

New fossil Vitimotauliidae (Insecta: Trichoptera) from the Jehol Biota of Liaoning Province, China

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ABSTRACT

A new genus *Sinomodus* gen. nov. with three new species of Vitimotauliidae are described and illustrated from Jehol Biota, the Yixian Formation in western Liaoning Province, northeastern China. Based on these well-preserved specimens, diagnosis of this family is revised, key to genera of Vitimotauliidae and key to species of *Sinomodus* gen. nov. are given. The age of *Sinomodus* gen. nov. and the distribution of Family Vitimotauliidae are proposed. The variability of the wing venation of this family is discussed for the first time.

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1. Introduction

Vitimotauliidae, an important extinct family of caddisfly, was erected by Sukatcheva in 1968 based on characters of wing venation. This family is common in lower Cretaceous all over Eurasia, but scarce or absent in Jurassic (Sukatcheva, 1998). Up to now, it consists of three genera: *Multimodus* Sukatcheva, 1968 (14 species) (Sukatcheva, 1968; Sukatcheva, 1982; Sukatcheva, 1990; Sukatcheva, 1992; Ren, 1995); *Vitimotaulius* Sukatcheva, 1968 (3 species) (Sukatcheva, 1968; Sukatcheva, 1990); and *Purbimodus* Sukatcheva and Jarzembowski, 2001 (4 species) (Sukatcheva and Jarzembowski, 2001). Species of *Multimodus* and *Vitimotaulius* were discovered in Southeastern Siberia, Zabaykal and Mongolia of the Early Cretaceous, and *Purbimodus* was reported in South England of the Early Cretaceous (Berriasian; Sukatcheva and Jarzembowski, 2001). In Northern China, Ren described 3 species of *Multimodus* in 1995, which belong to the Yixian Formation of Jehol Biota.

Recently, we discovered several new fossil Vitimotauliidae specimens from the Yixian Formation of western Liaoning Province, they are referred to a new genus: *Sinomodus* gen. nov. and 3 new species: *S. spatiosus* Wang and Ren sp. nov., *S. peltatus* Wang and

Ren sp. nov. and *S. macilentus* Wang and Ren sp. nov. These new findings are significant because of well-preserved head, thorax and part of hindwing, as most described species of this family were incomplete, and known from isolated wings. The excellent preservation of these new specimens enables us to describe more complete and detailed characters of Vitimotauliidae and to provide precious materials for studying evolution of Mesozoic caddisflies in the future.

The age of the Yixian Formation is still controversial. Generally, three opinions were proposed: the Late Jurassic, the Late Jurassic–Early Cretaceous and the Early Cretaceous (Chang et al., 2007). According to the isotopic study of samples obtained from the volcanic-sedimentary rock, age of the Yixian Formation in Yixian and Beipiao areas range roughly from 132 ± 1 Ma to 112 ± 3 Ma (Ji et al., 2004). Comparing the fossils discovered in the Yixian Formation (birds, dinosaurs, fish, conchostracans, insects, bivalves and plants et al) with correlative fossils from the Solnhofen biota of Germany, the Purbeck biota in England, Late Jurassic Terori-type and Ryoseki-type floras in Japan, the Middle Jurassic Yorkshire flora and the Great Estuarine conchostracans fauna, the synthetic age of the Yixian Stage may be determined as Late Tithonian to Berriasian (Wang et al., 2005). In this article, we tentatively agree with the viewpoint of the Late Jurassic–Early Cretaceous (Late Tithonian to Berriasian). We can't ascertain the exact age just based on the fossils described in this paper.

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2. Materials and methods

The fossils described herein were collected from Huangbanji-gou, Chaomidian Village, Shangyuan town, Beipiao City, western Liaoning Province, NE China, Jianshangou Bed, the Yixian Formation, the Late Jurassic to Early Cretaceous. They were examined using a Leica MZ12.5 dissecting microscopes and illustrated with the aid of a drawing tube attachment. Line drawings were made with CorelDRAW 12 graphic software. Photographs were taken by Nikon Digital Camera DXM 1200C.

The type specimens described here are housed in the Key Laboratory of Insect Evolution and Environmental Change, College of Life Science, Capital Normal University, Beijing, China.

The body length was measured from the apex of the head to the apex of the abdomen. The wing length was measured from the basal to the apex of the wing. The length of antenna was measured from the base to the apex.

Morphological terms used here are explained by Holzenthal et al. (2007).

3. Systematic paleontology

Order Trichoptera Kirby, 1815
 Suborder Integripalpia Martynov, 1924
 Family Vitimotauliidae Sukatcheva, 1968

Sukatcheva described the characters of Vitimotauliidae (Sukatcheva, 1968) only from forewing venation. Based on well-preserved head and thorax of these specimens in this study, we revised family diagnosis as follows:

Revised diagnosis. Insect large, antennae slender, a little shorter than or equal to forewing length, base of antennae stout. Symmetrical setal warts present on head, pronotum, mesoscutum and scutellum. Length of forewing varies between 6 mm and 20 mm. Rs branches earlier than M, and M branches earlier than Cu₁. D cell and M cell closed by cross veins r and m, stem of Rs shorter than D cell, F1-F5 complete, Cu₁ forks before or at the same level of F1. Cu₂ and 1A reaches posterior margin of forewing at the same point or with a short distance. In hind wing, F4 absent. Cross veins r, m and m-cu visible. Two apical spurs present in foreleg. Entire body was covered with dense hairs.

Genus *Sinomodus* gen. nov.

Derivation of name. Generic name is a combination of Greek “sina” (China) and Latin “modus” (meaning “form”).

Type species. *Sinomodus spatiosus* Wang et Ren sp. nov.

Species included. *Sinomodus spatiosus* Wang et Ren gen. et sp. nov., *Sinomodus peltatus* Wang et Ren gen. et sp. nov., *Sinomodus macilentus* Wang et Ren gen. et sp. nov.

Diagnosis. Antennae slender, a little shorter than forewing. Symmetrical setal warts present on the head. Prothorax narrow and long, two pairs of pronotal setal warts are visible on pronotum. The inner pair long, the outer pair round. Mesothorax larger than prothorax, mesoscutum is broad, with a pair of long symmetrical scutal setal warts. Scutellum narrow anteriorly and broad posteriorly, two setal warts present, fused or not. In forewing, D cell, M cell and T cell closed, D cell equals to M cell. Apices of F1 and F2 located between 1/2 and 1/3 of wing length, apices of F3 and F4 located between 1/3 and 1/4 of wing length, Cu_{1a} branches at the same level of F1. Cu₂ and 1A reaches hind margin of forewing beyond mid-length.

Comparison. The new genus mainly differs from three other genera by the locations of apices of F1-F5.



Fig. 1. *Sinomodus spatiosus* gen. et sp. nov., photograph of holotype, No. TNP-42592-1, the scale bar is 5 mm.

3.1. Key to genera of Family Vitimotauliidae

- 1. Cu_{1a} branches at the same level of F1, apices of F1 and F2 locate between 1/2 and 1/3 of wing length, apices of F3 and F4 locate between 1/3 and 1/4 of wing length..... *Sinomodus*
- Cu_{1a} branches before F1, apices of F1-F4 locate between 1/2 and 1/3 of wing length..... 2

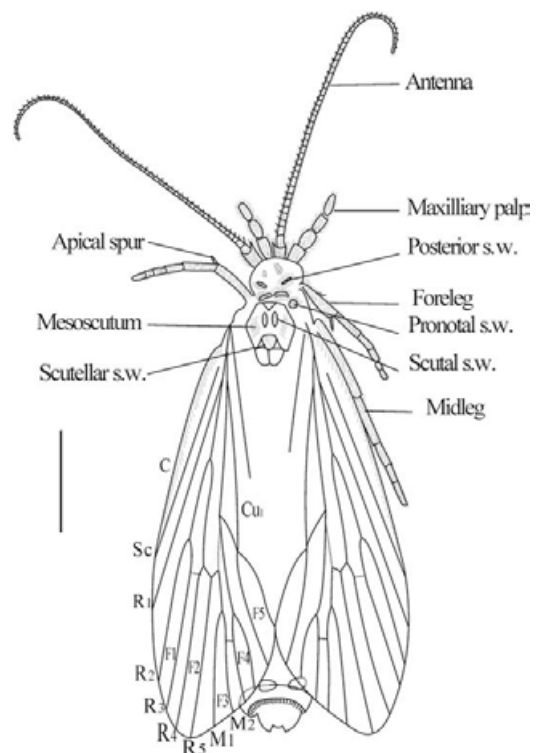


Fig. 2. *Sinomodus spatiosus* gen. et sp. nov., line drawing of holotype, No. TNP-42592-1, the scale bar is 5 mm, s.w. is short for setal wart.

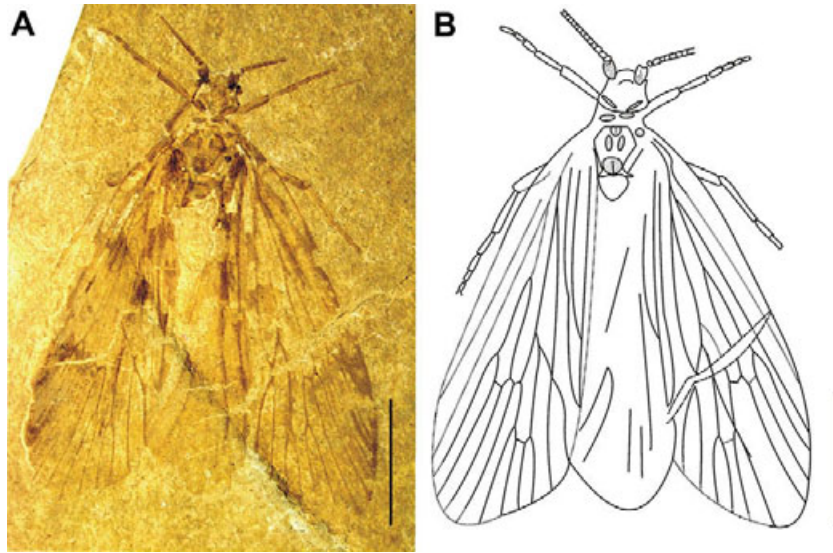


Fig. 3. *Sinomodus peltatus* gen. et sp. nov., photograph and line drawing of holotype, No. CNU-T-LB-2007006-1, the scale bar is 5 mm. A, Photograph. B, Line drawing.

- 2. Forewing length 6–10 mm, Cu₂ and 1A reaches hind margin of forewing a little before mid-length, apices of F1 and F2 locate near mid-length.....*Purbimodus*
Forewing length longer than 10 mm, Cu₂ and 1A reaches hind margin of forewing a little at or beyond mid-length, apices of F1 and F2 locate near 1/3 forewing length.....3
- 3. D cell a little longer than M cell, T cell open.....*Vitimotaulius*
M cell equal to 2/3 of D cell, T cell closed.....*Multimodus*

Sinomodus spatiosus Wang et Ren gen. et sp. nov.

Figs. 1 and 2

Derivation of name. “spatiosus” means long, indicates elongated antennae and body.

Holotype. male. No.TNP-42592-1, with counterpart No.TNP-42592-2. Antennae, maxillary palp, setal warts on head and thorax, hairs on the body, forewing and part of legs are well-preserved.

Type locality and stratigraphic horizon. Huangbanjigou, Chaomidian Village, Shangyuan town, Beipiao City, western Liaoning Province, NE China; Jianshangou Bed, the Yixian Formation, the Late Jurassic to Early Cretaceous.

Diagnosis. On Scutellum, two setal warts fused into one. M branches beyond cross vein m-cu₁.

Description. Body length 21 mm, antennae 16 mm, forewing length 19 mm.

Head: Four setal warts present on the dorsal view, the posterior pair long and oblique; the anterior pair small and obscure. Maxillary palp 4 or 5 segmented, covered with dense hairs, sg1-sg4 similar with equal length. The scape of antennae stout, flagellum slender and long, but antennae shorter than fore wing. Many spines are distributed in the inner side of antennae. Dense hairs are clearly visible on antennae.

Thorax: Characters of prothorax same as the diagnosis of this genus. Mesothorax large, anteriorly wide and posteriorly narrow, a pair of elongated symmetrical scutal setal warts visible on meso-scutum, some hairs present on the left and right side of meso-scutum. Two scutellar setal warts fused on scutellum.

Wing: Only forewings preserved, margin of wings covered with hairs, some hairs arranged along veins. Sc straight, reaches costal margin beyond 1/2 of wing length. Rs furcates at 1/3 of wing length. F1 parallel to F2. M branches beyond cross vein m-cu₁. M₁₊₂ and M₃₊₄ fork behind Rs₂. Rs₂ fork behind Rs₁. D cell, M cell and T cell closed by cross veins of r, m and m-cu₁. M cell equals to D cell, T cell longest.

Legs and abdomen: Legs are covered with dense hairs, apical spurs are preserved in foreleg. In midleg, only tarsi preserved, five segments. Last segments of abdomen are preserved. Two clear imprints of clusters of hairs and a ring of hairs are visible on the terminal of dorsal abdomen.

Sinomodus peltatus Wang et Ren gen. et sp. nov.

Figs. 3–5

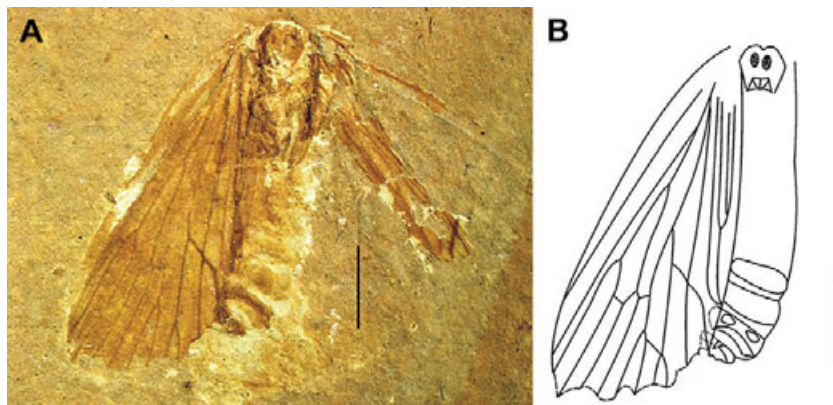


Fig. 4. *Sinomodus peltatus* gen. et sp. nov., photograph and line drawing of paratype, No. CNU-T-LB-2007010, the scale bar is 5 mm. A, Photograph. B, Line drawing.

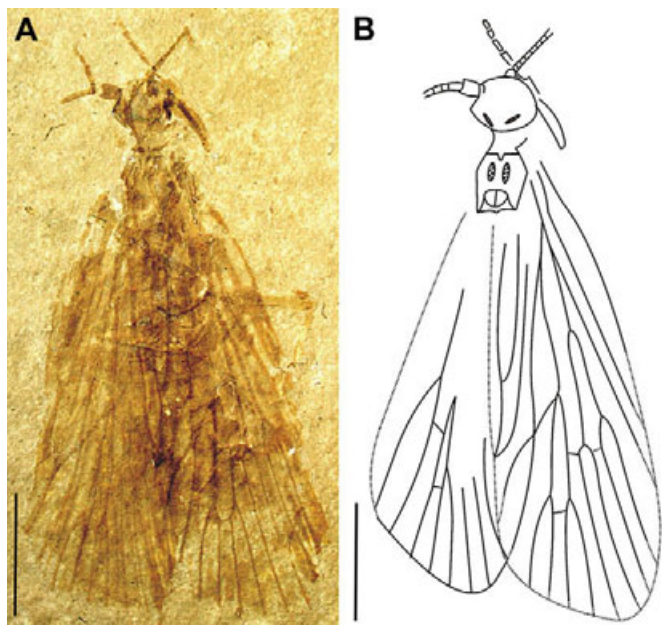


Fig. 5. *Sinomodius peltatus* gen. et sp. nov., photograph and line drawing of paratype, No. CNU-T-LB-2007011, the scale bar is 5 mm. A, Photograph. B, Line drawing.

Derivation of name. “Peltatus” means shield in English, implies that the mesothorax resembles a shield.

Holotype. part CNU-T-LB-2007006-1 (Fig. 3) and counterpart CNU-T-LB-2007006-2, with two forewings, thorax, head, antennae and legs. Paratype: CNU-T-LB-2007010 (Fig. 4), part of body and left forewing preserved, and CNU-T-LB-2007011 (Fig. 5), head, mesothorax, forewing, part of hind wing and antennae preserved.

Type locality and stratigraphic horizon. Huangbanjigou, Chaomidian Village, Shangyuan Town, Beipiao City, western Liaoning Province, NE China; Jianshangou Bed, the Yixian Formation, the Late Jurassic to Early Cretaceous.

Diagnosis. Two large scutellar setal warts present on scutellum, not fused. In forewing, M branches earlier than cross vein $m-cu_1$. 2A slightly shorter than 3A.

Description. Forewing length: 18 mm.

Head: One pair of long posterior setal warts present on the head, the anterior pair is not preserved, base of the antennae stout (Fig. 3).

Thorax: Characters of prothorax as described in diagnosis of the genus. On mesothorax, one pair of elongated symmetrical setal warts appear on mesoscutum. On scutellum, two large setal warts present, not fused.

Wing: Forewing incomplete, costal area poorly preserved. R_1 branches from R basally. All apical forks exist, F1 longer than F2, F3 equal to or longer than F4. Cross veins r and m straight and oblique, $m-cu_1$ a little curved toward base of forewing. Cu_1 furcates from the stem of M proximally. In anal area, 2A a little shorter than 3A, longer than 1/2 of 3A, 3A loops into 1A (Fig. 4). Hind wing partially preserved, F4 absent, cross veins m and $m-cu_1$ visible (Fig. 5).

Legs and abdomen: Legs slender, with 5 tarsal segments and a pair of simple terminal claws (Fig. 3B). Abdomen shorter than forewing, two imprints of hair clusters appear on the dorsal abdomen (Fig. 4).

Sinomodius macilentus Wang et Ren gen. et sp. nov.

Figs. 6–10

Derivation of name. “macilentus” derives from Latin, means slender, indicating slender antennae.

Holotype. part No. CNU-T-LB-2007009-1 (Figs. 6 A, 7A) and counterpart No. CNU-T-LB-2007009-2 (Figs. 6 A, 7A), with well-preserved mesothorax and forewings, part of head, hind wings and forelegs. Paratype: CNU-T-LB-2007012 (Fig. 8), with well-preserved head and mesothorax, part of forewings; CNU-T-LB-2007002 (Fig. 9), with forewing and part of antennae; CNU-T-LB-2007003 (Fig. 10), with variability of venation of left and right wing.

Type locality and stratigraphic horizon. Huangbanjigou, Chaomidian Village, Shangyuan Town, Beipiao City, western Liaoning Province, NE China; Jianshangou Bed, the Yixian Formation, the Late Jurassic to Early Cretaceous.

Diagnosis. Two small round scutellar setal warts are clearly visible on the anterior part of scutellum; in forewing, M branches earlier than $m-cu_1$. The length of 2A is 1/3 of 3A.

Description. Body length: 13 mm, antennae 14 mm, forewing length 17–19 mm.

Head: Large, three pairs of setal warts present on the head. The posterior pair elongated and oblique, the anterior pair small and round, the lateral pair similar to the anterior pair. Compound eyes

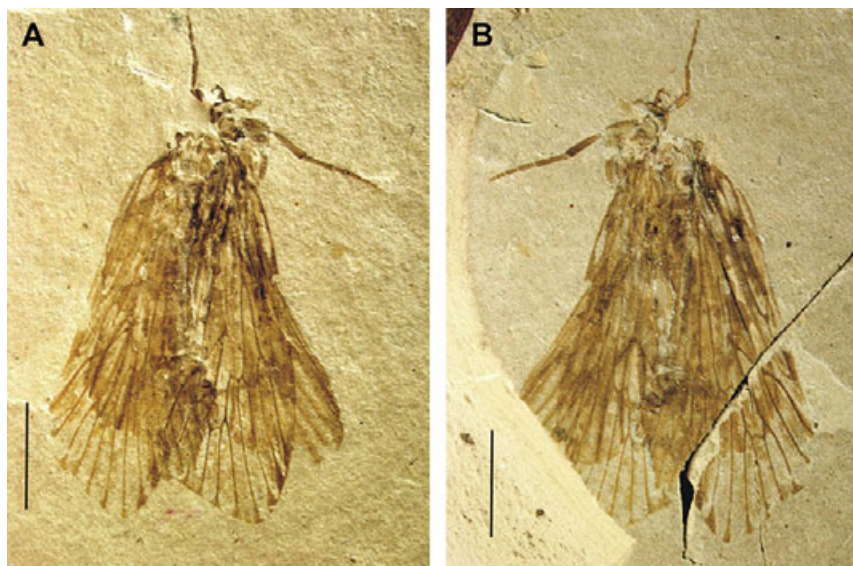


Fig. 6. *Sinomodius macilentus* gen. et sp. nov., photographs of holotype, the scale bar is 5 mm. A, part, No. CNU-T-LB-2007009-1. B, counterpart, No. CNU-T-LB-2007009-2.

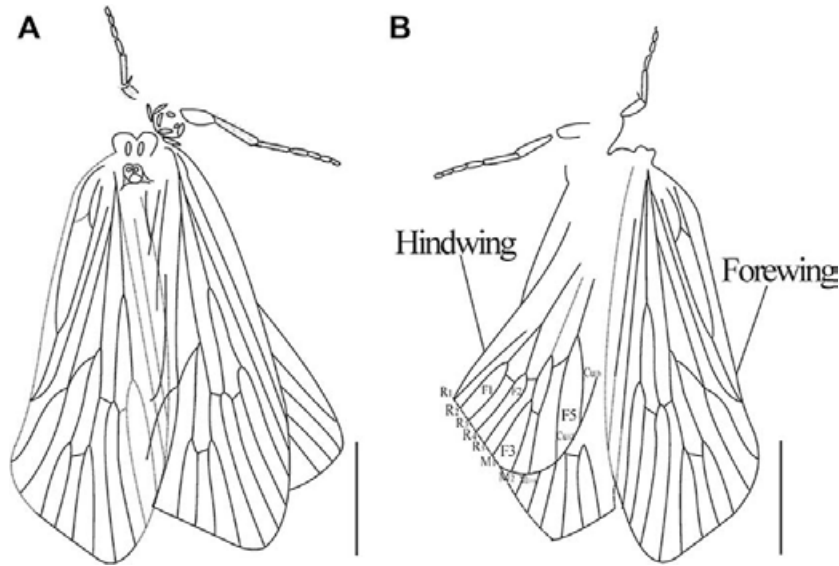


Fig. 7. *Sinomodus macilentus* gen. et sp. nov., line drawings of holotype, the scale bar is 5 mm. A, part, No. CNU-T-LB-2007009-1. B, counterpart, No. CNU-T-LB-2007009-2.

large, covered with hairs (Fig. 8). Scape of antennae stout, dense hairs cover the antennae (Fig. 9).

Thorax: Prothorax as described in the diagnosis of genus. Mesothorax large, a pair of elongated symmetrical setal warts present on mesoscutum. Two small round scutellar setal warts are clearly shown on the anterior part of scutellum (Figs. 6A, 7A).

Wing: In forewing, Sc straight, reaching costal margin beyond 1/2 of wing length. D cell, M cell and T cell closed. M cell equals to D cell, T cell longest. F1-F4 sessil. M branches earlier than m-cu₁. Apex of forewing locates in end of R₅. Cu₂ and 1A reaches hind margin at one point. beyond 1/2 of wing length. 2A shortest, 1/3 of length of 3A, length of 3A 2/3 of 1A. One cross vein present in anal vein area. M₁₊₂ forks earlier or later than M₃₊₄. Some hairs arrange along veins (Fig. 8). In hind wing, F4 absent, cross veins r, r-m and m shown (Figs. 6B, 7B).

Legs: Only a pair of forelegs preserved in holotype, covered with hairs, slender and apical spurs visible. Tarsi 5 segments (Figs. 6A, 7A).

3.2. Key to species of *Sinomodus* gen. nov

1. Two scutellar setal warts fused into one on scutellum, M branches beyond cross vein m-cu₁.....*S. spatiosus* Wang and Ren sp. nov.
Two scutellar setal warts not fused, M branches before cross vein m-cu₁.....2
2. Scutellar setal warts large, 2A long, a little shorter than 3A.....*S. peltatus* Wang and Ren sp. nov.
Scutellar setal warts small and round, 2A shorter, equal to about 1/3 of 3A length.....*S. macilentus* Wang and Ren sp. nov.

4. Discussion

The differences at genus level of Vitimotauliidae are not significant. The locations of apices of F3-F5 become the most prominent

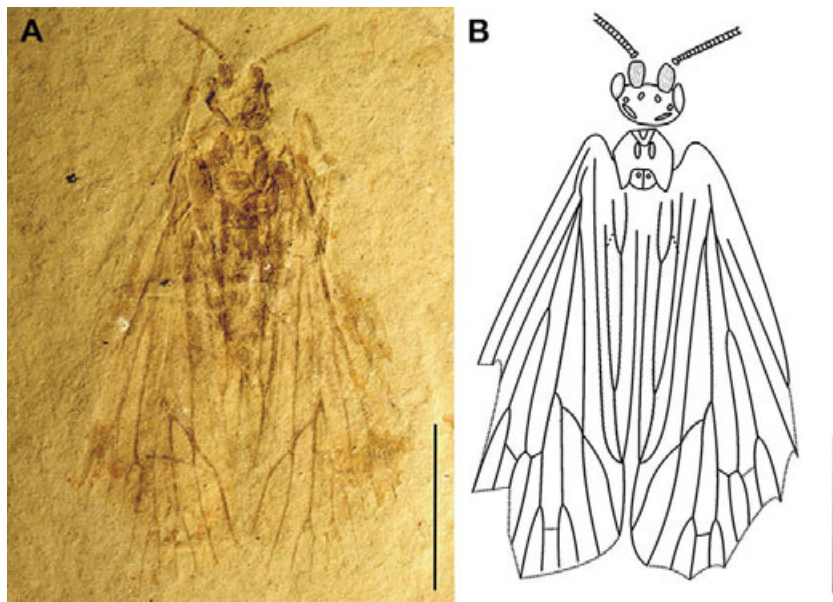


Fig. 8. *Sinomodus macilentus* gen. et sp. nov., photograph and line drawing of paratype, No. CNU-T-LB-2007012, the scale bar is 5 mm. A, Photograph. B, Line drawing.

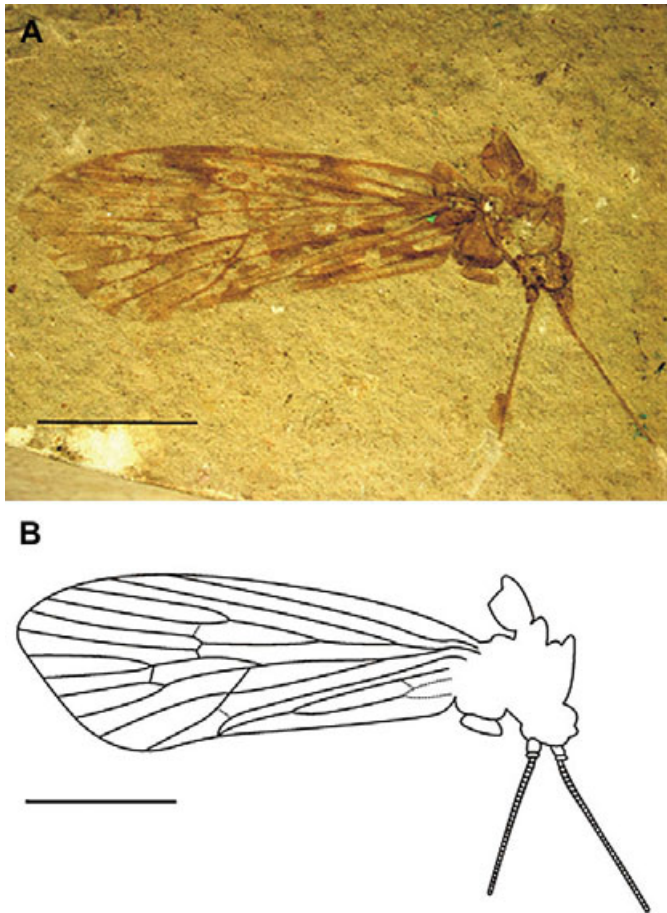


Fig. 9. *Sinomodus macilentus* gen. et sp. nov., photograph and line drawing of paratype, No. CNU-T-LB-2007001, the scale bar is 5 mm. A, Photograph. B, Line drawing.

differences. In genus *Purbimodus*, all apical forks branch near 1/2 of forewing length, but in genera *Multimodus* and *Vitimotaulius*, F3 and F4 forks between 1/2 and 1/3, but near 1/3 of forewing length. In the new genus *Sinomodus*, F3 and F4 forks after 1/3 of forewing length, meanwhile, Cu_1 branches at the level of F1, moving towards terminal of forewing, the same as F3 and F4, comparing to the other three genera. Based on comparison of characters, we propose that the four genera might have co-existed in the same age, or their geochronologic intervals were short. Besides, the isotopic age of lava at Huangbanjigou which Peng *et al* measured in 2003 is 127 ± 1.3 Ma (Peng *et al.*, 2003), indicating the Early Cretaceous. Therefore, we propose the age of genus *Sinomodus* is close to the Early Cretaceous.

Vitimotauliidae is abundant in the Early Cretaceous (Ivanov and Sukatcheva, 2002), and fossils of this family have only been discovered in Eurasia, but no fossils reported in the South Hemisphere up to now. Its distribution was provincial and entirely Laurasian. One reason for this may be Vitimotauliidae was little known in Gondwanan of the Mesozoic, another reason is that its distribution might be affected by fragmenting of Pangaea (Grimaldi and Engel, 2005). Pangaea began to rift in late Triassic (Ji, 2002), it was fragmented into Laurasian and Gondwanan before the Late Jurassic, but after the Middle Jurassic (Ji *et al.*, 2004). The proposal is that when Vitimotauliidae appeared and radiated in Late Mesozoic, the Pangaea have already been rifted entirely, which prevented expansion of Vitimotauliidae into Gondwanan.

The variability of venation between the left and right wings in the same individual is discovered in *Sinomodus macilentus* gen. et sp. nov. (Fig. 10). In the left wing, M_{1+2} branches slightly earlier

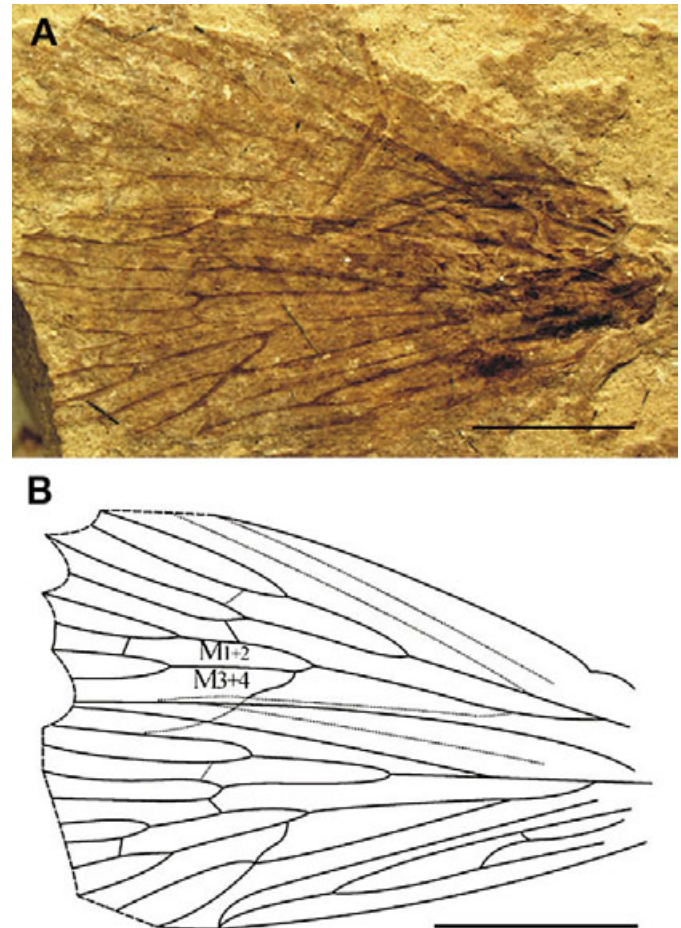


Fig. 10. *Sinomodus macilentus* gen. et sp. nov., photograph and line drawing of paratype, No. CNU-T-LB-2007003, the scale bar is 5 mm. A, Photograph. B, Line drawing.

than M_{3+4} , but in the right wing, M_{1+2} branches later than M_{3+4} . This is the first report of variability of venation of Vitimotauliidae. An appreciation of the venational variability is very important in identifying fossil caddisflies, especially when only isolated or fragmented wings are available.

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