Zootaxa 5297 (1): 115–123
https://www.mapress.com/zt/

Article

ISSN 1175-5326 (print edition)
ZOOTAXA
ISSN 1175-5334 (online edition)

https://doi.org/10.11646/zootaxa.5297.1.6
http://zoobank.org/urn:lsid:zoobank.org:pub:00D5DDBC-A69B-41AA-BDF9-A2FE1EDD5881

Fossil Hemerobiidae (Neuroptera) from the Eocene Tadushi Formation, the Russian Far East, with description of a new genus

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Abstract

Three specimens of Hemerobiidae (Neuroptera) are described from the early/middle Eocene Tadushi Formation of the Russian Far East. They clearly belong to three species, but only one can be named, *Archibaldia aristovi* **gen. et sp. nov.**; the other two are fragmentary and treated as genus and species A and B. The new genus also includes *A. wehri* (Makarkin), **comb. nov.** from the early Eocene of western North America. The forewing venation of *Archibaldia* **gen. nov.** is most similar to that of the Eocene genus *Proneuronema* Makarkin *et al*., but differs from it and other genera of the family by the following character states: the basal crossvein 1r-m is present; crossveins between RA and RP1/RP2 are present; RP1 has anteriorly directed pectinate branches; M is dichotomously branched; CuP is forked proximad the first gradate series; and there are crossveins between branches of CuP. The presence of the basal crossvein 1r-m separates *Archibaldia* **gen. nov.** from all other hemerobiids and is here interpreted as an autapomorphy of the genus.

Key words: Hemerobiidae, *Archibaldia aristovi, Proneuronema*, Eocene, Tadushi Formation

Introduction

The family Hemerobiidae is rather speciose, with more than 500 species dominating extant temperate zone neuropteran assemblages of forest habitats along with the Chrysopidae and Coniopterygidae. The fossil history of the family begins in the Middle Jurassic, when they were abundant, at least in China (pers. obs.). They then became rare, possibly as an artefact of taphonomy. Hemerobiids again became common in the Eocene, with 14 Eocene fossil species described from Europe and North America (Henriksen 1922; Pictet-Baraban & Hagen 1856; Krüger 1923; Jarzembowski 1980; Makarkin & Wedmann 2009; Jepson *et al*. 2010; Nel & Jarzembowski 2019; Makarkin & Perkovsky 2020; Perkovsky & Makarkin 2020). Numerous other fossil specimens await examination, especially from the Fur Formation of Denmark.

Outside Europe and North America, no Eocene Hemerobiidae have been described, although some from the Tadushi Formation of the Russian Far East have been previously mentioned (Zherikhin 1978; Makarkin 2014; Makarkin & Perkovsky 2020). Here, three hemerobiid specimens are described from that formation with one of them being named.

Material and methods

The specimens described here were collected in 1972 during an expedition of the Paleontological Institute, Russian Academy of Sciences, Moscow (PIN) under the guidance of Dr. V.V. Zherikhin and deposited in the PIN.

The Tadushi Formation is distributed in the basin of the Zerkalnaya [=Tadushi] River (Kavalerovo District, eastern Primorskii Krai in the Russian Far East). A number of outcrops of this formation are known within the river valley and lower reaches of its tributaries. Current knowledge of the age of the Tadushi Formation was summarized by Makarkin (2014) indicating that it is most likely late early Eocene. A wider range (*i.e.*, early/middle Eocene) is also possible based on the age of basalts of the Suvorovo Formation conformably overlaying the Tadushi Formation,

Accepted by D. Bowles: 15 May. 2023; published: 31 May 2023

which is middle Eocene, from 41±3 Ma to 47.3±1.2 Ma (Arakelyants *et al*. 1982; Otofuji *et al*. 1995, 2002; Okamura *et al*. 1998; Martynov 1999).

Venational terminology follows Breitkreuz *et al*. (2017), except details of which (*e.g*., spaces, veinlets, traces, oblique radial branches' ("ORB") concept) that follows Oswald (1993a). Crossveins are designated by the longitudinal veins to which they connect and are numbered in sequence from the wing base, *e.g*., 1sc-r, first (proximal-most) crossvein connecting Sc and R/RA; 2r-m, crossvein in second gradate series between RA/RP and M/MA.

Abbreviations: A1–A3, first to third anal veins; CuA, anterior cubitus; CuP, posterior cubitus; MA, anterior media; MP, posterior media; ORB1–ORB3, first to third oblique radial branches; RA, anterior radius; RP, posterior radius; RP1, proximal-most branch of RP; RP2, branch of RP distad RP1; rv, recurrent veinlet; Sc, subcosta.

Systematic paleontology

Order Neuroptera Linnaeus, 1758

Family Hemerobiidae Leach, 1815

Subfamily Drepanepteryginae Krüger, 1922

Genus *Archibaldia* gen. nov.

Type species. *Cretomerobius wehri* Makarkin *et al*., 2003.

Etymology. From the surname of S. Bruce Archibald, in recognition of his gigantic efforts in collecting and study of fossil insects from the Eocene of western North America.

Species included. *Archibaldia wehri* (early Eocene of western North America), and *A*. *aristovi* **sp. nov.** (early/middle Eocene of the Russian Far East).

Diagnosis. Relatively large hemerobiids (forewing 10–14 mm long), which may be distinguished from other genera by possession of all of the following forewing character states: (1) crossvein 1r-m present; (2) one to three crossveins between RA and RP1 or RP2; (3) RP1 (=ORB1) with anteriorly directed pectinate branches; (4) M dichotomously branched, *i.e*., three or more long branches originating proximad third gradate series; (5) CuP forked proximad first gradate series; (6) crossveins between branches of CuP.

Remarks. The new genus is most closely related to the Eocene genus *Proneuronema* Makarkin *et al*., 2016, which includes five species (Makarkin & Perkovsky 2020): *P. wehri*, an undescribed species from the Tadushi Formation (*A. aristovi* **sp. nov.**), *P. gradatum* Makarkin *et al*., 2016 and *P. minor* Makarkin *et al*., 2016 from late Eocene of Baltic amber, and *P. sidorchukae* Makarkin & Perkovsky, 2020 from late Eocene of Rovno amber. The authors believed that the forewing venation of two former species (*P. wehri* and the Tadushi species) are more similar to each other than either is to the European Eocene species, except *P. gradatum,* which is more or less similar to the former by the presence of character states (3) to (6). These character states occur rather often in some genera of the *Megalomus*-group (see Makarkin *et al*., 2016), but their complete set is present only in the new genus, *P. gradatum*, and the mid-Cretaceous *Cretoneuronema jarzembowskii* Liu *et al*., 2022. By this reason, *P. gradatum* may also belong to *Archibaldia* **gen. nov.**, except that it lacks crossvein 1r-m and those between RA and RP1/RP2. However, their absence might be explained by secondary reduction. Futhermore, the maculation of *P. gradatum* and *A. aristovi* **sp. nov.** is similar. *Megalomus densistriatus* Henriksen, 1922 from the earliest Eocene of Denmark may also belong to *Archibaldia* **gen. nov.**, but this would require reexamination of the holotype or additional specimens.

The forewing of *Cretoneuronema* Liu *et al*., 2022 is also very similar to that of the new genus, but differs from it by the distal fusion of Sc and RA, and by the absence of crossvein 1r-m and those between RA and RP1.

The crossvein between RA and RP1 is present only in *A. wehri*, *A. aristovi* **sp. nov.**, and three extant genera, the Australian *Carobius* Banks, 1909 and *Notherobius* New, 1988 (Carobiinae), and the mainly Oriental *Zachobiella* Banks, 1920 (Zachobiellinae). It is strange but this crossvein is absent in other genera of the *Megalomus*-group, which have rich crossvenation.

In Hemerobiidae, the crossvein 1r-m is present only in *A. wehri* and *A*. *aristovi* **sp. nov.** In the holotype of *P. wehri*, there are two thin crossveins connecting the basal stem of M and RA before the origin of RP1, either of which might be considered 1r-m (or 1r-m and 1^br-m) (Fig. 1). These are poorly discernible and were overlooked in the original description (Makarkin *et al.* 2003). Therefore, this character state may be interpreted as an autapomorphy of *Archibaldia* **gen. nov.** Unfortunately, it cannot be reliably identified in impression fossils, and its presence in the oldest hemerobiids is possible.

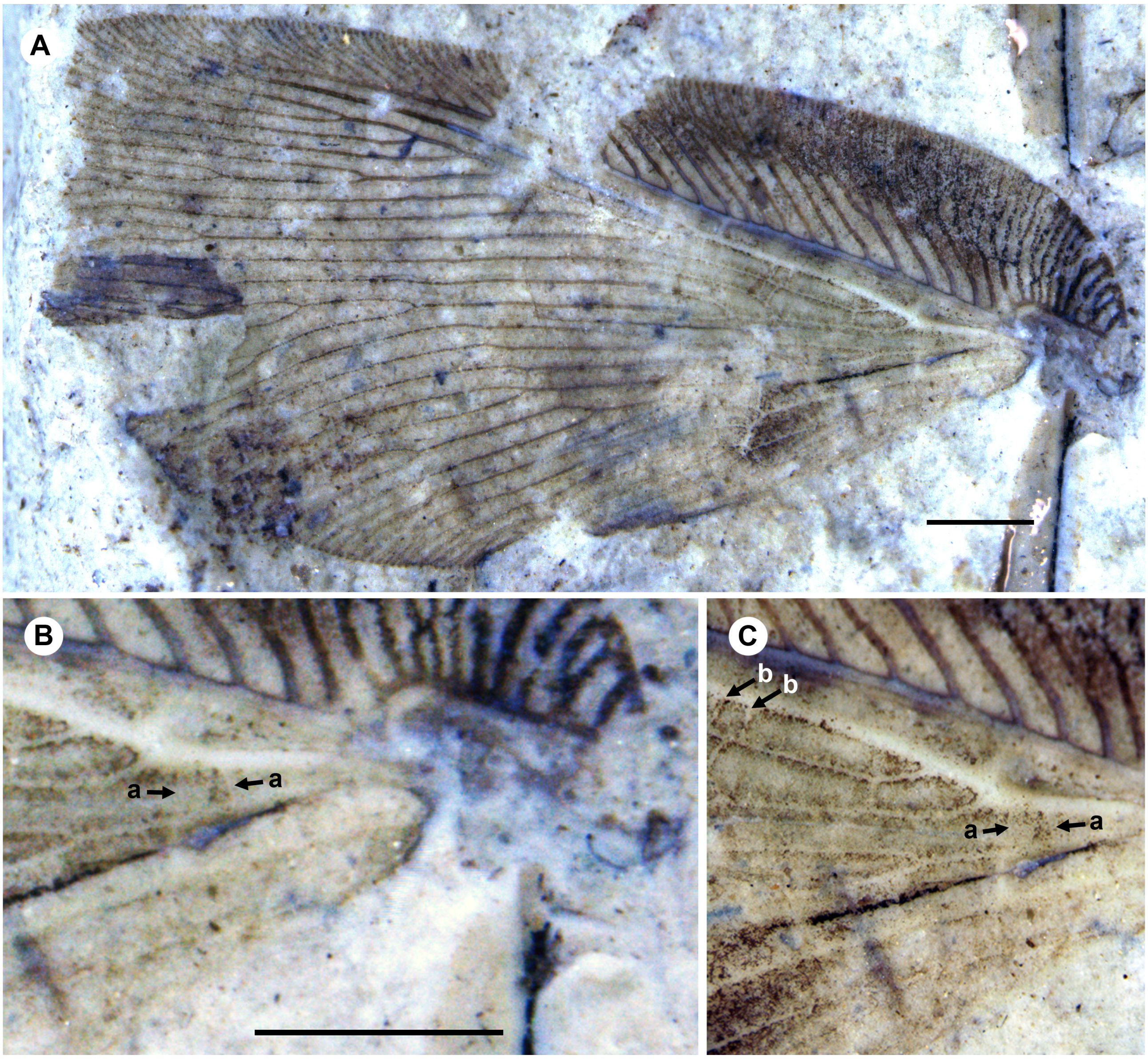

FIGURE 1. *Archibaldia wehri* (Makarkin *et al*., 2003), **comb. nov.**, holotype UWBM77543 (wetted with ethanol). A, forewing; B, its basal part; C, same, taken under different lighting. a, two basal crossveins between R and M; b, crossveins between RA and RP2. Scale bars = 1 mm (B is not to scale).

Archibaldia aristovi **gen. et sp. nov.**
Fig. 2

Etymology. From the surname of Daniil S. Aristov (1979–2022), in recognition of his achievements in study of fossil insects.

Holotype. PIN 3364/3746 (part and counterpart); a rather well preserved basal part of a forewing.

Type locality and horizon. Sadovaya [=Yushangou] River, a right tributary of Zerkal'naya [=Tadushi] River, Sikhote-Alin Mountains, Primorskii Krai, Russian Far East. Tadushi Formation; early/middle Eocene.

Diagnosis. This species may be distinguished from *P. wehri* by the presence of numerous small transverse brownish spots over radial to cubital spaces [absent in *P. wehri*].

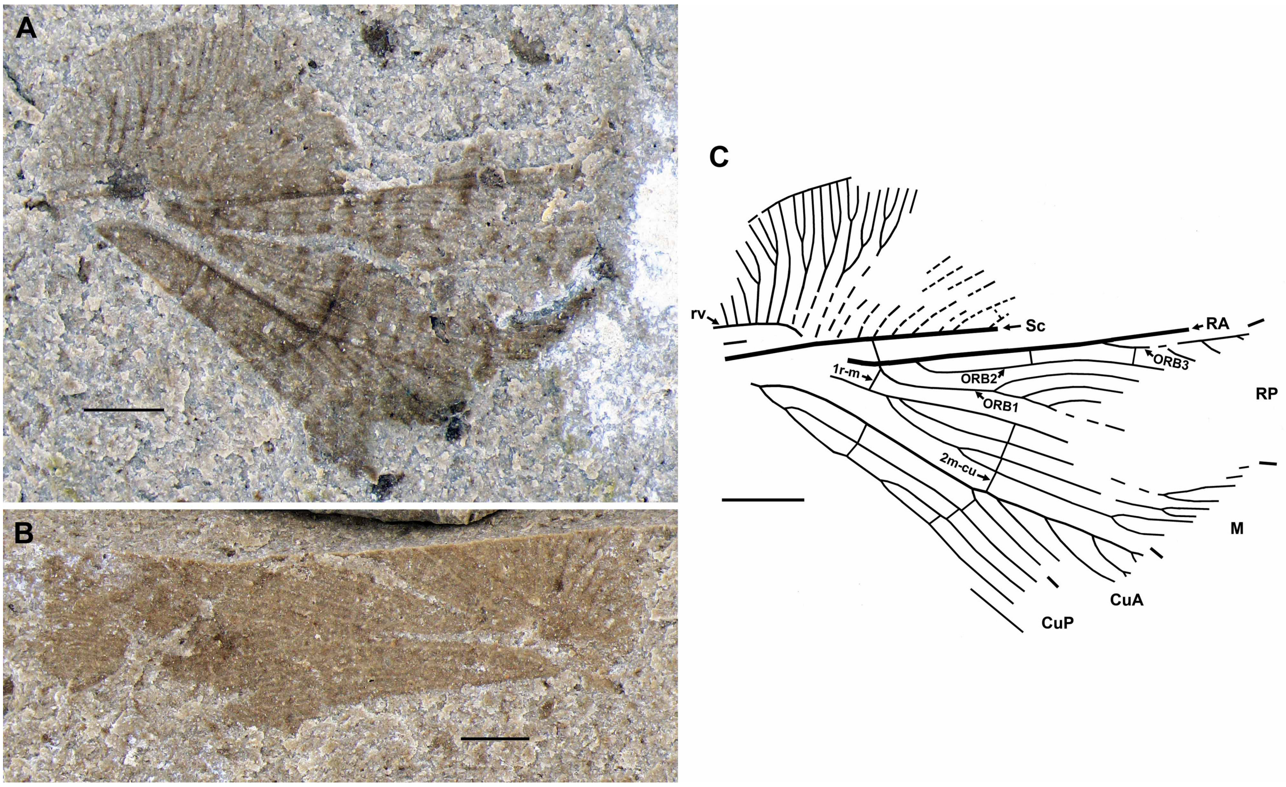

FIGURE 2. *Archibaldia aristovi* **gen. et sp. nov.**, holotype PIN 3364/3746 (dry). A, part; B, counterpart; C, forewing venation. Scale bars = 1 mm.

Description. Forewing 7.5 mm long as preserved (estimated complete length *ca*. 14 mm), 5.5 mm wide as preserved (estimated complete width *ca*. 6.5–7 mm). Costal space very broad basally. Humeral subcostal veinlet well developed, with eight branches (four simple, others forked once to twice). Three proximal-most subcostal veinlets forked three times; others incomplete. Basal subcostal crossvein located at level of origin of RP1. RA space (between RA and ORB3) narrow proximally. RP consists of three branches separately originating on RA. Posterior trace of ORB1 (RP1) sinuous proximally, deeply forked, with three anteriorly directed branches; ORB2 (RP2) sinuous proximally, originating close to origin of RP1, parallel to anterior branch of RP1; ORB3 (RP proper) originating very distant to origin of RP2, with three preserved basal parts of branches. M dichotomously forked opposite sc-ra1, with four long branches; medial space broadens distally. Cu dividing into CuA and CuP very close to wing base. CuA with five incompletely preserved branches; CuA1 originating at second gradate series of crossveins. Posterior trace of CuP nearly straight (slightly curved), with two deeply forked anteriorly directed branches. Two gradate series of crossveins partially preserved. In first (basal) series four crossveins detected: 1sc-r; 1r-m (long, connecting ORB1 at its origin and stem of M); 1cua-cup; 1icup. Second series consists of seven crossveins, from posterior trace of ORB1 (RP1) to posterior trace of CuP. Maculation: Second gradate series of crossveins broadly margined with dark brown; basal subcostal veinlets narrowly margined with brownish; numerous small transverse brownish spots over radial to cubital spaces (similar to that of extant *Dilar* Rambur, 1838).

Hemerobiidae gen. et sp. A

Figs 3, 4

Material examined. PIN 3364/3751 (part and counterpart); a poorly preserved incomplete forewing.

Locality and horizon. Uglovoi Stream, a right tributary of the Zerkal'naya [=Tadushi] River, eastern Sikhote-Alin Mts, Primorskii Krai, Russian Far East. Tadushi Formation; early/middle Eocene.

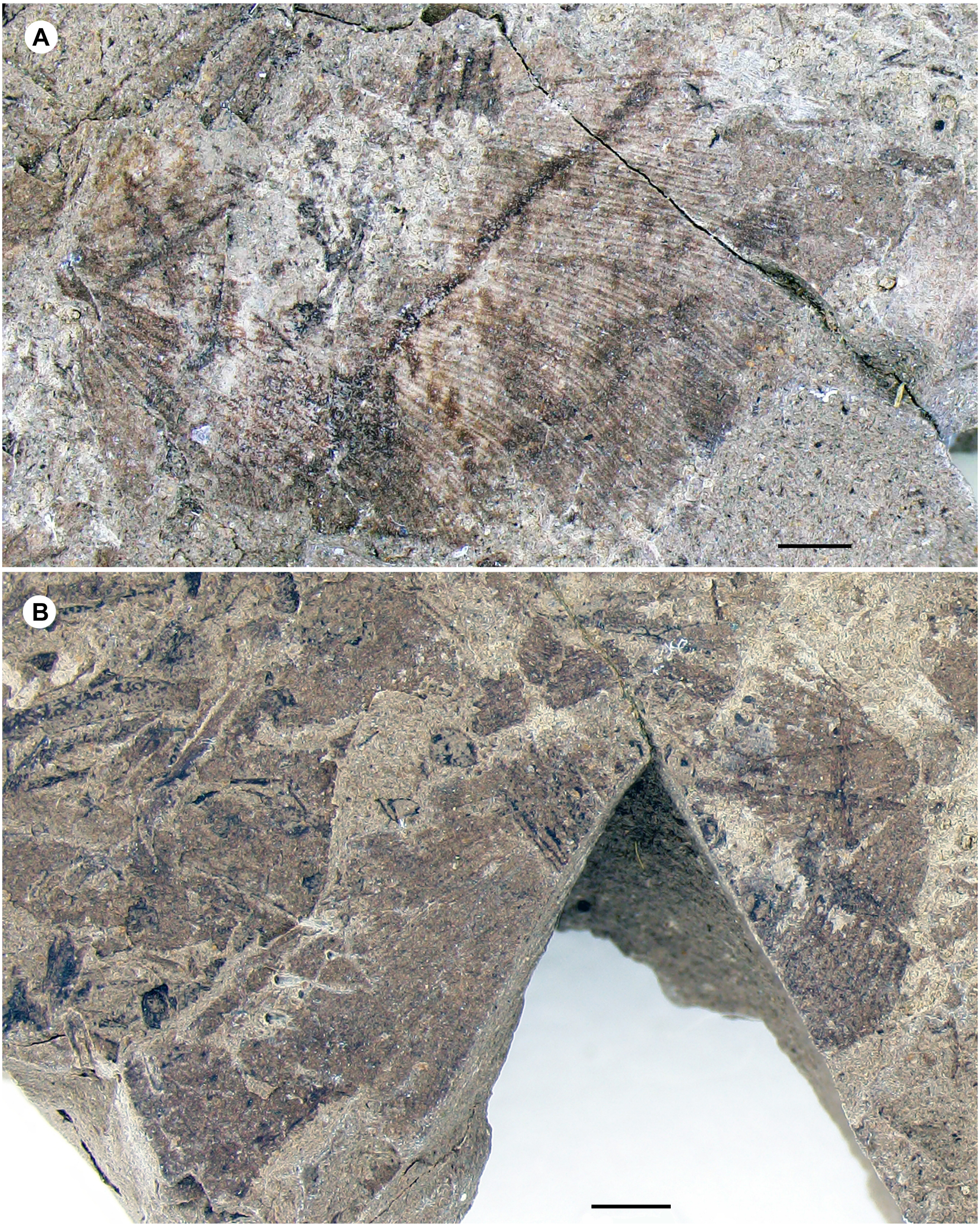

FIGURE 3. Hemerobiidae gen. et sp. A, specimen PIN 3364/3751 (dry). A, part; B, counterpart. Scale bars = 1 mm.

Description. Forewing *ca*. 10 mm as preserved (estimated complete length *ca*. 14–15 mm), *ca*. 6.6 mm wide as preserved (estimated complete width *ca*. 7 mm). Costal space fragmentarily preserved; its costal margin poorly discernible, approximately twice broader than subcostal space in distal part; basal subcostal veinlets probably once forked; distal subcostal veinlets probably simple. Subcostal space very broad through entire length. RA space moderately broad. RP basally poorly discernible, some branches distally rather deeply forked; RP1 at least once deeply forked (alternatively: ORB1 (RP1) deeply forked, with two to three preserved anteriorly directed branches). M forked at level of RP1, probably profusely branched (most part of that space not preserved); branches slightly sigmoidal distally. CuA with six long branches; CuA1 located very proximally. CuP probably with three long branches. Presumable A1 dichotomously forked distally; anterior trace of presumable A2 similarly forked. No clear crossveins discernible. Maculation: very dark transverse stripe over radial to medial spaces continuous in cubital space by large dark spot; numerous irregular brownish spots over radial to medial spaces distad dark stripe.

Remarks. The counterpart is very poorly preserved and completely uninformative (Fig. 3B). This species is well distinguishable by wing maculation, and it will be undoubtedly assigned to a genus and species when more complete forewing is found.

The very proximal origin of CuA1 as found in this specimen (slightly distad the origin of RP) is an unusual condition in the family. In most hemerobiid taxa, it originates far distad the origin of RP, and very rarely slightly distad it (*e.g.*, in *Biramus lunatus* Oswald, 1993b).

Also, the presence of the slightly sigmoidal branches of M is a very unusual condition in Hemerobiidae. It is found probably only in two genera, *i.e.*, the mid-Cretaceous *Cretoneuronema* and the extant *Hemerobiella* Kimmins, 1940 (see Oswald 1993a: Fig. 60; Liu *et al*. 2022: Fig. 3).

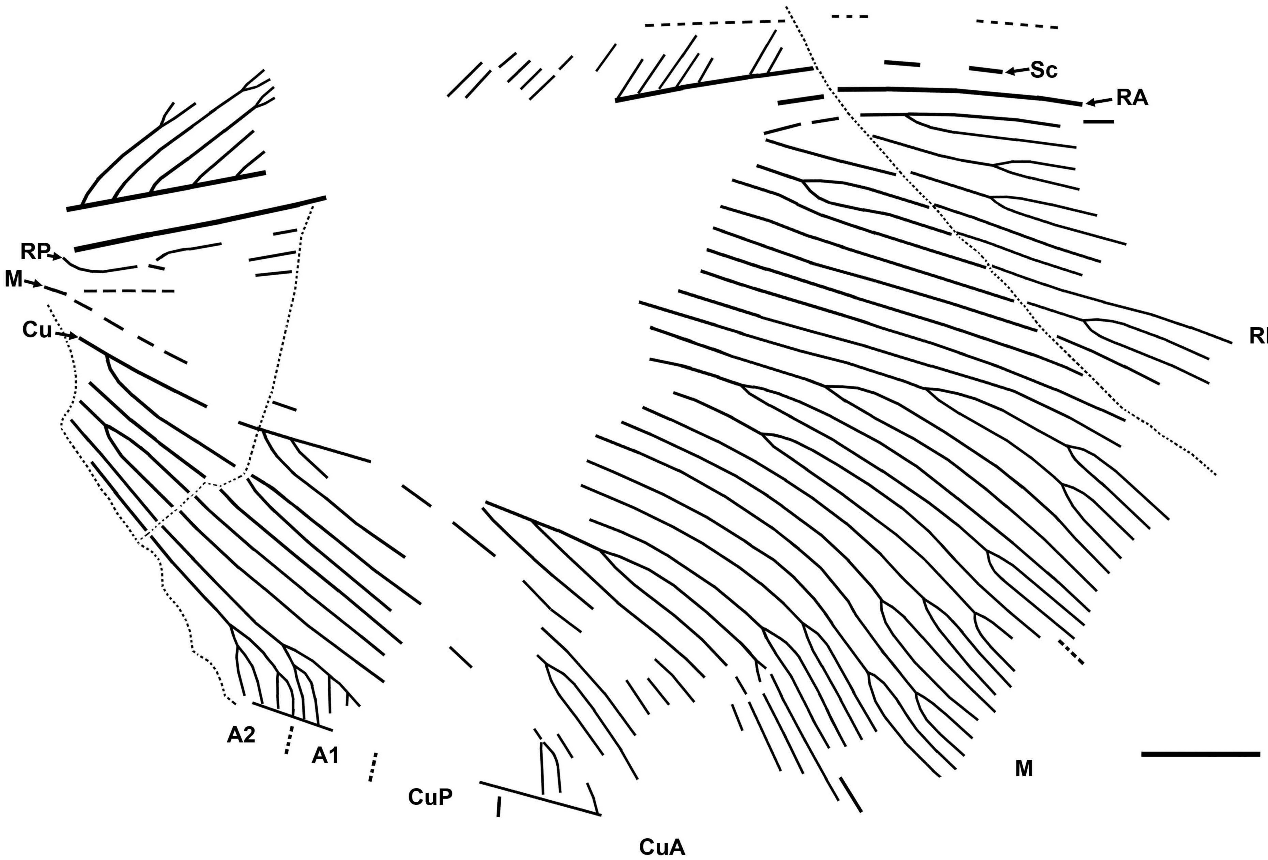

FIGURE 4. Hemerobiidae gen. et sp. A, specimen PIN 3364/3751, drawing of the forewing venation. Scale bar = 1 mm.

Hemerobiidae gen. et sp. B

Fig. 5

Material examined. PIN 3364/3749 (part); a basal fragment of a forewing.

Locality and horizon. Sadovaya [=Yushangou] River, a right tributary of Zerkal'naya [=Tadushi] River, eastern Sikhote-Alin Mountains of Primorskii Krai, Russian Far East. Tadushi Formation, early/middle Eocene.

Description. Forewing 2.5 mm as preserved (estimated complete length *ca*. 7 mm), *ca*. 2.4 mm wide as preserved (estimated complete width *ca*. 3.5 mm). Costal space proximally broad. Humeral subcostal veinlet well developed, with seven branches (distal-most once forked, other simple). Two proximal-most subcostal veinlets once forked; third subcostal veinlet twice forked; other three only proximally preserved. Basal subcostal crossvein (1sc-r) located at level of origin of RP1. RP1 deeply forked. Preserved basal part of M not forked (likely forked much distad origin of RP1). Cu dividing into CuA and CuP basally. A1 forked far distad division of Cu. Crossvein between CuP and A1 short (highly likely belonging to second gradate series).

Remarks. The venation of this forewing fragment is generally typical for many genera of Hemerobiidae. However, the deeply forked A1 occurs in most genera of the *Megalomus*-group, and rarely in other genera.

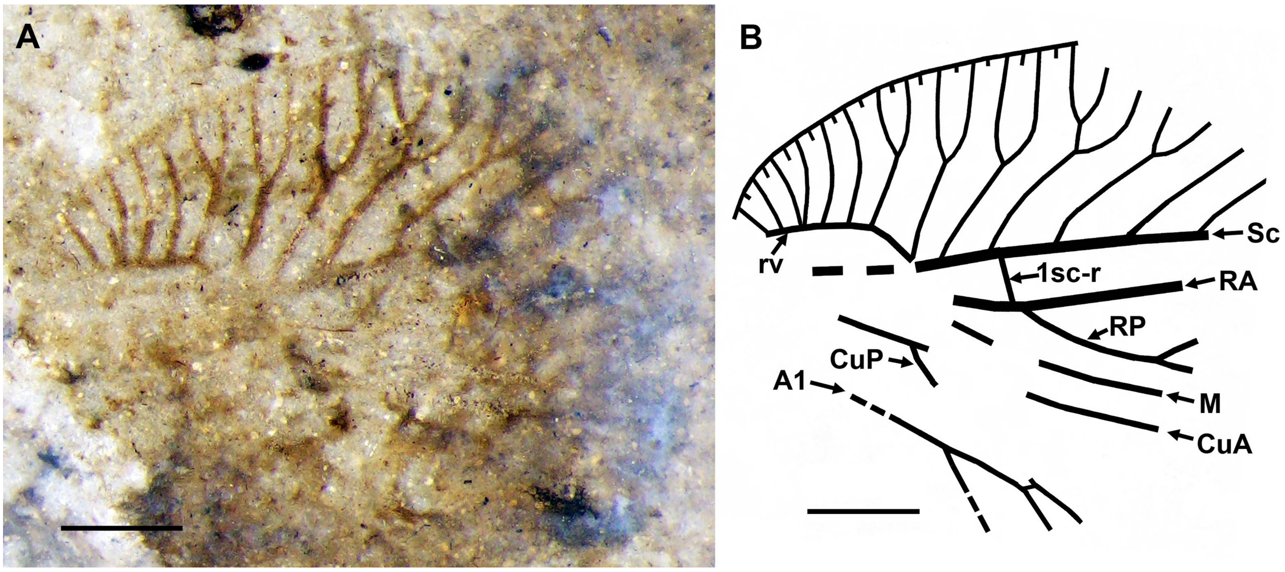

FIGURE 5. Hemerobiidae gen. et sp. B, specimen PIN 3364/3749. A, specimen as preserved (wetted with ethanol); B, forewing venation. Scale bars = 0.5 mm.

Discussion

The three specimens described here clearly belong to different species. The forewing of *Archibaldia aristovi* **sp. nov.** and Hemerobiidae gen. et sp. A have similar size and shape, but differ in particular by the location of the origin of CuA1. The forewing of Hemerobiidae gen. et sp. B is half the size of the other two species and further differs from them by the distal fork of its M.

All of the Tadushi species likely belong to genera of the informal *Megalomus*-group (see Makarkin *et al*. 2016). Species of this group dominate among hemerobiids in the early Eocene localities of Europe, *i.e*., the Fur Formation of Denmark and coeval localities in northern Germany. In fact, no taxa of other groups have been found from these localities; the vast majority of specimens belong to *Proneuronema*. Species of the *Megalomus*-group occur in the early Eocene of North America, but the representatives of other groups are also represented there, *e.g*., the hemerobiine *Wesmaelius mathewesi* Makarkin *et al*., 2003 from the Okanagan Highland locality of Quilchena, and an undescribed taxon likely belonging to Carobiinae from the Green River Formation (pers. obs.). Four species of Baltic and Rovno ambers Hemerobiidae belong to the *Megalomus*-group (species of *Proneuronema* and *Drepanepteryx* Leach, 1815), the other five to Sympherobiinae (Makarkin *et al*. 2016; Makarkin & Perkovsky 2020; Perkovsky & Makarkin 2020). Therefore, the hemerobiid assemblage of the Tadushi Formation resembles those of other Eocene localities.

Two species from the Tadushi Formation (*Archibaldia aristovi* **sp. nov.** and Hemerobiidae gen. et sp. A) possess the anteriorly directed pectinate RP1 (presumed for the latter species). The pectinate forewing RP1 is probably a simplesiomorphic state as it is characteristic of all known taxa from the Jurassic/ Early Cretaceous taxa, *i.e*., undescribed taxa from the late Middle/early Late Jurassic of Daohugou, China; *Promegalomus anomalus* Panfilov, 1980 from the Late Jurassic of Karatau, Kazakhstan; *Cretomerobius disjunctus* Ponomarenko, 1992 from the Early Cretaceous of Bon-Tsagaan, Mongolia. Most Cenozoic and extant representatives of the *Megalomus*-group also possess this character state.

Acknowledgements

I thank Valery M. Loktionov (Federal Scientific Center of the East Asia Terrestrial Biodiversity, Vladivostok, Russia) for help in photography; S. Bruce Archibald (Department of Earth, Ocean, and Atmospheric Sciences, University of British Columbia, Canada) for editing the English. The research was carried out within the state assignment of Ministry of Science and Higher Education of the Russian Federation (theme No. 121031000151-3).

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