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## Revision of the genus *Sinogranulus* (Hemiptera, Granulidae) with description of a new species from the Middle Triassic of China

YAN-ZHE FU<sup>1,2</sup>, JIAN GAO<sup>1</sup> & DI-YING HUANG<sup>1,\*</sup>

<sup>1</sup>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

<sup>2</sup>University of Chinese Academy of Science, Beijing 100049, China

✉ [yzfu@nigpas.ac.cn](mailto:yzfu@nigpas.ac.cn); <https://orcid.org/0000-0002-7819-1703>

✉ [jiangao@nigpas.ac.cn](mailto:jiangao@nigpas.ac.cn); <https://orcid.org/0000-0001-8817-8599>

✉ [dyhuang@nigpas.ac.cn](mailto:dyhuang@nigpas.ac.cn); <https://orcid.org/0000-0002-5637-4867>

\*Corresponding author

### Abstract

Granulidae is a small extinct hemipteran family with only two genera from the Middle Triassic of northern China. Here we describe and illustrate a new species of Granulidae, *Sinogranulus jinsuoguanensis* Fu & Huang **sp. nov.**, from the Middle Triassic Yanchang Formation of Tongchuan City, Shaanxi Province, northern China, representing the second species of *Sinogranulus* Zhang, Chen & Zhang, 2022, adding new information on morphological diversity of this genus. In addition, *Sinogranulus* is emended and provided with a supplemental description for the type species *Sinogranulus qishuiheensis* based on four specimens from the same locality of Yanchang Formation with *S. jinsuoguanensis* **sp. nov.**, and the intra-specific variation of venation in two species of *Sinogranulus* is discussed.

**Keywords:** Granulidae, Triassic, Yanchang Formation, taxonomy, *Sinogranulus*

### Introduction

The extinct hemipteran superfamily Scytinopteroidea Handlirsch, 1906 consists of seven families (*i.e.*, Scytinopteridae Handlirsch, 1906; Ipsviciidae Tillyard, 1919; Paraknightiidae Evans, 1950; Stenoviciidae Evans, 1956; Granulidae Hong, 1980; Serpentinaevidae Shcherbakov, 1984; and Saaloscytinidae Brauckmann, Martins-Neto & Gallego, 2006) reported from the Permian (Roadian) to the Cretaceous (Aptian). However, Scytinopteroidea is considered paraphyletic (Szwedo, 2018). Hong (1980) established the extinct family Granulidae on the basis of an isolated forewing specimen from the Middle Triassic Tongchuan Formation (= lower parts of the Yanchang Formation, see below) of Tongchuan City, Shaanxi Province, northern China. It was originally

placed in the superfamily Cicadelloidea Latreille, 1802 (Hong, 1980). Subsequently, Hamilton (1992, 1996) transferred it to Ipsvicioidea Tillyard, 1919, but Szwedo (2018) downgraded Ipsvicioidea as a family belonging to the superfamily Scytinopteroidea Handlirsch, 1906 (infraorder Scytinopteromorpha Szwedo, 2018), and placed Granulidae into Scytinopteroidea. Very recently, Zhang *et al.* (2022) reported the second genus and species of Granulidae (*Sinogranulus qishuiheensis*), from the Middle Triassic Tongchuan Formation of Tongchuan City, Shaanxi Province, northern China.

We herein describe a new species of *Sinogranulus*, *Sinogranulus jinsuoguanensis* **sp. nov.**, and provide a supplemental description for *S. qishuiheensis* from the Middle Triassic Yanchang Formation of Hejiafang Village, Jinsuoguan Township, Yintai District, Tongchuan City, Shaanxi Province, China.

### Material and methods

The new species *Sinogranulus jinsuoguanensis* **sp. nov.** is described based on four specimens (NIGP179639–NIGP179642); and the type species of *Sinogranulus* (*i.e.*, *S. qishuiheensis*) is emended based on four additional specimens (NIGP179635–NIGP179638). All studied specimens were preserved in greenish grey shale, collected from the lower parts of the Middle-Upper Triassic Yanchang Formation (cited as the Tongchuan Formation in most palaeontological studies), at the lacustrine deposit near Hejiafang Village, Jinsuoguan Township, Yintai District, Tongchuan City, Shaanxi Province, northern China (for detailed location of fossil site, see Fu *et al.*, 2021, figure 1).

The specimens were carefully prepared using a sharp



blade. Photographs were taken with a Zeiss AxioZoom V16 stereoscope. The raw digital images were processed with Helicon Focus 7.0.2 to increase the depth of field. All images were optimised and grouped into plates using Adobe Photoshop CS6. Line drawings were drafted with Adobe Illustrator CC 2018. The material studied here is deposited in the Nanjing Institute of Geology and Palaeontology (NIGP), Chinese Academy of Sciences, Nanjing, China.

Wing venation terminology and cell nomenclature follow Nel *et al.* (2012) and Bourgoïn *et al.* (2015). All measurements are presented in millimeters.

## Systematic palaeontology

**Order Hemiptera Linnaeus, 1758**

**Suborder Cicadomorpha Evans, 1946**

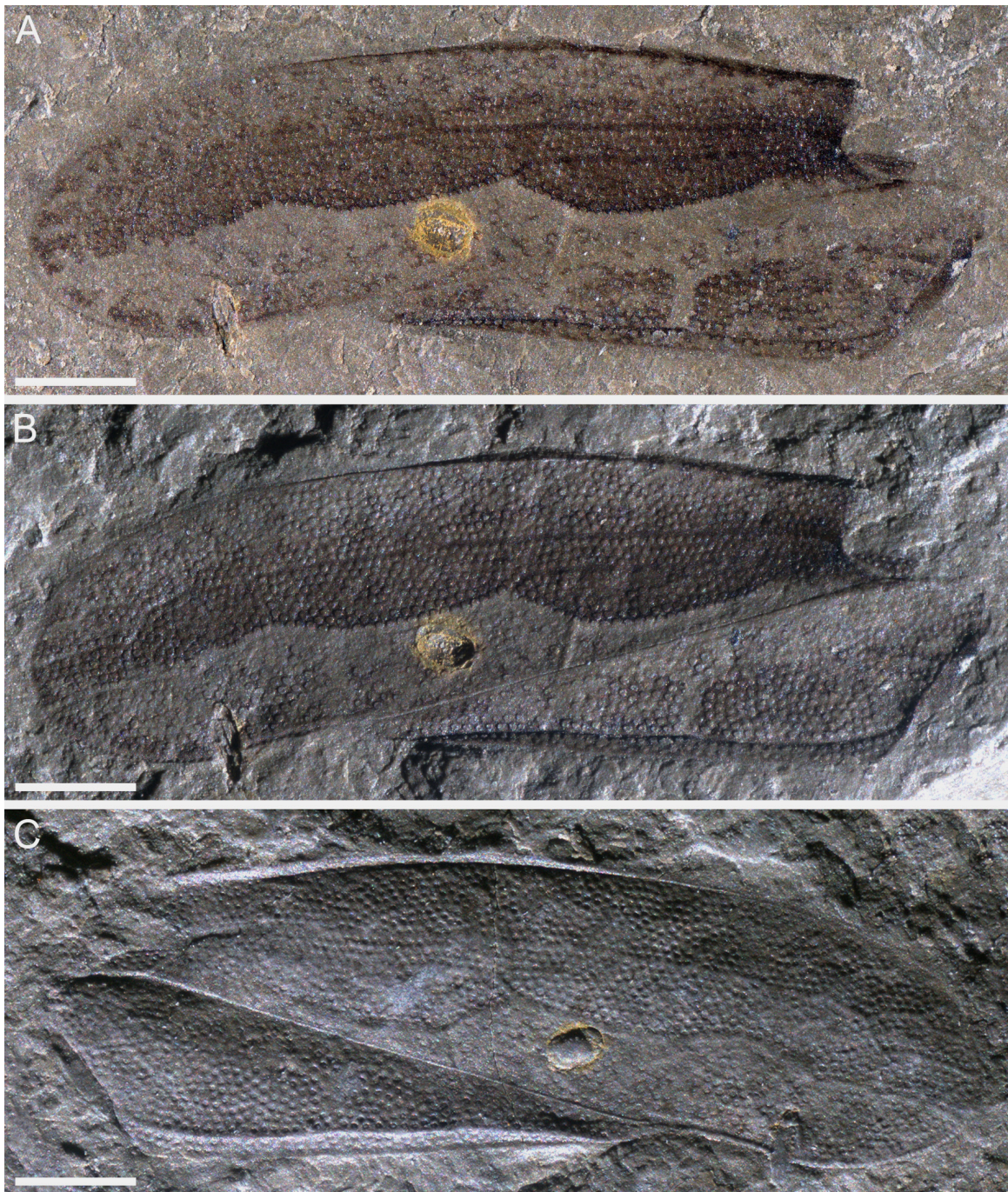
**Superfamily Scytinopteroidea Handlirsch, 1906**

**Family Granulidae Hong, 1980**

**Genus *Sinogranulus* Zhang, Chen & Zhang, 2022**

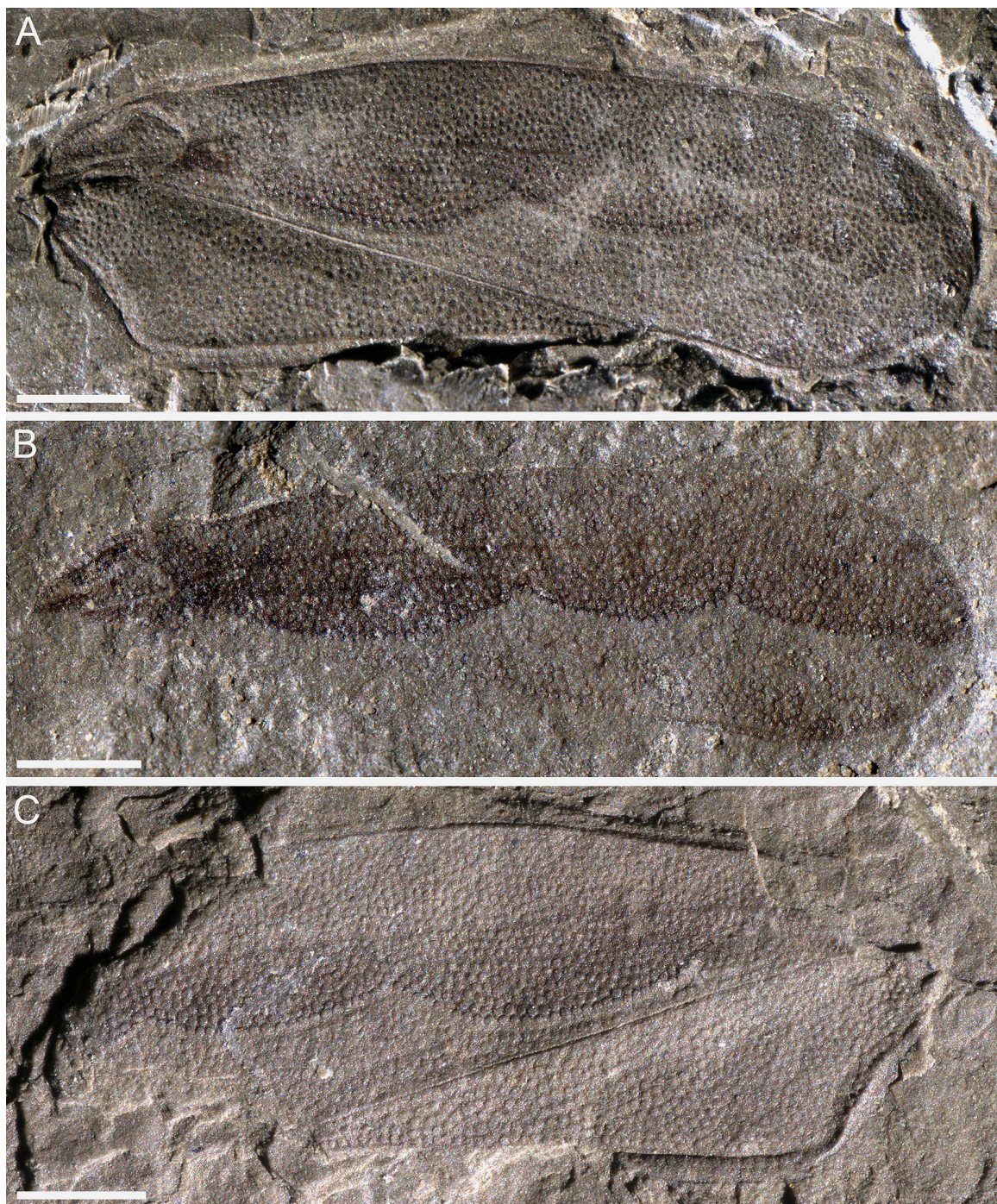
**Type species.** *Sinogranulus qishuiheensis* Zhang, Chen & Zhang, 2022; by original designation.

**Diagnosis** (revised after Zhang *et al.*, 2022). Tegmen coriaceous, mottled or with contrasting colour



**FIGURE 1.** *Sinogranulus qishuiheensis*, photographs (NIGP179635), lower parts of the Yanchang Formation, Shaanxi Province, northern China. **A**, Part, NIGP179635a. **B**, NIGP179635a, part. **C**, NIGP179635b, counterpart. Scale bar = 1 mm.





**FIGURE 2.** *Sinogranulus qishuiheensis*, lower parts of the Yanchang Formation, Shaanxi Province, northern China, photographs. **A**, NIGP179636. **B**, NIGP179637. **C**, NIGP179638. Scale bar = 1 mm.

pattern; with granules, covering it uniformly; regular elongate-oval in shape, and apical margin nearly rounded (tegmen apparently narrowed apically, and tegminal apex somewhat truncate in *Granulus* Hong, 1980); postcostal cell widened; stems R, MP and CuA separated from common stem R+MP+CuA nearly at same point (vein R separated from common stem much earlier in *Granulus*); stem R almost straight, subparallel to costal margin; veins R and MP with several terminals; at least two crossveins

*r-mp* making cell C2 closed; crossvein *mp-cua* long and strongly inclined; and marginal membrane present.

***Sinogranulus qishuiheensis* Zhang, Chen & Zhang, 2022**

(Figs 1–3)

**Material.** Four isolated forewings (NIGP179635–NIGP179638), deposited in the Nanjing Institute of



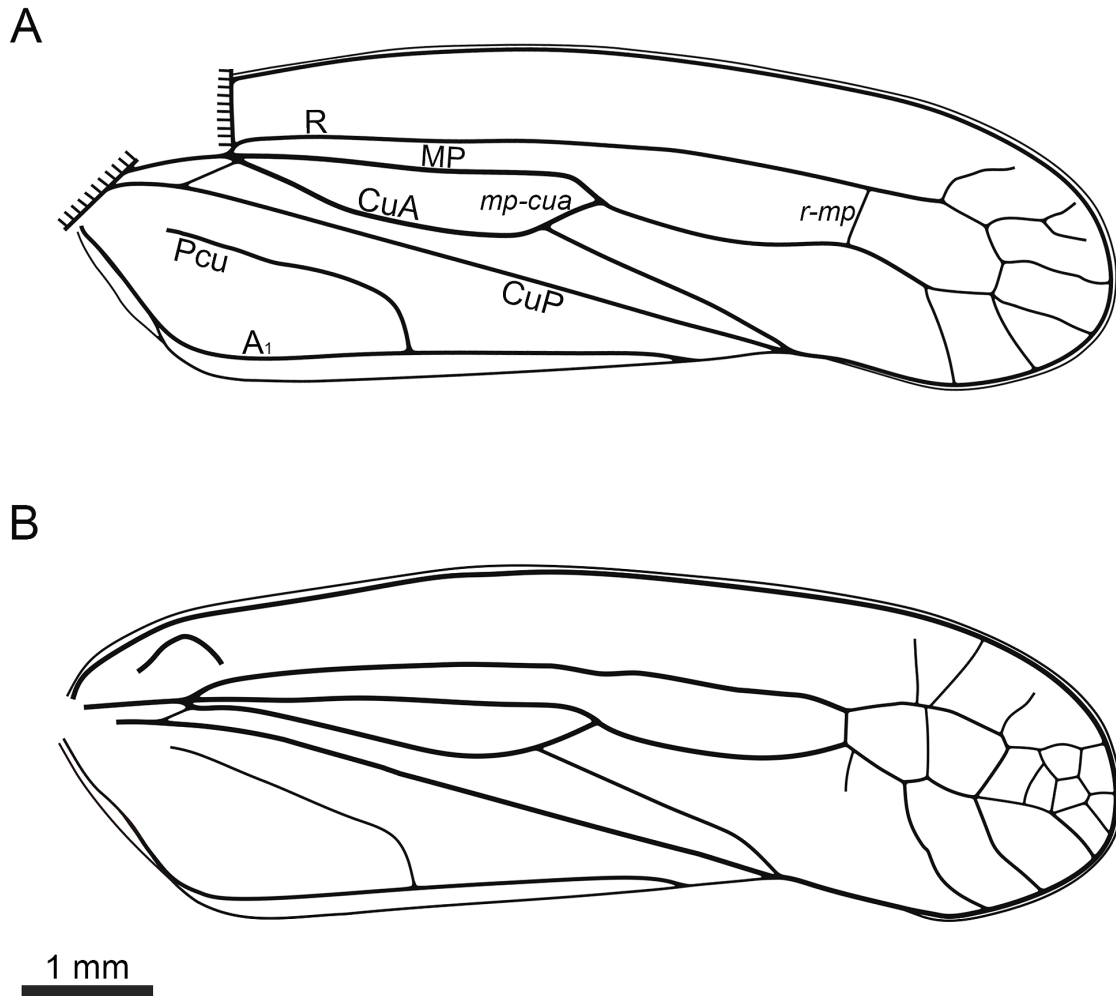


FIGURE 3. *Sinogramulus qishuiheensis*, line drawings. A, NIGP179635. B, NIGP179636.

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**Diagnostic characters** (revised after Zhang *et al.*, 2022). Tegmen with stem MP gently curved posteriorly and fused to CuA<sub>1</sub>; MP forked obviously apicad of basal crossvein *r-mp*, with three terminal branches; stem CuA sinuous.

**Type locality and horizon.** Hejiafang Village, Jinsuoguan Township, Yintai District, Tongchuan City, Shaanxi Province, China; lower parts of the Yanchang Formation; Middle Triassic.

**Description** (after Zhang *et al.*, 2022). Tegmen length 7.5–8.2 mm, maximum width 2.4–2.6 mm; costal margin smoothly arched, thickened; anteroapical and posteroapical angles widely rounded; apical margin rounded; postclaval margin convex at level of termination of CuP; hyposubcostal carina (= basal section of ScP) strongly convex; basal cell short, with apex sharp; basal crossvein *cua-cup* greatly inclined; postcostal cell much wider than radial and median cells; stem R with 3–4 terminal branches; at least two crossveins *r-mp* present;

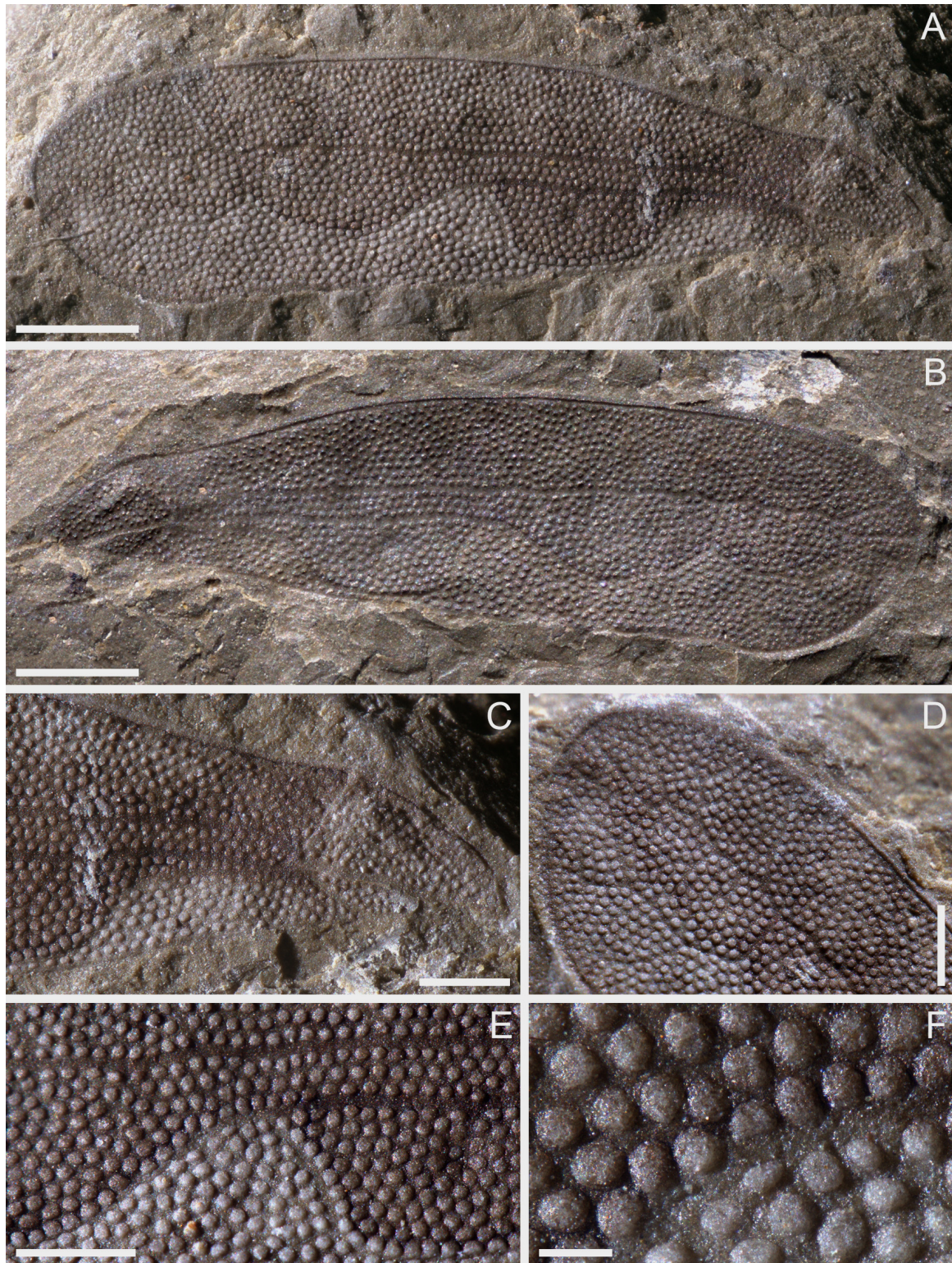
MP nearly straight until tegmenal mid-length, then curved posteriorly, forked at basal 0.80 of tegmen length; CuA<sub>1</sub> entirely fused to stem MP and crossvein *mp-cua* replaced by free base of CuA<sub>1</sub> (MP+CuA<sub>1</sub> referred to below as MP); Pcu slightly sinuous basally and nearly turning vertically to postclaval margin; claval veins Pcu and A<sub>1</sub> fused at about 1/3 of tegmen length, their common portion reaching posterior margin at basal 0.60 of tegmen length; radial cell as wide as or slightly wider than median cell.

***Sinogramulus jinsuoguanensis* Fu & Huang sp. nov.** (Figs 4–7)

**Material.** Holotype, NIGP179639, isolated forewing, with part and counterpart; paratypes, three isolated forewings (NIGP179640–NIGP179642); deposited in the Nanjing Institute of Geology and Palaeontology, Chinese Academy of Sciences, Nanjing, China.

**Etymology.** The specific epithet is derived from “Jinsuoguan”, the name of a town where the specimens were discovered.





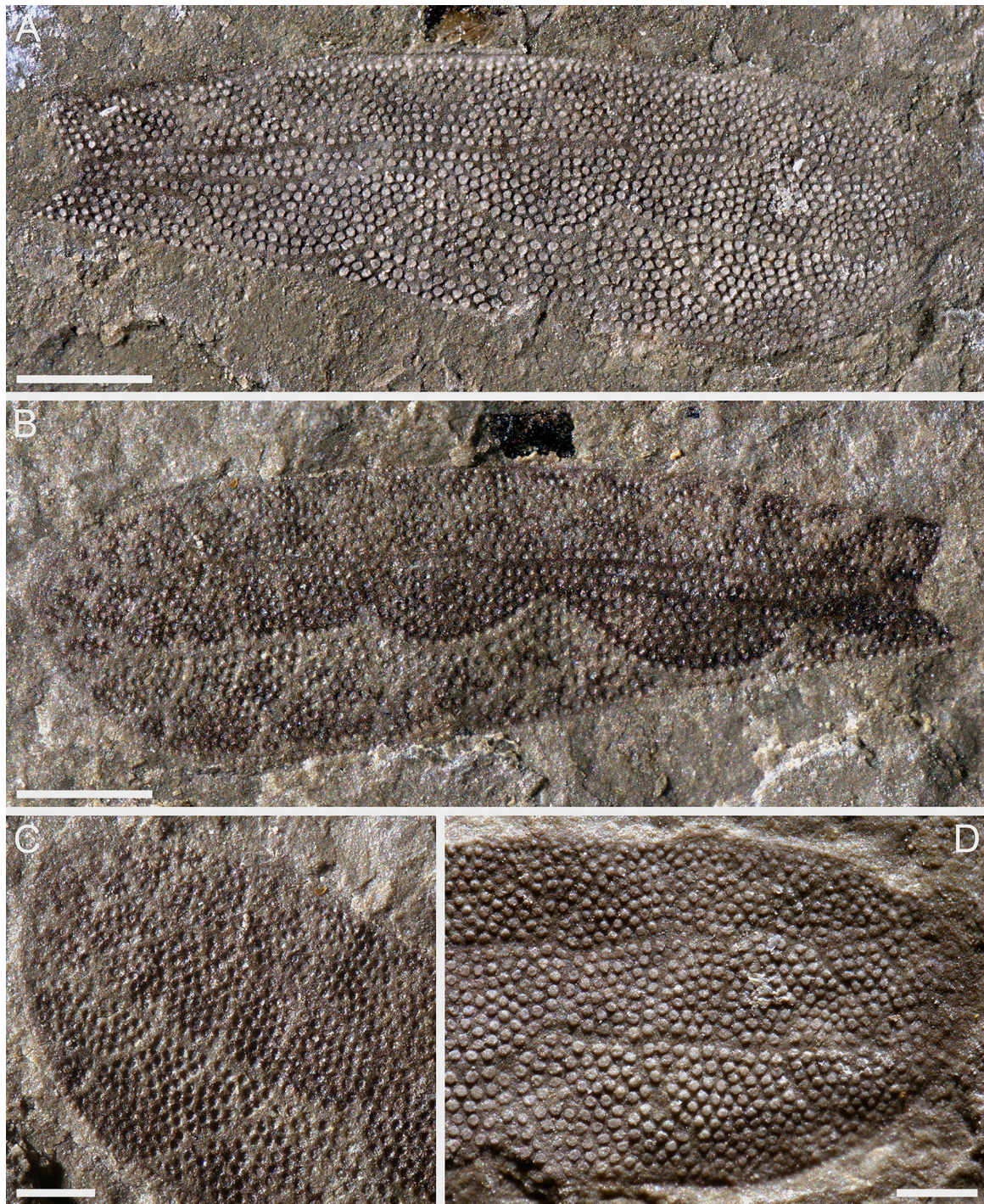
**FIGURE 4.** *Sinogranulus jinsuoguanensis* sp. nov., photographs of holotype, lower parts of the Yanchang Formation, Shaanxi Province, northern China. **A**, Part, NIGP179639a. **B**, Counterpart, NIGP179639b. **C**, Basal portion of wing. **D**, Apical portion of wing. **E**, Granular ornamentations. **F**, Enlargement of **E**. Scale bars: 1 mm in **A**, **B**, 500 µm in **C–E**, 100µm in **F**.

**Diagnosis.** Tegmen with stem R deeply forked, with 5–7 terminal branches (3–4 terminal branches in *S. qishuiheensis*); stem MP curved towards CuA, forked basad of basal crossvein *r-mp* (MP forked obviously

apicad of basal crossvein *r-mp* in *S. qishuiheensis*); CuA bent strongly and very close to CuP, creating broad, spoon-shaped radial and median cells.

**Type locality and horizon.** A locality near Hejiafang





**FIGURE 5.** *Sinogranulus jinsuoguanensis* sp. nov., photographs of paratype (NIGP179640), lower parts of the Yanchang Formation, Shaanxi Province, northern China. **A**, Part, NIGP179640a. **B**, Counterpart, NIGP179640b. **C**, Enlargement of **B**, showing apical portion of wing. **D**, Enlargement of **A**, showing apical portion of wing. Scale bars: 1 mm in **A**, **B**, 500  $\mu$ m in **C**, **D**.

Village, Jinsuoguan Township, Yintai District, Tongchuan City, Shaanxi Province, China; lower parts of the Yanchang Formation; Middle Triassic.

**Description.** Tegmen length 6.3–7.3 mm; granular ornamentations evenly distributed over tegmen surface with different diameter; with dark-colored bands distributed in radial and median cells, and mottled for its remaining part;

costal margin smoothly arched, thickened; anteroapical and posteroapical angles widely rounded; apical margin rounded; outer membrane narrow; hyposubcostal carina strongly convex; basal cell short; basal crossvein *cua-cup* inclined; postcostal cell nearly as wide as widest portion of radial and median cells; stem R long, curved basally, then almost straight, with 5–7 terminal branches; stem MP





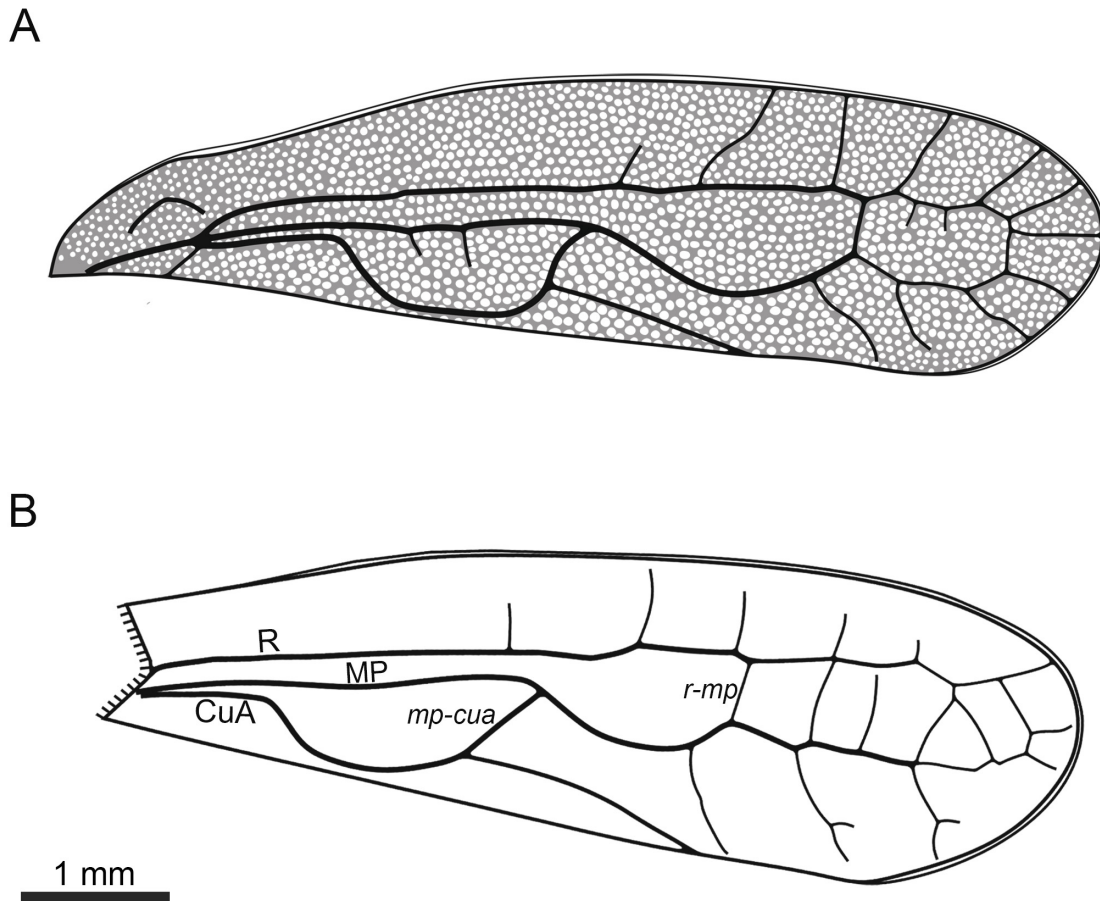
**FIGURE 6.** *Sinogranulus jinsuoguanensis* **sp. nov.**, photographs of paratypes, lower parts of the Yanchang Formation, Shaanxi Province, northern China **A**, NIGP179641. **B**, NIGP179642. **C**, Enlargement of **B**, showing basal portion of wing. **D**, Enlargement of **A**, showing apical portion of wing. Scale bars: 1 mm in **A**, **B**, 500 µm in **C**, **D**.

almost straight and subparallel to R before tegminal mid-length, then strongly curved toward CuA, MP with at least four terminal branches; stem CuA subparallel to MP after separated from common stem R+MP+CuA, then strongly curved and close to vein CuP at basal about 1/4 tegminal length; CuA<sub>1</sub> entirely fused to stem MP and crossvein *mp-cua* replaced by free base of CuA<sub>1</sub>; crossvein *mp-cua* long and inclined; CuP straight; clavus missing.

## Discussion

The new taxon can be placed into the family Granulidae based on its tegminal surface covered with large granular ornamentations and pigmented bands, vein CuA curved, and CuA<sub>1</sub> entirely fused to stem MP (Hong, 1980; Zhang *et al.*, 2022). The palaeodiversity of the family Granulidae is very low, with only two monotypic genera confined to the Middle Triassic Yanchang Formation





**FIGURE 7.** *Sinogranulus jinsuoguanensis* sp. nov., line drawings of **A**, NIGP179639. **B**, NIGP179640.

of Tongchuan City, Shaanxi Province, northern China. They include *Granulus tongchuanensis* Hong, 1980, and *Sinogranulus qishuiheensis* Zhang, Chen & Zhang, 2022. Furthermore, assignment to the genus *Sinogranulus* is supported by the tegmen having a similar colour pattern, regular shape, apex rounded, widened postcostal cell, developed cell C2, stems R, MP and CuA separated from common stem R+MP+CuA almost at same point, and crossvein *mp-cua* long and inclined. The new species, *Sinogranulus jinsuoguanensis* Fu & Huang sp. nov. can be distinguished from the type species of *Sinogranulus* mainly in tegmen with stems MP and CuA strongly curved posteriorly, making broad, spoon-shaped radial and median cells (stems MP and CuA gently curved in *S. qishuiheensis*); and MP forked basad of basal crossvein *r-mp* (MP forked obviously apicad of basal crossvein *r-mp* in *S. qishuiheensis*).

*Sinogranulus qishuiheensis* was established by Zhang, Chen & Zhang, (2022) on the basis of a single damaged forewing specimen with basal cell area, and apical portion not preserved (Zhang *et al.*, 2022). Herein we are supplementing the morphological characters of *S. qishuiheensis* based on four additional forewing

specimens, including features of the hyposubcostal carina, basal cell, apical margin, and terminal branches of R and MP. The tegminal characters of *Sinogranulus* having the hyposubcostal carina strongly convex, basal cell with apex sharp, closed by inclined basal crossvein *cua-cup*, resembles the pattern found in most genera of Scytinopteridae. Besides, several morphological revisions of *S. qishuiheensis* are as follows: 1) the apical margin actually is rounded in all new specimens described herein, while the apex is truncate in the hypothetical line drawing plate 3a in Zhang *et al.* (2022); 2) vein Pcu is not mentioned in the depiction and line drawing in Zhang *et al.* (2022) where the so-called vein 'A<sub>1</sub>' should actually be Pcu, so that A<sub>1</sub>, Pcu+A<sub>1</sub> are missing; 3) one crossvein is shown between veins CuP and 'A<sub>1</sub>' in the depiction and line drawing plate 3a in Zhang *et al.* (2022), but the crossvein is invisible in all the new specimens examined herein, thus, the so-called crossvein is likely to be a stripe or preservation artifact.

The eight individuals of two species of *Sinogranulus* show considerable intraspecific variation in venation involving the number of terminal branches of stems R and MP and crossvein *r-mp*, position of stems R and MP



forking, and length of cell C2. It is worth mentioning that the veinlets distributed in the apical portion between terminal R and MP<sub>1+2</sub> are highly variable in the two species of *Sinogranulus*. There are two crossveins *r-mp* closing cell C2 in NIGP179635 of *S. qishuiheensis* (Fig. 3a) and the holotype (NIGP179639) of *S. jinsuoguanensis* (Fig. 7a), and two indistinct veinlets are separated from R but not extending to MP<sub>1+2</sub> in the holotype of *S. jinsuoguanensis* (Fig. 7a), while five distinct crossveins *r-mp* are present, and the area between terminal R and MP<sub>1+2</sub> is filled with a large meshwork of veinlets in NIGP179636 of *S. qishuiheensis* (Fig. 3b) and NIGP179640 of *S. jinsuoguanensis* (Fig. 7b). The new data represents the third species of granulid and the second species of *Sinogranulus*, enriching the palaeodiversity of this extinct little-known family.

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