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New findings of *Flagellisargus* J Zhang, 2012 (Diptera, Brachycera, Archisargidae), with discussion of the placements of some controversial taxa

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Abstract

A new species of a new subgenus and a similar known species referred to the genus *Flagellisargus* J Zhang, 2012 are described and illustrated based on a male and a female impression fossils of these flies: *Flagellisargus* (*Changbingisargus*) *parvus* **subgen. et sp. n.** and *Flagellisargus* (*Flagellisargus*) cf. *sinicus* J Zhang, 2012. The latter taxon is the first record of a female *Flagellisargus.* Recently taken out of Archisargoidea, this study concludes that *Flagellisargus* should be an archisargid genus based on the known (male) and new (female) impression fossils. The placement of *Daohugosargus* J Zhang, 2012b is reassessed. It demonstrates close similarities in body structure and wing venation to archisargid flies, and can be retained as an archisargid genus. *Archirhagio mostovskii* J Zhang, 2015 is separated from *Archirhagio zhangi* K Zhang et al., 2009. *Helempis* Ren, 1998 could be, as a separate genus, placed in Archisarginae, Archisargidae.

Introduction

Archisargidae is an important, primitive, extinct family of the Lower Brachycera, Diptera. It is undoubtedly the largest early brachycerous group in the Mesozoic. To date, 55 species referred to 14 genera within two subfamilies have been recorded (J Zhang 2015, Wang et al. 2017). Archisargid flies range from the late Middle Jurassic – early Late Jurassic (Callovian – Oxfordian) through to the Early Cretaceous in Laurasia and Gondwana. The vast majority of archisargids are from the Jurassic "Daohugou Formation" (Daohugou Bed), China (29 species, 11 genera) and the Karabastau Formation, Kazakhstan (17 species, eight genera). Both archisargid-bearing sedimentary rocks formations belong to the same geological age: Callovian or Oxfordian (J Zhang 2015), and contain more than 82% of species total. Only a few species occur in the Jurassic Haifanggou Formation, China, Shara-Teg Bed, Mongolia, Talbragar Fish Bed, Australia and the Lower Cretaceous Yixian Formation, China (Rohdendorf 1938, Mostovski 1996a,b, 1997, J Zhang and H Zhang 2003, K Zhang et al. 2007a,b, 2008, 2009, 2010a,b, J Zhang 2010, 2012a,b, 2015, Oberprieler and Yeates 2012, Wang et al. 2017). An updated list of all the archisargid species is presented herein (see Table 1). Among them, the placement of *Helempis yixianensis* Ren, 1998 has been transformed. A recently erected species *Archirhagio gracilentus* Wang et al., 2017 and a new species *Flagellisargus* (*Changbingisargus*) *parvus* sp. n. described below are also supplemented (see Table 1).

Material and methods

Material. The specimens of shale fossil impression of a male and a female archisargid flies described herein are deposited in the collections of the Nanjing Institute of Geology and Palaeontology (NIGP), the Chinese Academy

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Table 1. Species of Archisargidae with ages, localities and strata (updated).

Name	Age	Locality	Stratum
Archirhagio gracilentus Wang et al., 2017	Callovian–Oxfordian	Daohuguo, China	Daohugou Bed
Archirhagio mostovskii Zhang, 2015	Callovian–Oxfordian	Daohuguo, China	Daohugou Bed
Archirhagio obscures Rohdendorf, 1938	Callovian–Oxfordian	Karatau, Kazakhstan	Karabastau Formation
Archirhagio striatus Zhang & Zhang, 2003	Callovian–Oxfordian	Daohuguo, China	Daohugou Bed
Archirhagio varius Zhang, 2015	Callovian–Oxfordian	Daohuguo, China	Daohugou Bed
Archirhagio zhangi Zhang et al., 2009	Callovian–Oxfordian	Daohuguo, China	Daohugou Bed
Archisargus maximus Mostovski, 1997	Callovian–Oxfordian	Karatau, Kazakhstan	Karabastau Formation
Archisargus pulcher Rohdendorf, 1938	Callovian–Oxfordian	Karatau, Kazakhstan	Karabastau Formation
Archisargus spurivenius Zhang et al., 2007	Callovian–Oxfordian	Daohuguo, China	Daohugou Bed
Archisargus strigatus Zhang et al., 2007	Callovian–Oxfordian	Daohuguo, China	Daohugou Bed
Calosargus (*Calosargus*) *antiquus* Zhang et al., 2007	Callovian–Oxfordian	Daohuguo, China	Daohugou Bed
Calosargus (*Calosargus*) *bellus* Zhang et al., 2007	Callovian–Oxfordian	Daohuguo, China	Daohugou Bed
Calosargus (*Calosargus*) *daohugouensis* Zhang et al., 2007	Callovian–Oxfordian	Daohuguo, China	Daohugou Bed
Calosargus (*Calosargus*) *hani* Zhang et al., 2007	Callovian–Oxfordian	Daohuguo, China	Daohugou Bed
Calosargus (*Calosargus*) *niger* Mostovski, 1997	Callovian–Oxfordian	Karatau, Kazakhstan	Karabastau Formation
Calosargus (*Calosargus*) *tatianae* Mostovski, 1997	Callovian–Oxfordian	Karatau, Kazakhstan	Karabastau Formation
Calosargus (*Calosargus*) *talbragarensis* Oberprieler & Yeates, 2012	Kimmeridgian	Gulgong, Australia	Talbragar Fish Bed
Calosargus (*Calosargus*) *tenuicellulatus* Zhang et al., 2007	Callovian–Oxfordian	Daohuguo, China	Daohugou Bed
Calosargus (*Calosargus*) *validus* Zhang et al., 2007	Callovian–Oxfordian	Daohuguo, China	Daohugou Bed
Calosargus (*Pterosargus*) *sinicus* Zhang, 2010	Callovian–Oxfordian	Daohuguo, China	Daohugou Bed
Calosargus (*Pterosargus*) *thanasymus* Mostovski, 1997	Callovian–Oxfordian	Karatau, Kazakhstan	Karabastau Formation
Daohugousargus eximius (Zhang et al., 2008)	Callovian–Oxfordian	Daohuguo, China	Daohugou Bed
Flagellisargus (*Changbingsargus*) *parvus* sp. n.	Callovian–Oxfordian	Daohuguo, China	Daohugou Bed
Flagellisargus (*Flaggelisargus*) *robustus* Zhang, 2012	Callovian–Oxfordian	Daohuguo, China	Daohugou Bed
Flagellisargus (*Flaggelisargus*) *sinicus* Zhang, 2012	Callovian–Oxfordian	Daohuguo, China	Daohugou Bed
Flagellisargus (*Flaggelisargus*) *venustus* Zhang, 2012	Callovian–Oxfordian	Daohuguo, China	Daohugou Bed
Helempis yixianensis Ren, 1998	Early Cretaceous	Huangbanjigou, China	Yixian Formation
Mesosolva angustocellulata Mostovski, 1996	Callovian–Oxfordian	Karatau, Kazakhstan	Karabastau Formation
Mesosolva balyshevae Mostovski, 1996	Callovian–Oxfordian	Karatau, Kazakhstan	Karabastau Formation
Mesosolva daohugouensis Zhang & Zhang, 2003	Callovian–Oxfordian	Daohuguo,China	Daohugou Bed
Mesosolva dolosa Mostovski, 1996	Callovian–Oxfordian	Karatau, Kazakhstan	Karabastau Formation
Mesosolva hennigi Mostovski, 1996	Callovian–Oxfordian	Karatau, Kazakhstan	Karabastau Formation
Mesosolva huabiensis (Hong, 1983)	Callovian–Oxfordian	Yujiagou, China	Haifanggou Formation
Mesosolva imperfecta Mostovski, 1996	Callovian–Oxfordian	Karatau, Kazakhstan	Karabastau Formation
Mesosolva karataviensis (Mostovski, 1996)	Callovian–Oxfordian	Karatau, Kazakhstan	Karabastau Formation
Mesosolva longivena Mostovski, 1996	Late Jurassic	Shara-Teg, Mongolia	Shara-Teg Bed
Mesosolva parva Hong, 1983	Callovian–Oxfordian	Yujiagou, China	Haifanggou Formation
Mesosolva rohdendorfi Mostovski, 1996	Callovian–Oxfordian	Karatau, Kazakhstan	Karabastau Formation
Mesosolva sinensis Zhang et al., 2010	Callovian–Oxfordian	Daohuguo, China	Daohugou Bed
Mesosolva zhangae Zhang, 2012	Callovian–Oxfordian	Daohuguo, China	Daohugou Bed
Novisargus rarus Zhang, 2015	Callovian–Oxfordian	Daohuguo, China	Daohugou Bed
Origoasilus pingquanensis Zhang et al., 2011	Early Cretaceous	Yangshuling, China	Yixian Formation
Ovisargus gracilis Mostovski, 1996	Callovian–Oxfordian	Karatau, Kazakhstan	Karabastau Formation
Ovisargus singulus Zhang, 2015	Callovian–Oxfordian	Daohuguo, China	Daohugou Bed
Parvisargus malus Mostovski, 1996	Callovian–Oxfordian	Karatau, Kazakhstan	Karabastau Formation
Parvisargus peior Mostovski, 1996	Callovian–Oxfordian	Karatau, Kazakhstan	Karabastau Formation
Sharasargus fortis Zhang et al., 2008	Callovian–Oxfordian	Daohuguo, China	Daohugou Bed
Sharasargus maculus Zhang, 2015	Callovian–Oxfordian	Daohuguo, China	Daohugou Bed
Sharasargus oresbia (Ren, 1998)	Early Cretaceous	Huangbanjigou, China	Yixian Formation
Sharasargus ruptus Mostovski, 1996	Late Jurassic	Shara-Teg, Mongolia	Shara-Teg Bed
Sharasargus spiniger Mostovski, 1996	Callovian–Oxfordian	Karatau, Kazakhstan	Karabastau Formation
Sinallomyia ruderalis (Ren, 1998)	Early Cretaceous	Huangbanjigou, China	Yixian Formation
Tabanisargus daohugous Zhang, 2015	Callovian–Oxfordian	Daohuguo, China	Daohugou Bed
Uranorhagio asymmetricus (Zhang et al., 2010)	Callovian–Oxfordian	Daohuguo, China	Daohugou Bed
Uranorhagio daohugouensis Zhang et al., 2010	Callovian–Oxfordian	Daohuguo, China	Daohugou Bed
Uranorhagio deviatus Zhang et al., 2010	Callovian–Oxfordian	Daohuguo, China	Daohugou Bed

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of Sciences, no. NIGP DHG01701 and no. DHG01702. The fly-bearing sedimentary rocks of the "Daohugou Formation" (Daohugou Bed) are located near the village of Daohugou, Wuhua Township, Ningcheng County, Chifeng City, Inner Mongolia, China.

Illustrations. Specimen descriptions, photomicrographs and line drawings were done without immersion with the exception of photographs of details of the antennae and tibial spurs. The line drawings were produced with the aid of a camera lucida and the digital photomicrographs were taken using a stereomicroscope.

Colour described here refers to that of the fossil, where patterning is preserved.

Wing venation terminology follows that of Wootton and Ennos (1989) and Shcherbakov et al. (1995). The cell traditionally named the anal cell is, in fact, considered to be the cubital cell herein.

Taxonomy

Archisargoidea Rohdendorf, 1962
Archisargidae Rohdendorf, 1962
Archisarginae Rohdendorf, 1962
***Flagellisargus* J Zhang, 2012a**

***Flagellisargus* (*Changbingisargus*) subgen. n.**

http://zoobank.org/A0D230D5-38BB-4401-8B50-5DB9116C2420

Type-species. *Flagellisargus* (*Changbingisargus*) *parvus* sp. n. (by monotypy)

Included species. The type species only.

Diagnosis. Small-size archisargid flies (body excluding antenna and genitalia less than 5 mm long); antennal scape long; arista (or stylus) absent; fork of R4+5 shallow, distad of level of R2+3 end; R5 ending before wing tip; discal cell short and wide (nearly 2.3 times as long as wide).

Etymology. From Chinese "changbing" (long scape), and sargus referring to the Recent genus *Sargus*.

Distribution. Jurassic, China.

Remarks. The subgenus *Flagellisargus* (*Flagellisargus*) stat. n. includes three known species: *Flagellisargus* (*Flagellisargus*) *robustus* J Zhang, 2012a, *Flagellisargus* (*Flagellisargus*) *sinicus* J Zhang, 2012a and *Flagellisargus* (*Flagellisargus*) *venustus* J Zhang, 2012a. Among them, the first and the third species are erected based on nearly complete male flies, the second one with head and abdomen missing. This known subgenus differs from *Flagellisargus* (*Changbingisargus*) subgen. n. in the following aspects: moderate-size archisargid flies (body excluding antenna and genitalia more than 9 mm long); antennal scape short; arista (or stylus) present; fork of R4+5 relatively deep, just at level of R2+3 end; R5 ending just at wing tip; discal cell narrow and long (nearly three times or more as long as wide).

Although the head and abdomen are missing, *Flagellisargus* (*Flagellisargus*) *venustus* demonstrates close similarities in wing venation to that of *Flagellisargus* (*Flagellisargus*) *sinicus* and *Flagellisargus* (*Flagellisargus*) *robustus*: fork of R4+5 relatively deep, just at level of R2+3 end; R5 ending at wing tip; discal cell narrow and long, nearly 3.5 times as long as wide (Fig. 3A–C). Thus, *Flagellisargus* (*Flagellisargus*) *venustus* should be retained in *Flagellisargus* (*Flagellisargus*) rather than be assigned to *Flagellisargus* (*Changbingisargus*) subgen. n.

***Flagellisargus* (*Changbingisargus*) *parvus* sp. n.**

http://zoobank.org/6369B635-3716-4AF5-BB41-5375E625DAED
Figs 1, 2, 3D

Diagnosis. Male archisargid flies 4.9 mm long (excluding antenna); antenna longer than head, scape more than one half of flagellum length; stem of Rs nearly as long as bR4+5; first fork of Rs slightly basad of level of M fork; crossvein r-m linking anterior margin of discal cell near to M fork; crossvein m-m long; section of mM3+4 short; male genitalia large, gonostylus subquadrate with apical denticle medially.

Description. Small male archisargid flies. Body dark brown but antenna, legs and wings yellowish brown (Fig. 1A). Head moderately large, nearly semiglobose; eyes large, holoptic, occupying anterior part of head (Figs 1A, 2A); antenna very long, clavate, nearly 1.7 times as long as head length, scape elongated, nearly 3.7 times as long as wide; pedicel short, subquadrate, wider than long; flagellum elongate-conical, four times as long as wide, ratio of scape, pedicel and flagellum 1.0:0.3:1.7, arista absent (Figs 1B, 2B).

Thorax subovate, longer and wider than head (Figs 1A, 2A). Wing narrow and long, about 3.1 times as long as wide, C not circumambient, terminating just at wing tip; C, Sc, R1 and Rs clearly stouter than M and its branches; Sc long, more than one half of wing length; R1 straight, nearly third-fourths of wing length; origin of Rs slightly basad to wing midlength, Rs stem short, nearly as long as section bR4+5; first fork of Rs basad to d base; R2+3 straight, ending at C far apart from R1 end; section dR4+5 straight, nearly seven times as long as section bR4+5, 3.8 times as long as R5, R4+5 fork distad to level of R2+3 end, R4 slightly shorter than R5, both veins dR4+5 and R5, more or less, not in line, R5 slightly curved downwards, ending at C clearly before wing tip; ratio of costal sections Sc-R1, R1-R2+3, R2+3-R4 and R4-R5 1.0:0.7:0.4:0.3; ratio of Rs, bR4+5, dR4+5 and R5 1.0:1.0:6.5:1.9; r-m shorter than bR4+5, meeting anterior margin of d close to its base; ratio of bM1+2 and dM1+2 1.0:4.3; M1 slightly arched intermediately; M2 and M3+4 straight, bM2 nearly a quarter of m-m length; ratio of bM3+4, mM3+4 and dM3+4 1.0:0.4:1.9; cell br slightly wider but shorter than cell bm; discal cell hexagonal, about 2.3 times as long as wide; m-cu relatively short, its posterior end distad to M fork; cell cu (traditionally anal cell) narrow, widely open (Figs 1A, 2A). Femur of hindleg moderately long and stout, clavate, nearly reach-

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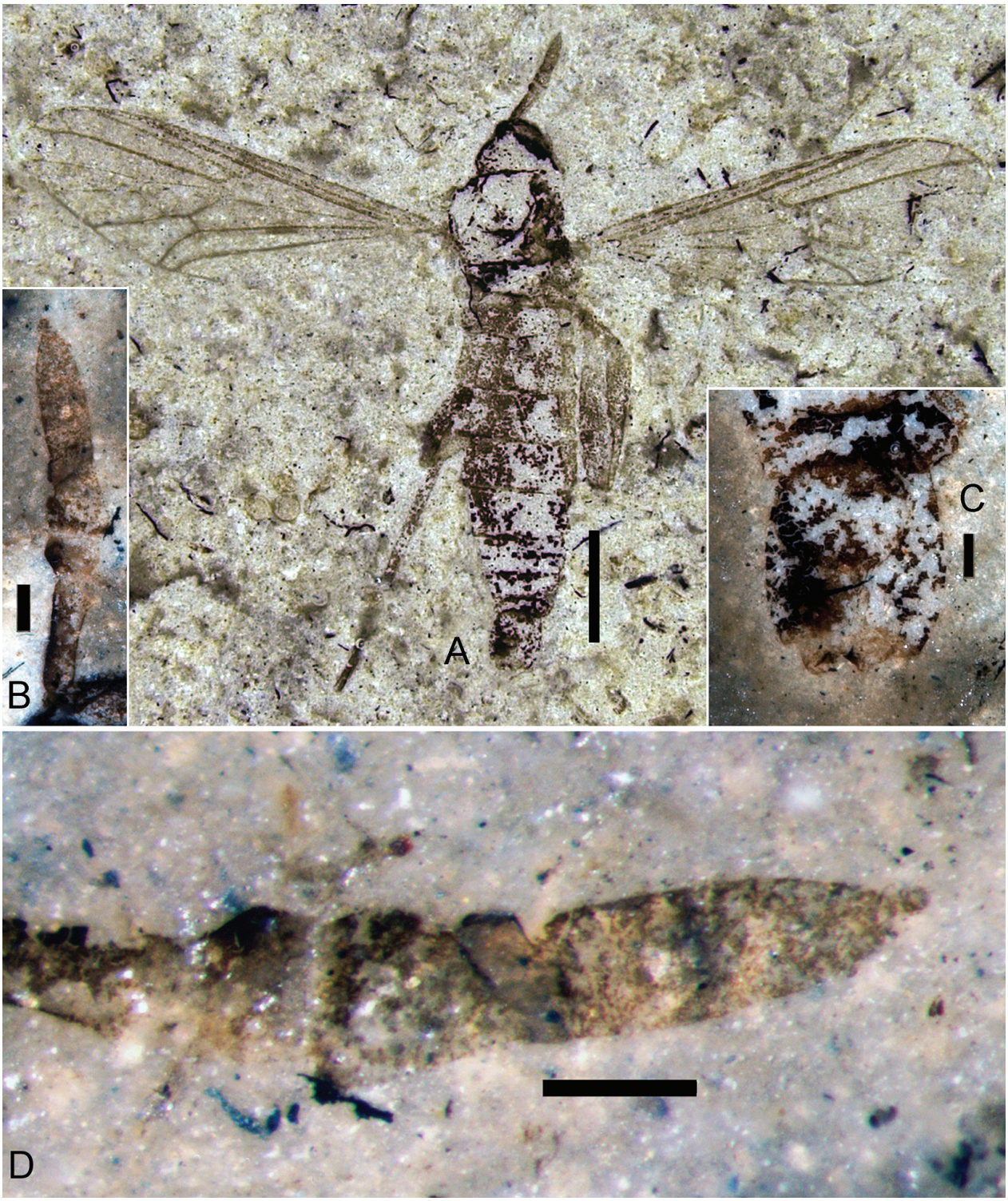

Figure 1. *Flagellisargus* (*Changbingisargus*) *parvus* subgen. et sp. n., photomicrographs, holotype NIGP DHG01701, **A** habitus (dorsal view), **B** antenna, **C** male genitalia, **D** enlarged flagellum. Scale bar 1 mm (**A**), 0.1 mm (**B, C, D**).

ing posterior margin of fourth abdominal segment, tibia shorter and slightly narrower than femur, tarsus ill-preserved, cylindrical, distinctly thinner than tibia.

Abdomen with seven segments visible, nearly ovate-oblong, fourth widest, and nearly as wide as thorax, 1.8 times longer than head (excluding antenna) and thorax combined; genitalia rather large, subovate, longer but narrower than seventh abdominal segment, gonocoxite more or less oblong with its inner and outer margins slightly curved outwards, gonostylus subquadrate, wider than long, with a triangular apical denticle curved upwards, aedeagus invisible (Figs 1C, 2C).

Dimensions. Holotype (NIGP DHG 201701): length of body, 4.9 mm; head (excluding antenna), 0.7 mm;

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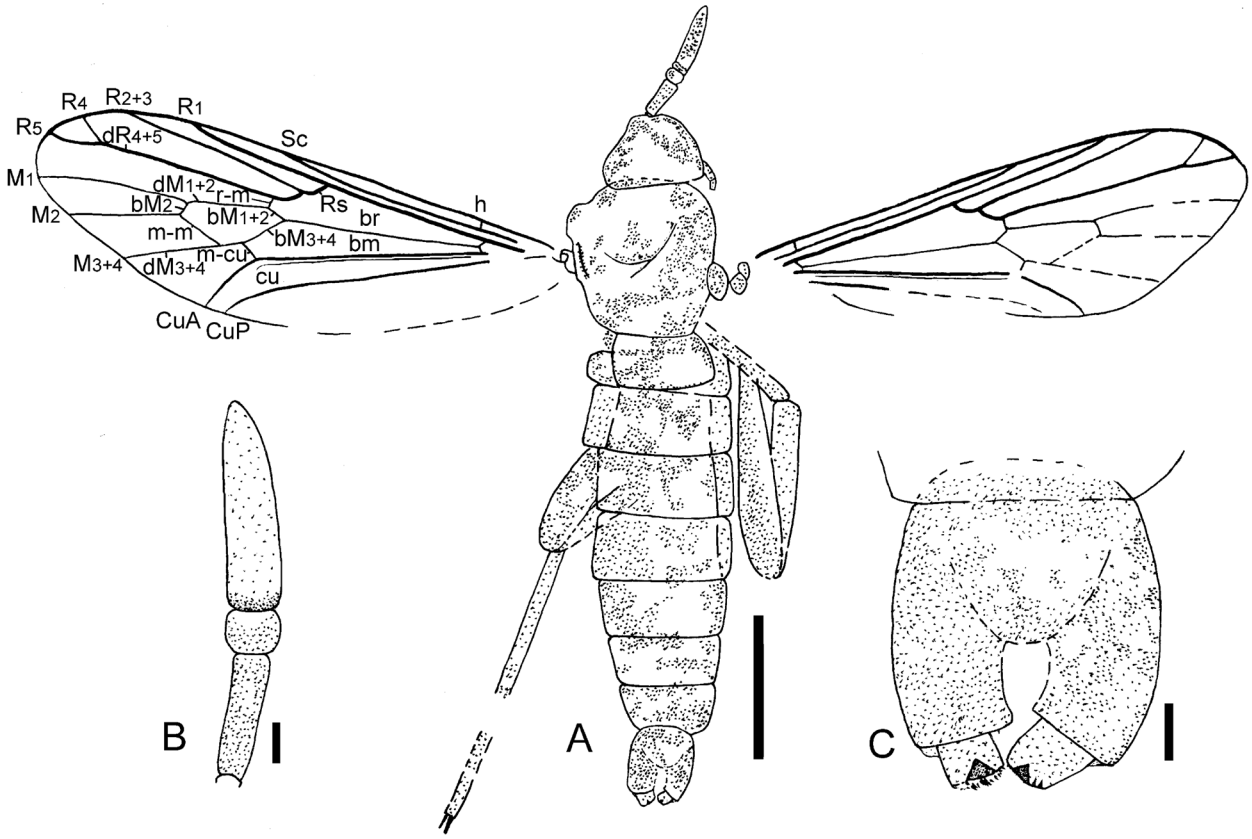

Figure 2. *Flagellisargus* (*Changbingisargus*) *parvus* subgen. et sp. n. line drawings of holotype NIGP DHG01701, **A** habitus (dorsal view), **B** antenna, **C** male genitalia. Scale bar 1 mm (**A**) 0.1 mm, (**B, C**).

thorax, 1.0 mm; abdomen (including genitalia), 3.2 mm. Length of wing, 3.8 mm, width of wing, 1.2 mm.

Distribution. The "Daohugou Formation" (Daohugou Bed), Callovian-Oxfordian; Daohugou, Wuhua, Ningcheng, Inner Mongolia, China.

Remarks. It should pointed out that the antennal flagellum (first flagellomere) is ill-preserved near to its base. On first view, it may look like the flagellum has two (or multi) flagellomeres (Figs 1B, 2A), but, the flagellum is, in fact, unsegmented (Figs 1D, 2B).

Flagellisargus (*Flagellisargus*) J Zhang, 2012a, stat. n.

Type species. *Flagellisargus* (*Flagellisargus*) *sinicus* J Zhang, 2012a

Included species. *Flagellisargus* (*Flagellisargus*) *robustus* J Zhang, 2012a, *Flagellisargus* (*Flagellisargus*) *sinicus* J Zhang, 2012a and *Flagellisargus* (*Flagellisargus*) *venustus* J Zhang, 2012a.

Diagnosis. Moderate-size archisargid flies (body excluding antenna and genitalia more than 9 mm long); antennal scape short; arista (or stylus) present; fork of R4+5 relatively deep, just at level of R2+3 end; R5 ending just at wing tip; discal cell narrow and long (nearly three times or more as long as wide).

Distribution. Jurassic, China.

Flagellisargus (*Flagellisargus*) cf. *sinicus* J. Zhang, 2012a

Fig. 4

2012a *Flagellisargus sinicus* J Zhang, 879–880, figs 1–3.

Description. Moderate-size female archisargid fly; body yellowish brown (Fig. 4A). Head moderately large, nearly semiglobose; eyes large, dichoptic, occupying most parts of head; antenna long, clavate, nearly 1.5 times as long as head length, scape not elongated, slightly longer than wide, pedicel short, subquadrate, wider than long, flagellum elongate-conical, nearly three times as long as wide, with a darkish brown longitudinal furrow near to its outer margin and connecting base of arista which is darkish brown, stylate, and distinctly curved inwards, ratio of scape, pedicel and flagellum 2.0:1.0:9.0, arista (or stylus) about a quarter of flagellum length (Fig. 4B).

Thorax nearly globose, as long as wide, slightly wider than head (Fig. 4A). Wing narrow and long, about 3.5 times as long as wide, C terminating at wing tip; C, Sc, R1 and Rs clearly stouter than M1 and M2; Sc long, more than one half of wing length; R1 straight, nearly fourth-fifths of wing length; origin of Rs slightly basad to wing midlength, Rs stem short, nearly as long as section bR4+5; R2+3 straight, ending at C far apart from R1 end; section dR4+5 straight, nearly four times as long as section bR4+5, 3.7 times as long as R5, R4+5 fork at level

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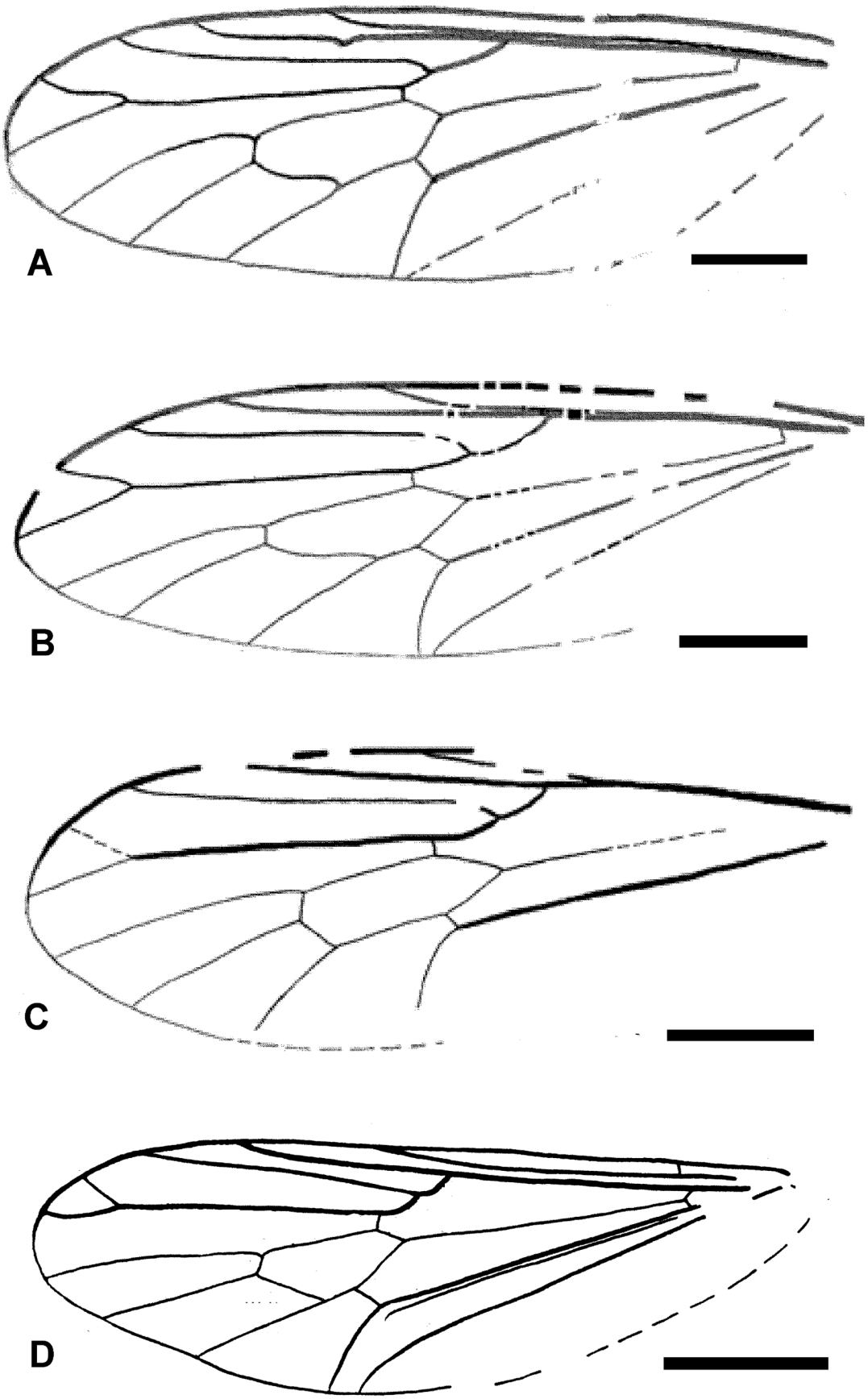

Figure 3. Difference and similarity between four sets of wings, line drawings of holotypes, **A** *Flagellisargus* (*Flagellisargus*) *sinicus* J Zhang, 2012a, **B** *Flagellisargus* (*Flagellisargus*) *venustus* J Zhang, 2012a, **C** *Flagellisargus* (*Flagellisargus*) *robustus* J Zhang, 2012a, **D** *Flagellisargus* (*Changbingisargus*) *parvus* subgen. et sp. n. Scale bas 1 mm.

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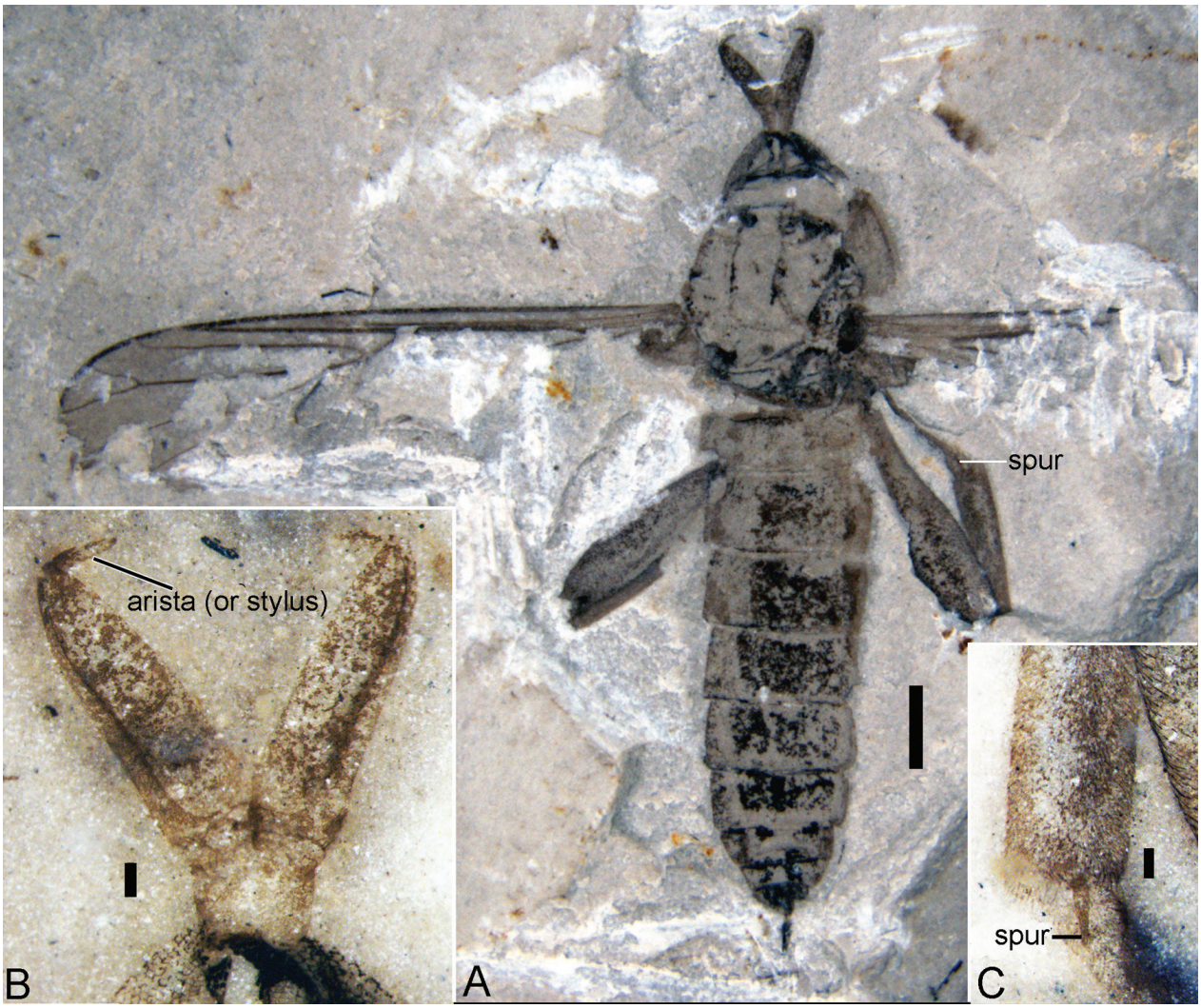

Figure 4. *Flagellisargus* (*Flagellisargus*) cf. *sinicus* J Zhang, 2012a, photomicrographs, NIGP L201702, **A** habitus (dorsal view), **B** antennae, **C** tibial spur of hindleg. Scale bar 1 mm (**A**), 0.1 mm (**B, C**).

of R2+3 end, R4 shorter than R5, both veins dR4+5 and R5, more or less, not in line, R5 slightly curved downwards, ending at wing tip; ratio of costal sections Sc-R1, R1-R2+3, R2+3-R4 and R4-R5 1.0:0.3:0.4:0.4; ratio of Rs, bR4+5, dR4+5 and R5 1.0:1.0:4.1:1.8; M1 and M2 almost straight, subparallel (Fig. 4A). Femur of hindleg long and stout, clavate, nearly reaching posterior margin of third abdominal segment, tibia at least with a needle-like spur, and shorter than width of tibia (Fig. 4C).

Abdomen with nine segments visible, nearly cylindrical, just a little narrower than thorax, 1.9 times longer than head (excluding antenna) and thorax combined; each of tergites with a wide, longitudinal, intermediate marking which is darkish brown; apex of abdomen with a sclerotized, needle-like ovipositor, and slightly longer than ninth segment (Fig. 4A).

Dimensions. NIGP DHG 201702: length of body (excluding antenna and ovipositor), 9.6 mm; head, 1.3 mm; thorax, 2.1 mm; abdomen (excluding ovipositor), 6.2 mm; ovipositor ca. 0.5 mm. Length of wing, 7.9 mm, width of wing, ca. 2.3 mm.

Distribution. The "Daohugou Formation" (Daohugou Bed), Callovian-Oxfordian; Daohugou, Wuhua, Ningcheng, Inner Mongolia, China.

Remarks. On the following characters, this fly could be assigned to *Flagellisargus* (*Flagellisargus*): body (excluding antenna and ovipositor) moderate-size (more than 9 mm long); antennal scape short (not elongated); arista (or stylus) well developed (about a quarter of flagellum length); fork of R4+5 just at level of R2+3 end; and R5 ending at wing tip.

Owing to having special characteristics (antennal flagellum with a darkish brown longitudinal furrow near to its outer margin and connecting base of arista and a tibial spur of hindleg well developed) this specimen shows close similarities in antennal and leg's structures to that of the known species *Flagellisargus* (*Flagellisargus*) *sinicus*. Unfortunately, its wing is incompletely preserved, and the discal cell, posterior branch of M, CuA, CuP and crossvein m-cu are rather ambiguous or invisible. For this reason, this impression fly could only be identified as *Flagellisargus* (*Flagellisargus*) cf. *sinicus*.

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Discussion

Recently, Grimaldi and Barden (2016) proposed a single most-parsimonious tree indicating the relationships within the superfamily Archisargoidea. They considered that three genera possessing the plesiomorphic condition of unmodified (non aculeate) female terminalia are not basal to Archisargoidea: *Daohugosargus* J Zhang, 2012b, *Orientosargus* J Zhang, 2012b and *Uranorhagio* K Zhang, 2010. Meanwhile, "*Flagellisargus* has a plesiomorphic, non stylate type of antenna and may also lie outside the Archisargoidea sensu stricto, but this would need to be confirmed with female specimens (only males presently are known)" (Grimaldi and Barden 2016: 17).

However, this study argues that *Flagellisargus* has a well developed arista (or stylus) although it is short. This crucial character had been illustrated in the original generic diagnosis and specific descriptions (J Zhang 2012a: 879, 881, Figs 3, 7). Furthermore, the female *Flagellisargus* has been discovered, and described herein. *Flagellisargus* (*Flagellisargus*) cf. *sinicus* has a scelerotized, needle-like ovipositor (Fig 4A). It is clear that *Flagellisargus* should be an arichsargid genus even according to the alternative classification proposed by Grimaldi and Barden (2016).

As for *Daohugosargus*, this genus was proposed for *Sharasargus eximius* K Zhang et al., 2008, which is a monotypic genus based on an incomplete impression fly with terminal abdominal segments missing (K Zhang et al. 2008). Its sex is uncertain. It is difficult to see how this genus could be distinguished as a female fly, let alone with unmodified (non aculeate) female terminalia. *Daohugosargus* demonstrates plesiomorphic similarities in body structures (as preserved) and in wing venation to those uncontested archisargids, and differs only from them by the characteristic vein R2+3 which is short, S-shaped, and arising late from Rs. It would be unreasonable to move this genus out of the superfamily Archisargoidea based only on this difference. This study considers that *Daohugosargus* is related rather to Archisargidae, Archisargoidea than to any other superfamilial groups.

Furthermore, the conclusion is debatable whether genera having non-aculeate female terminalia lie outside of Archisargoidea. For example, there are two species, *Archirhagio striatus* J Zhang et H Zhang, 2003 and *Archirhagio varius* J Zhang, 2015, belonging to the archisargid genus *Archihagio* Rohdendorf, 1938 that need consideration. The former species has a highly sclerotized, aculeate ovipositor; while, the latter one possesses a blunt, enlarged, fleshy, hook-like ovipositor (Wang et al. 2017: Figs 4D, E, originally the "ovipositor" was labelled as a "hypogynial valve"). However, *Archirhagio varius* cannot be excluded from *Archihagio* based on its species diagnosis although it has a non-aculeate female terminalia. Another example is the two species of *Ovisargus* Mostovski, 1996: *O. gracilis* Mostovski, 1996 and *O. singulus* J Zhang, 2015. The former species has an aculeate ovipositor but the latter one has a podgy, conical (non aculeate) ovipositor. *O. singulus* should be assigned to *Ovisargus* based on the similarities in body structures and wing venation to that of *O. gricilis* regardless of the ovipositor. In addition, an aculeate ovipositor has evolved homoplastically in Diptera. It occurs in various groups, including a few Tipulidae, Phoridae, Pipunculidae, some Conopidae, Tephritoidea, Cryptochaetidae and Tachinidae (Pritchard 1983, Feener and Brown 1997, Skevington & Dang 2002, Stireman 2006, Grimaldi et al. 2011, Q Zhang et al. 2016). None of these groups (superfamilies or families) are distinguished based only on the specialized ovipositor. It is evident that the aculeate ovipositor is a convergent development in functional morphology, and does not reveal relationships between these taxa.

Using a geometric morphometric analysis, Wang et al. (2017) reviewed and revised the classification of *Archirhagio.* They redefined the diagnosis of *Archirhagio zhangi* K Zhang et al., 2009, and proposed *Archirhagio mostovskii* J Zhang, 2015 to be a junior synonym for *Archirhagio zhangi* based mainly on some similarities of wing venation and shape of abdominal segments. This study argues that both species were erected based on almost complete impression fossils of the male flies. As the placement is debatable, an overall, further comparative analysis in body structures and wing venation was necessary. Wang et al. (2017) ignored the sharp difference between both holotypes in some key taxonomic characteristics. *Archirhagio mostovskii* differs from *Archirhagio zhangi* in the following aspects: (1) male holoptic *vs* male dichoptic; (2) markings on abdominal tergites differ sharply; (3) size and shape of wing and wing venation differ distinctly; and (4) male genitalia differ distinctly. Thus, *Archirhagio mostovskii* can be separated from *Archirhagio zhangi.* Some detailed explanations are given as follows. In Diptera, the eyes of most families are holoptic (Cumming and Wood 2009); only a few families have a dichoptic male that is used in the family diagnosis in Lower Brachycera, e.g. Asilidae and Xylophigidae (Fisher 2009, Woodley 2009a). It is clear that the condition (male holoptic or dichoptic) is an important diagnosis for the identification of the Lower Brachycera. Both species, *Archirhagio mostovskii* and *Archirhagio zhangi*, are erected based on males, the former species having holoptic eyes with a very long midline (J Zhang 2015: Figs 2B, 4A); in contrast, the latter one has dichoptic eyes, which are widely separate (K Zhang et al. 2009: Fig. 2). It is impossible that the different compound eye types of the male mentioned above occur in the same species. On the basis of these crucial taxonomic characters, *Archirhagio mostovskii* should be separated from *Archirhagio zhangi*.

Secondly, the shape and arrangement of the abdominal markings frequently provide useful taxonomic characters for dividing various groups of the Lower Brachycera, at least at species level, and many such studies have been published (Jones and Anthony 1964, Smith 1989, Woodley 2009a,b, etc.). *Archirhagio zhangi* shows each of abdominal tergites I-VI with a patch at the posterolateral corner (a left patch in segments II-IV is also present but badly preserved to judge from the original photomicrograph – see K Zhang et al. 2009: Fig. 1A, Fig. 5B herein). In contrast, *Archirhagio mostovskii* has a wide, medially longitudinal stripe and a wide transverse band along the

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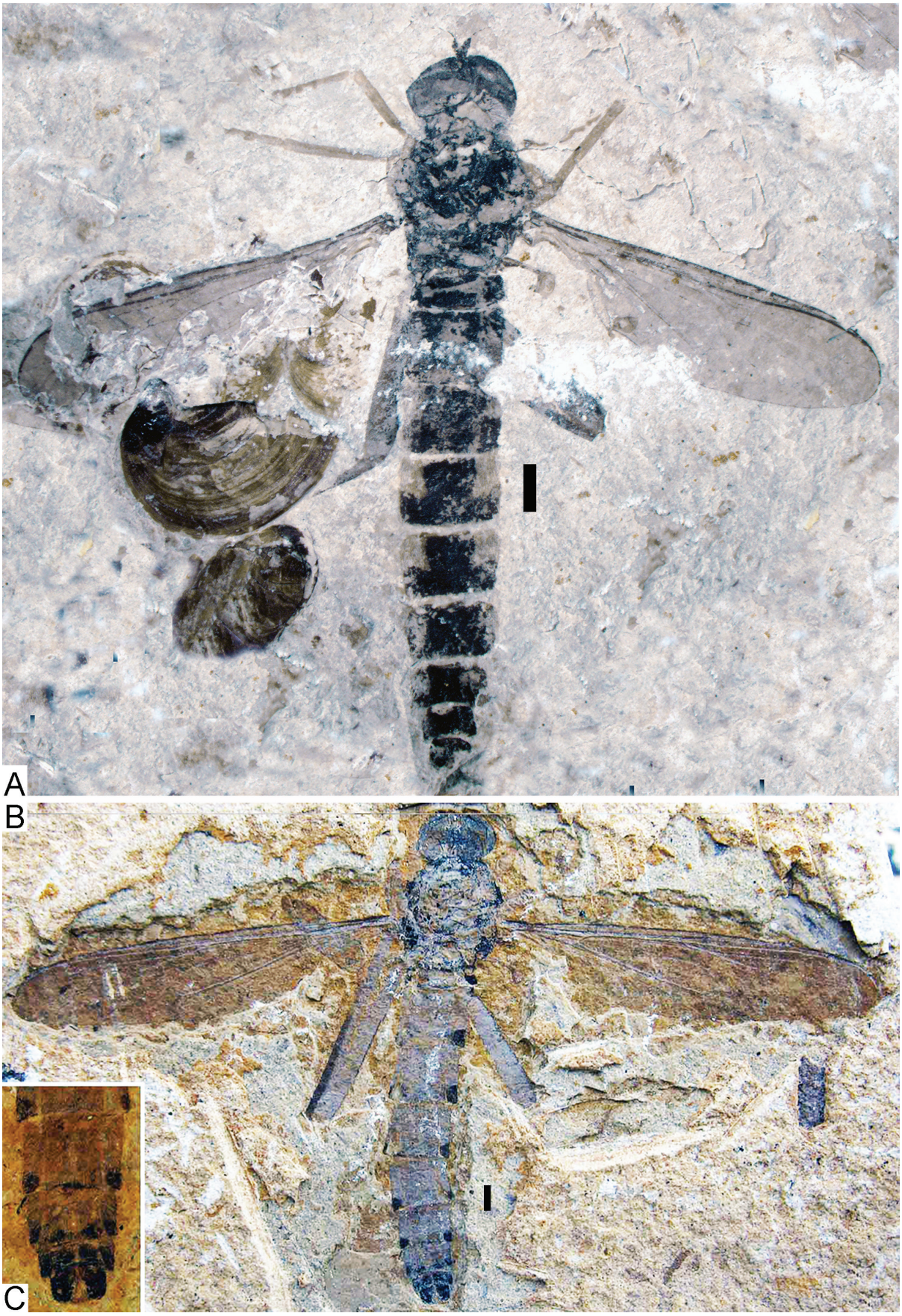

Figure 5. *Archirhagio mostovskii* J Zhang, 2015 and *Archirhagio zhangi* K Zhang et al., 2009, photomicrographs of holotypes (males) **A** *Archirhagio mostovskii* J Zhang, 2015, **B** *Archirhagio zhangi* K Zhang et al., 2009 (after K Zhang et al., 2009, modified), **C** male terminalia (after K Zhang et al., 2009, modified). Scale bars 1mm.

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hind margin on each of the abdominal tergites IV-VII, and the markings occupy almost the whole of tergites I-III (Fig. 5A herein). The sharply different markings on the abdominal tergites indicate that both male holotypes cannot be assigned to one and the same species.

Thirdly, *Archirhagio mostovskii* shows the wings are clearly shorter and wider than that of *Archirhagio zhangi*, (wing 12.1–13 mm long, 3.0–3.4 mm wide, about three times as long as wide *vs* wing 17.5 mm long, 3.8 mm wide, 4.6 times as long as wide); the wing is about one half of body length in the former species *vs* about fourth-fifths in the latter one. It should be pointed out that the revised diagnosis of *Archirhagio zhangi* defining body length between 29 and 32 mm, wing length between 20 and 23 mm, is questionable because the holotype of *Archirhagio zhangi* (body 21 mm long, wing 17.5 mm long) and the holotype of *Archirhagio mostovskii* (body 22.2 mm long, wing 12.1-13 mm long) falls distinctly short of that size. This revised diagnosis is related neither to *Archirhagio zhangi* nor to *Archirhagio mostovskii*. Furthermore, in wing venation the character of cell r1 closed or nearly so is an important diagnosis for *Archirhagio mostovskii*, differing from *Archirhagio zhangi*, in which cell r1 is clearly open. This crucial character demonstrates close similarity to that of *Calosargus* Mostovski, 1997, another archisargid genus. Nevertheless, in *Calosargus* the cell r1 is closed before the anterior margin of the wing, which has a very short or relatively long petiole apically [e.g. *Calosargus* (*Pterosargus*) *sinicus* J Zhang, 2010 and *Calosargus* (*Pterosargus*) *thanasymus* Mostovski, 1997]. This key character mainly differentiates *Calosargus* from *Archirhagio.* It is interesting that *Archirhagio mostovskii* is considered as a connecting link between *Archirhagio* and *Calosargus*. On balance, one should keep *Archirhagio mostovskii* as a separate species referred to *Archirhagio* but closely related to *Calosargus*.

Finally, the structural characteristics of male terminalia provide an unparalleled array of taxonomic characters in Diptera (McAlpine et al. 1981). "Male terminalia are a key morphological source of characters used to distinguish species in the vast majority of Diptera families and there are few modern taxonomic studies that do not include illustrations of male terminalia to aid in species diagnoses" (Sinclair et al. 2013). However, Wang et al. (2017) did not describe and illustrate the characteristics of male terminalia in the revised species diagnosis of *Archirhagio zhangi*, although they also commented that the original description of the male terminalia was incorrect. They only supplied two photomicrographs of an unnumbered specimen instead of the holotype male terminalia of *Archirhagio zhangi* (Wang et al. 2017: Figs 4B, C). Furthermore, they claimed that there are no significant modifications in male terminalia across the genus *Archirhagio*, consisting of the reduced ninth tergite, unsegmented gonocoxites, and pair of large parameres (Wang et al. 2017). Meanwhile, without providing any reference and citation, they declared that the terminology "aedeagus" used by J Zhang (2015) is incorrect, and should be instead of paired "parameres" (Wang et al. 2017). These deductions proposed by them clearly run counter to what many dipterists have concluded (McAlpine et al. 1981, Woodley 1989, Cumming and Wood 2009, Sinclair et al. 2013). This study argues that the kidney-shaped gonocoxite, bipectinate gonostylus and short and stout aedeagus demonstrate *Archirhagio mostovskii* as having distinctly different structures in the male terminalia from the specimens provided by Wang et al. (2017: Figs 4A,B,C). Unfortunately, there is neither description nor line drawing of the male terminalia of *Archirhagio* provided in their article; and thus a further comparison of male terminalia between *Archirhagio mostovskii* and *Archirhagio zhangi* is difficult herein. On the other hand, if those male terminalia investigated by them possess the same structures, then those specimens most likely belong to one and the same species that differs from *Archirhagio mostovskii*. It should be also noted that in Stratiomyomorpha + Muscomorpha sensu Woodley (1989), the aedeagus is indistinguishably fused to the parameral sheath to form the phallus (Cumming and Wood 2009). Currently, Archisargidae is assigned either within or near to the Stratiomyomorpha (Oberprielar and Yeates 2012) or Archisargoidea is probably an extinct sister group to the Muscomorpha (Grimaldi and Barden 2016). In any case, the paired parameres should be indistinguishable in the male terminalia of archisargids [e.g. *Flagellisargus* (*Flagellisargus*) *sinicus* – see J Zhang 2012a: Fig. 3] The so-called parameres of *Arichrhagio*, an undouble archisargid genus, identified by Wang et al. (2017) should be phallus "(aedeagus sensu authors concerning Stratiomyomorpha and Muscomorpha sensu Woodley, 1989)" (Cumming and Wood 2009).

Originally, the genus *Helempis* Ren, 1998 including two species: *H. yixianensis* and *H. eucalla* Ren, 1998 was placed in Protempididae (Ren 1998). The present author (J Zhang 2012b) thought that the two species could be united into one species, namely *H. yixianensis*, and *Helempis*, as a subgenus, could be transferred into *Ovisargus* referred to Archisardinae, Archisargidae. Through further contrastive studying, it could be reasonable to retain *Helempis* as a separate genus within the Archisarginae, Archisargidae. It differs from *Ovisargus* by the elongated discal cell and the deeper fork of R4+5, which is distinctly basad to R2+3 end.

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