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Short communication

New mimarachnids in mid-Cretaceous amber from northern Myanmar (Hemiptera, Fulgoromorpha)

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ABSTRACT

Mimarachnidae is an extinct planthopper family of the superfamily Fulgoroidea, with a broad geographical distribution, known exclusively from the Cretaceous. Here, a new fossil species of *Ayaimatum* Jiang and Szwedo, 2020, *Ayaimatum minutum* sp. nov., is described and illustrated on the basis of two specimens from the mid-Cretaceous amber of northern Myanmar. We herein revised the diagnostic characters of *Ayaimatum*, and the intra-specific variation of *A. minutum* is discussed. Additionally, a new genus and species of Mimarachnidae, *Mimaeurypterus burmiticus* gen. et sp. nov., from the same Burmese (Myanmar) amber, is herein described. *Mimaeurypterus* gen. nov. can be distinguished from other mimarachnids by its large body size, mesonotum with median carinae not reaching anterior margin, msoscutellum without distinct wrinkles, and broad, coriaceoustegmina with apical margin truncate. The new discovery further confirms that this extinct hemipteran group was diverse and had high morphological disparity during the late Mesozoic.

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1. Introduction

The hemipteran lineage Fulgoromorpha, or planthoppers, is a diversified group of more than 13,600 described species worldwide and can be subdivided into three superfamilies: Coleoscytoidea Martynov, 1935 confined to the Permian; Surijokocixioidea Shcherbakov, 2000 recorded in the Permian and Triassic; and Fulgoroidea Latreille, 1807 known since the Jurassic (Szwedo, 2018; Bourgoin, 2020) . Mesozoic planthoppers belong to three extant families (Cixiidae Spinola, 1839; Achilidae Stål, 1866; Dictyopharidae Emeljanov, 1983) and ten extinct families (two Jurassic ones: Fulgoridiidae Handlirsch, 1939 and Qiyangiricaniidae Szwedo, Wang et Zhang, 2011; and eight Cretaceous ones: Lalacidae Hamilton, 1990, Neazoniidae Szwedo, 2007, Perforissidae Shcherbakov, 2007a, Mimarachnidae Shcherbakov, 2007b, Dorytocidae Emeljanov et Shcherbakov, 2018, Jubisentidae Zhang, Ren et Yao, 2019, Yetkhatidae Song, Szwedo et Bourgoin, 2019, and Katlasidae Luo, Jiang et Szwedo, 2020) (Szwedo, 2018; Bourgoin, 2020; Luo et al., 2020a).

A small, extinct planthopper family named Mimarachnidae is considered to be the earliest recognized spider-mimic planthoppers, is placed in the group of 'cixiidae-like' planthoppers (Shcherbakov, 2007b; Bourgoin and Szwedo, 2008; Szwedo and Ansorge, 2015). Mimarachnidae was originally established to comprise two genera, *Mimarachne* Shcherbakov, 2007 and *Saltissus* Shcherbakov, 2007 based on fossils described from the Lower Cretaceous of Baissa (Russia) (Shcherbakov, 2007b). Subsequently, eight additional genera were assigned to Mimarachnidae in recent five years (Fujiyama, 1978; Szwedo, 2008; Szwedo and Ansorge, 2015; Shcherbakov, 2017; Zhang et al., 2018; Jiang et al., 2018, 2019, 2020; Fu et al., 2019; Fu and Huang, 2020; Luo et al., 2020b). They include *Nipponoridium* Fujiyama, 1978 from the Lower Cretaceous of Japan; *Mimamontsecia* Szwedo et Ansorge, 2015 and *Chalicoridulum* Szwedo et Ansorge, 2015 from the Lower Cretaceous of Spain; and *Burmissus* Shcherbakov, 2017, *Dachibangus* Jiang, Szwedo et Wang, 2018, *Jaculistilus* Zhang, Ren et Yao, 2018, *Mimaplax* Jiang, Szwedo et Wang, 2019, and *Cretodorus* Fu et Huang, 2020 from the mid-Cretaceous amber of Myanmar, representing the youngest record of this extinct family, providing an opportunity to know detailed morphological characters of body structure and peculiar camouflaged configuration (Jiang et al., 2019; Fu and Huang, 2020).

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Here we describe a new genus and new species of Mimarachnidae, *Mimaeurypterus burmiticus* gen. et sp. nov., and a new species of *Ayaimatum* preserved in Burmese amber.

2. Material and methods

The three mimarachnid specimens (NIGP172394, NIGP172395, and NIGP173217) described herein are contained in three amber pieces from the Hukawng Valley, Kachin State of northern Myanmar (locality as indicated in Yin et al., 2018: fig. 1A). The amber pieces containing our inclusions were cut using a handheld engraving tool, and polished using emery papers of different grain sizes and rare earth polishing powder, as described in Azar et al. (2003) and Sidorchuk and Vorontsov (2018). Photographs were taken with a Zeiss AxioZoom V16 stereoscope and a Zeiss AXIO Imager Z2 compound microscope (green fluorescence). The raw digital images were processed with Helicon focus stacking software. Line drawings were drafted with Adobe Illustrator CC 2018 graphic software. The material studied here is deposited in the Nanjing Institute of Geology and Palaeontology, Chinese Academy of Sciences, Nanjing, China.

Burmese amber harbors probably the most diverse Mesozoic palaeobiota (Ross, 2019, 2020). A few recently detected species have been associated with marine groups, suggesting that the sedimentary environment was located in a coastal area (Mao et al., 2018; Xing et al., 2018; Yu et al., 2019). U–Pb zircon dating constrained the Burmese amber to a maximum age of 98.79 ± 0.62 Ma (Shi et al., 2012). Mao et al. (2018) discussed that the current given zircon U–Pb SIMS age probably younger than in reality and suggested an age closer to the boundary between the Albian and Cenomanian.

The venation terminologies used herein follows the standardized terminology of the forewing venation in Fulgoromorpha (Bourgoin et al., 2015). Measurements are given in millimeters.

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3. Systematic palaeontology

Order Hemiptera Linnaeus, 1758
Suborder Fulgoromorpha Evans, 1946
Superfamily Fulgoroidea Latreille, 1807
Family Mimarachnidae Shcherbakov, 2007

Genus ***Ayaimatum*** Jiang and Szwedo, 2020
Type species: *Ayaimatum trilobatum*; by original designation and monotypy.

Diagnosis (revised after Jiang et al., 2020). The genus is characterized by the following combination of characters: head triangular in dorsal view, without distinct protuberance (elongated head in *Jaculistilus* and *Cretodorus*), lateral edges of vertex sinuous, expanded above compound eyes, posterior margin of vertex concave; trigons not visible in dorsal view; rostrum moderate, extending to metacoxa (as in *Mimaplax*, far beyond metacoxa in *Chalicoridulum*, *Burmissus*, *Jaculistilus*, and *Cretodorus*); distinctly convex pronotum and mesonotum with elevated median carinae (as in *Mimaplax* and *Cretodorus*, less convex or elevated in other genera); tegmen with apical margin rounded (obliquely truncate in *Mimarachne*, *Saltissus*, and *Mimamontsecia*), common stem ScP + R + MP+(CuA) before separation of MP almost as long as stem ScP + R; RP unbranched (RP with 2–3 terminal branches in *Mimarachne*, *Saltissus*, and *Mimamontsecia*), MP with 2 terminal branches (MP single in *Cretodorus*, with 4–6 terminals in *Dachibangus* and *Jaculistilus*); and stem CuA forked nearly at half of tegmen length, slightly basad of claval veins Pcu and A1 junction (CuA forked apicad of claval veins junction in *Saltissus*, *Chalicoridulum*, *Burmissus*, and *Cretodorus*).

Ayaimatum minutum sp. nov.
Zoobank LSID urn:lsid:zoobank.org:act:7A9D69A4-078A-4A29-BE3E-C096F12E91CB.
(Figs. 1–4)

Etymology. The specific epithet refers to its small size.
Material. Holotype: NIGP172394, a well-preserved male adult insect, embedded in a piece of transparent yellowish amber. Paratype: NIGP172395, head missing, abdomen obscure and gender unknown, embedded in a piece of relatively opaque, orange amber.
Locality and horizon. Burmese amber, from deposits near the Tanai Village in the Hukawng Valley of northern Myanmar; mid-Cretaceous.
Diagnosis. The species is characterized by the type species by following characters: body length 8–9 mm (*A. trilobatum* much larger); metatibio-metatarsal formula (apical teeth) 5: 5: 5; tegmen length 7–9 mm, with length/width ratio 2.4 (length/width ratio about 3.3 in *A. trilobatum*), without distinctive dark bands or some irregular patches of darker areas preserved (tegmen mottled in *A. trilobatum*), Pc + CP submerged to margin at about half of tegmen length (Pc + CP extremely short in *A. trilobatum*); postcostal cell distinctly wider than cell C1 (postcostal cell relatively narrow in *A. trilobatum*); and hind wing with stem CuA forked apparently basad of stem ScP + R fork (CuA forked slightly basad of ScP + R fork in *A. trilobatum*).
Description. Body length 8.3 mm in the holotype (NIGP172394), and 9.1 mm in NIGP172395, body with tegmina tectiform in repose (Figs. 1A, B, 3A, B). Tegmen length 7.7 mm and width 3.2 mm in the holotype, and 8.7 mm and 3.6 mm in NIGP172395. The following measurements are based on the holotype.
Head (Figs. 2A, B, 4A, B). Head triangular in dorsal view, length about 1.08 mm and width 1.71 mm; vertex with lateral edges slightly sinuous, with several small dark patches, diverging posteriad, expanded above compound eyes, posterior margin slightly concave; disc of frons verrucose, frons with distinct median carina, lateral margins carinate, with several small dark patches; compound eyes bulging, anterior margin nearly at half of head length; postclypeus broken, with median carina present; anteclypeus narrow; rostrum length about 2.06 mm, stylet fascicle slightly longer than labium.
Thorax. Pronotum and mesonotum densely and evenly punctate by remains of sensory pits. Pronotum about 1.6× as wide as head (Figs. 2B, 3C, 4B); anterior margin slightly convex; anterolateral margin carinate, diverging posteriad, with small dark patches; posterolateral margin sinuous; posterior margin concave medially, widely W-shaped; anterior angle obtuse, posterolateral angle less than 90°; both sides declivous; median carinae elevated, reaching anterior and posterior margins of pronotum. Mesonotum (Figs. 2B, 3C, 4B) with doubled median carinae, elevated, diverging posteriad before mesoscutellum; two lateral carinae arcuate; mesoscutellum triangular, transversely wrinkled. Tegula subquadrate. Legs with rows of short bristles along, segments length in mm (femur/tibia/tarsus): prothoracic leg 1.85/1.62/0.55, mesothoracic leg 1.97/2.21/0.53, metathoracic leg 1.62/2.33/1.54; procoxa elongate, cylindrical; protarsus with claw hooked, with tip sharp, longer than arolium (Fig. 2G); mesotarsus with claw relatively large, arolium symmetrical, wide (Figs. 2C, 4C); metatibia distinctly widened apically, with row of five apical teeth (Fig. 4D); metatarsus setose, with basi- and midtarsomere widened apically, with row of five apical teeth, apical tarsomere very thin, with tarsal claw small (Figs. 2D, 4D).
Tegmen (Figs. 1C, 3E, 4E). Length/width ratio about 2.4; filled with meshwork of veinlets, forming irregular polygonal cells and these

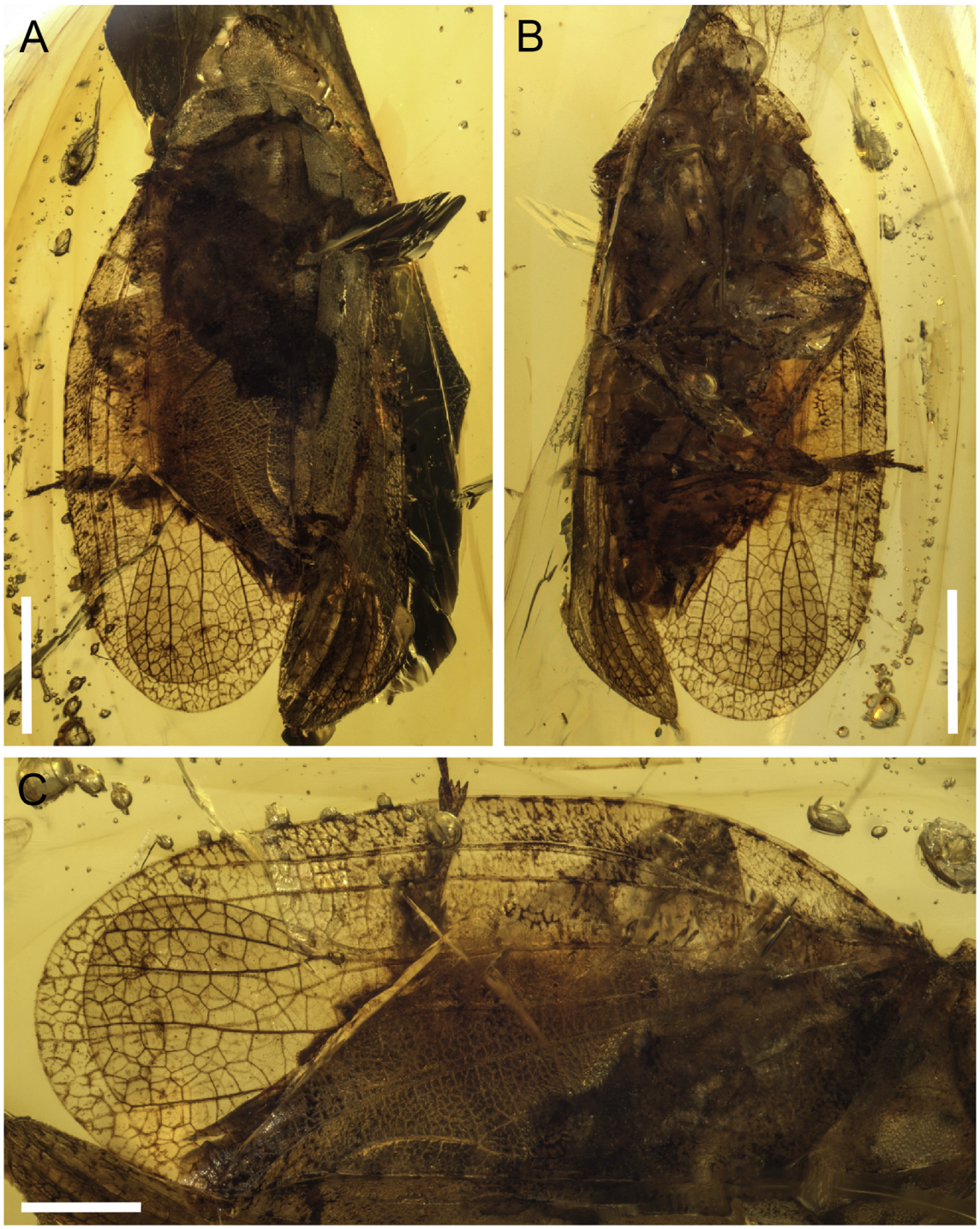

Fig. 1. Photographs of the holotype (NIGP172394) of *Ayaimatum minutum* sp. nov., from the mid-Cretaceous Burmese amber. A. general habitus in dorsal view; B. general habitus in ventral view; C. left tegmen. Scale bars: 2 mm in A, B; 1 mm in C.

polygonal nets become bigger in apical portion of tegmen; with small dark patches along veins; costal margin widely curved at base, then straight; broadest at about half of tegmen length; apical margin rounded; claval margin and posterior margin almost straight; costal area very narrow; postcostal cell narrower than radial cell, apparently wider than cell C1; Pc + CP sub-parallel to costal margin at base, submerged to margin nearly at half of tegmen length; stem MP separating from common stem ScP + R + MP slightly basad of *cua-cup* connection; stem CuA almost straight, forked nearly at half of tegmen length; CuA_1 widely S-shaped, CuA_2 strongly curved at base and approaching claval CuP closely, then slightly sinuous and becoming sub-parallel to CuA_1; CuP almost straight in foreside, then arcuately curved; claval veins Pcu and A1 fused slightly apicad of stem CuA fork; stem Pcu + A1 arcuate, reaching wing-coupling fore fold (WCFF). Hind wing partly visible, membranous, translucent; polygonal nets

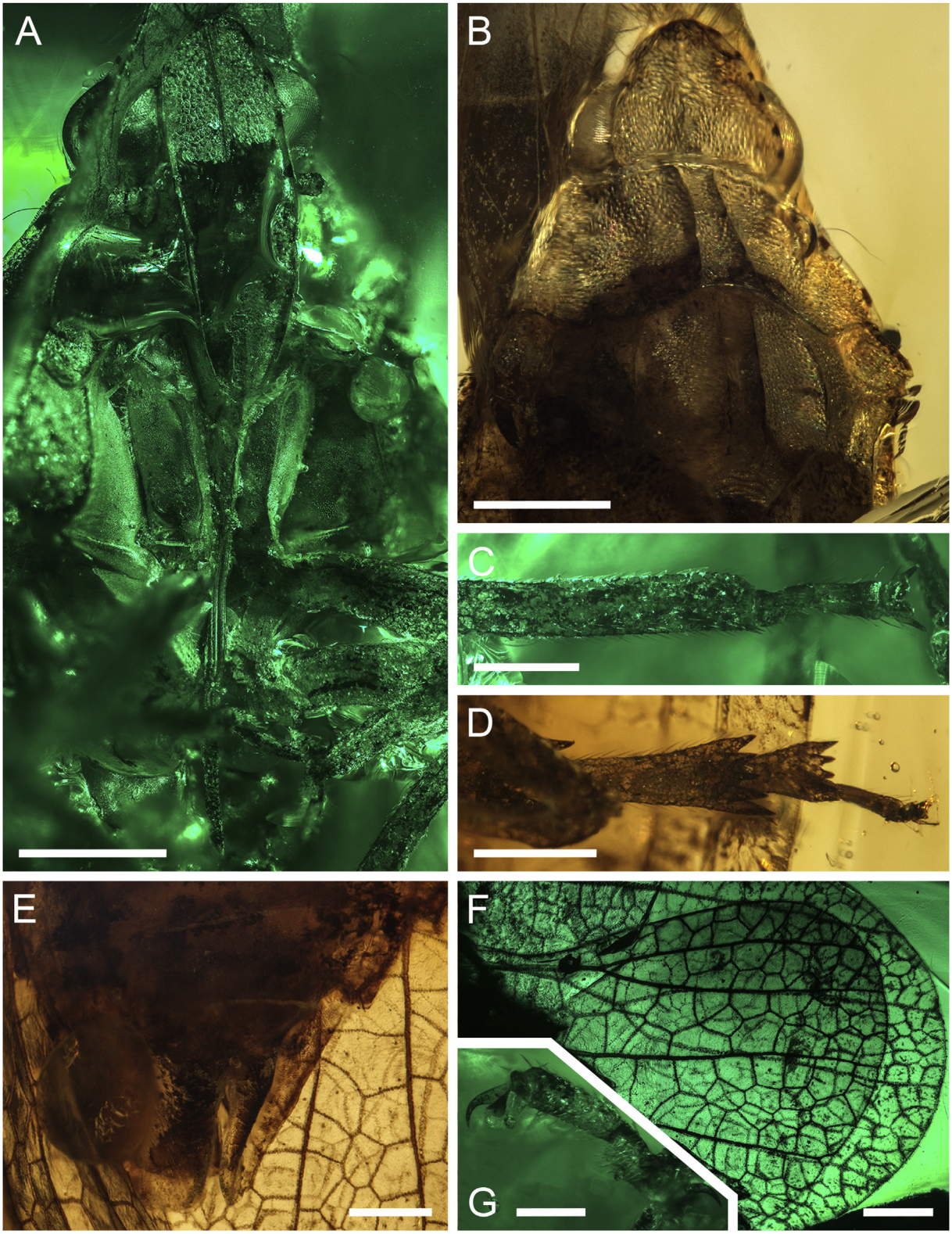

Fig. 2. Enlargements of the holotype of *Ayaimatum minutum* sp. nov. A. head in ventral view, showing compound eyes, clypeus and rostrum, under green fluorescence; B. head, pronotum and mesonotum in dorsal view; C. left mesotibia, mesotarsus, and claw with arolium, under green fluorescence; D. right metatarsus; E. abdomen and terminalia in ventral view; F. hind wing, under green fluorescence; G. protarsus and claw, under green fluorescence. Scale bars: 1 mm in A, B; 0.5 mm in C–F; 0.2 mm in G.

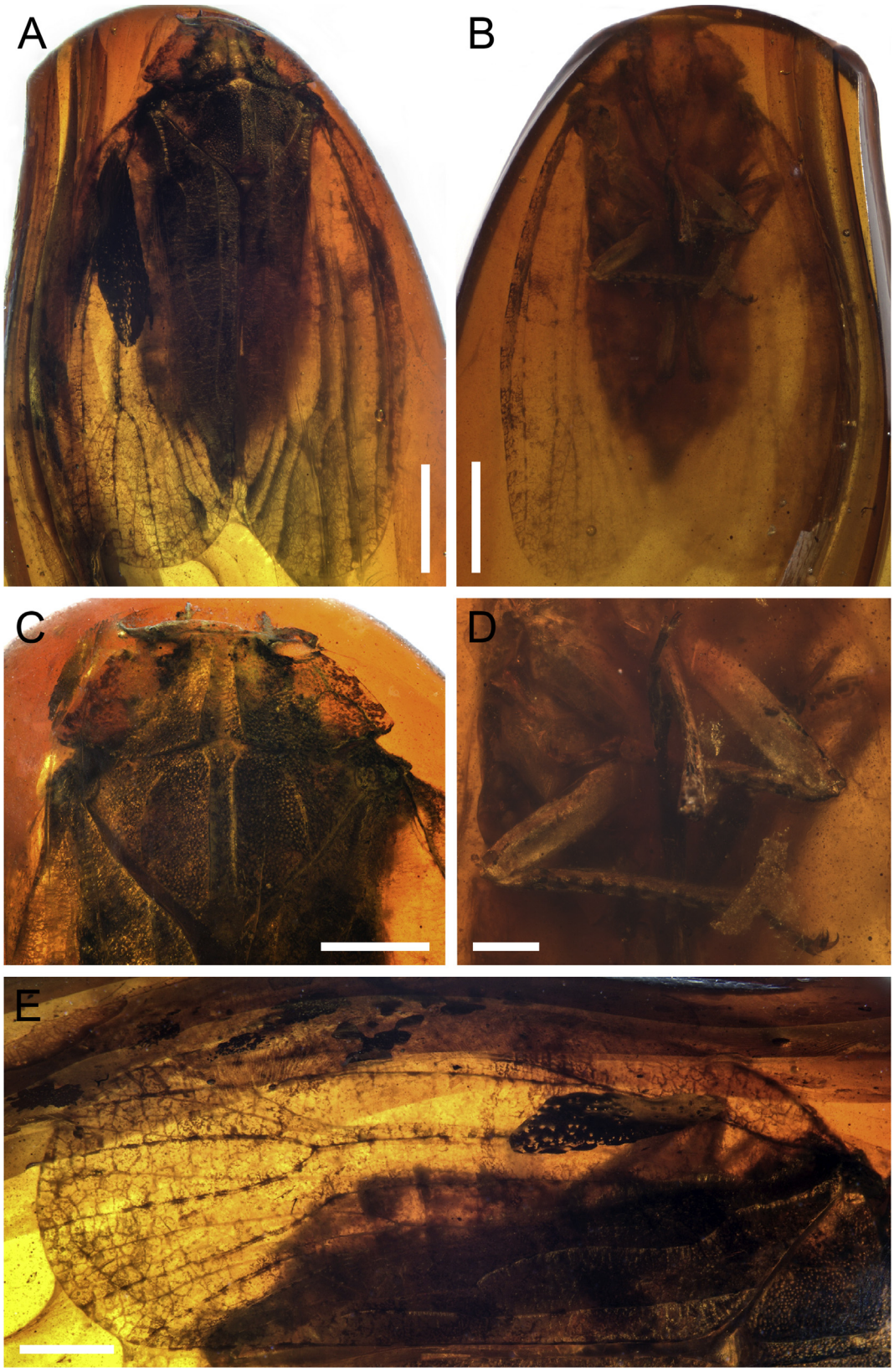

Fig. 3. Photographs of the paratype (NIGP172395) of *Ayaimatum minutum* sp. nov., from the mid-Cretaceous Burmese amber. A. general habitus in dorsal view; B. general habitus in ventral view; C. pronotum and mesonotum; D. legs; E. left tegmen. Scale bars: 2 mm in A, B; 1 mm in C, E; 0.5 mm in E.

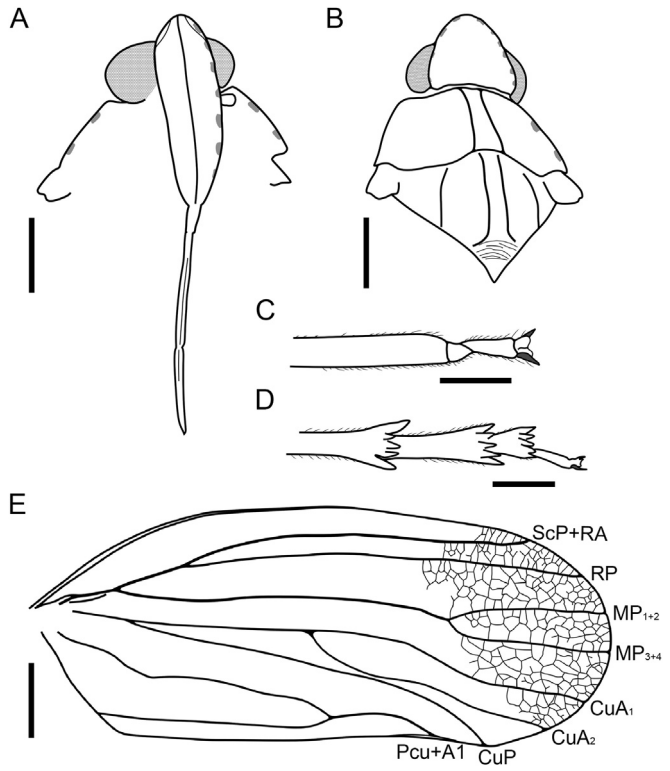

Fig. 4. Line drawings of *Ayaimatum minutum* sp. nov., from Burmese amber. A. head in ventral view, showing compound eyes, clypeus and rostrum; B. head, pronotum and mesonotum in dorsal view; C. mesotibia and mesotarsus; D. metatarsus; E. tegmen. Scale bar: 1 mm in A, B, E; 0.5 mm in C, D.

bigger than tegmen; stem ScP + R sub-parallel to costal margin; stem ScP + R forked apicad of CuA fork; RP unbranched; MP single, almost straight.
Abdomen. Abdomen not reaching tips of tegmina; segment III broadest, wider than thorax. Male terminalia (Fig. 2E) with two symmetrical lobes covering most of genital structures in ventral view; pygofer translucent, with carina in mid line.

Genus ***Mimaeurypterus*** gen. nov.
Zoobank urn:lsid:zoobank.org:act:250D2DF7-EC73-421F-8A91-4117E810341C.
Type species: *Mimaeurypterus burmiticus* gen. et sp. nov.; by original designation and monotypy.

Etymology. The name is derived from family Mimarachnidae, and 'eury' (wide, large), 'pterus' (winged), which indicates the wider wings of this new genus. Gender: masculine.
Diagnosis. Differs from other genera of Mimarachnidae in the following characters: mesonotum developed, with doubled median carinae parallel and close to each other, not reaching anterior margin of mesonotum. Msoscutellum flattened, without distinct wrinkles. Tegmen broad, length/width ratio about 2.1 (as in *Mimaplax*, much slender in other genera); coriaceous (membranous in most genera); anterobasal angle widely rounded; apical margin-truncate, sinuate; postcostal cell wide; common stem ScP + R + MP+(CuA) before separation of MP distinctly shorter than stem ScP + R; RP unbranched; and stem CuA forked deeply, basad of claval veins Pcu and A1 junction.

Mimaeurypterus burmiticus sp. nov.
LSID urn:lsid:zoobank.org:act:22332100-8C4A-4B7E-B321-C2938151D609.
(Fig. 5)

Etymology. The specific epithet refers to the occurrence of the fossil in Burmite (Burmese amber).
Material. Holotype: NIGP173217, head and legs missing, abdomen obscure and gender unknown.
Locality and horizon. Burmese amber, from deposits near the Tanai Village in the Hukawng Valley of northern Myanmar; mid-Cretaceous.
Diagnosis. As for the genus with the following additions: mesonotum with two clusters of densely punctures arranged in elongate-ovate on both sides of median carinae. Tegmen length about 19.6 mm; mosaic, especially medioposterior portion; postcostal cell apparently wider than cell C1 but narrower than radial cell; Pc + CP submerged to margin at about 1/3 of tegmen length; MP with 3 terminal branches; wing-coupling fore fold (WCFF) long; and hind wing with subequal ScP + R and CuA forks.
Description. Pronotum broken, width about 7.7 mm (Fig. 5B). Mesonotum (Fig. 5B) densely punctate by remains of sensory pits, unevenly, with two clusters of bigger punctures arranged in elongate-ovate on both sides of median carinae; median carinae doubled, straight, diverging posteriad before mesoscutellum; lateral carinae arcuate, faint before converging anteriad with median carinae; large fossae oval present, between median carinae and lateral carinae. Mesoscutellum triangular, flattened, without distinct transverse wrinkles.
Tegmen (Figs. 5C, D) length about 19.6 mm and width 9.3 mm; filled with meshwork of veinlets, forming extremely small irregular polygonal cells; costal margin strongly arched at base, then straight; apical margin obliquely truncate slightly, not smooth; tornus merely convex; claval margin and posterior margin almost straight; Pc + CP submerged to margin nearly at 1/3 of tegmen length; stem ScP + R almost straight, forking into ScP + RA and RP at basal 0.27 of tegmen length; stem MP separating from common stem ScP + R + MP slightly basad of *cua-cup* connection; MP_{1+2} single, MP_{3+4} with two branches; stem CuA forked nearly at 1/3 of tegmen length, apicad of ScP + R fork; CuA_1 sinuous, CuA_2 strongly curved at base and approaching claval CuP closely; claval veins Pcu and A1 fused apicad of stem CuA fork; free portion of A1 about 2.5× as long as claval stalk Pcu + A1; stem Pcu + A1 reaching mid-point of wing-coupling fore fold (WCFF); WCFF length about 6.5 mm.
Hind wing membranous, translucent (Figs. 5A, E); shorter than tegmen; polygonal nets apparently bigger than tegmen; coupling lobe slightly apicad of wing mid-length; stem ScP + R sub-parallel and very close to costal margin, forked nearly at level of coupling lobe; ScP + RA, RP and MP unbranched; stem CuA forked nearly at level of stem ScP + R; CuP almost straight, Pcu arcuate; A1 and A2 slightly sinuous.

4. Discussion

The mid-Cretaceous Burmese amber harbours recognized as one of the most diverse Mesozoic palaeobiota, providing a valuable opportunity to explore the highly diverse insect assemblage and the evolution of Mesozoic insects (Cruickshank and Ko, 2003; Ross, 2019, 2020). Among all the burmite bioinclusions, several fossil planthoppers have been reported, including two extant families (Cixiidae and Achilidae) and six extinct ones (Perforissidae, Mimarachnidae, Dorytocidae, Jubisentidae, Yetkhatidae, and Katlasidae) (Ross, 2020; Bourgoin, 2020). In recent three years, six genera and ten species of Mimarachnidae have been reported in Burmese amber (Shcherbakov, 2017; Zhang et al., 2018; Jiang et al., 2018, 2019, 2020; Fu et al., 2019; Fu and Huang, 2020; Luo et al., 2020b).
Head and thorax provide some crucial traits for generic level classification within Mimarachnidae but only five genera (*Burmissus*, *Jaculistilus*, *Mimaplax*, *Cretodorus*, and *Ayaimatum*) from

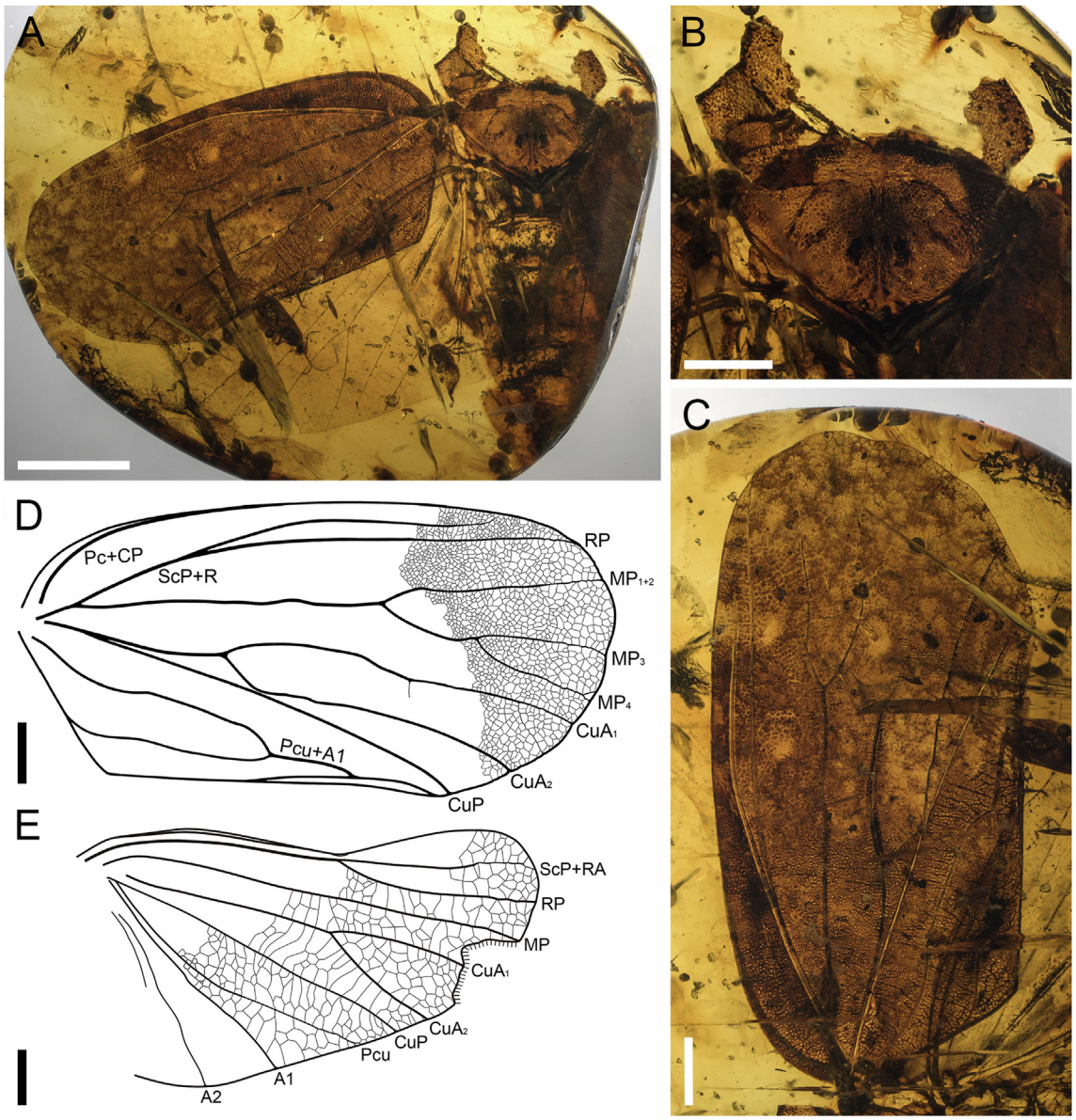

Fig. 5. Photographs of the holotype (NIGP173217) of *Mimaeurypterus burmiticus* gen. et sp. nov., from the mid-Cretaceous Burmese amber. A. general habitus; B. pronotum and mesonotum; C. tegmen; D. line drawing of tegmen; E. line drawing of hind wing. Scale bar: 5 mm in A; 2 mm in B–E.

Burmese amber preserved nearly complete head structure as well as weakly preserved in *Chalicoridulum* from Spain, which caused some difficulties in taxonomy within this extinct family (Fu et al., 2019). *Ayaimatum* possesses a head without distinct protuberance, with lateral edges expanded above compound eyes, anterior margin of compound eyes nearly at half of head length, and moderate rostrum, which are morphologically similar to *Mimaplax* but remarkably differs from *Burmissus*, *Jaculistilus*, and *Cretodorus*. *Ayaimatum* shows that pronotum structure distinguished from other known members of mimarachnids as follow: anterior margin smoothly convex (acutely convex in *Jaculistilus* and *Cretodorus*, W-shaped in *Mimaplax*); posterior margin widely W-shaped (almost straight in *Dachibangus*); doubled median carinae throughout (anterior portion separated from posterior by arcuate furrow, median carina single, not reaching anterior margin in *Dachibangus*), cristated (as in *Mimaplax* and *Cretodorus*, no such uplifted in other genera), completely independent (fused medially, Y-shaped in *Jaculistilus*); and lateral carina absent (two lateral carinae present in *Burmissus*, *Jaculistilus*, and *Cretodorus*).

The two individuals of *Ayaimatum minutum* sp. nov. described herein on the basis of two specimens from Burmese amber show high intraspecific variations on tegminal venation as follows: 1) stem ScP + RA about 4.5× longer than ScP + R in the holotype, but ScP + RA 2.9× longer than ScP + R in NIGP172395; 2) MP forked at basal 0.72 of tegmen length in the holotype, but 0.65 in NIGP172395; and 3) the free portion of A1 about 2.7× longer than claval stalk Pcu + A1 in the holotype, but only 1.3× longer than claval stalk Pcu + A1 in NIGP172395. Therefore, it is not appropriate to erect new taxa of mimarachnid based on a few slight relative bifurcating position of tegminal venation, especeilly veins R and MP.

Mimaeurypterus gen. nov. described herein from Burmese amber belongs to Mimarachnidae based on the following easily identified characters: mesonotum with doubled median carinae, wings with simplified venation and abundant irregular meshwork of veinlets, tegmen with weakened basal cell, deeply forked stem ScP + R and less deeply forked stem CuA (Shcherbakov, 2007b; Szwedo and Ansorge, 2015). The new genus clearly possesses the

mesonotum with median carinae not reaching anterior margin, which is an important diagnostic differs from all other described mimarachnids except *Chalicoridulum* Szwedo et Ansorge, 2015 from the Lower Cretaceous of Spain. Msoscutellum without distinct wrinkles appears to be unique within Mimarachnidae. *Mimaeurypterus* possesses the broad tegmen with length/width ratio about 2.1, which is more similar to *Mimaplax* (Jiang et al., 2019). It shares a similar venation pattern with *Chalicoridulum*, *Mimaplax*, and *Ayaimatum*, including ScP + RA and RP unbranched, MP with 2–3 terminal branches, and CuA deeply forked, basad of claval veins Pcu and A1 junction (Szwedo and Ansorge, 2015; Jiang et al., 2019, 2020). However, *Mimaeurypterus* can be differentiated from these genera by its larger size, coriaceous tegmen (membranous in *Chalicoridulum*, *Mimaplax*, and *Ayaimatum*), and apical margin of tegmen is truncate and sinuate (rounded apical margin in *Chalicoridulum*, *Mimaplax*, and *Ayaimatum*). Given all traits discussed above, we conclude that *Mimaeurypterus* constitutes a new genus of Mimarachnidae.

5. Concluding remarks

The diversity of fossil mimarachnids is gradually increasing in recent five years. Fourteen species ascribed to ten genera have been attributed to Mimarachnidae from theCretaceous in Russia, Spain, Japan, and Myanmar. *Ayaimatum minutum* sp. nov. is described in mid-Cretaceous amber of northern Myanmar, representing the second species of *Ayaimatum*, bearing considerable intraspecific variation on bifurcating position of tegminal venation. As the seventh mimarachnid reported from Burmese amber, *Mimaeurypterus* gen. nov. displays peculiar morphology of its mesonotum structure and tegmina shape, adding valuable information about the morphological disparity of this extinct family. Further phylogenetic studies will be necessary to elucidate the internal relationships within Mimarachnidae.

Acknowledgments

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