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FOSSIL AMIIDS (PISCES) OF CHINA AND THEIR BIOSTRATIGRAPHIC SIGNIFICANCE

LIU H. T. and Su D.-Z.: Fossil amiids (Pisces) of China and their biostratigraphic significance. *Acta Palaeont. Polonica*, 28, 1—2, 181—194, 1983.

This paper reviews the Sinamiliidae. The supplementary descriptions of *Sinamia huananensis* and *Ikechaoamia orientalis* are made. The specific characters of these two genera have been emended. On the basis of this, the geological and geographical distributions of *Sinamia* and *Ikechaoamia* are discussed. The sinamiliids yielded from the *Lycoptera*-bearing beds in North China are *S. zdanskyi* and *I. orientalis*, and from the *Mesoclupea*-bearing beds in Southeast China are *S. huananensis* and *I. meridionalis*. Based on the characters of the fish faunas stated above, the formations containing these two fish faunas in North and Southeast China should be Upper Jurassic and can be correlated generally.

Key words: pisces, Sinamiliidae, Upper Jurassic, China.

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Sinamia and *Ikechaoamia* were indigenous fresh-water fishes of eastern Asia during the Late Mesozoic, and flourished in the Late Jurassic. The type species of *Sinamia* is *S. zdanskyi*, first described by Stensio, based on materials collected by Tan and Zdansky from Mengyin Series in 1923. Later, Liu, Liu and Su (1963) described many well preserved specimens collected from different localities around the Ordos Plateau. Su (1973) established *S. huananensis* based on materials collected from Anhui, and considered a fossil amiid found in Zhejiang province as *S. huananensis* also Wei (1976) established *S. chinchuaensis* based on a specimen from Wuyi, Zhejiang.

The type species of *Ikechaoamia* is *I. orientalis*, first described by H. T. Liu (1961) based on materials from Nei Mongol. Zhang and Zhang (1980) described a new form, *I. meridionalis* discovered from Jinyun, Zhejiang. Recently, a great number of well preserved *I. orientalis* have been collected from the type locality, Ikechaomeng, Nei Mongol. New

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materials of *Sinamia* and *Ikechaoamia* have been discovered from different localities in North China and South China. Therefore, it is desirable to provide further details about them (fig. 1).

The specimens are stored in the Institute of Vertebrate Palaeontology and Palaeoanthropology, Beijing, abbreviated as IVPP and in Museum of Geology, Ministry of Geology, Beijing, abbreviated as MG.

SYSTEMATIC PART

Family *Sinamiidae* Berg, 1940

Diagnosis: See Berg (1940), Liu, Liu and Su (1963).

Genus *Sinamia* Stensiö, 1935

Diagnosis: See Stensiö (1935), Liu, Liu and Su (1963).

Sinamia zdanskyi Stensiö, 1935

1935. *Sinamia zdanskyi* Stensiö: 1—46, figs. 1, 2, 7, 8, 14—20, pls. 1—17.

1963. *S. zdanskyi* Stensiö; Liu, Liu and Su 1—30, figs. 2—5, pls. 1—8.

Diagnosis.—Body slender, fusiform, slightly compressed. Head depressed and relatively long. Head length about 1/4 to 1/5 of the total length of the fish, and 1.4 times the maximum depth of body. Lateral margin of parietal with broad blunt process. Posterior part of the median gular plate smaller than that in *S. huananensis*. Dorsal fin rather long and comparatively low with 27 rays. The scales of the abdominal and caudal regions with few denticles. The exposed area of the scale with shallow concentric grooves. The total number of transverse scale rows is about 46—48. Fin formula: P 10—12; V 6 (approx.); A 7—9; C 13.

Stratigraphic and geographic range.—Upper Jurassic. Kujieertou, Zhuozhishan, Hadatuhe and Deliding, Nei Mongol; Guanyuangou, Guyuan, Ningxia; Hedaochuan, Huanxian and Fengjiawan, Lintao, Hekou and Lanzhou, Gansu; Baiyushan and Chenjiabian Wuqi, Shaanxi; Ningjiagou, Mengyin, Shandong.

Sinamia huananensis Su, 1973

(figs. 2—4)

1963. *Sinamia zdanskyi* Stensiö; P'an: 124, figs. 1—3, pls. 1, 2.

1973. *Sinamia huananensis* Su: 150, pl. 1.

1977. *Sinamia huananensis* Su; Chang and Chou: 6, pls. 2, 3.

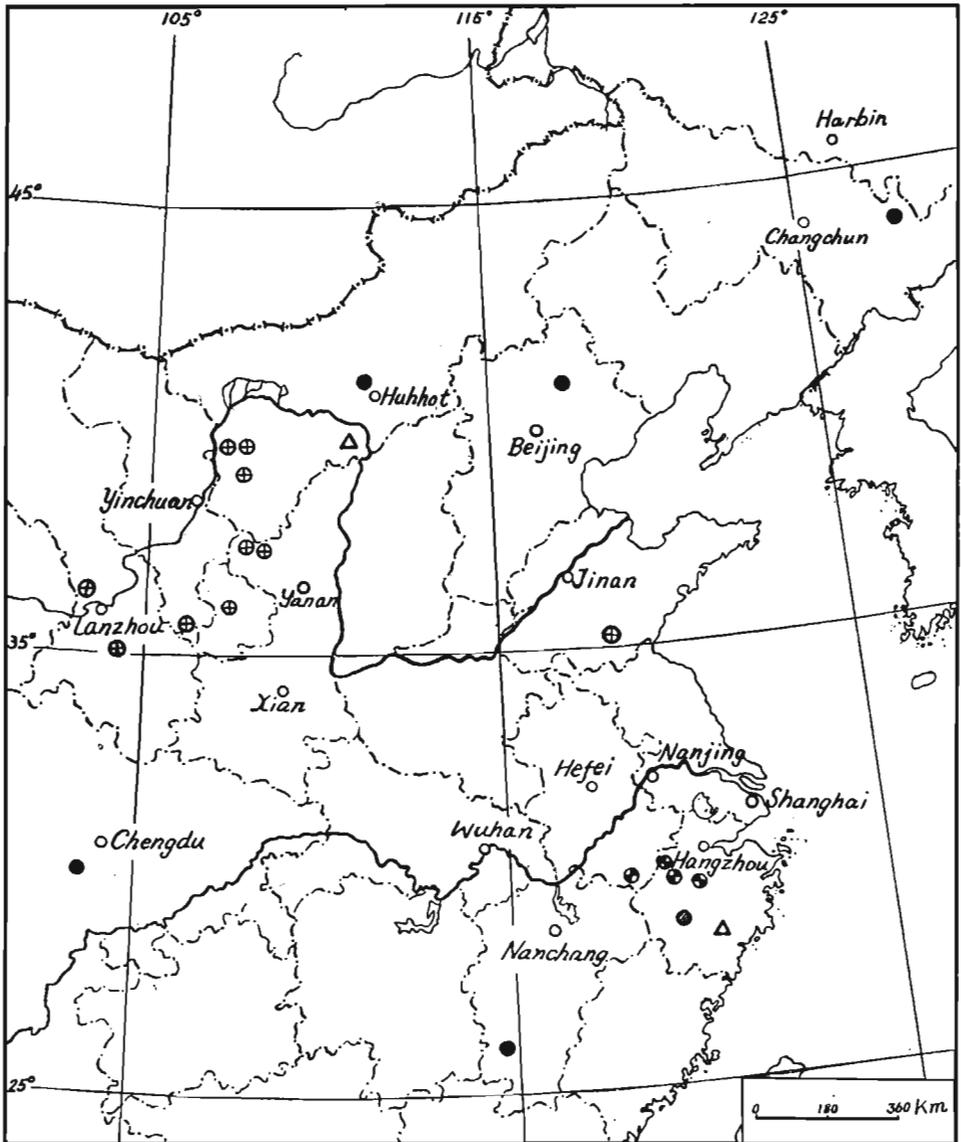
Holotype: The specimen figured by Su 1973: pl. 1. IVPP V4087.

Plesiotype: The specimen figured by P'an 1963: pl. 1: 1—2. MG V.725a-b, V.1518; IVPP V2983.

Diagnosis.—Body elongate fusiform. Head fairly short. Snout blunt. Parietal relatively short, its lateral margin almost straight or with a very small process. Median gular plate with large posterior part. Dorsal fin comparatively high, its base shorter than that of *S. zdanskyi*, arising from the middle point of body length or slightly before that point, with 22—23 rays. Two postcleithra. Posterior margin of scales almost smooth.

Description.—**Skull**. Dermal bones of skull roof resemble those in *S. zdanskyi*. The rostral is badly preserved and not clearly defined. The nasals are large. The

The geographical distribution of *Sinamia* and *Ikechaoamia*



- ⊕ *S. zdanskyi* △ *I. orientalis*, *I. meridionalis*
 ⊙ *S. huananensis* ● *Sinamia chinhuaensis* ● *Sinamia* sp.

Fig. 1. The geographical distribution of *Sinamia* and *Ikechaoamia*.

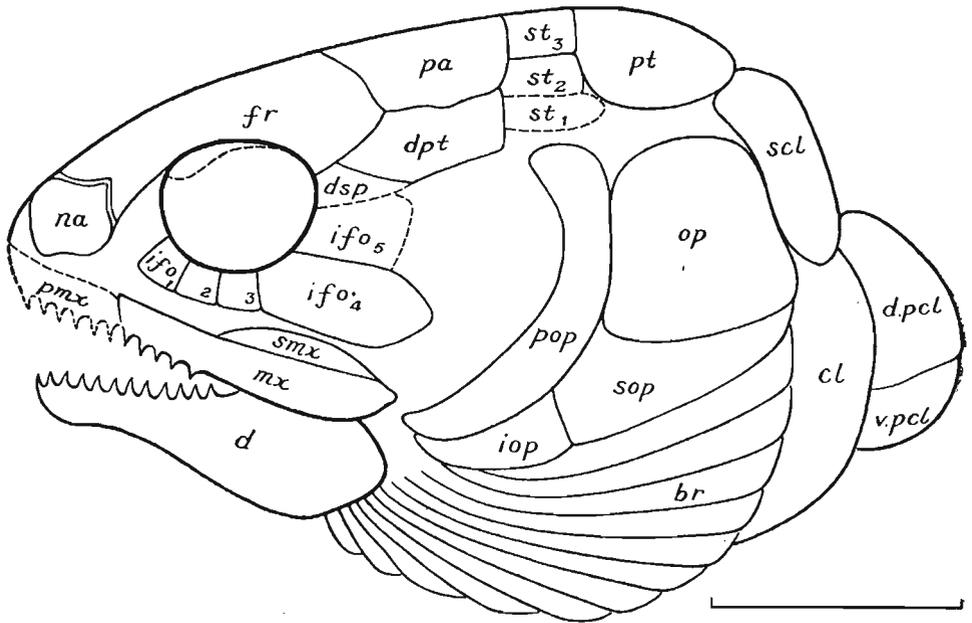


Fig. 2. *Sinamia huananensis* Su. Restoration of head in lateral view. Scale bar is 8 mm.

frontals markedly constricted between the orbits and rather enlarged posteriorly, the suture between them is almost straight. The parietal is large and resembles that in *S. zdanskyi*, but it is relatively short and its lateral margin is almost straight or bears a very small process. The dermopterotic is imperfectly preserved, but as far as can be judged it resembles that in *S. zdanskyi*. The supratemporals are three on each side of the midline. The circumorbital ring is incompletely preserved. Infraorbital 5 is badly preserved, but as far as can be judged it is smaller than infraorbital 4. There is also a wide gap among them and the preoperculum. The premaxillary is broken, but judging from its impression it appears to be similar

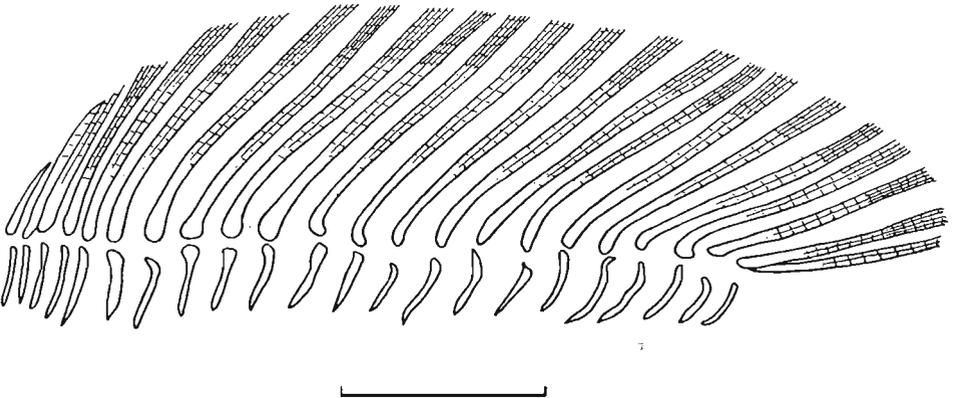


Fig. 3. *Sinamia huananensis* Su. Fin-rays and supporting structures of the dorsal fin. From MG V.725b. Scale bar is 15 mm.

to that in *S. zdanskyi*. The maxillary is long and robust, increases somewhat in height backwards, with almost straight oral border. A small low supramaxillary is present above the posterior part of the maxillary. The dentalo-splénial is essentially as that of *S. zdanskyi*, but its lower border is slightly concave. The oral borders of both upper and lower jaws bear long and conical teeth.

The operculum is a large four-sided plate, which is higher than broad. Its shape is slightly different from that in *S. zdanskyi*. The suboperculum is much smaller than the operculum, and with a longer ascending process at antero-superior angle. The preoperculum is high and narrow, and almost crescent-shaped. The interoperculum is very small and triangular in shape. The brachiostragal rays number

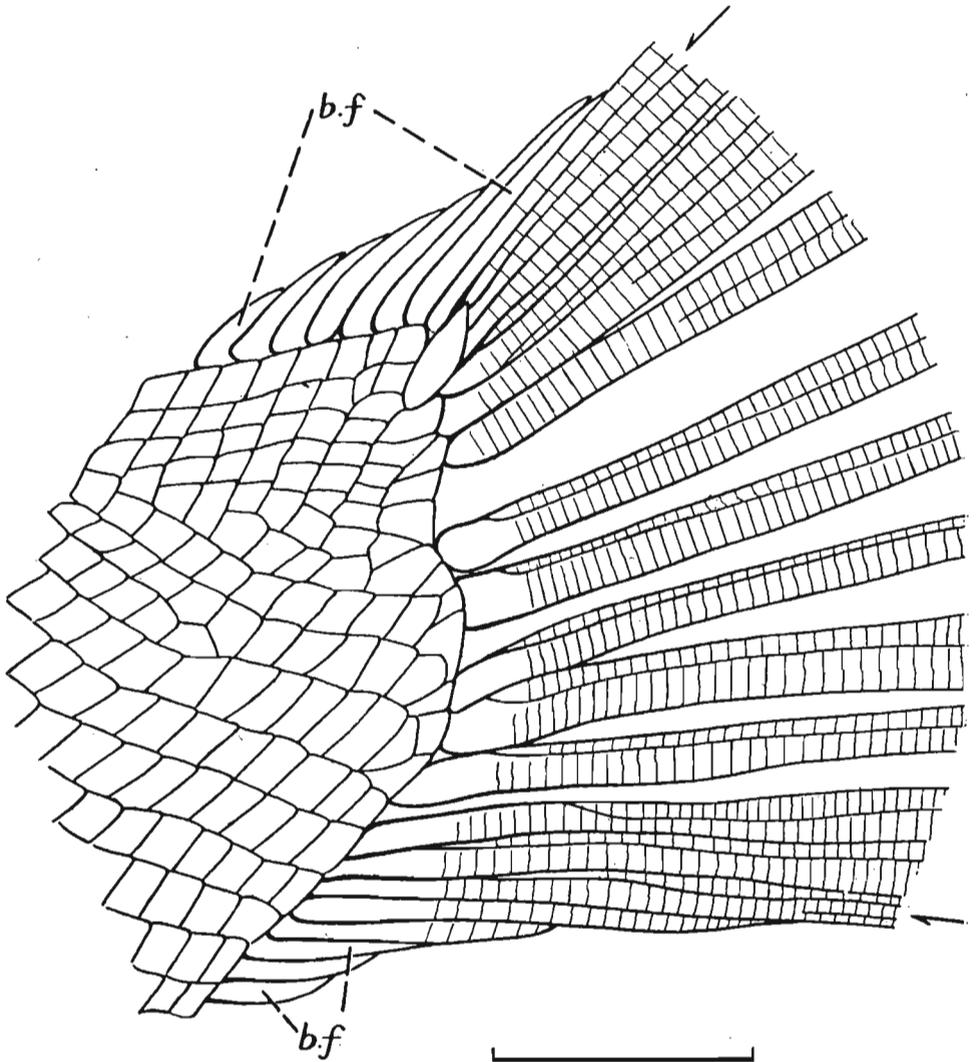


Fig. 4. *Sinamia huananensis* Su. The squamation of the caudal region and the base of the caudal fin, based on MG V.725. Arrows indicate the uppermost and the lowermost principal fin-rays. bf basal fulcrum. Scale bar is 10 mm.

about 12 and are rather robust. The median gular plate is large and almost isocetes triangular; its posterior part is larger than that in *S. zdanskyi*. All dermal bones of head covered with ganoine, but their ornamentation is weak (fig. 2).

Axial skeleton. Some of trunk and caudal centra, which can be seen in the holotype, are cylindrical and slightly constricted at the middle, with lateral ridges and pits. The ribs are short, not extending to abdominal border.

Girdles and paired fins. The suprascapulars are rather large and triangular in shape. The supracleithrum is relatively high and robust. The cleithrum is rather large, with a dorsal and a broad ventral limb. There are two postcleithral plates, of which the upper one is large and deep. The lower one is almost triangular in shape. The pectoral fins are rather long, consisting of about 11 rays. The ventral fins are very small, with about 7 rays.

Unpaired fins. The dorsal fin is rather long, but it is shorter and higher than that in *S. zdanskyi*, consisting of 22—23 well spaced rays (fig. 3). The anal fin consists of about 9 rays. The caudal fin is abbreviate hemiheterocercal, with a convex hinder border, it includes 12—13 principal rays. The bases of the epaxial and hypaxial lobes bear basal fulcra. The rays of all fins are segmented and branched distally except that the first and second rays are unbranched. The rays of caudal fin segmented throughout their length, except for a rather short proximal portion (fig. 4).

Squamation. The scales are rhombic and covered with thick ganoine on their exposed area. All scales are lower than long, having internal medial ridges generally. The exposed area of the scales is almost smooth, but some scales exhibit weak concentric ornamentation. The total number of transverse scale rows is about 41—43, with about 25 rows in maximum depth of body.

Stratigraphic and geographic range.—Upper Jurassic, Yantang Formation: Yantang, Shexian, Anhui; Shouchang Formation: Pujiang, Shouchang, and Chunan, Zhejiang.

Ikechaoamia Liu, 1961

Type species: Ikechaoamia orientalis Liu, 1961

Revised diagnosis.—Trunk moderate elongate and laterally compressed. Head rather large, parietal unpaired, supratemporals numerous. All of marginal teeth large and conical, dentary ones the largest. Vertebral centra completely ossified, each centrum with lateral excavations on each side, ribs short and delicate. Supraneural present. Fins without fulcra. Dorsal fin long-based and high, anal fin small, caudal fin with convex hinder border. Epurals more than five, epaxial fin-ray present or absent. Urodermal present. Scales rhombic and elliptical, lateral line scales elliptical and pierced by prominent sensory pores.

Ikechaoamia orientalis Liu, 1961

(figs. 5—8, pl. 6:1—3)

1961. *Ikechaoamia orientalis* Liu: 125, pls. 1, 2.

Holotype: A nearly complete fish, IVPP V2519.

Plesiotypes: Several specimens, IVPP V6708; figs. 5—7, pl. 6:1—3.

Description.—**Skull.** The dermal cranial roof is fairly thick. The general pattern of the dermal bones is similar to that of holotype (Liu 1961). Some elements not shown in the holotype were preserved in the present specimens. The nasal is four-sided large bone, with distinct sensory pores. The antorbital is somewhat

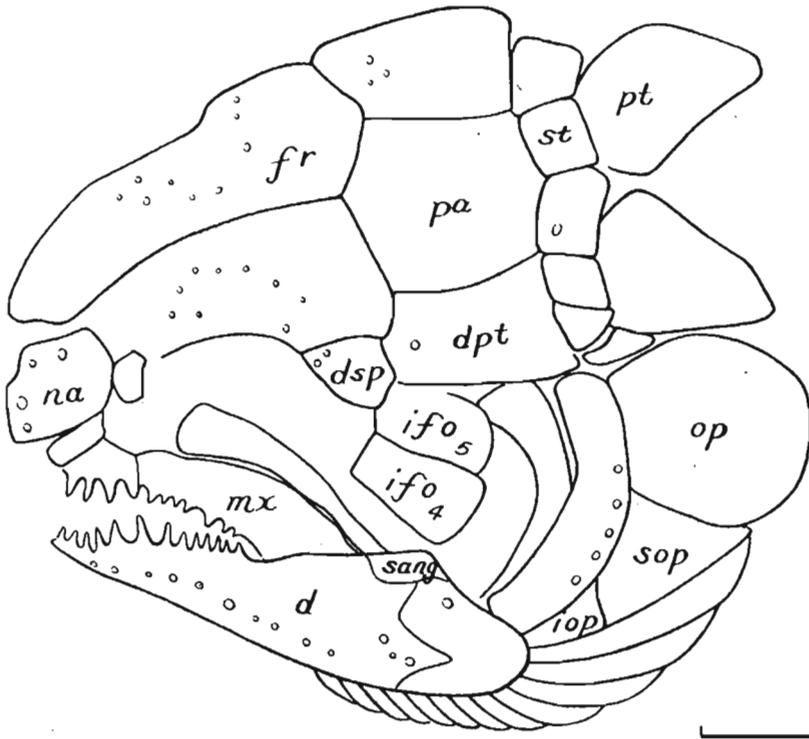


Fig. 5. *Ikechaoamia orientalis* Liu. Head, dorsal and lateral views. From IVPP V6708.4. The specimen is 28 mm long. Scale bar is 6 mm.

rounded. Infraorbitals 2 and 3 cannot be observed, but the postorbital bones, infraorbitals 4 and 5 were preserved; both of them are large and extend posteriorly further than those in *Sinamia*, but not reaching the anterior border of preoperculum as is usual in *Amia*. In other words, the gap between postorbitals and preoperculum is smaller than that of *Sinamia*. The supraorbitals are not well preserved; there are impressions beside the lateral margin of frontal. The dermosphenotic is large, nearly triangular in shape (figs. 5, 8).

The premaxillary and maxillary are visible, with large conical teeth. The supramaxillary is very indistinct. The dentary is long and fairly robust, with larger conical teeth. The angular and supra-angular are large (fig. 5).

The preoperculum is high and narrow. The operculum is a large four-sided plate, which is slightly higher than broad. Its posterior margin, which is the longest of the four sides, is rather convex. The suboperculum is much smaller than the operculum. It has four margins, and it is nearly the same shape as in *Sinamia* and *Amia*. The anteroventral margin is fairly short. The interoperculum is a rather small triangular plate. Branchiostegal rays numerous, about 12 in number. The gular plate is invisible in the present specimens.

The sensory canals of head are well developed and open outward with large pores. The supraorbital and infraorbital canals can be traced out by the preserved sensory pores, and show a pattern similar to that of *Sinamia*.

Axial skeleton. The vertebral column is well preserved, and consists of about 45 vertebrae. All of the vertebral centra are well ossified and are marked by two excavations on each side. The centrum is longer than deep, biconcave and with

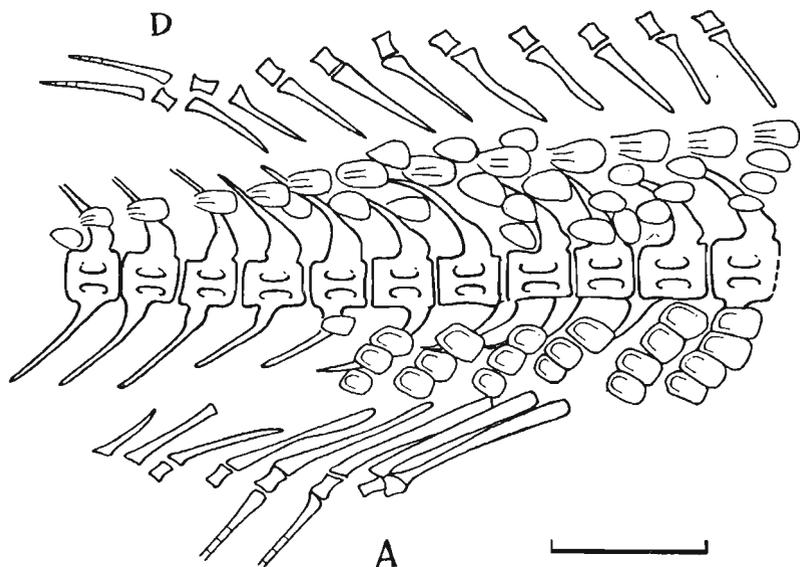


Fig. 6. *Ikechaoamia orientalis* Liu. A portion of trunk, right lateral view, showing shape of scales. From IVPP V6708.3. Scale bar is 3,5 mm.

a distinct hole in centre. Neural spines are short, the base of the neural arch is broad. Anteriorly, a series of about 12 supraneurals closely contact the distal ends of the corresponding neural spines. In the caudal region the neural and haemal arches are symmetrical until the base of caudal fin, at which point about 9 haemals predominate both in length and stoutness. A one-to-one relationship exists between the hypurals and the caudal fin-rays. Seven epurals can be seen in specimen V6708.1 (fig. 7).

Paired and unpaired fins. The fins of *Ikechaoamia* have been described previously by Liu (1961); only the unpaired fin supports need be mentioned here. The unpaired fin supports are arranged in two series and may be spoken of as axonosts and baseosts. They are equal in number, but the axonost is much longer than baseost; the latter is very short. Their shape and arrangement are similar to those in certain palaeoniscids (fig. 6).

Squamation. The scales of *Ikechaoamia* vary in shape. Along and near the vertebral axis there are about 8—9 scale rows. On and below the vertebral column they are basically rhombic, but somewhat rounded at each corner. Above the axial they became elliptical and sharpened at the hind border. The lateral line scales are well preserved in specimen V6708.2. This kind of scale is longer than deep, and is pierced by lateral line sensory canal at its hind portion. According to our observations the scales of *Ikechaoamia orientalis* are both rhombic and elliptical. The covered portion exhibits fine concentric lines of growth, the exposed portion is thickened with ganoine. It seems that the areas above the neural spine and below the haemal spine do not exhibit any kind of scale. We think that probably it is naked or covered with very thin scales on these areas. There are some scales behind the occipital region which appear irregular in outline. All of the scales are attached to the body by a pronounced vertical medial ridge. At the upper portion of the tail, a long bony lamina (urodermal) is present on the terminus of the vertebral column (fig. 7).

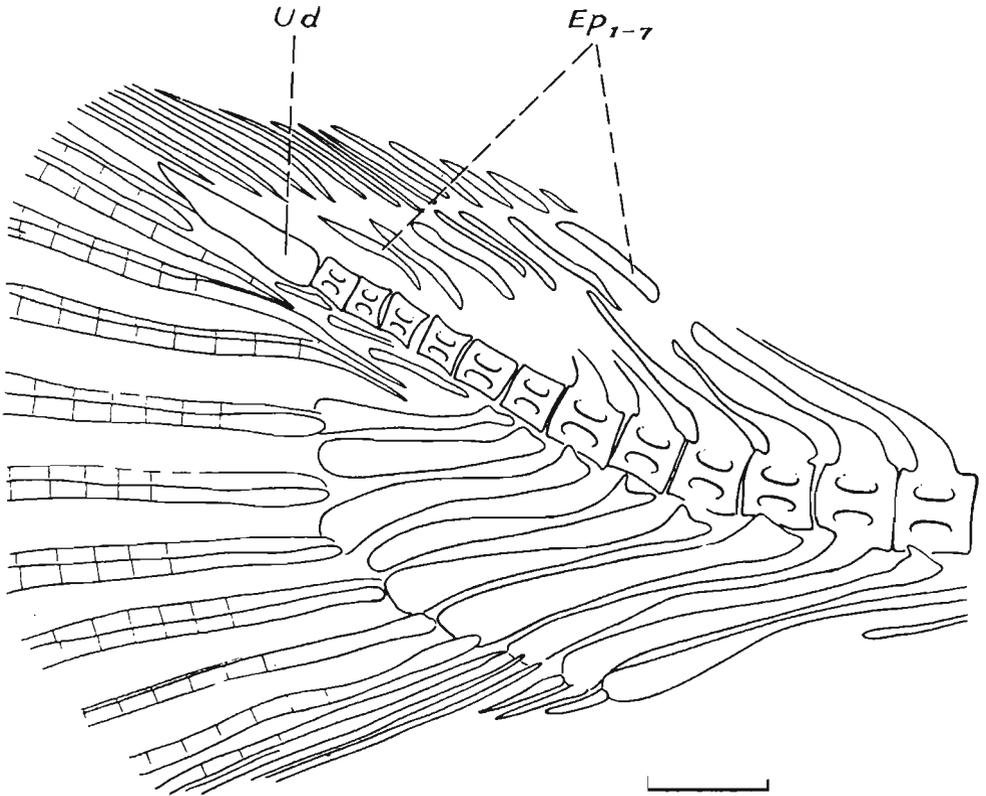


Fig. 7. *Ikechaoamia orientalis* Liu. Caudal skeleton preserved in IVPP V6708.3. Ep₁₋₇ epurals, Ud urodermals. Scale bar is 2,5 mm.

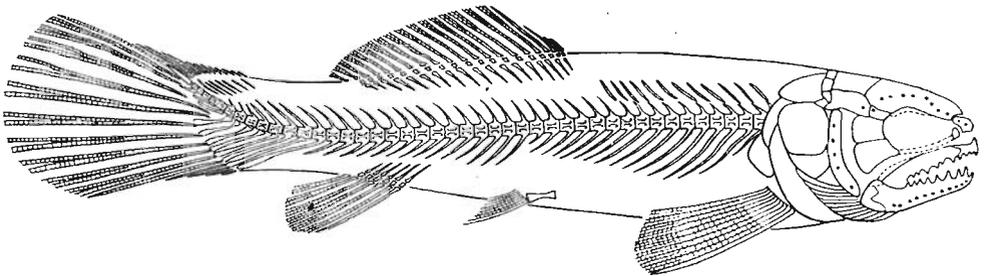


Fig. 8. *Ikechaoamia orientalis* Liu. Restoration in lateral aspect.

Based on the above observation a tentative reconstruction of *Ikechaoamia orientalis* can be made (fig. 8).

Stratigraphic and geographic range.—Upper Jurassic, Jingchuan Formation: 200 metres south of Talakou, Hungjin Qi, Ikechaomeng, Nei Mongol.

Ikechaoamia meridionalis Zhang et Zhang, 1980

1980. *Ikechaoamia meridionalis* Zhang et Zhang: 81, figs. 1—4, pl. 1.

Holotype: *I. meridionalis* Zhang et Zhang, 1980: figs. 1—4, pl. 1, IVPP V5805.

Specific characters.—Body rather elongate. Number of vertebrae more than 50.

Epaxial fin-ray present. Most of the scales rhombic, except the lateral line scales. Dorsal fin with 25 fin-rays; anal fin with about 9 rays. Body length 3 times head length; 7 times body depth. One series of fin supports in unpaired fins.

Stratigraphic and geographic range.—Upper Jurassic, Shouchang Formation: Huzhen, Jinyun, Zhejiang.

DISCUSSION

Since *Sinamia* was first discovered by Tan and Zdansky from Mengyin Group of Shandong in 1923, it has been found from many different localities that correlate with the Mengyin Group in North and South China. The *Ikechaoamia*-like *Sinamia* was found from Inner Mongolia, North China, in 1960. It also has been found from Zhejiang, Southeast China. All these discoveries are of great interest to the study of the palaeontology and stratigraphy in China.

The Mengyin Group, which yielded the type species of *Sinamia*, is a continental deposit first studied by Tan (1923). On account of its stratigraphic position and lithological character, Tan correlated this group with the Laiyang Formation which yields *Lycoptera sinensis* and other fossils. Grabau, after studying the mollusks, insects (1923) and *Lycoptera* (1928) from the Laiyang Formation and related formations from western Liaoning, and eastern Gansu, advocated that the fish-bearing beds are Lower Cretaceous in age.

Other vertebrates have been found in the Mengyin Group along with *Sinamia zdanskyi*. These include remains of a sauropod, *Helopus zdanskyi*, and the turtles, *Sinemys lens*, *Sinchelys applanata* and *Scutemys tecta*, all found by Tan and Zdansky. All these forms were studied by Wiman (1929, 1930). Their age was also considered by Wiman as Lower Cretaceous.

Since the end of the fifties, based on new palaeontological finds and also from a critical study of the previously described fauna and flora, most authors have determined that these supposedly Lower Cretaceous beds are Upper Jurassic and even older in age. For instance, Young (1958), from a study on the new materials of sauropods from Shandong has pointed out that the geological age represented by *Helopus zdanskyi* is probably Upper Jurassic. Liu *et al.* (1963), after studying the lycoperid ichthyofauna of northern China, revised the classification of these fishes and found that three *Lycoptera* zones can be established, and all of them were confined to the Upper Jurassic (Liu, Su, Huang and Chang 1963).

Some badly preserved *Lycoptera* have been found in Mengyin Group with *Sinamia zdanskyi*, which is a form usually found in zone III of Liu's designation (Liu, Liu and Su 1963). At Hadatuhe on the western border of the Ordos plateau, *Sinamia zdanskyi* was also found at a successive section of stratigraphy, below the *Lycoptera woodwardi* Zone and above the *L. kansuensis* Zone.

From Hodaochuan and Baiyushan, in Zhidan (Paoan) Group, *Sinamia zdanskyi* was found from both the Jingchuan Formation and the Huachi-Huanhe Formation, which are stratigraphically correlated with the Liupanshan Group.

From west of Lanzhou, *Sinamia zdanskyi* was found from the Hekou Group; it shows that this group can be correlated with the Zhidan Group.

From northern Hebei, *Sinamia* was discovered together with *Lycoptera* and *Peipiaosteus* from the Rehe (Jehol) Group, *Peipiaosteus* being closely related to Jurassic *Chondrosteus*.

Sinamia huanenensis differs from *S. zdanskyi* in several points, but shares the same primitive characters as the latter. It was found together with *Mesoclupea showchangensis*, which resembles Jurassic species of *Thrissops* from the Shouchang Formation of Zhejiang. From the Yantang Formation (South Anhui), we found *S. huananensis* also, together with *Huashia*. The age of the above mentioned fish fauna was considered as Upper Jurassic (Su 1973; Chang and Chou 1977).

An imperfectly known species, *S. chienhuaensis*, described by Wei *et al.* (1976), was found from the Guantou Formation of Zhejiang; it closely resembles *S. huananensis* in its skull structure, fins and scales, but with a longer dorsal fin and a greater number of transverse scale rows.

An interesting form of Sinamiidae, *Ikechaoamia orientalis* which was discovered from Jingchuan-Luhandong Formation of Zhidan Group, bears characteristics closely resembling *Sinamia* in its skull structure but with a shortened dorsal fin, different squamation and fairly enlarged postorbitals (If_4 and If_5). The formation containing *I. orientalis* was at first considered by Liu (1961) as lowermost Lower Cretaceous, and later changed to Upper Jurassic by himself (Liu *et al.* 1963). A new discovery of *Ikechaoamia* (*I. meridionalis*) from the Shouchang Formation in Zhejiang has further emphasized the resemblance between the Upper Jurassic fish fauna in North and east South China. Up to now, the sinamiids yielded from the *Lycoptera*-bearing beds in North China are *S. zdanskyi* and *I. orientalis*; and from the *Mesoclupea*-bearing bed in Southeast China they are *S. huananensis* and *I. meridionalis*. Based on the fish fauna mentioned above there is sufficient evidence to show that the age of these two fish faunas in North and Southeast China should be Upper Jurassic and can be correlated generally.

On the basis of the reasons mentioned above, a correlation of the deposits containing the above mentioned fishes is proposed (table 1). This is a rough correlation, but is significant for the division of the widely distributed Mesozoic continental deposits in China.

Recently, above the lycoperid ichthyofauna-bearing beds, a new fish fauna, the *Kuyangichthys*-*Kuntulunia* ichthyofauna, has been found from the overlying Guyang Formation. The members of this new fish

Table 1

The stratigraphic and geographic distribution of *Sinamia* and *Ikechaoamia* in China

Series	Region	North China					Southeast China		
		Shan-dong	North Hebei	Jilin	North Shaanxi Nei Mongol	Gan-su	Zhejiang	South Anhui	Jiangxi
Lower Cretaceous				Yanji group <i>Sinamia</i> sp.			Guantou Fm. <i>S. chinhuaensis</i> <i>Paralycoptera</i> etc.		
	Upper Jurassic	Mengyin group <i>S. zdanskyi</i>	Nandian Fm. <i>Lycoptera</i> <i>Peipiaosteus</i> Huajiying Fm. <i>Lycoptera</i> <i>Peipiaosteus</i> Xiquayuan Fm. <i>Sinamia</i> sp. <i>Lycoptera</i> Dabeigou Fm. <i>Lycoptera</i> <i>Peipiaosteus</i>	Zhidan (Paoan) group	Jingchuan - Luhandong Fm. <i>I. orientalis</i> <i>S. zdanskyi</i> Huachi - Huanhe Fm. <i>S. zdanskyi</i> Luohe Fm. Yijun Fm.	Hekou group <i>S. zdanskyi</i>	Shouchang Fm. <i>S. huananensis</i> <i>I. meridionalis</i> <i>Mesoclupea</i> etc. Huangjian Fm. Laocun Fm.	Yantang Fm. <i>S. huananensis</i> <i>Huashia</i> Shiling Fm. Bingqin Fm.	Lengshuiwu Fm. <i>Sinamia</i> sp. <i>Mesoclupea</i> Ehuling Fm. Daguding Fm.
L.-M. Jurassic		Houcheng Fm. Palaeoniscoides Ptycholepoides							

fauna possess a more advanced level of organization than the *Lycoptera* fauna and judging from the absence of advanced teleosts in this new fish fauna, its geological age should be early Early Cretaceous (Liu *et al.*, 1982). Underlying the lycoperid ichthyofauna-bearing bed a new palaeoniscid fauna has been found in the Houcheng Formation (North Hebei) and the Tuchengzi Formation (Liaoning). The age of these two formations was considered as Middle Jurassic or even older.

All of these facts indicate that the age of the lycoperid ichthyofauna bed and related deposits should be Upper Jurassic.

New discoveries of *Sinamia* and *Ikechaoamia* from many different localities in North and South China indicate that these fishes were widely distributed during late Mesozoic, especially Late Jurassic (fig. 1, Table 1).

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EXPLANATION OF THE PLATE

Plate 6

Ikechaoamia orientalis Liu

1. A nearly complete individual. IVPP V6708.2.
2. A portion of trunk with well preserved caudal fin. IVPP V6708.3.
3. Head and anterior portion of trunk, indicating the shape and scales. IVPP V6708.4.

