

Two new fossil wasps (Insecta: Hymenoptera: Apocrita) from northeastern China

LongFeng Li* and ChungKun Shih

College of Life Sciences, Capital Normal University, Haidian District, Beijing, China

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Praeaulacus obtutus sp. nov., assigned to the subfamily of Praeaulacinae Rasnitsyn, 1972 in the family Praeaulacidae, Rasnitsyn, 1972, and *Proapocritus bialatus* sp. nov., in the family Ephialtitidae, are described and illustrated. These specimens were collected from the Middle Jurassic of Jiulongshan Formation at Daohugou in Inner Mongolia, northeastern China. *Praeaulacus obtutus* sp. nov. was erected by a combination of differential characters: the short and stout mesosoma, pronotum comparatively long, mesonotum not very long, the combination of pronotum and mesonotum transversely ridged and nearly arched; long hind legs. *Proapocritus bialatus* sp. nov. is assigned to *Proapocritus* Rasnitsyn, 1975 due to the following characters: wings venation complete, forewing with 1-Rs directed slightly posterodistally; 1r-rs, 2r-m, 3r-m, 2m-cu, 2A and a₁-a₂ present; hind wing with enclosed cell; Rs originating not basad of M + Cu fork. These findings provide new characters of these two groups and broaden the diversity of *Praeaulacus* and *Proapocritus*.

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Keywords: fossil wasps; Praeaulacidae; Ephialtitidae; Middle Jurassic; China

Introduction

Praeaulacidae Rasnitsyn, 1972, which is supposed to belong to the stem group of Evanioidea, plays a very important role in the evolutionary history of Evanioidea (Rasnitsyn 1988; Zhang and Rasnitsyn 2008). Praeaulacidae comprise four subfamilies: Cretocleistogastrinae Rasnitsyn, 1990 from the Lower Cretaceous of East Asia and Australia (Rasnitsyn 1972, 1990a, 1990b), Praeaulacinae Rasnitsyn, 1972, Anomopterellinae Rasnitsyn, 1975 and Nevaniinae Zhang and Rasnitsyn, 2007 from the Middle Jurassic of northeastern China and the Late Jurassic of south Kazakhstan (Rasnitsyn 1972, 1975; Zhang and Rasnitsyn 2007, 2008; Rasnitsyn and Zhang 2010). As an extinct subfamily known from the Middle Jurassic to the Early Cretaceous (Rasnitsyn 1972, 1983; Zhang and Rasnitsyn 2008; Rasnitsyn and Zhang 2010; Oberprieler et al. 2012), most genera in Praeaulacinae have been found from Daohugou deposits of northeastern China (Jiulongshan Formation) and Karatau of south Kazakhstan (Karabastau Formation) (Rasnitsyn 1972, 1975; Zhang and Rasnitsyn 2008; Rasnitsyn and Zhang 2010).

The family Ephialtitidae was established in 1906 by the type genus *Ephialtitis* from the Early Cretaceous of Spain. So far, 28 genera with 90 species of ephialtitids have been described (Rasnitsyn and Zhang 2010; Li, Shih, et al. 2013). The genus *Proapocritus*, 1975

*Email: fenger4499@163.com

was erected from a hymenopteran forewing from the Early or Middle Jurassic Kyrgyzstan. Until 2010, other characteristics of this genus were based on the new and complete specimens from Daohugou village, China (Rasnitsyn and Zhang 2010).

Herein, we describe two new fossil wasps, *Praeaulacus obtutus* sp. nov. of Praeaulacidae and *Proapocritus bialatus* sp. nov. of Ephialtitidae, both of which were collected from the Jiulongshan Formation at Daohugou village, Ningcheng County, Inner Mongolia, China.

The age of Jiulongshan Formation is late Middle Jurassic, about 165 million years ago (Ma) (Chen et al. 2004; Gao and Ren 2006; Ren, Shih, Gao et al. 2010; Ren et al. 2012), corresponding to the Callovian–Bathonian boundary from the most recent geochronological time scale (Gradstein et al. 2008, 2012). The palaeoenvironment reconstructed for the Daohugou area is a volcanic region with mountain streams and lakes, the climate was humid and warm-temperate (Shih et al. 2009). This area contains a diverse insect fauna, for example, Dermaptera (Zhao et al. 2010), Neuroptera (Wang et al. 2010; Yang, Makarkin, et al. 2012), Mecoptera (Ren et al. 2009; Ren, Shih, Labandeira 2010; Wang, Labandeira, et al. 2012; Yang, Shih, et al. 2012), Odonata (Li et al. 2012; Li, Nel, et al. 2013), Trichoptera (Gao et al. 2013), Coleoptera (Chang and Ren 2008; Pan et al. 2011; Tan et al. 2012), Hemiptera (Wang and Ren 2009), Orthoptera (Gu et al. 2012), Heteroptera (Yao et al. 2012), Chresmodidae (Zhang et al. 2010), Diptera (Zhang et al. 2011), Ephemeroptera (Huang et al. 2007), Plecoptera (Liu et al. 2007), and especially many hymenopteran fossils (Gao et al. 2009; Shih et al. 2009; Liu et al. 2011; Wang, Shih, et al. 2012).

Material and methods

All the specimens were collected from the Jiulongshan Formation at Daohugou, Ningcheng County, Inner Mongolia, China. The type specimens are deposited in the Key Laboratory of Insect Evolution & Environmental Changes, Capital Normal University, Beijing, China (CNU).

These specimens were examined under a Leica MZ 12.5 dissecting microscope and illustrated with the aid of a camera lucida attached to the microscope. The figures were drawn with Adobe Photoshop CS5 and CorelDraw 12.0. Wing venation terminology is adapted from Zhang and Rasnitsyn (2008) and Rasnitsyn and Zhang (2010).

Venation nomenclature. Rs, radial sector; M, media; Cu, cubitus; 1r-rs, the first radial crossvein; 2r-rs, the second radial crossvein; cu-a, the first anal crossvein; 2cu-a, the second anal crossvein; 1m-cu, the first mediocubita crossvein; 2m-cu, the second mediocubita crossvein; 2r-m, the first radiomedial crossvein; 3r-m, the second radiomedial crossvein.

Systematic palaeontology

- Superfamily EVANIOIDEA Latreille, 1802
 Family PRAEAULACIDAE Rasnitsyn, 1972
 Subfamily PRAEAULACINAE Rasnitsyn, 1972
 Genus *Praeaulacus* Rasnitsyn, 1972

*Type species**Praeaulacus ramosus* Rasnitsyn, 1972*Included species*

Eight species: *P. cephalotus*, *P. cubocephalus*, *P. elegans*, *P. leptogaster*, *P. magnus*, *P. obscures*, *P. ramosus* and *P. ventricosus*, are from Upper Jurassic of Karatau-Mikhailovka in Kazakhstan; eight species (including a new species): *P. orientalis*, *P. daohugouensis*, *P. scabratus*, *P. exquisitus*, *P. sculptus*, *P. robustus*, *P. afflatus* and *P. obtutus* sp. nov. from Middle Jurassic of Jiulongshan Formation in China; two species: *P. patiens* and *P. sharteg*, from Lower Cretaceous of Shar-Teg in Mongolia.

***Praeaulacus obtutus* Li, Shih & Ren sp. nov.**
(Figures 1, 2)

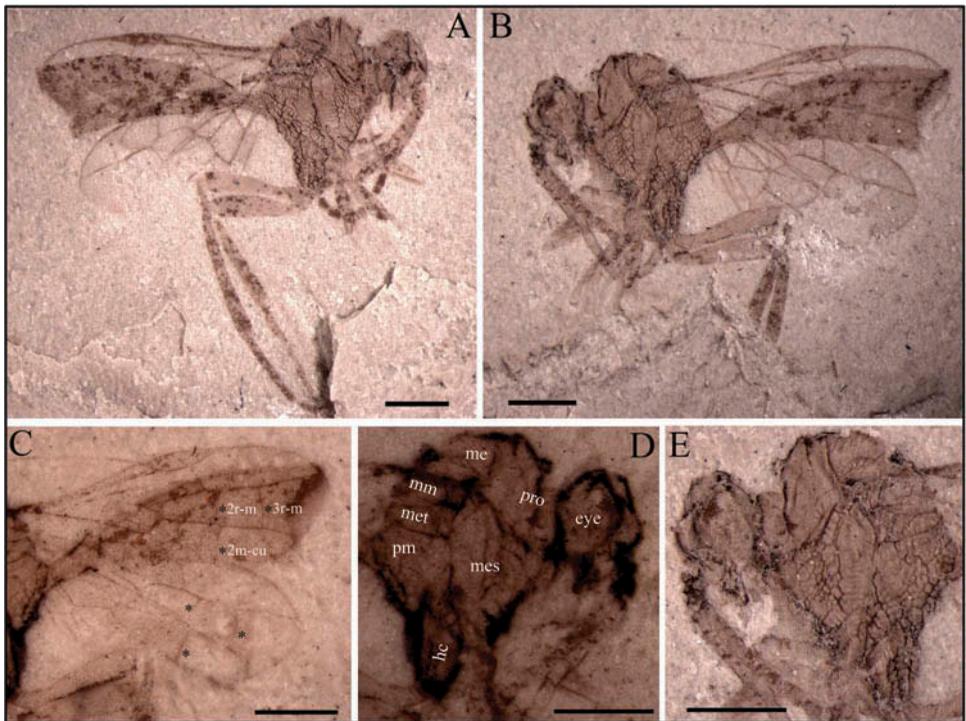


Figure 1. *Praeaulacus obtutus* sp. nov., photographs of holotype CNU-HYM-NN-2012039p/c. (A) Part (CNU-HYM-NN-2012039p); (B) counterpart (CNU-HYM-NN-2012039c); (C) wings of counterpart (with alcohol); (D) head and thorax of part (with alcohol); (E) head and thorax of counterpart. pro, pronotum; me, mesonotum; mm, mesoscutellum; met, metanotum; pm, propodeum; hc, hind coxa. Scale bars = 1 mm.

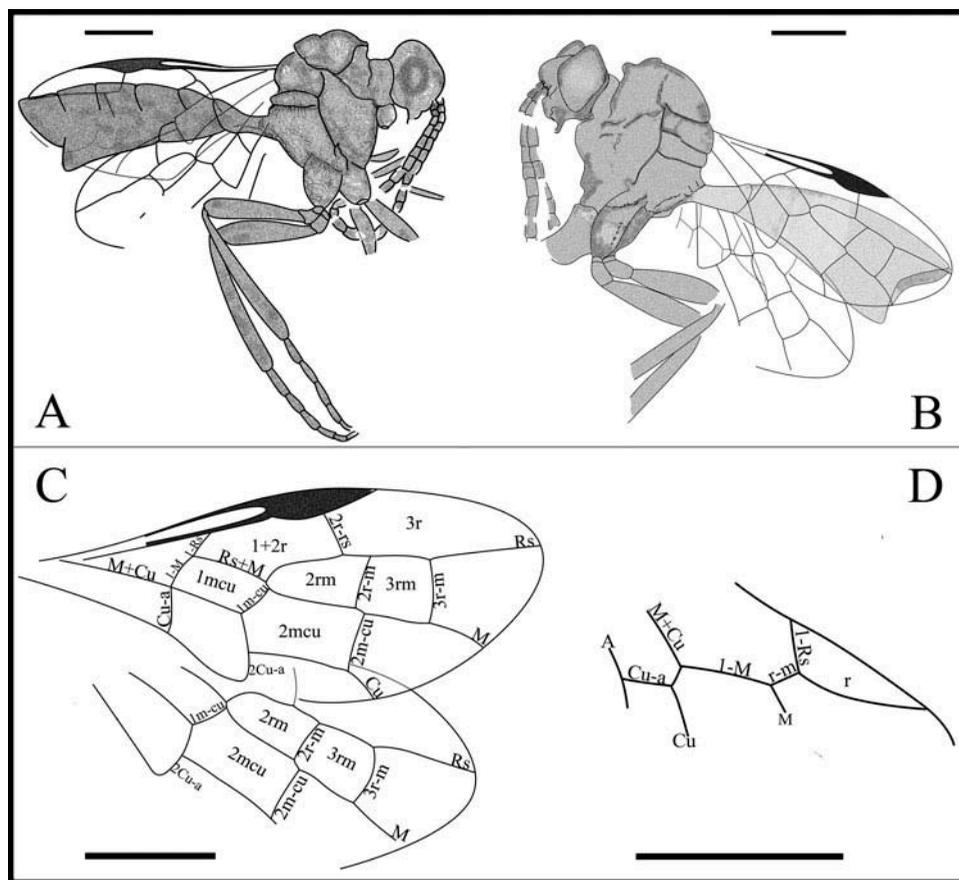


Figure 2. *Praeaulacus obtutus* sp. nov. line drawings of holotype. (A) Body with wings (CNU-HYM-NN-2012039p); (B) body with wings (CNU-HYM-NN-2012039c); (C) forewings of counterpart; (D) hind wing of counterpart. Scale bars = 1 mm.

Etymology

The specific epithet is derived from the Latin word *obtutus* (contemplation), indicating the posture of this wasp.

Material

Holotype CNU-HYM-NN-2012039p/c, part and counterpart.

Locality and horizon

Jiulongshan Formation, Daohugou Village, Shantou Township, Ningcheng County, Inner Mongolia, China; Middle Jurassic.

Diagnosis

Antenna longer than mesosoma. Mesosoma short and stout; pronotum comparatively long; mesonotum not very long, combination of pronotum and mesonotum transversely ridged and nearly arched. Forewing with first abscissa of Rs (1-Rs) shorter than its distance to pterostigma; 2r-rs meeting Rs basad of 2r-m and slightly shorter than the maximal width of 2rm; 3rm shorter than 2rm, with 3r-m bending; 2rm in contact with 1mcu by a short section of M; cu-a interstitial. Hind wing with M and Cu possessing free ends; cu-a strongly oblique, meeting Cu distad of M + Cu fork. Hind legs very long.

Description

A wasp in lateral view; body and wings well preserved; forewing, hind wing and metasoma partially overlapping, but the venation mostly discernible with alcohol (Figure 1C).

Body 6.2 mm long; head medium-sized, 0.9 mm long and 1.2 mm high, with large eyes and irregular oval-shape; antenna, longer than mesosoma, with 16 antennomeres, as preserved and 2.5 mm long (Figure 1A, B); mesosoma stout, 1.9 mm long and 2.0 mm high (Figure 1D, E); pronotum, mesonotum, mesoscutellum, metanotum, propodeum, mesopleuron and hind coxa are clearly discernible (Figure 1D, E); the pronotum comparatively long; mesonotum not very long, the combine of pronotum and mesonotum transversely ridged and nearly arched; the mesoscutellum nearly as long and wide as metanotum; propodeum short, but broad in profile aspect; metasoma is 3.6 mm long with first segment petiole-like (0.8 mm long and 0.5 mm maximal width); propodeal foramen attached high on propodeum and much closer to metanotum than to hind coxa; hind legs very long, the lengths (in mm) of hind leg, coxa, trochanter, femur, tibia and the 1st to 5th tarsus: 0.7: 0.3: 1.4: 2.3: 0.4: 0.4: 0.2: 0.2 (Figure 1A).

Forewing 3.8 mm long and 1.6 mm wide, with first abscissa of Rs (1-Rs) shorter than that of M (1-M), also shorter than its distance to pterostigma, measurements (in mm) of 1-Rs, 1-M, and the distance from 1-Rs to pterostigma about 0.2: 0.3: 0.5; vein 2r-rs arising from pterostigma about its basal one-half length, slightly shorter than the maximal width of cell 2rm and meeting Rs considerably basad of 2r-m; vein 2r-m nearly straight and 3r-m slightly bending; cell 2rm longer than 3rm, the latter wider than 2rm; cell 1mcu nearly parallelogrammic, about twice as long as wide; vein 2m-cu meeting 3rm at one-fifth of its posterior margin; cell 2mcu 1.5 times as broad as 1mcu and 1.4 times as long as 1mcu; vein cu-a interstitial and longer than 1-M, 2cu-a about half as long as cu-a.

Hind wing 1.3 mm long and 1.1 mm wide as preserved, with r-m straight and about 0.7 times as long as 1-Rs; the first section of M (1-M) nearly straight, 2.5 times as long as r-m; vein cu-a strongly oblique, meeting Cu beyond the forking of M + Cu into M and Cu; anal vein A present.

Remarks

Praeaulacus obtutus sp. nov. is assigned to Praeaulacidae based on a combination of forewing and body characters: medial mesonotal suture well developed, forewing venation with most of the main veins and metasoma attached high. It is attributed to Praeaulacinae based on several characters: antenna with more than 15 antennomeres, mesonotum transversely ridged, forewing with 2r-m, 3r-m and

2m-cu present, cu-a interstitial, and 1r-rs and 2A absent, hind wing with R strong and reaching apex of Rs. Praeaulacidae is a paraphyletic group in respect to the other Evanioidea. All the clade of Evanioidea is synapomorphic in having upper attachment of metasoma on the propodeum, which is closed below the attachment foramen. Praeaulacidae other than Nevaniinae are synapomorphic in lost 2A vein and a1-a2 crossvein, Nevaniinae is synapomorphic in having two-segmented petiole, but Praeaulacidae as a whole has no synapomorphies.

Praeaulacus obtutus sp. nov. differs from other species of *Praeaulacus* by the following characters: mesosoma short and stout, nearly as long as high; pronotum comparatively long; mesonotum slightly shorter than pronotum and legs very long; forewing with first abscissa of Rs (1-Rs) shorter than its distance to pterostigma, 2r-rs slightly shorter than the maximal width of 2rm.

Family **EPHIALTITIDAE**
Proapocritus Rasnitsyn, 1975

Emended diagnosis

Wings with complete venation, forewing with 1-Rs directed slightly posterodistally; 1r-rs, 2r-m, 3r-m, 2m-cu, 2A and a₁-a₂ present, cu-a interstitial or postfurcal; hind wing with enclosed cell r; Rs originating not basad of M + Cu fork.

Type species

Proapocritus praecuesor Rasnitsyn, 1975

Included species

The type species and *Proapocritus densipediculus*, Rasnitsyn and Zhang, 2010; *Proapocritus sculptus*, *Proapocritus formosus*, *Proapocritus atropus*, *Proapocritus longantennatus*, *Proapocritus elegans* and *Proapocritus bialatus* sp. nov.

Proapocritus bialatus Li, Shih and Ren sp. nov.
(Figures 3, 4)

Etymology

The specific epithet is derived from the Latin word *bialatus* (a pair of wings), indicating the well-preserved and out-stretched wings.

Material

Holotype female CNU-HYM-NN-2012040.

Locality and horizon

Jiulongshan Formation, Daohugou Village, Shantou Township, Ningcheng County, Inner Mongolia, China; Middle Jurassic.

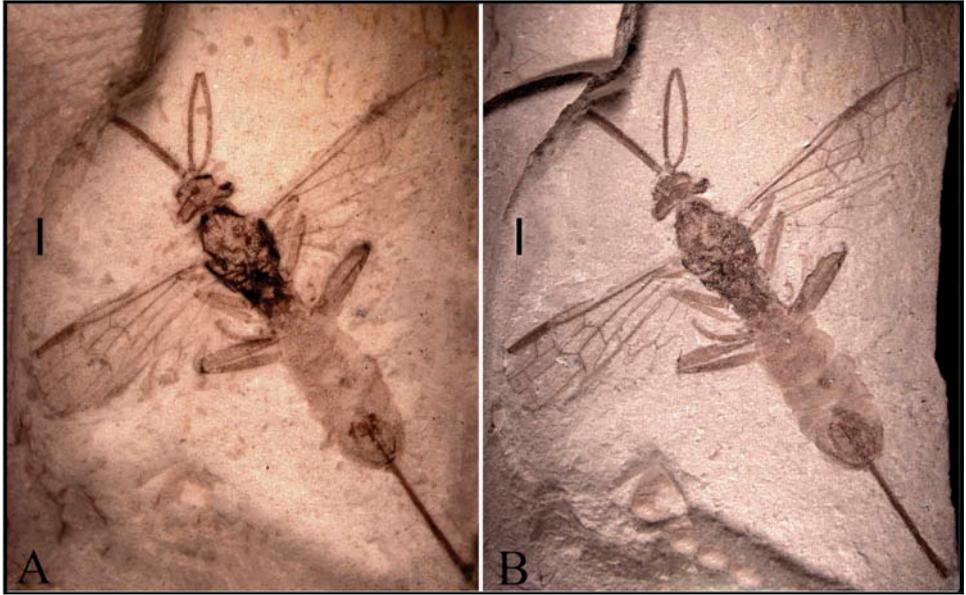


Figure 3. *Proapocritus bialatus* sp. nov., photographs of holotype (CNU-HYM-NN-2012040). (A) Body with wings with alcohol; (B) body with wings without alcohol. Scale bars = 1 mm.

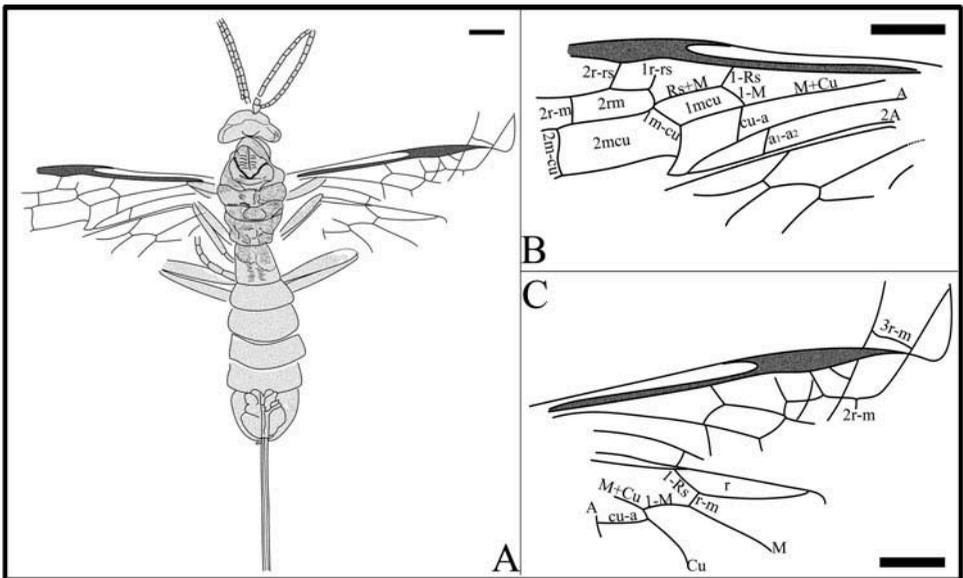


Figure 4. *Proapocritus bialatus* sp. nov., line drawings of holotype. (A) Body with wings; (B) left wings; (C) right wings. Scale bars = 1 mm.

Diagnosis

Antenna slim, with more than 25 segments. Forewing with cu-a slightly postfurcal, 1r-rs vein reduced near R and pterostigma, 2r-m, 3r-m slightly bent (not vertical); 2m-cu wavy curved; hind wing with 1-Rs originating not basad of M + Cu fork, 1-M and cu-a nearly parallel. First metasomal segment nearly trapezoid.

Description

Female wasp in dorsal view; left and right wings well preserved with main veins clearly discernible (Figure 3A, B).

Body 15.8 mm long including the antennae and ovipositor (body 9.6 mm long excluding the antennae and ovipositor); the head transversely broad, about 0.9 mm long and 1.8 mm wide; antenna thin and well preserved, with 25 antennomeres and about 5.4 mm long, pedicel short and slightly narrower than distal part of the scape, flagellomeres equal in length and width; mesosoma long and slender, about 3.1 mm long and 1.9 mm wide; pronotum, mesonotum, mesoscutellum, metanotum, metascutellum and propodeum discernible (Figure 3A, B); the mesonotum with notauli nearly V-shaped and reaching transscutal suture; mesoscutellum slightly wider and longer than metanotum; propodeum longer than metanotum; metasoma 5.5 mm long excluding the ovipositor, with six segments visible, the first metasomal segment nearly trapezoid, apical part about 1.5 times as wide as basal part. Ovipositor 5.2 mm long with sheaths; legs partially preserved and the hind legs longer and wider than the forelegs and mid legs.

Forewing 6.7 mm long and 2.1 mm wide as preserved, with pterostigma long and acuminate, issuing 2r-rs at its mid-length (Figure 3A, B); the first abscissa of Rs (1-Rs, 0.3 mm long) subvertical to R and slightly shorter than that of M (1-M, 0.4 mm long); vein 1r-rs present but reduced near R and pterostigma, and the distance of 1r-rs to Rs base longer than that to 2r-rs base; vein 2r-rs slightly longer than the width of pterostigma and nearly as long as the maximal width of cell 2rm, and about half the length of 2rm, and subparallel to 1r-rs and 1-Rs; cell 1m-cu nearly parallelogrammic, about 2.5 times as long as wide; vein 1m-cu (0.4 mm long) meeting 2rm slightly beyond Rs + M forking and slightly shorter than cu-a (0.5 mm long); vein cu-a slightly postfurcal, parallel to a₁-a₂ and 1.6 times as long as a₁-a₂; vein 2m-cu bending and 1.5 times as long as 1m-cu; vein 2A completely preserved.

Hind wing 3.6 mm long and 1.5 mm wide as preserved, distinguishable with 1-Rs origin at the same level of M + Cu forking; cell r closed; vein r-m straight and 0.6 times as long as 1-Rs; the first abscissa of M (1-M) slightly arched and about three times as long as r-m; vein cu-a long and strongly oblique, meeting Cu beyond M + Cu forking; vein A present, free M and Cu long.

Remarks and comparison

The genus *Proapocritus*, 1975 was erected by a hymenopteran forewing from the Early or Middle Jurassic Kyrgyzstan, and tentatively placed in Karatavitidae (Karatavitidae was considered to be the most primitive apocritans). *Proapocritus* was considered to almost completely cover the hiatus between *Karatavites* of Symphyta and Ephialtitidae of Apocrita (Rasnitsyn 1975). Until 2010, Rasnitsyn

and Zhang have reported six new species (*Proapocritus densipediculus*, *Proapocritus sculptus*, *Proapocritus formosus*, *Proapocritus atropus*, *Proapocritus longantennatus*, *Proapocritus elegans*) of this genus, all specimens from the Middle Jurassic Jiulongshan Formation at Daohugou Village of China. New and complete material not only provides new characters of this group but also broadens the diversity of Ephialtitidae.

Proapocritus bialatus sp. nov. is assigned to to *Proapocritus* Rasnitsyn, 1975 because of the following characters: wings with complete venation, forewing with 1-Rs directed slightly posterodistally; 1r-rs, 2r-m, 3r-m, 2m-cu, 2A and a₁-a₂ present; hind wing with enclosed cell r; Rs originating not basad of M + Cu fork and so on. This new species differs from other species (except *Proapocritus densipediculus*) of the genus *Proapocritus* in the forewing with cu-a slightly postfurcal (versus other species of the genus with cu-a intersitial); differs from *Proapocritus densipediculus* in forewing with 2r-m, 3r-m slightly bend and 2m-cu wavy curved and the first metasomal segment nearly trapezoid (versus *Proapocritus densipediculus* with 2r-m, 3r-m vertical while 2m-cu not preserved, and the first metasomal segment as wide as propodeal foramen, subcylindrical).

Discussion

Praeaulacid wasps were widely distributed during the Mesozoic of Australia and Asia (e.g. Rasnitsyn 1972, 1990a, 1990b; Jell and Duncan 1986). As aforementioned, *Praeaulacus obtutus* sp. nov. has interesting and special body characters, which can be distinguished from other known wasps in Praeaulacinae: short and stout mesosoma, the combination of pronotum and mesonotum transversely ridged and nearly arched, and long legs. However, *Praeaulacus obtutus* sp. nov. with the metasoma attaching high and much closer to metanotum than to hind coxa, is similar to those known in other subfamilies of Praeaulacidae.

Grimaldi and Engel (2005) mentioned that evanioid wasps shared a distinctive trait that the the metasoma is connected with the propodeum, and the earliest evidence of evanioids was found in the extinct family Praeaulacidae. Praeaulacidae shares many characters with other evanioids, e.g. the dorsal propodeal articulation with the metasoma, but is otherwise primitive in other features (e.g. wing venation with moderately more main veins), perhaps representing a stem group to the remaining groups in the superfamily (Grimaldi and Engel 2005). This well-preserved new material from Daohugou not only shows the typical propodeal–metasomal articulation, but also broadens the diversity of Praeaulacinae.

To date, seven species, including this new species, have been reported within *Proapocritus* Rasnitsyn, 1975 in the literature. Except for the type species *Proapocritus praecuesor* Rasnitsyn, 1975 from the Early or Middle Jurassic Kyrgyzstan, other species are all from the Middle Jurassic Jiulongshan Formation at Daohugou Village of China. New and complete material from Daohugou shows that this genus is uniform in wing venation and propodeum but diverse in the form of the first metasomal segment. So, *Proapocritus bialatus* sp. nov. described in this paper can expand our knowledge of the ephialtitid propodeal–metasomal articulation after the highly diverse patterns of propodeal–metasomal articulation observed in *Proapocritus* (Rasnitsyn and Zhang 2010).

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