VOLUMINA JURASSICA, 2011, IX: 21–42

# Dinosaur assemblages from the Middle Jurassic Shaximiao Formation and Chuanjie Formation in the Sichuan-Yunnan Basin, China

Kui LI[1], Jian LIU[1], Chunyan YANG[1], Fang HU[1]

**Key words:** dinosaurs, Shaximiao Formation, Chuanjie Formation, Sichuan Basin, Yunnan Basin, Middle Jurassic.

**Abstract.** The Shaximiao Formation (Sichuan Basin, China), and the corresponding Chuanjie Formation of the neighboring Yunnan Basin (Sichuan-Yunnan Basin), representing continental Mesozoic strata, are distinguished from other Chinese Mesozoic units because of the large area over which they are distributed, their lithological characteristics and their abundant vertebrate fossils. This paper analyses and summarizes the dinosaur fossils from the Shaximiao Formation and compares them to other vertebrate groups of the same or similar ages, both in China and abroad. For the first time, this paper presents the viewpoint that the upper member of the Shaximiao Formation is of Middle Jurassic age (Bathonian–Callovian). Furthermore, we claim that the entire Shaximiao Formation is of Bajocian–Callovian age (middle-late part of Middle Jurassic). This conclusion is supported by the age inferred from invertebrate fossils and radiometric dating (165–178 Ma). The composition, evolution and geological age of the vertebrate fauna (particularly dinosaur fossils), as well as their comparison to the dinosaur fauna from the other parts of the Sichuan-Yunnan Basin (Chuanjie Fm.) is discussed. Middle Jurassic dinosaur assemblages from China show marked differences compared with other dinosaur assemblages in the world, and this is explained by geographical isolation.

## INTRODUCTION

The Sichuan Basin is a large Mesozoic basin in Central China, containing continental, often red-bed strata, of an alluvial-lacustrine origin. It extends southward to Yunnan Province, therefore one can also distinguish a larger Sichuan-Yunnan basin (Fig. 1). The profile of these strata is very thick (1500–4700 m in total) and spans the time interval from Late Triassic to Late Cretaceous. The Middle Jurassic Shaximiao Fm. (Fig. 1) is of the widest spatial extent of all Mesozoic formations in Sichuan Basin and contains the most abundant vertebrate fossils. So far, this formation has yielded over 75% of the total number of vertebrate fossil sites in the Sichuan Basin and 29 genera and 42 species of dinosaurs have been reported from the Shaximiao Fm. The aim of present paper is to characterize the composition of the Shaximiao vertebrate assemblages in order to compare them with other assemblages in the Sichuan Basin and elsewhere in order to determine their geological age and geographical distribution. In 1964, Yang Boquan and Sun Wanquan created the name “Shaximiao Beds” for the red strata outcropping in Shaximiao village, situated to the south of Hechuan County town. In 1957, the Petroleum Survey Team of Sichuan Geology Bureau divided this unit into the lower Shaximiao beds and the upper Shaximiao beds. These names were subsequently transformed by the Regional Geological Survey Team of Sichuan Province into the “lower Shaximiao Formation” and the “upper Shaximiao Formation”, separated by a characteristic bed of shale, rich in conchostracans. The stratotype of both “formations” is located still at Shaximiao village near Hechuan. These names have been used from 1962 until today as informal lithostratigraphic units, although they are not in agreement with international lithostratigraphic standards. Consequently, these names should be revised. Provisionally, we propose to use only the name Shaximiao Formation, including both the “lower” and “upper” Shaximiao Formation

[1] Museum of Chengdu University of Technology, Chengdu 610059, China; e-mail: likui9988@sina.com

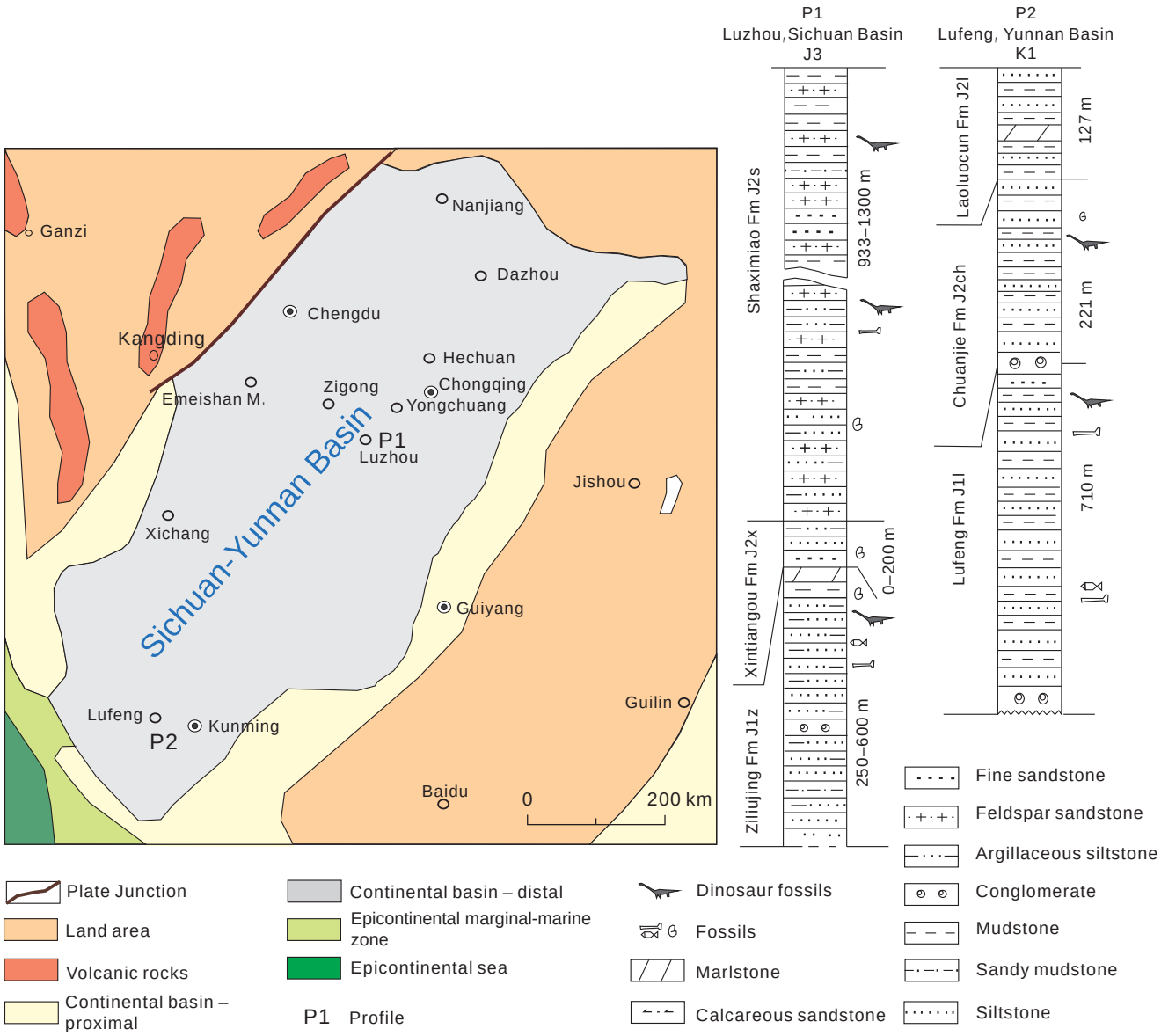



**Fig. 1. Middle Jurassic paleogeographic map of the Sichuan-Yunnan Basin and lithostratigraphical profiles of the Middle Jurassic in the Sichuan-Yunnan Basin with location of dinosaur-bearing strata**

(Fig. 1). Consequently, we suggest that provisionarily lower and upper members of the Shaximiao Formation (currently unnamed) should be introduced, to replace the "lower" and "upper" Shaximiao Fm. The Shaximiao Formation would be still divided into these two subunits by the conchostracan--bearing shale. Noteworthy, most of the formation's invertebrate fossils, including bivalves, ostracods and conchostracans, come from this "conchostracan shale" occurring at the top of the lower member. Plant remains from the Shaximiao Formation were described by Wang *et al.* (2008).

## GEOLOGICAL BACKGROUND

In general, the Shaximiao Formation is composed of purplish-red mudstones, sandy mudstones and siltstones interbedded with yellow-grey sandstones. The lower boundary with the Xintiangou Formation is marked by the characteristic, medium-grained, cross-bedded Guankou Sandstone, while the upper boundary of the Shaximiao Formation is less conspicuous, and is placed where the variegated, dark-purplish mudstones, greenish clays and purplish sandstones

pass into the red mudstones of the overlying Suining Formation, which in turn passes into the Penglaizhen Formation (Wang *et al*., 2010). The sedimentation shows the conspicuous cyclicity of alternating mudstones and sandstones, and occasionally also carbonaceous intercalations. Sandstones (with total accumulate thickness of 650–2500 m in the whole profile) in individual layers show conspicuous cross bedding and are often of channelized character.

The lower member of the Shaximiao Formation shows a maximum thickness of 246.5 m. Its spatial extent is approximately bounded by the line linking Daxian-Chongqing-Luzhou (Fig. 1) and it extends to the west by less than 300 km, and only about 100 km in the Zigong and Weiyuan area, from the stratotype. The range to the east is wider, more than 300 km, and up to 600 km in Wanyuan area (Fig. 1).

The upper member of the Shaximiao Formation shows more conspicuous cyclicity of sedimentation expressed by alternating violet-purple mudstones with calcareous concretions and yellow-grey feldspar-quartz sandstones. The sandstones show differentiated grain size, which is a characteristic feature of the upper member of the Shaximiao Formation. Thick sandstone layers are usually divided into thinner beds, separated by mudstone intercalations. Sandstone bodies are usually lens-shaped, often bifurcated, and show different types of bedding from parallel to cross-bedding. Large-scale, low-angle cross bedding reflects probably lateral migration of channels, while scour-and-fill channel structures (occasionally with conglomerates) and cross bedding produced by migration of megaripples or sand waves are also common. This member gets thicker from the southwest to the northwest part of Sichuan Basin. It is thinnest in Renshou-Jingyan area (about 450 m), while to the northwest it attains 700–1200 m in thickness. The maximum thickness of the upper member is recorded from the Nanjiang and Wanyuan area (1900–2100 m).

The invertebrate fossils of the upper member of the Shaximiao Formation include ostracods, bivalves, conchostracans, and gastropods. Additionally, aquatic green algae (Characeae) have been found.

It should be pointed out that the division between the upper and lower members of the Shaximiao Formation is difficult to determine in the western part of Sichuan Basin (middle and south sections of Longmen Mountain to the front edge of the big snow mountain area – Hanyuan area) because of the absence of the "conchostracan shale". In the Dujiangyan area and Dayi area, the Shaximiao Formation and other Jurassic formations pass laterally into a 1100–1300 m thick set of alluvial fan deposits composed of conglomerates mixed with sandstones and mudstones, lying directly on the Triassic Xujiahe Formation.

## VERTEBRATE FOSSIL ASSEMBLAGE OF THE SHAXIMIAO FORMATION

### THE LOWER MEMBER

The famous vertebrate fossil assemblage, called the *Shunosaurus-Omeisaurus* assemblage (from the lower member of Shaximiao Formation) mostly comes from the middle, southern and eastern part of Sichuan Province – Dashanpu of Zigong and Jinji of Kaijiang (Young, 1954; Yang, Zhao, 1972; Dong, 1980; Dong *et al*., 1983, 1997; Dong, Tang, 1984; He *et al*., 1986, 1988; Li *et al*., 1997; Ye, Pi, 1997; Peng *et al*., 2005; Wang *et al*., 2010). The characteristic taxa of the *Shunosaurus-Omeisaurus* assemblage are the following:

Saurischia
- Theropoda
  - *Chuandongocoelurus primitivus* He, 1984 [1]
  - Coeluroidae gen. et sp. indet.
  - Megalosauridae
    - *Leshansaurus qianweiensis* Li et al., 2009
    - *Szechuanosaurus zigongensis* Gao, 1993
    - *Xuanhanosaurus qilixiaensis* Dong, 1984
    - *Kaijiangosaurus lini* He, 1984
    - *Gasosaurus constructus* Dong et Tang, 1984
- Sauropodomorpha
  - Cetiosauridae
    - *Shunosaurus lii* Dong et al., 1983 (see Dong *et al*., 1983; Zhang, 1988)
    - *Protognathosaurus oxyodon* Zhang, 1988
  - Mamenchisauridae
    - *Omeisaurus luoquanensis* Li, 1988
    - *Omeisaurus tianfuensis* He et al., 1984 (see He *et al*., 1984, 1988)
    - *Omeisaurus junghsiensis* Young, 1938
    - *Datousaurus bashanensis* Dong et Tang, 1983

Ornithischia
- Fabrosauridae
  - *Agilisaurus louderbacki* Peng, 1992
  - *Xiaosaurus dashanpuensis* Dong et Tang, 1983
- Hypsilophodontidae
  - *Yandusaurus multidens* He et Cai, 1983
- Stegosauridae
  - *Huayangosaurus taibaii* Dong, Tang et Zhou, 1982

Pterosauria
- Rhamphorhynchoidae
  - *Angustinaripterus longicephalus* He et al., 1983

[1] Note that *Chuandongocoelurus primitivus* was distinguished based on a tooth and is probably not a valid taxon

Testudines
- Chengyuchelyidae
  - *Chengyuchelys baenoides* Young et Chow, 1953
  - *Chengyuchelys zigongensis* Yeh, 1982
  - *Chengyuchelys dashanpuensis* Fang, 1987
  - *Chengyuchelys* sp.
  - *Sichuanchelys chowi* Ye et Pi, 1997
  - Chengyuchelyidae indet.
- Plesiochelyidae
  - *Plesiochelys jingyanensis*, Yeh et Fang, 1982
- Trionychidae
  - *Trionyx* sp.

Crocodyliformes
- Teleosauridae
  - *Teleosaurus* sp. He, 1984
- Goniopholididae
  - *Sunosuchus shunanensis* Fu et al., 2005
  - *Hsisosuchus dashanpuensis* Gao, 2001

Sauropterygia
- Pliosauridae
  - Pliosauridae indet.

Therapsida
- Tritylodontidae
  - *Bienotheroides zigongensis* Sun, 1986
  - *Polistodon chuannanensis* He, 1984
  - Tritylodontidae gen. et sp. indet.

Beside reptilians, the *Shunosaurus-Omeisaurus* assemblage also includes other vertebrate fossils, such as:

Chondrichthyes

Selachii
- *Hybodus* sp.

Osteichthyes

Pahwonisciformes
- Ptycholepidae
  - *Yuchoulepis szechuanensis* Su, 1974

Semionotiformes
- Semionotidae
  - *Lepidotes luchowensis* Wang, 1974

Dipnoi
- *Ceratodus zigongensis* Yu, 1990

Amphibia
- Temnospondylia
  - Brachyopidae
    - *Sinobrachyops placenticephalus* Dong, 1985

## THE UPPER MEMBER

The upper member of the Shaximiao Fm., is well known for its famous *Mamenchisaurus* dinosaur assemblage (Li *et al*., 1997; Li, 1998). The *Mamenchisaurus* assemblage is widely distributed across Sichuan Basin and more than 300 fossil sites have been hitherto reported from the upper member of the Shaximiao Fm. Saurischian dinosaurs are the most abundant (3 genera and 11 species of Sauropoda; 4 genera and 6 species of Theropoda); ornithopods are less abundant with 5 genera and 5 species recorded. The *Mamenchisaurus* assemblage is dominated by the uniform assemblage of long-necked sauropod species such as *Mamenchisaurus*; noteworthy, primitive short-necked sauropods (Cetiosauridae) are missing (Wang *et al*., 2003; Peng *et al*., 2005; Li *et al*., 2009). This assemblage contains abundant dinosaurs and other vertebrates, such as:

Saurischia
- Theropoda
  - *Sinocoelurus fragilis* Young, 1942
  - Megalosauridae
    - *Szechuanosaurus campi* Young, 1942
    - *Yangchuanosaurus shangyouensis* Dong et al., 1978
    - *Yangchuanosaurus magnus* Dong et al., 1983
    - *Yangchuanosaurus hepingensis* Gao, 1992
    - *Chienkosaurus ceratosauroides* Yong, 1942
- Sauropodomorpha
  - Mamenchisauridae
    - *Mamenchisaurus constructus* Yong, 1954
    - *Mamenchisaurus hochuanensis* Young et Chao, 1972
    - *Mamenchisaurus fuxiensis* (= *Zigongosaurus fuxiensis*) Hou et al., 1976
    - *Mamenchisaurus anyueensis* He et al., 1996
    - *Mamenchisaurus youngi* Pi et al., 1996
    - *Mamenchisaurus jingyanensis* Zhang et al., 1998
    - *Omeisaurus changshouensis* Young., 1958
    - *Omeisaurus maoi* Tang et al., 2001
    - *Omeisaurus fuxiensis* Dong et al., 1983
  - Brachiosauridae
    - *Daanosaurus zhangi* Ye et al., 2005

Ornithischia
- Fabrosauridae
  - *Gongbusaurus shiyii* Dong et al., 1983
- Hypsilophodontidae
  - *Yandusaurus hongheensis* He, 1979
- Stegosauridae
  - *Chialingosaurus kuani* Young, 1959
  - *Tuojangosaurus multispinus* Dong et al., 1977

*Chungkingosaurus jiangbeiensis* Dong et al., 1983
*Gigantospinosaurus sichuanensis* Ouyang, 1992

There may also be another species of *Mamenchisaurus*, but that is still unpublished. The *Mamenchisaurus* assemblage also includes other vertebrate fossils, such as:

Osteichthyes
Pahwonisciformes
Chungkingichthyidae
*Chungkingichthys tachuensis* Su, 1974
Dipnoi
*Ceratodus zigongensis* Yu, 1990
*Ceratodus minor* Liu et Yeh, 1957

Reptilia

Therapsida
Tritylodontidae
*Bienotheroides wansienesis* Young, 1981

Testudines
Chengyuchelyidae Yeh, 1990
*Chengyuchelys baenoides* Young et Chow, 1953
Plesiochelyidae Baur, 1888
*Plesiochelys radiplicatus* Young et Chow, 1953
*Plesiochelys latimarginalis* Young et Chow, 1953
*Plesiochelys chungkingensis* Young et Chow, 1953
*Plesiochelys tatsuensis* Yeh, 1963
*Plesiochelys kwanganensis* Yeh, 1963
*Plesiochelys jingyanensis* Yeh et Fang, 1982
*Plesiochelys zigongensis* Peng et al., 2005
*Yanduchelys delicatus* Peng et al., 2005
*Plesiosauria* gen. et sp. indet.
*Tienfuchelys tzuyangensis* Young et Chow, 1953
Trionychidae Bell, 1828
*Sinospideretes wimani* Young et Chow, 1953

Crocodyliformes
Protosuchia
*Sichuanosuchus huidongensis* Peng, 1995
Teleosauridae
*Peipehsuchus teleorhinus* Yong, 1948
Hsisosuchidae
*Hsisosuchus chungkingensis* Young et Chow, 1953
*Hsisosuchus chowi* Peng et Shu, 2005

Mamallia
*Shunotherium dongi* Zhou et Rich, 1982.

## DINOSAUR ASSEMBLAGES AND AGE OF THE SHAXIMIAO FORMATION

For many years, the geological age of the upper member of the Shaximiao Formation was a matter of controversy. Based on its invertebrate fossil record, this member, along with the entire Shaximiao Formation, was assigned to the Middle Jurassic, although vertebrate fossils tended to indicate a Late Jurassic age for the upper member of the Shaximiao Formation.

Currently, the age of the vertebrates of the *Mamenchisaurus* Fauna is regarded as Middle Jurassic. For example, *Lepidotes* belonging to the semionotiformes, as one of the most common fish fossils in Sichuan, is known from many quite complete specimens and its definite stratigraphic range is from the lower part of the Ziliujing Formation to the upper member of the Shaximiao Formation; *Yuchoulepis* and *Chunkingichthys* (both palaeonisciforms) are preserved quite completely, and the positions of these two genera are both in the lower and the upper parts of the Shaximiao Formation, and their age is considered to be Middle Jurassic by Su Dezao (1974).

Among the bivalve fossils, *Cuneopsis* is the most common (Sichuan Bureau of Geological Minerals Prospecting and Developing, 1990), and it belongs to the *Cuneopsis-Psilunio-Eolamprotula* assemblage of the freshwater bivalve fauna. *Cuneopsis* has a comparatively large body, a comparatively thick shell, and quite well developed shell ornament and it is regarded as Middle Jurassic in age. This conclusion is in accordance with independent stratigraphical data, such as the distribution of other invertebrates.

More importantly, electron spin resonance (ESR) analyses performed in Dayi and Dujiangyan, Sichuan Province (Gou, Shi, 1997; Gou *et al*., 2000) point to a 165–172 Ma age range for the Shaximiao Formation, which, according to Gradstein *et al*. (2004) corresponds to a Bajocian–Bathonian age. To sum up, the upper member of the Shaximiao Formation should belong to a mid to late part of the Middle Jurassic, namely the Bajocian–Bathonian.

The first striking phenomenon is the great difference between the *Shunosaurus-Omeisaurus* dinosaur assemblage from the lower member of the Shaximiao Fm. and the *Mamenchisaurus* assemblage of the upper member, both in terms of the taxonomic composition of these two assemblages and the evolutionary level (proportion of more primitive and more derived species) of dinosaurs (Table 1; Figs 2–4; Pls 1–4). Herein, we attempt to discuss previous and new finds of dinosaur remains in order to discuss the age of the relevant strata of the Shaximiao Formation.

Sauropods of the *Mamenchisaurus* type (Fig. 3; Pl. 1: 3) with a proximal procelous caudal vertebra, abundant in the upper member, are totally absent from the lower member. Contrarily, the representatives of the short-necked primitive sauropods (Pl. 1: 1, 2) from the lower member (*i.e. Shunosaurus*) did not persist into the upper member.

Coelurosaurs belonging to the Theropoda are rare elements in the lower member (such as *Gasosaurus constructus* – Pl. 2: 3). Relatively common *Chuandongocoelurus* fossils come from Kaijiang and show some features of Triassic theropods. Of the carnivorous dinosaurs from the lower member, *Kaijiangosaurus* evidently does not possess many

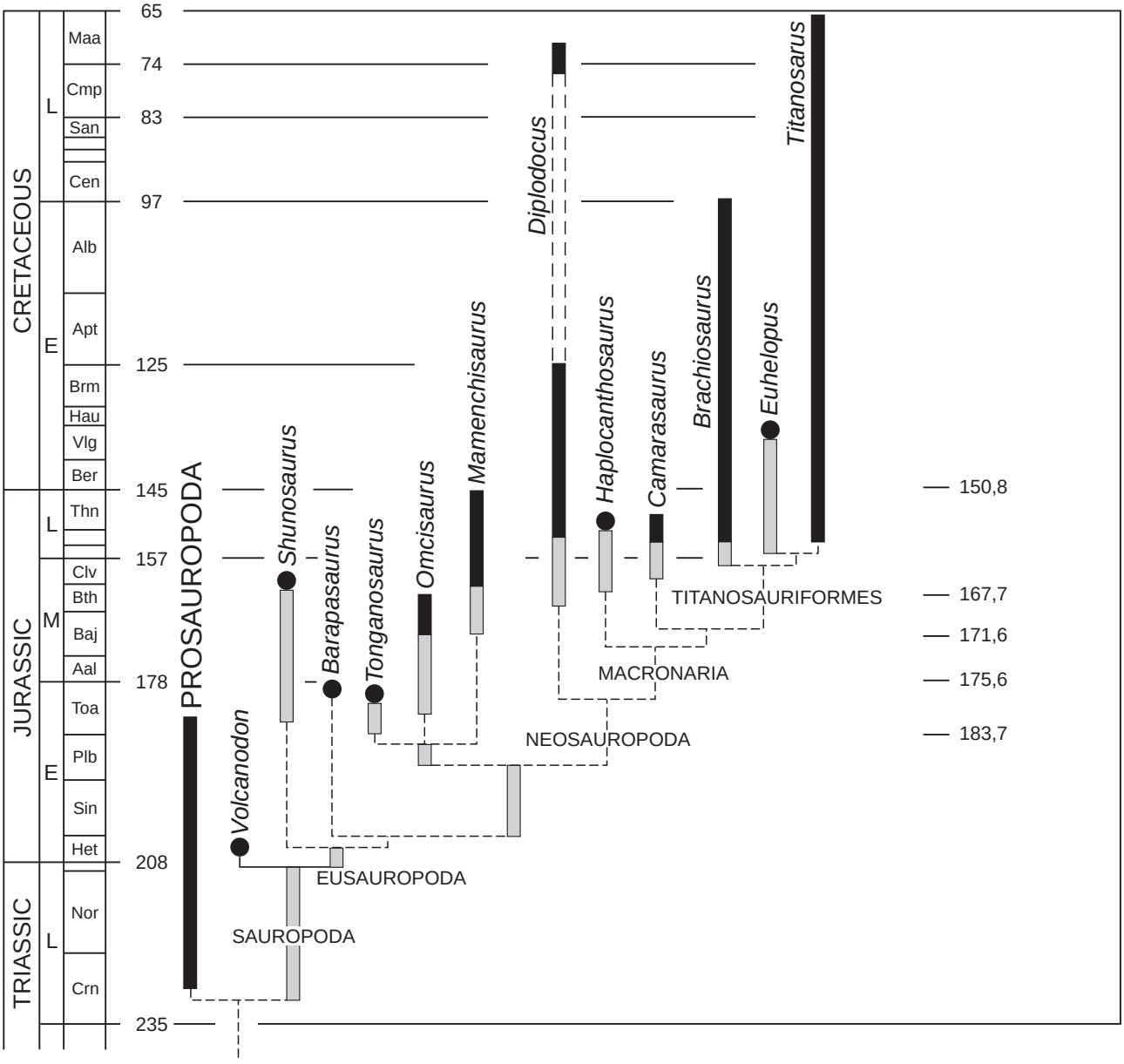



**Fig. 2. A calibrated phylogeny of sauropodomorphs based on their cladistic relationships with position of *Shunosaurus*, *Omeisaurus* and *Mamenchisaurus* (based on Wilson, Sereno, 1998)**

**Table 1**

**Distribution of dinosaur fauna in the two members of the Shaximiao Formation of Sichuan Basin, China**

| Dinosaur category | Lower member of the Shaximiao Fm. | Upper member of the Shaximiao Fm. |
|---|---|---|
| Theropoda | *Chuandongocoelurus primitives* | *Sinocoelurus fragilis* |
| | *Xuanhanosaurus qilixiaensis*<br>*Gasosaurus constructus*,<br>*Kaijiangosaurus lini* | *Chienkosaurus ceratosauroides*,<br>*Szechuanosaurus campi*,<br>*Yangchuanosaurus shangyouensis*,<br>*Y. magnus* |
| Sauropoda | *Shunosaurus lii*<br>*Datousaurus bashanensis*<br>*Zizhongosaurus chuanchengensis*<br>*Omeisaurus luoquanensis*,<br>*O. tianfuensis*,<br>*O. junghsiensis* | *Mamenchisaurus hochuanensis*,<br>*M. constructus*,<br>*Omeisaurus maoi*,<br>*O. fuxiensis*,<br>*O. changshouensis* |
| Ornithopoda | *Yandusaurus multidens*<br>*Xiaosaurus dashanpuensis*<br>*Agilisaurus louderbacki* | *Gongbusaurus shiyii*,<br>*Yandusaurus hongheensis* |
| Stegosauria | *Huayangosaurus taibaii* | *Chungkingosaurus jiangbeiensis*,<br>*Gigantspinosaurus sichuanensis*,<br>*Gigantspinosaurus* sp.,<br>*Chialingosaurus kuani*,<br>*Tuojangosaurus multispinus* |

features of the *Szechuanosaurus* and *Yangchuanosaurus* (Pl. 2: 1, 2) from the upper member (He, 1984), although all of them belong to the same Megalosauridae family (Fig. 4).

*Huayangosaurus* (Stegosauria) (Pl. 4: 2) from the lower member has many different characteristics from *Tuojangosaurus* and *Jialinosaurus* (Pl. 4: 1) of the upper member. Small-sized ornithopods – *Yandusaurus multidens*, *Xiaosaurus dashanpuensis* and *Agilisaurus louderbacki* (Pl. 3: 1, 3) from the lower member in Dashanpu are all of a much smaller size than *Yandusaurus hongheensis* (Pl. 3: 2) from the upper member in Hongheba, Zigong. Besides, the older ornithopoda, such as *Yandusaurus multidens*, *Xiaosaurus dashanpuensis* and *Agilisaurus louderbacki*, differ from younger relatives such as *Yandusaurus hongheensis* in their skeletal features (see Pl. 3).

Although many other representatives of these two vertebrate assemblages are generally similar, containing theropods, sauropods, ornithopods, stegosaurians, plesiosaurians, crocodilians, testudines, chondrichthyans, dipnomorphs, actinopterygian fossils and so on, there are also obvious differences between them, relating to the actual genera and species that are found in each assemblage.

The most outstanding difference is in the character of the two different dinosaur groups – the *Shunosaurus-Omeisaurus* assemblage of the lower member and the *Mamenchisaurus* assemblage of the upper member (Table 1; Figs 2–4; Pls 1–4).

The *Shunosaurus-Omeisaurus* assemblage is characterized by the following: besides the relatively primitive Cetiosauridae – *Shunosaurus lii* (Pl. 1: 1), there are also more derived Mamenchisauridae (Wilson, Sereno, 1998; Figs 2–4) such as *Omeisaurus tianfuensis* (Pl. 1: 4), *O. junghsiensis* and *O. luoquanensis*. Furthermore, it is notable that basal sauropodomorphs ("prosauropods" in the traditional

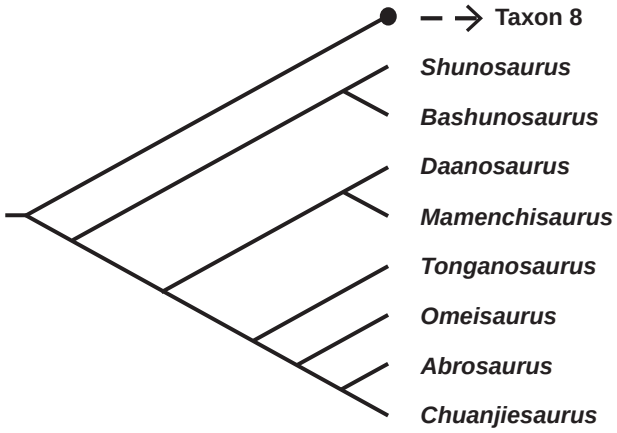



**Fig. 3. Phylogeny of Sauropod from Sichuan Basin**

L = 163, CI = 64, RI = 40; Taxon 8 is out-group, its characters are all "0"

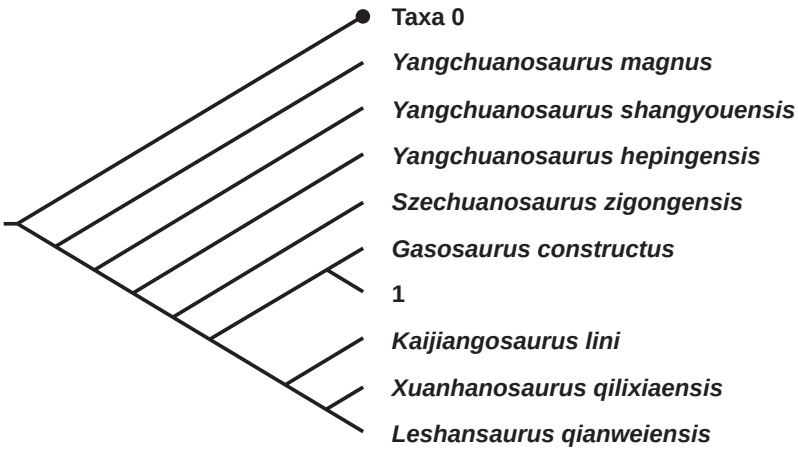



**Fig. 4. Phylogeny of Megalosauridae from Sichuan Basin**

L = 140, CI = 77, RI = 50; Taxon 1 stands for Szechuanoaurus campi. Taxon 0 is out-group, its characters are all "0"

sense) are absent. The structure of this fauna is obviously more progressive than the Early Jurassic *Gongxiansaurus-Zizhongosaurus* assemblage from the Sichuan Basin (Wang *et al*., 2010), but less derived than the *Mamenchisaurus* Fauna (Wang *et al*., 2008, p. 33–34) – Figs 2–4. *Mamenchisaurus* is the most progressive species of the Mamenchisauridae (He *et al*., 1984; Li *et al*., 1997) and this form is specific to the East Asian province (Fig. 2).

Thus, we are of opinion that the age of the *Shunosaurus-Omeisaurus* assemblage should be older – Bajocian–Bathonian, leaving an Aalenian–Bajocian time for the underlying, Middle Jurassic Xintiangou Formation (Table 1, 2).

It is obvious that the dinosaur assemblage from the upper member of the Shaximiao Formation contains more derived species and in evolutionary terms is more progressive than the relatively more primitive assemblage of the lower member (Wilson and Sereno, 1998 – Figs 2–4). This is the case with all the relevant groups of dinosaurs, such as coelurosaurs, carnosaurs, sauropods, ornithopods, stegosaurians, and others. A calibrated phylogeny of sauropodomorphs (based on Wilson, Sereno, 1998, their figs 46, 47 and 49) supports our conclusion (Fig. 2).

To sum up, the two dinosaur assemblages from the lower and upper members of the Shaximiao Fm. are conspicuously different and they represent two different faunas of different evolutionary level, though these assemblages still have genetic and evolutionary relationships (Fig. 2).

**Table 2**

**Stratigraphic distribution of dinosaur fauna in Sichuan Basin and Yunnan Basin, China**

<table>
<tr><td rowspan="2"></td><td colspan="3">Formation</td><td colspan="2">Dinosaur Fauna</td></tr>
<tr><td colspan="2">Sichuan Basin</td><td>Yunnan Basin</td><td>Sichuan Basin</td><td>Yunnan Basin</td></tr>
<tr><td rowspan="3">Upper Jurassic</td><td colspan="2">Penglaizhen Fm.</td><td>Anning Fm.</td><td rowspan="2">*Mamenchisaurus* Fauna</td><td rowspan="2">*Chuanjiesaurus* Fauna</td></tr>
<tr><td colspan="2">Suining Fm.</td><td>Madishan Fm.</td></tr>
<tr><td rowspan="4">Middle Jurassic</td><td rowspan="3">Shaximiao Fm.</td><td>upper member</td><td>Laoluocun Fm.</td><td>*Mamenchisaurus* Fauna</td><td>*Chuanjiesaurus* Fauna</td></tr>
<tr><td rowspan="2">lower member</td><td rowspan="2">Chuanjie Fm.</td><td rowspan="2">*Shunosaurus-Omeisaurus* fauna</td><td rowspan="2">*Shunosaurus-Yunmousaurus* fauna</td></tr>
<tr><td colspan="2">Xintiangou Fm.</td></tr>
<tr><td rowspan="2">Lower Jurassic</td><td colspan="2" rowspan="2">Ziliujing Fm.</td><td rowspan="2">Lufeng Fm.</td><td>*Gongxianosaurus-Zizhongosaurus* fauna</td><td></td></tr>
<tr><td>*Lufengosaurus* Fauna</td><td>*Lufengosaurus* Fauna</td></tr>
</table>

Additionally, it seems that the dinosaur (in particular Sauropoda) assemblages from Sichuan are differentiated not only in terms of geological time, but also concerning their spatial distribution. Commonly several genera and species of sauropods have been found in the same layer, which points to a high differentiation of each local assemblage, whereas at the same time the same kinds of sauropods from other areas show different characteristics, which points to a strong provincialism. It may also suggest a rapid radiation of sauropods in Middle Jurassic times, at least in the area studied.

## THE COMPARISON OF THE VERTEBRATE FAUNA FROM THE UPPER MEMBER OF THE SHAXIMIAO FORMATION AND FROM THE CHUANJIE FORMATION, YUNNAN BASIN

In 1997, in the Middle Jurassic Chuanjie Formation, hamlet of Ana, Chuanjie village, Lufeng County (Cheng *et al*., 2004; Ye, 1975) – Fig. 1, a new dinosaur fossil assemblage was excavated. In this excavation, sauropod and theropod dinosaur fossils were recovered, and the assemblage composition appeared very similar to the *Mamenchisaurus* and *Yangchuanosaurus* assemblage, known from the Sichuan Basin. Within the abundant fossil assemblage of Ana there are more than 10 sauropod and theropod individuals, as well as a number of plesiosaurian fossils, all displayed in the museum hall. In 2000, Fang Xiaosi and others studied the sauropod fossils from this fossil site and distinguished a new genus and a new species, *Chuanjiesaurus anaensis* (Fang, Li, 2008). They also characterized the dinosaur fauna of Yunnan, naming it as *Chuanjiesaurus anaensis* association and correlated this assemblage as approximately coeval with the *Shunosaurus-Omeisaurus* fauna from Dashanpu of Sichuan. In the present paper, we challenge this correlation.

Firstly, the skeletal characteristics of *Chuanjiesaurus* point to much more progressive features than those present in *Shunosaurus* (Pl. 1: 2) and *Omeisaurus* (Pl. 1: 3) from Dashanpu: the body length of *Chuanjiesaurus* is 27 m, the cervical ribs, whose length is more than twice that of the vertebral body length, are thin and long, the spines of the posterior cervical and anterior dorsal are bifurcated, and the anterior caudals are procoelous, and those characteristics are similar to *Mamenchisaurus* sp. (Pl. 1: 3). In the *Shunosaurus-Omeisaurus* fauna, the biggest dinosaur body length is 20 m, the spines of posterior cervical and anterior dorsal are not bifurcated, and the anterior caudals are amplicoelous. As stated above, *Chuanjiesaurus* is more derived than representatives of the *Shunosaurus-Omeisaurus* fauna and corresponds rather to the *Mamenchisaurus* in Sichuan Basin.

Secondly, the *Chuanjiesaurus* assemblage is monotonous in its composition, including only the long-necked *Chuanjiesaurus*. In contrast, the short-necked *Shunosaurus* (Pl. 1: 1), the most characteristic representative of the *Shunosaurus-Omeisaurus* fauna, is missing. Therefore, we are of opinion that *Chuanjiesaurus* and *Mamenchisaurus* are probably close relatives because they share some osteological features. Therefore, the dinosaur assemblage from the Chuanjie Fm. should be compared to the *Mamenchisaurus* Fauna of the upper member of the Shaximiao Fm., and both assemblages should be regarded as approximately coeval.

## THE DIFFERENCES BETWEEN THE VERTEBRATE FAUNA FROM THE UPPER MEMBER OF THE SHAXIMIAO FORMATION AND THE VERTEBRATE FAUNA OF THE LATE JURASSIC IN EUROPE AND AMERICA

The *Shunosaurus-Omeisaurus* Fauna and the *Mamenchisaurus* Fauna of the Middle Jurassic in Sichuan Basin (Table 1; Pls 1–4) include many kinds of vertebrates collected in a single basin, while specimens from contemporary or younger fossil sites in other areas of the world are all scattered, so it is difficult to make comparisons and discuss similarities and differences.

On the other hand, the rich fossiliferous sites overseas are regarded as being younger than the Shaximiao Formation, as they are mostly regarded as Late Jurassic in age – this is the case with regards to both the *Diplodocus* fauna from the Morrison Formation (Upper Jurassic in the western states of North America – Ostrom, McIntosh, 1966; Breithaupt, 1998; Litwin *et al*., 1998; Monaco, 1998; Engelmann *et al*., 2004), as well as *Brachiosaurus* sp. and *Dicraeosaurus* sp. from the Tendaguru Formation (Upper Jurassic in Tanzania in East Africa – Durand, 2005; Gillette, 1999; Gradstein *et al*., 2004). When attempting to compare the *Mamenchisaurus* Fauna from the upper member of the Shaximiao Formation with the assemblages from North America and East Africa, we can indicate several significant differences.

Firstly, both North American and East African assemblages do not share common genera and species with East Asia. The *Mamenchisaurus* fauna is unique, while dinosaur faunas from North America and East Africa have close relationships to each other and share many common genera (or species). For example, Galton (1981) pointed out that *Dysalotosaurus* from East Africa is similar to *Dryosaurus* from North America and that these represent two genera of Hypsilophodontidae (Ornithopoda) which should be regarded as synonymous. Furthermore, he concluded that of more than 10 families and genera, the Morrison fauna and the Tendaguru fauna shared 7 common families and 5 common

genera. This is conventionally explained by the close connection in Late Jurassic times of East Africa, North America and Europe.

In addition, there are marked differences between the sauropods included in the *Mamenchisaurus* Fauna and the sauropods from North America and East Africa (Janensch, 1935–1936; McIntosh, 1990; Sereno *et al*., 1999; Monbaron *et al*., 1999). Firstly, *Mamenchisaurus* has 17–19 cervical vertebrae and it has the most cervical vertebrae among all sauropods. *Mamenchisaurus* (Pl. 1: 3) has a very long neck which is more than 40% of its whole body length. It also has very long cervical ribs, the longest cervical rib being about 3 times of the length of the longest cervical vertebra. Moreover, *Mamenchisaurus* has a comparatively short tail and does not possess the very thin and long wipe-shaped tails as in *Diplodocus*, but have a hammer-shaped tail instead. Although *Mamenchisaurus* shares some characteristics with *Diplodocus* and *Camarasaurus* in North America (*Mamenchisaurus* has the same spoon-shaped teeth as *Camarasaurus* and the same strongly procelous proximal caudal centrum and obviously bifurcated spines of the anterior vertebrae as those of *Diplodocus*), most of the anatomical features indicate that *Mamenchisaurus* of Sichuan is a peculiar dinosaur species, endemic to East Asia, which has more primitive features than sauropod dinosaurs of the Late Jurassic from North America and East Africa.

Moreover, the *Mamenchisaurus* assemblage does not include any sauropod genera and species with nail-shaped teeth (= pencil-like teeth). In North America and East Africa, Late Jurassic sauropods with nail-shaped teeth are common, while in Sichuan they are totally absent. Apparently, the sauropods with nail-shaped teeth appeared in the early Late Jurassic and flourished in the Late Jurassic-Early Cretaceous (Table 3).

Many of the vertebrates from the *Mamenchisaurus* Fauna have fewer representatives and are generally less numerous (Chure *et al*., 1998; Turner, Peterson, 2004) than those from North America and East Africa. For example, the *Mamenchisaurus* Fauna has an extremely uniform species composition, it comprises only 1 sauropod genus (namely: *Mamenchisaurus*), while there are at least 5 genera of Sauropoda in the Morisson Formation of the Late Jurassic in North America (Dodson *et al*., 1980a, b; Carpenter *et al*., 1998; Gillette, 1999). Small-bodied theropod fossils from the upper member of the Shaximiao Formation are very scarce, with only tooth fossils preserved, while small-bodied theropod fossils from North America are more abundant and are well preserved. Also genera and species of the Iguanodontidae have not been found in Sichuan Province. There are less non-dinosaur vertebrates in Sichuan than in East Africa and North America. For example, there are less mammals in Sichuan than in North America (as many as nearly 50 kinds of

**Table 3**

**Comparison of dinosaurs from North America, East Africa and the Shaximiao Formation of Sichuan Basin, China**

| Dinosaur category | North America<br>Morrison Fm. | East Africa<br>Tendaguru Fm. | The Upper Member<br>of the Shaximiao Fm. |
|---|---|---|---|
| Theropoda | *Stokesosaurus* | *Elaphrosaurus* | *Sinocoelurus* |
| | *Coelurus* | | |
| | *Ceratosaurus* | *Ceratosaurus*<br>?*Megalosaurus* | *Szechuanosaurus*<br>*Yangchuanosaurus* |
| | *Allosaurus* | *Allosaurus* | |
| Sauropoda | *Haplocanthosaurus* | | |
| | *Brachiosaurus*<br>*Camarosaurus*<br>*Apatosaurus, Diplodocus* | *Brachiosaurus*<br>*Dicraeosaurus*<br>*Torniosaurus* | *Mamenchisaurus*<br>*Omeisaurus, Daanosaurus* |
| Ornithopoda | *Dryosaurus*<br>*Camptosaurus* | *Dysalotosaurus* | *Yandusaurus* |
| Stegosauria | *Stegosaurus* | *Kentrosaurus* | *Gigantspinosaurus*<br>*Chialingosaurus*<br>*Tuojangosaurus* |

mammal fossils are reported from the Upper Jurassic Morisson Formation in the western part of the U.S.A).

The most probable explanation for these marked differences (Table 3) is that East Asia was a faraway continent at that time, separated from East Africa, North America and Europe by extensive seaways and the Tethys ocean (see: Scotese, 2002), which made land vertebrate migrations between East Asia and other continents difficult or impossible.

However, besides natural reasons such as geographical isolation (and/or geological age) the observed differences can be at least partly attributed to insufficient collection and research.

## CONCLUSIONS

Two major assemblages of dinosaurs from the Middle Jurassic (Bajocian–Bathonian) Shaximiao Formation of Sichuan Basin have been distinguished: the *Shunosaurus-Omeisaurus* association in the lower member of the Shaximiao Formation and the *Mamenchisaurus* association in the upper member of the Shaximiao Formation. The *Mamenchisaurus* association is more derived, while the *Shunosaurus-Omeisaurus* association contains both primitive sauropods like *Shunosaurus* and comparatively progressive *Omeisaurus* sauropods. The *Mamenchisaurus* association derived from the previous *Shunosaurus-Omeisaurus* association, because *Omeisaurus* and *Mamenchisaurus* are close relatives.

The *Mamenchisaurus* assemblage from the upper member of the Shaximiao Formation is similar to the *Chuanjiesaurus* assemblage of Middle Jurassic age in Yunnan Province, in all aspects of its anatomical and assemblage affinity, and consequently the *Chuanjiesaurus* association of the Lufeng Basin (Chuanjie Basin), Yunnan Province and the *Mamenchisaurus* association of Sichuan Basin should be regarded as approximately coeval, *i.e*. of Middle Jurassic age. Both of these assemblages continue to Late Jurassic strata.

A comparison between the *Mamenchisaurus* association from the upper member of the Shaximiao Formation and overseas dinosaur assemblages of Late Jurassic age shows very few similarities and common genera or species cannot be indicated. There are no sauropods with nail-shaped teeth in the Chinese sites, while they are common in Jurassic strata elsewhere. All Middle Jurassic vertebrates from the *Mamenchisaurus* assemblage from the upper member of Shaximiao Formation are in all respects less derived than the Late Jurassic vertebrates of East Africa and North America. This is both a result of difference in age, and strong endemism, caused by the geographical isolation.

**Acknowledgements.** This project was supported by the National Natural Science Funds Projects (No: 40572016). We are thankful to Prof. Grzegorz Pieńkowski and Dr Steve Brusatte for their discerning reviews which improved the present paper.

## REFERENCES

BREITHAUPT B.H., 1998 — Railroads blizzards and dinosaurs: a history of collecting in the Morrison Formation of Wyoming during the nineteenth century. *In*: The Upper Jurassic Morrison Formation: an interdisciplinary study (Eds K. Carpenter *et al*.). *Modern Geology*, **23**: 441–463.

CARPENTER K., CHURE D.J., KIRKLAND J.I. (Eds.), 1998 — The Upper Jurassic Morrison Formation: an interdisciplinary study. *Modern Geology*, **22**, 1–4, Pt. 1, 533 pp. Pt. 2, 537 pp.

CHENG Z.W., LI P.X., PANG Q.Q., ZHANG Z.X., ZHANG Z.J., JIN Y.G., LU L.W., FANG X.S., 2004 — New progress in the study of the Jurassic of central Yunnan. *Geol Bull. China*, 2004, **23**, 2: 154–159 [in Chinese with English abstract].

CHURE D.J., CARPENTER K., LITWIN R.J., HASIOTIS S.T., 1998 — Appendix, the fauna and flora of the Morrison Formation. *In*: The Upper Jurassic Morrison Formation: An Interdisciplinary Study (Eds K. Carpenter *et al*.). *Modern Geology*, **23**: 507–537.

DODSON P., BEHRENSMEYER A.K., BAKKER R.T., 1980a — Taphonomy of the Morrison Formation (Kimmeridgian–Portlandian) and Cloverly Formation (Aptian–Albian) of the western United States. Société Géologique de France Mémoire, No. 139. Ecosystèmes Continentaux du Mésozoique, Paris, France: 87–93.

DODSON P., BEHRENSMEYER A.K., BAKKER R.T., McINTOSH J.S., 1980b — Taphonomy and paleoecology of the dinosaur beds of the Jurassic Morrison Formation. *Paleobiology*, **6**, 2: 208–232.

DONG Z.M., LI X.M., ZHOU S.W., 1997 — On the Stegosauruian remain from Zigong (Tzekung), Zsechuan Province. *Vertebrata PalAsiatica*, **15**, 4: 307–312 [in Chinese].

DONG Z.M., 1980 — China dinosaur fauna and their horizon. *Journal of Stratigraphy*, **4**, 4: 256–263 [in Chinese].

DONG Z.M., TANG Y.L., 1984 — Note on a new mid Jurassic sauropod (*Datousaurus bashanensis* gen. et sp. nov. ) from Sichuan Basin, China. *Vertebrata PalAsiatica*, **22**, 1: 69–75 [in Chinese with English abstract].

DONG Z.M., ZHOU S.W., ZHANG Y.H., 1983 — The dinosaurian remains from Sichuan Basin, China. *Palaeont Sin*, New Ser C, 23: l–145 [in Chinese with English summary].

DURAND J.F., 2005 — Major African contributions to Palaeozoic and Mesozoic vertebrate palaeontology. *Journal of African Earth Sciences*, **43**: 53–82.

ENGELMANN G.F., CHUREB D.J., FIORILLO A.R., 2004 — The implications of a dry climate for the paleoecology of the

fauna of the Upper Jurassic Morrison Formation. *Sedimentary Geology*, **167**: 297–308.

FANG X.S., LI P.X., 2008 — Jurassic Red Bed in the Central Yunnan of China. Beijing, Geological Publishing House: 1—111 [in Chinese with English summary].

GALTON P.M., 1981 — *Dryosaurus*, a hypsilophodontid dinosaur from the Upper Jurassic of North America and Africa. Postcranial skeleton. *Palaeontologische Zeitschrift*, **55**, 3/4: 271–312.

GILLETTE D.D., 1999 — Vertebrate paleontology of Utah. *Geological Survey of Utah Miscellaneous Publication*: 554 pp.

GOU Z.H, SHI H., 1997 — The Jurassic System of Dujiangyan, Pengzhou and Shifang, Sichuan. *Journal of Stratigraphy*, **21**, 3: 192–202 [in Chinese with English summary].

GOU Z.H., ZHAO B., WU S., 2000 — Jurassic system of Dayi, Chongzhou, Wenchuan and Dujiangyan, Sichuan. *Journal of Chengdu University of Technology*, **27**, 1: 31–39 [in Chinese with English summary].

GRADSTEIN F.M., OGG J.G., SMITH A.G., BLEEKER W.L., LOURENS J., 2004 — A new Geological Time Scale, with special reference to Precambrian and Neogene. *Episodes*, **27**, 2: 83–100.

HE X.L., 1984 — Vertebrate Fossils of Sichuan Province. Chengdu, Sichuan Publishing House of Science and Technology: 1–188 [in Chinese with English summary].

HE X.L., LI K., CAI K.J., GAO Y.H., 1984 — A new species of *Omeisaurus* from Zigong Dashanpu, Sichuan. *Journal of Chengdu Geology College*, **11** (Suppl. 2): 13–32.

HE X.L., YANG X.H., CAI K.J., LI K., LIU Z.W., 1986 — New discovery of *Mamenchisaurus* (Sauropoda). Collected papers of geological sciences. China economy press, Beijing: 83–86 [in Chinese with English summary].

HE X.L., LI K., CAI K.J., 1988 — The Middle Jurassic Dinosaur Fauna from Dashanpu, Zigong, Sichuan. Vol. 4, Sauropod Dinosaurs (2), *Omeisaurus tianfuensis*. Chengdu, Sichuan Publishing House of Science and Technology: 1–143 [in Chinese with English summary].

JANENSCH W., 1935–1936 — Die Schädel der Sauropoden *Brachiosaurus*, *Barosaurus* und *Dicraeosaurusaus* den Tendaguruschichten Deutsch-Ostafrikas. *Palaeontographica* (Suppl. 7), **2**: 147–298.

LI F., PENG G.Z., YE Y., JIANG S., HUANG D.X., 2009 — A new Carnosaur from the Late Jurassic of Qianwei, Sichuan, China. *Acta Geologica Sinica*, **83**, 9: 1203–1213 [in Chinese with English summary].

LI K., XIE W., ZHANG Y.G., 1997 — Dinosaurian remains from the Jurassic of Sichuan, China. *Exploration of Nature*, **16**, 1: 66–70 [in Chinese with English summary].

LI K., CAI K.J., 1997 — Classification and evolution of Mamenchisaurus. *Journal of Chengdu Institute of Technology*, **24**, 2: 102–107 [in Chinese with English summary].

LI K., 1998 — The Sauropoda fossils and their stratigraphical distribution in China. *Journal of Chengdu Institute of Technology*, **25**, 1: 54–60 [in Chinese with English summary].

LITWIN R.J., TURNE C.E., PETERSON F., 1998 — Palynological evidence on the age of the Morrison Formation, Western Interior U.S. *Modern Geology*, **22**, 1–4: 297–319.

MCINTOSH J.S., 1990 — Sauropoda. *In*: The Dinosauria (Eds D.B. Weishampel *et al*.). University of California Press: 345–401.

MONBARON M., RUSSELL D.A., TAQUET P., 1999 — *Atlasaurus imelakeii* n.g., n.sp., a brachiosaurid-like sauropod from the Middle Jurassic of Morocco. *Comptes Rendus de l'Académie des Sciences. Sciences de la Terre des Planet*, **329**: 519–526.

MONACO P.E., 1998 — A short history of dinosaur collecting in the Garden Park fossil area, Canon City, Colorado. *In*: The Upper Jurassic Morrison Formation: An Interdisciplinary Study (Eds K. Carpenter *et al*.). *Modern Geology*, **23**: 465–480.

OSTROM J.H., McINTOSH J.S., 1966 — Marsh's Dinosaurs: The Collections from Como Bluff. Yale Univ. Press, New Haven.

PENG G.Z., YE Y., GAO Y.G., SHU C.K., JIANG S., 2005 — Jurassic Dinosaur Faunas in Zigong. Sichuan Peoples Publishing House, Chengdu: 69–98 [in Chinese].

PI X.Z., OUYANG H., YE Y., 1996 — A new species of sauropod from Zigong, Sichuan. Symposium of Geological Science. Beijing, Economy Publishing House: 87–91.

SCOTESE, C.R., 2002 — Palaeomap project; www.scotese.com.

SERENO P.C., BECK A.L., DUTHEIL D.B., 1999 — Cretaceous sauropods from the Sahara and the uneven rate of skeletal evolution among dinosaurs. *Science*, **286**: 1342–1347.

SICHUAN BUREAU OF GEOLOGICAL MINERALS PROSPECTING AND DEVELOPING, 1990 — Sichuan province regional geological volunteers. Geology Publishing House Beijing [in Chinese].

SU D.Z., 1974 — New Jurassic ptycholepid fishes from Szechuan, SW China. *Vertebrata PalAsiatica*, **12**, 1: 1–20 [in Chinese with English summary].

TURNER C.E., PETERSON F., 2004 — Reconstruction of the Upper Jurassic Morrison Formation extinct ecosystem – a synthesis. *Sedimentary Geology*, **167**: 309–355.

WANG Z.X., LI K., LIU J., 2003 — *Mamenchisaurus* from upper Jurassic of Jianyang, Sichuan. *Journal of Chengdu University of Technology (Science & Technology Edition)*, **30**, 5: 485–490.

WANG Q.W., LIANG B., KAN Z.Z., 2008 — Paleoenvironmental reconstruction of Mesozoic Dinosaurs Fauna in Sichuan Basin. The Geological Publishing House, Beijing: 1–189 [in Chinese with English summary].

WANG Y., FU B., XIE X., HUANG Q., LI K., LI G., LIU Z., YU J., PAN Y., TIAN N., JIANG Z., 2010 — The terrestrial Triassic and Jurassic Systems in the Sichuan Basin, China. Contributions to the 8th International Congress on the Jurassic System, University of Science & Technology of China Press, Hefei: 216 pp.

WILSON J.A., SERENO P.C., 1998 — Early evolution and Higher-level Phylogeny of Sauropod Dinosaurs. *Journal of Vertebrate Paleontology* [S], Memoir **5**: 1–68.

YOUNG C.C., 1954 — On a new sauropod from Yiping, Szechuan, China. *Scientia Sinica*, **2**, 2: 355–369.

YANG Z.J., ZHAO X.J., 1972 — Mamenchisaurus hochuanensis. *Mem. Inst. Vert. Paleont. Paleoanthrop. Acad. Sin*., 8: 1–30 [in Chinese]

YE C.H., 1975 — The Jurassic systerm of Yunnan Province, from Yunnan Mesozoic Red Bed. Science Press, Beijing: 11–30 [in Chinese].

YE Y., PI X.Z., 1997 — A new genus of Chengyuchelyidae from Dashanpu, Zigong, Sichuan. *Vertebrata PalAsiatica*, **35**, 3: 182–188 [in Chinese with English abstract].

YOUNG C.C., 1938 — On a new Sauropoda, with notes on other fragmentary reptiles from Szechuan. *Bulletin of Geological Society of China*, **3**: 279–315.

YANG Z.J., 1941 — New Mesozoic Reptiles from Szechuan. *Geological Review*, **6**, 3/4: 215–218 [in Chinese with English summary].

ZHANG Y.H., 1988 — The Middle Jurassic Dinosaur Fauna from Dashanpu, Zigong, Sichuan, Sauropod Dinosaur (I) Shunosaurus. Chengdu: Sichuan Publishing House of Science and Technology: 1–88 [in Chinese with English summary].

# PLATE 1

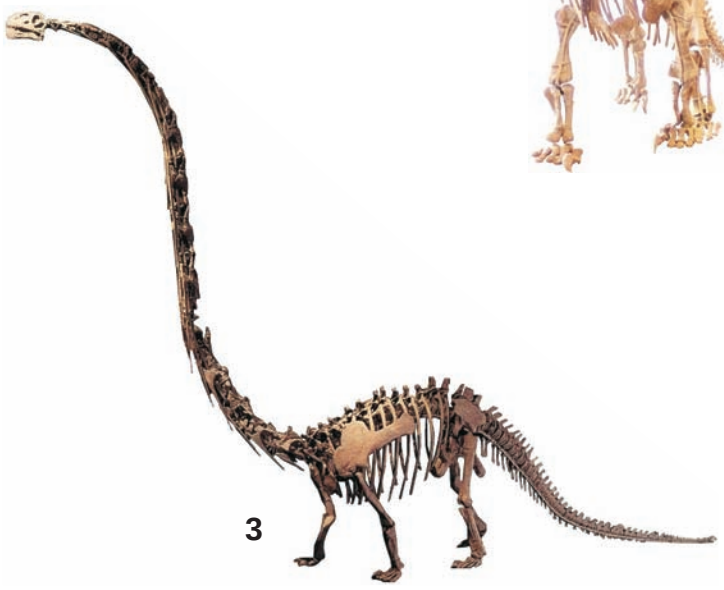
Fig. 1. *Shunosaurus lii* Dong et al. (lower member of Shaximiao Fm.)

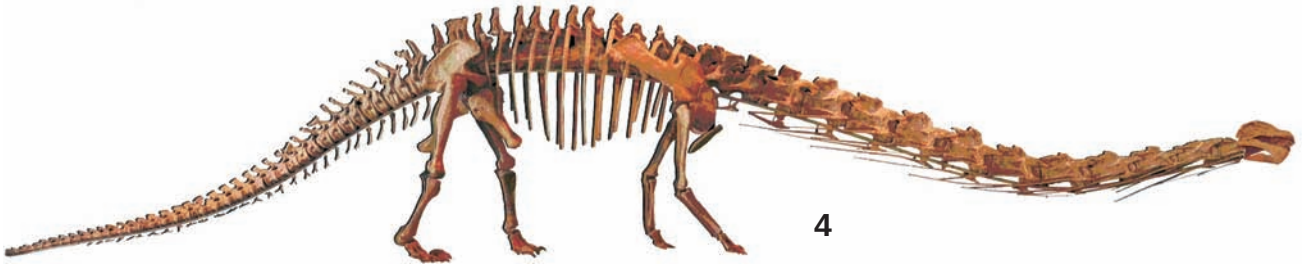
Fig. 2. *Datousaurus bashanensis* Dong et Tang (lower member of Shaximiao Fm.)

Fig. 3. *Mamenchisaurus hochuanensis* Young et Chao (upper member of Shaximiao Fm.)

Fig. 4. *Omeisaurus tianfuensis* He et al. (lower member of Shaximiao Fm.)






Kui LI *et al.* — Dinosaur assemblages from the Middle Jurassic Shaximiao Formation and Chuanjie Formation in the Sichuan-Yunnan Basin, China

# PLATE 2

Fig. 1. *Yangchuanosaurus hepingensis* Gao (upper member of Shaximiao Fm.)

Fig. 2. *Szechuanosaurus campi* Young (upper member of Shaximiao Fm.)

Fig. 3. *Gasosaurus constructus* Dong et Tang (lower member of Shaximiao Fm.)


Kui LI *et al.* — Dinosaur assemblages from the Middle Jurassic Shaximiao Formation and Chuanjie Formation in the Sichuan-Yunnan Basin, China

# PLATE 3

Fig. 1. *Yandusaurus multidens* He et Cai (lower member of Shaximiao Fm.)

Fig. 2. *Yandusaurus hongheensis* He (upper member of Shaximiao Fm.)

Fig. 3. *Agilisaurus louderbacki* Peng (lower member of Shaximiao Fm.)

Fig. 4. *Agilisaurus multidens* He et Cai (lower member of Shaximiao Fm.)


Kui LI *et al.* — Dinosaur assemblages from the Middle Jurassic Shaximiao Formation and Chuanjie Formation in the Sichuan-Yunnan Basin, China

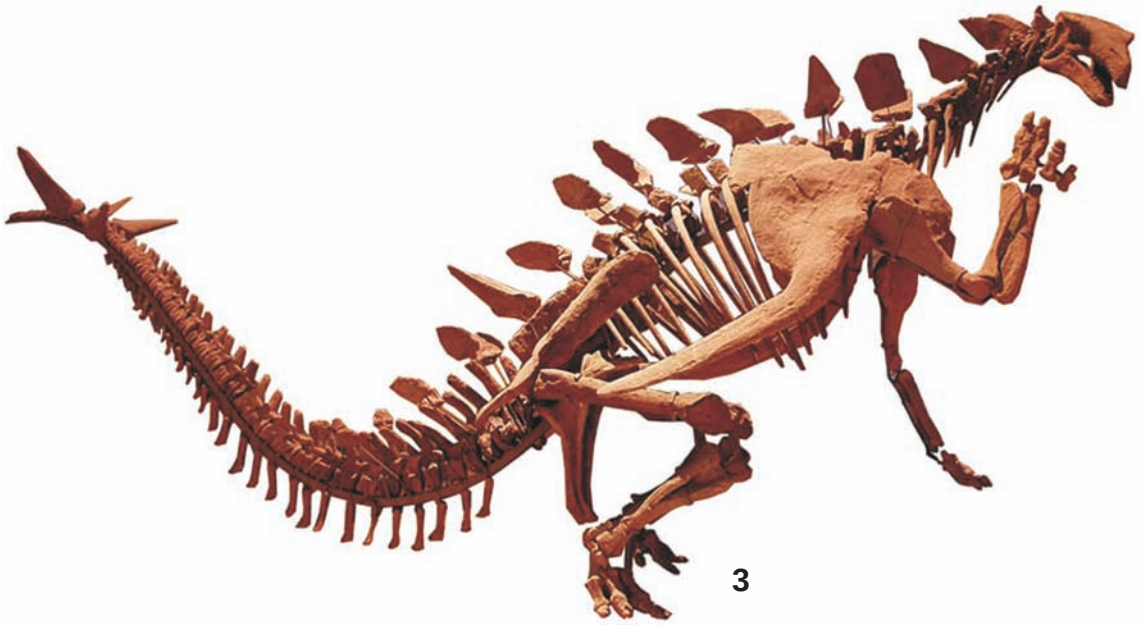
# PLATE 4

Fig. 1. *Tuojangosaurus multispinus* Dong et al. (upper member of Shaximiao Fm.)

Fig. 2. *Huayangosaurus taibaii* Dong et al. (lower member of Shaximiao Fm.)

Fig. 3. *Gigantspinosaurus sichuanensis* Ouyang (upper member of Shaximiao Fm.)






Kui LI *et al.* — Dinosaur assemblages from the Middle Jurassic Shaximiao Formation and Chuanjie Formation in the Sichuan-Yunnan Basin, China