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A fossil paper wasp (Vespidae: Polistinae) from the Chibanian (Middle Pleistocene) Shiobara Group in Tochigi Prefecture, Japan

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Abstract. A specimen belonging to the genus *Polistes* (Vespidae: Polistinae) is described from the Chibanian (Middle Pleistocene) Shiobara Group, Tochigi Prefecture, Japan. The morphology of the forewing and first gastral tergum indicated a more accurate assignment of *Polistes* sp. This specimen the first fossil of a paper wasp to be identified in Japan.

Key words: insect, Pleistocene, Polistinae, Shiobara Group, Vespidae

Introduction

The Chibanian (Middle Pleistocene) Shiobara Group (Yabe, 1929) in Nasushiobara City, Tochigi Prefecture, Japan, is one of the best-known Konservat-Lagerstätten in

Japan (Allison *et al*., 2008; Tuzino *et al*., 2009). The Shiobara Group has yielded a number of fossil leaves, traditionally called “Konoha-ishi” in Japanese, as well as exceptionally well-preserved insect fossils. The earliest studies of these fossil insects were conducted in the 1930s (Oishi, 1931; Naora, 1933), with further occasional publications until 2015 (Asahina, 1959; Hiura, 1966; Fujiyama, 1968, 1969, 1979, 1983). Aiba (2015) reviewed these studies 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. However, further paleontological studies of this material are needed because more precise descriptions and identifications are required, and additional new specimens have since been discovered.

For these reasons, Aiba and his colleagues have produced more than 15 publications on arthropod fossils during the last five years. These studies involved re-examination of some specimens, new descriptions of the pupae and larvae of water penny beetles (Hayashi and Aiba, 2016; Hayashi *et al*., 2020), and documentation of fragmentary preserved specimens belonging to Lucanidae and Scolopendromorpha with taphonomic remarks (Takahashi *et al*., 2017a), sciarid flies exhibiting copulating behavior (Takahashi *et al*., 2017b), the hindwing of the cicada *Terpnosia nigricosta* (Motschulsky, 1866) by Nakano *et al*. (2018), and a gomphid dragonfly with wing veins slightly different from those of modern species (Aiba *et al*., 2019). Other studies have described some pentatomid specimens closely related to the modern *Pentatoma semiannulat*a (Motschulsky, 1860) (Aiba, 2019a), a pentatomid bug *Okeanos quelpartensis* Distant, 1911 (Aiba, 2019b), a reduviid bug *Epidaus tuberosus* Yang, 1940 (Aiba, 2019c), and

an elaterid beetle *Cryptalaus yamato* (Nakane, 1957) by Suzuki *et al*. (2019). In addition, eight heteropteran species were described by Aiba (2020a) and Aiba (2021a) *Philostephanus fulvus* (Jakovlev, 1882); *Adomerus variegatus* (Signoret, 1884); *Dinorhynchus dybowskyi* Jakovlev, 1876; *Lelia decempunctata* Motschulsky, 1860; *Homalogonia grisea* Josifov and Kerzhner, 1978; *Pentatoma metallifera* (Motschulsky, 1860); *Pentatoma rufipes* (Linnaeus, 1758); and *Menida disjecta* (Uhler, 1860). Other notable fossils described by Aiba and colleagues include a noctuoid moth specimen (Aiba, 2020b), a *Camponotus* queen ant (Aiba and Terayama, 2020), a jumping plant-louse (Horiguchi *et al*., 2020), a lace bug (Aiba *et al*., 2021), and acridid fossils (Aiba, 2021b).

Here we re-examine a hymenopteran specimen described by Aiba (2015). The specimen was tentatively identified as the vespid *Vespula* sp. because of its large body length with wing folding. However, we found that the specimen morphology indicates a different taxonomic assignment.

Geological Setting

The Chibanian (Middle Pleistocene) Shiobara Group consists of lake deposits formed in a paleo-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 (Figure 1). The lake deposits adjoin and unconformably overlie the basement rocks of

the Miocene volcanic and sedimentary rocks on the western, northern, and eastern sides, whereas lavas derived from the Takahara Volcano overlie or are intercalated with the lake sediments on the southern side. The K–Ar ages of the lavas suggest an age of ca. 0.3 Ma for the lake deposits (Itaya *et al.*, 1989). The Shiobara Group contains a succession of sandstone, tuffaceous 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 terrigenous marginal facies and includes coarse-grained sedimentary rocks. The Miyajima Formation, which occurs in the center of the basin, represents the deep facies of the caldera lake and is mainly composed of diatomaceous laminated mudstones. This formation is exposed in the Konoha Fossil Museum, and the specimens examined in this study were derived from a quarry in the museum.

Systematic Paleontology

The studied specimen is deposited in Keio Yochisha Elementary School, Tokyo, Japan with repository number KYFSI003. We follow the terminology of Vespidae given in Carpenter (1982), with abbreviations for wing venation 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.

Order Hymenoptera Linnaeus, 1758

Family Vespidae Latreille, 1802

Subfamily Polistinae Lepeletier, 1836

Tribe Polistini Lepeletier, 1836

Genus *Polistes* Latreille, 1802

***Polistes* sp.**

Figure 2 A–F

Material examined. —KYFSI003 is composed of two small pieces KYFSI003a and b (counterpart). KYFSI003a (65 mm × 52 mm ×13 mm in size) preserves almost entire part of the insect body (Figure 2 A). KYFSI003b (47 mm ×23 mm ×6 mm in size) preserves the propodeum, metasoma, a hind leg and forewing (Figure 2 D).

Description. —Head as wide as metasoma. Head length 1.46 mm and width 3.52 mm. Antennae more than four flagellomeres. An entirely preserved flagellomere longer than wide.

Mesosoma (Figure 2 A, B, C) longer than wide, both anteriorly and posteriorly rounded. Mesosoma length 5.34 mm and the width 4.52 mm. Pronotum wider than long. Tegula located posterolateral part of the pronotum. Parategula absent. Mesonotum dived into mesoscutum and scutellum. Mesoscuteum large, dorsally straight and lacking

notauli. Scutellum transversely flattened. Propodeum ornamented with fine transverse striae, and medial portion of propodeum concave. Mid-tibia with two spurs.

Forewing (Figure 2 E, F) dark-colored and longitudinally folded. Marginal cell distally pointed onto costa and not appendiculate. first discal cell elongated. Partially preserved basal cell narrow and long. Three submarginal cells present, and second one narrowest with almost equal in length and width. 1Rs about two times as long as Rs+M. 2Rs almost straight. 3Rs much shorter than 4Rs. 2r-m slightly bent as inverted S-shaped. Pterostigma (ptStg) short, and prestigma (prStg) shorter than ptStg. PrStg apex not recurved. Due to wing folding, 2m-cu and 2Cu1 reversal, and second and third submarginal cells slightly distorted. Measurable veins as follows: 5Rs 0.92 mm; 4Rs 0.76 mm; 3Rs 0.23 mm; 2Rs 0.49 mm; 2r-rs 1.29 mm; 1R 2.78 mm; prStg 0.30 mm; ptStg 0.74 mm; 1Rs probably 1.18 mm; Rs+ M 2.47 mm.

Metasoma (Figure 2 A, B, D) spindle-shaped with six segments. Metasoma length 10.82 mm and the width 4.09 mm. First gastral tergum (T1) conical in shape and wider than long. T2 widest and largest, and T6 with a sting. Total body length 17.61 mm.

Discussion

The presence of three marginal cells and two mid-tibial spurs is diagnostics of most aculeates, and is present in most Vespidae (Brothers, 1975; Carpenter, 1982). Longitudinal wing folding is also a characteristic of the family (Carpenter, 1982). The

2nd submarginal cell is narrowed in Vespidae, except in the subfamily Stenogastrinae (Carpenter, 1982). Narrowing of the marginal cell toward or along the costa and extension toward the wing apex is recognized in the subfamilies Eumeninae, Vespinae, Polistinae, and Stenogastrinae. The lack of a parategula indicates that this specimen does not belong to Eumeninae (Carpenter, 1982). Thus, these features place this specimen in the subfamilies Vespinae or Polistinae. The conical shape of the first gastral tergum (T1) is an autapomorphy of *Polistes* (Figure 2 G), the only genus in the tribe Polistini of the Polistinae (Carpenter, 1996), whereas T1 abruptly declivous anteriorly in Vespinae and other tribes of Polistinae bear a more anteroposteriorly elongated T1. Therefore, we conclude that this specimen (KYFSI003) is attributed to genus *Polistes*. More detailed species-level identification of the specimen is difficult because of the lack of color pattern information.

This specimen represents a valuable record of the subfamily Polistinae. This subfamily is the most diverse cosmopolitan group of social wasps, with more than 950 extant species described from 26 recognized genera and four tribes (Pickett and Carpenter, 2010), of which 12 species belonging to three genera are known in modern Japan (Terayama *et al*., 2016). The fossil record of this group is limited to Konservat-Lagerstätten in some countries. Six extinct species of the modern genus *Polistes* are known as fossils from Europe (*e. g.* Statz, 1936; Piton, 1940; Heer, 1849). Three extinct monotypic genera with uncertain tribal assignments, *Palaeopolistes*, *Protopolistes*, and *Palaeopolybia* have also been described from these regions (Cockerell, 1921; Perrard *et al*., 2014). There is only one previous record of the group from outside Europe: *Agelaia*,

a member of the tribe Epionini, has been reported from Dominican amber (Carpenter and Grimaldi, 1997). In detail, the oldest polistine fossil is *Polistes vergnei* Piton, 1940 from the Paleocene Menat Pit fossil site, France. Other records are of *P. attavinus* Heer, 1849 from lower Miocene strata at Parschlug, Austria; *P. industrius* Théobald, 1937 from the middle Oligocene of Céreste, France; and *P. signatus* Statz, 1936 from upper Oligocene rocks of Rott, Germany. Two late Miocene examples, *Polistes kirbyanus* Cockerell, 1915 and *P. primitiva* Heer, 1865, were reported from Öhningen, Germany, but the latter is thought to be a *nomen nudum* (Perrard *et al*., 2014). Two Oligocene species, *Polybia anglica* Cockerell, 1921a, and *Poly. oblita* Cockerell, 1921b, have been described from the Isle of Wight, UK. Carpenter and Grimaldi (1997) described *Agelaia electra* from Miocene Dominican amber and pointed out that the identification and systematic positions of Cockerell's specimens are debatable. The British specimens were re-described as *Palaeopolybia anglica* (Cockerell, 1921) and *Protopolistes oblitus* (Cockerell, 1921) by Antropov *et al.* (2013). More recently, Perrard *et al*. (2014) described a new genus and species, *Paleopolistes jattioti*, from the upper Eocene Monteils Formation in Gard, France. Finally, Kotthoff (2005) figured and briefly described three unnamed Polistinae gen. et sp. indet. from lower Miocene deposits of Randeck Maar, Germany. The specimen examined in this study represents a new polistine fossil and is the first fossil record of the subfamily in Japan, located at the eastern end of Asia. Thus, the studied specimen contributes to our knowledge of the diversity of the subfamily and genus, and at the same time proves the existence of *Polistes* in Japanese insect fauna during the Chibanian (Middle Pleistocene).

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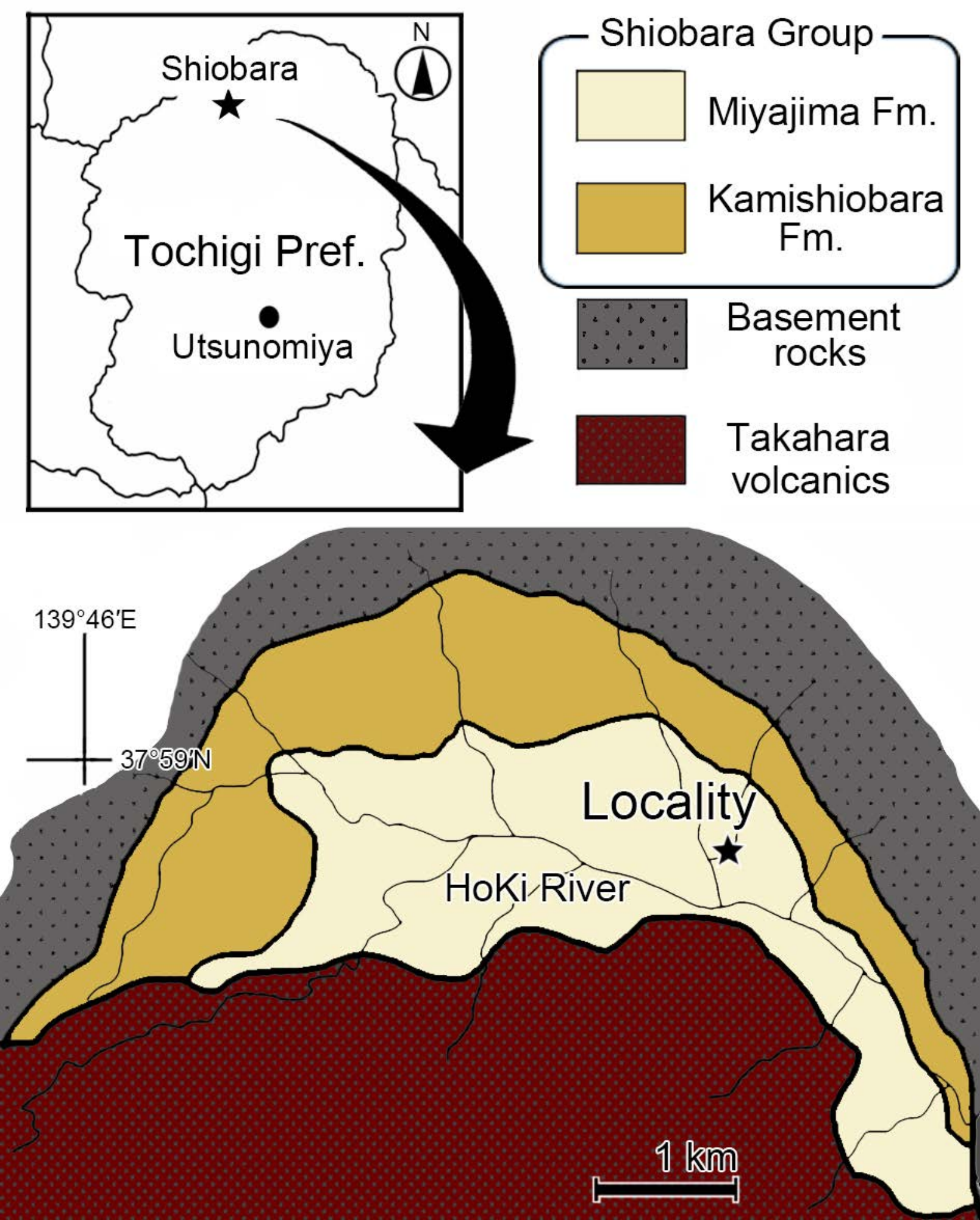
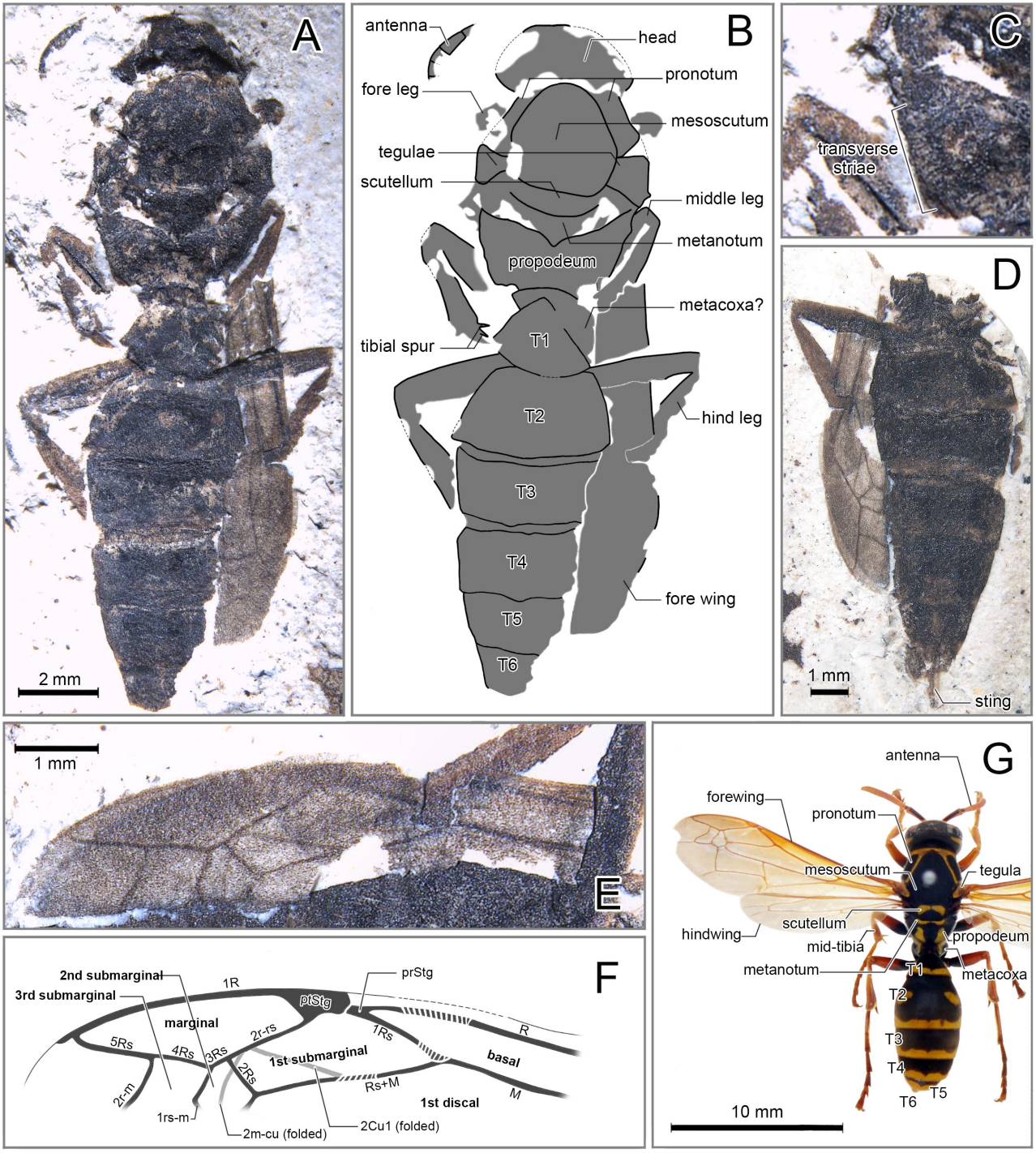
Figure captions

Figure 1. The schematic map at the upper left shows the location of Shiobara in Tochigi Prefecture, Japan. The lower part is a simplified local geological map of Shiobara (after Tuzino *et al*., 2009). The star shows the location of the Konoha Fossil Museum.

Figure 2. Dorsal views of *Polistes* sp. (specimen KYFSI003) from the Pleistocene Shiobara Group. **A,** KYFSI003a. **B,** interpretation of A. **C,** left side of propodeum showing striae. **D,** KYFSI003b, counter part of A. **E,** forewing of KYFSI003b. **F,**

interpretation of E. **G,** modern Japanese species *Polistes chinensis* (Fabricus, 1793). Abbreviations: 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 vein and radial sector; m-cu = cross-vein between median and cubital vein; T = tergum.


N
Shiobara
Tochigi Pref.
Utsunomiya
Shiobara Group
Miyajima Fm.
Kamishiobara Fm.
Basement rocks
Takahara volcanics
139°46′E
37°59′N
Locality
HoKi River
1 km


A
2 mm
B
antenna
head
pronotum
fore leg
mesoscutum
tegulae
scutellum
middle leg
metanotum
propodeum
metacoxa?
tibial spur
T1
T2
hind leg
T3
T4
fore wing
T5
T6
C
transverse striae
D
1 mm
sting
E
1 mm
F
2nd submarginal
3rd submarginal
1R
prStg
ptStg
marginal
2r-rs
1Rs
R
5Rs
4Rs
3Rs
1st submarginal
basal
2Rs
Rs+M
M
2r-m
1rs-m
1st discal
2m-cu (folded)
2Cu1 (folded)
G
antenna
forewing
pronotum
mesoscutum
tegula
hindwing
scutellum
propodeum
mid-tibia
metanotum
T1
metacoxa
T2
T3
T4
T6
T5
10 mm