GEOLOGICA CARPATHICA, DECEMBER 2010, 61, 6, 463–468 doi: 10.2478/v10096-010-0028-x

New male pelecinid wasps (Hymenoptera: Pelecinidae) from the Yixian Formation of western Liaoning (China)

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(Manuscript received April 22, 2010; accepted in revised form June 10, 2010)

Abstract: Two new genera and species *Abropelecinus annulatus* gen. et sp. nov. and *Azygopelecinus clavatus* gen. et sp. nov., placed in the subfamily Iscopininae of the family Pelecinidae, are described and illustrated. *Sinopecinus viriosus* Zhang, Rasnitsyn & Zhang, 2002 are re-described. All these male specimens were collected from the Yixian Formation of Beipiao City, Liaoning Province, northeastern China. A key to the male species of the subfamily Iscopininae is given. In addition, sexual dimorphism in Pelecinidae and the paleoclimate of the Yixian Formation are briefly discussed.

Key words: Pelecinidae, Proctotrupoidea, Hymenoptera, new taxa, Yixian Formation, China.

Introduction

Pelecinidae, a family with only one extant genus, *Pelecinus* Latreille, 1802, belongs to the superfamily Proctorupoidea (Rasnitsyn 1980, 1988; Masner 1993). *Pelecinus* contains three extant species distributed in North and South Americas (Johnson & Musetti 1999). Pelecinids are highly sexually dimorphic and the sexes can easily be recognized by the form of metasoma. The metasoma of extant males, usually with seven segments but only six visible externally, is strongly clavate or tubular (Johnson & Musetti 1998) and less than twice as long as the head and mesosoma combined. In contrast, the metasoma of the females, usually with six segments visible, is linear or tubular and more than twice as long as the head and mesosoma combined. In North America, the females are commonly found, but the males on the other hand are very rarely seen (Brues 1928; Johnson & Musetti 1998, 1999). Brues believed that *Pelecinus* is most probably an example of geographical parthenogenesis and its reproduction mode, either bisexual or parthenogenetic, may be related to climate conditions.

Twelve fossil genera with 43 species within this family have been described (Brues 1933; Kozlov 1974; Johnson 1998; Engel 2002; Zhang et al. 2002; Zhang & Rasnitsyn 2004; Zhang 2005; Zhang & Rasnitsyn 2006; Engel & Grimaldi 2006; Duan & Cheng 2006; Rasnitsyn 2008; Shih et al. 2009; Liu et al. 2009, 2011). Like the extant male pelecinid wasp, the males of fossil pelecinids are also quite rare. Only eight of the 43 described fossil species were erected on the basis of male specimens: four from Baissa, Russia, one from the Baltic, one from New Jersey, one from Shar Teg, Mongolia, and one from Beipiao, China. They are summarized in Rasnitsyn (2008) and Shih et al. (2009). Three of these are placed in the subfamily Pelecininae: *Pelecinopteron tubuliforme* Brues, 1933 (Engel, 2002) from Baltic amber; *Protopelecinus regularis* Zhang & Rasnitsyn, 2004 from Baissa, Russia; *Henopelecinus pygmaeus* Engel & Grimaldi, 2006, from New Jersey amber. The remaining five are placed in the subfamily Iscopininae: *Iscopinus baissicus* Kozlov, 1974, *I. simplex* Zhang & Rasnitsyn, 2004 and ?*I. suspectus* Zhang & Rasnitsyn, 2004, all from Baissa, Russia; *Sinopelecinus viriosus* Zhang, Rasnitsyn & Zhang, 2002 from Beipiao, China, and *Praescopinus excellens* Rasnitsyn, 2008 from southwestern Mongolia, Shar Teg.

Recently we collected a total of 112 fossil specimens of pelecinids, 14 of which were males, from the Yixian Formation, Huangbanjigou, near Chaomidian Village, Shangyuan Township, Beipiao City, Liaoning Province (Fig. 1), China. Because the forewing venation is comparatively reduced and the 'X' pattern formed by 2r-rs, Rs, Rs_1 and Rs_2 is absent, we assigned the fossils to the subfamily Iscopininae. We de-

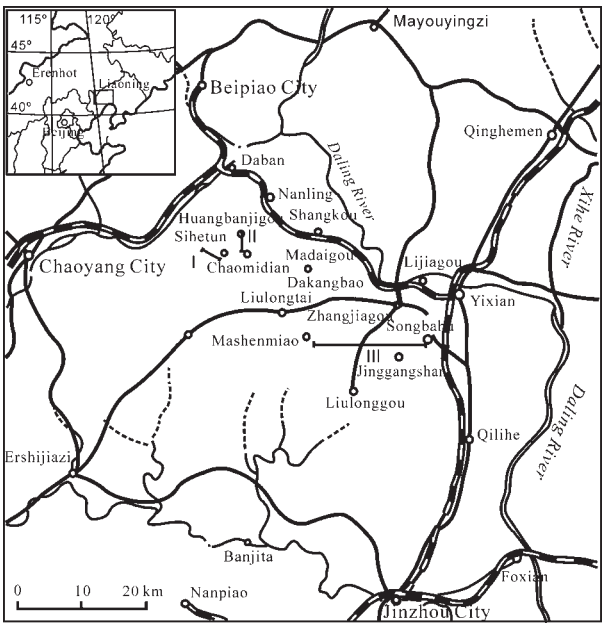

Fig. 1. Index map showing section localities of the Yixian Formation in Jinzhou–Yixian area, western Liaoning (after Ren et al. 1997). I — Sihetun section; II — Huangbanjigou section; III —Mashenmiao-Songbahu section.

scribe two new genera with one new species each, *Abropelecinus annulatus* gen. et sp. nov. and *Azygopelecinus clavatus* gen. et sp. nov. Using information and data from the new fossils, we re-describe *Sinopecinus viriosus* Zhang, Rasnitsyn & Zhang, 2002.

The exact age of the Yixian Formation is still undecided. There are three main opinions: the Late Jurassic (Ren et al. 1997; Zheng et al. 2003); the Late Jurassic–Early Cretaceous (Chen et al. 2004; Wang et al. 2004, 2005) and the Early Cretaceous (Swisher et al. 1999; Zhou et al.). By comparing the Yixian biota with the Solnhofen biota of Germany, the Purbeck biota from England and Late Jurassic Terori-type and Ryoseki-type floras from Japan, Wang et al. (Wang et al. 2005) considered the age of the Yixian Formation to be the Late Jurassic to Early Cretaceous (Late Tithonian to the Berriasian).

Materials and methods

The fossil specimens are deposited in the Key Laboratory of Insect Evolution & Environmental Changes, Capital Normal University Beijing, China (CNU). They were examined using Leica MZ12.5 dissecting microscopes and illustrated with the aid of an attached drawing tube. The final line illustrations were produced with Photoshop CS graphic software. Photos were taken with a Nikon DXM1200C digital camera. Morphological terminology and the system used here follow that of Mason (1986), Johnson & Musetti (1999), and Zhang & Rasnitsyn (2004).

The following standards were used for measurements: body length was measured from the apex of the head to the apex of the metasoma; head length from the vertex to the base of the head; head width at the maximal width of the head; mesosoma, metasoma, trochanter, femur, tibia, at the midline; wing length, from the base to the apex, wing width, at the maximal width of the wing. All measurements are in millimeters (mm).

Systematic paleontology

Order: **Hymenoptera** Linnaeus, 1758
Suborder: **Apocrita** Gerstäcker, 1867
Superfamily: **Proctotrupoidea** Latreille, 1802
Family: **Pelecinidae** Haliday, 1840
Subfamily: **Iscopininae** Rasnitsyn, 1980

Genus: *Abropelecinus* gen. nov.

Type species: *Abropelecinus annulatus* sp. nov.

Etymology: The generic name is a combination of the Greek prefix '*abro*' (graceful) and *Pelecinus* (the type genus of this family). Gender masculine.

Diagnosis: Male, antenna with 13 segments. Forewing with only two veins present (C and R). Metasoma with the seventh segment oblong, slightly acute apically (sometimes tergum and sternum separated to an extent).

Species included: Type only.

Abropelecinus annulatus sp. nov.
Figs. 2 and 3

Etymology: The species name is derived from the Latin '*annulatus*', meaning ringed.

Holotype: CNU-HYM-LB2006046-P & -C (part and counterpart). A complete insect except for missing part of legs.

Paratype: CNU-HYM-LB2006052-P & -C (part and counterpart); CNU-HYM-LB2006067-P & -C (part and counterpart); CNU-HYM-LB2006075-P & -C (part and counterpart); CNU-HYM-LB2006076; CNU-HYM-LB2006077; CNU-HYM-LB2006079; CNU-HYM-LB2006083; CNU-HYM-LB2006084-P & -C (part and counterpart).

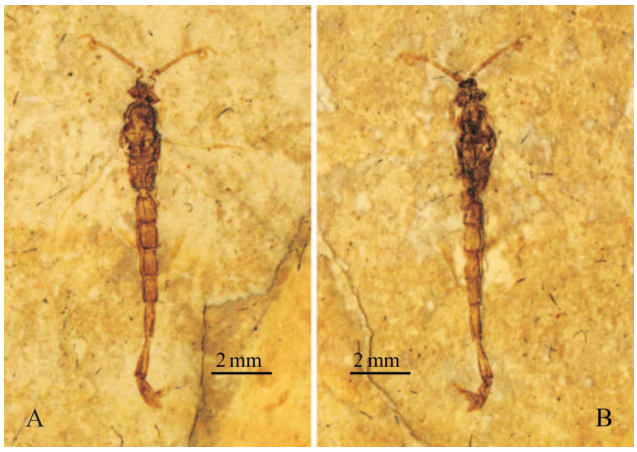

Fig. 2. *Abropelecinus annulatus* gen. et sp. nov., photograph of holotype, part and counterpart. **A** — CNU-HYM-LB2006046C; **B** — CNU-HYM-LB2006046P.

Fig. 3. *Abropelecinus annulatus* gen. et sp. nov., line drawing of holotype. CNU-HYM-LB2006046C.

Type locality and horizon: Collected from Huangbanjigou, near Chaomidian Village, Shangyuan Township, Beipiao City, Liaoning Province, China, the Yixian Formation, Late Jurassic to Early Cretaceous.

Diagnosis: Same as for the genus.

Description: Male; female unknown. Body length 10.9 mm; Head broadly transverse, length 0.8 mm and width 1.1 mm; compound eyes large, nearly oval; antenna with 13 segments, filiform but strong and thick. In both antennae, segments from 7 to 11 are preserved in coils. Of nine specimens collected, six have complete antennae preserved: four have antennae coiled, but two have antennae preserved straight. Scape trapezoid, thinner basally and thicker apically, apex slightly wider than pedicel and flagellum; pedicel shorter than half of scape, rectangular, slightly wider than long; flagellomeres cylindrical, the first flagellomere longer than scape and pedicel combined, subsequent ones also cylindrical and homonomous, with slightly decreasing length, but terminal flagellomere longer than the preceding one and acute.

Mesosoma length 2.9 mm, width 1.3 mm. Pronotum short dorsally. Mesoscutum large. Scutellum semicicular. Propodeum comparatively narrow, trapezoid. Metanotum and propodeum with irregular and coarse reticulate sculpture.

Forewing narrow and long, with only two veins (C and R) visible, R straight; pterostigma elongate and narrow, tapering to a point on anterior wing margin; M+Cu indistinct and weak. Hind wing slightly shorter than half length of forewing, with only C present.

Fore leg with only right coxa and partial femur are preserved. Mid leg discernible, mesocoxa comparatively small, mesotrochanter subrectangular, mesofemur and mesotibia incomplete but thinner than corresponding parts of hind leg, mesotarsus with only four segments preserved, basitarsus longer than remaining combined. Hind leg incomplete and distinctly paler than antennae, metacoxa big, round; metatrochanter trapezoid, metafemur slightly widened, metatibia narrow basally and gradually widened apically, slightly longer than metafemur, metatarsus narrow but incomplete.

Metasoma slender, length of 7.2 mm is about 7/10 of body length, and slightly paler than antennae. Seven segments visible, lengths are 0.8 mm, 0.8 mm, 0.8 mm, 0.8 mm, 1.1 mm, 1.3 mm and 1.6 mm; first and second metasomal segments alike and nearly square; third, fourth and fifth metasomal segments rectangular and becoming narrower; fifth metasomal segment nearly 3 times as long as wide; sixth metasomal segment trapezoid, narrowest basally of the entire metasoma; seventh metasomal segment approximately as long as sixth one and sternum acute apically; length ratio of metasomal segments is 1.0:1.0:1.0:1.0:1.4:1.6:2.0.

Genus: *Azygopelecinus* gen. nov.

Type species: *Azygopelecinus clavatus* sp. nov.

Etymology: The generic name is a combination of the Greek prefix '*azygo*' (odd) and *Pelecinus* (the type genus of this family). Gender masculine.

Diagnosis: Male, antenna with 15? segments. Forewing with only two veins distinct (C and R), 2r-rs issuing medial 1/3 of pterostigma, Rs short. M+Cu discernible, straight. First metasomal segment thin and rectangular, second and third ones nearly triangular, very narrow basally, fourth to sixth ones nearly trapeziform, last metasomal segment short triangular.

Species included: Type only.

Azygopelecinus clavatus sp. nov.
Figs. 4 and 5

Etymology: The species name is derived from the Latin '*clavatus*', meaning clavate.

Holotype: CNU-HYM-LB2006033. A complete insect except for missing part of legs.

Fig. 4. *Azygopelecinus clavatus* gen. et sp. nov., photograph of holotype. CNU-HYM-LB2006033.

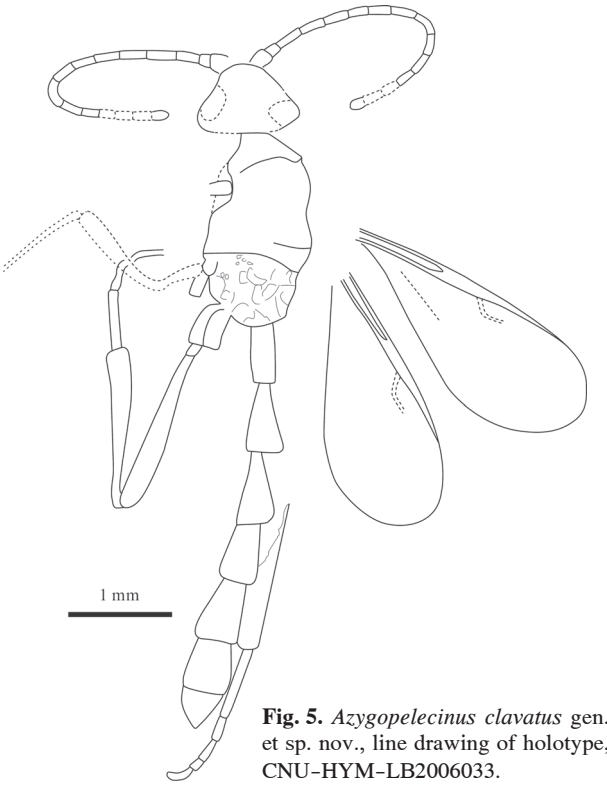

Fig. 5. *Azygopelecinus clavatus* gen. et sp. nov., line drawing of holotype, CNU-HYM-LB2006033.

Type locality and horizon: Collected from Huangbanjigou, near Chaomidian Village, Shangyuan Township, Beipiao City, Liaoning Province, China, the Yixian Formation, Late Jurassic to Early Cretaceous.

Diagnosis: Same as for the genus.

Description: Male; female unknown. Body size small, 6.4 mm. Head medium-sized, length 0.6 mm, width 1.0 mm, vertex narrow; compound eyes unclear; antenna with 15? segments, filiform, paler than mesosoma but scape and terminal segment darker than others; scape trapezoid, thinner apically and thicker basally, pedicel short, nearly half of scape, rectangular, flagellomeres cylindrical, first flagellomere as long as scape and pedicel combined, subsequent flagellomeres also cylindrical and homonomous, with slightly decreasing length, terminal flagellomere slightly expanded apically.

Mesosoma length 1.8 mm, width 1.0 mm. Pronotum comparatively long dorsally. Propodeum with irregularly coarsely reticulate.

Forewing length 2.7 mm, width 1.1 mm, with venation pale, two veins (C and R) darker and clearer, R straight, 2r-rs issuing nearly midpoint of pterostigma, Rs short, almost spectral, oblique apicad. M+Cu discernible and straight. Pterostigma elongate and narrow, tapering to a point on anterior wing margin.

Fore leg with only coxa partially preserved. Mid leg discernible but with contour not clear, thinner than hind leg, pale-yellow like hind leg, but both paler than mesosoma. Hind leg incomplete, metacoxa big, trapeziform; metafemur slightly widened, metatibia as long as metafemur, narrow basally and gradually widened apically, metatarsus narrow and incomplete.

Metasoma slender, 6/10 of body length; 7 segments visible, lengths are 0.5 mm, 0.7 mm, 0.7 mm, 0.6 mm, 0.6 mm, 0.5 mm and 0.4 mm; first metasomal segment thinner than other segments, rectangular, approximately 2.4 times as long as wide; second and third metasomal segments nearly triangular, very narrow basally; fourth to sixth metasomal segments nearly trapeziform and gradually broadening; last metasomal segment triangular, shortest, joining broadly with the former; length ratio of metasomal segments is 1.0 : 1.4 : 1.4 : 1.2 : 1.2 : 1.0 : 0.4.

Genus: *Sinopelecinus* Zhang, Rasnitsyn & Zhang, 2002

Type species: *Sinopelecinus viriosus* Zhang, Rasnitsyn & Zhang, 2002.

Revised diagnosis: Male, antenna with 15 segments, forewing with two veins (C and R), R slightly bent; 2r-rs oblique apicad and slightly longer than width of pterostigma; Rs short, almost spectral; M+Cu distinguishable and straight, bearing short rudiments of free M and 1cu-a. Metasoma with 1–6 segments nearly parallel-sided, rectangular, last segment triangular.

Species included: Type only.

Sinopelecinus viriosus Zhang, Rasnitsyn & Zhang, 2002
Figs. 6 and 7

Material: CNU-HYM-LB2006026; CNU-HYM-LB2006078-P & -C (part and counterpart); CNU-HYM-LB2006082; CNU-HYM-LB2006042.

Redescription: Male; female unknown. Body length 9.8 mm. Head medium-sized, length 0.9 mm and width 1.3 mm; compound eyes nearly oval; antenna with 15 segments, filiform but very strong, slightly longer than the head and mesosoma combined, scape trapezoid, thicker apically and thinner basally, cupped apically, pedicel short, inserted in scape, flagellomeres cylindrical and homonomous, with slightly decreasing length and width.

Fig. 6. *Sinopecinus viriosus* Zhang, Rasnitsyn & Zhang 2002, photograph of CNU-HYM-LB2006026.

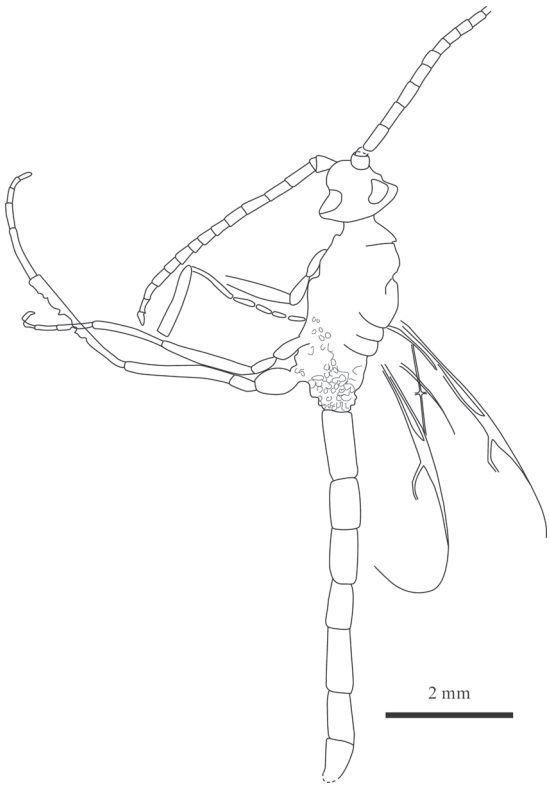

Fig. 7. *Sinopecinus viriosus* Zhang, Rasnitsyn & Zhang 2002, line drawing of CNU-HYM-LB2006026.

Mesosoma length 3.0 mm, width 1.5 mm. Pronotum comparatively long dorsally. Propodeum well produced above metacoxa, with irregular and coarse reticulate sculpture.

Forewing length 4.2 mm. C straight, R slightly bent, darker than C; pterostigma elongate and narrow, tapering to a point on anterior wing margin; 2r-rs arising in middle 1/3 of pterostigma, oblique apicad, two times as long as pterostigmal width; Rs short; M+Cu discernible and straight, bearing short rudiments of free M and 1cu-a. Hind wing shorter than half of forewing.

Fore legs not well preserved with only procoxa and protrochanter complete, procoxa oblong, protrochanter nearly as long as procoxa; mesocoxa slightly wider than procoxa, elongate oval; mesotrochanter smaller than mesocoxa, mesofemur stick-like, not gradually widened apically, mesotibia shorter and thinner than mesofemur, stick-like, slightly widened apically, mesotarsus incomplete, only 4 segments preserved, mesobasitarsus longest tarsomere; metacoxa oval, bigger than mesocoxa, metatrochanter as long as mesotrochanter, metafemur slightly longer than mesofemur, stick-like, not gradually widened apically, metatibia stick-like, just slightly widened apically, metatarsus thin, 5 segmented, metabasitarsus longest tarsomere, about twice as long as second metatarsomere, but shorter than half metatibia, fourth tarsomere shortest.

Metasoma slender and elongate, 6/10 of body length, 7 segments visible, stick-like, lengths are 1.1 mm, 0.8 mm, 0.9 mm, 0.7 mm, 1.0 mm, 0.7 mm and 0.7 mm; 1–6 segments nearly parallel-sided, rectangular. First metasomal segment slightly more than 2 times as long as wide, fifth one 2.2 times as long as wide, seventh one triangular, apex not acute; length ratio of metasomal segments is 1.0 : 0.7 : 0.8 : 0.6 : 0.9 : 0.6 : 0.6.

Remarks

Although different from other known pelecinids, the wasps described here are undoubtedly members of the Pelecinidae according to their metasoma and wing venation (Zhang & Rasnitsyn 2004). Zhang and Rasnitsyn have erected three genera (*Sinopelecinus, Eopelecinus, Scorpiopelecinus*) mainly based on whether the forewing venation was complete or reduced and the configuration of the first three segments of the metasoma. We follow them and adopt the shape of metasoma as a key diagnostic feature. These two new genera and species are significantly different from other 'male' species.

Key to male species of the subfamily Iscopininae:

1. Forewing with r closed 2
   Forewing with r opened or absent 5
2 (1). Forewing 'Rs_2' present .... *Iscopinus baissicus* Kozlov, 1974
   Forewing 'Rs_2' absent 3
3 (2). Forewing m-cu absent .... *Iscopinus simplex* Zhang & Rasnitsyn, 2004
   Forewing m-cu present 4
4 (3). Forewing first abscissa Rs shorter than that of M .... ?*Iscopinus suspectus* Zhang & Rasnitsyn, 2004
   Forewing first abscissa Rs longer than that of M ..... *Praescopinus excellens* Rasnitsyn, 2008
5 (1). Antenna with 13 segments; forewing with only C and R veins present .... *Abropelecinus annulatus* gen. et sp. nov.
   Antenna with 15 segments; forewing with C, R veins and 2r-rs crossvein, Rs short 6
6 (5). Metasomal 6th segment trapezoid, its basal point narrowest, 7th segment slightly acute apically .... *Azygopelecinus clavatus* gen. et sp. nov.
   Metasomal 6th segment same as the preceding one but shorter, 7th segment triangular .... *Sinopelecinus viriosus* Zhang, Rasnitsyn & Zhang, 2002.

Discussion

Among fossil Pelecinidae, only *Pelecinopteron* Brues, 1933 and *Sinopelecinus* Zhang, Rasnitsyn & Zhang, 2002 were described based on both male and female specimens preserved in Baltic ambers and in Beipiao, China respectively. All other known species have been based on either male or female specimens only, and none of these have subsequently been associated. We initially hoped that we could match our new male specimens with already described 'female' species from the same horizon and locality. But due to the low numbers of pelecinid fossils and their state of preservation, we could not associate the fossil male and female specimens with sufficient degree of confidence. Therefore, we tentatively erect two new genera and species.

In extant male pelecinids, the metasoma is composed of seven segments, but only six are visible externally (Johnson & Musetti 1999). Up to date, all reported fossil male pelecinids have metasoma with seven distinct segments, but the 7th metasomal segment is variable in shape. In *Pelecinopteron* and *Henopelecinus* it is falcate (Engel 2002; Engel & Grimaldi 2006). In *Protopelecinus*, the 7th metasomal segment is the same as the preceding one but shorter (Zhang & Rasnitsyn 2004). In *Iscopinus* and *Sinopelecinus*, the 7th segment is as wide as the 6th basally and gradually tapering apicad (Kozlov 1974; Zhang et al. 2002). We assume that the shape of the terminal segment may be related to mating behavior which may result in further speciation. If this is true, the terminal segment may be important in taxonomic studies of male pelecinids.

In the Beipiao locality during the Late Jurassic to Early Cretaceous, the paleoenvironment comprised large lakes surrounded by hygrophilous plants, dominated by shore-line equisetales and filicales. The climate was warm and humid with many arboreal gymnosperms, such as ginkgoes and conifers. This area also had forests on high mountains which were distant from the lake shore under a temperate but arid microclimate (Zhang H.C. & Zhang J.F. 2000). Brues (1928) highlighted *Pelecinus polyturator* as an example of geographic parthenogenesis: tropical, or at least warmer climate populations are bisexual whereas populations in more temperate climates consist of only females. Johnson & Musetti (1998 and 1999) analysed the data on distribution of genders separately. The populations in the USA and Canada are primarily thelytokous. Males account for approximately 4 % of

the collected specimens. The nearest populations in northern Mexico have males occurring at the same, or higher frequency as in the rest of tropical America. They partially supported Brues' point of view.

In our collection of 14 male and 98 female pelecinid fossils from the Yixian Formation, the males account for approximately 12.5 % of all collected specimens. Therefore, we propose that the composition of male pelecinids supports Zhang et Zhang's point of view about paleoenvironment and consistent with other fossil insects found in this locality and horizon.

Acknowledgments: We are sincerely grateful to Wang Yongjie (Department of Entomology, China Agricultural University), Gao Taiping, Yue Yanli, Yang Xiaoguang (College of Life Sciences, Capital Normal University) and Chen Huayan (College of Natural Resources and Environment, Southern China Agricultural University) for their valuable comments and suggestion on the manuscript. We also thank anonymous reviewers for providing valuable suggestions and comments in improving this manuscript. This work was supported by the National Natural Science Foundation of China (No. 40872022, 31071964), Nature Science Foundation of Beijing (No. 5082002) and the PHR20090509 Project of Beijing Municipal Commission of Education.

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