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A new species of the extinct family Procercopidae (Hemiptera: Cercopoidea) from the Jurassic of northeastern China

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Abstract

A new fossil species of Procercopidae, *Anthoscytina daidaleos* **sp. nov.**, is described and illustrated based on five adult specimens from the Middle to Upper Jurassic Haifanggou Formation at Daohugou, Inner Mongolia, northeastern China. The new species can be distinguished from other species of *Anthoscytina* Hong, 1983 by the combination of maculated wings and veins RA and RP multi-branched. Our new find sheds further light on the diversity of Jurassic procercopids in the early assemblage of the Yanliao biota from the Daohugou beds.

Key words: Procercopidae, Middle to Upper Jurassic, Palaeodiversity, Daohugou, new species

Introduction

Froghoppers (Cercopoidea) comprise more than 3,000 described species distributed among 340 genera and five extant families: Cercopidae, Aphrophoridae, Clastopteridae, Machaerotidae, and Epipygidae (Cryan & Svenson, 2010; Paladini *et al.,* 2018). Nymphs of Cercopoidea also are commonly known as spittlebugs owing to the habit of nymphs to surround themselves with a foamed excretion on roots or exposed plant parts thereby insulating them and simultaneously providing protection from parasites and predators (Rakitov, 2002). Adults are exceptional jumpers and can exceed the height leapt by fleas relative to their body length (Burrows, 2003). Unfortunately, Cercopoidea are comparatively little-studied among Cicadomorpha, with the most extensive studies undertaken on the European, North American, and New Zealand (Hamilton, 2001; Cryan & Svenson, 2010). In addition to their modern diversity, Cercopoidea include three extinct families, known only from the Mesozoic: Procercopidae, Sinoalidae, and Cercopionidae.

The oldest lineage of froghoppers is the extinct family Procercopidae, a group known from the Early Jurassic through the Early Cretaceous in Australia and Eurasia (Evans, 1956; Hamilton, 1992; Shcherbakov & Popov, 2002). Up to now, Procercopidae have included eight valid genera: *Procercopis* Handlirsch, 1906, *Procercopina* Martynov, 1937, *Liassocercopsis* Ansorge, 1996, *Jurocercopis* Wang & Zhang, 2009, and *Titanocercopis* Chen *et al.*, 2015b from the Jurassic; *Sinocercopis* Hong, 1982 and *Cretocercopis* Ren, 1995 from the Early Cretaceous of China; and *Anthoscytina* Hong, 1983 from the Early Jurassic to the Early Cretaceous. *Anthoscytina* is the largest genus within Procercopidae, currently including eleven valid species and reported from the Early Jurassic to the Early Cretaceous of the northern Asia (Chen *et al*., 2015a). The species recognized include *Anthoscytina reducta* Becker-Migdisova, 1949, described from the Lower Jurassic of Kyrgyzstan; *A. daica* Shcherbakov, 1988, from the Upper Jurassic to the Lower Cretaceous of Chita, Siberia, Russia; *A. parallelica* Ren, 1995, from the Middle to Upper Jurassic of Zhouyingzi, Hebei, China; *A. liugouensis* Hong, 1983, from the Middle to Upper Jurassic of Luanping, Hebei, China; *A. longa* Hong, 1983, *A. hongi* Chen *et al.*, 2015c, from the Middle to Upper Jurassic of Haifanggou, Beipiao, China; *A. perpetua* Li *et al.*, 2013, *A. brevineura* Chen *et al.*, 2015c and *A. elegans* Chen *et al.*, 2015c, from the Middle to Upper Jurassic Daohugou beds, Inner Mongolia, China; and *A. trinervus* Ren, 1995 and *A. pustulosus* Ren, 1995, from the Lower Cretaceous of Lushangfen, Beijing, China.

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Herein we report a new species of procercopid, *Anthoscytina daidaleos* **sp. nov.**, from the Middle to Upper Jurassic Daohugou beds, Inner Mongolia, northeastern China.

Material and methods

A newly recognized species is established on the basis of five well-preserved adult specimens (four females and one of indeterminate sex). All specimens are preserved in grayish tuffaceous shale collected at the Xiaobaishan locality, which occurs in the conchostracan layers, middle-upper section of the Daohugou beds (for a map of the fossil layers that yielded material as well as locations near Daohugou, see Liao *et al.*, 2017, Jiang & Huang, 2017). The geological age of the deposit could be close to the Middle to Upper Jurassic boundary (163.5 Ma), earlier than the Karatau fauna from Kazakhstan (Huang, 2015, 2016).

All specimens were carefully prepared using a sharp knife. Photographs were taken using a digital camera attached to a Zeiss Discovery V16 microscope, and some were moistened with 70% ethanol to provide added contrast and reveal fine details. The invert function in Photoshop CS6 software was used to invert colors of specimen images to show certain details more clearly. Line drawings were prepared using a binocular Olympus SZX7 microscope and a camera lucida attachment, and optimized using CorelDRAW X7. The material studied here is deposited in the Nanjing Institute of Geology and Palaeontology, Chinese Academy of Sciences, Nanjing, China.

Wing venation terminology largely follows Nel *et al.* (2012) as well as that based on forewing-venation patterns among Fulgoromorpha (Bourgoin *et al.*, 2015). The following standards were used for measurements: body length measured from the apex of the vertex to the apex of the abdomen; tegmen length measured from the base to the apex of the tegmen; tegmen width measured at the widest part of the tegmen from costal margin to posterior margin. All measurements are presented in millimetres.

Systematic palaeontology

Family Procercopide Handlirsch, 1906

Genus *Anthoscytina* Hong, 1983

Anthoscytina daidaleos **sp. nov.**
(Figs. 1–3)

Material. Holotype, NIGP169481, a well-preserved adult female in dorsal-ventral aspect. Paratypes: three females (NIGP169483, NIGP169484, and NIGP169485), and one individual of unknown sex (NIGP169482). All material is deposited in the Nanjing Institute of Geology and Palaeontology, Chinese Academy of Sciences, Nanjing, China.

Etymology. The specific epithet derives from the Greek, *daidaleos*, meaning, "spotted" or "dappled", and is a generalized reference to the patterning of the tegmina and hind wings.

Type locality, formation, and age. Daohugou Village, Wuhua Township, Ningcheng County, Chifeng City, Inner Mongolia, China; Middle to Upper Jurassic (near the boundary of Callovian and Oxfordian); Haifanggou Formation.

Diagnosis. The new species differs from other known species of *Anthoscytina* by the following combination of features: body length small, about 13 mm; flagellum with five elongate flagellomeres; tegmen dotted with six subcircular color bands; RA with 2–3 branches; ScP + RA more than twice longer than ScP + R; RP with 1–2 branches; MP with 2 branches; and hind wings marked with irregular patches.

Description. Body length 12.6–13.5 mm; tegmen length 13.5–14.3 mm; remaining metrics in description based on holotype.

Head rounded apically, narrower than pronotum; compound eyes large, positioned laterally; antenna setiform (Figs. 1C, 3B); scape hardly visible; pedicel 0.24 mm long; flagellum with five elongate flagellomeres, flagellum thinner and longer than pedicel, flagellomeres I–V becoming progressively thinner; postclypeus bulging, with transverse impressions and a longitudinal impression, 1.13 mm long, 0.55 mm wide; clypeus triangularly elongate; rostrum straight, extending to base of metacoxa, about 1.8 mm long. Pronotum irregularly hexagonal, nearly 1.5 times wider than head, anterior margin nearly straight; mesonotum partly visible, with mesoscutellum triangular, wider proximally than long.

Tegmina exceeding length of body, length 14.2 mm, width 4.4 mm, length/width ratio about 3.2; tegmen dotted with five light-colored, subcircular color bands, punctate from base to apex (Figs. 1E, F, 3D); costal margin thickened, slightly arched at base, posterior margin nearly straight, apical margin rounded; basal cell nearly 0.22 times as long as tegmen; Pc + CP short, not extended beyond apex of basal cell, reaching 0.19 of tegmen length; stem ScP + R leaving basal cell slightly basal of MP + CuA; ScP + R branching into ScP + RA and RP reaching 0.32 of tegmen length; stem ScP + RA nearly 2.7 times longer than ScP + R; RA with 2–3 branches (RA with 3 branches in right tegmen but with only 2 branches in left tegmen), connected to vein RP by crossvein ir; RP with 1–2 branches (RP simple in right tegmen but with 2

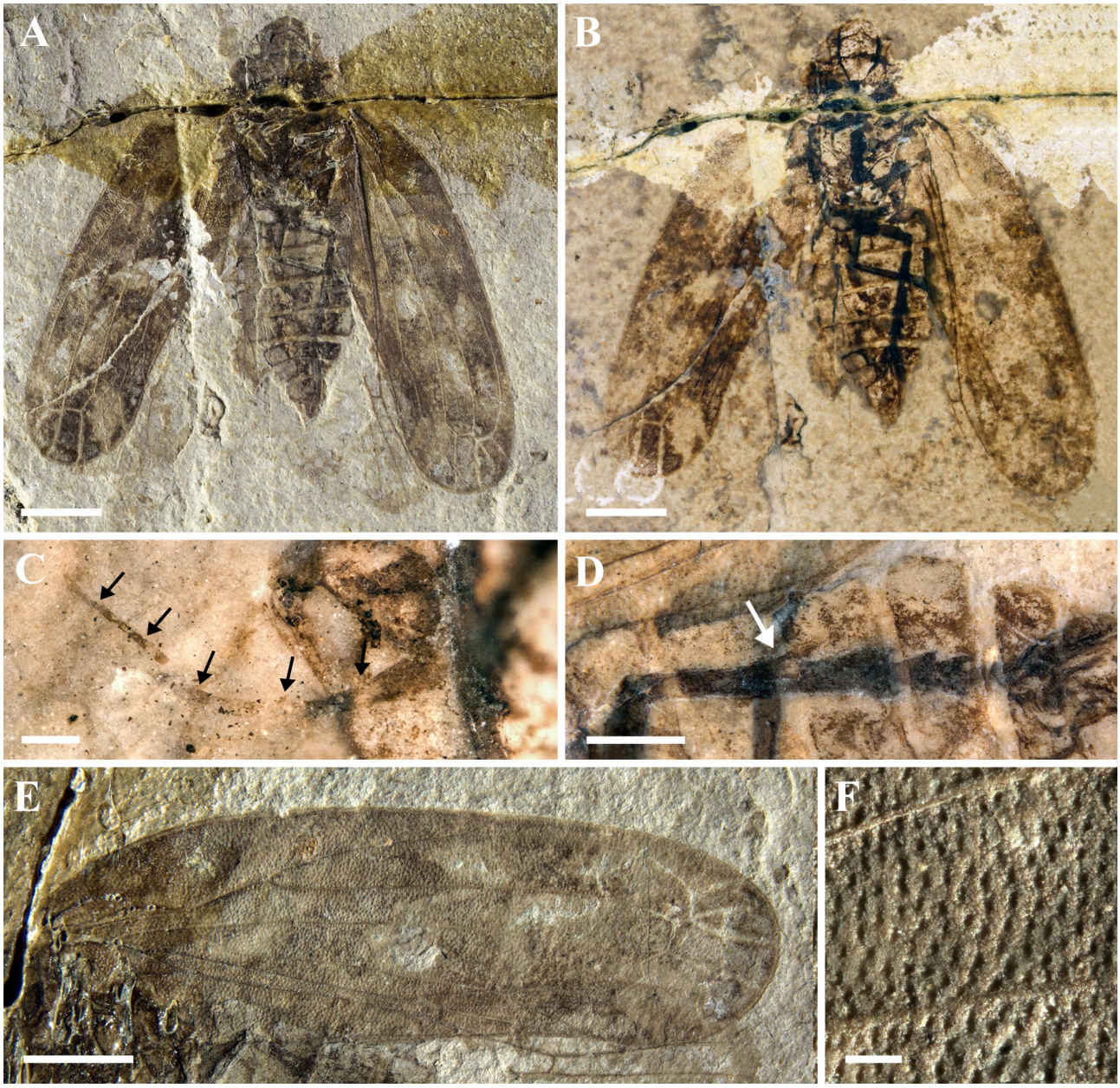

FIGURE 1. Holotype (NIGP169481) of *Anthoscytina daidaleos* **sp. nov.** from the Middle to Upper Jurassic Haifanggou Formation at Daohugou. A—general habitus; B—general habitus moistened with 70% ethanol; C—enlargements of B, showing details of left antenna (numbers indicate flagellomeres); D—enlargements of B, showing details of right metatibia with single spine (white arrows). E—enlargements of A, showing details of right tegmen. F—enlargements of E, showing details of punctation. (Scale bars = 2 mm in A, B, E; 1 mm in D; 0.2 mm in C, F).

branches in left tegmen), connected to MP_{1+2} by crossvein r-m; crossvein ir confluent with or slightly distad r-m; MP branching into MP_{1+2} and MP_{3+4} distinctly after CuA branching, reaching 0.80 of tegmen length; crossvein im absent; CuA curved anteriorly, branching into CuA_1 and CuA_2 slightly basal of ScP, reaching 0.63 of tegmen length; CuA_1 nearly 1.6 times longer than CuA_2; crossvein m-cu slanted, connecting CuA_1 and MP_{3+4}; CuP almost straight, terminating just basal of CuA_2 termination; PCu slightly curved, ending slightly after midpoint of wing; A1 simple. Hind wings nearly complete in NIGP169482 (Fig. 3E), subtriangular, peripheral membrane wide, marked with irregular color pattern; RA and RP simple, MP with 2 branches, branching into MP_{1+2} and MP_{3+4} distinctly after CuA branching; CuA with 2 branches; crossvein r-m distinctly distad m-cu; CuP slightly curved.

Profemur robust, 0.98 mm long, 0.51 mm wide; protibia 2.0 mm long; protarsus 0.85 mm long; mesofemur more slender than profemur; mesotibia slightly longer than protibia; metacoxae enlarged; metatrochanter cylindrical in shape, 0.46 mm long; metatibia with a lateral spine (Figs. 1D, 3C), 2.7 mm long, nearly twice as long as

FIGURE 2. Paratypes of *Anthoscytina daidaleos* **sp. nov.**, from Daohuguo. A—NIGP169482, general habitus with right tegmen and hind wing extended; B—NIGP169483, showing general habitus; C—NIGP169484, general habitus with forewings (tegmina) extended; D—NIGP169485, general habitus with left tegmen extended. (Scale bars = 2 mm).

metafemur; metatibia widened apically, armed with two rows of tiny teeth; metatarsus 1.46 mm long; all tarsi trimerous; basal and second tarsomeres armed with some apical, short, stout spines, widened apically, basitarsus longer than second tarsomere; third tarsomere distinctly thinner than basal and second tarsomeres; pretarsal claws and arolium present.

Abdomen with six segments visible; segment IV broadest, slightly wider than thorax; sternites strongly sclerotized; anal tube elongate, ovipositor long, almost 1.9 times longer than metafemur.

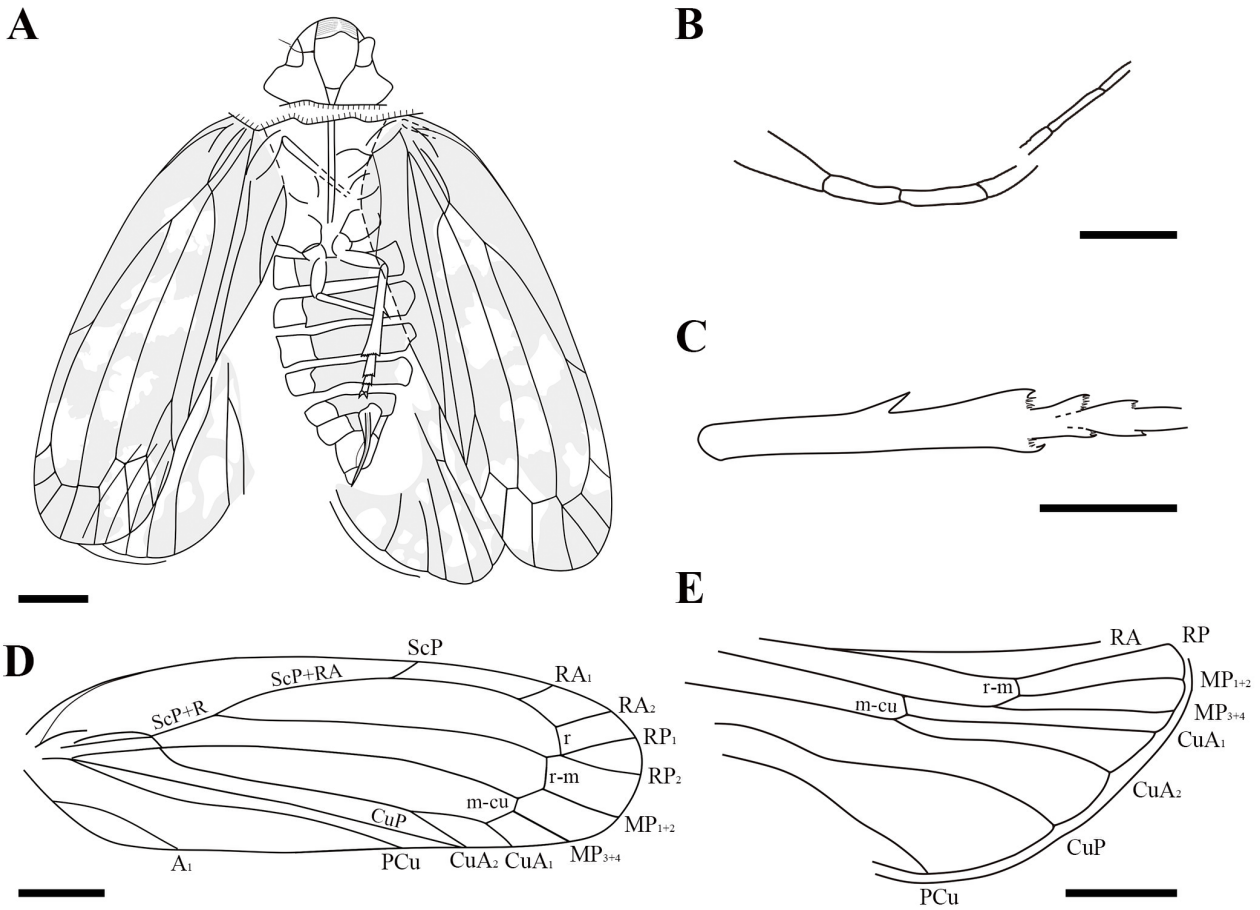

FIGURE 3. Line drawings of *Anthoscytina daidaleos* **sp. nov.** A—general habitus of holotype (NIGP169481); B—antenna of holotype (NIGP169481); C—metatibia and part of metatarsus of holotype (NIGP169481); D—left tegmen of holotype (NIGP169481); E—hind wing of NIGP169482. (Scale bars = 2 mm in A, D, E; 1 mm in C; 0.2 mm in B).

Discussion

To date, the Daohugou biota has yielded abundant cicadomorphan insects, including Procercopidae, Palaeontinidae, Tettigarctidae, and Hylicellidae (Wang & Zhang, 2009). In fact, Procercopidae are the most abundant group in the Daohugou biota, with most individuals belonging to *Anthoscytina*, with a lesser number in the genera *Jurocercopis* and *Titanocercopis*. Despite their abundance, *Anthoscytina* have a comparatively low diversity in the Daohugou biota, presently with only three species: *A. perpetua* Li *et al.*, 2013, *A. brevineura* Chen *et al.*, 2015c, and *A. elegans* Chen *et al.*, 2015c. The new species can be assigned to *Anthoscytina* based on the following apomorphic features: tegmen completely punctate from base to apex; Pc + CP not extended beyond apex of basal cell; MP with at most three branches; crossvein im absent; hind wings with peripheral membrane wide.

The new species, *A. daidaleos* **sp. nov.,** shares several critical characters of forewing venation with the coeval *A. elegans* Chen *et al.*, 2015c in the similar shape of RA and the forewing dotted with colored patches. However, it differs from the latter by the following characters: 1) body small, 12–13 mm long in contrast to a body length more than 20 mm in *A. elegans*; 2) RA with 2–3 branches and RP with 1–2 branches in the new species, versus RA and RP simple in *A. elegans*; 3) MP branching distinctly after CuA branching in the new species versus MP branching nearly at the same level with CuA branching in *A. elegans*. The new species also resembles *A. daica* Shcherbakov, 1988 from the Upper Jurassic to Lower Cretaceous of Russia owing to a similar body size, similar length/width ratio, and relatively complex forewing venation. However, it differs from the Russian species as follows: 1) forewing dotted with six subcircular color patches (lacking in the Russian species); 2) RA with 2–3 branches (versus RA with five branches in *A. daica*); 2) MP with 2 terminals (MP with 3 terminals in *A. daica*); and 3) CuA_1 nearly 1.6 times longer than CuA_2 (CuA_1 more than 2.5 times longer than CuA_2 in the Russian species).

Our discovery of an additional species of *Anthoscytina*

from Daohugou further highlights the many discoveries remaining to be made from careful examination of these deposits. In addition, the new species adds valuable information to our knowledge of the morphological disparity among procercopids and increases the documented palaeodiversity of Jurassic Procercopidae in the early assemblage of the Yanliao biota of the Daohugou beds.

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