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Source: Paleontological Research, 29(1) : 44-53

Published By: The Palaeontological Society of Japan

URL: https://doi.org/10.2517/prpsj.240017

PR

DOI: https://doi.org/10.2517/prpsj.240017
Paleontological Research, vol. 29, p. 44–53, 2025

https://www.jstage.jst.go.jp/browse/prpsj

Article

A new genus and species of Microphysidae (Hemiptera: Heteroptera) with long labium in Late Cretaceous Iwaki amber from Futaba Group of Iwaki City, Fukushima Prefecture, Japan

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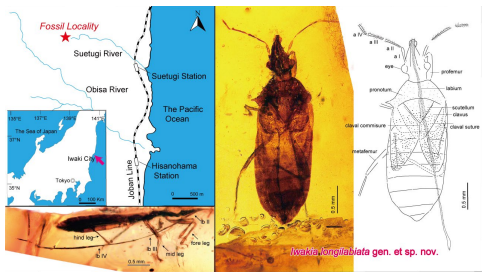
[Received August 22, 2024; Revised manuscript accepted December 25, 2024; Published online March 17, 2025]

ABSTRACT



The Iwaki insect-bearing amber from Fukushima Prefecture, northeastern Honshu, Japan, is considered from the Late Cretaceous Coniacian age. The insect-bearing amber localities from that period are few worldwide. Here, we report *Iwakia longilabiata* gen. et sp. nov., a new fossil genus and species of the infraorder Cimicomorpha Leston, Pendergrast and Southwood, 1954 (Hemiptera: Heteroptera) from the Futaba Group of Iwaki City. Although the preservation is incomplete, this fossil is provisionally placed in the family Microphysidae Dohrn, 1859 based on the general consistency of the diagnostic characters of the family. The fossil is distinguishable from any genus of Cimicomorpha including Microphysidae because of its long labium and brachypterous female. Additionally, the fossil shares the female diagnostic characteristics of the Palaearctic and Nearctic taxa, suggesting that it is an early stage in the evolution of sexual dimorphism of the family Microphysidae. The evolution of sexual dimorphism in Microphysidae may have already occurred in East Asia during the Late Cretaceous Coniacian age. This fossil may be the first discovery from Asia and the oldest record of the family Microphysidae.

ZooBank registration: urn:lsid:zoobank.org:pub:CC4DAF02-7182-4D9E-871F-A3B81BFFBDFD

Keywords: fossil insect, Iwaki amber, labium, Late Cretaceous, Microphysidae

Introduction

The Iwaki insect-bearing amber (hereinafter Iwaki amber) which was excavated from Fukushima Prefecture in northeastern Honshu, Japan, is considered to have originated from the Late Cretaceous Coniacian age (Saegusa and Tomida, 2011), and few fossils from this period are available worldwide (Rasnitsyn and Quicke, 2002). In addition, little is known about the occurrence of insect-bearing amber in East Asia, except for Burmese amber (Cenomanian) (Seyfullah *et al*., 2018; Ross, 2023). Therefore, the study of insect fossils from the Iwaki amber is important from both paleobiogeographic and geological perspectives and will provide valuable data for unraveling the evolutionary history of insects. However, little paleontological research has been conducted on Iwaki amber. Aiba and Inose (2024) described a new species, *Archaeromma chisatoi*, which is a small group of microscopic parasitic wasps from Iwaki amber. This

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discovery represents the first description of a new species from Iwaki amber.

The true bug family Microphysidae Dohrn, 1859 (Hemiptera: Heteroptera: Cimicomorpha: Microphysoidea), little pirate bugs or minute bugs, is one of the smallest heteropteran families, approximately 30 species in five extant genera that have not been well studied because of their small size (1.5 to 3.0 mm), cryptic habitats, and limited distribution (Schuh and Slater, 1995; Péricart, 1996; Yasunaga, 2001; Schuh and Weirauch, 2020). This taxon was first treated as a separate family by Fieber (1861) but classified by Reuter (1884) as a subfamily Microphysina in Anthocoridae. However, Microphysidae has been treated as an independent family belonging to the superfamily Microphysoidea of the infraorder Cimicomorpha by molecular phylogenetic analyses in recent studies (Schuh *et al*., 2009; Weirauch *et al*., 2019; Ye *et al*., 2022). This family comprises approximately 30 species belonging to the following five extant genera: *Chinaola* Blatchley, 1928; *Ciorulla* Pericart, 1974; *Loricula* Curtis, 1833; *Mallochiola* Bergroth, 1925; and *Nabidomorpha* Poppius, 1910 (Yasunaga and Yamada, 2017). The genera *Ciorulla* and *Loricula* were originally distributed in the Palaearctic region. They had sexual dimorphism, in which males resemble the Anthocoridae and possess rather long, delicate forewings with well-developed membranes. However, females lack membrane of forewing and possess coleopteroid, macropterous, or staphylinoid forewings and sometimes rounded and posteriorly widened abdomen (Yasunaga and Yamada, 2017). However, six species are distributed in the Nearctic Region. Among these, only two monotypic genera, *Chinaola* and *Mallochiola*, are considered native. The other four species are immigrants from the Palaearctic Region (Blinn, 2011). Genera *Chinaola* and *Mallochiola* do not exhibit sexual dimorphism. Females do not differ noticeably from males (Wheeler, 1992).

To date, eleven fossil species of Microphysidae have been known, ten of which are from the Eocene Baltic and Ukraine Rovno amber (Putshkov and Popov, 2003; Popov, 2004; Popov, 2006; Popov *et al*., 2008; Popov and Herczek, 2009). Only one from the Mesozoic is from the Late Cretaceous (Campanian) Canadian amber (Mckellar and Engel, 2011). All these fossils are from Europe and North America, and none have yet been found in Asia.

Recently, we examined true bug fossils from Iwaki amber. Thus, we identified it as a new genus and species of the infraorder Cimicomorpha Leston, Pendergrast and Southwood, 1954 and provisionally assigned it to the family Microphysidae. This fossil may represent the first discovery from Asia and may be the oldest record of the family Microphysidae. This study is the second paleontological description of a new species from Iwaki amber.

Geological setting

The Futaba Group is mainly distributed along the Pacific coast of northeastern Japan, from Naraha-machi, Futaba-gun, Iwaki City in Fukushima Prefecture. It is subdivided into the Ashizawa, Kasamatsu, and Tamayama formations (Figure 1). The Tamayama Formation is subdivided into the Kohisagawa and Irimazawa members (Ando *et al.*, 1995; Kubo *et al.*, 2002). A fossil insect dealt with in this study was discovered in amber from the Kohisagawa Member of the Tamayama Formation (Aiba *et al.*, 2023; Aiba and Inose, 2024).

The Irimazawa Member is a shallow marine deposit above the Kohisagawa Member that yielded marine invertebrate and vertebrate fossils dated from the late Coniacian to early Santonian (Obata and Suzuki, 1969). The lower Kohisagawa Member of the Kasamatsu Formation has not yielded any age-determining fossils. However, Matsumoto *et al.* (1982) considered it to be upper Coniacian based on marine faunal fossils from the overlying stratum, the Irimazawa Member, and the underlying stratum, the Ashizawa Formation. Recently, Hasegawa *et al.* (2020) suggested that the uppermost part of the Tamayama Formation extends into the early Campanian based on U-Pb ages. Therefore, it is reasonable to consider the age of the Kohisagawa Member of the Tamayama Formation, which bears fossil amber, as late Coniacian (86–87 Ma) (Gradstein *et al.*, 2004; Saegusa and Tomida, 2011).

Material and methods

Chisato Suzuki discovered this fossil on August 23, 1986. The studied specimen was deposited at the Fukushima Museum, Fukushima Prefecture, Japan, under repository number FM-N202200012.

The amber was thinly sliced, and the surfaces were polished using an abrasive. Observations were performed using a Leica M205C stereomicroscope (Leica Corporation, Wetzlar, Germany). Thin, light-transparent materials were observed at low magnification using an Olympus CX43 optical microscope (Olympus Corporation, Tokyo, Japan). Photographs and measurements were obtained using a Leica MC170HD Macroscope with Leica Application Suite Version 4.1.3 (Leica Corporation) and an Olympus TG4 optical microscope (Olympus Corporation). The morphological terminology was according to Yasunaga and Yamada (2017), Yasunaga *et al.* (2020), and Rédei (2024).

Systematic paleontology

Order Hemiptera Linnaeus, 1758
Suborder Heteroptera Latreille, 1810

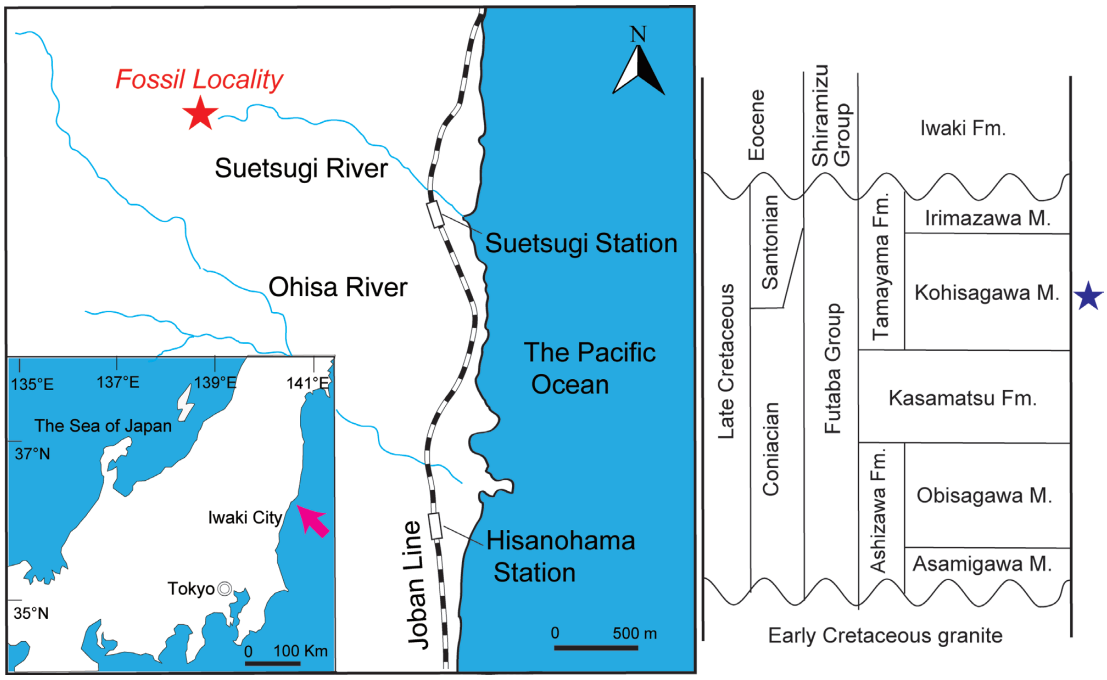

Figure 1. Geographic and stratigraphic location of the Iwaki amber from Futaba Group. Fossil location denoted with a red star. Stratigraphic position denoted with a blue star. Stratigraphic chart modified from Ando *et al*. (1995).

Infraorder Cimicomorpha Leston, Pendergrast and Southwood, 1954
Superfamily Microphysoidea Dohrn, 1859
Family Microphysidae? Dohrn, 1859
***Iwakia* gen. nov.**
[New Japanese name: Kuchinaga-futagatakamemushi-zoku]

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Type species.—***Iwakia longilabiata* sp. nov.**

Etymology.—The genus epithet is Iwaki City, referring to the fossil locality; the gender is feminine.

Diagnosis.—Female brachypterous morph. Head prognathous, elongated, triangular, flattened, 1.5 times as long as maximum width across compound eyes. Ocelli absent in female. Labium extremely long, reaching beyond apex of abdomen, 1.3 times as long as body length. Forewing covering anterior half of abdomen, without membrane, reaching posterior margin of abdominal tergite V, with claval suture. Tarsi 2-segmented.

***Iwakia longilabiata* sp. nov.**
[New Japanese name: Kuchinaga-futagatakamemushi]

Figures 2–4

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Diagnosis.—As for the genus.

Material.—Holotype: FM-N202200012; Incompletely preserved dorsal (Figure 2A), ventral (Figure 2B), and lateral views (Figure 2C).

Type locality and horizon.—The specimen was collected from amber in the muddy sandstone of the Upper Cretaceous (Coniacian) Kohisagawa Member of the Tamayama Formation of the Futaba Group, exposed at an outcrop quarry (37°10′51″N, 140°57′54″E) located in the upstream Suetsugi River in Suetsugi, Hisanohama-machi, Iwaki City, Fukushima Prefecture, Northeast Japan.

Etymology.—The species epithet is the Latin adjective “longus” (meaning long) and “labiatus” (meaning labiate), referring to the long labium.

Description of holotype.—Brachypterous Female: Body oblong, flattened, weakly sclerotized. Lateral margins parallel to each other (Figures 2A, 2B, 2C, and 4A).

Head: Prognathous, elongated, triangular, flattened, 1.5 times as long as maximum width across compound eyes, not punctate. Clypeus darker, reaching beyond apex of mandibular plate. Buccula visible in dorsal view, widened laterally, pale, bearing fine setae (Figures 3A, B). Compound eyes conspicuously protruding laterally (Figure 2A). Ocelli absent. Labrum very short, visible in

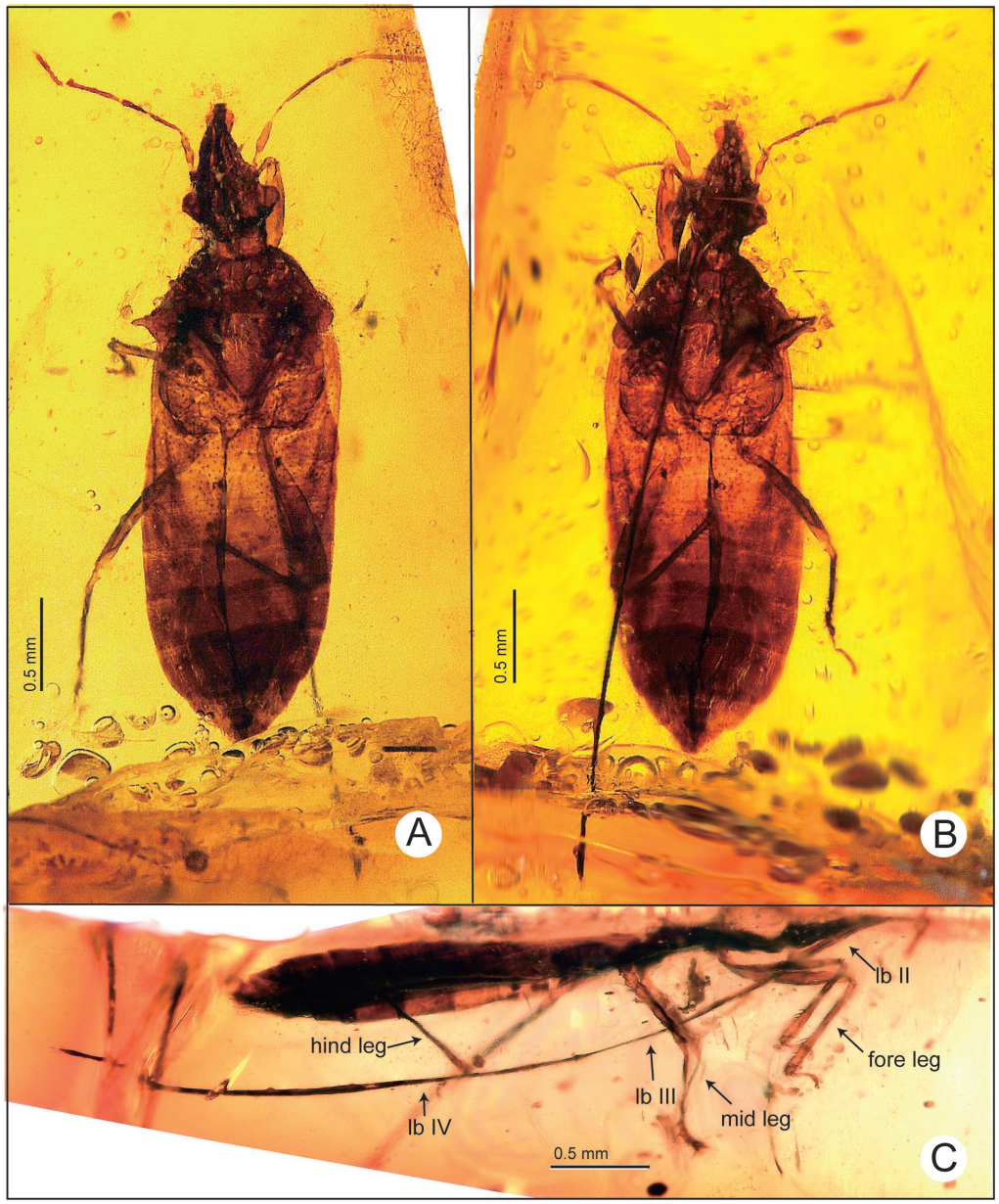

Figure 2. *Iwakia longilabiata* gen. et sp. nov., holotype (FM-N202200012). **A,** habitus, dorsal view; **B,** habitus, ventral view; **C,** habitus, lateral view. Abbreviations: lb II – IV, labial segment II – IV; st, stylets.

lateral and ventral views (Figure 3B). Antenna (Figure 3C) filiform, relatively short, 1.7 times as long as head length; segment I somewhat swollen, not bearing setae, not reaching beyond apex of head; segment II longest, 1.7 times as long as segment I, bearing short setae; segment III as long as segment II; segment IV as long as segment I. Labium extremely long, semitransparent (Figures 2B–F, 4), reaching beyond apex of abdomen, 1.3 times as long as body length; segment I very short (boundary between segments I and II not visible but presumed behind labrum); segment II 2.3 times as long as segment I; segment III 2.3 times as long as segment II, gradually widened posteriorly, constricted in posterior quarter, bearing short setae (Figure 4B); segment IV longest among labial segments, 2.9 times as long as segment III, gradually narrowed posteriorly slightly swollen at apex, serrate in lateral margin, bearing short setae (Figures 3E, F, 4C). Stylet darker, completely visible.

Thorax: Pronotum campanulate, 3.7 times as wide as long, uniformly covered with minute punctures; anterior

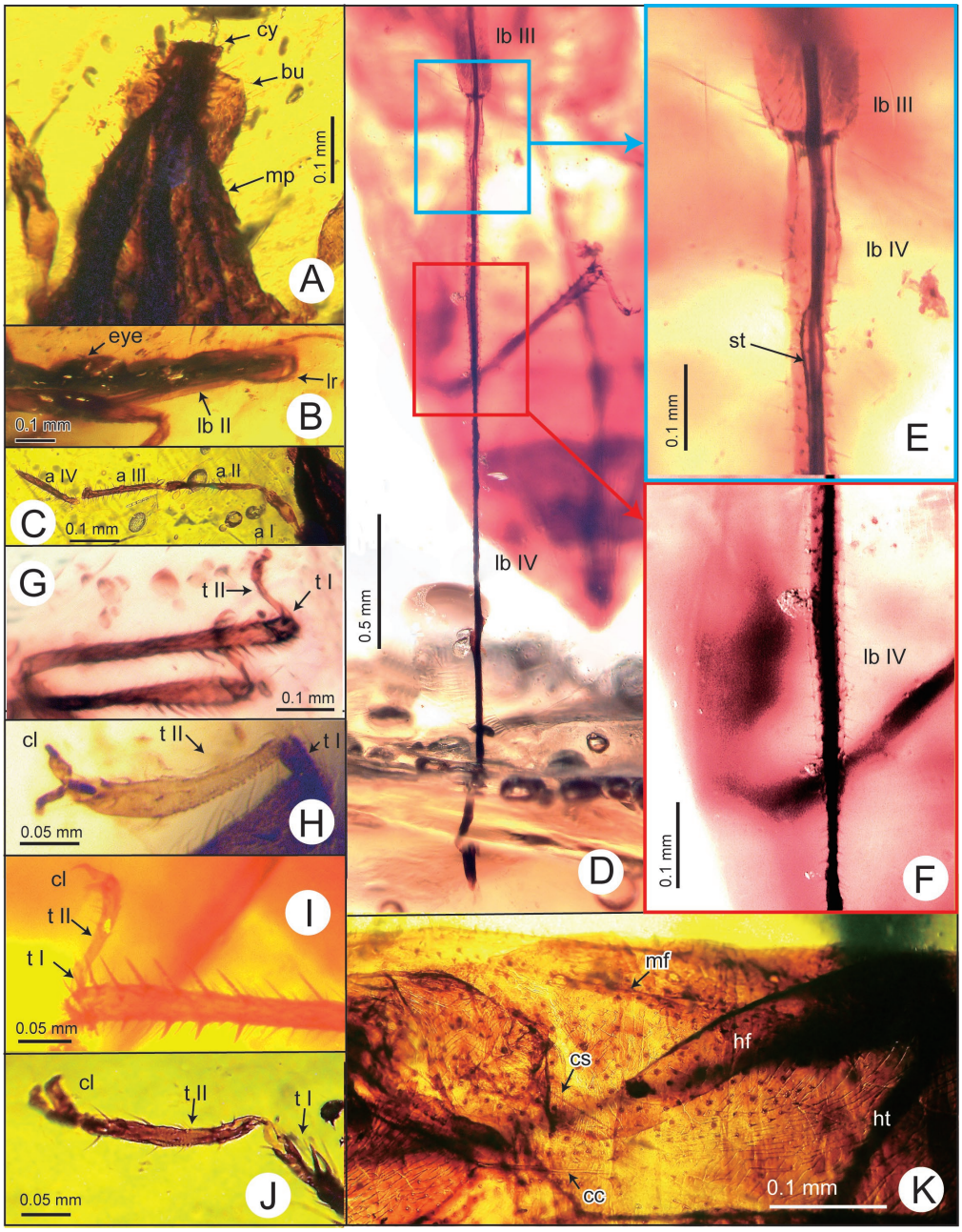

Figure 3. *Iwakia longilabiata* gen. et sp. nov., holotype (FM-N202200012). **A,** details of the head (dorsal view); **B,** details of the head (lateral view); **C,** details of the antennae; **D,** details of labium and stylets; **E,** enlargement of the boundary between labial segment III and IV; **F,** enlargement of the apex of labial segment IV; **G,** details of the fore legs; **H,** details of the right mid leg; **I,** details of the right hind leg; **J,** details of the left hind leg; **K,** details of the forewing. Abbreviations: a I – a IV, anntenal segment I – IV; bu, buccula; cc, claval commissure; cl, claw; cs, claval suture; cv, costal vein; cy, clypeus; hf, hind leg femur; ht, hind leg tibia; lb II – IV, labial segment II – IV; mf, medial fracture; mp, mandibular plate; st, stylets; t I – t II, tarsus segments I – II.

margin slightly concave; posterior margin deeply concave. Humeral angles preserved on left side and deformed on right side; apex acute on left side and shrunken on right side (Figures 2A, 4A). Calli absent. Scutellum triangular, coarsely punctate in posterior half. Forewing covering anterior half of abdomen, semi-transparent, sparsely punctate (Figures 3K, 4A); puncture with short setae, denser towards apex; claval suture and medial fracture slightly visible (Figure 3K), costal fracture and membranous portion absent. Cuneus unclear. Forewing mem-

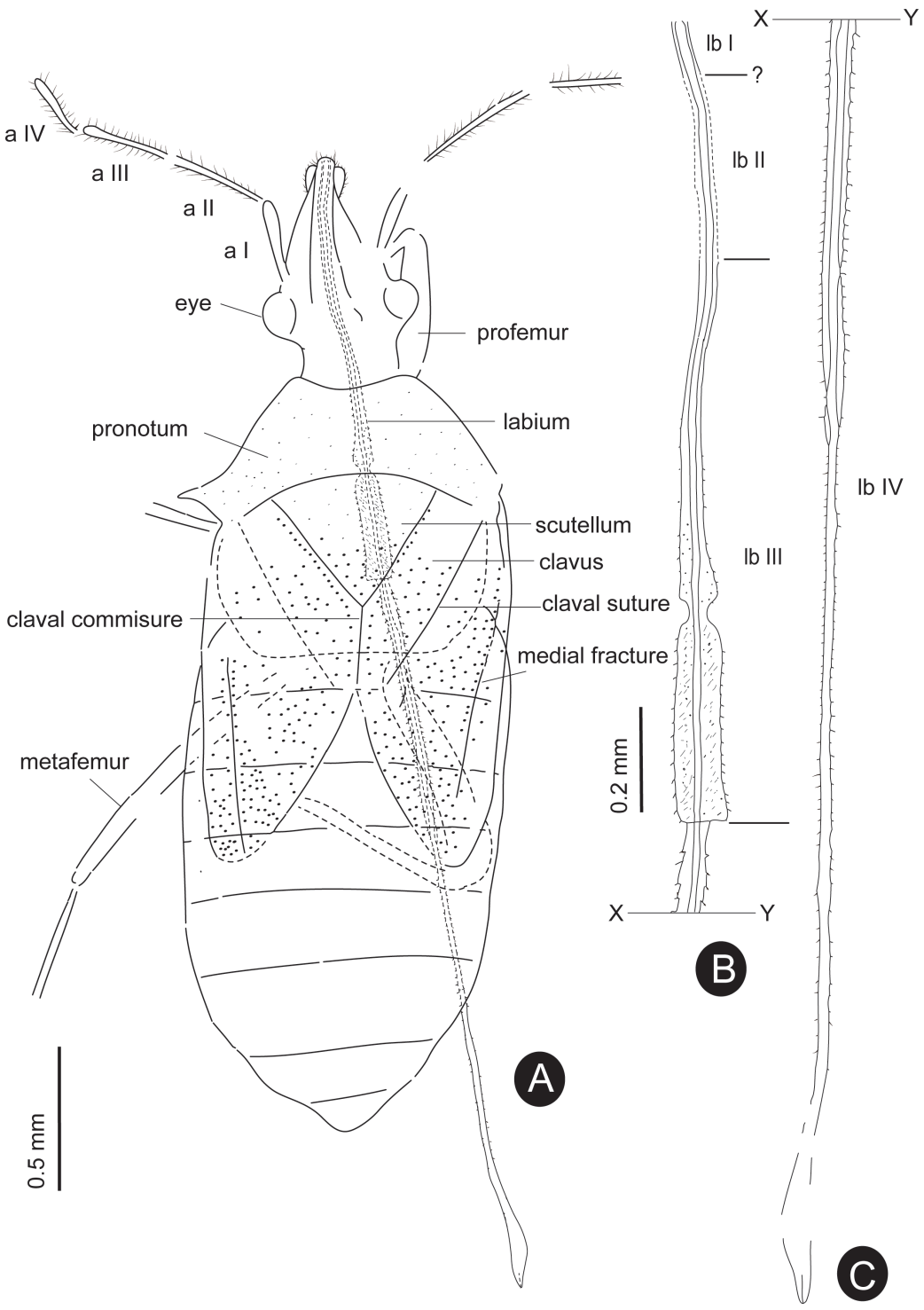

Figure 4. Line drawing of *Iwakia longilabiata* gen. et sp. nov. (FM-N202200012). **A,** habitus, dorsal view; **B,** labial segment I – III; **C,** labial segment IV, XY line is continuous. Abbreviations: a I – a IV, anntenal segment I – IV; lb I – IV, labial segment I – IV.

brane absent or invisible. Fore and middle legs same in length (Figure 3G, H); hind leg twice as long as fore leg (Figure 3I, J); femora slightly swollen; tibiae with short spines in fore and middle legs, and long spines in hind leg; tarsi 2-segmented; claws simple, without pulvillus.

Abdomen: Abdomen oblong-oval, semitransparent

coarsely punctate; puncture bearing setae. Lateral margin straight, parallel to each other. Abdominal tergites III–VI subequal in length; tergite VII longest among abdominal tergite; tergite VIII and IX 0.5 times as long as tergite VII; connexivum undeveloped. Small spiracles visible on dorsal and ventral sides because of semitransparent abdomen (Figure 2A, B). Detailed structures of terminalia not clearly visible, making presence or absence of ovipositor uncertain.

Measurements (in mm): Body length 3.38; length of head 0.83; maximum width across compound eyes of head 0.54; diameter of compound eye 0.12; lengths of antennal segments I to IV 0.22, 0.38, 0.32, 0.26, respectively; length of labrum 0.12; total length of labium 4.34; length of labial segments I to IV 0.19?, 0.41?, 0.94, and 2.80, respectively; maximum width of labial segment IV 0.05; length of pronotum 0.51; anterior pronotal width 0.45; maximum width of pronotum across humeri 1.14; median length of scutellum 0.37; maximum width of scutellum 0.57; maximum length of forewing 1.37; maximum width of forewing 0.55; length of profemur 0.61; length of protibia 0.55; length of protarsus 0.18; length of mesofemur 0.45; length of mesotibia 0.37; length of mesotarsus 0.16; length of metafemur 1.10; length of metatibia 0.37; length of metatarsus 0.16; lengths of abdominal segments III to IX 0.23, 0.22, 0.24, 0.26, 0.33, 0.16, and 0.11, respectively; maximum width of abdominal segments III to IX 1.10, 1.11, 1.09, 1.06, 1.02, 0.66, and 0.24, respectively.

Discussion

Morphological comparison

The fossil species described above resembles the family Aradidae (Pentatomomorpha: Aradoidea), and its long mandibular and maxillary stylets and flattened body are consistent with diagnostic characteristics of Aradidae. However, this fossil is clearly distinguishable from Aradidae in the following characteristics (e.g. Larivière and Larochelle, 2006; Schuh and Weirauch, 2020): dorsal structure semitransparent (granular or rugose in Aradidae); labium extremely long, reaching beyond apex of abdomen (usually short and stout, not reaching abdominal sternite in Aradidae); connexivum not developed (broadly developed in Aradidae); claw without pulvilli (with pulvilli in most members of Aradidae); and abdomen with microtrichia (without microtrichia in Aradidae).

Additionally, the fossil is distinguishable from other species of the infraorder Pentatomomorpha based on the following features (Schuh and Weirauch, 2020): antennae fragelliform (never fragelliform in Pentatomomorpha); labial segment I short and not developed (well-developed in Pentatomomorpha). We consider the fossil to belong to the infraorder Cimicomorpha because of its small, wispy body, prognathous head, labium anteriorly inserted on head, and flagellated antennae (Schuh and Weirauch, 2020).

Moreover, the fossil is identified as belonging to the Superfamily Microphysoidea based on its tiny body, short labial segment I, 2-segmented tarsi, and simple claw without pulvilli (Schuh and Weirauch, 2020). The Superfamily Microphysoidea includes two families, Microphysidae and Joppeicidae Reuter, 1910 (Weirauch *et al.*, 2019), and the Joppeicidae consists of only one species, *Joppeicus paradoxus* Puton, 1881 (Schuh and Weirauch, 2020). The fossil is similar to *J. paradoxus* in that the head morphology is long and triangular, and the buccula is visible in the dorsal view and widened laterally (Schuh and Štys, 1991). However, the fossil is clearly distinguishable from *J. paradoxus* based on many features, such as the absence of hind wing, ocelli, and membranes. Schuh and Weirauch (2020) summarized the characteristics of the Family Microphysidae as follows: body length 1.5–3.0 mm; many species similar to small cimicoids; head weakly prognathous; labium 4-segmented; labial segment I shortest among labial segments; and tarsi 2-segmented. Furthermore, they mentioned that the genera of Microphysidae from the Palaearctic Region exhibit sexual dimorphism, and females lack membrane of forewing. All these characteristics are consistent with those of the fossil, except the slightly larger size. Yasunaga and Yamada (2017) also characterized the genus *Loricula*, the type genus of Microphysidae, as follows: females lack ocelli; antennal segment II usually longer than segment IV; female pronotum trapezoid or campanulate; and posterior margin of pronotum concave. These characteristics are also consistent with fossil features. Based on the general consistency of the diagnostic characters, this fossil is considered to belong to Microphysidae or a closely related new family. However, because this fossil is incompletely preserved, we could not examine all the detailed morphological characteristics and avoided establishing a new family here. Therefore, we provisionally identify the fossil as a member of Microphysidae.

Microphysidae comprises five extant genera (*Ciorulla*, *Loricula*, *Myrmedobia*, *Chinaola*, and *Mallochiola*) and two fossil genera (*Tytthophysa* Popov and Herczek, 2009 and *Popovophysa* McKellar and Engel, 2011) in the Holarctic Region (Schuh and Weirauch, 2020). This fossil is easily distinguished from any of those genera in the extremely long labium 1.3 times as long as body. In addition, females of the genera *Ciorulla* and *Loricula* from the Palaearctic region, which are sexually dimorphic, are clearly distinguishable from the studied fossil in that they possess smaller bodies (approximately 1.5 mm) and a broad and thickened abdomen (Yasunaga and Yamada, 2017). Furthermore, this fossil specimen is distinguished

from both genera in the brachypterous female. The genera *Chinaola* and *Mallochiola* from the Nearctic Region do not exhibit sexual dimorphism; therefore, females possess the same oblong body with well-developed membrane of forewing as males. The ground plan of the Nearctic species is the same as that of the other known fossil species (Popov, 2006; Schuh and Weirauch, 2020). Moreover, the studied fossil is distinctly differentiated from the other fossils by the absence of ocelli and forewing membranes.

In conclusion, this fossil specimen is not consistent with any of the five extant and two fossil genera of Microphysidae, and *Iwakia* gen. nov. was described to accommodate the fossil specimen in the above section.

Considerations from fossil morphology

The fossil characteristics of the absence of ocelli and membranes in females are consistent with the diagnostic characteristics of females of the Palaearctic genera (Yasunaga and Yamada, 2017). However, the oblong body and attributes of the forewing (presence of clavus) in females are consistent with the diagnostic characteristics of the Nearctic genera (Wheeler, 1992; Blinn, 2011).

The morphological characteristics of the studied fossil, which share the female diagnostic characters of the Palaearctic and Nearctic taxa, probably represent an early stage in the evolution of sexual dimorphism in the family Microphysidae and suggest that the evolution of sexual dimorphism in this family had already occurred in East Asia during the Late Cretaceous Coniacian. On the other hand, the following four fossil microphysid species, which are macropterous females and unlikely to possess sexual dimorphism, have been reported from the Middle Eocene Baltic amber of the western Palaearctic Region: *Loricula* (*Eocenophysa*) *damzeni* Popov, 2004, *L*. (*Myrmericula*) *ocellata* Popov, 2006, *L*. (*M*.) *samlandi* Popov, 2006, and *Tytthophysa sylwiae* Popov and Herczek, 2009, suggesting that microphysid species possessing sexual dimorphism may not have been distributed in the western Palaearctic Region, at least during the Middle Eocene period.

The studied fossil has an extremely long labium compared to the other species of Microphysidae. The length of the labium is insufficient to judge the feeding habits of the fossil species, but the fact that the labium is longer than the body length may indicate that the food of this fossil is different from that of the other species of the family.

According to the previous studies (Slater, 1975; Henry, 2012), heteropteran wing forms are divided into aptery, microptery, staphylinoidy, coleoptery, brachyptery, submacroptery, and macroptery. The studied fossil resembles macroptery or submacroptery in that it has the claval suture, making corium and clavus are differentiated. However, this fossil can be clearly distinguished from macroptery and submacroptery by the absence of membranes. Consequently, the fossil is inconsistent with any of the seven heteropteran wing forms but is provisionally treated as brachyptery in the present study based on the absence of a forewing membrane and the fully exposed abdominal tergite VI.

In this study, we provisionally identified the fossil as a member of Microphysidae. However, the studied fossil has unique morphological features, such as an extremely long labium and a forewing with a claval suture and without a membrane, which are partly inconsistent with the diagnostic characters of the family. Therefore, the identification of the family of this fossil may be changed by further observation of the morphological characteristics with new methods or by the discovery of additional specimens.

Acknowledgments

We thank Chisato Suzuki for discovering the specimen. Additionally, we are grateful to the editor and the two anonymous reviewers of Paleontological Research for their critical comments to the manuscript.

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Author contributions

H. A. initiated the study, drafted the manuscript, and compiled all the figures. J. S. revised the manuscript and provided taxonomic input. H. I. revised the manuscript and provided geological input. All authors contributed to the writing of the manuscript.