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Short communication

# First mayfly larva of Leptophlebiidae (Insecta: Ephemeroptera) in mid-Cretaceous Kachin amber, northern Myanmar

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ABSTRACT

A new genus and species of mayfly, *Kachinophlebia zhouchangfai* gen. et sp. nov. (Ephemeroptera: Leptophlebiidae), is described and illustrated based on a larva in the mid-Cretaceous amber from Kachin, northern Myanmar. The new taxa are established primarily based on the morphological characters of the mouthparts, legs, abdominal gills, and caudal filaments. The new amber mayfly is the first report of Leptophlebiidae from mid-Cretaceous Kachin amber.



## 1. Introduction

Ephemeroptera (mayfly) is a rather small aquatic insect order with over 3200 species in 42 extant families and 20 extinct families (Huang et al., 2007; Godunko et al., 2015; Sartori and Brittain, 2015). Mayflies are distributed worldwide (except Antarctica) and inhabit freshwater and sometimes brackish waters. This insect group has a unique process of molting in the adult stage: the larva molts into a winged subimago, which molts again into the sexually mature imago (Needham et al., 1935).

The family Leptophlebiidae is one of the most diverse groups of mayflies, with at least 131 genera and over 640 species (Godunko et al., 2015; Sartori and Brittain, 2015). The higher-level phylogeny of Leptophlebiidae is still debatable; the different classifications of subfamilies are not united (Godunko et al., 2015). Besides, the systematic positions of the fossil taxa presumably from Leptophlebiidae are mostly unclear (Kluge, 2004).

The mid-Cretaceous amber from Kachin, northern Myanmar contains many special fossil insects and is providing evolutionary implications for both the extinct and the extant lineages (Grimaldi et al., 2002). However, there are only four mayfly families recorded in Kachin amber, including Prosopistomatidae (Sinitshenkova, 2000; Lin et al., 2018), Australiphemeridae (McCafferty and Santiago-Blay, 2008), Baetidae (Poinar, 2011), and Hexagenitidae (Lin et al., 2018; Brandão et al., 2021). In the present study, we describe the first representative of Leptophlebiidae based on a larva from the mid-Cretaceous Kachin amber.

## 2. Materials and methods

The studied Kachin amber was legally obtained from Kachin State, Hukawng Valley of northern Myanmar (26°20′N, 96°36′E, as in Kania et al., 2015: fig. 1) before June 2017 (see 'Affidavit' and 'Museum Catalogue entry' in Supplementary material). The age of Kachin amber was recognized as the earliest Cenomanian (98.79 ± 0.62 Ma), mid-Cretaceous, according to Shi et al. (2012) and Yu et al. (2019). Examination and measurements were conducted with an SDPTOP SZM45 stereomicroscope. Photographs were taken by a Canon EOS 6D digital camera equipped with a Canon MP-E 65 mm 5× macro lens. All photographs and line drawings were optimized and assembled into plates with Adobe Photoshop CS6. The holotype is deposited in the Insect Collection of Jiangsu University of Science and Technology (CZT-EPH-MA1). The following abbreviations are used in the figures: md, mandible; mp, maxillary palp; lp, labial palp; la, labium; lb, labrum; mx, maxilla; fe, femur; ti, tibia; ta, tarsi; cl, claw.

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## 3. Systematic paleontology

Class: Insecta Linnaeus, 1758
Order: Ephemeroptera Latreille, 1810
Suborder: Euplectoptera Tillyard, 1932
Infraorder Anteriotorna Kluge, 1993
Family: Leptophlebiidae Banks, 1900
Subfamily: Leptophlebiinae Banks, 1900

Genus ***Kachinophlebia*** gen. nov.
urn:lsid:zoobank.org:act:F8D66D53-B571-42D3-96B5-804431B4BC73
*Type species. Kachinophlebia zhouchangfai* gen. et sp. nov., by monotypy.

*Etymology.* The genus name is a combination of the words *Kachio* and *phlebia*. The first word refers to the Kachin State; the second word is a frequently used suffix of the extant genera of Leptophlebiidae.
*Diagnosis.* Body slender and flattened, head near trapezoidal; labrum with shallow anteromedial emargination; maxillary palpi slender, three-segmented; third maxillary palpal segment elongated, sub-equal to the first segment and, longer than the second segment, with several slender hairs on the inner margin; maxilla with a dense brush of setae on apical margin; labial palp three-segmented; thorax without notal shield; femur flattened and broad, longer than tarsi, with rounded posterior margin and irregular blunt setae along the margin; tibia without distinct long hairs along outer margin; claws non-segmented, slender, without distinct denticles; abdominal gills laterally located, elongated, lamellate, and basally forked, without obvious fringe; tracheae basally forked; caudal filaments much longer than body, almost glabrous except for tiny denticles around articulations.

***Kachinophlebia zhouchangfai*** sp. nov.
urn:lsid:zoobank.org:act:A851B835-33D6-46A4-A61F-58708C2F8F47
(Figs. 1–3)

*Etymology.* The species is named after Dr. Chang-Fa Zhou for his academic contributions to the Ephemeroptera.
*Type material.* Holotype larva (No. CZT-EPH-MA1), probably a male larva due to its large compound eyes, deposited in the Insect Collection of Jiangsu University of Science and Technology (ICJUST).
*Type locality.* Hukawng Valley of southwest Maingkhwan, Kachin State (26°20N, 96°36E), Myanmar, uppermost Albian-lowermost Cenomanian (mid-Cretaceous).
*Description of holotype.* Body length (excluding cerci) 4.0 mm; median caudal filament at least 2 times longer than body length (Fig. 1). General body coloration yellow to pale brown.
Head length subequal to its width, posterior margin rounded (Fig. 2A, B); ocellar area dark brown; ecdysial suture clear. Compound eyes oval-shaped. Antennae length ca. 1.5 mm, ca. 3× head width, each segment longer than wide (Fig. 2A, B). Clypeus near trapezoidal (Fig. 2A, B). Labrum dark brown, slightly wider than clypeus, with a rounded, mesal emargination anteriorly, dorsally set with conspicuous setae near anterior margin (Figs. 2A, B, 3A–C). Mandible with lateral margin smoothly rounded; several thin setae present along lateral margin, one near middle, another near posterior; incisor, prostheca, and molar hardly visible (Figs. 2A, B, 3A–C). Inner half of the top of maxilla with a dense row of bristles; maxillary palpi slender, three segmented, about 1.0:0.7:1.0 in length, terminal segment with numerous long and soft setae on inner side (Fig. 3C). Mentum semicircular. Labial palp three segmented, length of the segments subequal, first segment larger and broader than other segments. Other mouthparts hardly visible.
Pronotum wider than head (Fig. 2A, B), short in length, anterior margin hidden beneath head, median suture conspicuous, lateral margins rounded, posterior margin with a deep median notch. Mesonotum slightly narrower but longer than pronotum, median suture distinct; forewing pads subtriangular (Fig. 2A, B). Metanotum similar to mesonotum; hindwing pads invisible. Legs similar in shape (Fig. 2A, B), femur:tibia:tarsus:claw = 2.5:2.5:1.0:0.5 in length (Figs. 2A, B, 3D). Femora thick, flat and elliptical, posterior margin arc-shaped; femora of forelegs each with a transverse row of short sharp spines on dorsal surface at 1/3 near apex, anterior margin with several sharp spines near the base, posterior margin fringed with sparse blunt cylindrical long setae; tibiae near cylindrical, with short setae on inner margin, without obvious setae or spines on outer margin; tarsi thin and glabrous. Claws sharp and glabrous, with several inconspicuous tiny denticles on the middle part. Midlegs and hindlegs similar to forelegs, except for the absence of the transverse row of spines on femora, with more blunt setae on posterior margin and sharp spines along entire inner edge. Abdominal segments 8–10 with sharp posterolateral projections, those of segment 9 longest (Figs. 2A, B, 3A). Tergum 10 as long as tergum 9, elongated posteriorly, with a rounded posterior margin. Most gills absent or highly mutilated and illegible, except for the left one on abdominal segment 4, 5, and 7 (Figs. 2A, B). Gills slender, sub-equal to the length of abdominal segment; gills and tracheae bifurcated at the base, without distinct fringe. Caudal filaments slender (Figs. 1, 2A, B, 3A), almost glabrous, with tiny denticles around articulations (Fig. 3E), median filament twice the length of lateral ones (Fig. 1).

## 4. Discussion

All of the extant and most of the extinct mayflies belong to the suborder Euplectoptera. The new fossil mayfly is attributed to Euplectoptera in having non-segmented larval tarsus and single claw, which are considered autapomorphies of the suborder (Kluge, 2004). Most mayflies of Euplectoptera belong to the infraorder Anteriotorna Kluge, 1993, and others are included in the infraorder Posteritorna Kluge, Studemann, Landolt and Gonser, 1995 based on their tornus of forewings located behind the CuP vein. Posteritorna only includes two families, Prosopistomatidae and Baetiscidae (Kluge, 2004). Larvae of the two families are characterized by an integral notal shield fused by the pronotum, mesonotum, and forewing buds (Kluge, 2004). The absence of such a notal shield suggests the attribution of the new mayfly to the other infraorder Anteriotorna.

*Kachinophlebia* gen. nov. is easily attributed to the family Leptophlebiidae by the combination of characters: body slender and flattened, head near trapezoidal, maxillary and labial palpi three-segmented, apical margin of maxilla with a dense brush of setae, abdominal gills lamellate and forked, three caudal filaments longer than the body (Edmunds et al., 1976; Elliott et al., 1988; Kluge, 2004). The shallow anteromedial emargination of the labrum, slender body and maxillary palpi, the elongated apical segment of maxillary palpi, and forked, elongated gills without obvious fringe, together support *Kachinophlebia* gen. nov. in the subfamily Leptophlebiinae (Peters and Edmunds, 1970; Peters, 1980; Kluge, 1994; Bauernfeind and Soldan, 2012). The slender maxillary palpi with a third segment longer than the second and the forked, laterally located abdominal gills further distinguishes *Kachinophlebia* gen.

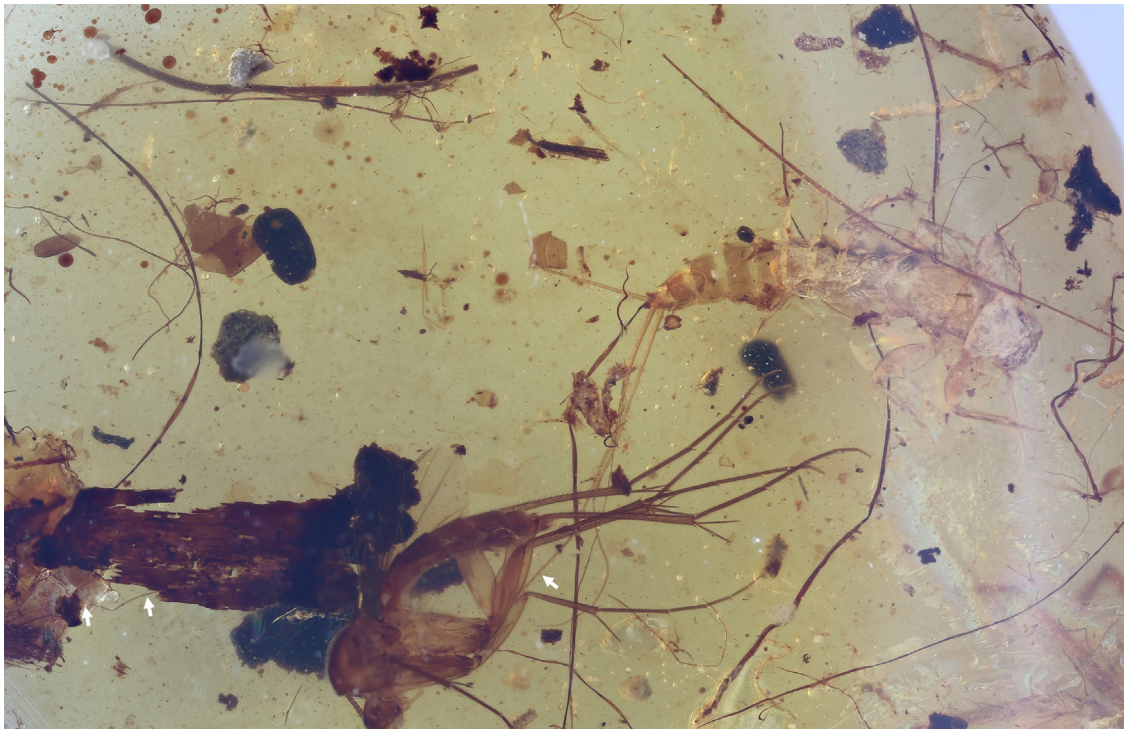

**Fig. 1.** *Kachinophlebia zhouchangfai* gen. et sp. nov., holotype larva (CZT-EPH-MA1). Complete habitus photo, dorsal view. Median caudal filament indicated with white arrowheads.

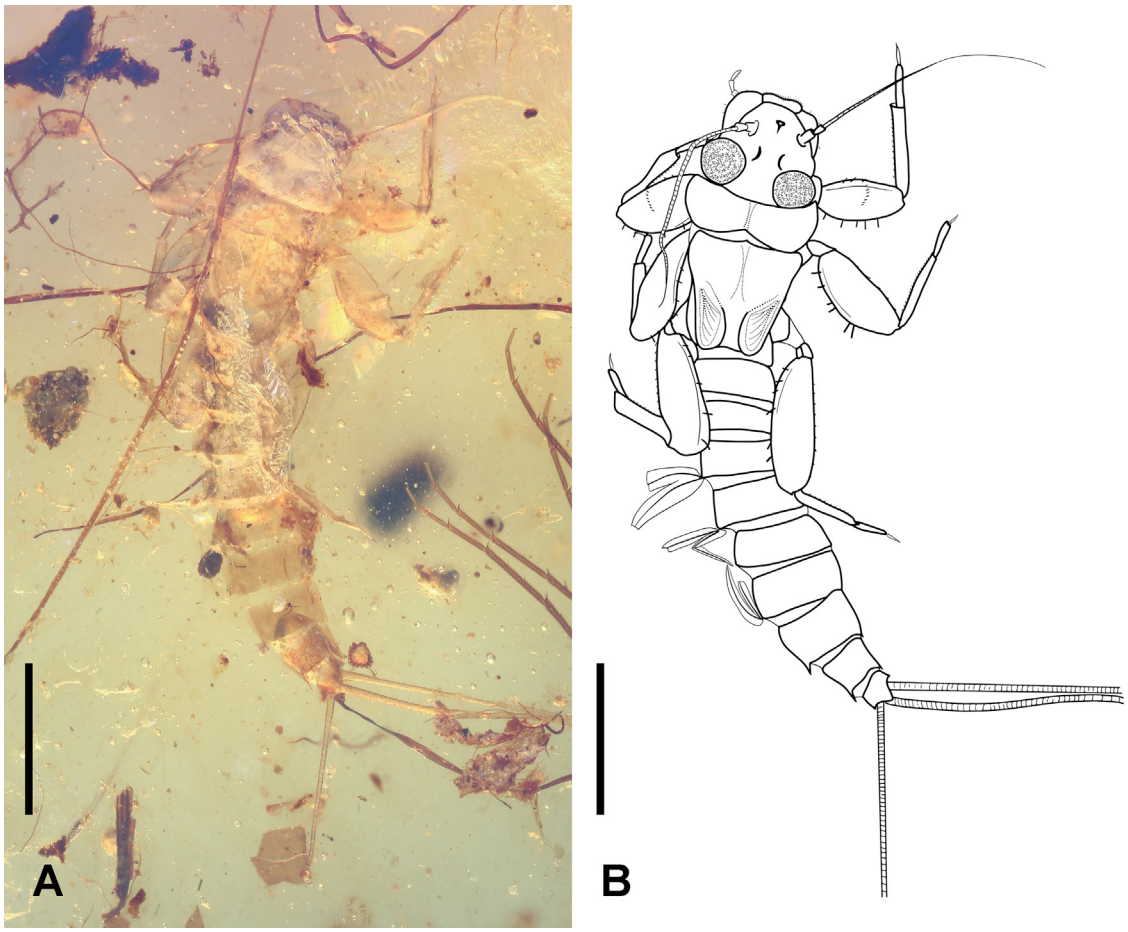


**Fig. 2.** *Kachinophlebia zhouchangfai* gen. et sp. nov., holotype larva (CZT-EPH-MA1). A. Habitus photo, dorsal view; B. Drawing of habitus, dorsal view. Scale bars = 1.0 mm.

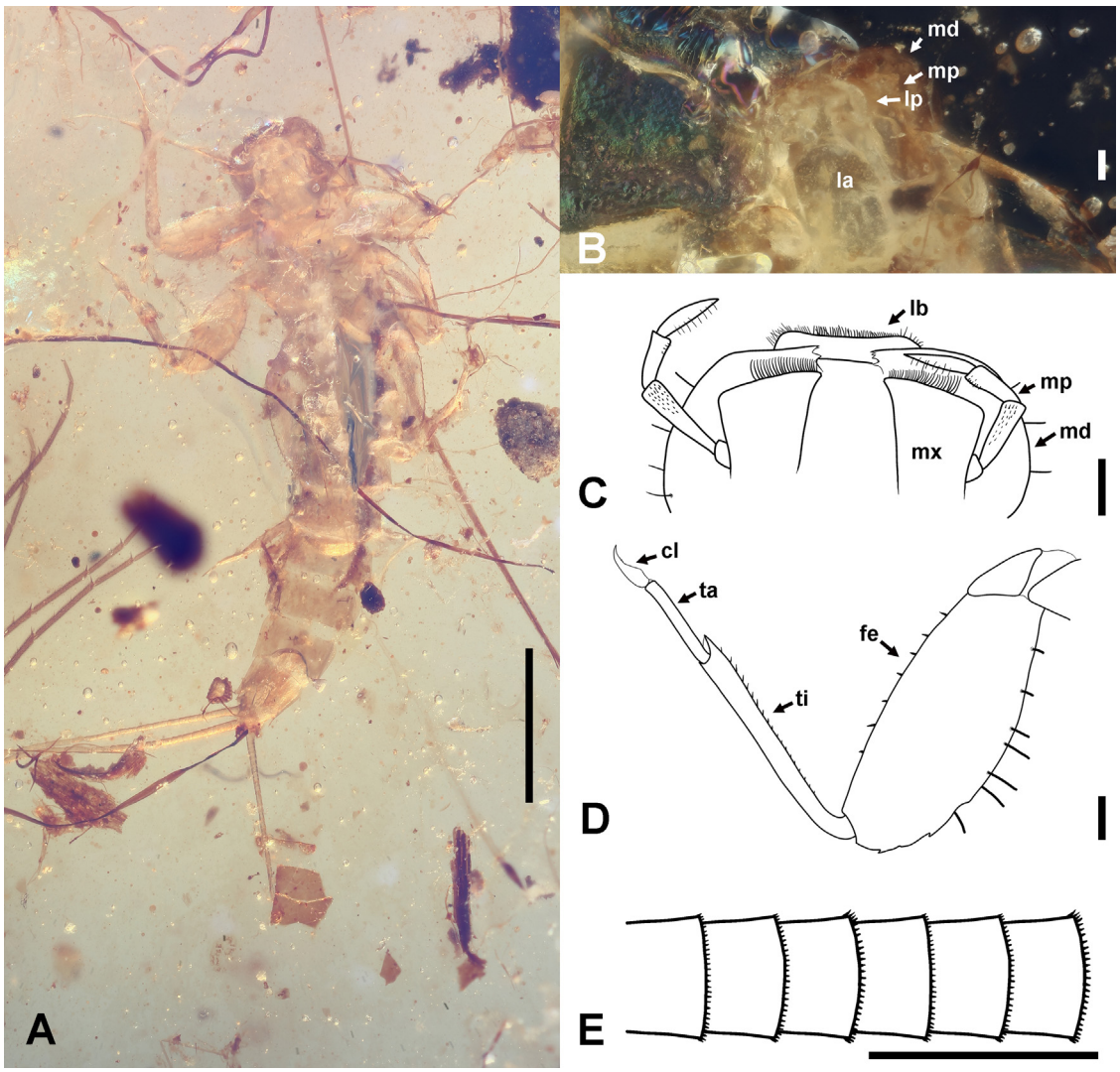


**Fig. 3.** *Kachinophlebia zhouchangfai* gen. et sp. nov., holotype larva (CZT-EPH-MA1). A. Habitus photo, ventral view; B. Head photo, ventral view; C. Drawing of visible mouthparts, ventral view; D. Drawing of right midleg, ventral view; E. Drawing of basal caudal filaments, dorsal view. Scale bars = 1.0 mm for A and 0.1 mm for B–E. Abbreviations: md, mandible; mp, maxillary palp; lp, labial palp; la, labium; lb, labrum; mx, maxilla; fe, femur; ti, tibia; ta, tarsi; cl, claw.

nov. from the remaining Leptophlebiinae except for *Habrophlebiodes* Ulmer, 1920, *Paraleptophlebia* Lestage, 1917, and *Neoleptophlebia* Kluge, 1997 (Peters and Edmunds, 1970; Tiunova and Kluge, 2016), but the basally forked gills and tracheae reminiscent of *Indialis* Peters and Edmunds, 1970 and *Leptophlebia* Westwood, 1840 can separate *Kachinophlebia* gen. nov. from the above three genera (Peters and Edmunds, 1970). In addition, the new mayfly possesses a series of other diagnostic characters that distinguish it from other extant leptophlebiid genera: the third segment of maxillary palpi with only several slender hairs regularly on the inner margin; slender claws without distinct denticles; femur flattened and broad, with rounded posterior margin and irregular blunt setae along the margin; tibia without distinct long hairs along outer margin; caudal filaments almost glabrous except for tiny denticles around articulations.

When compared with *Mesoneta* Brauer, Redtenbacher and Ganglbauer, 1889 and *Cretoneta* Tshernova, 1971 known from the Cretaceous deposits in the polar regions of Siberia, *Kachinophlebia* gen. nov. can be distinguished by the thick legs, longer tibia than tarsi, slender forked gills, and glabrous caudal filaments longer than the body (Tshernova, 1971). Another Cretaceous genus of Leptophlebiidae, *Conovirilus* McCafferty, 1997, is known only by a male adult preserved in Lebanese amber. Due to lack of larval description, *Conovirilus* cannot be directly compared with *Kachinophlebia* gen. nov. but it was placed in the subfamily Atalophlebiinae and thus differs from the new fossil mayfly (McCafferty, 1997). Another Cretaceous leptophlebiid genus from New Jersey amber, *Aureophlebia* Peters and Peters, 2000, was also placed in the subfamily Leptophlebiinae with a close relationship with *Habrophlebiodes* based on wing morphology of female subimago (Peters and Peters, 2000). *Kachinophlebia* gen. nov. is unlikely to be congeneric with *Aureophlebia* due to its distinct larval difference from *Habrophlebiodes* and the geographical isolation between New Jersey and Myanmar.

The new mayfly larva has strong mandibles, relatively hairless maxillary palpi, and underdeveloped hairbrushes on the top of maxillae, which implies it may chew or scrap debris in water for food similar to *Habrophlebiodes*, instead of being a filter-feeder or a predator (Kluge, 2004). The discovery of larval mayflies in amber is striking since most extant mayfly species inhabit rivers, streams, or lakes in nymphal stages, leaving a very small possibility for the formation of such amber in running water. However, the new

mayfly is tightly and perfectly wrapped in the center of the amber, clear and free of cracks or bubbles, accompanied by some Hymenoptera, Diptera, Blattaria, Acarina, and a spider which do not inhabit the water environment. The mayfly larva might live in a seasonal water puddle of the Cretaceous Burmese forest, with similar habits to some extant Leptophlebiidae such as *Thraulus* Eaton, 1881 and *Habrophlebiodes* (Dudgeon, 1982). When the puddle was about to dry up, the larva was stuck by a dripping resin in areas where there is almost no water. Another hypothesis is that the larva was active in wet areas above water, which is already found in the extant *Platybaetis* Müller-Liebenau, 1980 whose activity is mainly restricted to the exposed surface of the stones in running water, being stuck on a stone surface or a trunk near the water (Müller-Liebenau, 1980).

## 5. Concluding remarks

This study reports a new mid-Cretaceous mayfly, *Kachinophlebia zhouchangfai* gen. et sp. nov., based on the well-preserved mayfly larva in amber. This is also the first fossil record of the family Leptophlebiidae in Kachin amber. The new fossil larva exhibits some similarities with the extant leptophlebiids but can be distinguished by the characters of the mouthparts, legs, abdominal gills, and caudal filaments. The discovery of more extinct mayfly larvae is expected to elucidate their paleobiology and paleoecology.

## Data availability

The data that has been used is confidential.

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## Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.cretres.2022.105354.