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Report

Winged formicine ant fossils (Hymenoptera, Formicidae) from the Chibanian (Middle Pleistocene) Shiobara Group, Tochigi Prefecture, Japan

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Abstract: Fossil winged ants (family Formicidae) are sometimes found in lacustrine deposits. In the Shiobara Group, however, only a fossil of a large wingless queen ant has been described. Two types of fossil winged ants belonging to the subfamily Formicinae are newly described here and identified as *Lasius* sp. and *Camponotus* sp.

Keywords: *Camponotus*, Formicidae, Formicinae, *Lasius*, Shiobara Group

Introduction

Ants are one of the most familiar insects to us because they are also a most successful insect groups in terrestrial ecosystem (e.g., Folgarait, 1998). Most ants mate during or after flights, where males and queens liberate from their natal nests to find mating partners from other colonies. Once, or several times a year in some species, abundant emergence of winged individuals flying out of their nest, called nuptial fight (e.g., Terayama et al., 2014). These winged individuals sometimes fall into water during their flights, and are occasionally preserved as fossils in lake fine deposits (LaPolla et al., 2013).

For above reason, fossil winged ants, traces of copulatings, are commonly obtained from lacustrine deposits in Japan as well (e.g., Fujiyama, 1985; Koshimizu, 1982). However winged ants have not been recognized from the Shiobara Group, one of the best-known conservation Lagerstätten in Japan. Only a fossil of large queen ant *Camponotus* (s.str.) sp. belonging the subfamily Formicinae is described recently (Aiba and Terayama, 2020). This is because of two reasons, compression or imprint fossils are found by splitting stones, and as a result small individuals are easily overlooked, and large queens relatively well discovered (LaPolla et al., 2013). Additionally, not well-preserved winged ants are inclined to recognized as small unsure hymenopterans. In this study, we found fossil winged ants belonging to the subfamily Formicinae from the Shiobara Group, and described them here.

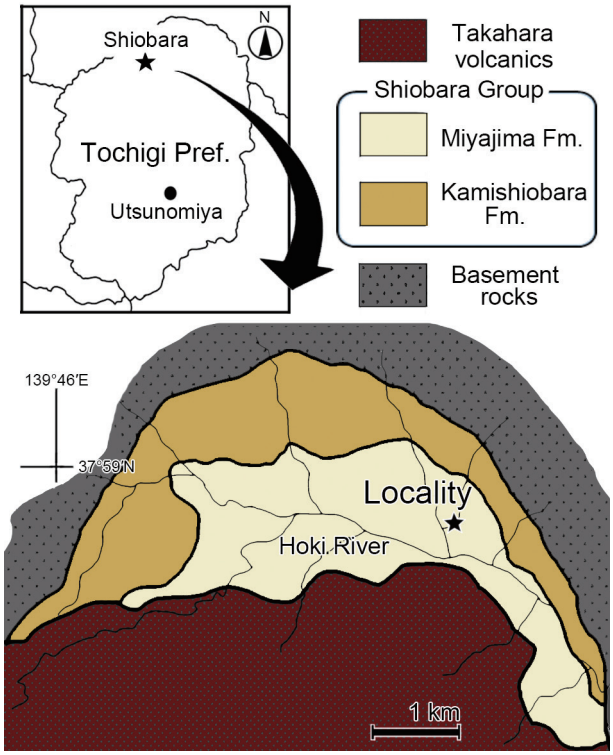

Fig. 1. The map in the upper left shows the location of Shiobara in Tochigi Prefecture, Japan, and the lower map is a simplified geological map of Shiobara (from Takahashi and Aiba, 2023). The star shows the location of the Konoha Fossil Museum.

Geological settings

The Chibanian (Middle Pleistocene) Shiobara Group (Yabe, 1929) is the lake deposits of past caldera lake (Tsujino and Maeda, 1999). The caldera basin is located on the northern slope of the Quaternary Takahara Volcano situated along the Hoki River (Fig. 1). The lake de-

posits adjoins and unconformably covers the basement rocks of the Miocene volcanic and sedimentary rocks on the west, north, and east sides, and the lavas derived from the Takahara Volcano lay or intercalate on the south side. The K-Ar ages of lavas suggested that age of the lake deposits were *ca.* 0.3 Ma (Itaya et al., 1989). The Shiobara Group includes a series consisting of sandstone, taffaceous mudstone, diatomaceous laminated mudstone, and conglomerate. The group shows lateral lithological variation and is composed of two formations (the Kamishiobara and Miyajima formations), representing contemporaneous heterotopic facies (Tsujino and Maeda, 1999). The Kamishiobara Formation represents a terrigenous marginal facies and includes coarse sediments. The Miyajima Formation, distributed in the center of the basin, shows profound facies of the lake and is composed mainly of diatomaceous laminated mudstones. This formation is exposed in the Konoha Fossil Museum), and the studied specimens preserved in white laminae are being derived from a quarry in the museum.

Aiba (2015) reviewed previous works and described new fossil specimens including 89 arthropod (insect and spider) species belonging to 31 families in ten orders, revealing the framework of the Shiobara insect fauna. Takahashi and Aiba (2023) tentatively summarized works in recent years and reported the first fossil paper wasp in Japan. Very recently, An acridid fossil *Ognevia* cfr. *longipennis* (Shiraki, 1910) and cerambycid *Xylotrechus villioni* (Villard, 1892) were described (Aiba, 2021; Aiba and Okabe, 2022). Aiba et al. (2022) also described staphylinid beetles belonging to three subfamilies, and also Acanthosomatid bugs *Acanthosoma* spp. and cixiid members (Aiba, 2022; Aiba and Hayashi, 2022). Sato et al. (2022) described larvae of gomphid dragonfly *Sieboldius albardae* Sélys, 1886 with remarks of larval instars and a paleoenvironmental implication.

Systematic paleontology

The six specimens used here are deposited in the two different places, Keio Yochisha Elementary School, Tokyo, Japan and the Konoha Fossil Museum, Tochigi Prefecture, Japan. Repository numbers belonging to the former are KYFSI139 and 195. Other four numbers to latter are SFMA0096, 0383, 0651 and 0652.

The terminology used to describe above specimens follows Perfilieva (2000, 2010) and Yoshimura and Fisher (2009), with abbreviations for wing venations and cells (italicized) as follows: Cu = cubital vein; M = median vein; R = radial vein; RS = radial sector; rs-m = cross-veins between RS and M; r-rs = cross-vein between radial and radial sector; and m-cu = cross-vein between median and cubital veins; pt = pterostigma; *mcu* = mediocubital cell; *r* = radial cells; *rm* = radiomedial cell; *cua* = cubito-anal cell.

Family Formicidae Latreille, 1809
Subfamily Formicinae Latreille, 1809
Genus *Lasius* Fabricius, 1804
Lasius sp.
Figure. 2

Material examined.—SFMA0096 (Fig. 2A), male, body in ventral view. Head poorly preserved with partial antennae. Mesosoma also poorly, with fore and wings. Legs quite partial. Metasoma only outline visible. SFMA0651 (Fig. 2C), male, body in dorsal view. Head with partial antennae. Mesosoma not well preserved, with partial fore wings. Legs partially preserved. Metasoma only outline visible. SFMA 0383 (Fig. 2D), male, body in dorsal view. Head mostly lacking. Mesosoma also poorly preserved, with petiole and partially left fore wings. Legs partially preserved. Metasoma only outline visible.

Description.—Total body length 3.9–4.7 mm. Head in dorsal view 0.8 times longer than wide, with massive and triangular mandible. Anterior margin of clypeus slightly convex. Antennae filiform with long scape, number of antennal segments uncertain. Mesosoma in dorsal view large with oval outline, 1.4–1.5 times longer than wide. Fine structures hard to interpret.

Fore wing 4.0–4.7 mm in length and 1.6–1.8 mm in width, with closed cell *mcu*. Fore wing cell *mcu* trapezoid, distant to level of pterostigma base, its length 1.2–1.5 times longer than height. Pterostigma elongated and triangular, 4.5–4.9 times longer than wide. Fore wing vein 1Cu 1.3–1.6 times longer than 1M, almost same length as 2Cu. Fore wing cross vein m-cu slightly shorter than fore wing vein 1Cu. Fore wing cells *1+2r* and *3r* present, apex of cell *3r* touches wing margin. Fore wing cell *3r* long, 4.6 times longer than wide, about 2 times longer than fore wing cell *1+2r*. Fore wing cell *1+2r* 2.4–2.6 times longer than wide. Fore wing vein 2RS+M long, 3.6–3.9 times longer than fore wing vein 1RS+M. Fore wing vein 5RS almost straight, 1.5 times longer than fore wing vein 2RS+M. Fore wing crossvein 2r-rs inclined towards wing apex. Fore wing vein 4M long, originate near end of fore wing crossvein 2r-rs, almost straight and slightly sinuate basally. Fore wing cell *rm* absent. Fore wing vein 3Cu long and anteriorly arched, 3 times longer than fore wing 2Cu vein. Fore wing crossvein cu-a short, vertical to fore wing veins M+Cu and A. Fore wing vein A straight, not touching forewing

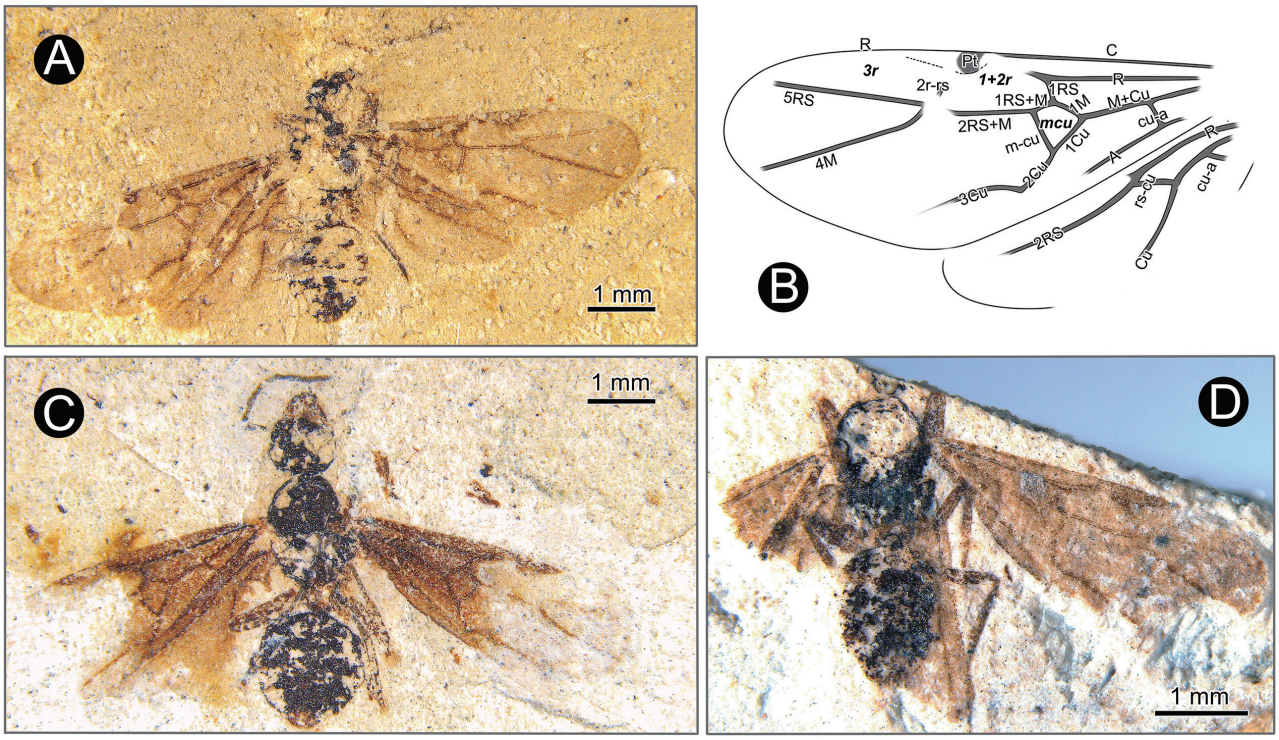

Fig. 2. Specimen photographs and an illustration of *Lasius* sp. (A) Specimen SFMA0096. (B) Interpretation of the fore and hind wing venations of specimen SFMA0096. (C) Specimen SFMA0651. (D) Specimen SFMA0383.

vein Cu. Fore wing cell *cua* absent. Hind wing 2.8 mm in length and 1.0 mm in width, without jugal lobe. Free branch of hind wing vein M absent. Median hooks also absent. Hind wing crossvein rs-cu long, slightly curved.

Legs poorly preserved, long and slender. Femora not swollen. Metasoma with single, short and small petiole. Following segments forming quite rounded outline in dorsal view, 1.2–1.4 times longer than wide. Due to poor preservation, fine structures difficult to interpret.

Remarks.—Studied specimens are characterized by having of petiole and unique fore wing venations such as presence fore wing cells *1+2r* and *3r*, fore wing vein 4M and fore wing vein 1RS distant to pterostigma. These characteristics indicate that they belong to the family Formicidae (e.g., Perfilieva, 2010). Perfilieva (2010) studied wing venations among seventeen subfamilies of the family and classified the fore wing venations into sixteen types based on collections of the Zoological Museum of Moscow State University. Redction of fore wing cell *rm*, fore wing vein 4M originating near end of fore wing crossvein 2r-rs suggest the studied specimens have IIId type of fore wing. This type of fore wings is shared by some subfamilies such as Dolichoderinae, Formicinae and Myrmicinae (Perfilieva, 2010). Perfilieva (2010) also mentioned that wings of the subfamily Formicinae are characterized by absence of fore wing cell *cua*, cell *mcu* hardly reaching the pterostigma base, and hind wings without free branch of M, the jugal lobes and median hooks. They are shared with studied specimens. These fore wing characteristics are certainly observed in modern Japanese formicine ant genera *Lasius* and *Camponotus* (Fig. 4). Additionally, single small petiole is a diagnosis of subfamily Formicinae (Terayama et al., 2014). Therefore, studied specimens are belong to the subfamily Formicinae. Presence of fore wing crossvein m-cu suggested these specimens are belong to the genera *Formica*, *Lasius*, *Polyergus* in Japanese fauna (Terayama, personal communication), and actually modern *Lasius* have such characteristics (Fig. 4A). But triangular mandible of studied specimens differs from sickle-shaped mandible of *Polyergus*. Total body length approximately 4–5 mm of the studied specimens is smaller than male of *Formica* and *Polyergus* (Terayama, personal communication). Therefore, the specimens are identified as members of *Lasius*.

Nuptial fights of modern Japanese members of *Lasius* are relatively well observed, and they are occurred in spring and summer seasons (Terayama et al., 2014). White laminae of the Shiobara Group, which embracing these specimens are derived from planktonic diatom

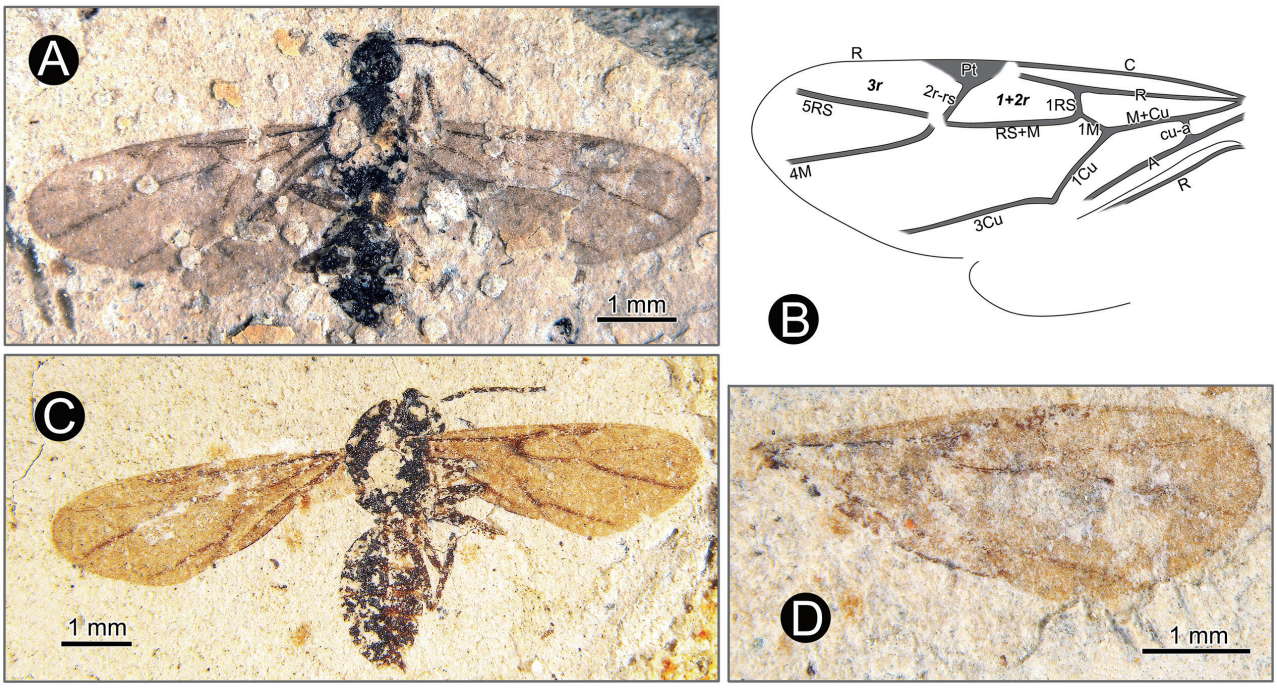

Fig. 3. Specimen photographs and an illustration of *Camponotus* sp. (A) Specimen KYFSI195. (B) Interpretation of fore and hind wing venations of specimen KYFSI195. (C) Specimen SFMA0652. (D) Specimen KYFSI139 (fore wing only).

blooming in spring–summer (Allison et al., 2008). These facts suggested that nuptial fight seasons of Japanese fossil formicine ant *Lasius* have not been largely changed since the Chibanian (Middle Pleistocene).

Genus *Camponotus* Mayr, 1861

Camponotus sp.

Figure 3

Material examined.—KYFSI195 (Fig. 3A), male, body in dorsal view. Head with antennae. Mesosoma poorly preserved, with fore and hind wings. Legs not well preserved. Mesosoma only outline visible. SFMA0652 (Fig. 3C), male, body in lateral view. Head with antennae. Mesosoma poorly preserved, but petiole visible. Fore wings almost complete. Legs not well preserved. Metasoma also not well preserved. KYFSI139 (Fig. 3D), sex uncertain, only a not well-preserved fore wing.

Description.—Total body length 3.7–4.1 mm. Head poorly preserved, in dorsal view 1.1 times longer than wide, 1.5 times higher than long. Antennae filiform with long scape. Antennal segments 13. Mesosoma large, in dorsal view oval, 1.3 times longer than wide. In lateral view dorsal outline of mesosoma round and smooth without spines, 1. 3 times longer than high. But fine structures hard to interpret.

Fore wing 4.0–4.5 mm in length and 1.6–1.8 mm in width, without closed cell *mcu*. Pterostigma elongated and triangular, 4.1–4.6 times longer than wide. Fore wing cells *1+2r* and *3r* present. Fore wing cell *3r* long, 4.4–4.7 times longer than wide, about 1.5–2.0 times longer than fore wing cell *1+2r*, apex of the cell touching wing margin. Fore wing vein 5RS long sinuate apically, 4.0–5.0 times longer than fore wing crossvein 2r-rs. Fore wing cell *1+2r* 2.4–2.6 times longer than wide. Fore wing cell *rm* absent. Fore wing vein 3Cu long and slightly arched anteriorly, 1.5–2.0 times longer than fore wing vein 1Cu. Fore wing vein RS+M weekly bowed posteriorly, 5.0–5.3 times longer than fore wing vein 1RS, 2.7–2.9 times longer than fore wing crossvein 2r-rs. Fore wing crossvein 2r-rs inclined towards wing apex. Fore wing vein 4M long, originate near end of fore wing crossvein 2r-rs, almost straight and slightly sinuate basally. Fore wing vein A straight, not touching forewing vein Cu. Fore wing cell *cua* absent. Fore wing crossvein cu-a short, vertical to fore wing veins M+Cu and A. The hind wing 2.4 mm in length, venation poorly preserved.

Legs not well preserved, long and slender. Femora not swollen. Petiole single, short, small and dorsally reverse V-shaped in lateral view. Following metasomal part with more five segments, forming quite rounded outline, 1.5 times longer than wide in dorsal view, 1.6 times longer than high in lateral view. Constriction between 1st

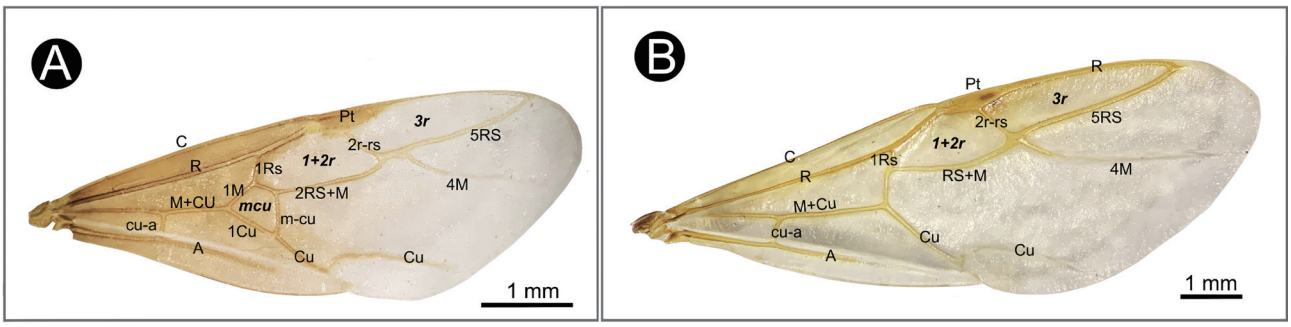

Fig. 4. Fore wings of modern winged formicine ants. (A) Male *Lasius* sp. and (B) male *Camponotus japonicus* Mayr, 1866.

and 2nd metasomal segments absent. Due to poor preservation, fine structures difficult to interpret.

Remarks.—As mentioned above, due to having of petiole and fore wing unique venations, these specimens are belonging to family Formicidae. Reduction of fore wing cell *rm* and *mcu*, Fore wing vein 4M originating near end of fore wing crossvein 2r-rs suggest the studied specimens have IVe type of Perfilieva (2010). This type of fore wings is shared by two subfamilies Formicinae and Myrmicinae (Perfilieva, 2010). These fore wing characteristics are certainly observed in modern Japanese formicine ant genus *Camponotus*. (Fig. 4B). Addition to this, single small petiole and lacking constriction between 1st and 2nd metasomal segments is a diagnosis of subfamily Formicinae (Terayama et al., 2014). Therefore, studied specimens are belong to the subfamily Formicinae. Absence of fore wing crossvein m-cu indicates that studied specimens are members of *Camponotus*, *Nylanderia* and *Polyrhachis* in Japanese fauna (Terayama, personal communication), and actually modern *Camponotus* have such characteristics (Fig. 4B). These fossils are much smaller than male of *Polyrhachis* and much larger than *Nylanderia* (Terayama, personal communication). *Camponotus* has wide variety of body length and studied specimens are probably small sized members of *Camponotus*.

Conclusion

Winged ants of Shiobara Groups are divided into two types by presence of fore wing cell *mcu*. They are identified as *Lasius* sp. and *Camponotus* sp. due to body size, single small petiole and wing venations. This is not only a definite report of winged ants, and also a first fossil record of the genus *Lasius* from the Chibanian (Middle Pleistocene) lacustrine deposits of the Shiobara Group.

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1) in Japanese
2) in French
3) in Latin
4) in German
5) in Japanese with English abstract
* English translation from the original written in Japanese

（著者貢献）
高橋 唯　全体の執筆及び化石の分類記載を担当
相場博明　化石の分類記載を担当

（用語対比）
Hoki River　箒川
Kamishiobara Formation　上塩原層
Miyajima Formation　宮島層
Shiobara Group　塩原層群
Takahara Volcano　高原火山