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New Surijokocixiidae (Insecta: Hemiptera: Fulgoromorpha) from the Middle Triassic of China

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Abstract

A new Middle Triassic (Ladinian) planthopper of the family Surijokocixiidae (Surijokocixioidea, Fulgoromorpha) from the Tongchuan Formation in Shaanxi, NW China is established as *Sinosurijikocixius tongchuanensis* gen. et sp. nov. All the known taxa assigned to Surijokocixiidae are reviewed and compared. The palaeogeographic distributional pattern of Surijokocixiidae from the middle Permian to Late Triassic is summarized.

KEYWORDS

ancestral planthopper, Ladinian, palaeogeographic distribution, *Sinosurijikocixius tongchuanensis* gen. et sp. nov., Surijokocixiidae

1 | INTRODUCTION

Planthoppers (Fulgoromorpha, Hemiptera) are a diverse and common group of insects nowadays, distributed worldwide (Bartlett et al., 2018; Szwedo, 2018). Fossil record of the suborder reaches the Upper Permian, with Coleoscytoidea Martynov, 1935 and the Permian and Triassic Surijokocixioidea Shcherbakov, 2000, each monotaxic with one family, and the extant Fulgoroidea Latreille, 1807 are known since the Triassic (Szwedo, 2018; Zhang et al., 2021). The early history and systematic position of ancestral Fulgoromorpha remains obscure before the early Mesozoic. The extinct family Surijokocixiidae of the Fulgoromorpha was established by Shcherbakov (2000) and classified as the superfamily Surijokocixioidea by Szwedo et al. (2004). Known from adpression fossils, mostly tegmina, these relatively small to moderate in size planthoppers had been recorded from middle Permian to Late Triassic strata in Australia, China, Kyrgyzstan and Russia (see juxtaposition in Zhang, Szwedo, et al., 2021). The tegminal characters of this family were overviewed by Shcherbakov (2000, 2004) and Bourgoin and Szwedo (2008). The phylogenetic relationships of Coleoscytidae (Coleoscytoidea), Surijokocixiidae (Surijokocixioidea) and Fulgoroidea within the Fulgoromorpha are still disputable (Lambkin, 2020; Shcherbakov & Popov, 2002; Szwedo, 2018).

Here we describe a new genus and species of Surijokocixiidae from the Middle Triassic (Ladinian) Tongchuan Formation of northwestern China. This is the second surijokocixiid species reported from the Tongchuan Formation and it increases the knowledge of

the hemipteran diversity of Tongchuan Entomofauna and the family Surijokocixiidae as a whole. It further provides evolutionary evidence for ancient planthoppers in diversity and disparity.

2 | MATERIAL AND METHODS

The tegmen described here was collected from the Middle-Upper Triassic Tongchuan Formation of the Qishuihe outcrop near Hejiafang Village, Jinsuoguan Town, Tongchuan City, Shaanxi Province, NW China (Figure 1a–c). The lithostratigraphic column of the Tongchuan Formation follows Zhang, Szwedo, et al. (2021) and Zheng et al. (2018) (Figure 1d). The insect-bearing light gray shale interval is located on the top horizon of the lower Tongchuan Formation and is dated to 238–237 Ma (a Ladinian deposit) by U–Pb geochronology (Zheng et al., 2018).

The tegminal venation used here follows the general Hemipteran wing scheme (Bourgoin et al., 2015; Nel

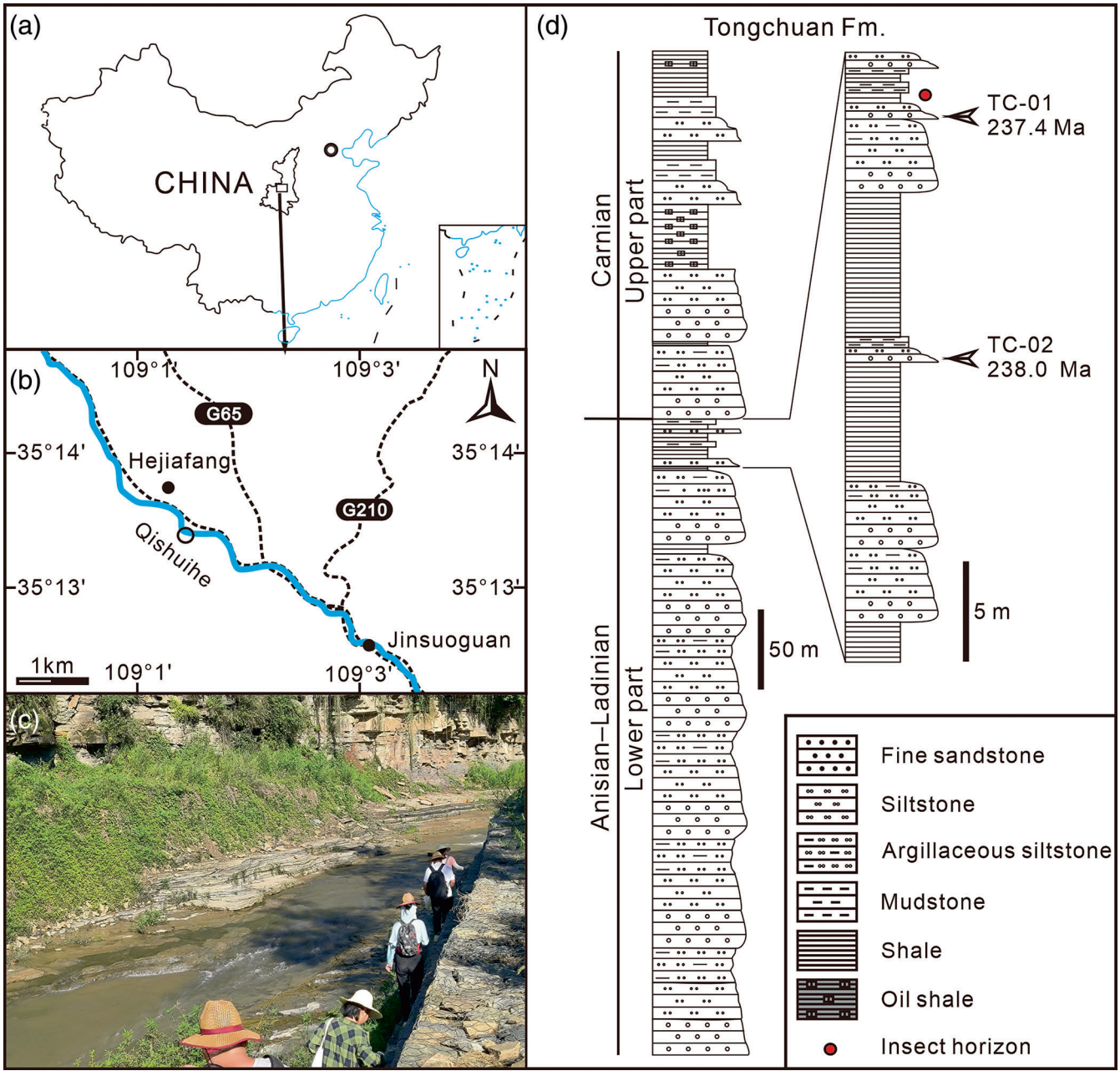

FIGURE 1 Geology of the Qishuihe section in Tongchuan City, Shaanxi Province, NW China (redrawn from Zheng et al., 2018). (a) Geographical map showing the location of Hejiafang area in China; (b) geographical map showing the location of Qishuihe section; (c) photograph of the Tongchuan formation in the Qishuihe outcrop; (d) stratigraphic column of the Tongchuan formation with fossil horizon and U–Pb dating ages

et al., 2012). The detailed abbreviations of venational and cellular terminology same with explanation listed by Zhang, Szwedo, et al. (2021).

The fossil tegmen studied here was examined and photographed using a stereomicroscope system (ZEISS Stereo Discovery V16) in the Nanjing Institute of Geology and Paleontology, Chinese Academy of Sciences (NIGPAS). Cropped image and illustrated line drawings were both achieved using software CorelDRAW X9. The specimen described here is housed in NIGPAS (NIGP200737).

3 | SYSTEMATIC PALEONTOLOGY

Order Hemiptera Linnaeus, 1758.

Suborder Fulgoromorpha Evans, 1946.

Superfamily Surijokocixioidea Shcherbakov, 2000.

Family Surijokocixiidae Shcherbakov, 2000.

Type genus. *Surijokocixius* Becker-Migdisova, 1961; by original designation.

Sinosurijokocixius Zhang, Szwedo et Zhang, gen. nov.

The nomenclatural acts established herein are registered under Zoo-Bank LSID: http://www.zoobank.org/urn:lsid:zoobank.org:pub:F7590802-A347-4E32-952D-ED286D2A43D7.

- Etymology: The genus name is from the Latin *Sinae* ("China") and the generic name *Surijokocixius*. Gender: masculine.
- Type species: *Sinosurijokocixius tongchuanensis* Zhang, Szwedo et Zhang, gen et sp. nov., by present designation and monotypy.
- Diagnosis: Differ from *Boreocixius* by tegminal shape, with anterior section of costal margin distinctly more curved, slightly incised; distinctly shifted and more arcuate bScP at level of basal cell (closer to basal cell and subparallel in *Boreocixius*); branch ScP + RA distinctly bent after separation from RP (not bent, slightly arcuate only in *Boreocixius*); fewer MP terminals in number; three branches of CuA (two branches in *Boreocixius*); CuA forked more distally from ScP + R forking than in *Boreocixius*. Differ from other surijokocixiid genera by larger tegminal size and more branches of RA.
- Description: Tegmen wide, length/width ratio 1.65, preserved portion roundly triangular in shape (clavus is missing). Appendix narrow, along apical margin, with transverse striations presented. Basal cell irregular, about three times as long as wide. Vein Pc + CP curved anteriorly, costal area gradually narrower from base to apex (slightly basad of terminal ScP + RA_1); stem ScP + R leaving basal cell basad of stem MP and first forked at basal one-fourth of tegmen length; branch ScP + RA strongly curved anteriorly after originating from stem ScP + R, forming four terminals; branch RP slightly curved with three terminals; initial dividing level of branch ScP + RA slightly anteriad of that of RP, but slightly posteriad of that of MP. Median area much narrower than radial area. Stem CuA about twice as long as stem ScP + R, trifurcated curvedly, CuA_1 with two terminals, CuA_2 not strongly curved. Pigmentation present on tegminal surface in form of two wide, transverse bands at basal second quarter and in apical quarter.
- Age and occurrence: Middle Triassic (Ladinian); Tongchuan City, Shaanxi Province, China.
- Species included: Type species only.

Sinosurijokocixius tongchuanensis Zhang, Szwedo et Zhang, gen. et sp. nov. (Figures 2 and 3a)

The nomenclatural acts established herein are registered under Zoo-Bank LSID: http://www.zoobank.org/urn:lsid:zoobank.org:pub:F7590802-A347-4E32-952D-ED286D2A43D7.

- Etymology: The specific epithet is from Tongchuan City where the holotype was collected.
- Holotype: NIGP200737 (a tegmen lacking clavus, part and counterpart), housed in NIGPAS.

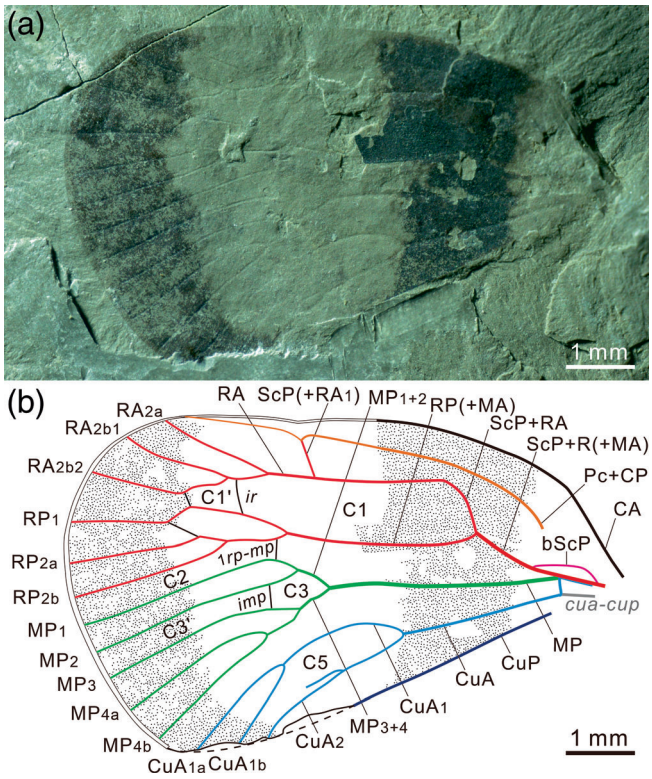

FIGURE 2 *Sinosurijokocixius tongchuanensis* Zhang, Szwedo et Zhang, gen. et sp. nov., holotype (NIGP200737), tegmen. (a), photograph; (b), reconstruction and venation

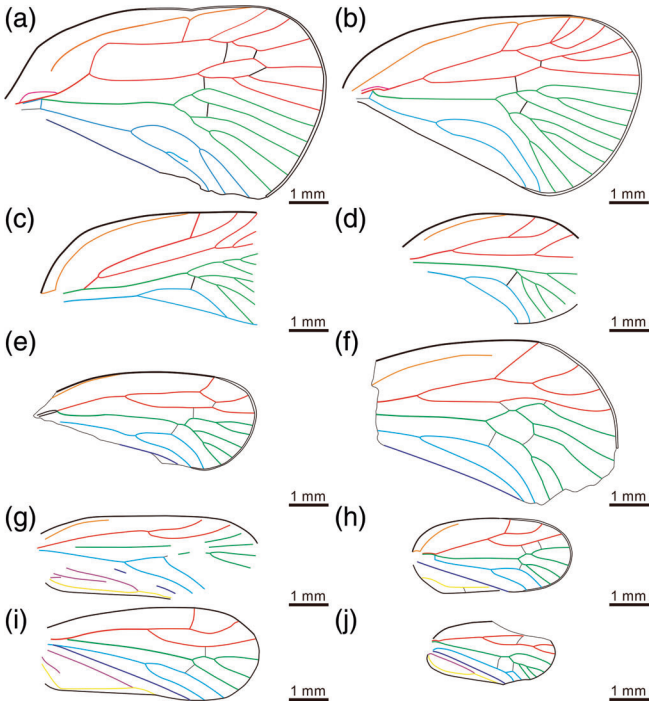

FIGURE 3 Tegminal venational comparison of species of Surijokocixiidae. (a) *Sinosurijokocixius tongchuanensis* gen. et sp. nov.; (b) *Boreocixius tongchuanensis* Zhang, Szwedo, et al., 2021; (c) *B. sibiricus* Becker-Migdisova, 1955; (d) *B. rotundatus* Becker-Migdisova, 1955; (e) *Crosbixius carsburgi* Lambkin, 2020; (f) *Karesmina punicea* Lambkin, 2020; (g) *Paraprygalogus* Aristov & Rasnitsyn, 2014 (h) *Surijokocixius tomiensis* Becker-Migdisova, 1961; (i) *Scytocixius mendax* Martynov, 1937; (j) Tricrosbia minuta Evans, 1971

- Diagnosis: As for genus.
- Description: Tegmen with clavus missing and posterior margin partly damaged, preserved portion roundly subtriangular in shape, 8.1 mm long, 4.9 mm wide, length/width ratio 1.65. Costal margin curved basally, slightly incised, nearly straight in median portion before anteroapical angle; anteroapical angle widely rounded, posteriad to posteroapical angle; apical margin widely rounded, posteroapical angle angulately rounded, estimated length of tornus about 0.25 of clavus, apendix distinct, but not widened, with transverse striations. Stem CA thick, basally arched, then slightly curved and straight in middle anterior margin. Stem Pc + CP shifted from CA (probably near the base of tegmen), long and distinctly curved basally, obliquely converging to CA basally except for connection with vein ScP(+RA_1). Vein bScP thin and arched, longer than basal cell. Stalk ScP + R + MP + CuA slightly curved at end level of basal cell, then stretched strongly and straight as stem ScP + R(+MP). First forked to ScP + RA and RP(+MA) at basal 0.25 tegminal length; branch ScP + RA strongly protruded towards costal margin, then extended parallelly to costal margin. Tegminal ScP(+RA_1) separated from branch ScP + RA slightly apicad of middle of tegmen, slightly oblique, reaching vein Pc + CP. Stalk RA subequal to vein ScP(+RA_1) length, forked into veins RA_{2a} and RA_{2b} at basal 0.64 tegminal length, entering anteroapical angle, vein RA_{2a} single, RA_{2b} two-branched (RA_{2b1}, RA_{2b2}). Vein RP(+MA) shifted mediad, nearly parallel to middle section of anterior margin and forked into veins RP_1 and RP_2 at basal 0.59 tegminal length; terminal RP_1 S-curved, vein RP_2 two-branched (RP_{2a}, RP_{2b}). Stem MP basally curved, parallel to vein RP(+MA) in general, bifurcated on corium into veins MP_{1+2} and MP_{3+4} at basal 0.52 tegminal length, initial forking level of veins MP_{1+2} and MP_{3+4} slightly basal of vein RP(+MA), terminals MP_1, MP_2 and MP_3 single and parallel each other, stalk MP_4 much shorter than stalk MP_3, two-forked (MP_{4a} and MP_{4b}), apical of level of vein RP(+MA), medial area much narrower than radial area. Stem CuA much longer than stem ScP + R(+MA), first forked at basal 0.38 tegminal length; vein CuA_1 strongly curved mediad, forked into vein CuA_{1a} and CuA_{1b} at level of vein RP(+MA) forking, vein CuA_2 nearly straight, subparallel to veins CuA_1 and CuA_{1a}. Stem CuP preserved straight. Crossveins developed on membrane, crossvein *ir* closing cell C1 long, postnodal *ir* (between RA_{2b} and RP_1), 1*rp-mp* (between RP_2 and MP_1) and *imp* (between MP_2 and MP_3) and 2*rp-mp* (between RP and MP_{1a}), *cua-cup* short. Cell C1 much longer than C1', cells C2 and C3' subrectangular; cell C3 pentagonal, about as long as cell C1'; cell C5 open. Two irregular pigmented bands, basal, darker at level of second quarter of tegmen length, apical, lighter in apical quarter, on membrane, subparallel to apical margin.
- Horizon and locality: Top of the lower of Tongchuan Formation; Qishuihe outcrop near Hejiafang Village, Jinsuoguan Town, Tongchuan City, Shaanxi Province, NW China.

4 | DISCUSSION

The Permian–Triassic family Surijokocixiidae is characterized in tegmen by costal margin slightly angulate at base, costal area broad, basally widened precostal carina, costal area present, basal cell wide and apically quadrate, intraveinal cells and C4 open; C2 sometimes closed, a relatively short common stem ScP + R, more distal

TABLE 1 List of species assigned to Surijokocixiidae Shcherbakov, 2000

Genus and species	Horizon and age	Locality	References
Surijokocixius tomiensis Becker-Migdisova, 1961	Kazankovo-Markinskaya Fm., Wordian (P_2)	Kemerovo, western Siberia, Russia	Becker-Migdisova, 1961
Scytocixius mendax Martynov, 1937	Amanak Fm., Capitanian (P_2)	Orenburg, southwestern Russia	Martynov, 1937
Paraprygalogus Aristov & Rasnitsyn, 2014	Vokhma Fm., Changhsingian (P_3)	Vologda, western Russia	Aristov & Rasnitsyn, 2014
Boreocixius rotundatus Becker-Migdisova, 1955 *Boreocixius sibiricus* Becker-Migdisova, 1955	Induan (T_1)	Malaya Kheta, northern Russia	Becker-Migdisova, 1955
Boreocixius tongchuanensis Zhang, Szwedo, et al., 2021	Lower Tongchuan Fm., Ladinian (T_2)	Tongchuan, northwestern China	Zheng et al., 2018; Zhang, Szwedo, et al., 2021
Sinosurijokocixius tongchuanensis Zhang, Szwedo et Zhang, gen. et sp. nov.	Lower Tongchuan Fm., Ladinian (T_2)	Tongchuan, northwestern China	This article
surijokocixiid	Madygen Fm., Ladinian–Carnian (T_2 -T_3)	Madygen, Kyrgyzstan	Shcherbakov, 2011
Tricrosbia minuta Evans, 1971	Mount Crosby Fm., Norian (T_3)	Queensland, Australia	Evans, 1971
Crosbixius carsburgi Lambkin, 2020	Mount Crosby Fm., Norian (T_3)	Queensland, Australia	Lambkin, 2020
Karesmina punicea Lambkin, 2020	Esk Fm., Anisian (T_2)	Queensland, Australia	Lambkin, 2020

branchings of R and CuA, MP at least twice forked, *cup-pcu* absent, Pcu + A1 joining claval suture (Bourgoin & Szwedo, 2008; Shcherbakov, 2004; Szwedo et al., 2004). There are 10 species so far assigned to seven genera reported in the family Surijokocixiidae (Lambkin, 2020; Zhang, Szwedo, et al., 2021) (Table 1) (Figure 3).

Sinosurijokocixius tongchuanensis Zhang, Szwedo et Zhang, gen. et sp. nov. is similar to *Boreocixius tongchuanensis* Zhang, Szwedo, et al., 2021, from the same layer of the Tongchuan Formation. A general venational comparison of *S. tongchuanensis* Zhang, Szwedo et Zhang, gen. et sp. nov. (Figure 3a) with all the three *Boreocixius* species (Figure 3b–d) shows that *S. tongchuanensis* Zhang, Szwedo et Zhang, gen. et sp. nov. has the largest preserved tegmen in Surijokocixiidae, characterized by thickened and slightly S-shaped anterior portion of costal margin (similarly as in some Coleoscytidae), the unique basal direction of ScP + RA basal section, three terminals of branch CuA (as in some Fulgoridiidae). *S. tongchuanensis* Zhang, Szwedo et Zhang, gen. et sp. nov. differs from *Crosbixius carsburgi* Lambkin, 2020, *Paraprygalogus* Aristov & Rasnitsyn, 2014, *Surijokocixius tomiensis* Becker-Migdisova, 1961, *Scytocixius mendax* Martynov, 1937 and *Tricrosbia minuta* Evans, 1971 (Figure 3e,g–j) by significantly larger tegmen and more branches of RA. The tegminal length of Surijokocixiidae reached the maximum (*Boreocixius*, *Sinosurijokocixius* and *Karesmina*) during the Middle Triassic (Figure 3a,b, f), but the factors and reasons for this size increase remain unknown.

The Surijokocixiidae has a wide distribution in Asia, Australia and Europe (Zhang, Szwedo, et al., 2021), but its detailed palaeogeographic distribution and history of its changes have not been explored. Fossil records suggest that the Surijokocixiidae was distributionally limited to mid-latitudes of northern Pangaea east to Ural Sea during the middle to late Permian (Figure 4a,b), indicating origination of the Surijokocixiidae probably in the early Permian. During the earliest Triassic, this family appeared in the same area, indicating its survival of the end-Permian mass extinction (EPME) with a potential refuge for the family in present northern Russia (Figure 4c). During the

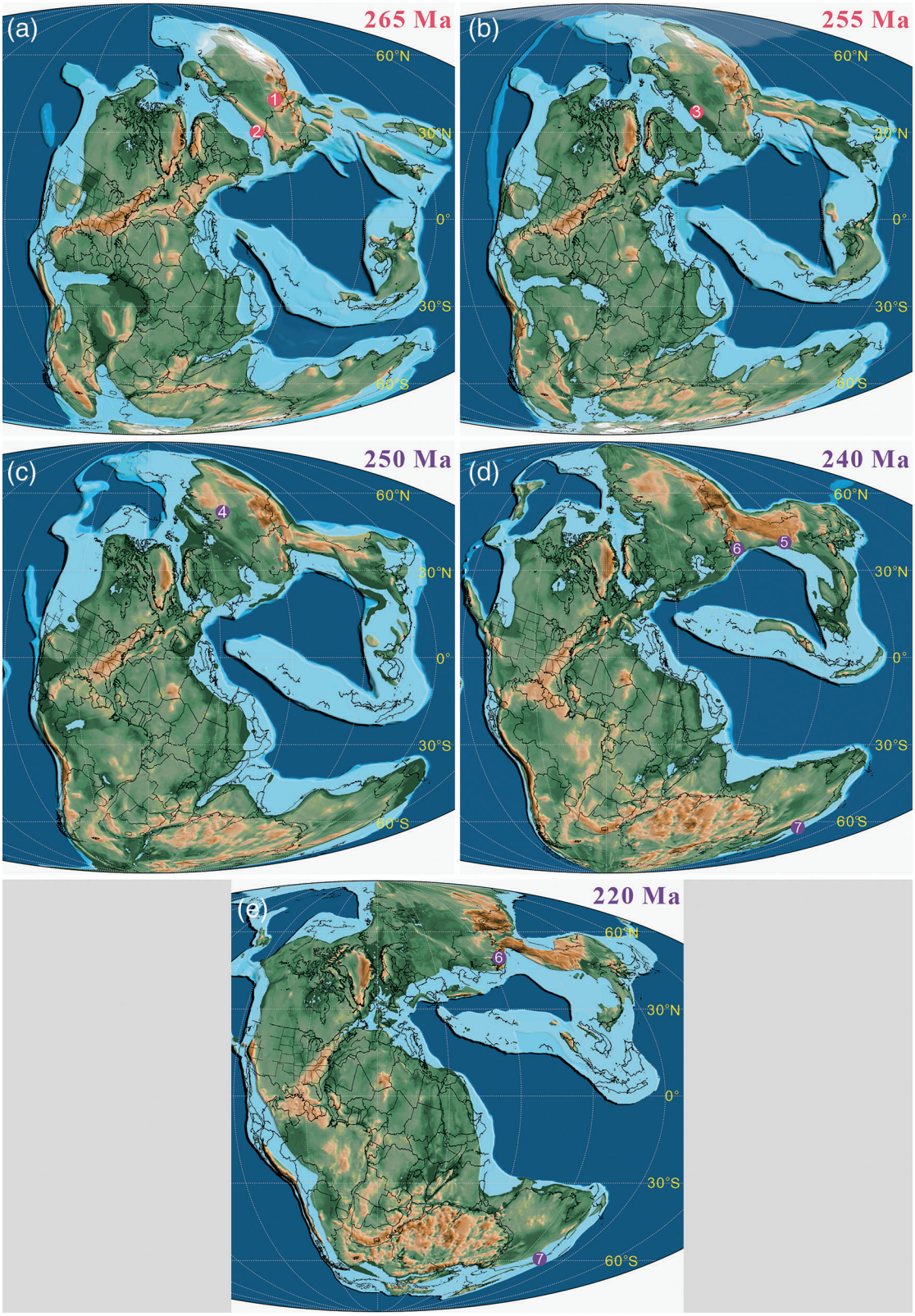

FIGURE 4 Palaeogeographic distribution of the Surijokocixiidae: (1) Kemerovo, Russia (Wordian, P2); (2) Orenburg, Russia (Capitanian, P2); (3) Vologda, Russia (Changhsingian, P3); (4) Malaya Kheta, Russia (Induan, T1); (5) Shaanxi, China (Ladinian, T2); (6) Madygen, Kyrgyzstan (Ladinian-Carnian, T2-3); (7) Queensland, Australia (Anisian, T2; Norian, T3). Palaeogeographic maps modified from Scotese (2021)

Middle Triassic, this family expanded its distribution to high-latitude coastal areas (near the Panthalassa) in southern Gondwana and mid-latitude coastal areas (near the Paleo-Tethys) in eastern Laurasia (Figure 4d). During the early-middle Late Triassic, the Surijokocixiidae had the same distribution pattern as in the Middle Triassic, and probably became extinct at the end of the Triassic (Figure 4e).

5 | CONCLUSION

As a rarely found representative of the Triassic planthoppers, *Sinosurijikocixius tongchuanensis* Zhang, Szwedo et Zhang, gen. et sp. nov. is the second reported surijokocixiid with detailed description from the Middle Triassic Tongchuan Entomofauna. The new genus is characterized by an enlarger tegmen, some venational characters as more developed branching of RA and trifurcated CuA, separating it clearly from other taxa of Surijokocixiidae. For the first time, the palaeogeographic distribution of Surijokocixidae, hypothesized on known fossil records, is summarized, presenting distribution of the family from the middle Permian to Late Triassic in the Boreal and Gondwana areas, and indicating that surijokocixiids migrated southward since the Early Triassic, and reached maximum distribution to southern Gondwana from the Middle to early-middle Late Triassic. The new genus and species not only increases the known taxonomic diversity of Surijokocixiidae and of the planthoppers in the Tongchuan Entomofauna., but gives new insight into morphological disparity of the group, and to the knowledge of the hemipteran planthoppers of the Tongchuan Entomofauna.

AUTHOR CONTRIBUTIONS

Qianqi Zhang: Conceptualization; data curation; software; writing – original draft. **Jacek Szwedo:** Funding acquisition; supervision; writing – review and editing. **Daran Zheng:** Investigation; visualization; writing – review and editing.

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