A New False Fairy Wasp (Hymenoptera: Mymarommatoidea: Mymarommatidae) in Late Cretaceous Iwaki Amber from Futaba Group of Iwaki City, Fukushima Prefecture, Japan

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A new false fairy wasp (Hymenoptera: Mymarommatoidea: Mymarommatidae) in Late Cretaceous Iwaki amber from Futaba Group of Iwaki City, Fukushima Prefecture, Japan

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Abstract. **A new fossil species of the genus *Archaeromma* Yoshimoto, 1975 was discovered in Iwaki amber from the Tamayama Formation (Late Cretaceous Coniacian) in Iwaki City, Fukushima Prefecture, Japan. The genus *Archaeromma* belongs to the family Mymarommatidae, and the members are called false fairy wasps because of their small bodies; only 10 species have been described from Cretaceous amber (Albian to Campanian). In this paper, we have described the new fossil species as *Archaeromma chisatoi* sp. nov. To the best of our knowledge, this is the second report of a fossil of the genus *Archaeromma* from Japan; the first one was found in Kuji amber, Iwate Prefecture. However, this is the first report of a fossil species from the Coniacian age and the first paleontological description from Iwaki amber.**

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Keywords: *Archaeromma*, false fairy wasp, fossil insect, Iwaki amber, Late Cretaceous, Mymarommatoidea

Introduction

The superfamily Mymarommatoidea (Hymenoptera) is composed of the smallest microhymenopterans, only 0.3–0.8 mm in body length, and it is considered the most enigmatic wasp taxon (Givson *et al*., 2007). The superfamily Mymarommatoidea consists of three extinct families, Alavarommatidae Ortega-Blanco *et al*., 2011, Dipterommatidae Rasnitsyn *et al*., 2019, and Gallorommatidae Gibson *et al*., 2007, and one extant family, Mymarommatidae Debauche, 1948.

The family Mymarommatidae is a small group of microscopic parasitic wasps, also called false fairy wasps. The family Mymarommatidae consists of two extinct genera, *Palaeomymar* Meunier, 1901 and *Archaeromma* Yoshimoto, 1975, and three extant genera, *Mymaromma* Girault, 1920, *Mymaromella* Girault, 1931 and *Zealaromma* Gibson *et al*., 2007.

The extinct genus *Archaeromma* has been found in Cretaceous amber, and 10 species have been described to date. The oldest species is *Archaeromma hispanicum* Ortega-Blanco *et al*., 2011 from Spanish amber (Albian). In addition, *Archaeromma gibsoni* Engel and Grimaldi, 2007 from Burmese amber (Cenomanian), *Archaeromma carnifex* Engel and Grimaldi, 2007 from New Jersey amber (Turonian), *Archaeromma mandibulatum* (Kozlov and Rasnitsyn, 1979) and *Archaeromma senonicum* (Kozlov and Rasnitsyn, 1979) from Siberian amber (Santonian), *Archaeromma japonicum* (Fursov *et al*., 2002) from Japanese Kuji amber (Campanian), and *Archaeromma masneri* (Yoshimoto, 1975), *Archaeromma minutissimum* (Brues, 1937), *Archaeromma nearcticum* Yoshimoto, 1975, and *Archaeromma trigonokephalion* Cockx *et al*., 2020 from Canadian amber (Campanian) have been described.

Iwaki amber is from the Tamayama Formation of the Futaba Group distributed in Iwaki City, Fukushima Prefecture, Japan, and it is considered to be Late Cretaceous Coniacian in age (Saegusa and Tomida, 2011). In 1985, Chisato Suzuki discovered the first insect-containing amber in the Tamayama Formation. Since then, 93 insect-containing amber have been found, and Aiba *et al*. (2023) reported a list of 10 orders and 13 families, and photographs. However, no paleontological description has yet been made.

There have been few fossil localities in the world since

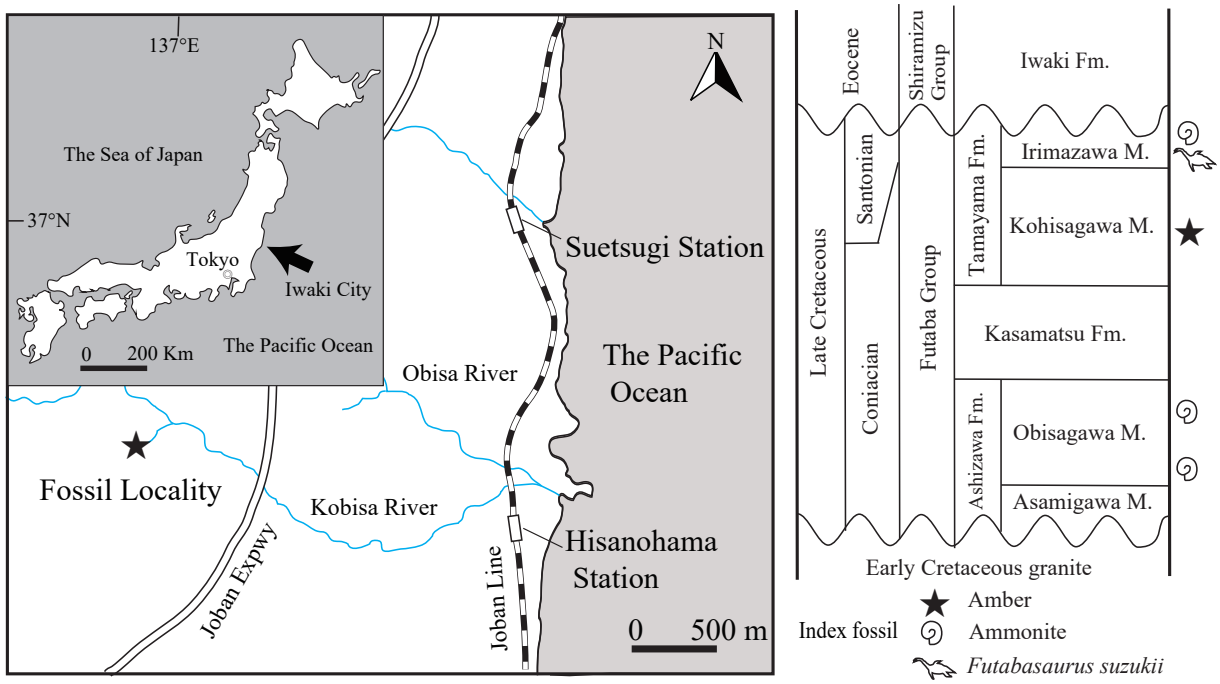

Figure 1. Geographic and stratigraphic location of the Iwaki amber from Futaba Group. Fossil location denoted with a black star. Stratigraphic chart modified from Ando *et al*. (1995).

the Coniacian, in which the Iwaki amber was produced (Rasnitsyn and Quicke, 2002). In addition, the only known Late Cretaceous amber localities in East Asia are Kuji amber in Iwate Prefecture, Japan, and Iwaki amber. Therefore, paleontological studies of Iwaki amber are important for understanding the evolution of insects and their biogeography (Aiba *et al*., 2023).

In this study, we report a new species of the fossil genus *Archaeromma* found in Iwaki amber. To the best of our knowledge, this is the first paleontological description of a new species from Iwaki amber.

Geological setting

The Futaba Group is distributed along the Pacific Ocean coast of northeastern Japan, from Naraha-machi, Futaba-gun, Fukushima Prefecture to Iwaki City (Figure 1). The Futaba Group is subdivided into the Ashizawa, Kasamatsu, and Tamayama formations. The Ashizawa Formation is subdivided into the Asamigawa and Obisagawa members, and the Tamayama Formation is subdivided into the Kohisagawa and Irimazawa members (Ando *et al*., 1995; Kubo *et al*., 2002).

The fossil-bearing amber was obtained from the blackish sandstone of the Kohisagawa Member of the Tamayama Formation. The depositional environment of the Kohisagawa Member is considered to be terrestrial deposits of reticulated rivers (Ando *et al*., 1995).

The upper part of the Tamayama Formation, the Irimazawa Member, is a shallow marine deposit that yields marine invertebrates and an elasmosaurid plesiosaur species of vertebrates, *Futabasaurus suzukii* Sato *et al*., 2006. Its age is considered to be late Coniacian to early Santonian from the *Inoceramus mihoensis* zone to *Inoceramus amakusensis* zone (Obata and Suzuki, 1969). Recently, Hasegawa *et al*. (2020) suggested that the uppermost part of the Tamayama Formation extends to the early Campanian, based on a U-Pb age.

The Kasamatsu Formation in the lower part of the Kohisagawa Member has not yielded any significant fossils that can be dated, but Matsumoto *et al*. (1982) considered it to be upper Coniacian. Furthermore, ammonite fossils have been recovered from the lower part of the Ashizawa Formation, Obisagawa Member, which has been dated to the Early to Middle Coniacian (Matsumoto *et al*., 1990; Kubo *et al*., 2002).

Therefore, it is reasonable to consider the age of the Kohisagawa Member of the Tamayama Formation, which bears fossil amber, to be Late Coniacian (Saegusa and Tomida, 2011).

Material and methods

The fossils were discovered by Chisato Suzuki in May

1993. The studied specimens have been deposited at the Fukushima Museum, Fukushima Prefecture, Japan, under repository numbers FM-N202200015, FM-N202200057, and FM-N202200062.

The ambers were sliced as thinly as possible, and the surfaces were polished using an abrasive. Observations were performed using a Leica M205C stereomicroscope (Leica Corporation, Wetzlar, Germany). For thin materials with light transmission, an Olympus CX43 optical microscope (Olympus Corporation, Tokyo, Japan) was used to observe the material at low magnification. 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 Gibson *et al*. (2007), with the following abbreviations: cl: clava, cl_1–cl_4: clava segment 1–4; fu: funicle, fu_1–fu_7: fufunicular segments 1–7; hc: hyperoccipital band, pt_1–pt_2: petiolar segment 1–2; ps: posterobasal seta, sc: scape, pe: pedical, t_1–t_5: tarsus segment 1–5.

Systematic paleontology

Order: Hymenoptera Linnaeus, 1758
Superfamily Mymarommatoidea Debauche, 1948
Family Mymarommatidae Debauche, 1948
Genus *Archaeromma* Yoshimoto, 1975
Archaeromma chisatoi sp. nov.
[New Japanese name: Chisato-mukashi-hosohane-kobachi]

Figures 2–4

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Type species.—*Archaeromma minutissimum* (Brues, 1937).

Holotype (male).—FM-N202200057: Almost completely preserved, dorsal view (Figures 2, 4A, D).

Allotype (female).—FM-N202200062: Almost completely preserved, lateral view (Figures 3A–D, 4B, E).

Paratype (sex unknown).—FM-N202200015: Body separated (Figures 3E, 4C).

Type locality and horizon.—The specimens were 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 located in the tributaries of the Kobisa River in Iwaki City, Fukushima Prefecture, Northeast Japan (Figure 1).

Etymology.—After Chisato Suzuki, fossil discoverer.

Diagnosis.—Both sexes have a 13-segmented antenna with seven-segmented funicle and distinctly compact four-segmented clava. Forewings spoon-shaped, not reticulate, very narrow basally with 31 distinctly elongated erect marginal setae apically, each deeply embedded in the membrane. Petiole two-segmented and first segment two times as long as second segment.

Description.—Male (Holotype): Dorsal view observed, body length 0.42 mm, head, mesosoma, and gaster dark-brown, legs, antenna, and petiole lighter brown (Figure 2A). Head transverse in dorsal view, 0.07 mm length, 0.11 mm maximum width, with rounded anterior margin and emarginated occipital margin. Ocelli and mandibles not visible. Antennae filiform, slender, 13-segmented, and approximately 0.20 mm length (Figures 2B, 4D); scape elongated; pedicle almost as long as scape, but broken vertically; funicle seven-segmented, each segment short and almost same length, with long fine setae (Figure 2C); clava four-segmented, elongate, not swollen; cl_4 slightly preserved, most elongated as long as scape; relative ratio of each antennomere as follows (length × width): Sc, 15 × 6; Pe, 16 × 6; fu_1, 6 × 5; fu_2, 6 × 4; fu_3, 5 × 4; fu_4, 5 × 4; fu_5, 5 × 5; fu_6, 6 × 5; fu_7, 6 × 5; cl_1, 7 × 5.; cl_2, 10 × 5; cl_3, 10 × 5; cl_4, 15 × 5. Mesosoma oblong-triangular, 0.13 mm length, 0.09 mm maximum width, slightly narrower head, with rounded anterior margin and tapering occipital margin, details not visible. Forewing spoon-shaped, with very narrow basally, long marginal fringe, 0.33 mm length (excluding length of marginal setae), 0.12 mm maximum width, not reticulate (Figures 2D, 4A); marginal fringe with 31 long erect marginal setae deeply embedded in membrane and bent base in lateral view (Figure 2E); 14 anterior short setae, including two mid-sized, and eight posterior short setae, including three mid-sized and thin single long posterobasal seta (Figures 2D, 4A); proximal part of forewing stalk with six dark round macrochaetae visible (Figure 2F). Legs partially preserved. Right mesotibia almost straight, 0.09 mm long. Mesotarsus dark brown, details not visible. Petiole lighter brown, two-segmented; pt_1 two times as long as pt_2, 0.06 mm length 0.03 mm maximum width; pt_2 0.03 mm length, 0.03 mm maximum width (Figure 2G). Gaster oblong, as wide as mesosoma, 0.15 mm length, 0.09 mm maximum width, details not visible (Figure 2G).

Female (allotype): Body length 0.36 mm, lateral view observed (Figure 3A). Head subglobular, posteriorly vertical with hyperoccipital band (Figure 3B). Relatively large compound eyes faintly visible (Figure 3B), mandibles not visible. Antenna clavate, slender, 13-segmented, and approximately 0.30 mm length (Figure 3C); scape elongated and thick, two times as long as wide; pedicle swollen and half as long as scape; funicle seven-segmented, fu_1–fu_4 shortened and almost same length, fu_8–fu_7 elongated, three times as long as wide; clava four-

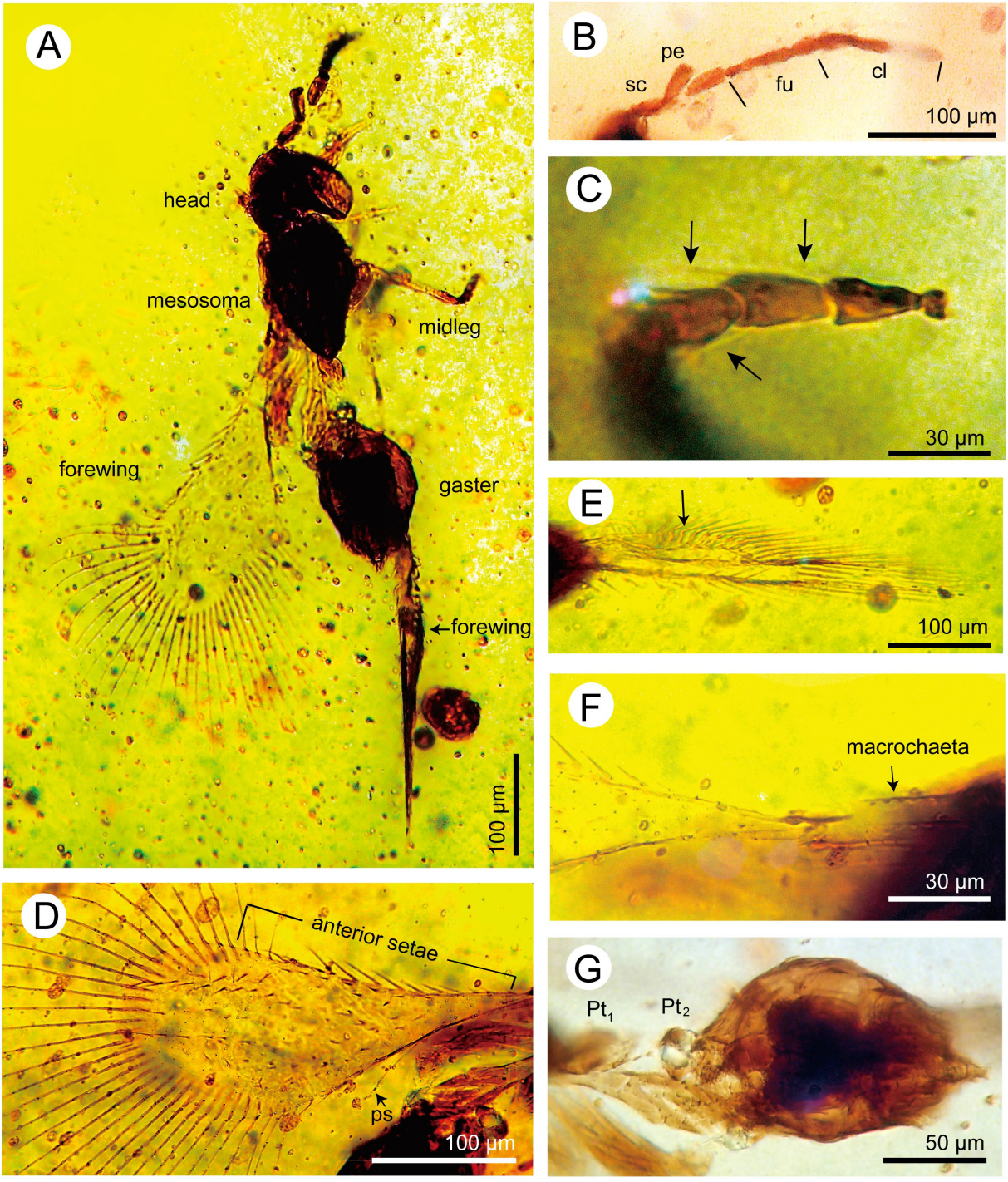

Figure 2. Holotype (FM-N202200057, male) of *Archaeromma chisatoi* sp. nov. (Mymarommatidae). **A,** habitus, dorsal view; **B,** details of the right antenna; **C,** details of the partially preserved left antenna funicle; arrows indicate long fine setae; **D,** details of the left forewing; **E,** lateral detail showing the right forewing; the arrow indicates bends at the erect marginal seta base; **F,** details of the stigmal complex and macrochaeta; **G,** details of the gaster and petiole. cl: clava, fu: funicle, ps: posterobasal seta, pe: pedicle, sc: scape, pt_1: petiole segment 1, pt_2: petiole segment 2.

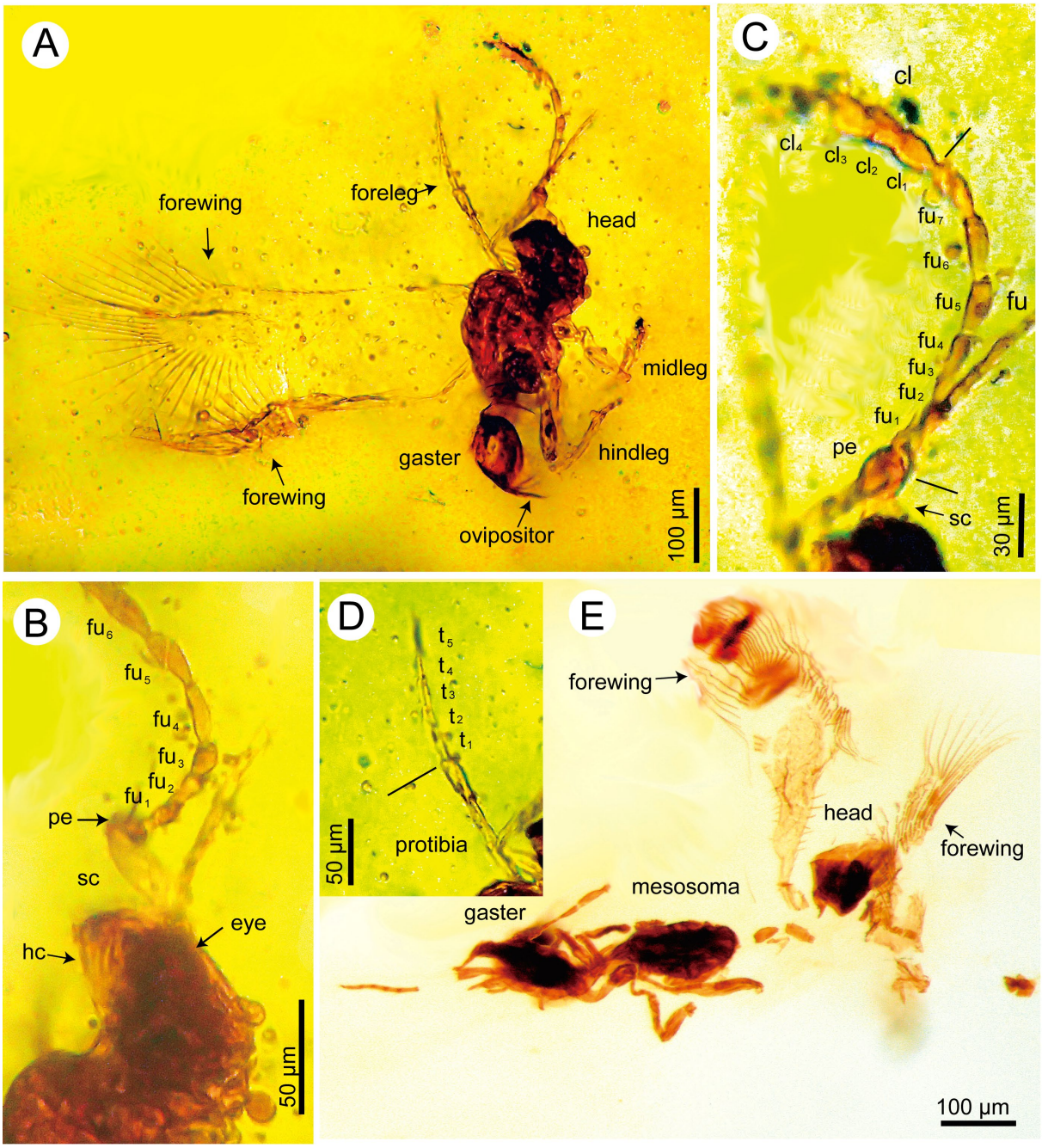

Figure 3. Allotype (A–D; FM-N202200062, female) and paratype (E; FM-N202200015, sex unknown) of *Archaeromma chisatoi* sp. nov. (Mymarommatidae). **A,** habitus, lateral view; **B,** details of the head; **C,** details of the antennae (broken apical segment); **D,** details of left protibia and protarsi; **E,** habitus dorsolateral view. cl: clava, cl_1–cl_4: clava segments 1–4, fu: funicle, fu_1–*fu*$_7$: funicular segments 1–7, hc: hyperoccipital band, sc: scape, pe: pedicle, t_1–t_5: tarsus segments 1–5.

segmented, swollen, cl_4 slightly preserved, elongated, as long as scape; relative ratio of each antennomere as follows (length × width): Sc, 22 × 10; Pe, 12 × 10; fu_1, 6 × 5; fu_2, 7 × 5; fu_3, 7 × 4; fu_4, 7 × 4; fu_5, 13 × 5; fu_6, 14 × 5; fu_7, 14 × 5; cl_1, 10 × 8.; cl_2, 8 × 8; cl_3, 10 × 9; cl_4, 15 × 9. Mesosoma obovate, 0.15 mm length, 0.09 mm maximum lateral height, details not visible. Forewing almost same morphology as male, 0.35 mm length (excluding length of marginal setae), 0.11 mm maximum width (Figures 3A, 4B). Both forelegs preserved; protibia

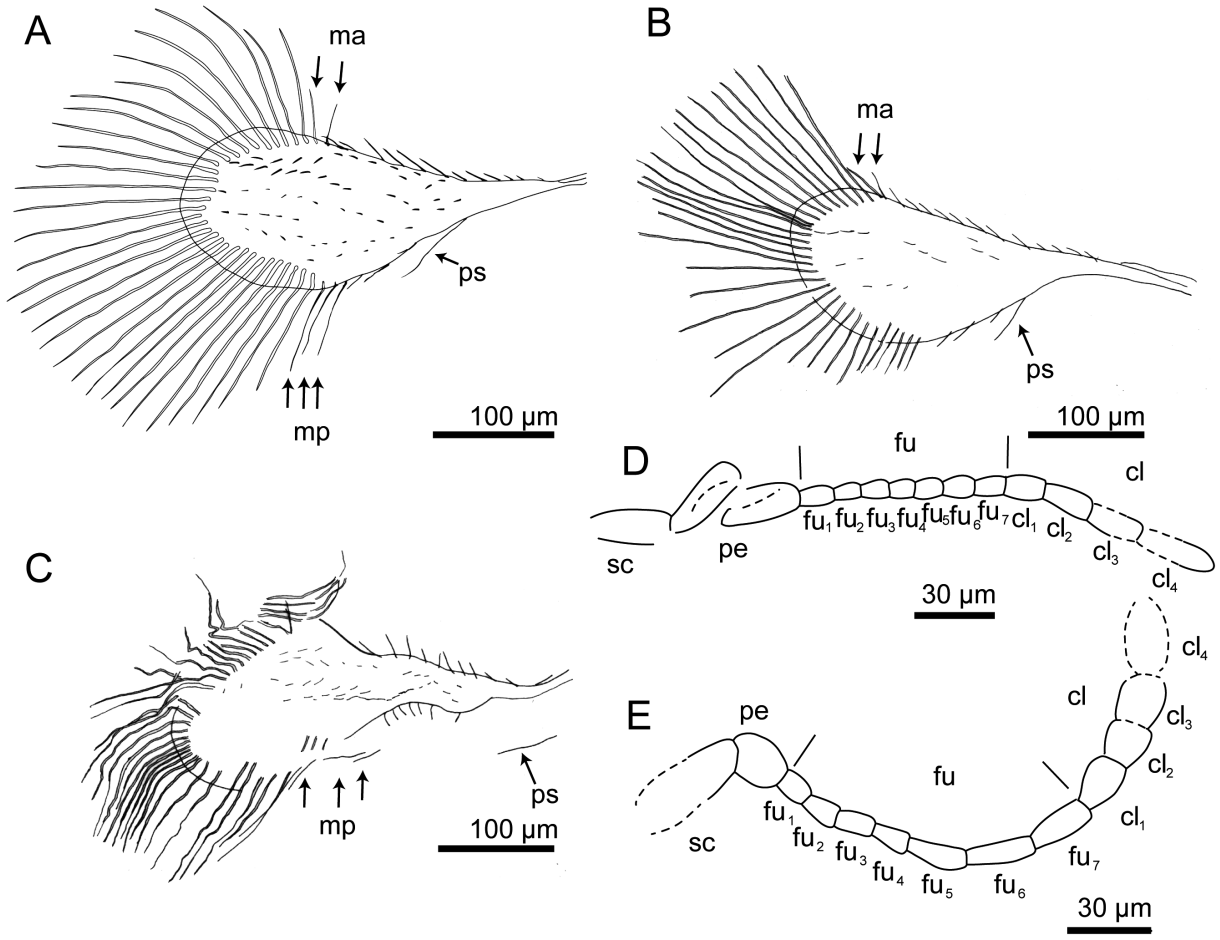

Figure 4. Line drawings of *Archaeromma chisatoi* sp. nov. (Mymarommatidae). **A,** line drawing of the forewing, holotype (FM-N202200057); **B,** line drawing of the forewing, allotype (FM-N202200062); and **C,** line drawing of the forewing, paratype (FM-N202200015); **D,** line drawing of the antennae, holotype (N202200057); **E,** line drawing of the antennae, allotype (N202200062). cl: clava, cl_1–cl_4: clava segments 1–4, fu: funicle, fu_1–fu_7: funicular segments 1–7, ma: mid-sized anterior setae, mp: mid-sized posterior setae, ps: posterobasal seta, sc: scape, pe: pedicle.

almost straight, 0.06 mm long; protarsi, five-segmented, slender, as long as protibia (Figure 3D). Midleg relatively short; mesofemur slightly swollen middle, 0.07 mm long; mesotibia almost straight, 0.06 mm length; mesotarsi not preserved. Hindleg almost same morphology as midleg. Gaster relatively small, oblong, half as long as mesosoma, 0.08 mm length, 0.05 mm maximum lateral height, thin ovipositor visible (Figure 3A).

Sex unknown (Paratype): Details unknown because of poor preservation and deformation (Figure 3E). Marginal fringe with 31 long setae visible (Figures 3E, 4C).

Remarks.—The three specimens were thought to belong to the same species, as they all have 31 erect marginal forewing setae.

These specimens clearly belong to the genus *Archaeromma* of the family Mymarommatidae because of the two-segmented petiole, female flagellum with seven funicular segments and four-segmented clava, and head capsule with a hyperoccipital band (Yoshimoto, 1975; Gibson *et al*., 2007).

These specimens can be distinguished from *A. hispanicum*, *A. gibsoni*, *A. carnifex*, *A. mandibulatum*, *A. senonicum* and *A. japonicum* by the small number (31) of forewing erect marginal setae (Table 1). In particular, *A. japonicum*, which has been described from the Japanese Kuji amber, is clearly distinguishable not only by the number of forewing erect marginal setae but also by its more slender legs (Fursov *et al*., 2002).

The other four species have no forewing erect marginal setae, either described or preserved (Table 1): *A. masneri* is clearly distinguished from this new species because its head is larger than its mesosoma (Yoshimoto, 1975); *A. minutissimum* is distinguished from these fossils by nine short setae distal to the long posterobasal seta (Gibson

Table 1. Comparison of the genus *Archaeromma*; brackets indicate female measurements.

Species	Author	Amber name (Country)	Stage	Body length (mm)	Antenna segments	Clavus	Erect marginal setae
Archaeromma hispanicum	Ortega-Blanco *et al*., 2011	Alava amber (Spain)	Albian	0.45	13	4	42–43
A. gibsoni	Engel and Grimaldi, 2007	Burmese amber (Myanmar)	Cenomanian	0.44	13	3	35–39
A. carnifex	Engel and Grimaldi, 2007	New Jersey amber (United States)	Turonian	0.64	13	3	55
***A. chisatoi* n. sp.**	**This study**	**Iwaki amber (Japan)**	**Coniasian**	**0.42 (0.36)**	**13 (13)**	**4 (4)**	**31 (31)**
A. mandibulatum	(Kozlov and Rasnitsyn, 1979)	Taimyr amber (Russian)	Santonian	(0.47–0.48)	(13)	(3)	(42)
A. senonicum	(Kozlov and Rasnitsyn, 1979)	Taimyr amber (Russian)	Santonian	(0.41–0.43)	(13)	(4)	(36–38)
A. japonicum	Fursov *et al*., 2002	Kuji amber (Japan)	Campanian	0.43	13	4	38
A. masneri	(Yoshimoto, 1975)	Canadian amber (Canada)	Campanian	(0.50)	(13)	(4)	—
A. minutissimum	(Brues, 1937)	Canadian amber (Canada)	Campanian	0.35–0.45 (0.35–0.55)	13	4	—
A. nearcticum	Yoshimoto, 1975	Canadian amber (Canada)	Campanian	0.30 (0.50)	13 (13)	4	—
A. trigonokephalion	Cockx *et al*., 2020	Canadian amber (Canada)	Campanian	0.36	13	3	—

et al., 2007); *A. nearcticum* is distinguished from these fossils by three long and three short setae basal to the much longer distal marginal setae (Gibson *et al*., 2007); *A. trigonokephalion* is distinguished from these fossils by its triangular head and three-segmented clava (Cockx *et al*., 2020).

Archaeromma chisatoi sp. nov. were discovered with both male and female fossils. This is the third example, in addition to *A. minutissimum* and *A. nearcticum*. In this new species, the female is smaller than the male. In comparison, in the other two species, females are larger than males (Table 1).

This new species is clearly distinguishable from the 10 congeneric species described previously. Thus, we describe these fossils as a new species.

Conclusion

We described a new fossil species of Mymarommatidae (Hymenoptera, Mymarommatoidea), *Archaeromma chisatoi* sp. nov. from the Late Cretaceous (Coniacian), Iwaki amber from Futaba Group of Iwaki City, Fukushima Prefecture, Japan. This is the 11th report of the genus *Archaeromma* and the second report from Japan. To the best of our knowledge, this is the first report of the genus *Archaeromma* from the Coniacian age.

A total of 141 fossil insects in 10 orders and 13 families have been found in Iwaki amber. The most abundant order was Diptera, accounting for 35.5% of the total, followed by Hymenoptera, 19.1% of the total, and the next most abundant order was Hemiptera, 10.6% of the total, with the other orders accounting for less than 3.5% of the total (Aiba *et al*., 2023).

However, these were all tentatively identified and had not yet been paleontologically described. This study is the first paleontological description from Iwaki amber, and it is expected that more paleontological descriptions from Iwaki amber will be made in the future.

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Author contributions

HA initiated the study, drafted the manuscript, and compiled all the figures. HI revised the manuscript and provided geological input. All authors contributed to the writing of the manuscript.