

Short communication

New females of Perlidae (Insecta: Plecoptera) from Cenomanian Burmese amber

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ABSTRACT

Two new stoneflies, *Starkoperla longusocollum* gen. et sp. nov. and *Zwickoperla brevicauda* gen. et sp. nov. are described and illustrated based on two well-preserved females in mid-Cretaceous Burmese amber. The two genera are new extinct members of Perlidae and exhibit distinctive external characters when compared with both extant and extinct perlids. Morphological comparisons have been made between the new taxa and similar taxa.

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1. Introduction

The Plecoptera in mid-Cretaceous Burmese amber are gradually known with new fossil taxa continuously reported (Chen, 2019). *Largusoperla* Chen et al., 2018 (Plecoptera: Perlidae, Acroneuriinae) is currently the most speciose genus known from Burmese amber, with males and putative females described for 12 named species (Chen & Wang, 2019). However, only four stonefly females are described from Burmese amber, including *Petroperla mickjaggeri* Sroka, Staniczek & Kondratieff (2018), *Lapisperla keithrichardsi* Sroka, Staniczek & Kondratieff (2018), *Largusoperla micktaylori* Sroka, Staniczek & Kondratieff (2018) and *Largusoperla brianjonesi* Sroka, Staniczek & Kondratieff (2018) (Sroka et al., 2018). In these females, the diagnostic shapes of subgenital plates vary from small triangular to large rounded or lobed (Sroka et al., 2018).

After a comprehensive literature research of extant Perlidae, herein we describe two new genera and species of the family Perlidae based on two well-preserved females in mid-Cretaceous Burmese amber. Although the comprehensive classification

system of females is lost in Perlidae, the two new genera have exhibited enough diagnostic characters to distinguish from both extant and extinct perlids. Other characters such as the color pattern, head and pronotum, wing venation and cercal segments are also used in generic delimitation of the new taxa.

2. Materials and methods

The ambers studied in this study was collected from Kachin, Hukawng Valley (26°20'N, 96°36'E), northern Myanmar (locality in Kania et al., 2015: fig. 1) and have an age from the earliest Cenomanian (98.79 ± 0.62 Ma) of mid-Cretaceous (Shi et al., 2012). The specimens are deposited in the Nanjing Institute of Geology and Palaeontology, China (NIGP). Observations and measurements were performed with a SDPTOP SZM45 stereo microscope. Photographs were taken by a Canon EOS 6D digital camera with a Canon MP-E 65 mm 5X macro lens. Photographs were optimized with Adobe Photoshop CS6. Line drawings were made by tracing the photographs and examined under the microscope. Morphological terminology follows Chen et al. (2018). Wing venation homology follows that of Béthoux (2005). Nomenclature and abbreviations are as follows: ScP, posterior subcosta; RA, anterior radius; RP, posterior radius; M, media; MA, anterior media; MP, posterior

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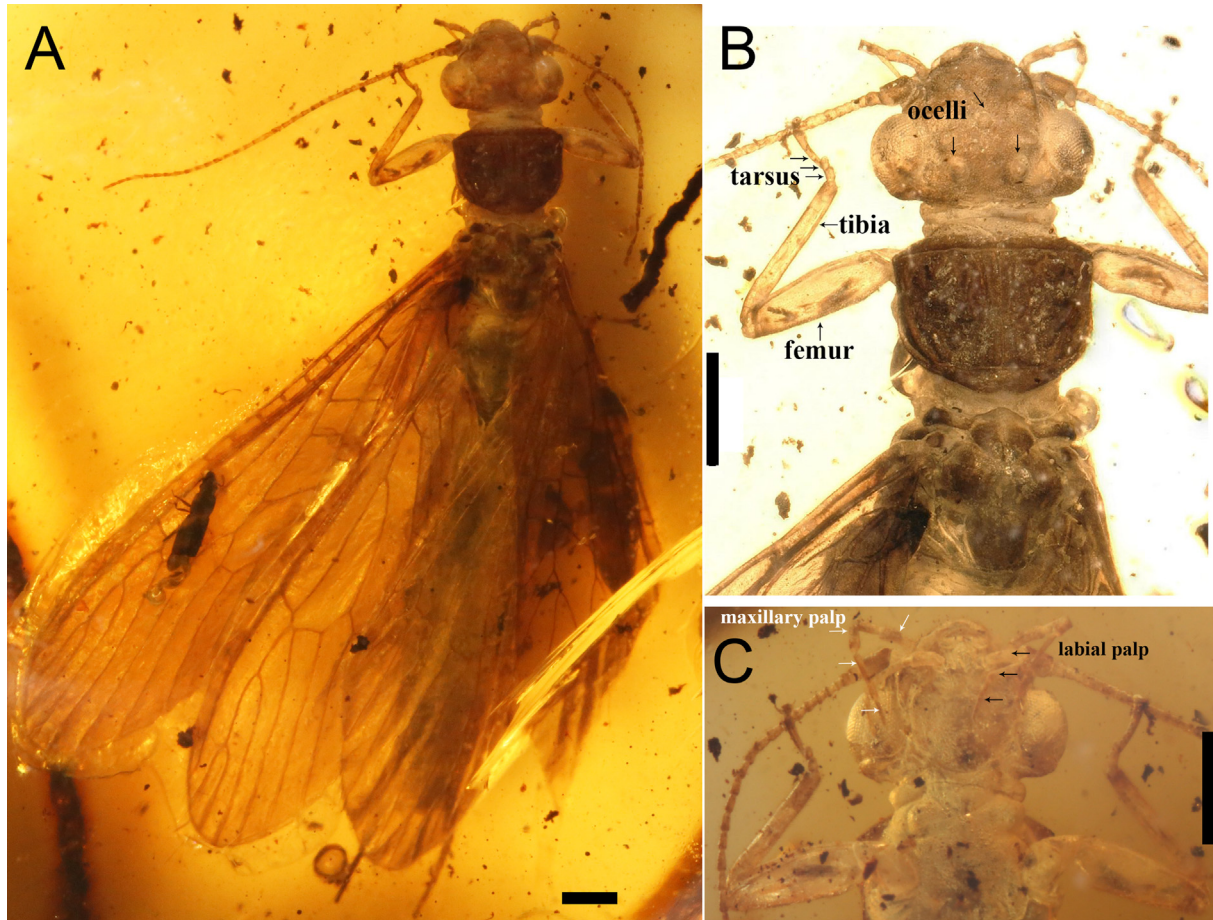


Fig. 1. *Starkoperla longusocollum* gen. et sp. nov., holotype female (NIGP170943). A. Habitus photo, dorsal view; B. Photo of head and thorax, dorsal view; C. Photo of head and thorax, ventral view. Scale bar is 0.5 mm.

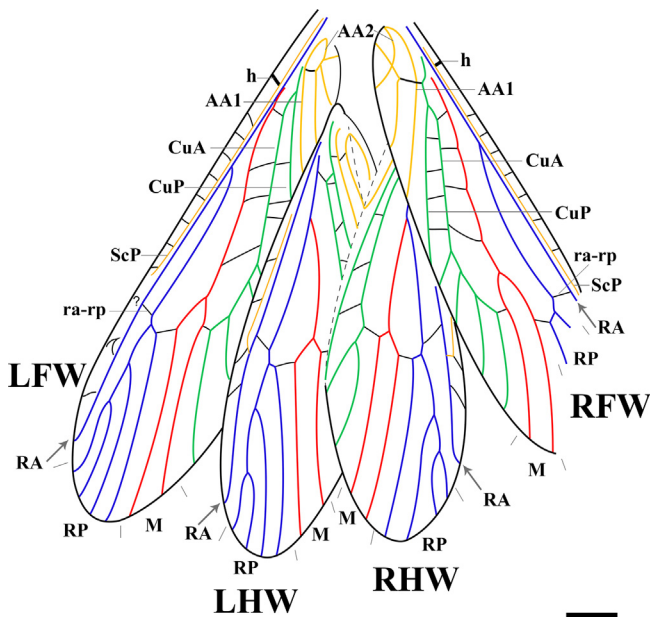


Fig. 2. *Starkoperla longusocollum* gen. et sp. nov., holotype female (NIGP170943). Drawing of wings. LFW: left forewing; LHW: left hind wing; RHW: Right hind wing; RFW: right forewing. Scale bar is 1.0 mm.

media; Cu, cubitus; CuA, anterior cubitus; CuP, posterior cubitus; AA, anterior analis; AA1, first anterior analis; AA2, second anterior analis; h, humeral cross vein; other crossveins are indicated according to the veins they connect.

3. Systematic paleontology

Class: Insecta [Linnaeus, 1758](#)
Order: Plecoptera [Burmeister, 1839](#)
Family: Perlidae [Latreille, 1802](#)

Genus *Starkoperla* gen. nov.

Type species: *Starkoperla longusocollum* gen. et sp. nov., by monotypy.

Etymology. The genus name is a combination of the words *Starko* and *perla*; the first word refers to our outstanding colleague Bill P. Stark, while the second word refers to the extant genus *Perla* [Geoffroy, 1762](#), which is the type genus of Perlidae.

Diagnosis. Body slender (ca. 11.0 mm); triocellate, head pale brown; maxillary palp four-segmented with shortened apical segment; labial palp three-segmented with slender apical segment; neck elongated; pronotum sub-trapezoidal and dark brown, anterior margin extended into a pale projection; ScP reaches RA beyond ra-rp; h vein stout; RP originating at basal $\frac{1}{3}$ of RA and with four visible branches; M forked at apical $\frac{1}{3}$ of the wing length; CuA with four branches; AA2 with three branches; hind wings with similar

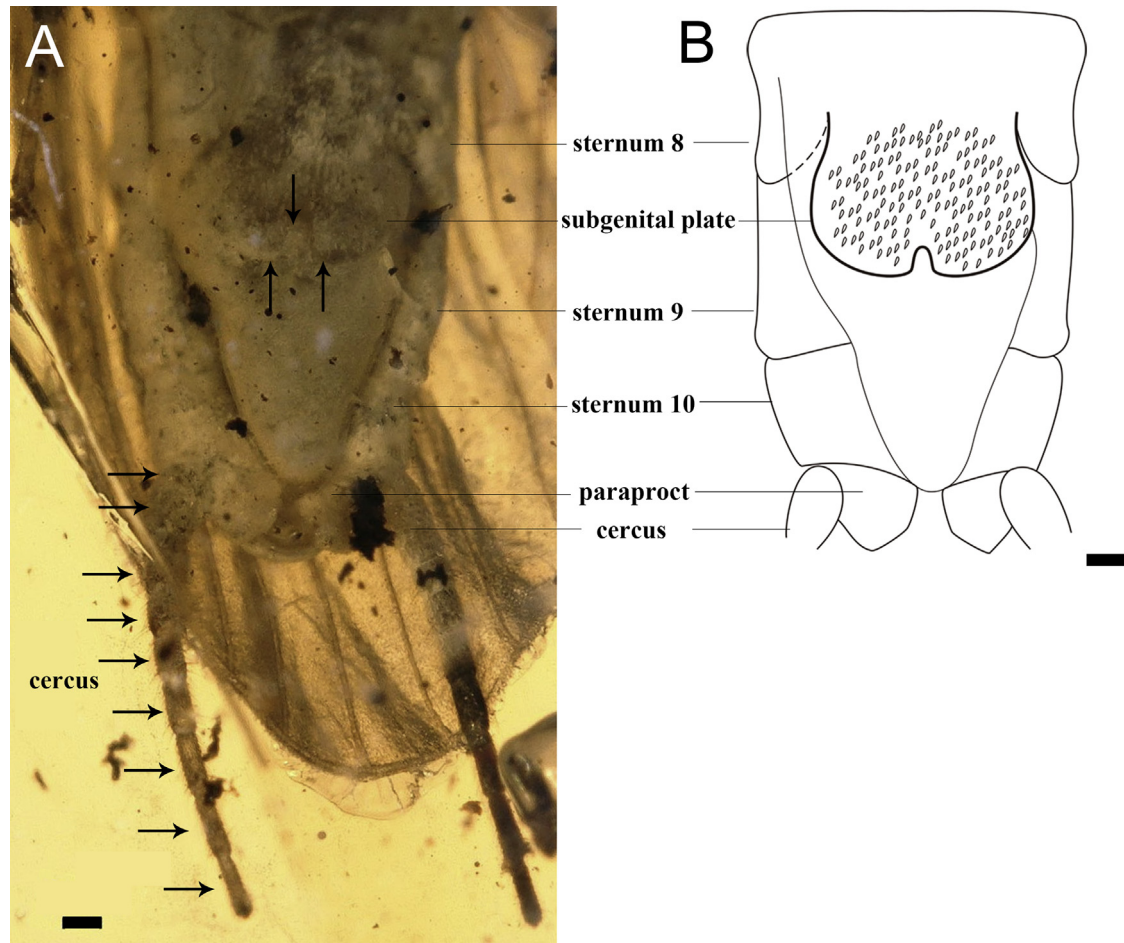


Fig. 3. *Starkoperla longuscollum* gen. et sp. nov., holotype female (NIGP170943). A. Photo of terminalia, ventral view; B. Drawing of terminalia, ventral view. Scale bar is 0.5 mm.

venation to forewings, anal area folded, width near half of the wing width; subgenital plate of sternum 8 broad and rounded with a subtriangular apical notch, covering half of sternum 9; paraprocts subquadrate and hairy; cercus dark brown and nine-segmented, each segment generally slender.

Comments. The new genus is assigned to the family Perlidae by sharing the unpolarized characters including the presence of tarsal euplantulae, short first and second tarsal segment, long and slender palps, the stout h vein, and the multiple basal crossveins in forewing's costal field (Zwick, 1980, 2000; Cui et al., 2015). Due to lack of comprehensive studies of females in Perlidae, the subfamilial assignment of the new genus is currently impossible. In the extant genera of Perlidae, only the four genera *Xanthoneuria* Uchida, Stark & Sivec (2011), *Enderleina* Jewett, 1960, *Kempnyia* Klapálek, 1914 and *Kiotina* Klapálek, 1907 of subfamily Acroneuriinae, and the two genera *Etrocorema* Klapálek, 1909 and *Kamimuria* Klapálek, 1907 of Perlinae have shown similarly large rounded subgenital plate with a deep apical notch (Wu & Claassen, 1934; Banks, 1939; Kawai, 1967; Zhiltzova, 1981; Froehlich, 1988; Sivec et al., 1988; Stark, 1989; Stark & Sivec, 2008; Asiah et al., 2009; Uchida et al., 2011). The new genus can be easily separated from these extant perlids by the combination of characters including triocellate, head pale brown, neck elongated, pronotum mostly dark and with a pale anterior projection, wing membrane pale brown, and each cercal segment slender. When compared with the four females *P. mickjaggeri*, *L. keithrichardsi*, *L. micktaylori* and *L. brianjonesi* from Burmese amber, the new genus can also be distinguished by the

unique color pattern, elongated neck, RA vein not reaching wing apex, and subgenital plate large rounded with an apical notch (Sroka et al., 2018). The distinctly elongated neck might be an autapomorphic character of *Starkoperla*.

***Starkoperla longuscollum* sp. nov.**
(Figs. 1–3)

Etymology. The specific epithet is derived from the Latin “*longus*” and “*collum*”, in reference to the elongated neck.

Type material. Holotype female (No. NIGP170943) deposited in the Nanjing Institute of Geology and Palaeontology, China (NIGP).

Type locality. Hukawng Valley, southwest Maingkhwan, Kachin State (26°20N, 96°36E), Myanmar, uppermost Albian-lowermost Cenomanian (mid-Cretaceous).

Description of holotype. Macropterous (Fig. 1A); body length (excluding antennae and cerci) ca. 11.0 mm, slender, generally brown. The specimen is well preserved; ventral aspect of the specimen is covered by unknown materials.

Syninclusions. An unidentified insect of Coleoptera.

Head (Fig. 1) oblong, generally pale brown. Triocellate, posterior ocelli bigger than the anterior one; compound eyes oval. Antenna pale brown and filiform, at least 45-segmented, length near half of the body length. Maxillary palp with four segments, apical segment shortened. Labial palp three-segmented, apical segment slender. Neck prolonged, posterior half covered by anterior of pronotum; cervical gills absent, instead with two small knobs.

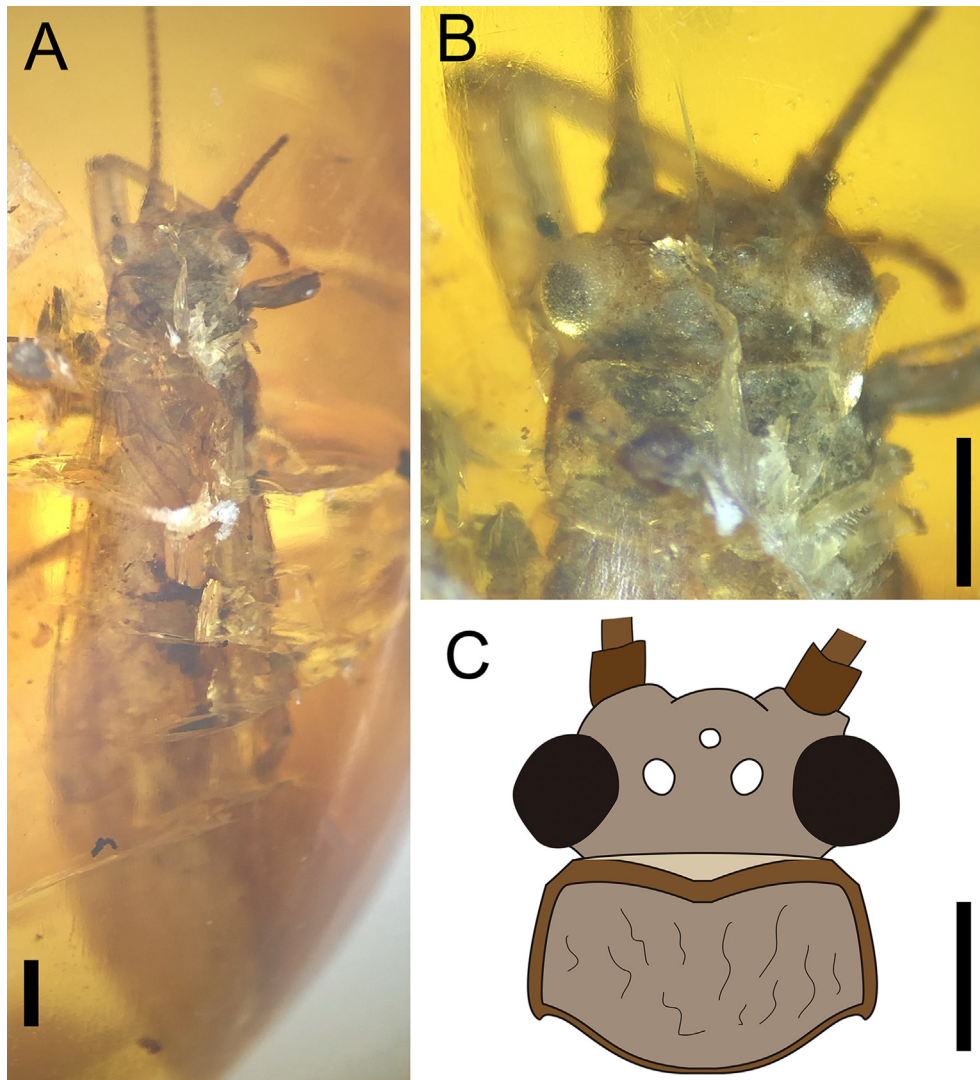


Fig. 4. *Zwickoperla brevicauda* gen. et sp. nov., holotype female (NIGP170944). A. Habitus photo, dorsal view; B. Photo of head and pronotum, dorsal view; C. Drawing of head and pronotum, dorsal view. Scale bar is 0.5 mm.

Pronotum (Fig. 1) slightly narrower than head, near trapezoidal with angled anterior corners, rugose and dark brown; anterior margin of pronotum extended forwards to cover half of the cervix; anterior, posterior and median suture distinct. Meso- and metanota mostly sclerotized, dorsal sclerites humped and distinct. Legs generally pale, joints and tarsus darker; femur thick, tibia thin; tibia spur indistinct; first two tarsal segments shortest with conspicuous euplantulae; arolium without setae.

Wings (Figs. 1A, 2) hyaline, veins dark brown. Forewings length ca. 10.5 mm; ScP probably reaches RA beyond ra-rp; h vein stout; at least eight crossveins present between Sc and the anterior margin; RP originates at basal $\frac{1}{3}$ of RA and with four visible branches in left forewing; M forked at apical $\frac{1}{3}$ of the wing length; CuA forked much basal to the fork of M and with four branches; CuP and AA1 simple; AA2 with three branches; area between M and CuA with five crossveins; area between CuA and CuP with three visible crossveins in left forewing and four crossveins in right forewing. Hind wings length ca. 8.5 mm, venation similar to forewings; anal area folded, width near half of the entire wing width.

Abdomen (Figs. 1A, 3) slightly longer than half of the body length, generally pale brown. Subgenital plate originates from half-length of sternum 8, broad and rounded with a subtriangular apical notch, covering half of sternum 9; surface of the subgenital plate covered with dense, stout hairs or spines. A long triangular unknown structure extended from beneath the subgenital plate to posterior margin of sternum 10. Paraprocts subquadrate and hairy. Cercus dark brown, total length ca. 1.8 mm, with nine segments, each segment generally slender and fringed with long bristles.

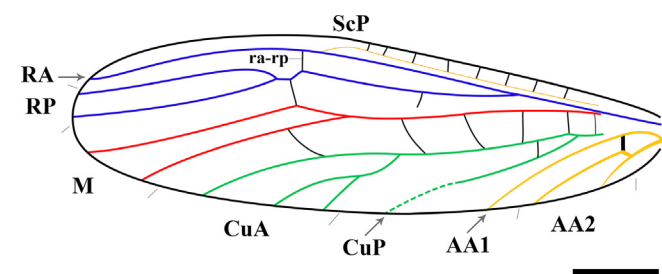


Fig. 5. *Zwickoperla brevicauda* gen. et sp. nov., holotype female (NIGP170944). Drawing of left forewing. Scale bar is 1.0 mm.

Genus *Zwickoperla* gen. nov.

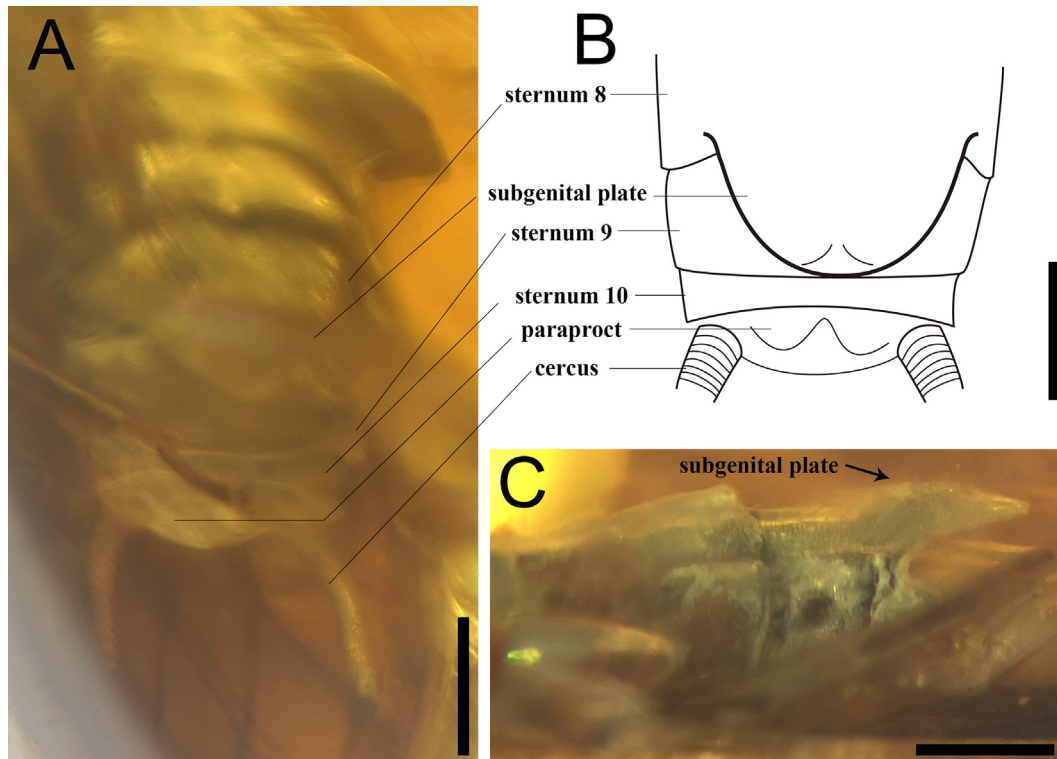


Fig. 6. *Zwickoperla brevicauda* gen. et sp. nov., holotype female (NIGP170944). A. Photo of terminalia, ventrocaudal view; B. Drawing of terminalia, ventral view; C. Photo of terminalia, lateral view. Scale bar is 0.5 mm.

Type species: *Zwickoperla brevicauda* gen. et sp. nov., by monotypy.

Etymology. The genus name is a combination of the words *Zwicko* and *perla*; the first word refers to our outstanding colleague Peter Zwick, while the second word refers to the extant genus *Perla* Geoffroy, 1762, which is the type genus of Perlidae.

Diagnosis. Body very short (ca. 7.0 mm); head strongly inserted into the pronotum, with a brown stigma covering the three ocelli and the anterior of head; third and fourth segments of antenna distinctly shortened than neighboring segments; maxillary palp three-segmented with unmodified apical segment; pronotum as wide as head, widened backwards except for the abruptly constricted, truncate posterior margin; ScP reaches RA beyond ra-rp; RA almost reaching wing apex; RP originating before half of RA and with two branches; M forked basal to the fork of RP; CuA forked basal to the fork of M and with three branches; CuP and AA1 simple; AA2 with two branches; subgenital plate of sternum 8 broad and large, posterior margin truncate, covering most of sternum 9; sternum 9 depressed and extended posteriorly, covering the short sternum 10; cercus very short but multi-segmented, each segment strongly shortened.

Comments. RA vein of the new genus almost reaches the wing apex, which has only been found in *Kargaloperla* Sinitshenkova, 1987 (Palaeoperlidae) from the Upper Permian of Ural, *Petroperla* Sroka, Staniczek & Kondratieff (2018) (Petroperlidae) and *Lapisperla* Sroka, Staniczek & Kondratieff (2018) (Petroperlidae) from mid-Cretaceous Burmese amber (Sinitshenkova, 1987; Sroka et al., 2018). The new genus seems similar to the two Cretaceous genera for sharing similar RA vein, similar body size and the co-existence in the same age, but the strongly inserted head (reminiscent of family Peltoperlidae), unique-shaped pronotum, large unnotched subgenital plate, and the strongly shortened cercal segment can separate the new genus from *Petroperla* and *Lapisperla*. Meanwhile, the new genus is herein not considered as a new member of the

fossil family Petroperlidae Sroka, Staniczek & Kondratieff (2018). Although the RA vein is unique, the key diagnostic character of Petroperlidae “glossae and paraglossae of approximately same size” was not congruent with Fig. 2A in Sroka et al. (2018) and is not a stable or reliable diagnostic character in Plecoptera (examples see Figs. 5 and 6 in Nelson & Hanson, 1971). Therefore, the fossil family Petroperlidae and its two genera, *Petroperla* and *Lapisperla*, should be treated with caution. Herein, the new genus is still assigned to Perlidae by sharing the unpolarized characters including the presence of tarsal euplantulae, short first tarsal segment, long and slender palps and the multiple crossveins in forewing’s costal field (Zwick, 1980, 2000). The posterolaterally projected pronotum and the strongly shortened cercal segments should be the autapomorphic characters of *Zwickoperla*.

***Zwickoperla brevicauda* sp. nov.**

(Figs. 4–6)

Etymology. The specific epithet is derived from the Latin “*brevis*” and “*cauda*”, in reference to the strongly shortened segments of cerci.

Type material. Holotype female (No. NIGP170944) deposited in the Nanjing Institute of Geology and Palaeontology, China (NIGP).

Type locality. Hukawng Valley, southwest Maingkhwan, Kachin State (26°20N, 96°36E), Myanmar, uppermost Albian-lowermost Cenomanian (mid- Cretaceous).

Description of holotype. Macropterous (Fig. 4A); body length (excluding antennae and cerci) ca. 7.0 mm, stout, generally brown. The specimen is mostly preserved but it’s located in edge of the amber and has some dorsal cracks, which caused difficulties in taking the photo of habitus. The cracks and the overlapped wings also make the venation of left forewing obscure. Ventral aspect of the terminalia is clearly visible under microscope, but it is difficult to obtain clear photos due to the cracks and the marginal location of specimen.

Syninclusions. Unidentified plant remains

Head (Fig. 4) elliptical, strongly inserted into the pronotum, with a brown stigma covering the three ocelli and the anterior of head, pigmentation of occipital area faded. The three ocelli considerably large and raised, forming a regular triangle; the two posterior ocelli slightly bigger than the anterior one. Compound eyes dark and swollen. Antenna filiform and dark brown, with 27 segments preserved; third and fourth segments distinctly shortened, near half-length of neighboring segments. Maxillary palp three-segmented, apical segment unmodified; labial palps invisible.

Pronotum (Fig. 4) as wide as head, gradually widened from anterior margin, then strongly constricted to a truncate posterior margin; margins of pronotum strongly sclerotized and thickened; surface brownish with obscure rugosities. Mesothorax and metathorax covered by wings, dark sclerotized and wider than pronotum. Leg mostly brown, tibia spur present; first two tarsal segments shortest with conspicuous euplantulae.

Wings (Figs. 4A, 5) subhyaline, veins brown. Left forewing length ca. 7.0 mm; ScP reaches RA beyond ra-rp; crossveins beyond ScP unclear; at least eight crossveins present between Sc and the anterior margin. RA simple, almost reaching wing apex; RP originating before half of RA and with two branches. M forked basal to fork of RP; ra-rp not connected with the opposite crossvein. CuA forked basal to the fork of M, with three branches; CuP and AA1 simple; AA2 with two branches. Area between M and CuA with at least six crossveins; area between CuA and CuP with one visible crossvein. Right forewing and hind wings not visible.

Abdomen (Fig. 6) near half of the body length, segments mostly dark brown. Terminal abdominal terga separated from sterna. Subgenital plate originates from sternum 8 and extended backwards, covering most of sternum 9; the subgenital plate broad and large, posterior margin truncate, raised from lateral view. Sternum 9 strongly depressed and enlarged posteriorly, covering the short and depressed sternum 10. Paraprocts subtriangular and seems connected. Cercus very short, total length ca. 0.8 mm, but with at least 17 segments, each segment strongly shortened.

4. Discussion

Females of Perlidae are often overlooked in past taxonomic studies due to their intraspecific variations and interspecific similarities of external genitalic structures. To date, no comprehensive study of all perlid females has been conducted, making it difficult to identify both extant and extinct females. Morphological characters of perlid females useful in generic delimitation are very few, but *Starkoperla* gen. nov. and *Zwickoperla* gen. nov. have exhibited distinctive characters in addition to the subgenital plates.

In adults of Perlidae, shape of pronotum is usually subquadrate or sub-trapezoidal with posterior margin equal or narrower than anterior margin; while the pronotum is oval in genus *Brahmana* Klapálek, 1914 and *Hansonoperla* Nelson, 1979. In *Zwickoperla* gen. nov., the pronotum widened backwards and constricted into a truncate apex, which has never been found in any known perlid. Contrary to *Starkoperla* gen. nov., the inserted head of *Zwickoperla* gen. nov. is uncommon in Perlidae, which is a similar situation occurs in *Brahmana* (Cao & Bae, 2013). The compressed cercal segment of *Zwickoperla* gen. nov. contrary to *Starkoperla* gen. nov. is also a distinctive character in Perlidae.

5. Concluding remarks

The females of Perlidae preserved in Burmese amber have revealed various shapes of subgenital plates, from slightly developed to large and modified shapes. In addition to the subgenital

plates, the color pattern, head, pronotum, wing venation, and length of cercal segment also performed well in generic delimitation of this study. A comprehensive study is necessary to establish a classification system for extant and extinct females of Perlidae.

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