side. Approaching the contact with the parietal, there are also three distinct small grooves and laminar ridges to facilitate ligament contact with the cervical region and thereby strengthen the relationship between head and neck.

The basisphenoid lies anterior to the basioccipital and contacts the prootic dorsally. Ventromedially it bears a deep sulcus in the shape of an isosceles triangle and laterally there project posteroventral mastoid processes that fuse with the anterior margin of the basioccipital. A pair of foramina lie dorsally to facilitate nerves for cervical mobility.

The alisphenoid is a small subtriangular element at the anteromedial wall of the lateral temporal fenestra. Dorsally it is in contact with the parietal, frontal, and postorbital, while posteroventrally it contacts the prootic. On CV00209 this element can not be distinguished, as it is surrounded by fused neighboring cranial elements.

The posterior and anterodorsal sides of the prootic contact the alisphenoid, exoccipitals, and basioccipital. A small, elliptically-shaped foramen for the facial cranial nerve lies between it and the alisphenoid.

The parietal is the highest element on the skull. Anteriorly it contacts the postfrontal and orbital, posterodorsally it contacts the squamosal and supraoccipital, and ventrally it contacts the alisphenoid and exoccipitals. The parietals are short elements that are expanded anteroposteriorly but constricted at their midpoint. Textural surface is smooth, glossy, and spherically convex with precipitous lateral sides that compose the medial wall of the supratemporal fenestra. On CV00209 the supratemporal fenestrae are 3.2 cm apart.

The frontals are relatively large elements with planar dorsal surfaces and a linear suture line fusing them. Laterally, the frontal contacts the postfrontal, anterior process of the postorbital, and the posterior process of the prefrontal; posteriorly it contacts the parietal; and anteriorly it contacts the nasals. Its lateral sides maintain a coarsened texture while posteroventrally there is a conspicuous transverse sulcus that overlies the olfactory lobe of the cranium. Its contact with the posterior nasals consists of a digit-shaped process projecting off the posterior nasal that becomes superimposed upon a medial surficial trough of the anterior frontals. CV00209 preserves vestigial traces of this contact.

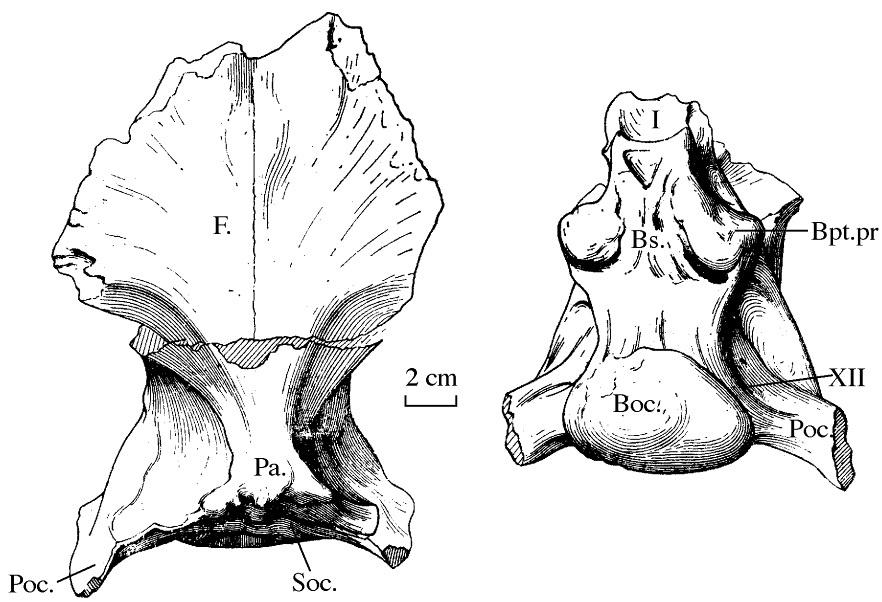


Figure 77. Cranium of *Tuojiangosaurus multispinus* (left) dorsal view and (right) ventral view.

The prefrontals are located laterally. On their lateral sides they contact the postfrontal, anterior supraorbital, and lacrimal, while on their medial side they contact the frontal and nasal. Only the right prefrontal is preserved on CV00209, configured as an extended ellipse and ornamented with coarsened tuberosities (Pl. XXXV, Fig. 6).

The lacrimal is inset between the maxilla, nasal, jugal, and prefrontal as an irregularly shaped element. On CV00209 the left lacrimal is well preserved and subtriangular in morphology.

From a dorsal perspective the supraorbital is irregularly shaped with undulating suture lines fusing it to the postorbital, prefrontal, and frontal, and is composed of either two or three elements. CV00209 preserves the left anterior and right posterior supraorbitals, both of which constitute the arched dorsal margin of the orbit, and medially contact the postfrontal and postorbital. Both elements are irregular in morphology and extremely thick. The anterior supraorbital is rectangular but posteriorly constricts to compose a blunt angle that is superimposed upon the anterior end of the posterior supraorbital, and constitutes over half of the dorsal margin of the orbit. The posterior supraorbital is both shorter and thicker than its counterpart. Laterally, it composes the posterodorsal margin of the orbit with a rough surficial texture consisting of swollen tuberosities.

Anteriorly the nasals contact the ascending branch of the premaxillae, posteriorly they are digit-shaped processes that overlap the anterior frontal, whereas laterally they contact the premaxilla, maxilla, lacrimal, and prefrontal. Anteriorly, they form the dorsal margin of the external nares. CV00209 displays the nasal as a thinly plated rectangular element with a smooth and glossy surficial texture (Pl. XXXV, Figs. 4&5).

The jugal is triradiate and composed of an anterior, dorsomedial, and posterior process. Specimen CV00208 preserves a nearly complete right jugal that is missing the terminus of the anterior process. Its preserved length from its posterior margin to the broken anterior margin is 8.0 cm, while its medial process is 4.8 cm high, with both the posterior and medial processes being thin and broad. The dorsomedial process contacts the ventromedial process of the postorbital to compose the posteroventral margin of the orbit. The dorsal margin of the posterior process fuses with the anteroventral margin of the quadratojugal. The anterior process is thin and long, extending directly anteriorly with a folded groove at its midpoint, and constitutes the ventral margin of the orbit. The anterior process contacts the maxilla and lacrimal which form the anterior margin of the orbit.

An 18.5 cm long portion of right maxilla is compressionally distorted and bears 14 teeth. Surficially it is smooth, glossy, and very slightly convex. Although it is distorted, its general morphology is unlike the robust maxilla on *Stegosaurus*. The dentition is tightly uniserial with the anterior teeth slightly smaller than the posterior teeth. The most notable character of the dentition is the rather regular pattern of overlapping teeth with the anterior lobe of a posterior tooth appressed against the posterior lobe of the preceding tooth. Dorsomedially on the maxilla, there lies a series of replacement teeth preparing to erupt into functional use.

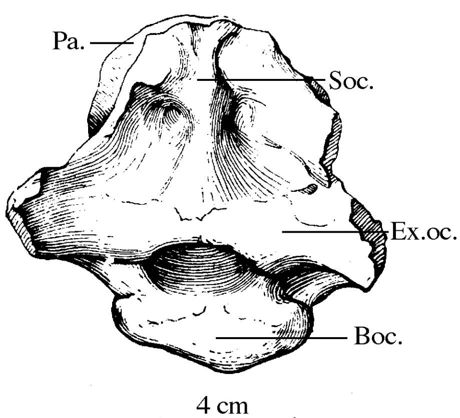


Figure 78. Posterior view of occipital region of *Tuojiangosaurus multispinus*.

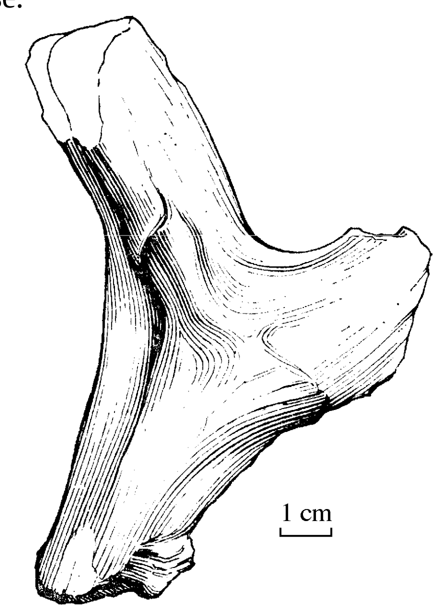


Figure 79. Quadratojugal of *Tuojiangosaurus multispinus*.

CV00209 Preserves a relatively complete 22.5 cm long right dentary with an anterolateral longitudinal groove to facilitate the predentary. The ventral margin of the dentary is thin, dorsal margin is thick, and lateral side is convex. The anterior end is low but the dentary gradually increases in height posteriorly. There are 26-27 alveolae present of which 13 house complete teeth. The dentition is closely packed with the anterior six teeth superimposed upon each other. Teeth in the posterior dentary do not overlap. Ridges on the tooth crowns gradually increase in height posteriorly. In overall development, the dentary is relatively thin and simple, unlike the thick and robust form on the North American *Stegosaurus*.

Dental morphology is consistent on CV00209, with teeth that are laterally compressed with fine striations and six to seven small denticles on the anterior and posterior carinae. The dentition gradually increases in height posteriorly, resembling precisely the condition of the Early Cretaceous *Priconodon* from Maryland as described by Marsh (1888). The labial side of the crown is very slightly convex while the lingual side is very slightly concave. Medially there lies a distinct swollen ridge in addition to a conspicuous cingulum present at the base of the crown which is particularly lingually projected at its midpoint to form a small mastoid process jutting from the cingulum. The crown is distinctly asymmetrical.

By nature, all members of the Dinosauria utilize the function of replacement teeth as noted on CV00209. Tooth wear among the functional teeth is moderate, with replacement teeth lying at the base of the root. Furthermore, the crowns of the functional teeth are aligned as acute blades with numerous teeth displaying oblique wear facets.

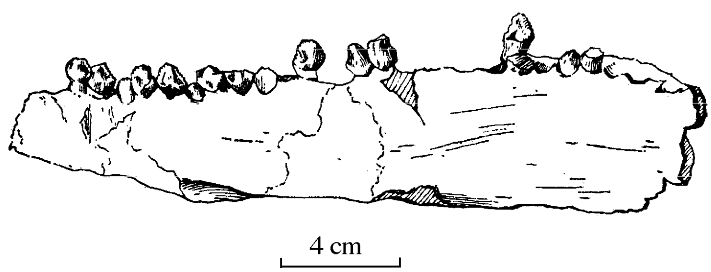


Figure 80. Right dentary of *Tuojiangosaurus multispinus.*

The skulls of stegosaurs bear numerous openings which may be recognized in two modes: the large fenestrae include the external nares, orbits, supratemporal fenestrae, lateral temporal fenestrae, posterior nares, palatine vacuities, and the foramen magnum; small foramina include those for the 12 cranial nerves and for additional blood vessels. CV00209 displays the following: The foramen magnum is elliptical and bounded ventrally by the basioccipital, while dorsally and laterally is bounded by the exoccipitals. The supraoccipitals do not participate in bordering this foramen. The orbits are extremely large in the Stegosauria, being elliptical in outline with their transverse diameter larger than the vertical diameter, and constituting one-fifth the total length of the skull. On CV00209 the orbit is bounded dorsally by the anterior and posterior supraorbitals, anteriorly by the lacrimal, and ventrally and posteriorly by the jugal. Consequently, the restoration of the size and orbital outline on the skull of *Tuojiangosaurus* is completely accurate with a transverse diameter of 9.6 cm and vertical diameter of 9.2 cm. With regard to the remaining fenestrae, some are incompletely preserved while others are completely lost and thus, further descriptions will not be conducted.

Five distinct pairs of foramina for cranial nerves are present on the cranium of *Tuojiangosaurus,* representing numbers XII, XI, X, IX, VIII, and VII and will be described posteroanteriorly (Text Fig. 81.). The hypoglossal (XII) is located posteroventrolaterally on the occiput to penetrate the lateral wall of the braincase. The glossopharyngeal, vagus, and accessory

(IX-XI) are expressed by a large foramen located on the ventrolateral exoccipital just barely anterior to the hypoglossal. Careful observation of this foramen suggests that an extremely thin bony plate divides the foramen into separate canals for the nerves. The facial (VII) is located on the lateral prootic, penetrating the braincase with a perfectly straight canal. The acoustic (VIII) is represented by an oval fenestra that lies between the facial foramen and the foramen for cranial nerves IX-XI. Several additional small foramina for blood vessels are also present on the occiput.

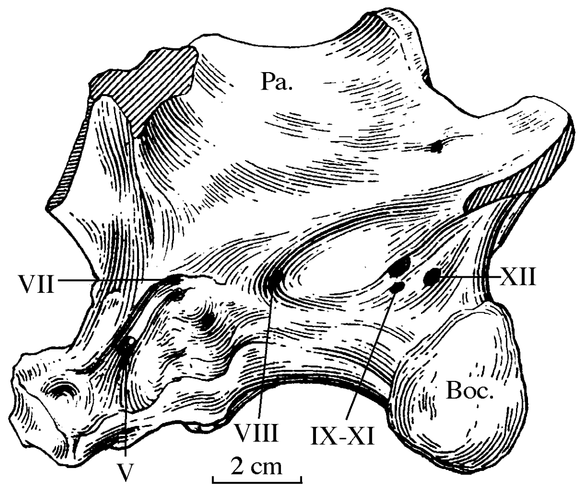


Figure 81. Lateral view of *Tuojiangosaurus multispinus* occipital region.

The vertebral count of *Tuojiangosaurus* is unclear, although an estimate may be made based upon the records made by Xuanmin Li during the excavation of the type and paratype, in addition to the studies of the stegosaurs *Stegosaurus* and *Kentrosaurus* by Gilmore (1914). In this manner, it is estimated that there are 10 cervicals, 17 dorsals, 4 sacrals (as preserved), and 45 caudals.

Within the cervical series, the atlas intercentrum is preserved, but among the remaining cervical vertebrae, only one is relatively well preserved with minor damage to its neural spine, the remaining are only represented by centra (Plate XXXVII, Fig. 1). The atlas on the Stegosauria is composed of an intercentrum, neural arch, and odontoid process, with the latter representing the atlas centrum. Specimen CV00209 preserves a crescentic intercentrum which is anteriorly concave for articulation with the occipital condyle while its posterior concave surface facilitates articulation with the odontoid process. Its maximum length is 5.7 cm and maximum width is 7.2 cm.

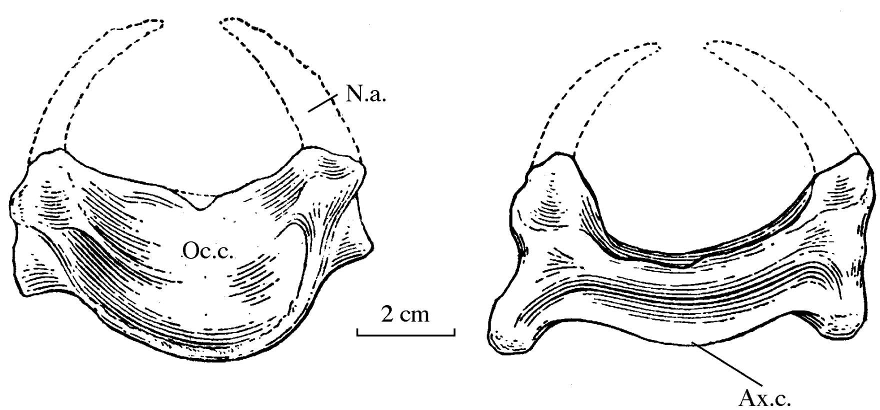


Figure. 82. Anterior (left) and posterior (right) views of *Tuojiangosaurus multispinus* atlas intercentrum

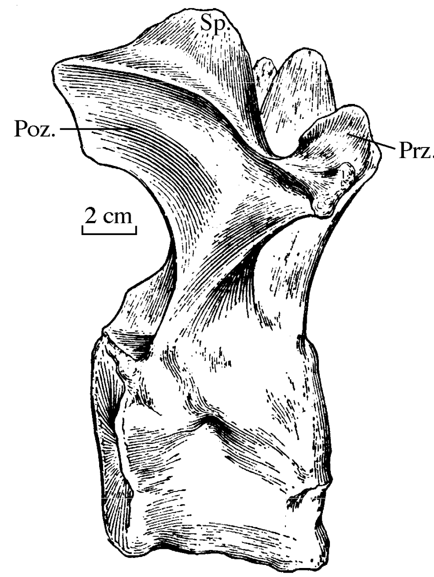


Figure 83. Right lateral view of *Tuojiangosaurus multispinus* fifth cervical vertebra.

Only the opisthocoelous centrum of the axis is preserved with a constricted midportion and a transversely expanded ventral face that lacks a keel. The postzygapophyses are more expansive than the prezygapophyses. Centrum length is 6.0 cm, anterior breadth is 5.5 cm., and posterior breadth is 7.5 cm.

Cervical vertebrae 3-10 on the Stegosauria are not particularly characteristic as all the centra are amphicoelous with the anterior facet shallow, posterior facet deep, and the ventral surface transversely broadened. Centra have all been compressionally distorted to become elliptical. Parapophyses are present on all centra anterodorsolaterally and gradually elevate in position posteriorly along the column. Also posteriorly along the column, the centra gradually increase in length and posterior breadth but posterior to Cv8 the centra then begin to shorten and approach the length and breadth of the dorsals. Thus Cv8 is the largest cervical with a 12.7 cm length and 11.5 cm breadth. Cv5 is relatively well preserved (Fig. 83) and as such a more detailed description will be conducted. Although compressional distortion has had an effect upon the centrum, parapophyses are present anterodorsolaterally, the neural canal is large, neural arch is dorsally elongated but is not as high as on more posterior cervicals, and it is not dorsally constricted as on the dorsals. Diapophyses extend dorsally and are composed of three laminae: the anterior lamina is in contact with the prezygapophyses, the lateral lamina unites with the postzygapophyses, and the ventral lamina extends to the midpoint of the neural arch. These three laminae unite to compose the articular nodes of the diapophyses. The prezygapophyses are composed of the anterior margins of two neural arch plates which extend and diverge dorsally in a V-shaped configuration. Prezygapophyseal articular surfaces are elliptical and dorsomedially oblique.

Table 15. Measurements of *Tuojiangosaurus multispinus* CV5 (mm).

Centrum length	7.9
Centrum anterior height	8.9
Centrum anterior breadth	6.0
Neural canal breadth	3.5
Diapophyses to base of centrum	14.0
Distance between diapophyseal articular surfaces	14.2
Distance between prezygapophyseal articular surfaces	5.6

There are 14 dorsals preserved among which 12 only preserve their centra, one has lost its neural spine, and one is completely preserved. *Tuojiangosaurus* dorsals are typically stegosaurian. The nearly amphyplatyan centra are laterally compressed, length exceeds breadth, a ventral keel is present, the neural arch is large and high, and the neural canal is large and circular but slightly smaller than the neural canal of *Kentrosaurus.* Diapophyses extend dorsolaterally and lie at an approximate 45° angle to the neural spine. Prezygapophyses are all large and expansive with medially oblique articular facets. Postzygapophyses are laterally oblique with smooth and glossy articular surfaces. Both pre- and postzygapophyses converge at their ventral margins to compose a V-shaped configuration in cross-section. The neural spine is lamelliform with an arcuate apex (Pl. XXXVII, Figs. 3, 5).

The six anterior centra are nearly equivalent in length. From D7 to D15 there is a gradual tendency to lengthen, after which the centra then shorten gradually until they nearly reach the length of the first sacral. Consequently, the relatively long centra are in the mid-series and the relatively short are the most posterior three.

On the type and paratype there are four fused sacral vertebrae which gradually shorten in length and increase in breadth posteriorly, are dorsoventrally elliptical, ventrally are spaciously rounded, ventral keels are absent, and the most terminal (caudal 1) has a circular posterior end with a slightly depressed articular surface. Sacral ribs and diapophyses are not completely fused such that in ventral view conspicuous suture lines are present.

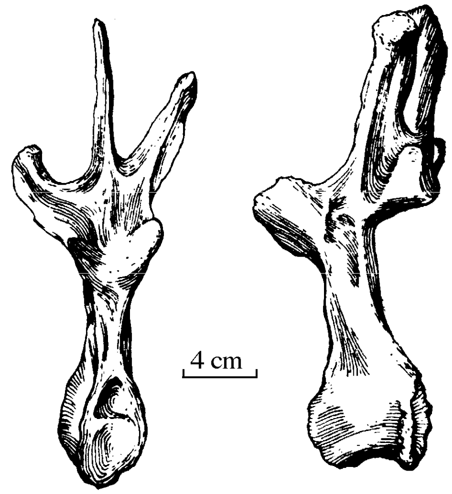


Figure 84. Anterior view (left) and lateral view (right) of *Tuojiangosaurus multispinus* dorsal vertebra.

There are 33 caudal vertebrae preserved which were collected scattered along the bedding plane with only three posterior elements articulated. Therefore the reconstruction is based upon the general count recognized for the Stegosauria (Pl. XXXIX, Figs. 6, 8). The specimens collected may be easily distinguished as representing anterior, medial, and posterior sections. The 17 anterior vertebrae are amphicoelous with a length less than the width, elliptical centra, and a high neural arch with a slightly transversely inflated apex and has a convex margin anteriorly and concave margin posteriorly. Diapophyses are present on all centra and gradually become shorter posteriorly along the column until Cd17 where they are recognized only as vestigial remnants. The posterior 12 centra gradually alter from an elliptical morphology to the more typical stegosaurian amphiplatyan hexagonal morphology. The medial series consists of Cd18-Cd37 with centra nearly equivalent in length, a longitudinal groove is present ventrally, neural spines have become broadened, and diapophyses have become lost. These represent the longest centra in the caudal series. The posterior series initiates with a shortened centrum at CD38 and then centra become narrow until CD46 which is the smallest centrum in the series.

Type CV00209 preserves both scapulae and paratype CV00201 preserves both scapulae with incomplete coracoids. The scapula is typically ornithischian and is nearly identical to those on the Ceratopsia although not as expanded. The blade is narrow and long, thickened at its midsection, laterally inflated, distal end is slightly expanded and thinned at its distal end, and thickest proximally at the glenoid fossae where the contact with the coracoid is a straight line. An incomplete, relatively thin coracoid is represented which is elliptical in outline. The circular coracoid fenestra perforates the coracoid close to the humeral contact.

The humerus is expanded both proximally and distally with the proximal end particularly wide and spacious. The proximolateral margin is arcuate and a relatively well developed deltopectoral crest expands laterally. The shaft is rather conspicuously curved causing the proximal and distal ends to lie on distinctly separate planes. The narrowest portion of the shaft is ventromedial. The two distal condyles are equivalent in size with a well developed posterior intercondylar groove, although anteriorly this feature is not well developed and gradually attenuates dorsally.

Table 16. Vertebral measurements of *Tuojiangosaurus multispinus* (after restoration) (cm).

Designation	Count	Length	Posterior height	Posteror breadth	Total height (with spine)
Cervical	1	6.0		7.5	
	2	6.0	5.5	7.5	10.0
	3	5.5	7.3	9.0	10.0
	4	7.0	6.0	9.0	10.0
	5	7.9	7.0	8.0	12.5
	6	10.3	6.5	8.0	15.0
	7	11.5	6.0	10.6	14.5
	8	12.7		11.5	16.4
	9	11.0	9.8	9.2	20.0
	10	10.5	9.0	8.0	13.5
Dorsal	1	10.0	10.0	8.3	26.0
	2	10.0	10.2	9.5	30.5
	3	11.5	8.5	7.0	31.0
	4				
	5	10.0	8.5	6.5	32.5
	6	10.0	9.0	8.0	32.5
	7	12.0	10.0	6.5	34.5
	8	11.5	9.0	7.0	34.0
	9	10.0	10.0	9.5	38.0
	10	11.0	7.5	7.0	36.0
	11	11.5	10.5	9.0	38.0
	12	11.5	10.0	7.5	39.0
	13				
	14	12.0	10.0	6.0	38.5
	15	9.0	10.5	7.0	36.0
	16				
	17	9.0	8.0	15.0	14.5
Caudal	1	7.0	14.5	16.0	42.0
	2	6.0	16.0	17.7	43.0
	3	4.3	15.0	16.0	43.5
	4	4.0	15.2	15.5	38.5
	5	4.1	14.3	16.0	38.2
	6	4.0	14.0	13.5	36.0
	7	3.8	11.0	13.5	32.0
	8	3.8	14.0	14.0	32.5
	9	36.0	11.2	12.2	33.0
	10				
	11				
	12	3.4	11.0	12.5	33.0
	13				
	14				
	15				
	16	8.5	11.5	8.0	26.5
	17	8.0	11.5	7.7	25.0

Table 16 Cont.

Designation	Count	Length	Posterior height	Posteror breadth	Total height (with spine)
Caudal	18				
	19				
	20				
	21	7.0	8.4	6.5	24.0
	22	8.0	9.0	7.0	24.0
	23	8.2	9.0	6.5	24.0
	24				
	25	7.0	10.0	5.5	24.0
	26	7.0	10.0		
	27	5.5	8.0	5.5	22.0
	28	6.5	8.0	5.0	20.0
	29	7.0	9.5	5.0	21.0
	30	6.5	9.0	6.0	
	31	6.5	7.5	6.0	
	32	8.0	9.0	4.5	
	33				
	34	7.0	9.0	5.0	
	35	8.0	8.0	4.7	
	36	7.0	8.0	5.0	
	37	7.0	6.0	4.0	8.5
	38	6.5	5.0	5.0	
	39				
	40	5.5	3.0	4.0	
	41	5.0	3.0	3.0	
	42	4.8	4.0	3.0	
	43				
	44	3.0	4.0	3.5	
	45				
	46	3.0	2.0	2.5	
	47				

Compared to other taxa this humerus is distinct from *Chialingosaurus* and more closely resembles *Wuerhosaurus* and *Kentrosaurus,* in addition to morphologically closely resembling a ceratopsian, and even more closely resembling the morphology of a dicynodont. This is probably due to functional adaptation in mobility.

The radius and ulna are absent, the forelimb only preserves metatarsals II and III which are short and have thick, robust tubercles for articulation with carpals. The unguals are thin and flat with slightly grooved proximal ends.

The pelvic girdle is well preserved and resembles *Wuerhosaurus* with its massive and elongated preacetabular crest. The posterior crest is expansive, flattened, and forms a short triangle. The acetabulum is shallow and pubic peduncle is not well developed. Only a left pubis is preserved which has lost its anterior process, although the posterior process is well preserved as being rod-shaped with a slightly inflated distal end. An ischium is not preserved.

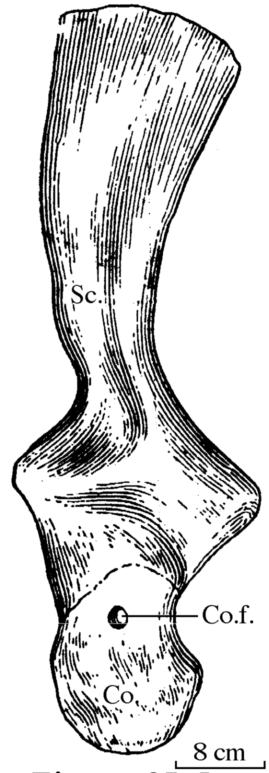


Figure 85. Lateral view of *Tuojiangosaurus multispinus* left scapula.

Both femora are completely preserved with straight and compressed shafts, large and small trochanters are undeveloped, and the fourth trochanter is a small crest located on the posterior midpoint of the shaft. The stegosaur femur is not readily distinguishable from a sauropod femur except for the degree of development of the fourth trochanter and its placement on the shaft. For instance, the fourth trochanter on *Omeisaurus* is located on the posterior upper third of the femur (Pl. XXXIX, Figs. 4, 5).

Both tibiae and fibulae are relatively well preserved on CV00209. The proximal tibia is slightly thin, posteriorly expanded, and the cnemial crest is not very well developed. The midshaft is rather thin and elongated. A distolateral tubercle is present as a vestigial object for fusion of the tibia and fibula with the astragalus and calcaneum. The fibula has expanded but thinly flattened ends. The shaft is gracile and columnar. In summary, the tibia and fibula of CV00209 are both distinctly thin and long.

The armor on *Tuojiangosaurus* is relatively well preserved with 19 plates represented: five cervicals, seven dorsals, a single sacral, and six caudals. Armor at the terminus of the tail is missing. The armor is large and diverse in morphology. In the cervical region it is lightly constructed, thin, and pear-shaped. In the dorsal region it is triangular, and in the sacral and caudal region proximal to the sacrum it is composed of high, flattened, conical spines. The entire set increases in height, size, and thickness from the cervical region to sacral region with the largest pair in the sacral region. This configuration resembles *Kentrosaurus.*

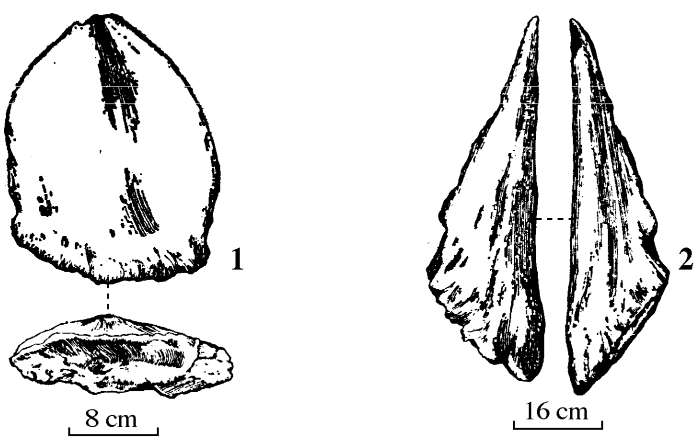


Figure 86. Fifth (left) and eleventh pair (right) of dermal armor of *Tuojiangosaurus multispinus.*

The armor is reconstructed to be aligned in opposition. This is determined from equivalence in size and morphology as illustrated by pair 11 in Figure 86 (Plate XXXVIII, Figs. 1-5). This paired configuration is known on most genera in the subfamily. Furthermore, on paratype CV00210 there were three articulated dorsal vertebrae excavated associated with an armor plate between the neural spine and diapophyes indicating that a single plate covered two vertebrae and leading to the calculation that there were a total of 17 pairs in the series.

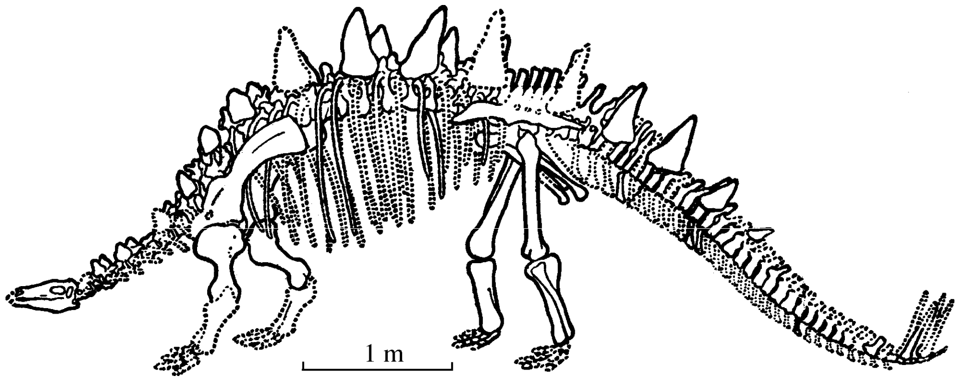


Figure 87. Reconstruction of *Tuojiangosaurus multispinus.*

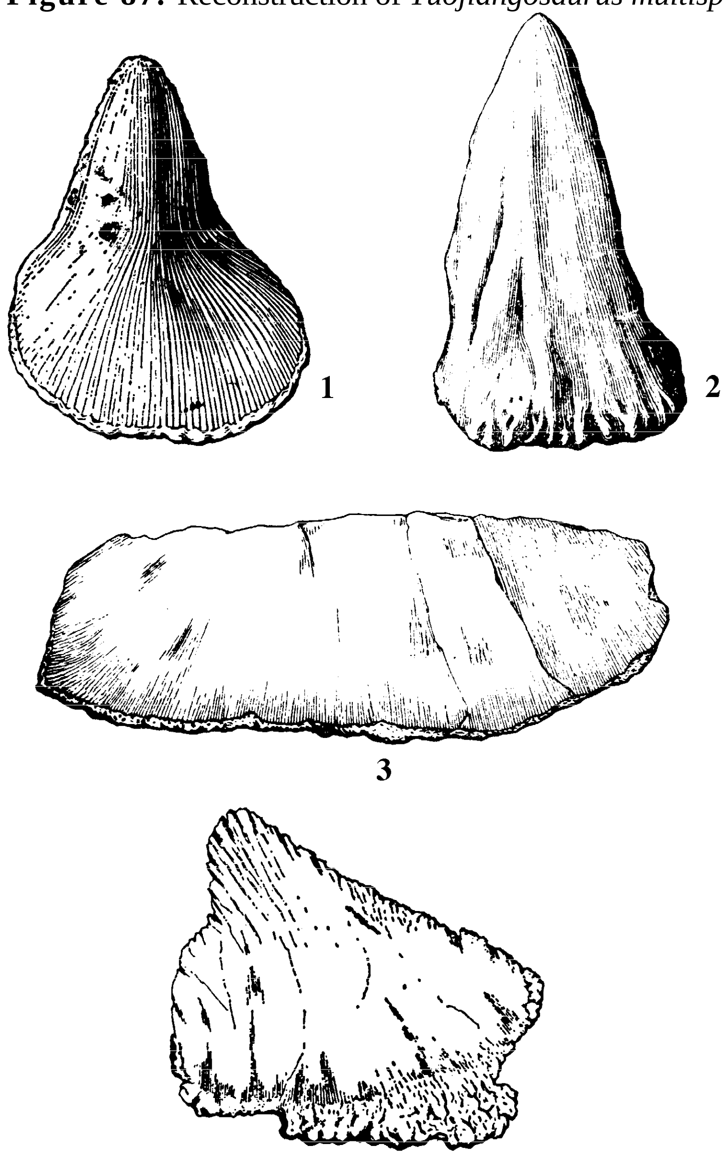


Figure 88. A comparison of presacral dermal armor of (1) *Chungkingosaurus,* (2) *Tuojiangosaurus,* (3) *Wuerhosaurus,* and (4) *Stegosaurus.*

Discussion: In a previous short report on the Stegosauria from Zigong, Sichuan, the phylogeny of *Tuojiangosaurus* was discussed. These specimens were assigned to the subfamily Stegosaurinae based upon the typical stegosaurian skull and vertebrae, undeveloped jugal, and the presence of two to three supraorbital bones. Literature regarding this subfamily is rather profuse and concerns numerous genera such as the North American *Stegosaurus*, East African *Kentrosaurus,* European *Omosaurus* (*Dacentrurus*), and the Asian *Chialingosaurus* and *Wuerhosaurus*. As these genera are all morphologically similar, particularly in their postcrania, the numerous genera that lack the crucial characters of cranial data have undergone taxonomic reassignments for many years, to the point where the European *Omosaurus* was once assigned to the North American *Stegosaurus*. Consequently, workers have utilized the treatise of Gilmore (1914) as the basis for their diagnoses.

Table 17. Pectoral girdle, forelimb, pelvic girdle, and hindlimb measurements of *Tuojiangosaurus multispinus* (cm).

		Left	Right
Ilium	Total length	103.0	105.0
	Pubic peduncle to preacetabular crest	52.0	53.0
	Ischiac peduncle to postacetabular crest	20.0	24.0
	Medial breadth of preacetabular crest	17.0	16.5
	Medial breadth of postacetabular crest	29.0	33.5
Femur	Maximum length	85.0	90.0
	Medial breadth	13.0	15.0
Fibula	Maximum length	57.0	57.0
	Proximal breadth	9.5	9.3
	Medial breadth	5.0	5.0
	Distal breadth	7.5	8.5
Tibia	Maximum length	6.1	6.2
	Proximal breadth	25.5	19.0
	Medial breadth	8.0	9.5
	Distal breadth	19.0	20.0
Humerus	Maximum length	54.0	55.0
	Proximal breadth	32.0	32.0
	Medial breadth	8.5	7.0
	Distal breadth	18.0	15.5
Scapula	Maximum length		90.0
	Dorsal breadth		26.0
	Ventral breadth		30.0
	Distal breadth		35.0

Currently, the two most well described genera in the subfamily are *Stegosaurus* and *Kentrosaurus*. In cranial morphology, the occiput of *Tuojiangosaurus* most closely resembles *Kentrosaurus* but in cranial outline and with its tuberculated supraoccipital it resembles *Stegosaurus*. Postcranially, is difficult to differentiate the genera in this subfamily with the exception of the morphology and configuration of the dermal armor. From this aspect it is obvious that *Tuojiangosaurus* is distinct from the North American *Stegosaurus* and Asian *Wuerhosaurus* (Text fig. 88) although there are resemblances to *Kentrosaurus* and *Chialingosaurus*. Hoffstetter (1958) documented the armor of *Omosaurus* as being predominantly spinous with plate-shaped elements rare. This indicates that there is an intimate relationship between the stegosaurs of Asia,

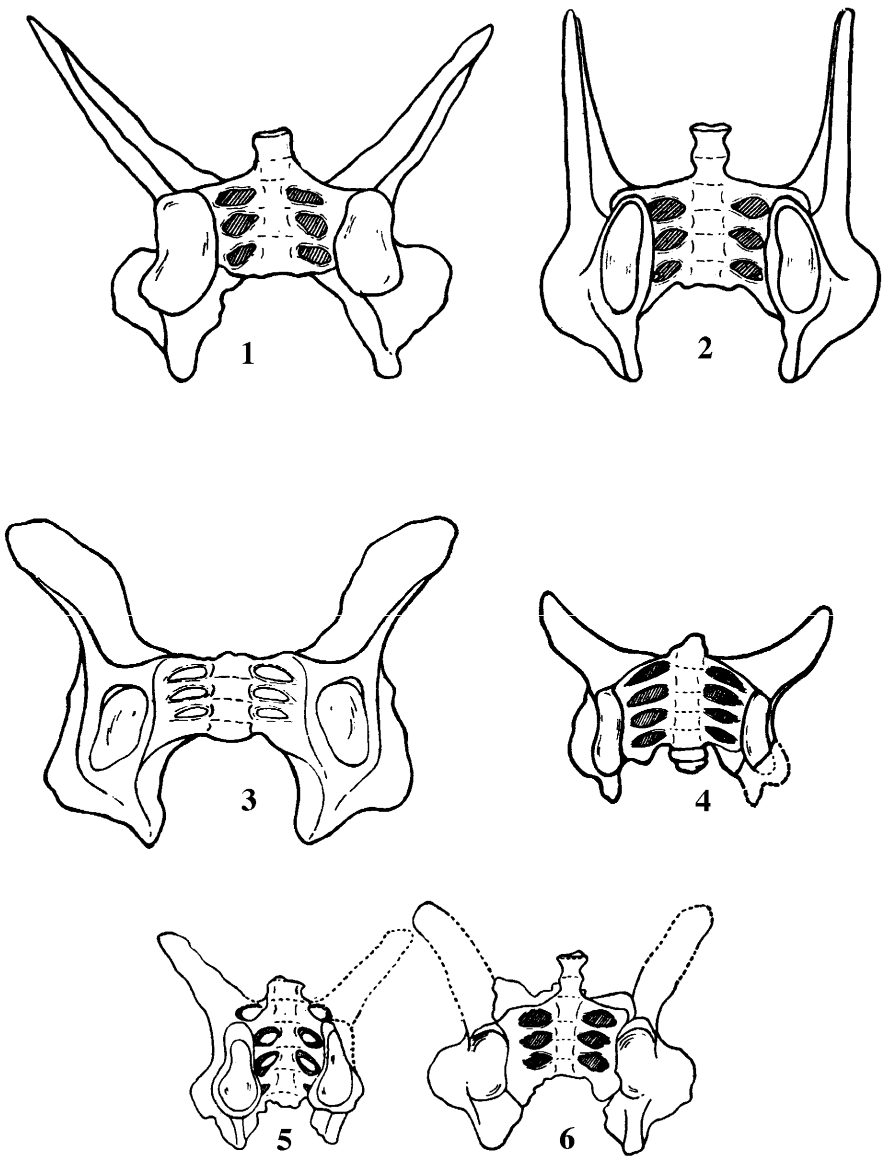


Figure 89. A comparison of sacra of (1) *Wuerhosaurus* (2) *Stegosaurus,* (3)*Tuojiangosaurus*, (4) *Kentrosaurus,* (5) *Chungkingosaurus,* and (6) *Omosaurus..*

Europe, and East Africa, and that it would be difficult to distinguish them on the basis of armor alone.

The sacrum of *Tuojiangosaurus* has three pairs of open fenestra which is one of the characteristic features of the Sichuan stegosaurs and distinguishes them easily from *Omosaurus, Kentrosaurus,* and *Wuerhosaurus* (Text fig. 89). In 1957, two pelvic girdles were excavated from the Kimmerigian of Portugal which Lapparent (1957) erected as the new species *Omosaurus armatus.* The femur and ilium of this species resembles *Tuojiangosaurus* although its dorsal sacrum is sealed.

Table 18. Dermal armor measurements of *Tuojiangosaurus multispinus* (cm).

	Sequence	Height	Basal breadth	Basal thickness
Left	1	6.2	4.0	1.6
	2	11.0	7.0	2.3
	8	41.0	27.0	11.5
	9	44.5	26.5	11.0
	11	49.0	22.0	10.0
	12	39.0	19.0	8.0
	13	34.0	20.0	7.0
	14	25.0	16.5	10.0
	15	12.0	10.0	5.0
Right	7	41.0	26.0	16.0
	8	41.0	27.0	11.0
	10	52.0	32.0	14.0
	11	49.0	22.0	7.0
	12	39.0	19.0	8.0

The crucial characters of *Tuojiangosaurus* lie in its comparison to *Chialingosaurus* as both are derived from contemporaneous sediments in the Sichuan Basin. Table 23 illustrates the distinct characters of two genera from Sichuan with their most distinguishing characteristics lying in their cranial morphology. The skull of *Chialingosaurus* is narrower and higher, its dentition is smaller, loosely spaced, and does not overlap. *Tuojiangosaurus* has a large compact dentition that overlaps. Furthermore, the dermal armor is distinct between the two, with *Tuojiangosaurus* maintaining a varying morphology and *Chialingosaurus* bearing a predominantly spinous morphology. *Chialingosaurus* appears to bear relatively plesiomorphic characters, prompting Steel (1969) to suggest that it may be ancestral to all Jurassic stegosaurs.

Chungkingosaurus gen. nov.

(Plates XL-XLIV)

Genus diagnosis: A moderate to small sized stegosaur with a relatively high skull, thick mandible, and small and slender tightly associated dentition with asymmetrical crowns that are not superimposed. Dorsal and caudal vertebrae are amphiplatyan, four to five sacral vertebrae are completely fused with strengthened centra but fenestrated dorsal surface. Armor consists of thick and large spinous plates. Femoral shaft is tubular and straight with an inconspicuous fourth trochanter. Femur-tibia ratio is 1.61-1.68.

Four species are recognized in the genus: *Chungkingosaurus jiangbeiensis* gen. et sp. nov., *C.* sp. 1, *C.* sp. 2., and *C.* sp. 3.

Chungkingosaurus jiangbeiensis Gen. and sp. nov.

(Plates XL-XLII)

Etymology: Genus and species are derived from the locality which produced the specimen: The Jiangbei district of Chungking municipality.

Diagnosis: This is a small stegosaur with a relatively high rostrum, thick mandible, tightly associated slender and small teeth with asymmetrical crowns and weak enamel. Dorsal and caudal vertebrae are amphiplatyan, four sacral and a single robust dorsosacral vertebrae are fused, dorsal sacrum is not completely sealed, and the large and thick armor is both spinous and plated. Humerus maintains a distinct shaft, acetabulum is shallow and flattened, and femur is tubular, straight, and lacks a fourth trochanter. Proximal tibia is conspicuously expanded with a rounded articular surface. Astragalus and calcaneum are completely fused to distal tibia and fibula.

Specimen: An incomplete skeleton is represented by the rostral region of the skull, 10 dorsal vertebrae, a relatively complete pelvic girdle and sacral region, 23 articulated caudal vertebrae, a pair of femora and tibia, a distal humerus, three metacarpals, and five pieces of plated armor (specimen #CV00206).

Locality and stratigraphic position: Maoershi, in the Jiangbei district of Chungking municipality, early Late Jurassic Upper Shaximiao Fm., Chungking Group.

Description: Only the rostrum to the antorbital region is preserved (Text Fig. 90), which has been subjected to lateral compressional distortion. Estimated length of the skull is 27.0 cm (Pl. XLI, Figs. 1&2). The premaxillary and rostral region has been slightly damaged, but still retains its U-shaped morphology that represents the nasal and maxillary branches. The nasals have been slightly weathered and only retain vestiges of the ventral region, which composed the dorsal and posterior margins of the external nares and suggests that the dorsal branch was extended posterodorsally to compose a high cranium. The maxillary branch is club-shaped and penetrates the nasal and premaxilla. Its dorsal margin composes the medial margin of the external nares. The external nares are 1.3 cm in diameter, elliptical, and laterally situated (Text Fig 99).

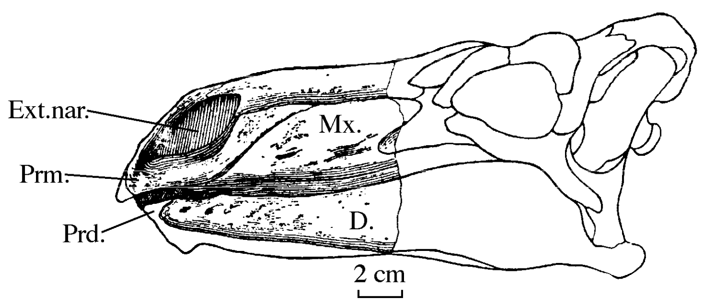


Figure 90. Lateral view of *Chungkingosaurus jiangbeiensis* skull. (Outlined elements represent hypothetical reconstruction)

Only 4.5 cm of the subtriangular maxillae are preserved, with the right side suffering compressional distortion but the left side as well preserved. Anteriorly they contact the posterior process of the premaxilla while dorsally they contact the nasals. They are distinctly thicker than in *Tuojiangosaurus,* with a straight ventral margin that is depressed medially, creating a lateral protrusion of the maxillary body. Lateral view of the dentition is impossible due to the fusion of the maxilla to the mandible.

The 9.3 cm long dentary is incomplete on the left side but well preserved on the right side. It is distinctly thicker and more robust than in *Tuojiangosaurus*, with a straight dorsal margin housing 16 slender teeth. At its midpoint it is very slightly constricted ventrally, while laterally it is flat and straight. A laterally flattened splenial is visible on the medial dentary that extends to beneath the seventh tooth.

Dentition count is unclear but dental morphology is typical for the subfamily. Teeth are small and thin, while crowns are asymmetrical and crescentic, with both lateral sides conspicuously inflated. The crown base is ornamented with tightly aligned striations, but the anterior and posterior margins are not conspicuously denticulated, which differs extremely from *Tuojiangosaurus*. Enamel is weak and tooth roots are conical. Maxillary teeth are in tight unilateral alignment but unlike *Tuojiangosaurus* are not superimposed. Teeth increase in size along the sequence anteroposteriorly. Maxillary and mandibular dentition are similar in morphology and size.

Vertebral count on the Jiangbei stegosaur is completely unknown as no cervical vertebrae are preserved and no complete dorsal or caudal specimen is represented. The data at hand enumerates 10 dorsals, among which three are relatively well preserved although they are missing their neural spines, and the rest are fragmentary; five sacral vertebrae are well preserved, with the dorsosacral fused to the series; and 23 caudals are preserved, the three anterior vertebrae have been weathered, are fragmentary, and are not articulated, but 20 posterior vertebrae are articulated and well preserved.

Table 19. *Chungkingosaurus jiangbeiensis* dorsal vertebrae measurements (cm).

Specimen #	Centrum			Max. height	Sequence #
	Length	Breadth	Height		
1	4.8	5.6 4.5	5.3 5.1		3
2	4.6	5.6 4.5	5.3 4.9		4
3	5.1	4.3 5.3	5.1 5.3		7
4	5.4	4.9 5.4	5.4 5.4		8
5	5.4	4.7 5.4	5.1 5.9		9
6	5.3	5.4 5.4	5.1 5.75		10
7	5.35	5.1 5.6	5.1 5.75		11
8	5.4	4.6 6.0	5.2 5.9	21.5	14
9	5.45	5.1 6.1	5.8 6.2		16
10	4.14	5.8 —	5.6 5.6		17

The 10 dorsals are unidentified as to which elements of the series they belong to due to their preservation and isolated occurrences. Gilmore’s (1914) discussion of the pattern of stegosaurian vertebral variation indicates a standard count of 17 dorsals. Therefore, if this model is adopted, there should be another seven dorsals in the column. Dorsal specimens No. 1 and No. 2 have pre- and postzygapophyseal articular facets that are smaller than those on the posterior dorsal series. Moreover, centra are shorter than the posterior series at 4.8 and 4.6 cm, breadth is slightly smaller at 4.5 cm, and height is lower at 5.1 and 4.9 cm (Pl. XL, Figs. 1-3). The pattern of stegosaurian dorsal variation suggests an elongation along the column posteriorly with an abrupt shortening at the most posterior two to three centra and a reduction of the neural spines. Therefore, centrum measurements suggest that dorsals 1, 2, 5, 6, 12, 13, and 15 are not represented. The ten dorsals that are represented are all amphiplatyan with prezygapophyseal articular facets larger than postzygapophyseal facets, the centra are medially constricted, and the neural arches are high. From a lateral perspective, at its contact with the centrum, the base of the neural arch is as long as the centrum but dorsally becomes anteroposteriorly constricted. The arch is narrowest at the base of the diapophyses but is still planar. The diapophyses extend dorsolaterally at a 45° angle to the neural spine, are relatively well developed with a thick anterior margin, have a thin posterior margin, and are triangular in cross-section. The elliptical parapophyses lie at the anteroventral base of the diapophyses. The prezygapophyses lie on the anterior neural arch extremely close to the ventral margin of the parapophyses but cannot be described in detail due to their poor preservation. An anteromedial ridge extends from between the prezygapophyses to the anterior margin of the neural spine. On the posterior neural spine, a medial ridge runs from its apex to the base of the diapophyses where it bifurcates to compose a rhomboid depressed node which constitutes the postzygapophyses. A distinct longitudinal blade-shaped ridge runs from the ventral margin of the postzygapophyses to the dorsal margin of the neural arch.

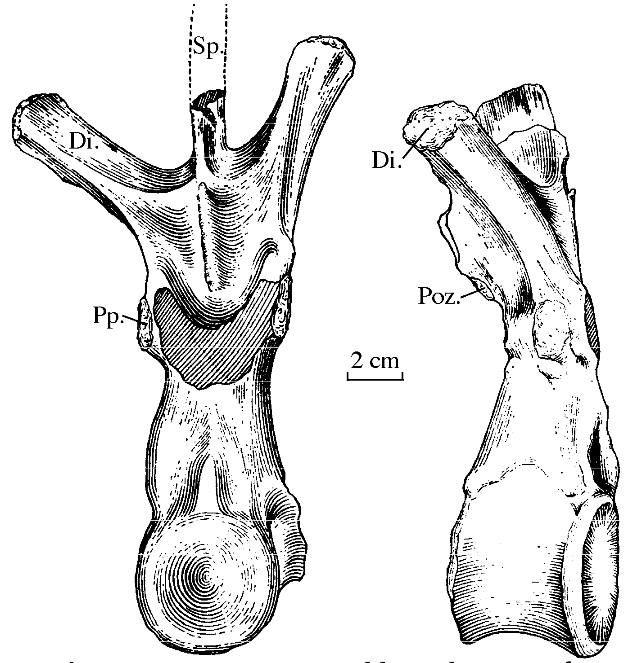


Figure 91. Anterior and lateral views of *Chungkingosaurus jiangbeiensis* dorsal vertebra.

Six fused vertebrae are represented in the sacrum with the first displaying diapophyses that are not dorsoventrally expanded and possessing ribs of conventional morphology, which obviously indicates that it is not a true sacral vertebra but a strengthened posterior dorsal. The second fused vertebra initiates dorsoventral expansion of the diapophyses which become thin and flat to contact the medial ilium and represents the dorsosacal centrum in the series. The most posterior sacral vertebra constitutes the largest of the centra in the sacral series. This sacral morphology is consistent with that of *Stegosaurus* (Pl. XLII, Figs. 1&2).

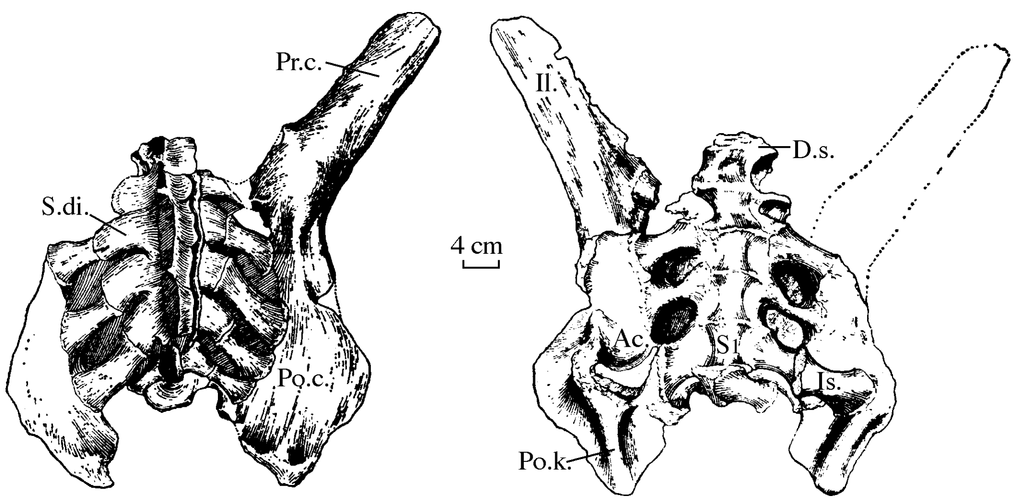


Figure 92. Dorsal and ventral views of *Chungkingosaurus jiangbeiensis* pelvic girdle.

From a ventral perspective, the centra are relatively round, spacious, and lack a ventral keel. Centra progressively increase in size along the series anteroposteriorly with prezygapophyses smaller than postzygapophyses. Laterally, sacral ribs lie between the centra to form thick partition plates that fuse with the diapophyses while extending and expanding posterolaterally to compose the sacral yoke that is perforated with a subcircular fenestra. The medial side of the fenestra is composed of the centrum whereas the lateral side is dominated by the yoke itself. This configuration differs from that in sauropods as the fenestrae are mutually linked to completely perforate the girdle as two pairs of fenestrae. Sacral neural arches are well preserved although they lack their spines. The fusion of the 27 cm long centra series causes the dorsal region to compose a single swollen longitudinal ridge with dorsally projected and greatly inflated arches that exceed the height of the dorsal margin of the ilia. Four sacral neural arch apices are recognized with remnants of their spines, which indicate that the bases of the spines are fused, although it is impossible to determine whether or not the apices of the spines are also fused, but the spines of the posterior dorsal and sacrocaudal are isolated.

Table 20. ***Chungkingosaurus jiangbeiensis*** **sacral measurements.**

	Centrum length	Centrum ventral breadth
S1 (dorsosacral)	5.3	6.0
S2 (sacral)	4.6	6.7
S3 (sacral)	5.0	7.0
S4 (sacral)	4.8	7.0
S5 (sacrocaudal)	4.6	7.5

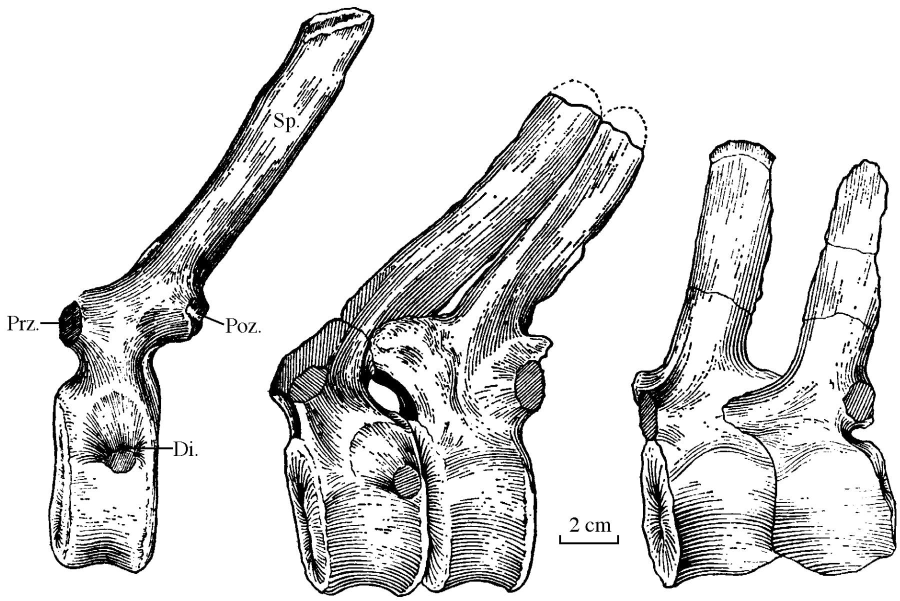


Figure 93. Lateral view of *Chungkingosaurus jiangbeiensis* caudals 5-7,10, and 11.

There are 23 caudal vertebrae preserved, although caudals 1, 2, and 5 have been lost to weathering and caudals 3 and 4 have been weathered and are incomplete, but the remaining 21 vertebrae are relatively well preserved. It is estimated that there should be an additional 19 posterior caudals. The anterior caudals are amphiplatyan with short centra and large circular pre- and postzygapophyses. Caudals 3, 4, and 7 display centra with breadths that are twice that of length. Centra gradually become hexagonal from Cd7 to Cd13, and from this point posteriorly become progressively smaller, laterally compressed, and more elongated to exceed their breadth. Initiating with Cd15 the centra begin to diminish in height. The longest centra in the series occur between Cd12 and Cd15 (Pl. LX, Fig. 4-6).

Diapophyses are missing on the most anterior three caudals but are present on the fourth and fifth caudal as acutely terminated cones with an inflated base that becomes abruptly constricted posteriorly and then gradually alters to a rounded apex as it curves ventrolaterally. Diapophyses become progressively reduced posteriorly, at their most posterior positions they project as small mastoid processes, and ultimately disappear by Cd16. Their position on the centrum also varies, for on the anterior series they are placed extremely anterolaterally, but posteriorly progressively migrate to a mediolateral position.

Anterior caudal neural spines are high and rod-shaped with very slightly expanded apices that resemble a chisel. From Cd8 posteriorly the spines become laterally compressed and lose their expanded termini. Spines progressively lower anteroposteriorly but at Cd11 initiate a rapid trend toward descent. Conforming with the trend of the centra from Cd8-Cd11, the spines also reduce in height by one-half. Initiating with Cd12, the spines compose thin plates that become progressively more posteriorly inclined and by Cd23 consist of an anteroposteriorly elongated ridge.

Pre- and postzygapophyses are in tight articulation at a 45° angle to the dorsal spines. This angle progressively expands posteriorly, and by Cd16 the zygapophyses become short, horizontal, and do not extend beyond the articular surfaces of the centrum. Ventral facets for contact with the haemal arch are conspicuous, although they are unclear on the anterior centra due to the condition of preservation; but it is generally recognized that the first three caudals on stegosaurs lack heamal arches. Four haemal arches are preserved although only one is complete and, according to excavation records, is associated with the fourth caudal. The haemal arches are relatively short although that on the fourth caudal is long with a 6.2 cm length and a 3.4 cm distal breadth. It is a Y-shaped element with two widely spaced pressure facets for fusion to the centrum but has yet compose an osteological bridge. The haemal canal is bounded by extremely large triangularly shaped plates. Anteriorly, there is a slender and small longitudinal ridge that does not extend to the posterior end.

The pelvic girdle is represented by a fused right ilium, sacral centra, and postacetabular process of the left ilium, none of which has shifted in position. In addition, there is a proximal right pubis, left prepubis, and distal ends of the right pubis and left ischium. The preacetabular crest is long and laterally compressed while the postacetabular process is short, thick, and triangular. From a lateral perspective the dorsal margin is nearly crescentic with the preacetabular crest extending anteroventrally. From a dorsal perspective, the preacetabular crests on both sides extend anterolaterally with a smooth and flat dorsal surface that displays bluntly rounded and constricted termini. Ventrally there is a conspicuous laminar ridge. Pubic and ischial shafts are solidly fused to the ilium. The acetabulum is conspicuously small, shallow, and flat with a coarsened surficial texture.

A 24 cm and 14 cm pair of fused elements represent the solidly club-shaped distal of the left and right pubes and ischia. The posterior processes of the ischia and pubis are equivalent in length, and the distal pubis is very slightly expanded, unlike the distal ischium which is not. The base of the prepubis is broadened while the anterior end becomes narrow and plate shaped.

Only 16 cm of a left humerus represents the forelimb of *C. jiangbeiensis* with a distal end that is particularly expanded and an intercondylar notch that is present as a shallow depression. The morphology and size of the two condyles are completely consistent, with extremely smooth and rounded articular surfaces. From a posterior perspective, it appears as if the medial condyle is slightly larger than the lateral condyle, but from a lateral perspective the two condyles cannot be distinguished. The humeral shaft is relatively well developed, circular in cross-section and lacks curvature. The missing proximal portion should constitute approximately 16 cm of shaft and head, or one half the total length.

Table 21. *Chungkingosaurus jiangbeiensis* humerus measurements (cm).

Shaft breadth	4.9
Distal breadth	14.2
Medial breadth	6.5
Lateral breadth	6.3

The hindlimb is represented by a complete pair of femora, a left tibia, proximal and distal ends of fibula in contact with the left tibia, and three left metatarsals which display diagnostic characters despite their weathered condition.

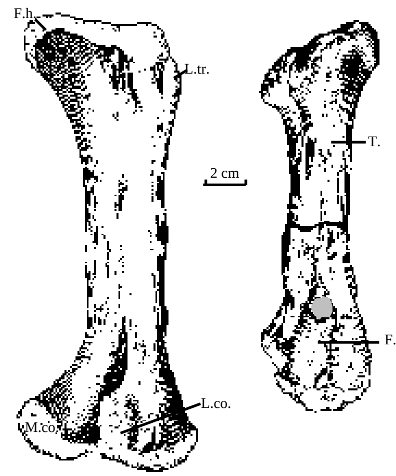


Figure 94. Lateral view of *Chungkingosaurus jiangbeiensis* femur, left tibia, and fibula.

The femora are 44 cm in length, being distinctly short and small with a tubular and straight shaft which lacks a fourth trochanter. The proximal end is surficially coarsened with an undeveloped greater trochanter but well developed lesser trochanter that resembles an inflated digit-shaped ridge. Distally, the medial condyle is larger than the lateral condyle, a trochlea is relatively smooth and well developed to compose a broad and shallow trough, and a shallow groove lies on the lateral side of the lateral condyle to facilitate supporting musculature. The femur-humerus ratio is approximately 1.6.

The tibia and fibula are incomplete as the tibia preserves 35 cm but has a weathered distal end. Compared to *Tuojiangosaurus* and *Chialingosaurus,* the tibia is distinctly more robust. During the process of fossilization both the tibia and fibula were preserved cemented together although the midsection of the fibula shaft has been lost. The femur-tibia ratio is 1.26 indicating a proportionally long tibia (on *Stegosaurus* the femur-tibia ratio is 1.68). The proximal tibia is expanded, not laterally compressed, displays a coarsened surficial texture, maintains a well developed fossa to facilitate contact with the proximal fibula, and anteriorly possesses a shallow trough to facilitate musculature. Distally, the tibia is laterally compressed and, from the perspective of its weathered surface, appears to have been fused with the astragalus and calcaneum.

Table 22. *Chungkingosaurus jiangbeiensis* tibia and fibula measurements (cm).

Length	35.0
Proximal breadth	14.7
Distal breadth	15.0
Midshaft breadth	6.2

Three metatarsals are preserved which are identified as MtII, III, and IV. The largest is MtIII, which is medially constricted, very gently laterally oblique, but medially precipitous. MtIV is small with a distinctly constricted midshaft, a proximal end more expanded than distal end, medial side is precipitous, but lateral side is gently curved. The lines representing the two opposing angles of the shaft, proximolaterally and distomedially, have a tendency to elongate. The distolateral side of MtIII and the distomedial side of MtIV bear small tuberosities. Proximal inflations on all the specimens are well developed.

Five armor plates are preserved, among which three are relatively complete while the other two preserve only their bases. In general morphology they resemble those on the dorsal and sacral region, and although *Chungkingosaurus* is a small individual, its large and thick armor is one of its defining characters. The dorsal armor is pear-shaped in outline with a constricted, thin, and acute apex. Its base is extremely thick, transversely expanded, and anteroposteriorly elongated. Anterior and posterior margins are symmetrically curved. (Pl. XLII, Figs 3&4). In outline the sacral armor is a triangular spike, is higher and larger than the dorsal armor, and gradually tapers

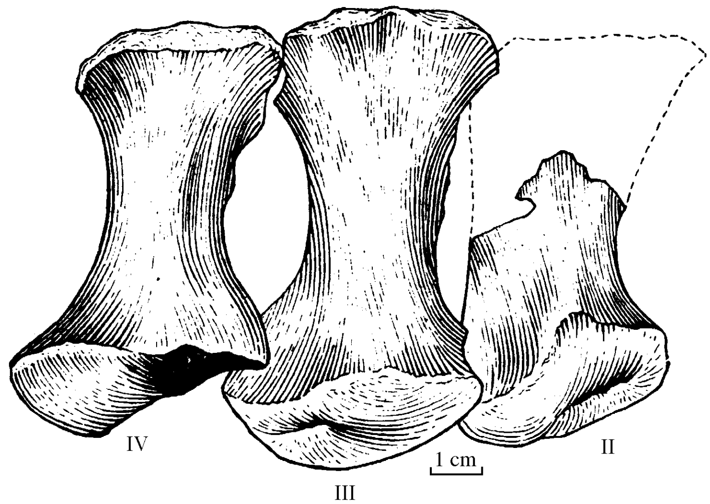


Figure 95. Anterior view of *Chungkingosaurus jiangbeiensis* metatarsals II,III, and IV.

and thins dorsally to terminate with an acute edge. The base is transversely expanded with surficial striations to facilitate musculature, and at its midsection it becomes thickened with undulating folds. The anterior margin contacts the base with an acute angle, one side of the base is high, while the other is low. This element is interpreted as belonging on the left side.

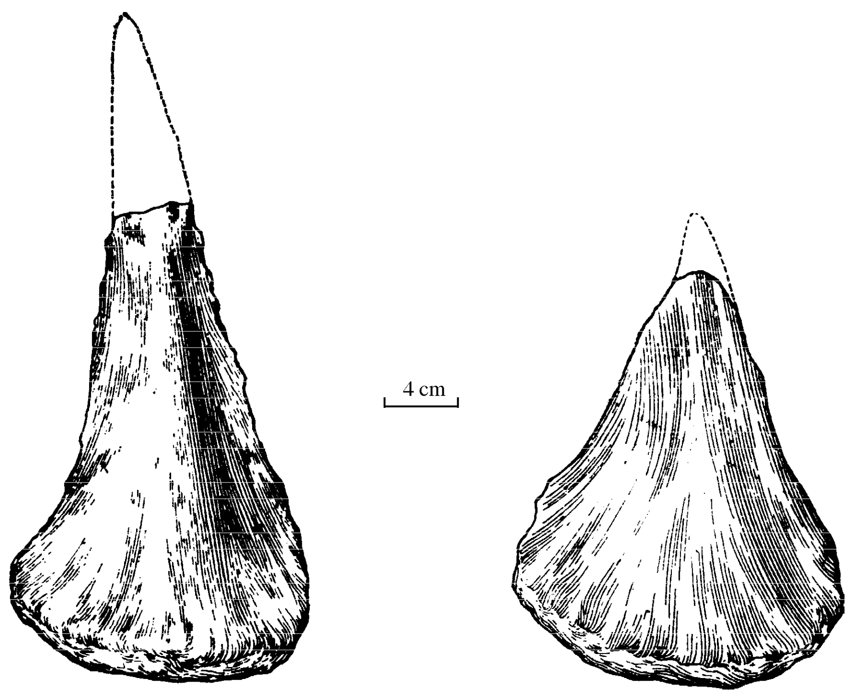


Figure 96. Right lateral view of *Chungkingosaurus jiangbeiensis* dorsal armor.

Diagnosis and discussion: Skeletal characters of *Chungkingosaurus jiangbeiensis* undoubtedly assign the specimen to the family Stegosauridae. A further assignment to the higher rank of Stegosaurinae is based upon characters such as the 45° angle between neural arches and diapophyses on dorsal vertebrae; diverse morphology of the tall, high, and large armor; a straight, slender, and long femur; fused sacrum with a strengthened dorsosacral centrum; and well developed anterior process of ribs.

Table 23. *Chungkingosaurus jiangbeiensis* metatarsal measurements (cm).

Sequence	Length	Prox. width	Dist. width
II	—	5.0	—
III	8.5	5.2	4.2
IV	8.7	5.6	4.4

The sacrum is fenestrated, easily distinguishing it from the North American *Stegosaurus*, the East African *Kentrosaurus,* the European *Omosaurus,* and *Wuerhosaurus* from the Xinjiang Autonomous Region of China. In contrast, *Chungkingosaurus, Tuojiangosaurus* and *Chialingosaurus* from the Sichuan basin all share the character of a fenestrated sacrum indicating that the Sichuan stegosaurs predate *Stegosaurus* and *Kentrosaurus.* Numerous addition postcranial characters are shared between the three, although in cranial morphology they are all distinct (Table 23). *Chungkingosaurus* maintains a higher and narrower skull than *Tuojiangosaurus* and more closely resembles the outline of *Chialingosaurus.* The Jiangbei Co. specimen also displays a dentition in tight alignment but is not superimposed as on *Tuojiangosuarus* or loosely spaced as on *Chialingosaurus.* The two latter taxa are large stegosaurs approximately six to seven meters in length with basically symmetrical arrangement of armor. *Tuojiangosaurus* has a light series of armor composed of plates and spines suggesting a certain amount of agility. *Chungkingosaurus* is relatively small and regarded as an adult based upon its fused sacral centra, fused tibia and fibula, and condition of the tarsals. Thus, a small taxon of stegosaur that did not exceed four meters in length coexisted with *Tuojiangosaurus* and *Chialingosaurus.*

Chungkingosaurus sp. 1

(Plate XLIII, Figures 3&4)

Specimens: A complete pelvic girdle lacking the neural spines, acetabulum on left ilium, and the region posterior to it. A pair of ischia lacking their distal ends (CV00207)

Locality and stratigraphic position: Ouling Public Park in the municipality of Chungking; early Late Jurassic Upper Shaximiao Fm., Chungking Group.

Description: There are five strongly fused sacral centra present but only two-thirds of the dorsosacral centrum is preserved tightly coossified with the next posterior centrum. Diapophyses and ribs are well represented on all four sacrals. From a ventral perspective the four centra are nearly equivalent in length, with S1 as 7.2 cm, S2 and S3 as 6.5 cm, and S4 as 5.8 cm. Ventrally, the first sacral has a smooth and glossy shallow groove which deepens as it approaches the articular surface for the second sacral and is bounded by rounded lateral laminae running anteroposteriorly. The second sacral is rather expanded and flattened ventrally, while the ventral aspect of the fourth sacrum is rather conspicuously inflated. Centra broaden anteroposteriorly with S1 as 8.5 cm, S2 and S3 as 9.5 cm. and S4 as 9.7 cm. At every fusion point for the centra there is a laminar ridge resembling the nodes of bamboo. Three pairs of large elliptical fenestrae are present on the sacrum which perforate both the dorsal and ventral surfaces, with dorsal fenestrae larger than ventral fenestra. The neural arches are completely fused and swollen dorsally to compose an inflated anteroposteriorly directed rectangle. The bases of the dorsosacral and three anterior neural spines are fused, but the fourth sacral spine is isolated. It cannot be determined whether the apices of the spines are also fused. The diapophyses and ribs are fused and expand laterally into the distal yoke-shaped processes supporting the ilia.

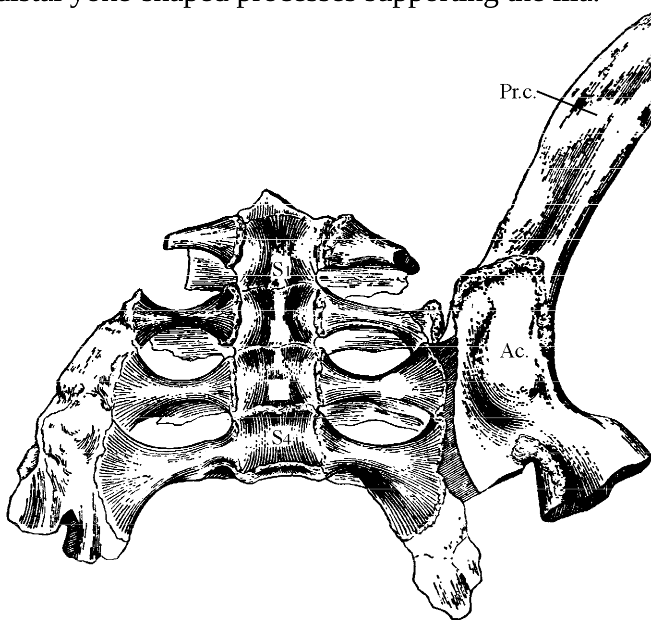


Figure 97. ***Chungkingosaurus*** **sp. 1** ventral view of pelvic girdle.

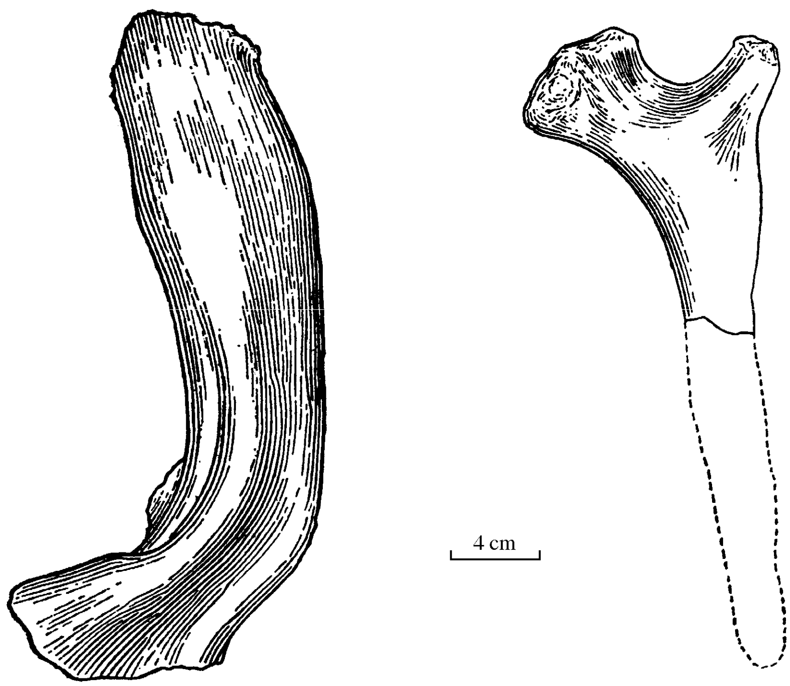


Figure 98. ***Chungkingosaurus*** **sp. 1** Lateral view of ilium and ischium.

The dorsal pelvic girdle is flat and expansive whereas ventrally it is concave. The maximum breadth at one side of the medial pelvic girdle is 34.0 cm (contrasted to 23.0 cm on *Tuojiangosaurus*). Including the ilia, the breadth increases to 58.0 cm (46.0 cm on *Tuojiangosaurus*). Only 67 cm of the preacetabular crest on the left ilium is preserved which extends anteriorly and curves ventrally to form a twisted plate with narrow margins, a thickened midsection, a concave medial surface, and a convex lateral surface. The preacetabular crest is 41 cm long, the pubic peduncle is a short, constricted plate-shaped process that extends ventrally, displays an unexpanded anterior end, is laterally flattened, and has a length of 7 cm and breadth of 10 cm. The contact surface of the pubic peduncle is coarsened. A depression lies ventrally between the pubic and ischial peduncles representing the acetabulum as a large, deep, elliptical, and a relatively smoothly textured fossa with diameters of 12.5cm and 9.5 cm. The ischial peduncle is extremely undeveloped with a coarsened contact surface which is shaped as a rounded rhomboid.

Left 37 cm and right 31 cm of the proximal ischia are present but the distal ends are missing. In outline they are Y-shaped with two proximal nodes for the contact with the pubis and the ilium, The contact for the ilium is large, inflated, and subtriangular with a coarse surficial texture. The ischial shaft is thin and flat, which differs from both the Jiangbei specimen and *Stegosaurus.*

Chungkingosaurus sp. 2

Specimens: CV00205 consists of four caudal vertebrae, a right humerus, a pair of femora, damaged sacral vertebrae, and several fragmentary unidentifiable elements, all which undoubtedly represent a single individual.

Locality and stratigraphic position: Huayibo, central Chungking municipality,; Early Late Jurassic Upper Shaximiao Fm., Chungking Group.

Description: First four anterior caudal vertebrae are identified based upon their morphology and excavation records. Three of the four specimens are nearly complete while the fourth has a complete centrum but has lost its neural spine and diapophyses. Centra are amphicoelous with shallow anterior and deep posterior articular surfaces. Centra bodies are thick and elliptical with the first caudal centrum being largest, and others gradually reducing in size posteriorly.

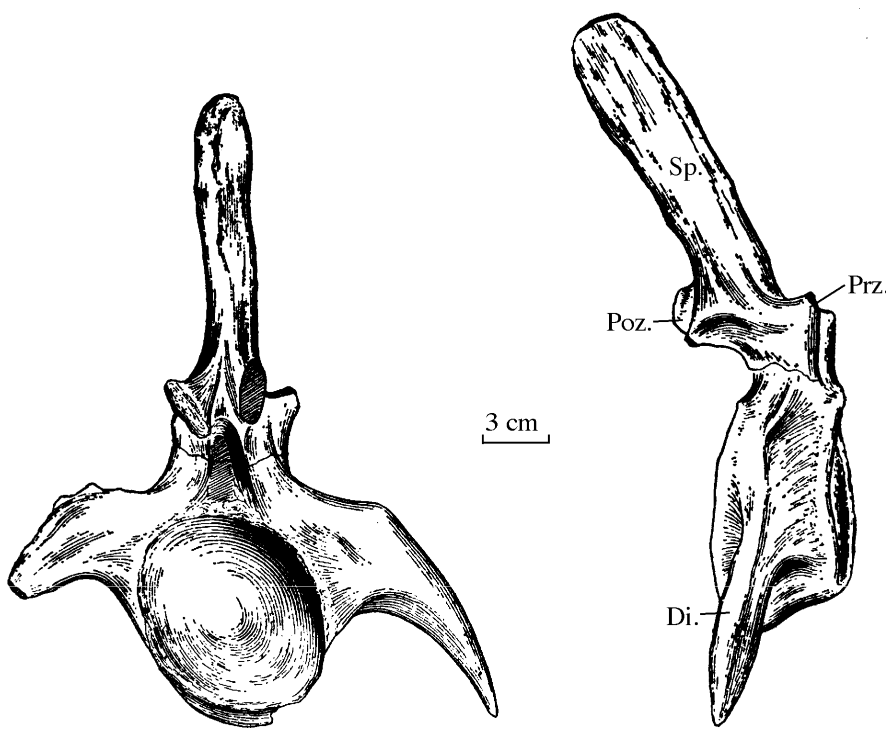


Figure 99. Anterior and lateral view of *Chungkingosaurus* sp. 2 second caudal vertebra.

Table 24. ***Chungkingosaurus*** **sp. 2 caudal vertebrae measurements (cm).**

Sequence	Length	Post. breadth	Neural spine
1	5.4	9.5	9.0
2	5.2	9.2	8.0
3	5.2	8.9	20.5
4	5.1	9.1	—

Humerus morphology is extremely close to *Tuojiangosaurus*, with a short and robust shaft, termini are expanded and lie on different planes due to the curvature of the shaft, the proximal end is broad and thick with a large elliptically rounded medial inflation, and anterodorsal margin expands with a fold that envelopes an extremely deep medial trough. Maximum width is 7.2 cm and minimum width is 5.3 cm. At the expanded distal end there is a single condylar process with a 5.1 cm diameter. Posteroproximolaterally are two condylar processes, one is 5.1 cm in diameter and the other has a transverse diameter of 13.2 cm. A large depression with a smooth and glossy surface is located between the condylar process and medial side of the humerus. A longitudinal depression lies posteroventromedially which resembles the femoral trochlea and divides the distal end into well developed lateral and medial condyles with smooth and rounded articular surfaces. The medial condyle is larger than the lateral condyle.

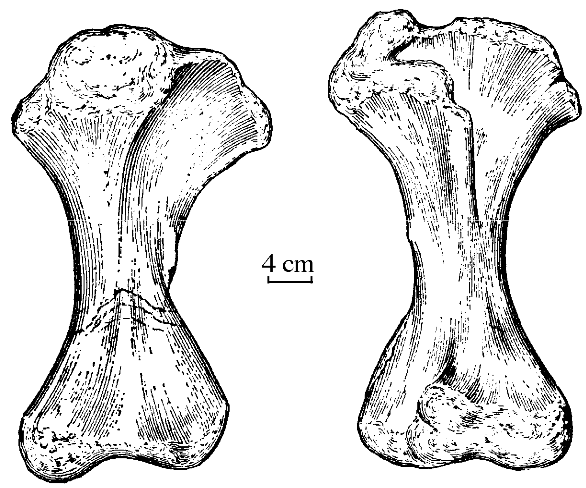


Figure 100. Anterior and posterior view of *Chungkingosaurus* sp. 2 right humerus.

Only a fragmentary 14 cm piece of what is assumed to be a distal radius is preserved, with a coarsely textured distal end expanded to a 10.4 cm diameter and a nearly flat articular surface for the radiale. Proximally, the shaft becomes reduced to a 3 cm diameter.

The hindlimb preserves a complete left femur, a right femur missing its proximal end, and a left tibia and fibula preserved in articulation. The 67 cm left femur is narrow and long, with a thin and flat shaft, and nearly equivalently expanded termini. The proximal end is relatively well developed but a lesser trochanter is absent. From a posterior perspective, the distomedial condyle is larger than the distolateral condyle, both of which are separated by a relatively deep trochlea. The humerus-femur ratio is 1:1.62.

Table 25. ***Chungkingosaurus*** **sp. 2 femur measurements (cm).**

	Left	Right
Length	—	67.0
Prox. breadth	22.0	21.6
Dist. breadth	18.5	21.0
Medial shaft	8.1	11.0

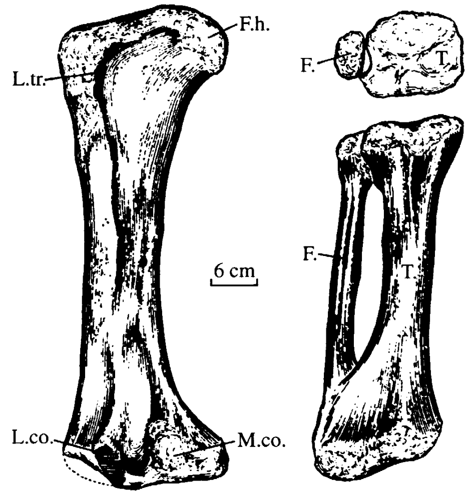


Figure 101. Posterior view of *Chungkingosaurus* sp. 2 left, femur, tibia, and fibula.

Distal tibia and fibula are completely fused although the proximal ends are not. The tibia is completely consistent with *Tuojiangosaurus*, being conspicuously thick and robust with an undeveloped cnemial crest, and a proximal articular surface that is nearly circular. The fibula shaft is gracile, weak, long, and does not differ in morphology from the typical stegosaurian morphology.

Discussion: Specimens CV00207 and CV00205 described above were derived from the middle to upper section of the Upper Shaximiao Fm. as was *Chungkingosaurus jiangbeiensis* gen. and sp. nov. All specimens were also recovered from the same geographical region of the municipality of Chungking. Characters shared between the specimens include equivalence in size, being four to five meters in length, similar robust skeletal morphology, and large, thickened spinous and plated armor. Moreover, they share femur-humerus ratios of 1.62-1.67, have a fenestrated sacrum, and a relatively expansive pelvic girdle. Consequently, specimens CV00205, 206, and 207 are congeneric. Species distinctions are recognized as follows:

C. jiangbeiensis (CV00206) is a particularly small individual, being nearly four meters in length with six fused vertebrae in the sacral region, five sacral centra, and a strengthened dorsosacral centrum. The acetabulum is shallow and flat while ischial and pubic shafts are rod shaped.

CV00207 is moderate in size with an approximate length of five meters, there are five fused vertebrae in the sacral region with four legitimate sacrals and a strengthened dorsosacral, it has a well developed acetabulum as an elongated depression, and a laterally compressed ischial shaft.

CV00205 is larger than the previous two specimens with an approximate length of over five meters, and an extremely well developed acetabulum, a relatively well developed greater trochanter on the femur, and a femur-humerus ratio that is slightly larger than the former two at 1.67. Furthermore, anterior caudal centra are thickened, neural spines are high and not expanded, and caudal ribs are particularly well developed as they extend past the ventral surface of the centra.

Although distinctions between the three specimens are clear, the latter two specimens are represented by fragmentary data and thus are insufficient for the erection of new nomenclature. Until more complete or supplemental data is recovered, these specimens are provisionally regarded with a numerical species status.

Chungkingosaurus sp. 3

Specimen: CV00208 consists of ten posterior caudal vertebrae with associated haemal arches, and three pairs of osteoderms. Notations made by the excavator, Yihong Zhang, state that the specimen was associated with a total of four pairs of caudal spines, the most anterior of which were lost due to weathering.

Locality and stratigraphic position: The municipality of Longshi, Hechuan Co, Sichuan; early late Jurassic Upper Shaximiao Fm.

Description: The vertebrae and spines are preserved in place with the three anterior osteoderms as compressed cones that are thickened medially and bear blade-shaped ridges on their anterior and posterior margins which become constricted at their apex to form acute blades. The terminal pair of osteoderms are conical with coarsened bases that are very slightly elongated and ascend posteriorly as acute conical termini. The base of each pair of caudal armor spans three vertebrae. Centra lengths do not vary greatly, neural spines gradually decrease in height posteriorly while vertebrae become more tightly articulated, and haemal arches are anteriorly long and straight while posteriorly they are short and curved. It is estimated that this specimen does not represent the terminal caudals and that there are still approximately eight additional terminal vertebrae missing. The ten centra are compressed and elongate, unlike the hexagonal terminal caudals of *Tuojiangosaurus* or *Stegosaurus.*

Table 26. *Chungkingosaurus* sp. 3 caudal vertebrae measurements (cm).

Sequence	Height	Basal breadth
2	43.0	13.0
3	34.0	12.0
4	22.0 (preserved)	4.0

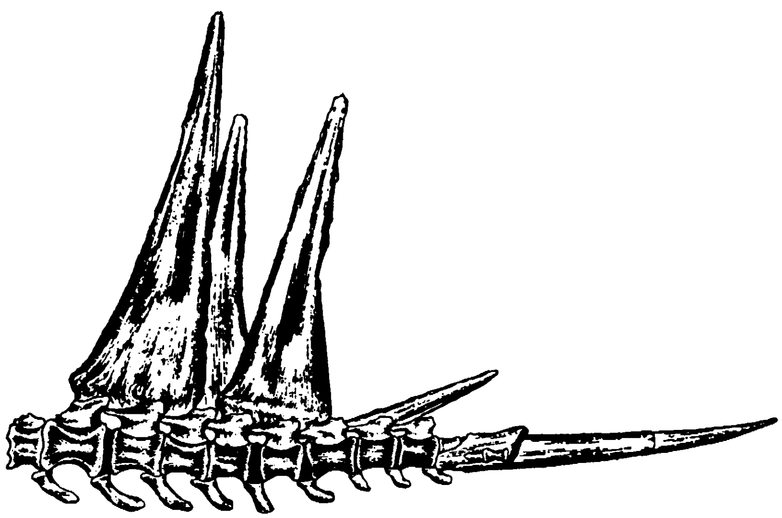


Figure 102. Lateral view of *Chungkingosaurus* sp. 3 caudal vertebrae and spines.

Diagnosis and comparison: The four pairs of caudal armor are aligned in opposition as compressed or acute cones. Each pair spans three compressed and elongated vertebrae which do not vary greatly in length. These characters assign the specimen to the subfamily Stegosaurinae, and is referred to *Chungkingosaurus.* sp. 3 due to its fragmentary nature.

Within the history of stegosaur research, there have been those who express skepticism regarding the presence of caudal osteoderms. But the accumulation of more recent data consisting of nearly perfect specimens has confirmed their presence. However, specimens such as the one recovered from Hechuan Co., which preserves caudal vertebrae and their associated spines in place, are indeed rare. In fact, this is the first occurrence of such a specimen in China and is here presented merely with a preliminary diagnosis. The discovery confirms the presence of four pairs of caudal osteoderms which contradicts the two pairs that are frequently illustrated in texts and which, in fact, may represent a character for North American stegosaurs.

V The significance of the dinosaur faunas in the Sichuan Basin.

(1) Early to Middle Jurassic faunas

A global marine transgression occurred in the Early Jurassic resulting in the general absence of terrestrial sedimentation. The rare terrestrial deposits that are recognized in this time period reflect xeric environments with depauperate faunas and floras. Vertebrates are particularly rare. It therefore appears that the once flourishing and abundant Triassic tetrapod faunas, including the prosauropods, became distinctly absent, reflecting a systematic decline of Early to Middle Jurassic terrestrial tetrapods. Among the European Early to Middle Jurassic dinosaurs are rare accounts in the English Channel region from marine sediments which record the Liassic *Scelidosaurus* and the Middle Jurassic *Megalosaurus,* both represented by fragmentary specimens that were shoreline inhabitants that drifted out to a marine burial.

In the Walloon series of New South Wales, Australia, Early Jurassic dinosaurs include *Rhoetosaurus* which co-occurs with plant-macro fossils. Longman (1927) initially interpreted the age to be Early Jurassic, but Arkell (19?), and Colbert (1975), both recognized it as a Middle Jurassic genus.

In the mid 1960’s Jain et al. (1964, 1975, 1977) reported on collections made from the Kota Fm. in India, the most notable genus being the large sauropod *Barapasaurus* which was diagnosed as Early Jurassic based on the presence of the typically Liassic fish such as *Tetragonolepis, Dapedium* and *Lepidotes.*

South Africa and North America both contain controversial Early to Middle Jurassic continental sediments that produce dinosaurs. Raath (1977) reported the presence of Sauropodomorpha from the Triassic-Jurassic boundary in Zimbabwe, while in North America their presence was recorded in the Newark Group. In South America, Bonaparte (1979) described three new cetiosaurines from the Middle Jurassic Roca Blanca beds. These data express the scarcity of Early to Middle Jurassic specimens and reflect the extremely limited knowledge of systematic relationships.

Abundant coexisting fauna should be present in sites that produce copious dinosaurs within a continuous sedimentary package. Vertebrate taxa adapted to the transition environments between terrestrial and marine facies such as Chelonia and Crocodilia should be present. Early Jurassic dinosaur data in Europe are extremely restricted due to their derivation from marine sediments, whereas the Triassic-Jurassic Newark Group in eastern North America which produces both dinosaurs and ichnotaxa and older sandstones that are devoid of fossil data may actually represent the Lower Jurassic. In Australia, sediments of this age and overlying sediments are discontinuous, fossils are undiagnostic, and there is controversy regarding geochronology. Paleontological data from the Kota Fm. of India is relatively abundant although nothing is recorded from sediments overlying or underlying this formation. Consequently, the only localities representing continuous Triassic-Jurassic sedimentation with an abundant fauna are the Sichuan Basin and Junggar basins in China.

Mesozoic terrestrial sedimentation in Sichuan initiates with the Late Triassic Shunjiahe Fm. and continues with the Early Jurassic Zhenzhuchong Fm, the Early to Middle Jurassic Ziliujing Fm., the Middle Jurassic Xintiangou and the Lower Shaximiao fms., and the Late Jurassic Upper Shaximiao, Suining, and Penglaizhen formations, for a combined thickness of two to three thousand meters of typical fluviolacustrine clastic sediments. Nearly all classes of biota are represented in these sediments with the Dinosauria being particularly abundant. Table 1 illustrates the relationships between the three dinosaur faunas in addition to coexisting taxa typical of European Jurassic marine sediments such as *Lepidotes*, the teleosaurid *Peipehsuchus*, the pliosaur *Bishanopliosaurus,* and the chelonian *Plesiochelys,* which are reliable index taxa.

Lithologic characters for each of these deposits have already been addressed in Chapter 2 (Fig. 3) and a synopsis of the three dinosaur faunas has been conducted. Within the Sauropoda, the genus *Shunosaurus* is recognized as an Early to Middle Jurassic transition form providing further data for sauropod evolutionary relationships. Primitive stegosaur specimens from the Lower Shaximiao Fm. provide data for the understanding of the evolutionary relationships between the Upper Shaximiao *Chialingosaurus* and *Tuojiangosaurus.* The *Shunosaurus* Fauna has a derived quality to it supplementing the comprehension of Early to Middle Jurassic dinosaur evolutionary stages.

(2) Early sauropod evolutionary relationships.

Lull (1914), in his discussion of Late Jurassic dinosaur faunas, proposed that only the more derived taxa were significant toward the diagnosis of stratigraphic ages, and therefore, the most significant evolutionary trend is the increase in body size. The Carnosauria was not regarded as biostratigraphically significant although sauropods were, as they developed unusually rapidly and dramatically from the Early Jurassic; are predominantly recovered from the Jurassic and Cretaceous, represented by numerous complete skeletons (such as *Diplodocus*, *Barapasaurus Brontosaurus* [*Apatosaurus*], *Brachiosaurus*, *Camarasaurus,* and *Mamenchisaurus*); and are also produced extensively from nearly every continent (excluding Antarctica). They attain the apex of their radiation in the Late Jurassic and begin to diminish in the Cretaceous with only the superfamily Homalosauropodidae extending into the Late Createceous. Evolutionary relationships of later sauropods are more clear than early sauropods, particularly from the Early to Middle Jurassic, as current knowledge of this time period is depauperate due to the lack of sediments and specimens. Therefore, the presence of *Shunosaurus* in Sichuan provides evidence for Early to Middle Jurassic morphological and evolutionary development.

The origins and evolution of the Sauropoda has been addressed by numerous workers, (Heune 1914, 1956; Romer, 1956; Charig et al., 1965; Raath, 1972; Cruickshank, 1975). Huene believed that the bipedal Triassic prosauropods were ancestral to the massive quadrupedal Jurassic sauropods, which is the concept that has been adopted by the majority of workers (Young, 1958; Romer, 1956). But the increase in paleontological data has extended the origin of the Sauropoda further back than previously visualized, such that now some recognize them as co-existing with the Prosauropoda (Charig et al, 1965), and as such, it is believed that no direct relationship exists between these two infraorders, and that they may represent convergence. A comparison of sauropod and theropod tarsals and vertebrae indicate shared characters and suggest that instead of being derived from prosauropods, the sauropods were derived directly from Middle to Late Triassic quadrupedal thecodonts.

Raath (1977) described the saurischian *Vulcanodon karibuensis* from the Triassic-Jurassic boundary of Zimbabwe and believed it to be ancestral to the Sauropoda. He described 20 characters shared between the Sauropoda and Prosauropoda but he ultimately made a taxonomic assignment to the Prosauropoda.

Galton (1976) conducted a systematic review of the North American prosauropods and proposed that several members of the Plateosauridae extended into the Early Jurassic, which is now confirmed in the Zhenzuchong Fm. in Sichuan and the Lower Lufeng Fm. in Yunnan Province. Currently, the co-occurrence of prosauropods with true sauropods is a concept that is not easily dismissed.

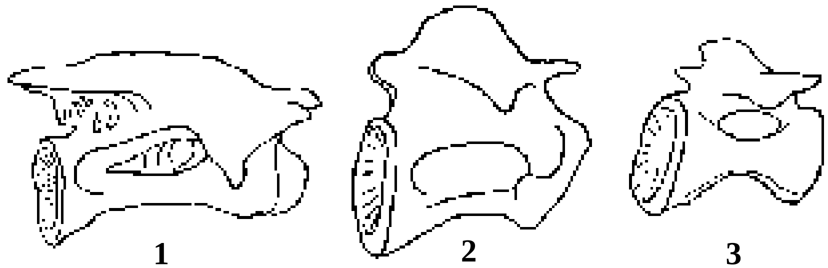


Figure 103. Evolution of prosauropod to sauropod cervical vertebrae.
1. Prosauropoda. 2. Primitive sauropod (*Shunosaurus*). 3. Late Jurassic sauropod (*Omeisaurus*).

Table 27. Comparison of three phases of sauropod evolution.

	Prosauropoda- *Lufengosaurus*	Primitive Sauropoda- *Shunosaurus*	Sauropoda- *Mamenchisaurus*
Cervical vertebrae	Long, amphiplatyan, anterior condyle absent, pleurocoels absent, centrum strong, simple neural spine morphology	Long, opisthocoelous, anterior condyle very slightly developed, neural arch low and simple in morphology, centrum strong and lacks pleurocoels	Long, opisthocoelous, anterior condyle well developed, large fenestrated pleurocoels, neural arch high, neural spine complex in morphology
Dorsal vertebrae	Short, amphicoelous, centrum strong, pleurocoels absent, simple plate-shaped neural spine	Amphyplatyan, very slight pleurocoels, centrum strong, high baton or plate-shaped neural spine	Opisthocoelous, anterior condyle well developed, pleurocoels well developed and fenestrated, neural arch high, neural spine morphology complex
Sacral vertebrae	Three fused sacrals, sacral spines unfused	Four fused sacrals, sacral spines unfused	Four fused sacrals, three anterior spines fused
Pelvic girdle	Ribs low, ilium thick and strong, ischium and pubis thick and strong	Ribs more elevated and thinned, pubis and ischium relatively thick and strong and have become plate-shaped	Ribs high, prepubic process long, ischium and pubis plate shaped
Forelimb	Short, humerus curved, shaft inconspicuous, carpals and digits complete	More elongated, humerus straight, digits incomplete, digit V reduced	Humerus straight, digits incomplete
Hindlimb	Femur curved, circular in cross-section, femoral head distinct, astragalus-calcaneum coossified	Femur straight, elliptical in cross section, femoral head semi developed, calcaneum simplified	Femur straight, strongly elliptical in cross section, calcaneum well developed

Charig et al. (1965), upon discussing the origins of sauropods, proposed the South African genus *Melanorosaurus* as the closest common ancestor, but as the type is fragmentary, they could not confirm their hypotheses. In summary, there is a lack of reliable data regarding the origin and evolution of early sauropods and a legitimate sauropod has still not been recorded from the Rheato-Liassic Lufeng Saurischian Fauna. *Shunosaurus* retains numerous prosauropod plesiomorphies suggesting that Raath's theory was accurate. Thus, the Sauropoda originated in the Middle to Late Triassic out of a Prosauropod stock, passed through a primitive *Shunosaurus* phase and terminated in the massive Late Mesozoic forms with each of the three phases maintaining numerous ancestral descendant characters. This concept of gradualism conforms best to the evolution of this group.

Characters presented in Table 27 (p. 115) illustrate the transitional phase of the primitive sauropod *Shunosaurus,* which lies between the Late Triassic Prosauropoda and the Late Jurassic Sauropoda. An ancestral-descendant relationship exists between the Prosauropoda and Sauropoda, both of which were derived from a middle Late Triassic thecodont to diverge along separate lineages. The prosauropods are relatively conservative in maintaining a morphological consistency until their extinction in the Early Jurassic. In contrast, the sauropods represent a lineage which displays relatively rapid variation in morphological development and within their lineage traverse short and provisional stages resembling prosauropods, as witnessed in *Vulcanodon* and *Barapasaurus* which maintain a mosaic of characters shared between the Prosauropoda and Sauropoda. This mosaic is preserved until the early Middle Jurassic where it is conspicuous in *Shunosaurus,* as illustrated in Figure 104.

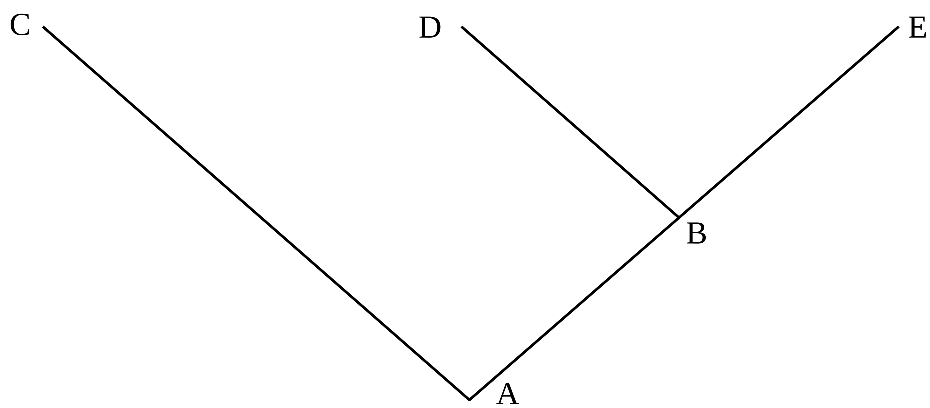


Figure 104. Phylogeny of the Sauropodomorpha.
A. Inferred Middle Triassic prosauropod; B. Primitive sauropod adapted to a new environment (Sauropodomorpha); C. Conservative Late Triassic Prosauropoda (Melanorosauridae); D. Derived pedicillate dentitioned forms (Atlantosauridae); E. Spatulate dentitioned forms (Camarasauridae).

The discovery of *Shunosaurus* suggests that the evolutionary trend of the Sauropoda initiated with a heightened skull and increased cranial weight, reduction of dentition size and broadening of tooth crown in association with limbs that increase in weight, resulting in the strengthening and plate-shaped tendency of the scapular and pelvic girdle, and finally followed by an increased complexity of the cervical and dorsal vertebrae.

(3) Evolution of the Stegosauria.

The Stegosauria is most commonly represented by species of the North American Late Jurassic *Stegosaurus* Marsh 1877 (*Hypsirhophus* Cope, 1878), and represents the most thoroughly studied genus, as undertaken by Gilmore (1914). Also notable is the East African *Kentrosaurus* (*Kentrurosaurus* Hennig 1916; *Doryphorosaurus* Nopcsa 1916) from the Tendaguru

Table 28. Comparison of several genera of stegosaurines.

	Stegosaurus	*Kentrosaurus*	*Omosaurus*	*Chialingo-saurus*	*Wuerhosaurus*	*Tuojiango-saurus*	*Chungkingo-saurus*
Occiput	Low	High		High		High	High
Supraorbital	Inflated tuberosities	Inconspicuous tuberosities				Pustulated tuberosities	
Dentition	Symmetrical, not superimposed	Small, symmetrical		Small, symmetrical, not superimposed		Numerous, asymmetrical, superimposed	Numerous, asymmetrical, not superimposed
Dorsal vertebrae	Pleurocoels absent	Pleurocoels absent	Pleurocoels present	Pleurocoels absent	Pleurocoels absent	Pleurocoels absent	Pleurocoels absent
Caudal spine	High, expanded apex	High, unexpanded apex	High, unexpanded apex	High, unexpanded apex	High, expanded apex	High, expanded apex	High, unexpanded apex
Pelvic girdle	Bolstered centra, incomplete dorsal S4 fusion, perforated	Bolstered centra, sealed dorsal region	Bolstered centra, sealed dorsal region	Narrow pelvic girdle	Bolstered centra, completely sealed sacrum	Unbolstered centra, 3 pair of fenestrae	Bolstered centra, incompletely sealed, 4 pair of fenestrae
4th trochanter on femur	Absent	Inconspicuous or vestigial	Present	Vestigial		Present	Absent
Femur-humerus ratio	1.8-2.3	1.6-1.68	1.44	1.6		1.57	1.62-1.67
Armor morphology	Large, plate-shaped	Spinous	Plate shaped and spinous	Spinous	Large, Plate-shaped	Plate-shaped and spinous	Plate-shaped and spinous

Fm. of Tanzania which is also regarded Late Jurassic. These two genera are represented by relatively complete collections, share numerous characters, particularly in the post crania, and are distinguished from each other most notably by the morphology and configuration of their osteoderms. The former genus predominantly displays plate shaped dorsal armor aligned in an alternating sequence and the latter displays predominantly spinous armor aligned symetrically in opposition. Femur-humerus ratios are also distinct with *Stegosaurus* as 1.8-2.3 and *Kentrosaurus* at 1.60-1.68 suggesting that the former is more derived.

In Europe, the Stegosauria are known from numerous localities and stratigraphic positions although the data is extremely fragmentary. *Omosaurus,* frequently recorded in Kimmeridgian age sediments, was initially erected by Owen (1875) from what was identified as a species of phytosaur by Leidy (1856). Lucas (1902), later proposed the reassignment to *Dacentrurusaurus.* As Liedy's nomenclature was a synonym for a phytosaur Owen's nomenclature was adopted for Kimmeridgian stegosaurs. *Omosaurus* possesses predominantly spinous armor but also maintains plated armor and has a forelimb-hindlimb ratio of 1.24. Nopcsa (1911) described *Omosaurus lennieri* from the vicinity of Heve peninsula in northern France. Lapparent (1946) and Zbyssewski (1957) later described *O. armatus* and *O. lennieri* from Portugal. Hoffstetter (1957) recognized two European Late Jurassic levels that produced Stegosauria: the Kimmeridgian Stage *Omosaurus,* and Callovian Stage specimens, which are numerous but fragmentary, and from osteoderm morphology may be distinguished from *Omosaurus* as the genus *Lexovisaurus.*

The Stegosauria in Asia were discovered comparatively later with the first record consisting of Wiman's (1929) description of a single plated osteoderm from the Mengyin Fm. of Shandong Province. More complete specimens were later recovered such as *Chialingosaurus,* produced from the Sichuan Basin in 1957, which C.C. Young believed resembled *Kentrosaurus,* and as such, used the African genus as a model for skeletal reconstruction, even though *Chialingosaurus* maintains characters that reflect a more conservative genus. *Wuerhosaurus* is a typical stegosaur derived from the Early Cretaceous Tulugu Group of Xinjiang Autonomous Region. The distinct nature of these two genera is probably due to their temporal discrepancies.

Recently, the Chungking Museum of Natural History made a collection of stegosaur specimens from the Sichuan Basin which is described in this text and may be regarded as the largest and best preserved specimens representing the Asian Stegosauria to date. Within this collection are relatively complete specimens of *Tuojiangosaurus, Chialingosaurus,* and *Chungkingosaurus,* in addition to relatively complete distal caudals with three pair of osteoderms (CV00208) for a total of eight individuals (Table 28 p. 114).

The Stegosauria represents a relatively early radiation of ornithischians which probably initiated with a lineage approaching *Scelidosaurus* in the Late Triassic or Liassic (Hoffstetter, 1957; Steel, 1969). Dollo (19??)believed the ancestral stegosaurs would probably possess a primitive ornithischian skull with foliate dentition, relatively numerous low and thick osteoderms, and would probably be small and bipedal.

Hoffstetter (1957) believed Europe to be the genesis for the Stegosauria due to the presence of the two Liassic genera *Scelidosaurus* and *Lusitanosaurus,* and that the Callovian Stage *Lexovisaurus* constituted the center of evolution for the radiation of the three Late Jurassic stegosaurs. Thus, his interpretation of the lineage would read *Scelidosaurus* — *Lexovisaurus* — *Stegosaurus, Omosaurus, Kentrosaurus.*

The morphology of *Lexovisaurus* approaches that of *Kentrosaurus* to the extent that Hoffstetter (1957) considered the possibility that it was a subgenus of the latter. The spinous osteoderms of *Chialingosaurus* also resemble *Lexovisaurus* and as it is generally contemporaneous, the cranial and armor morphology suggests a close affinity between the

European, East African, and Asian stegosaurs. These relationships may be illustrated as in Fig. 105.

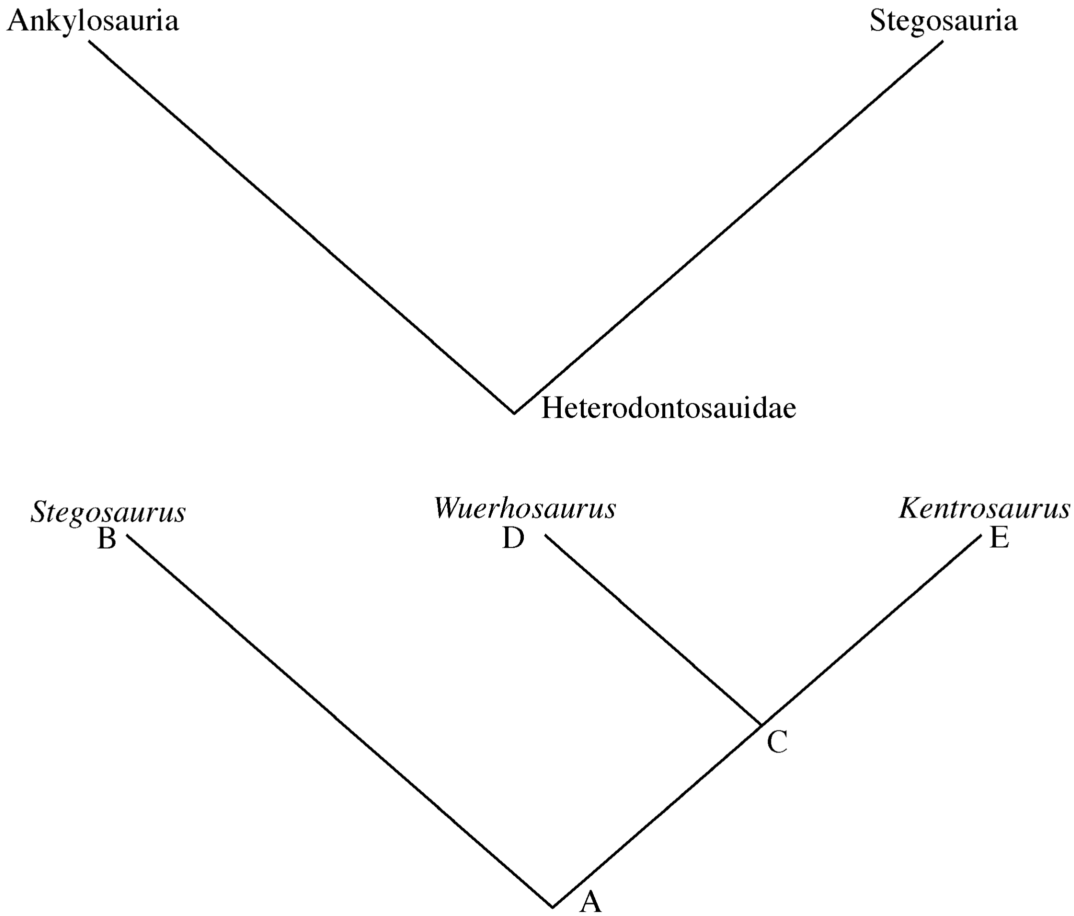


Figure 105. Phylogeny of the Stegosauria.

It is generally believed that an intimate relationship exists between the Stegosauria and Ankylosauria. Huene (19??) and others have suggested that from the middle to the Late Cretaceous, the ankylosaurs arose from a common ancestor with the stegosaurs and competed for the ecological niches of the stegosaurs promoting the extinction of the latter. The genus *Scelidosaurus* is commonly referred to the Stegosauria although recent reevaluation suggests that it possesses an ankylosaurid pelvic girdle. The fenestrated pelvic girdle of *Sichuanosaurus* is also ankylosaurid (Fig. 89). The genesis of both these ornithischians occurred probably in the Late Triassic from a small quadrapedal armored ornithischian that strengthened its pelvic morphology in the Early Jurassic due to a requirement for bipedality. Sacral diapophyses and ribs became fused to compose the scelidosaur morphology and due to divisions in ecological niches, the ankylosaur and stegosaur lineages diverged. The ankylosaur group occupied a niche of low vegetation, their bodies became lower and more broad, and osteoderms increased in number while becoming thicker. The stegosaur group occupied forested plateaus, their bodies increased in height, armor reduced in quantity while spines increased in height or modified to become plate-shaped.

One branch of the ancestral stegosaurs was represented by a diverse morphology of osteoderms and fenestrated sacrum which gave rise to a group that reduced its osteoderms in number to be aligned in an alternating plate-shaped arrangement and represent *Stegosaurus*. A second lineage developed a more gracile torso with spinous osteoderms to represent *Kentrosaurus*.

Several stegosaur plates were collected by Xinlu Ho of the Chengdu Academy of Geology from Laorungou at Jiangjinji Commune from the Middle Jurassic Shaximiao Fm. of the Sichuan Basin. In 1980 additional stegosaur specimens were collected from the *Shunosaurus* quarry of Dashanpu, Zigong Co., among which are two relatively well preserved skulls that are in the process of preparation and reconstruction. In 1979 one of the authors (Dong) attended a Triassic field conference in the southern Alps, where he was informed that S.L. Jain from the Indian Institute of Geology was in the process of studying Stegosauria from the Jurassic Kota Fm., which confirms the presence of the family in the Early to Middle Jurassic of South Asia.

There are three genera of small ornithischians recorded from the Lower Jurassic Lower Lufeng Fm.: *Dianchungosaurus*, *Tawasaurus*, and *Tatisaurus*. This indicates the possibility for an East Asian genesis for the Stegosauria, although future confirmation through actual specimens is required.

Postscript

In 1979 when this manuscript was being completed, a tooth was illustrated as belonging to *Shunosaurus*. Subsequently, in 1980 Xijing Zhao studied a collection from the Chaya Group around Qamdo, Tibet, which included twelve teeth of this same morphology, and which he assigned to the sauropod *Lancangosaurus*. Characters for the genus include being a large sauropod over 15 m in length with a large skull, large spoon-shaped dentition that gradually decreases in size posteriorly, a thick mandible, and robust limbs. There is no doubt that the teeth from Zigong Co. belong to this genus and the new data confirms the diagnosis conducted above. The presence of this genus in both the Sichuan and Changdu basins confirms contiguous sedimentation in both eastern Tibet and Sichuan with both regions sharing a *Shunosaurus* Fauna.

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[*] As numerous references in the Chinese text were omitted from the Bibliography, this translation lists the omissions with an asterisk followed by a brief description of the subject matter in parentheses in order to inform the reader that the literature exists but a complete citation is unkown at this time.-wd

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