

Short communication

Revision of the genus *Jiaotouia* (Hemiptera, Cercopoidea) with description of a new species from mid-Cretaceous Burmese amberYanzhe Fu ^{a, b}, Diying Huang ^{a, *}^a State Key Laboratory of Palaeobiology and Stratigraphy, Center for Excellence in Life and Palaeoenvironment, Nanjing Institute of Geology and Palaeontology, Chinese Academy of Sciences, Nanjing 210008, China^b University of Chinese Academy of Science, Beijing 100049, China

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ABSTRACT

The extinct froghopper family Sinoalidae is the most diverse amongst the infraorder Cicadomorpha at generic level in the mid-Cretaceous amber of northern Myanmar. Here we describe and illustrate a new species of Sinoalidae, *Jiaotouia burmitica* sp. nov. from Burmese amber, representing the second species of *Jiaotouia* Chen and Wang, 2019, adding new information on morphological diversity of this genus. The new taxon can be distinguished from the type species by its narrowed anteclypeus, antenna with flagellomere 1 and apical tarsomere of metatarsus elongate, tegmen in having the cross vein mp-cua well-developed rather than replaced with anastomosis. *Jiaotouia* is emended and provided detailed morphological characters of *J. minuta* on the basis of two well-preserved specimens from Burmese amber, and the intra-specific variation of *J. minuta* is discussed.

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1. Introduction

The Mesozoic froghoppers include three known extinct families: Procercopidae Handlirsch, 1906–1908 is accepted as an ancestral group of modern froghoppers, widely distributed in the Early Jurassic through the mid-Cretaceous of Eurasia (Chen et al., 2020a; Fu et al., 2020a); Cercopionidae Hamilton, 1990 with a sole genus and species confined to the Early Cretaceous of Brazil; and Sinoalidae Wang and Szewo, 2012, comprising 17 genera and 24 extinct species attributed into two subfamilies (i.e., Sinoalinae Wang and Szewo, 2012 with two tribes, and Chen et al., 2019a, occurring from the Middle Jurassic to the earliest Late Jurassic Yanliao biota of northeastern China and the mid-Cretaceous amber of northern Myanmar (Chen et al., 2019a,b,c,d,e, 2020b; Fu and Huang, 2019a,b,c,d).

As one of the early representatives of Cercopoidea, Sinoalidae is closely related to Jurassic Procercopidae and also shares some plesiomorphic characters with ancestral group Hyliculoidea (Wang et al., 2012; Chen et al., 2019a, 2020a). It was originally established by Wang and Szewo (2012) with 5 genera and 6 species from the

Middle–Upper Jurassic Jiulongshan (= Longmen) and Haifanggou formations of the Yanliao region, northeastern China. Subsequently, 4 genera and 8 species were assigned to Sinoalidae over the past three years, enriching the known palaeodiversity of Sinoalidae to 9 genera and 14 species in Yanliao biota (Chen et al., 2017, 2019a; Fu et al., 2018; Fu and Huang, 2018, 2019a, b, d). The first sinoalid froghopper from the mid-Cretaceous Burmese amber, *Fangyuania xiai* Chen, Szewo and Wang, 2018, was reported by Chen et al. (2018) on the basis of a complete male adult specimen, greatly widening the duration and biogeographic distribution of this extinct family (Chen et al., 2018). Subsequently, additional 8 genera and 10 species have been recently described from Burmese amber within two years: *Jiaotouia minuta* Chen et al., 2019b, *Ornatiala amoena* Chen et al., 2019c, *O. kachinensis* Chen, Zheng, Wei and Wang, 2020, *Cretadorus orientalis* Chen et al., 2019d, *Paraornatiala daidaleos* Fu and Huang, 2019d; *Cretosinoala tetraspina* Fu and Huang, 2019d, *Mesolongicapitis peii* Chen et al., 2019e, *Electrala muae* Chen et al., 2020b, *Makrosala elegans* Chen et al., 2020f, and *M. venusta* Chen et al., 2020f.

Here we report a new species of Sinoalidae, *Jiaotouia burmitica* sp. nov., from the mid-Cretaceous Burmese amber, and the morphological details of *Jiaotouia minuta* are supplemented.

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2. Material and methods

Two new specimens of *Jiaotouia minuta* (NIGP171739 and NIGP173213) are preserved in two pieces of transparent yellowish ambers, and the holotype of *Jiaotouia burmitica* (NIGP171740) is described based on a single specimen, persevered in a piece of relatively opaque, orange amber. All of the material originates from the Hukawng Valley of Kachin in North Myanmar (locality as indicated in Yin et al., 2018: fig. 1A). The age of the Burmese amber was generally assigned to be around the Albian–Cenomanian boundary (Cruikshank and Ko, 2003; Grimaldi et al., 2005; Shi et al., 2012; Rasnitsyn et al., 2016; Mao et al., 2018; Smith and Ross, 2018).

The amber pieces containing inclusions were cut, shaped, and polished manually, as described in Azar et al. (2003) and Sidorchuk and Vorontsov (2018). Photographs were taken with a Zeiss Axio-Zoom V16 stereoscope and a Zeiss AXIO Imager Z2 compound microscope (green fluorescence). Line drawings were drafted with Adobe Illustrator CC 2018. Helicon Focus 6 and Photoshop CS6 software packages were used for staking and processing the different photographs.

Wing venation terminology and cell nomenclature followed Nel et al. (2012) and Bourgoïn et al. (2015). All measurements are in millimeter. The nomenclatural acts established herein are registered under Zoo-Bank LSID urn:lsid:zoobank.org:pub:4DB8D720-BD1D-47DD-A7C5-4060625459DA.

3. Systematic palaeontology

Superfamily: Cercopoidea Leach, 1815

Family: Sinoalidae Wang and Szwedo, 2012

Subfamily Sinoalinae Wang and Szwedo, 2012

Tribe Fangyuaniini Chen and Wang, 2019

Genus: *Jiaotouia* Chen and Wang, 2019

Type species: *Jiaotouia minuta*; by original designation and monotypy.

Diagnosis (revised after Chen and Wang, 2019). Head triangular, wider than 2/3 the width of pronotum; crown with anterior margin angled in middle, coronal margin not expanded before compound eyes; compound eyes somewhat drop-shaped in dorsal view with anterior margin sharp; antennae 8-segmented (6 flagellomeres). Pronotum shortened. Metatibia with two rows of three lateral spines: single lateral anteroventral spine nearly at half of metatibia length, and two lateral anterodorsal spines in row at 0.1–0.15 and half of metatibia length respectively. Tegmen with apex sharp and appendix narrow; vein Pc+CP extending to apex, forming ambient vein; stem ScP+R+MP+CuA forking into ScP+R and MP+CuA at basal 0.3 of tegmen length, stem MP+CuA extremely short; stem ScP+R forked beyond midpoint of tegmen length. Hind wing with stem R long.

Jiaotouia minuta Chen et al., 2019b

Figs. 1–3, 6A

Material. NIGP171739 and NIGP173213 deposited in the Nanjing Institute of Geology and Palaeontology, Chinese Academy of Sciences, Nanjing, China.

Locality and horizon. Amber mine located near Noije Bum Village, Tanai Township, Myitkyina District, Kachin State, northern Myanmar; mid-Cretaceous.

Diagnosis (revised after Chen and Wang, 2019). Antenna with flagellomere 1 extremely short (ratio of flagellomere 1/flagellomere 2 length: 0.58:1); anteclypeus bulging, oval, with length/width ratio 1.5; tegmen with stem ScP+R 1.1–1.5× as long as ScP+RA;

CuA₁ strongly arched basally or medially, connected to MP₃₊₄ by fusing into a common portion instead of cross vein mp-cua; cell C4 nearly as long as C3'.

Supplemental description. Total length (including wings in repose) ca. 5.34 mm in NIGP171739 (Figs. 1A, B), and 5.86 mm in NIGP173213 (Fig. 3). The following measurements are mainly based on NIGP171739.

Head (Fig. 2A). Head with length/width ratio about 0.78; antenna length 0.65 mm, scape large, much thicker than pedicel, flagellum 6-segmented, length (in μm): 46.5/80.6/74.4/86.8/82.2/130.2, together about 0.50 mm long, flagellomeres 1 to 6 becoming progressively thinner (Figs. 2B, C).

Thorax. Pronotum about 1.35× as wide as head, with length/width ratio 0.32 (Fig. 2A). Metafemur with distinct ridge apically. Metatibia armed with three spines arranged in two rows (Figs. 2D, E, G), lateral margin of spines denticulate, with subapical seta (Figs. 2G, J): anteroventral lateral spine single, length 0.24–0.25 mm, nearly at half of metatibia length, basal anterodorsal lateral spine 0.26–0.28 mm at 1/7 of metatibia length, and apical one 0.23–0.28 mm at half of metatibia length; densely covered with setae, longer and denser along posterior than in centre and anterior; widened apically, armed with two rows of apical teeth: 7 teeth of basal row with setae short or even absent, and 8 teeth of apical row with long and thick subapical setae (Figs. 2E, I). Metatarsus setose, tarsomeres length (in mm): 0.26/0.12/0.15, basi- and midtarsomere not widened apically, armed with apical setae (Figs. 2D, G). Claw hooked, sharp apically, longer than arolium (Fig. 2H).

Tegmen. Length 4.05 mm and width 1.45 mm (Figs. 1C, 6A); costal margin and claval margin smoothly arched, widest nearly at half of tegmen length; anteroapical angle wide, placed apical of poster-oapical angle; apex of tegmen sharp, concave near MP₃₊₄ terminal; ScP fused with stem R+MP+CuA at basal 0.30 of basal cell length; stem ScP+R+MP+CuA slightly sinuous; basal cell with length 0.31 of tegmen length, narrow, almost 10.0× as long as wide, in apical portion acute; basal cross vein cua-cup distinctly curved; stem ScP+R leaving basal call basad of stem MP+CuA; stem ScP+R forked at basal 0.54 of tegmen length; RA₂ about 2.5× as long as ScP+RA₁; stem MP straight, forked slightly apical of CuA fork; MP₃₊₄ fused with CuA₁ by a common stalk; CuP sub-parallel to Pcu, strongly curved apically; A1 slightly sinuous.

Abdomen. Abdomen narrower than thorax, lateral margin with distinctly acute apex (Fig. 2F); pygofer long; ovipositor 0.98 mm long, ensiform, setiferous, not extending to tips of tegmina.

Jiaotouia burmitica sp. nov.

Figs. 4–5, 6B

Etymology. The specific epithet refers to the occurrence of the fossil in Burmite (Burmese amber). The species is registered under LSID urn:lsid:zoobank.org:act:759FD764-46FF-49C7-BF3F-72EE8F83496B.

Holotype. NIGP171740, adult, gender unknown; deposited in the Nanjing Institute of Geology and Palaeontology, Chinese Academy of Sciences, Nanjing, China.

Locality and horizon. Amber mine located near Noije Bum Village, Tanai Township, Myitkyina District, Kachin State, northern Myanmar; mid-Cretaceous.

Diagnosis. The species is characterized by the type species by following characters: antenna with flagellomere 1 nearly as long as flagellomere 2; anteclypeus narrow, with length/width ratio 2.3; tegmen with stem ScP+R almost 1.8× as long as ScP+RA; cross vein mp-cua well-developed, not replaced with anastomosis; cell C4 apparently longer and wider than C3'.

Description. Total length (including wings in repose) ca. 6.18 mm (Figs. 4A, B).

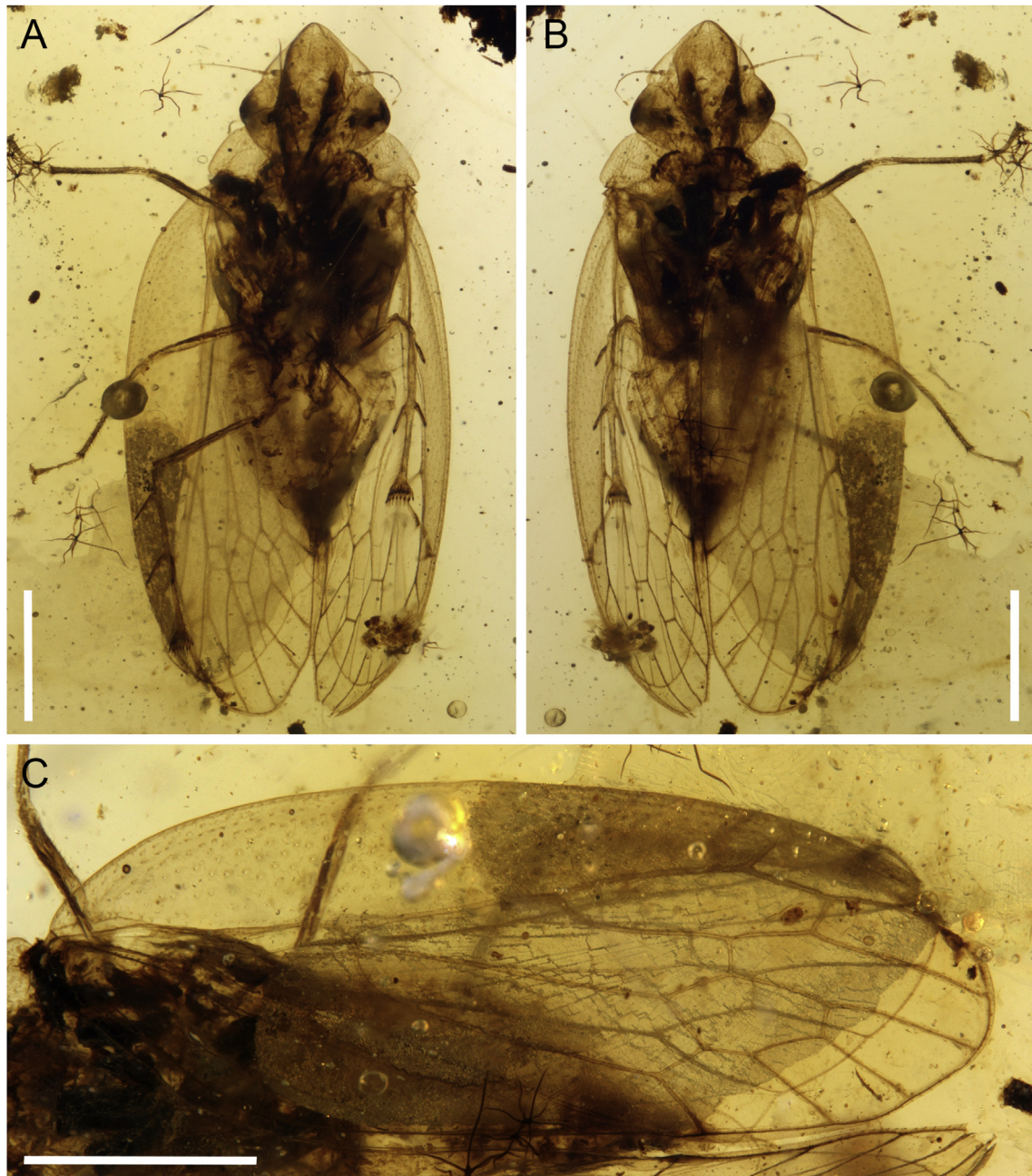


Fig. 1. Photographs of *Jiaotouia minuta* (NIGP171739). A. general habitus in ventral view; B. general habitus in dorsal view. C. forewing. Scale bar: 1 mm.

Head (Figs 5A, B). Head triangular in dorsal view, length 1.13 mm and width 0.89 mm; crown produced anteriorly; compound eyes drop-shaped; three ocelli between compound eyes, arranged in triangle, median ocellus oblong, two lateral ocelli globular; antenna with scape and pedicel much thicker than flagellum, flagellum 6-segmented, length 0.53 mm, flagellomeres 1–6 becoming progressively thinner (Figs. 5D, E); postclypeus widest near middle, with median longitudinal carina and transverse grooves, length 0.93 mm and width 0.41 mm; anteclypeus narrow, length 0.40 mm and width 0.13 mm, with a median longitudinal carina (Fig. 5C); rostrum very short, length 0.25 mm, not extending to mesocoxa; stylet fascicle slightly longer than labium.

Thorax (Fig. 5B). Pronotum length 0.56 mm and width 1.58 mm, almost 1.4× as wide as head; widest at posterolateral angle,

anterior margin sinuous, posterior margin smoothly concave medially, shorter in midline than at lateral margin. Mesonotum slightly wider than head. Leg segments length in mm (femur/tibia/tarsus): prothoracic leg 0.61/0.67/0.39, mesothoracic leg 0.78–0.81/0.94–0.98/0.31–0.36, metathoracic leg 0.84/1.35/0.57; procoxa cylindrical, thicker than mesocoxa and metacoxa; protrochanter slightly longer than meso- and metatrochanter; protarsus setose, tarsomeres length (in mm): 0.17/0.10/0.12, with tarsal claw hooked, sharp apically (Fig. 5F); metafemur with distinct ridge apically (Fig. 5G); three spines arranged in two rows on metatibia (Fig. 5F), spine with subapical seta: anteroventral lateral spine single, length 0.18 mm nearly at half of metatibia length, basal anterodorsal lateral spine 0.09 mm at 1/10 of metatibia length, and apical one 0.15 mm at half of metatibia length, widened apically,

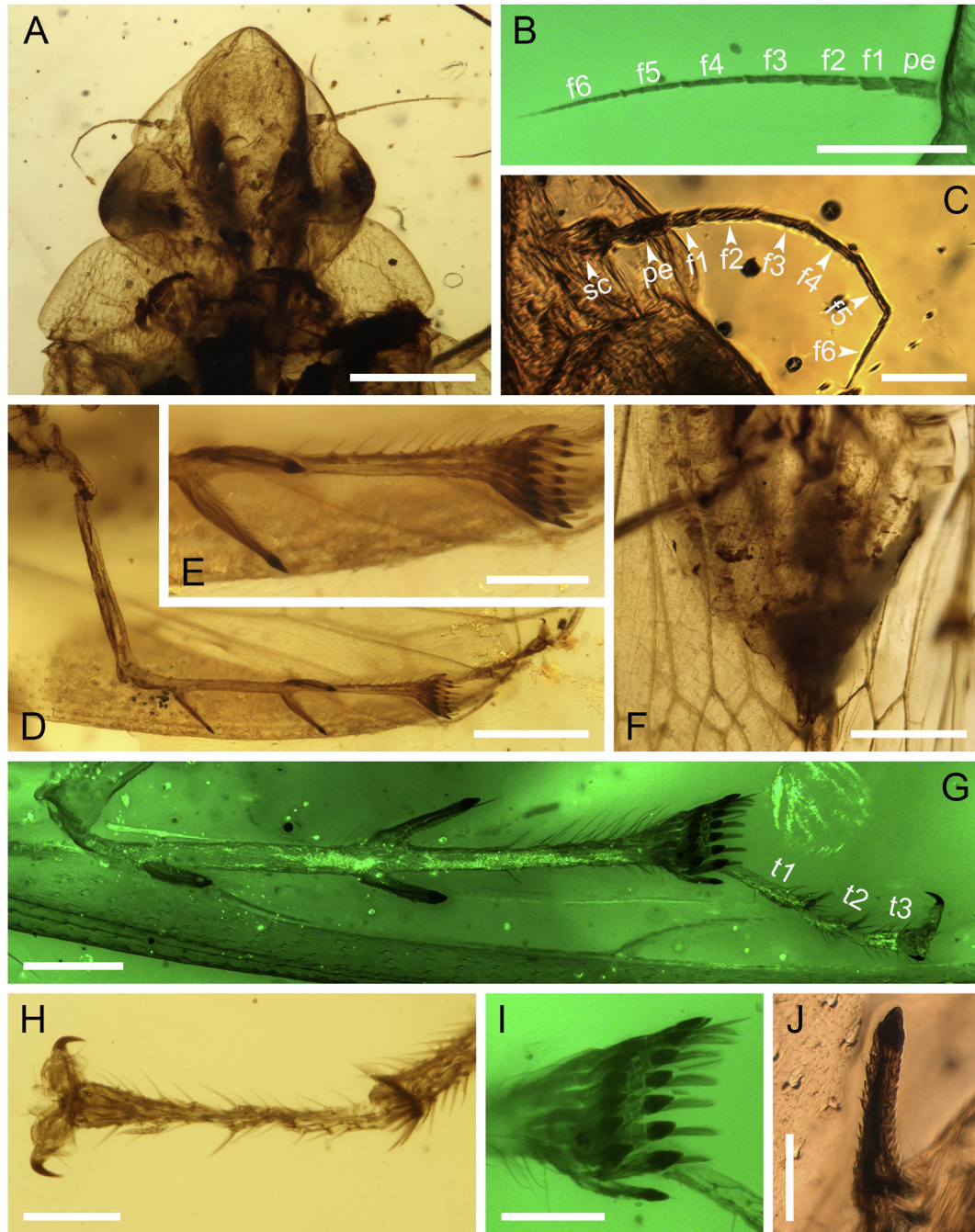


Fig. 2. Enlargements of *Jiaotouia minuta* (NIGP171739). A. head and pronotum; B. **left** antenna, under green fluorescence; C. **right** antenna; D. metathoracic leg; E. enlargement of D, showing details of spines and apical teeth on metatibia; F. abdomen; G. metatibia and metatarsus, under green fluorescence; H. mesotarsus; I. enlargement of G, showing details of apical teeth on metatibia, under green fluorescence; J. spine on metatibia. Abbreviations: sc, scape; pe, pedicel; f1–6, flagellum 1–6; t1–3, tarsomere 1–3. Scale bars: 0.5 mm in A, D, F; 0.2 mm in B, E, G; 0.1 mm in C, H–J.

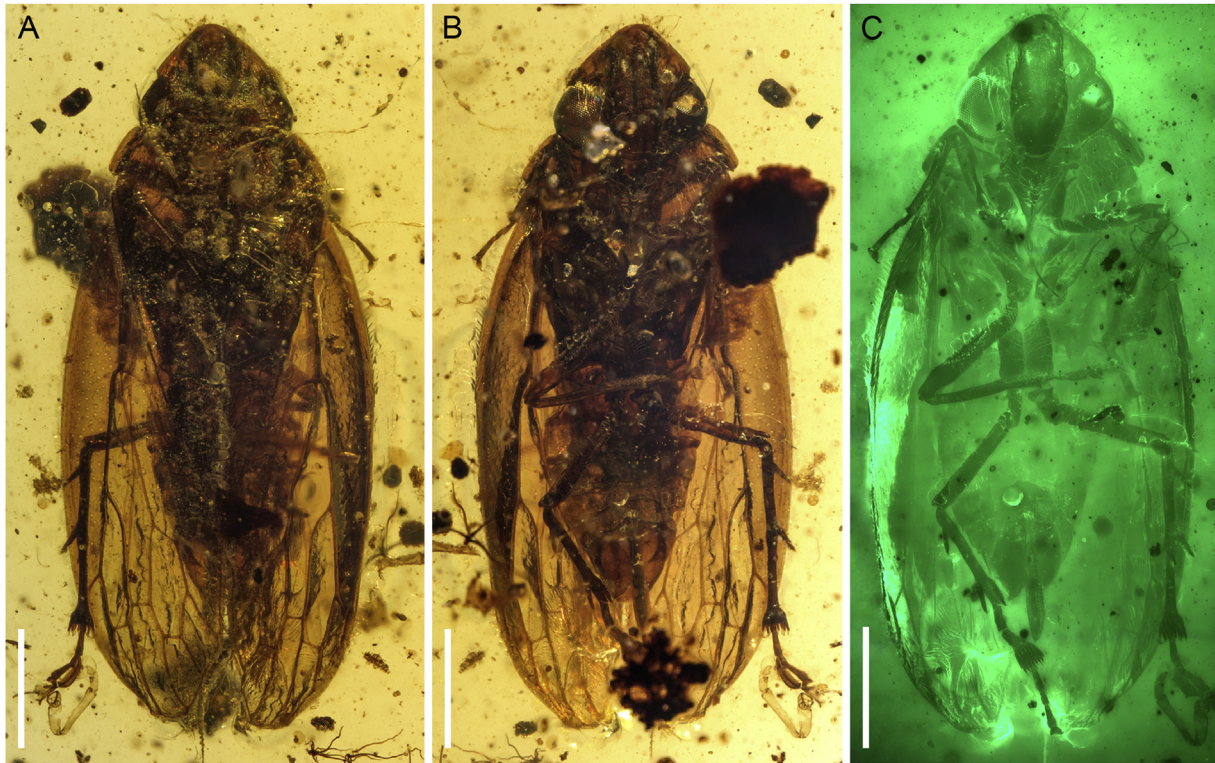


Fig. 3. General habitus of *Jiaotouia minuta* (NIGP173213). A. dorsal view; B. ventral view, under normal reflected light; C. ventral view, under green fluorescence. Scale bar: 1 mm.

with two rows of apical teeth, basal row obscure, 8 teeth of apical row with long and thick subapical setae; metatarsus with tarsomeres length (in mm): 0.25/0.13/0.19, basi- and midtarsomere not widened apically, armed with apical setae (Fig. 5F).

Tegmen (Figs. 4C, 6B). Length 4.43 mm and width 1.42 mm, ratio 3.1; costal area and clavus punctate and sclerotized; costal margin distinctly arcuate at base then less curved; claval margin smoothly arched; posterior margin nearly straight; apex of tegmen sharp, distinct concave near terminal MP_{3+4} ; ScP fused with stem $R+MP+CuA$ at basal 0.31 of basal cell length; $Pc+CP$ extending to terminal CuA_2 as ambient vein; stem $ScP+R+MP+CuA$ straight; basal cell with length 0.27 of tegmen length, narrow, almost $11.0\times$ as long as wide; basal cross vein cua-cup slightly sinuous, sub-parallel to stem $ScP+R+MP+CuA$, connected to stem $MP+CuA$ at its bifurcation; stem $ScP+R$ leaving basal call basad of stem $MP+CuA$, forked slightly basad of CuA fork; RA_2 about $2.7\times$ as long as $ScP+RA_1$; RP sinuous; stem MP forked distinctly apicad of CuA fork; stem CuA strongly curved at base, forking into CuA_1 and CuA_2 basad of claval apex; CuA_1 smoothly arched medially, about $2.3\times$ as long as CuA_2 ; CuP straight; Pcu slightly curved apically; A_1 simple; cell C_3 length 0.65 mm and width 0.23 mm, cell C_3' slightly longer than C_3 , cell C_4 about $1.4\times$ as long as C_3 , distinctly wider than C_3' . **Abdomen.** Abdomen tapered, obscure, apparently narrower than pronotum.

4. Discussion

The number of described species of the infraorder Cicadomorpha in the mid-Cretaceous amber of Myanmar has enriched to 20 valid genera ascribed to 6 families lately (incl., Tettigarctidae, Cicadellidae, Archijassidae, Sinoalidae, Proceropidae and Minlagerrontidae) (Fu and Huang, 2019d; Jiang et al., 2019; Ross, 2019; Wang et al., 2019; Chen et al., 2018, 2019b,c,d,e,f,g, 2020b,c,d,e,f,g;

Fu et al., 2019a, 2020a, b). With 9 genera and 11 species have been reported, the sinoalid froghoppers become the most diverse cicadomorphan group at the generic level in Burmese amber, and also showed high disparity morphological and ecological diversification in mid-Cretaceous (Fu and Huang, 2019d; Chen et al., 2019c, 2020b). However, its diversity in Burmese amber seems to be underestimated.

Jiaotouia minuta was reported in Burmese amber by Chen and Wang (2019) on the basis of a single specimen with abdomen not preserved and gender unknown (Chen et al., 2019b). Herein we provide more detailed morphological characters of *J. minuta* based on two well-preserved amber specimens from Myanmar: antennae 8-segmented (6 flagellomeres) instead of 7-segmented (5 flagellomeres) in the holotype of *J. minuta*; denticulate spines on metatibia, with subapical seta; apical metatibia armed with 7 teeth in basal row and 8 teeth in apical row; metatarsus with basi- and midtarsomere not distinctly widened apically, armed with apical setae instead of teeth.

Intraspecific variation of venation has been generally recorded in Sinoalidae such as *Stictocercopis* Fu and Huang, 2018, *Juroala* Chen and Wang, 2019, *Fangyuania* Chen, Szwedlo and Wang, 2018 etc (Fu and Huang, 2018, 2019a; Chen et al., 2019a, e). The three individuals of *J. minuta* also show considerable intraspecific variations as follows: 1) head, pronotum and tegmen with length/width ratio 0.60/0.23/3.0 in the holotype of Chen et al. (2019b), 0.64/0.34/3.3 in NIGP173213, and 0.78/0.32/2.8 in NIGP171739; 2) stem $ScP+R$ about $1.4\text{--}1.5\times$ as long as $ScP+RA$ in the holotype and NIGP173213, and RA_2 about $4.2\times$ as long as $ScP+RA_1$ in the holotype, whereas $ScP+R$ about $1.1\times$ as long as $ScP+RA$, and RA_2 $2.5\times$ as long as $ScP+RA_1$ in NIGP171739; 3) CuA_2 about $4.3\times$ as long as common stalk of MP_{3+4} and CuA_1 in the holotype, $1.5\times$ in NIGP171739, whereas CuA_2 nearly as long as common stalk of MP_{3+4} and CuA_1 in NIGP173213; 4) cell C_3' about $1.3\times$ as long as C_3 in the holotype, $1.5\times$ in NIGP173213, whereas C_3' nearly as long as C_3 in



Fig. 4. Photographs of the holotype (NIGP171740) of *Jiaotouia burmitica* sp. nov. A. general habitus in ventral view; B. general habitus in dorsal view. C. forewing. Scale bar: 1 mm.

NIGP171739. The length/width ratio is highly variable probably because of the difference of three-dimensional angle and taphonomic deformation of amber. Considering the same locality, identical size, venation and body structures, it is reasonable to assign these specimens to the same species.

Jiaotouia burmitica sp. nov. described herein from the same Burmese amber, sharing limited number of morphological differences with the type species *J. minuta*. It can be placed in *Jiaotouia* based on a series of characters: head triangular, compound eyes drop-shaped, pronotum shortened, tegmen with apex sharp, vein Pc+CP extending to terminal CuA₂, and stem ScP+R forked beyond midpoint of tegmen length. However, the new species differs from *J. minuta* in the following characters: 1) antenna with flagellomere 1 relatively long, nearly as long as flagellomere 2 (flagellomere 2 about 1.7× as long as flagellomere 1 in *J. minuta*); 2) anteclypeus

narrow, with length/width ratio 2.3 (anteclypeus bulging, with length/width ratio 1.5 in *J. minuta*); 3) metatarsus with basitarsomere almost 1.3× as long as apical tarsomere (basitarsomere elongate, about 1.5–1.7× as long as apical tarsomere in *J. minuta*); 4) tegmen with stem ScP+R much longer than ScP+RA (ScP+R relatively short in *J. minuta*); and 5) cross vein mp-cua long (CuA₁ fused with MP₃₊₄ by a common stalk, cross vein mp-cua absent in *J. minuta*). All above information of difference characteristics between two species of *Jiaotouia* suggest that MP₃₊₄ connected to CuA₁ by fusing into a common portion and metatarsus with basitarsomere much longer than apical tarsomere should not be regarded as the diagnostic characters at the generic level. Therefore, we present a revised diagnosis for *Jiaotouia*, contributing information about further phylogenetic studies of this highly diverse hemipteran family.

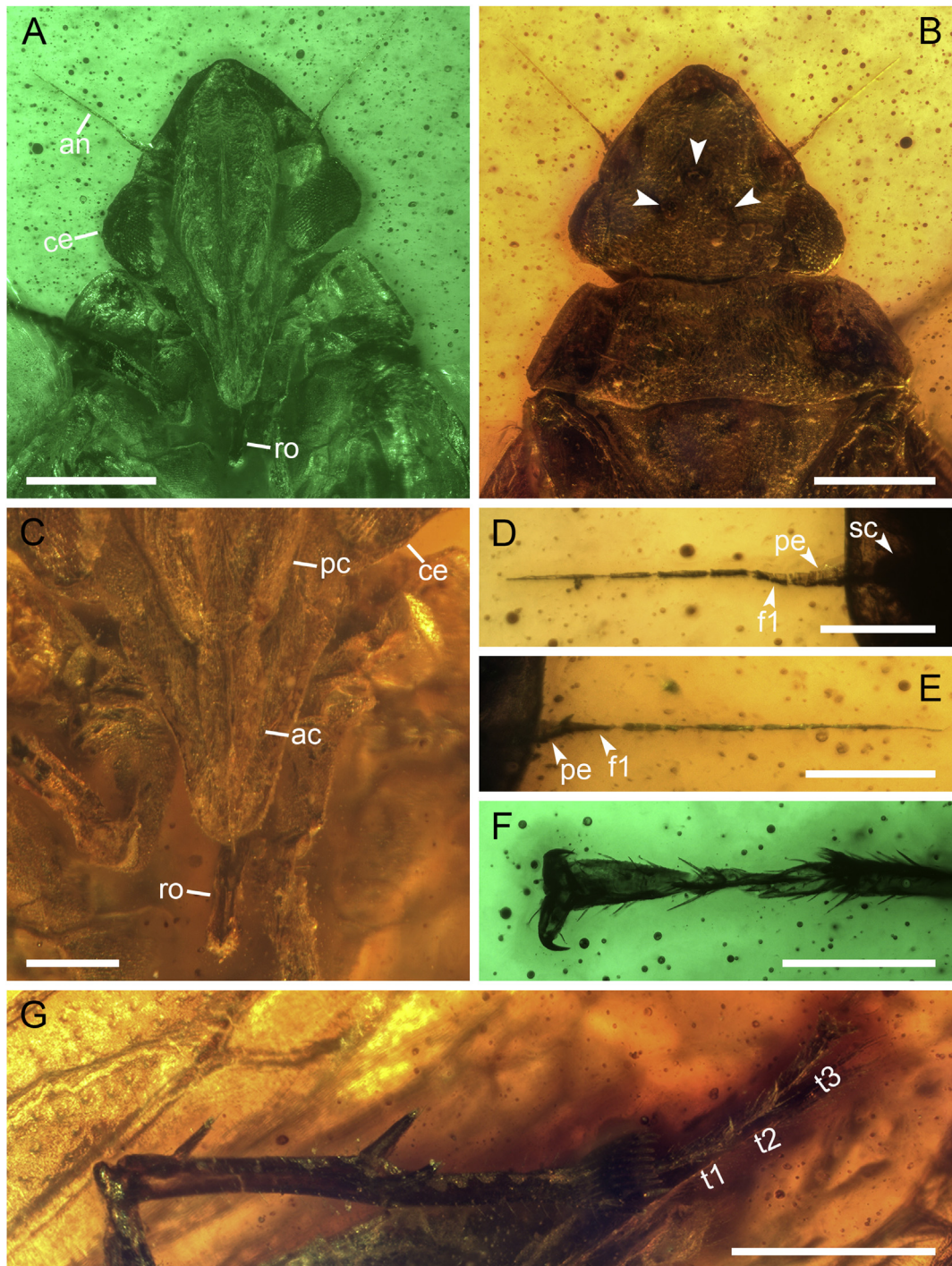


Fig. 5. Enlargements of the holotype (NIGP171740) of *Jiaotouia burmitica* sp. nov. A. head and pronotum in ventral view, under green fluorescence; B. head and pronotum in dorsal view with three ocelli (white arrows); C. clypeus and rostrum; D. left antenna; E. right antenna; F. protarsus; G. metatibia and metatarsus. Abbreviations: an, antenna; ce, compound eye; ro, rostrum; pc, postclypeus; ac, anteclypeus; sc, scape; pe, pedicel; f1, flagellum 1; t1–t5, tarsomere 1–5. Scale bars: 0.5 mm in A, B, G; 0.2 mm in C–F.

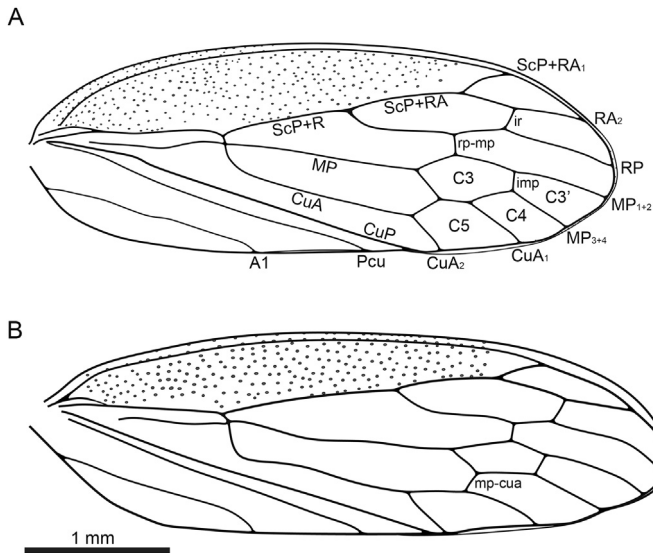


Fig. 6. Line drawings of forewing of *Jiaotouia*. A. *Jiaotouia minuta* (NIGP171739); B. *Jiaotouia burmitica* sp. nov. (NIGP171740). Scale bar: 1 mm.

5. Conclusions

Jiaotouia minuta bears considerable intraspecific variation in venation and corresponding cell patterns of tegmen, and more detailed morphological characters are provided (e.g., antenna, metatibia and metatarsus) on the basis of two well-preserved specimens from Burmese amber. Moreover, our discovery reveals a new fossil species of the Cretaceous sinoalids, *J. burmitica* sp. nov., enriching the documented palaeodiversity of this family at the species-level in Burmese amber to twelve species, placed in nine genera. According to these individuals we present a revised diagnosis for *Jiaotouia*, making it distinguished from other genera of the tribe Fangyuaniini and contributing to further phylogenetic studies of this extinct family.

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