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New Jurassic protopsyllidiids from the Yan'an Formation, North China (Insecta: Hemiptera)

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Abstract

The Middle-Late Jurassic Yanliao biota is a significant paleoecosystem for the understanding of the evolution of Life during the Mesozoic. The origin, distribution, and geology of the Yanliao biota are poorly understood to date. Here we describe and illustrate two new species of protopsyllidiids, namely *Sinopsocus yananensis* **sp. nov.** and *Subaphidulum sinica* **sp. nov.** from the Middle Jurassic Yan'an Formation near Yan'an City, Shaanxi Province, North China. *S. yananensis* **sp. nov.** closely resembles the type species *Sinopsocus oligovenus* from the Haifanggou Formation at Beipiao City, West Liaoning, Northeast China. The new discoveries not only increase the diversity of Mesozoic protopsyllidiids but also provide thread for understanding the origin of the Yanliao biota.

Keywords: Protopsyllidiidae, palaeobiodiversity, Middle Jurassic, Yanliao biota

Introduction

The superfamily Protopsyllidioidea is an extinct group of sucking Hemiptera. Protopsyllidioids are known from rocks and ambers worldwide (*e.g.*, Argentina, Australia, China, England, France, Germany, Kazakhstan, Kyrgyzstan, Lebanon, Mongolia, Myanmar, Russia, Tajikistan, and U.S.A.) from the early Permian (Artinskian) to the Late Cretaceous (Turonian) (*e.g.*, Becker-Migdisova, 1985; Klimaszewski, 1995; Ansoerge, 1996; Grimaldi, 2003; Drohojowska *et al.*, 2013, 2022; Hakim *et al.*, 2019, 2021, 2022; Huang *et al.*, 2022; Lara & Wang, 2016). Protopsyllidioids from Burmese amber are diverse and rather common, represented by the two families Postprotopsyllidiidae and Paraprotopsyllidiidae (Hakim

et al., 2019, 2021, 2022; Ross, 2020, 2022, 2023). The former family is known from amber only, with two genera and five species, namely *Postprotopsyllidium emilyae* from the Late Cretaceous New Jersey amber, and *P. rebecca*, *P. grimaldii*, *P. burmaticum* and *Megalophthallidion burmapteron* from the mid-Cretaceous Burmese amber (Grimaldi, 2003; Hakim *et al.*, 2019; Drohojowska *et al.*, 2022). The latter family is known only from Burmese amber with only one exception, *Paraprotopsyllidium shouchangense* Hakim & Huang, 2023, described from the Lower Cretaceous Shouchang Formation in East China (Hakim *et al.*, 2023).

Protopsyllidiidae is a family of Protopsyllidioidea recorded from the Late Permian to the Late Cretaceous. Most protopsyllidiids have been described from rock fossils, mostly as forewings (Grimaldi, 2003). Protopsyllidiids from China are very common in the Jurassic but rarely described, with only three species: *Sinopsocus oligovenus* from the Middle-Late Jurassic Haifanggou Formation at Beipiao, West Liaoning Province and *Poljanka hirsuta* and *P. strigosa* from the Haifanggou Formation at Daohugou, Inner Mongolia (Lin, 1976; Hong, 1983; Yang *et al.*, 2012, 2013). Moreover, some undescribed protopsyllidiids were illustrated, originating from the Middle-Late Jurassic Yanshangzhuang Formation of Jiyuan Basin, Henan Province, Central China (Xiu *et al.*, 2003: fig. 16-1; Zhang, 2003: fig. 46-2). This formation is considered a correlated strata with the Haifanggou Formation (Huang *et al.*, 2018, 2021; Huang, 2019). Another illustrated undescribed protopsyllidiid species was recorded from the Daohugou beds (Huang, 2016: fig. 5-57, first two photos).

The present paper describes two newly discovered protopsyllidiids from the Middle Jurassic Yan'an

Formation at a locality near the Peizhuang Village, Yan'an City, North China (Fig. 1).

Material and methods

The new fossils were collected from grayish shale at the middle-upper sections of the Middle Jurassic Yan'an Formation near the Peizhuang Village, Yan'an City, Shaanxi Province, North China. The co-occurring insect fossils are diverse, including at least 12 orders: Ephemeroptera, Odonata, Blattodea, Dermaptera, Orthoptera, Phasmatodea, Hemiptera, Neuroptera, Coleoptera, Mecoptera, Diptera, and Hymenoptera. From over 300 specimens, there are only two isolated forewings of protopsyllidiids, which have been examined and herein studied.

The fossils were carefully prepared by using a sharp awl. Photographs were taken with a digital camera attached to a Zeiss Discovery V16 microscope. The illustrations were processed with Helicon Focus 6 and

Adobe Photoshop CS6 software. The map was created using CorelDraw 2020 software. The holotype is deposited in the Nanjing Institute of Geology and Palaeontology, Chinese Academy of Sciences, Nanjing, China. We adopt the wing venation nomenclature of Nel *et al.* (2012).

Systematic palaeontology

Order Hemiptera Linnaeus, 1758

Suborder Sternorrhyncha Amyot & Audinet-Serville, 1843

Superfamily Protopsyllidoidea Carpenter, 1931

Family Protopsyllidiidae Carpenter, 1931

Genus *Sinopsocus* Lin, 1976

Type species. *Sinopsocus oligovenus* Lin, 1976.

Diagnosis (revised after Lin, 1976). Forewing only, small size with relatively elongate shape, covered with setae; veins RP, MP, and CuA parallel; RA without

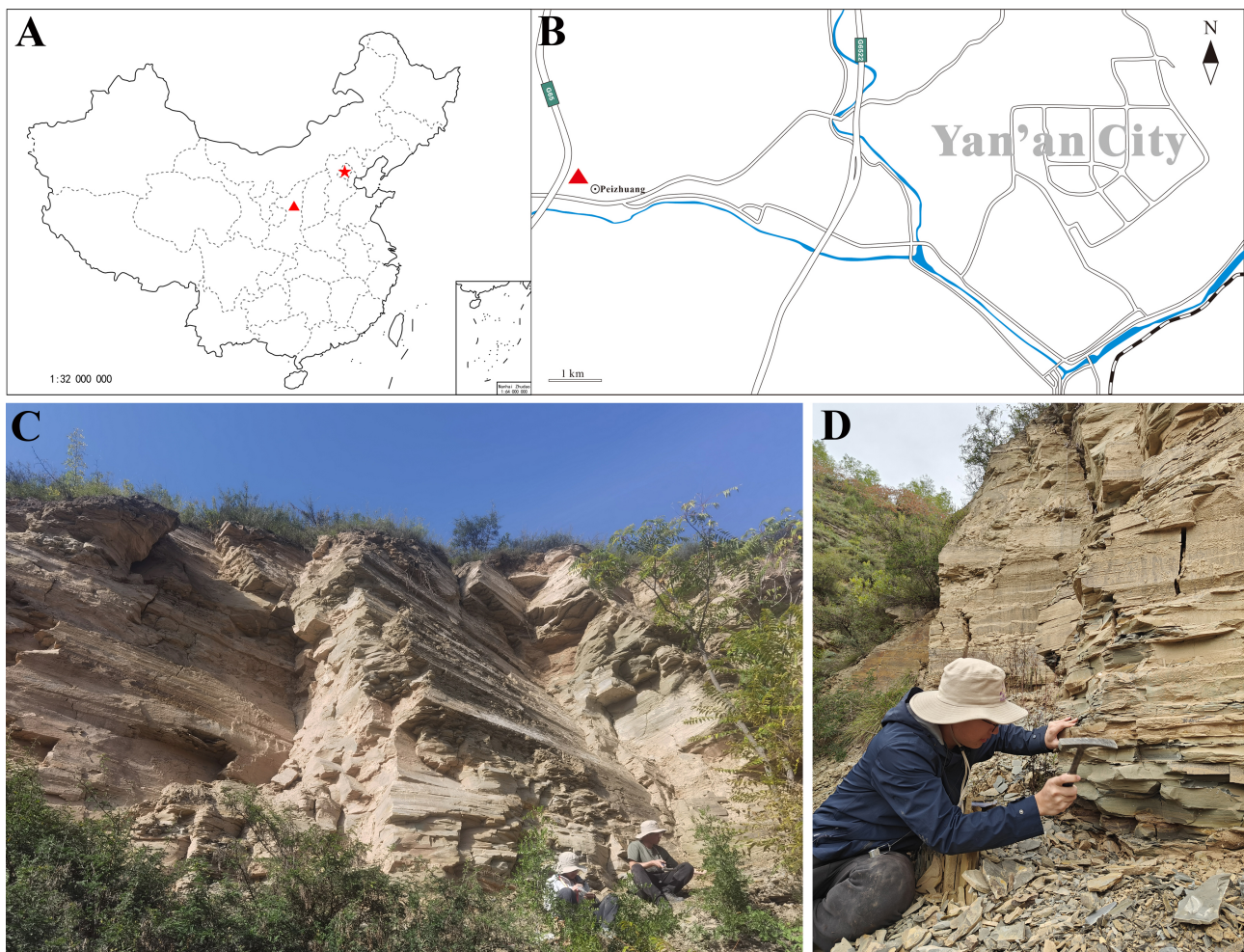


FIGURE 1. Fossil locality. **A**, Map of China with location of fossil outcrop (with red triangle). **B**, Map with fossil locality indicated by red triangle. **C**, General view of outcrop. **D**, Fossil collecting (Yehao Wang).

branches; MP forked earlier than CuA branches; CuA₁ ending near wing apex, CuA₂ short, forming an elongate areola postica; veins of anal area Y-shaped.

Remarks. Lin (1976) erected the genus *Sinopsocus* from the Middle Jurassic Haifanggou Formation and placed it in Psocoptera. It was later transferred to Protopsyllidiidae by Grimaldi (2003). The original diagnosis is as follows: Forewing oval shaped, its length nearly twice the width, covered with setae; ScP absent; R straight and long, Rs without branches, straight and long, divided at basal section of R; common stem of MP and Cu very short, stem of MP₁₊₂ and MP₃₊₄ short, forked slightly after separation of MP and CuA; MP long, slightly curved; CuA branched in the basal part of wing, with a small posterior branch; apex of CuA₂ and CuP connect; CuP

straight; A short, located at the basal part of anal area; anal area not small.

The original material of *Sinopsocus oligovenus* Lin, 1976 is missing. The length/width of *S. oligovenus* is ca. 2.6, the same as the new species. A very fine ScP is present in *Sinopsocus yananensis* **sp. nov.** but it cannot be defined as a critical difference with the type species due to it being very faint and close to the wing margin. Its presence is mainly indicated by the marginal setae rows in the new specimen. The original text stated that CuA of *S. oligovenus* bears a small branch, but it is not displayed in the drawing. Lin (1976) also indicated that MP is forked slightly after branching of R in *S. oligovenus*. However, Lin's description and drawing seem uncertain when compared to the available photos. As for the general

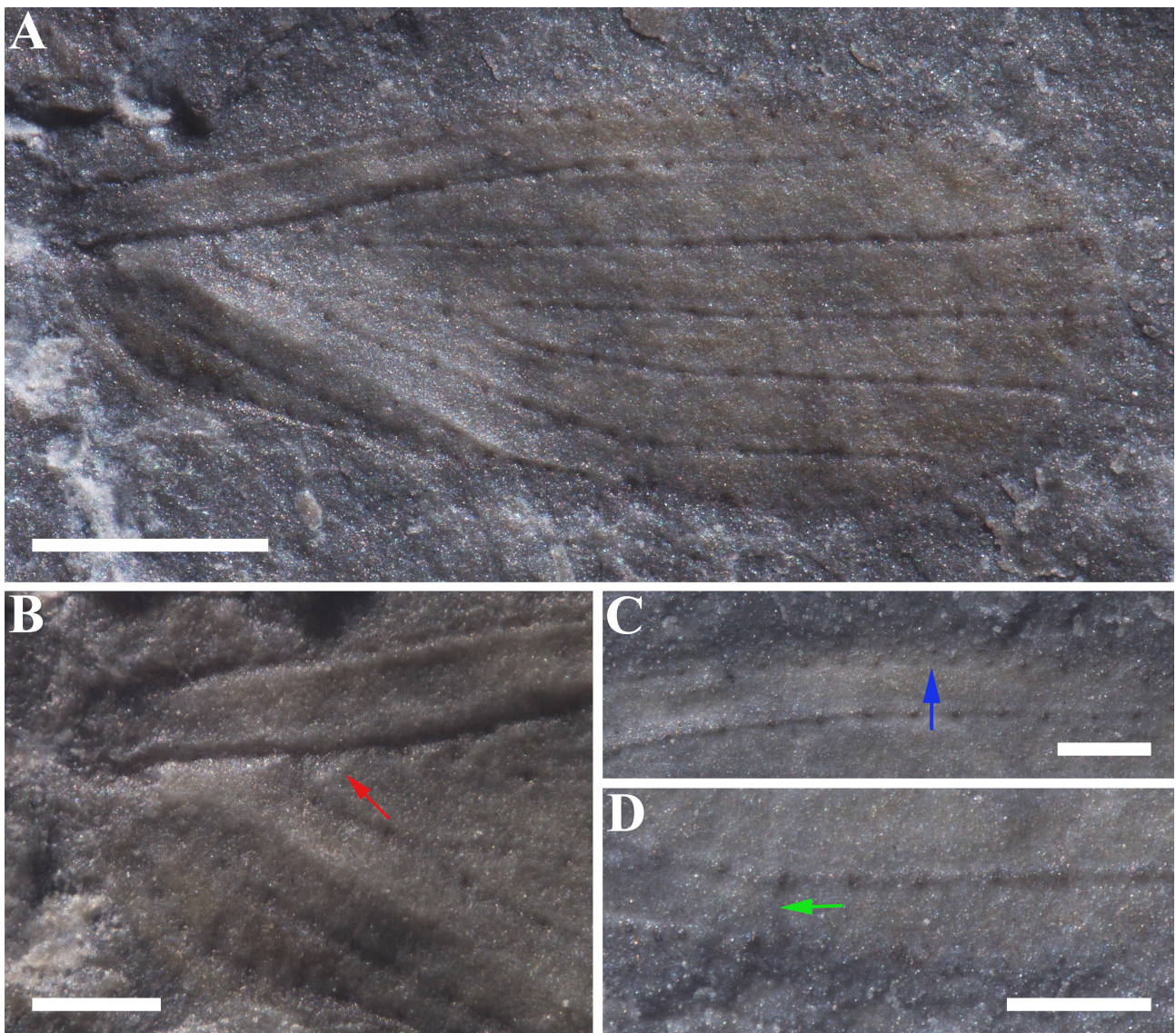


FIGURE 2. *Sinopsocus yananensis* **sp. nov.**, Middle Jurassic Yan'an Formation. **A**, General habitus (NIGP203299). **B**, Enlargement of wing base showing putative crossvein between R and MP+CuA, indicated by red arrow. **C**, Enlargement from **A** showing ScP, indicated by blue arrow. **D**, Enlargement from **A** showing the CuA₂, indicated by green arrow. Scale bars = 0.5 mm in **A**, 0.2 mm in **B–D**.

characters for forewing, the new species closely resembles the type species.

***Sinopsocus yananensis* sp. nov.**

(Figs 2, 4A)

Material. Single specimen, a complete forewing (NIGP203299), without counterpart.

Etymology. Named after Yan'an, the Chinese city near which the specimen was collected.

Diagnosis. Small-sized fore wing, all main veins covered with a row of relatively sparse setae except CuP; R, MP, and CuA₁ well-parallel; R forked early; RA long, ending near wing apex; MP forked early with symmetric branches.

Locality and horizon. Locality near the Peizhuang Village, Yan'an City, China; Middle Jurassic Yan'an Formation.

Description. Forewing 2.29 mm long, 0.89 mm wide, L/W = 2.57; relatively elongate wing with posterior edge round; nearly all main veins covered with relatively sparse setae excluding CuP; ScP faint but long, very close to wing margin, delimited by a second row of setae near wing margin (Fig. 2C); common stem of R, MP, and CuA short; stem of RA and RP very short; RA simple, long and slightly curved; RP simple, straight, ending near the apex; a putative crossvein between R and MP+CuA present (Fig. 2B); common stem of MP and CuA short, straight and perpendicular to stem R at basal section; common stem of MP relatively short, MP forked at middle of MP branched and CuA branched; MP and MP₃₊₄ straight, MP₁₊₂ ending at the wing apex; MP and CuA branched at the same level as R is forked; CuA forked near mid-length of wing, CuA₁ parallel with MP₁₊₂ and MP₃₊₄, CuA₂ very short and nearly straight (Fig. 2D), forming an elongate areola postica, its length circa 5 times to width; CuP straight, without setae, ending at 2/5 of the wing length.

Remarks. The new species is extremely close to the type species *Sinopsocus oligovenus* Lin, 1976 with only two minor differences: 1) the new species is distinctly smaller than the type species (2.3 mm long vs. ca. 4 mm long); 2) the apex of MP₃₊₄ is straight in the new species instead of distinctly curved in the type species. An undetermined protopsyllidiid insect from the Purbeck Group was assigned to *Sinopsocidium* that was also placed within Psocoptera (Coram *et al.*, 1994). The new species clearly differs from this fossil by the much shorter RA and the clearly longer stem of MP in the latter.

Sinopsocus yananensis sp. nov. shows several significant similarities with *Triassopsyllidiida pectinata* from the Middle Jurassic Tongchuan fauna of Shaanxi Province (Huang *et al.*, 2022). For example, a very faint and long ScP is close to the wing margin (no pterostigma in the forewing), and a putative crossvein between R and MP + CuA is present. These structures have not been included as diagnostic characters because these delicate structures were not mentioned nor visible in other material. Nevertheless, such structures could also represent plesiomorphic character states, valuable for a phylogeny of the Protopsyllidoidea.

Genus *Subaphidulum* Klimaszewski, 1995

Type species. *Subaphidulum ponomarenkoi* Klimaszewski, 1995

***Subaphidulum sinica* sp. nov.**

(Figs 3, 4B)

Material. Single specimen, a nearly complete forewing (NIGP203300), without counterpart.

Etymology. *Sinica*, referring to China.

Diagnosis. Forewing only, ScP vertical, emerging early, 'pterostigma' elongate; RP, MP and CuA relatively

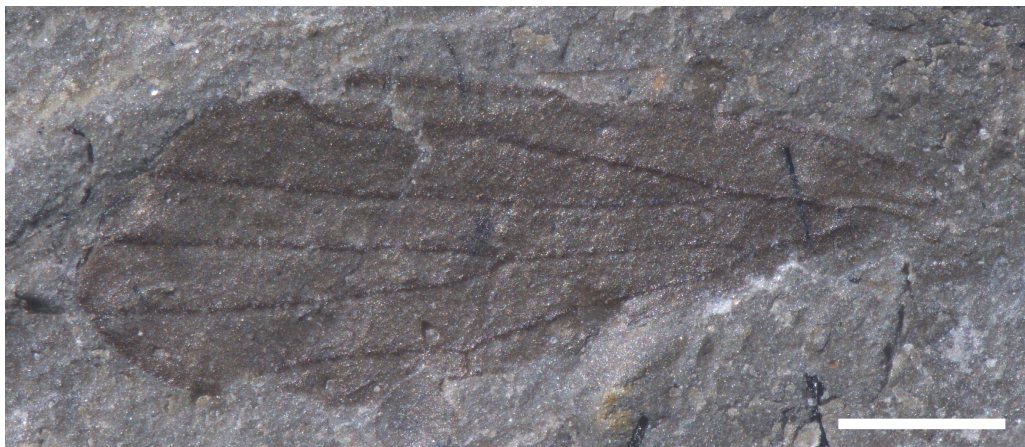


FIGURE 3. *Subaphidulum sinica* sp. nov. from the Middle Jurassic Yan'an Formation, general habitus (NIGP203300). Scale bar = 0.5 mm.

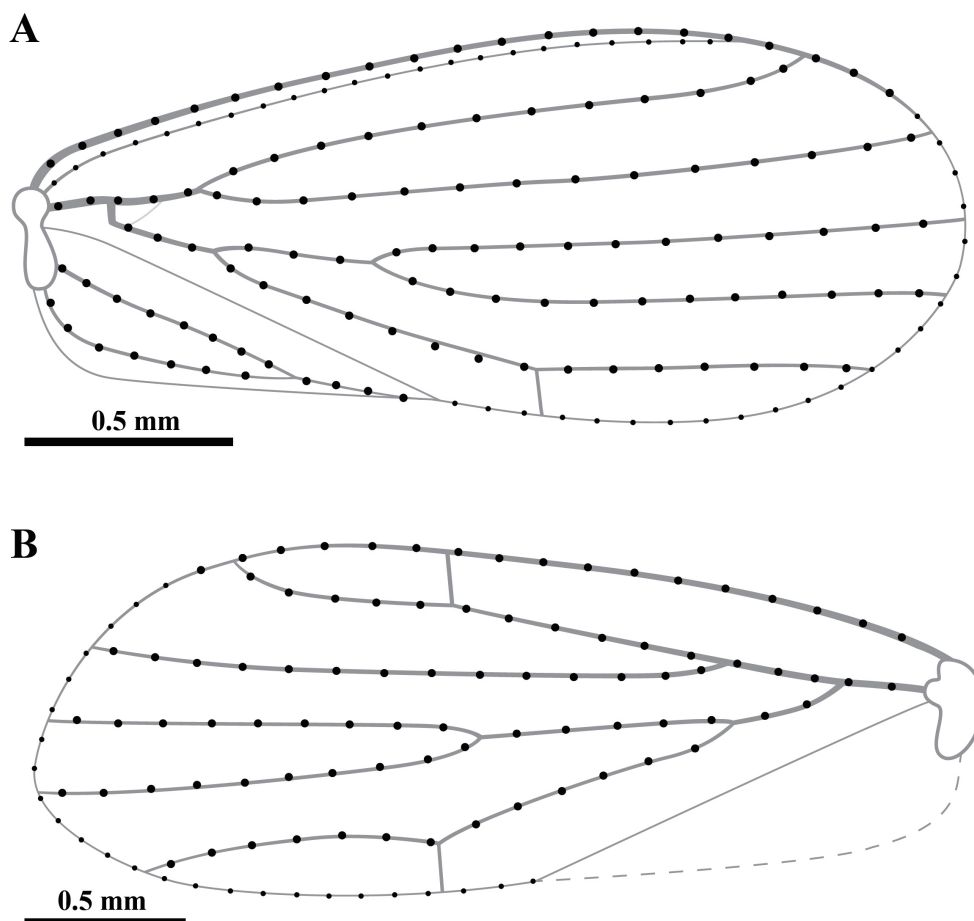


FIGURE 4. Reconstruction drawings. A, *Sinopsocus yananensis* sp. nov. B, *Subaphidulum sinica* sp. nov.

straight and somewhat parallel; wing apex slightly projecting forward, MP_{3+4} ending near wing apex; CuA_2 vertical, areola postica elongate.

Locality and horizon. Locality near the Peizhuang Village, Yan'an City, China; Middle Jurassic Yan'an Formation.

Description. Forewing 2.79 mm long, 0.98 mm wide, $L/W = 2.85$; relatively elongate wing with apex slightly projected forward near MP_{3+4} ; veins covered with densely fine setae; common stem of R, MP and CuA short; stem of RA and RP very short; 'pterostigma' elongate, more than three times as long as wide; MP and CuA branched opposite fork of R; MP forked more distally than fork of R but slightly more basal than that of CuA; areola postica elongate, nearly five times as long as wide.

Remarks. The new species clearly differs from the type species *Subaphidulum ponomarenkoi* and from *S. gobicum* from Mongolia by its elongate 'pterostigma' and areola postica. In addition, its veins RP, MP and CuA are relatively straight, another minor difference with the other two species. In the new species, MP is forked distinctly more distally than that of *S. ponomarenkoi* but similar to that of *S. gobicum* (Klimaszewski, 1995).

Discussion

The Middle-Late Jurassic Yanliao fauna is a window to the understanding the evolution of life in the Mesozoic with nearly 800 insect species described (Lian *et al.*, 2021). The Yanliao biota is mainly know from the Haifanggou Formation at West Liaoning, North Hebei provinces and the adjacent Inner Mongolia area (Huang *et al.*, 2018). Only a few insect species of the Yanliao biota have also been recorded from other areas, such as *Jurocercopis grandism*, which was also discovered from the Jiyuan Basin (Fu & Huang, 2020).

Huang (2019) divided the Yanliao biota into three stages: the initial stage, the early stage, and the late stage. The early stage of the Yanliao biota is represented by the Middle-Late Jurassic Daohugou biota, the late stage represented by the early-middle Late Jurassic Linglongta biota, and the initial stage represented by the underlying strata of the Daohugou beds and European Liassic (Huang, 2015, 2019, Huang *et al.*, 2015).

Recently, some authors obtained a high-precision U-Pb zircon geochronological age (CA-ID-TIMS) between 173.992 ± 0.053 Ma and 171.975 ± 0.047 Ma at the middle

sections of the Yan'an Formation at the northeastern Erdos Basin (Zhang *et al.*, 2021), which indicates that the fossil insect bearing layers at Yan'an City of the Yan'an Formation probably date from the middle parts of the Middle Jurassic, hence it is clearly older than the Haifanggou Formation at Daohugou and Beipiao. The discovery of *Sinopsocus yananensis* **sp. nov.**, a very close species from the Yan'an Formation to the type species from the Haifanggou Formation at Beipiao indicates a closely related fossil insect assemblage for both localities. Thus, the new discovery confirms the origin of the Daohugou fauna, namely the initial stage of the Yanliao biota has been inherited from the underlying strata with a prominent coal period.

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