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The earliest fossil record of true crickets belonging to the Baissogryllidae (Insecta, Orthoptera, Grylloidea)

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Abstract

Baissogryllidae is an extinct family of the insect superfamily Grylloidea, previously known from Late Jurassic – Early Cretaceous time. A new genus and species, *Sinagryllus xinjiangensis* gen. et sp. nov., is described here based on a well-preserved forewing from the Lower Jurassic Sangonghe Formation of Xinjiang, northwestern China. It can be attributed to Baissogryllidae based on the combination of the following characteristics: a true mirror in the male tegminal stridulatory apparatus; and a distinct widening of the area between CuA_2, lateral part of the diagonal vein, and proximal part of the proximal branch of $MP+CuA_1$. This find represents not only the earliest record of Baissogryllidae, but also the first fossil wing of Grylloidea reported from China.

1. Introduction

Grylloidea is a superfamily of insects commonly known as true crickets within the order Orthoptera, consisting of four recent families (Gryllidae, Mogoplistidae, Gryllotalpidae and Myrmecophilidae) (Resh & Cardé, 2009) and two fossil families (Baissogryllidae and Protogryllidae) (Cigliano *et al.* 2018). It occupies almost all terrestrial habitats occurring: in or near treetops and on bushes, grasses and other herbaceous plants; on the soil surface; in caves and burrows in logs or standing trees; and even on beaches (Resh & Cardé, 2009). The earliest fossil record of Grylloidea can be dated back to Middle Triassic time (Heads & Leuzinger, 2011), and fossil Grylloidea have been reported from America, Brazil, England, Germany, Mongolia, Myanmar, Russia and China (Cigliano *et al.* 2018). However, among these fossils, only one specimen belonging to Trigonidiidae has been found in China (Ren, 1998). Here we report the second grylloid fossil from China, a forewing attributed to the extinct family Baissogryllidae from the Lower Jurassic Sangonghe Formation of the Junggar Basin, northwestern China. This specimen represents not only the earliest record of Baissogryllidae, but also the first fossil grylloid wing with a sound-producing organ from China.

The Junggar Basin is one of the most famous walled sedimentary basins in western China, with Mesozoic and Cenozoic non-marine strata more than 11 km thick (Carroll *et al.* 2010). Of these strata, Jurassic deposits are widely distributed in the basin and have a total thickness of 4000 m, with several sedimentary centres located in the eastern and southern Junggar Basin (Deng *et al.* 2010). As one of the best stratigraphical sections of the terrestrial Jurassic System in China, the Haojiagou–Toutunhe section is situated on the southern margin of the Junggar Basin (Deng *et al.* 2010). Jurassic deposits are approximately 2400 m thick in the section and can be divided into six formations (in ascending order): the Badaowan, Sangonghe, Xishanyao, Toutunhe, Qigu and Kalazha formations (Deng *et al.* 2010). Until now, only two fossil insects have been reported from the Sangonghe Formation in this section, comprising *Artematopodites insculptus* (Zhang, 1997) Yan & Zhang, 2010 and *Eofulgoridium tenellum* Zhang *et al.* 2003 (Zhang, 1997; Zhang *et al.* 2003; Yan & Zhang, 2010). Most recently, several insects were unearthed from the Sangonghe Formation including a grylloidean forewing described in Section 4 below.

2. Geological setting

The stratotype of the Sangonghe Formation is located in Fukang, Xinjiang, northwestern China and this formation is represented by a set of lacustrine and delta sediments; the Sangonghe Formation occurs in the Junggar, Turpan–Hami, Santanghu, Kupu, Hoxtolgay and Hefeng basins in northern Xinjiang, China, and has a thickness ranging from over 10 m to 480 m (Deng *et al.* 2010). Abundant bivalves, gastropods, conchostracans, plants and palynomorphs have been found in the formation (Deng *et al.* 2010).

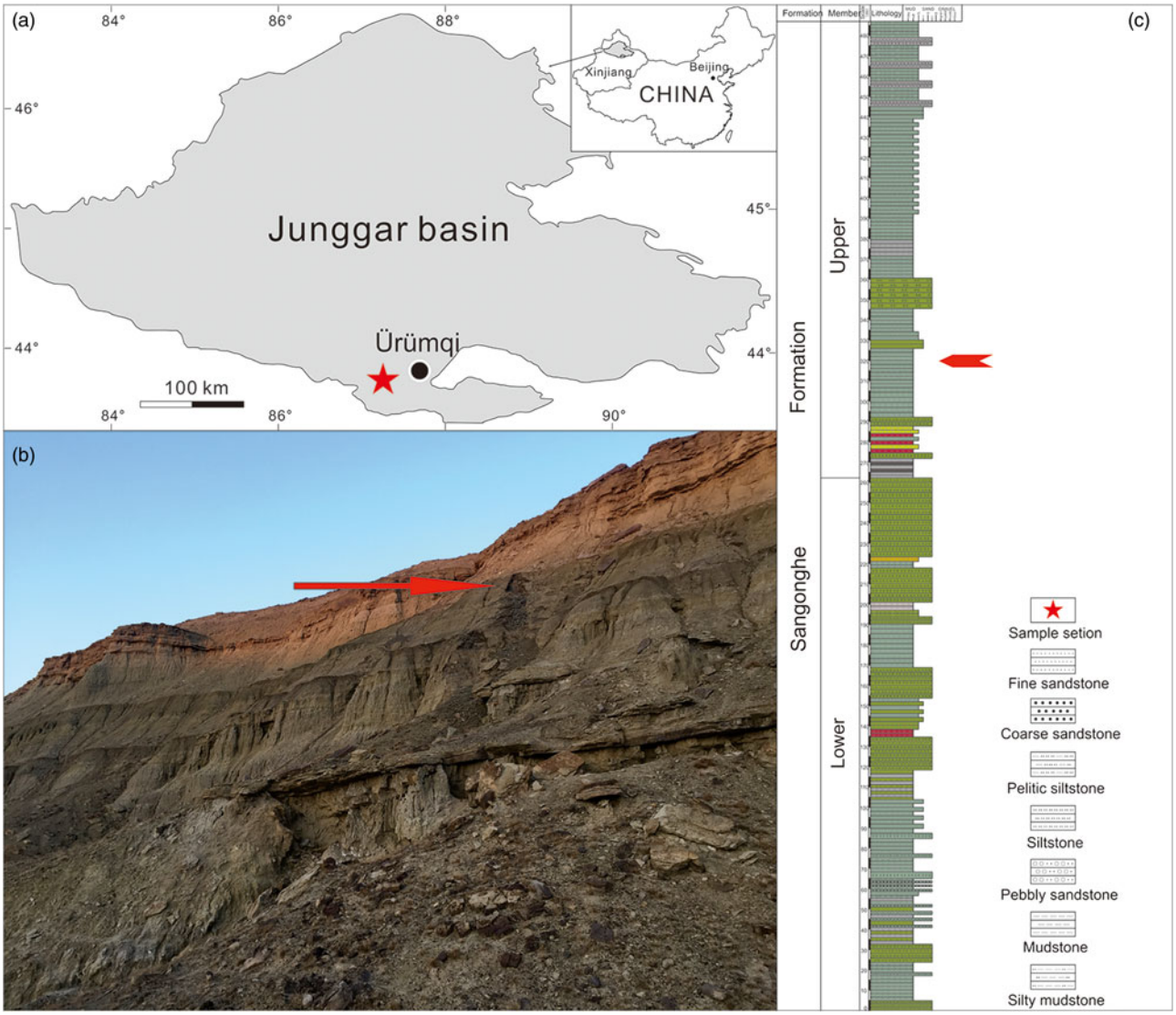

Fig. 1. (Colour online) (a) Geographical sketch map of the Junggar Basin, Xinjiang, China, showing the locality (star) of the Haojiagou–Toutunhe section. (b) Photograph of the insect-bearing beds (arrow) of the Sangonghe Formation in the Haojiagou–Toutunhe section. (c) Stratigraphical column showing the lithology of the Sangonghe Formation and position (arrow) of the new insect collected from the Sangonghe Formation (based on data from Deng *et al.* 2010).

The specimen described in this study was collected from the Sangonghe Formation in the Haojiagou–Toutunhe section, 40 km SW of Urumqi City (Fig. 1). In this section, the Sangonghe Formation is in conformity with the overlying Middle Jurassic Xishanyao Formation and the underlying Lower Jurassic Badaowan Formation, and is divided into two members with a total thickness of 486.87 m (Deng *et al.* 2010). The Upper Member mainly consists of greenish-grey and dark-grey, thin-bedded fine-grained sandstones and siltstones, silty mudstone, greyish-black mudstones intercalated with greyish-green medium-grained sandstones, and greyish-black carbonaceous mudstones with thin-bedded coal beds at base (Deng *et al.* 2010). The Lower Member is composed mainly of yellowish-green and greyish-green, thick-bedded or massive medium- to coarse-grained sandstones, pebble-bearing coarse-grained sandstones, fine-grained conglomerates and ferric, carbonaceous sandstones unequally alternating with greyish-green, dark-grey fine-grained sandstones and siltstones, silty mudstones intercalated with dark-grey mudstones, and carbonaceous and calcareous mudstones (Deng *et al.* 2010). The Sangonghe Formation in the Haojiagou–Toutunhe section yields abundant plants, spores and pollen, megaspores, bivalves, gastropods, conchostracans and ostracods (Deng *et al.* 2010).

Different fossil assemblages have been established from the Sangonghe Formation including the *Phlebopteris–Marattiopsis* plant assemblage, three spore and pollen assemblages (featuring a lack of fern spores in the lower part of the Lower Member, a high content of *Classopollis* in the upper part of the Lower Member and highly abundant fern spores in the Upper Member), the *Minerisporites institus–Kuqaia* megaspore assemblage, and the *Rhipidoblattina robusta – Liaossogomphites xinjiangicus* insect assemblage (Deng *et al.* 2010). According to the fossil assemblages and other fossils including bivalves and conchostracans, the age of the Sangonghe Formation can be quite confidently dated to Early Jurassic time. It is also possible that the top of this formation is of Middle Jurassic age (Deng *et al.* 2010), suggesting that the grylloid forewing described in Section 4 from the lower Upper Member of the Sangonghe Formation is late Early Jurassic in age.

3. Materials and methods

The specimen described here is preserved as an impression on the surface of greyish-green mudstones and lightly tectonically deformed. It was collected from the lower part of the Upper Member of the Sangonghe Formation in the Haojiagou–Toutunhe section, Urumqi, Xinjiang, China (Fig. 1c).

There is no consensus on the interpretation of wing-venation nomenclature of Orthoptera; here we follow that proposed by Zeuner (1939), Sharov (1968, 1971), and amended by Gorochov (1986, 1995). The venational abbreviations used by Béthoux and Nel (2001, 2002) are given here in parenthesis following the corresponding venational abbreviations used by Gorochov (1995) if any significant differences are present between the two terminologies: C (ScA), costa; Sc (ScP), subcosta; RA, radius anterior; RS (RP), radial sector; M (M+CuA), media; MA (M), media anterior; MP (CuA), media posterior; Cu (CuP), cubitus; CuA (CuPa), cubitus anterior; CuP (CuPb), cubitus posterior; A, analis; 1A, first anal vein; 2A, second anal vein; and handle vein, a special cross-vein between CuA_1 and CuA_2.

The specimen was examined dry and alcoholic using a Nikon SMZ1000 stereomicroscope. The photographs were taken using a Nikon D800 digital camera, and the line drawings were compiled by tracing the photographs using the image-editing software CorelDraw X5 and Adobe Photoshop CS. The specimen is deposited in the Nanjing Institute of Geology and Palaeontology (NIGP), Chinese Academy of Sciences, Nanjing, China.

4. Systematic palaeontology

Order ORTHOPTERA Olivier, 1789

Superfamily GRYLLOIDEA Laicharting, 1781

Family BAISSOGRYLLIDAE Gorochov, 1985

Subfamily BAISSOGRYLLINAE Gorochov, 1985

Genus *Sinagryllus* gen. nov.

Derivation of name. Latin for China and recent genus *Gryllus*.

Type species Sinagryllus xinjiangensis sp. nov.

Diagnosis. Sc long and sigmoidal; lancet-like area small; mirror small with three dividing veins; diagonal vein with both ends branched; oblique veins simple and slightly curved; cross-veins between branches of $MP+CuA_1$ reticulated basally and regularly straight distally; diagonal vein, CuA_2 and a cross-vein between them forming a triangular cell.

Included species. Type species only.

Sinagryllus xinjiangensis sp. nov.

(Fig. 2)

Etymology. The specific name derives from Xinjiang, in reference to the locality of the type material being in that autonomous region.

Diagnosis. As for genus.

Material. Holotype, NIGP167908, a well-preserved male forewing.

Locality and horizon. Haojiagou–Toutunhe section, Urumqi, Xinjiang, China; Sangonghe Formation, Lower Jurassic.

Description. Male forewing, slightly damaged basally; preserved length 14.5 mm; Sc long and sigmoidal, reaching anterior margin slightly beyond two-thirds of forewing length from base and giving off 15 distinct and strongly oblique branches; lancet-like area between R and the proximal part of MA small and devoid of cross-veins; true mirror present in male tegminal stridulatory apparatus; $MP+CuA_1$ slightly curved basically; area between CuA_2, lateral part of diagonal vein, and proximal part of branch of MP $+CuA_1$ wide; dividing veins (cross-veins) of mirror sigmoidal, more or less parallel to true oblique veins; mirror small with three dividing veins; diagonal vein with both ends branched; oblique veins simple and slightly curved; cross-veins between branches of $MP+CuA_1$ reticulated basally and regularly straight distally; diagonal vein, CuA_2 and cross-vein between them forming triangular cell; CuP, 1A and 2A fused at about one-fifth of forewing length from base and then branched.

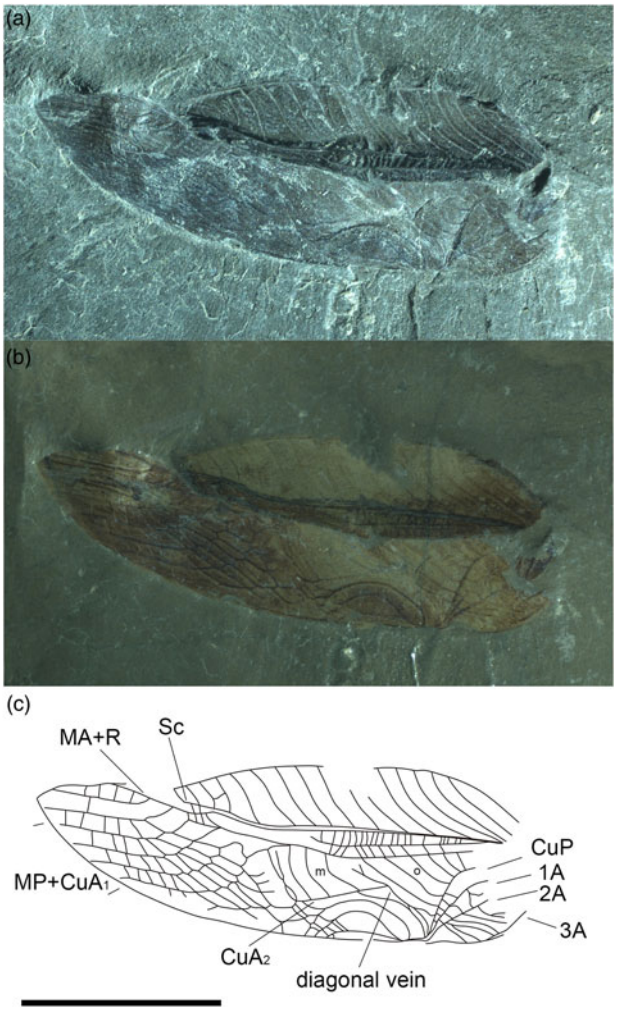

Fig. 2. (Colour online) *Sinagryllus xinjiangensis* gen. et sp. nov., holotype, NIGP167908. (a) General view; (b) in alcohol; (c) reconstruction. Scale bar: 10 mm.

5. Discussion

The new specimen is confidently attributable to Baissogryllidae based on the following associated features: a true mirror in the male tegminal stridulatory apparatus; distinct widening of the area between CuA_2, lateral part of diagonal vein, and proximal part of the proximal branch of $MP+CuA_1$; and dividing veins (cross-veins) of the mirror obliquely longitudinal and subparallel to the oblique veins. It is assigned to Baissogryllinae based on the small lancet-like area and the numerous and distinctly oblique dividing veins of the mirror.

Baissogryllinae includes the following genera: *Baissogryllus* Sharov, 1968, *Castilogryllus* Martins-Neto, 1995, *Eubaissogryllus* Gorochov, 1985, *Ponomarenkoana* Gorochov, 1992, *Speculogryllus* Gorochov *et al.*, 2006, *Storozhenkoana* Gorochov, 1992 and *Sinagryllus* gen. nov. with eight species. The new genus is different

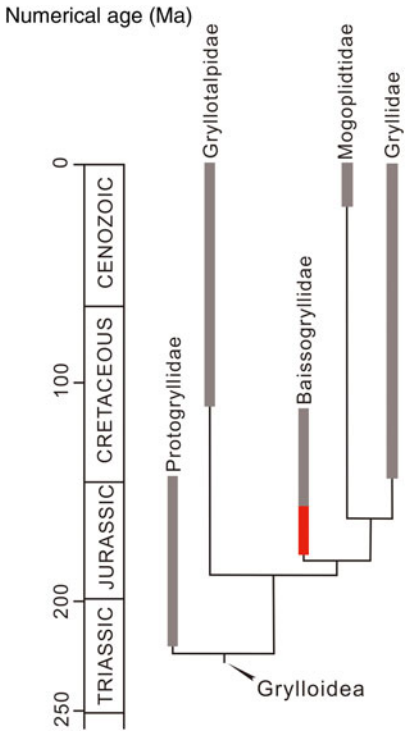

Fig. 3. (Colour online) Possible relationships among the Infraorder Gryllidea. Thick lines indicate known geological ranges, and thinner lines project likely ranges based on sister-group relationships. The red line indicates the extension of Baissogryllidae by the present study. Revised from Heads & Leuzinger (2011).

from *Baissogryllus* in lancet-like area devoid of cross-veins, fewer dividing veins, cross-veins between branches of MP+CuA_1 reticulated basally and regularly straight distally, and a triangular cell enveloped by a diagonal vein, CuA_2 and a cross-vein between them; from *Castilogryllus* mainly in having a smaller mirror with fewer dividing veins and fewer oblique veins; from *Eubaissogryllus* in having more oblique veins, cross-veins between branches of MP+CuA_1 reticulated basally and regularly straight distally, and a triangular cell enveloped by a diagonal vein, CuA_2 and a cross-vein between them; from *Ponomarenkoana* in having a smaller mirror, a diagonal vein with both ends branched, cross-veins between branches of MP+CuA_1 reticulated basally and regularly straight distally, a triangular cell enveloped by a diagonal vein, CuA_2 and a cross-vein between the two veins; from *Speculogryllus* in having a smaller mirror, oblique veins subparallel, and a triangular cell enveloped by a diagonal vein, CuA_2 and a cross-vein between them; from *Storozhenkoana* in having a relatively bigger mirror, cross-veins between branches of MP+CuA_1 reticulated basally and regularly straight distally, and a triangular cell enveloped by diagonal vein, CuA_2 and a cross-vein between them.

Untill now, 39 species and 21 genera have been attributed to Baissogryllidae (Cigliano *et al.* 2018; this study). Before this study, Baissogryllidae was only reported from Upper Jurassic – Lower Cretaceous strata of Brazil, England, Mongolia and Russia (Gorochov *et al.* 2006; Cigliano *et al.* 2018). A tentative reconstruction of relationships among major ensiferan groups, however, indicates that the Baissogryllidae lineage originated at least during late Early Jurassic time (Heads & Leuzinger, 2011), which is supported by our new discovery (Fig. 3). Furthermore, Baissogryllidae are mostly found in former warm temperate areas, with the exception of *Castillogryllus complicatus* Martins-Neto, 1995 reported from Brazil which was considered to be arid during Early Cretaceous time (Boucot *et al.* 2013). We therefore speculate that *Sinagryllus xinjiangensis* sp. nov. preferred to live in a warm environment, and that the palaeoclimate in the southern Junggar Basin was warm during late Early Jurassic time. This speculation is consistent with many thermophilous plants found in the Sangonghe Formation (Deng *et al.* 2010). More certainly, the highly specialized and distinctive venation of the fossil forewing was associated with mating and territorial sound production, showing that the Jurassic "bush" periodically reverberated to the sound of musical stridulation.

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