Discovery of the hind wing of the Early Cretaceous dragonfly Sinaktassia tangi Lin, Nel & Huang, 2010 (Odonata, Aktassiidae) from northeastern China

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A B S T R A C T

A well-preserved female hind wing of the petalurid dragonfly *Sinaktassia tangi* Lin, Nel & Huang, 1990 is described from the Lower Cretaceous Yixian Formation of Inner Mongolia, China. The discovery of this hind wing allows to complete the description of this Chinese Cretaceous taxon, provides an additional difference to other Aktassiidae. This dragonfly has a relatively wide distribution of in northeast China.

Keywords: *Sinaktassia tangi*, dragonfly, hind wing, Yixian Formation, earliest Aptian,

China

1. Introduction

The Petaluridae is a relatively small family of modern Anisoptera that belongs to the broader clade Petalurida with several Mesozoic families. Although quite rare in the fossil record, this group was widely distributed in Europe, Central Asia, China, and South America in the Mesozoic (Nel and Paicheler, 1992; Nel et al., 1998, 2001; Bechly, 2000; Petrulevičius and Nel, 2003; Nel and Bechly, 2009; Coram and Nel., 2009; Lin et al., 2010; Li et al., 2012). Nel et al. (1998) proposed a phylogenetic analysis of the fossil and modern Pelaturida with the following subdivisions: Protolindeniidae + (Cretapetaluridae + (Aktassiidae + Petaluridae). The Aktassiidae comprises the two sister subfamilies Pseudocymatophlebiinae and Aktassiinae (Nel et al., 1998). The subfamily Aktasiinae itself is composed of the three Mesozoic genera *Aktassia*, *Aeschnogomphus*, and *Sinaktassia* (Nel et al., 1998; Lin et al., 2010).

Untill now, only two petalurid species have been described from the Mesozoic of China: *Sinaktassia tangi* Lin, Nel & Huang, 2010 from the Lower Cretaceous Yixian Formation of western Liaoning Province (Lin et al., 2010), and *Pseudocymatophlebia boda* Li, Nel & Ren, 2012 from the Lower Cretaceous Yixian Formation of Liutiaogou Village, Inner Mongolia (Li et al., 2012). *S. tangi* was established just based on a forewing. Here we describe a well-preserved pelaturid hind wing from the Liutiaogou locality and attribute it to this species, allowing to precise the definition and position of this genus.

2. Geological settings

The specimen described herein was collected from the lower Yixian Formation of Liutiaogou Village, Ningcheng County, Chifeng City, Inner Mongolia, China (Fig. 1).

The fossils from the Liutiaogou outcrop are preserved in grey or yellow silty mudstone. Besides abundant insects (Wang et al., 2012), some well-preserved vertebrates have been discovered from this locality (Chang et al., 2006; Evans and Wang, 2010). The horizon at this locality is thought to be equivalent to either the Jianshangou Bed or the Dawangzhangzi Bed of the Yixian Formation (Evans and Wang, 2010; Wang et al., 2012), which was dated at ~124–123 Ma (earliest Aptian; Chang et al., 2009; Zhang et al., 2010; Cohen et al., 2014).

3. Material and methods

The specimen was examined dry using a Nikon SMZ1000 stereomicroscope. Photographs were prepared using a Canon 5D digital camera, and the line drawings were prepared from photographs using image-editing software (CorelDraw X5.0 and Adobe Photoshop CS6). The specimen is housed at the Nanjing Institute of Geology and Palaeontology, Chinese Academy of Sciences (NIGPAS).

The nomenclature of the dragonfly wing venation used in this paper is based on the interpretations of Riek (1976) and Riek and Kukalová-Peck (1984), as modified by Nel et al. (1993) and Bechly (1996). Wing abbreviations are as follows: AA, anal

anterior; Arc, arculus; AX0, AX1, AX2, primary antenodal cross-veins; CuAa, distal branch of cubitus anterior; CuAb, proximal branch of cubitus anterior; IR1, IR2, intercalary radial veins; MA, median anterior; MP, median posterior; Msp1, median supplement; N, nodus; 'O', oblique vein; Pt, pterostigma; RA, radius anterior; RP, radius posterior; Rsp1, radial supplement; ScP, subcostal.

The higher classification of fossil and extant Odonatoptera, as well as familial and generic characters followed in the present work, are based on the phylogenetic system proposed by Bechly (1996) and Nel et al. (1998) for the Mesozoic Petalurida. All measurements are given in mm.

4. Systematic palaeontology

Order Odonata Fabricius, 1793

Superfamily Petaluroidea Needham, 1903

Family Aktassiidae Pritykina, 1968

Subfamily Aktassinae Nel et al., 1998

Genus *Sinaktassia* Lin, Nel & Huang, 1990

Sinaktassia tangi Lin, Nel & Huang, 2010

(Figs. 2–3)

New Material. NIGP 161882, print of a slightly damaged female hind wing, deposited in Nanjing Institute of Geology and Palaeontology, Chinese Academy of Sciences, Nanjing, China.

Locality and Horizon. Liutiaogou Village, Ningcheng County, Chifeng City, Inner

Mongolia, China; Jianshangou Bed of the Yixian Formation, Early Cretaceous (earliest Aptian).

Revised Diagnosis. Wing characters only, body unknown. (1) Wing falcate, slender, and longer than 70 mm; (2) postnodal space very narrow, with many cells distal of Pt; (3) Pt elongate; (4) pterostigmal brace present and shifted slightly basal to Pt; (5) IR1 basally strongly zigzagged, long; (6) only one row of cells between RA and RP1 at level of Pt; (7) space between RP1 and RP2 greatly expanded, with more than 8–9 rows of cells; (8) PsA hypertrophied in the forewing; (9) subdiscoidal triangle widened in forewing, discoidal triangle T transverse; (10) subdiscoidal triangle divided by cross-veins in forewing, but free in hind wing; (11) more than two rows of cells in basal part of postdiscoidal area between level of distal angle of T and level of midfork; (12) groups of cells and secondary veins in areas between main veins; (13) Bqs-area ('bridge-space') narrowed; (14) distal side of T not angulated; (15) only three rows of cells in postdiscoidal area just distal of T; (16) no convex intercalary vein in postdiscoidal space; (17) area between RP3/4 and MA widened near posterior wing margin, with more than three rows of cells; (18) RP3/4 undulate and distally diverging from MA; (19) wing venation dense consisting of large number of cells; (20) few polygonal groups of cells separated by veinlets and intercalary veins between RP1 and IR1, IR2 and RP3/4, and MA and MP; (21) antenodal space longer than postnodal space; (22) T with a crossvein in forewing, but free in hind wing; (23) only two rows of cells in area between RP1 and RP2, IR2 and RP2 basal of Pt; (24) Rspl absent; (25) anal loop posteriorly closed and six-celled.

Remarks. The diagnosis was originally based on a nearly complete forewing (Lin et al., 2010) and is revised here based on a hind wing from the same horizon as the type material.

Description. Hind wing hyaline. Preserved length, 74.1 mm; width on the level of nodus N, 20.5 mm; distance from base to arculus, 6.5 mm, from arcus to N, 23.0 mm, from arculus to base of RP3/4, 14.0 mm, from N to wing apex, 44.7 mm, from N to pterostigma Pt, 23.8 mm, from Pt to wing apex, 15.9 mm. Pterostigmal length 7.8 mm and maxmum width 0.8 mm, narrow elongate, with basal side somewhat more oblique than distal side, and covering 10 cells. Pterostigmal brace weakly oblique, slightly proximal to basal side of Pt. Primary antenodal crossveins AX1 and AX2 aligned; AX1 1.3 mm basal of arculus, AX2 8.3 mm distal of AX1 and almost at the level of distal end of discoidal triangle T. No secondary antenodal cross-vein basal of primary antenodal cross-vein Ax1, five complete antenodal cross-veins of first row between Ax1 and Ax2, 12 antenodal cross-veins of first row and 11 of second row distal of Ax2. 2 oblique crossvein ‘O’ between RP2 and IR2, first one being one cell and second being nine cells distal of subnodus. RP and MA separated in arculus. Hypertriangle free, length 5.2 mm. T 1.8 mm distal of arculus, wide and not divided by crossveins with anterior side 5.0 mm in length, basal side 2.9 mm, and distal side MAb 5.2 mm. Postdiscoidal area with 1 row of cells basally, and 47 cells at wing margin. Rsp1 and Msp1 absent. Basal part of area between RA and RP with 4 cross-veins basal of RP3/4, and eight cross-veins distal of base of RP3/4 and basal of subnodus. Six antefurcal crossveins between RP and MA basal of RP-midfork. Base

of RP2 aligned with subnodus. Area between RP2 and IR2 distally widened with one row of cells basally and two rows below the pterostigmal brace, one row again distally to just below the middle part of Pt, and four rows at wing margin. Base of IR1 opposite second vein ‘O’, weak and zigzagged, but distal part of IR1 not zigzagged but weakly curved. Pseudo-IR1 well-defined branching five cells distal of Pt. Area between IR1 and RP1 with at least five rows of cells at wing margin, and between IR1 and RP2 with at least 12 rows. RP1 and RP2 with 1 row of cells basally and becoming divergent, with two rows just below pterostigmal brace. RP3/4 and MA running almost parallel, but slightly undulating at the level of second oblique crossvein ‘O’, with one row of cells basally, and four rows at wing margin. Postnodal space very narrow, 20 postnodal cross-veins, not aligned with 22 postsubnodal cross-veins. At least 24 cross-veins in long area between C and RA distal of Pt. Area between CuA and MP basally distinctly widened with one row of cells below T, and 14 cells near posterior wing margin. Median and submedian spaces free. Subdiscoidal space narrow and free, limited by a strong oblique PsA. Posterior wing margin rounded at base (female specimen). Anal area broad, with 12–13 rows of cells, and three posterior branches of AA directed towards posterior wing margin. Anal loop closed, elongate, and divided into six cells. CuAb strongly approaching secondary anal vein AA1b. Cubito-anal area broad, with 12–14 rows of cells between CuA and posterior wing margin; CuAa with five posterior branches.

5. Discussion

The attribution of the new specimen to the clade Petalurida Bechly, 1996 is

supported by the following synapomorphies: postnodal space very narrow, with many cells distal of pterostigma; pterostigmal brace vein shifted in the basal 2/3 of the wing, midway between nodus and apex; IR1 well-defined and rather long; wing space between RP1 and RP2 strongly expanded, with numerous rows of cells; more than two rows of cells in basal part of postdiscoidal area between the level of distal angle of discoidal triangle and that of midfork (Nel et al., 1998).

The presence of a closed anal loop and a free discoidal triangle in the hind wing excludes its affinities with Protolindeniidae Handlirsch, 1906. The specimen shares with Petalurodea Bechly, 1996 (Cretapetaluridae and Petaluroidea) the following synapomorphies: wings falcate and slender, and distinctly longer than 50 mm; Bqs-area distinctly narrowed; hind wing MP at least somewhat shortened, and terminating at the posterior margin slightly distal of the nodus. Affinities with the Cretapetaluridae are excluded because in this family the distal side of the discoidal triangle (MAb) is angulated, and the hind wing subtriangle is traversed by a crossvein.

The specimen has the synapomorphies of the Petaluroidea (Aktassiidae and Petaluridae): pterostigma elongated; RP3/4 undulate and distally strongly diverging from MA; hind wing MP distinctly shortened, and terminating at the posterior margin on the level of the nodus, or even somewhat basal of the nodus. It is attributed to the family Aktassiidae (Pseudocymatophlebiinae + Aktassiinae) by the presence of very dense wing venation with a distinctly increased number of cells. Affinities with the subfamily Pseudocymatophlebiinae are excluded because the IR1 vein vanishes distally in this family. It is attributed to the Aktassiinae by the following

synapomorphies: wings longer than 65 mm; IR1 secondarily very long and straight; characteristic pattern of veinlets and intercalary veins present between IR2 and RP3/4, and between MA and MP; the posterior margin of the hind wing remarkably straight between CuAa and the apex (Nel et al., 1998).

The subfamily Aktasiinae includes three Mesozoic genera: *Aktassia*, *Aeshnogomphus*, and *Sinaktassia*. The new specimen differs from the hind wing of *Aeschnogomphus* in the discoidal cell being free instead of being three-celled, and the anal loop being better defined and posteriorly closed, with six cells, instead of being posteriorly opened and only three-celled. It differs from that of *Aktassia* in the later having an eight-celled discoidal cell, and a posteriorly opened and two-celled anal loop (Pritykina, 1968).

Lin et al. (2010) proposed the following diagnosis for the genus *Sinaktassia* (Fig. 4): (1) wing falcate, slender, and longer than 80 mm; (2) postnodal space very narrow, with many cells distal of Pt; (3) Pt elongate; (4) pterostigmal brace present and shifted slightly basal to Pt; (5) IR1 basally strongly zigzagged, long; (6) only one row of cells between RA and RP1 at level of Pt; (7) space between RP1 and RP2 greatly expanded, with more than 8–9 rows of cells; (8) PsA hypertrophied; (9) subdiscoidal triangle widened, T transverse; (10) subdiscoidal triangle divided by cross-veins; (11) more than two rows of cells in basal part of postdiscoidal area between level of distal angle of T and level of midfork; (12) groups of cells and secondary veins in areas between main veins; (13) Bqs-area (‘bridge-space’) narrowed; (14) distal side of T not angulated; (15) only three rows of cells in postdiscoidal area just distal of T; (16) no

convex intercalary vein in postdiscoidal space; (17) area between RP3/4 and MA widened near posterior wing margin, with more than three rows of cells; (18) RP3/4 undulate and distally strongly diverging from MA; (19) wing venation dense consisting of large number of cells; (20) few polygonal groups of cells separated by veinlets and intercalary veins between RP1 and IR1, IR2 and RP3/4, and MA and MP; (21) antenodal space longer than postnodal space; (22) T with a crossvein; (23) only two rows of cells in area between RP1 and RP2 basal of Pt; (24) Rspl absent.

The new specimen shares almost all these characteristics except (1) (due to the fact that it is a hind wing, broader than the forewing), (9) & (10) (In the Petalurida, the subdiscoidal triangle is generally smaller in the hind wing than in the forewing), and (22) (due to the different shape of the fore- and hind wing discoidal cells in the Petalurida). The hind wing is 74.1 mm long and the holotype of *S. tangi*, a forewing, 87.6 mm long, congruent with the general tendency that a hind wing is shorter than the forewing in the Anisoptera. The subdiscoidal triangle is of 'normal' shape and free of crossveins, and the discoidal triangle is also free of crossveins in the hind wing. The free hind wing discoidal and subdiscoidal triangles are very variable characters, and bear a low phylogenetic significance (Nel et al., 1998). The pseudo-IR1 in this hind wing seems to be better defined than in the forewing of *S. tangi* (holotype), which, however, could be due to ill-preservation of this part of the holotype. The first oblique vein 'O' is shifted basally one cell distal of the subnodus in this hind wing, while it is three cells in the forewing (the holotype of *S. tangi*). This difference is a variable character in Petalurida (Nel et al., 1998). The only significant difference is the presence

of only four rows of cells between RP3/4 and MAa along the posterior wing margin in the hind wing, instead of seven in the forewing. Therefore we propose to attribute this hind wing to *S. tangi*.

Thus the diagnosis of *Sinaktassia* can be completed as follows: wings longer than 70 mm; hind wing discoidal and subdiscoidal triangles free; anal loop posteriorly closed and six-celled.

5. Conclusions

A very well-preserved female hind wing of a petalurid dragonfly is described from the Lower Cretaceous Yixian Formation of Inner Mongolia, China and assigned to *S. tangi* Lin, Nel & Huang, 1990. The discovery allows to complete the description and diagnosis of this dragonfly, and also shows that *Sinaktassia* was relatively widespread in the Early Cretaceous as this hind wing comes from Inner Mongolia while the holotype was collected from Liaoning Province, China.

Acknowledgements

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References

Bechly, G., 1996. Morphologische Untersuchungen am Flügelgeäder der rezenten Libellen und deren Sta mmgruppenvertreter (Insecta; Pterygota; Odonata), unter besonderer Berücksichtigung der Phylogenetischen Systematik und des

Grundplanes der Odonata. Petalura 2: 1–402.

Bechly, G., 2000. Two new fossil dragonfly species (Insecta: Odonata: Pananisoptera: Aeschnidiidae and Aktassiidae) from the Solnhofen Lithographic Limestones (Upper Jurassic of Germany). Stuttgarter Beiträge zur Naturkunde Serie B (Geologie und Paläontologie) 288: 1–9.

Chang, M.M., Zhang, J.Y., Miao, D.S., 2006. A lamprey from the Cretaceous Jehol biota of China. Nature 441: 972–974.

Chang, S.C., Zhang, H.C., Renne, P.R., Fang, Y., 2009. High-precision $^{40}Ar/^{39}Ar$ age for the Jehol Biota. Palaeogeography, Palaeoclimatology, Palaeoecology 280: 94–104.

Cohen, K.M., Finney, S.C., Gibbard, P.L., Fan, J.X., 2014. The ICS International Chronostratigraphic Chart. Episodes 36: 199–204.

Coram, R.A., Nel, A., 2009. A new petalurid dragonfly from the Lower Cretaceous of southern England (Odonata: Petalurida: ? Cretapetaluridae). Palaeodiversity 2: 205–208.

Evans, S. E., Wang, Y., 2010. A new lizard (Reptilia: Squamata) with exquisite preservation of soft tissue from the Lower Cretaceous of Inner Mongolia, China. Journal of Systematic Palaeontology 8: 81–95.

Li, Y.J., Han, G., Nel, A., Ren, D., Pang, H., Liu, X.L., 2012. A new fossil petalurid dragonfly (Odonata: Petaluroidea: Aktassiidae) from the Cretaceous of China. Alcheringa 36: 319–322.

Lin, Q.B., NEL, A., Huang, D.Y., 2010. Sinaktassia tangi, a new Chinese Mesozoic

genus and species of Aktassiidae (Odonata: Petaluroidea). Zootaxa 2359: 61–64.

Nel, A., Paicheler, J.C., 1992. Les Odonata fossiles: état actuel des connaissances. Deuxième partie: les Petaluridae et Cordulegastridae fossiles (Odonata, Anisoptera, Petaluroidea). Nouvelle Revue d'Entomologie, (N.S.) 9: 305–323.

Nel, A., Martinez-Delclos, X., Paicheler, J.C., Henrotay, M., 1993. Les 'Anisozygoptera' fossiles. Phylogénie et classification (Odonata). Martinia Hors Série 3: 1–311.

Nel, A., Bechly, G., Jarzembowski, E.A., Martínez-Delclòs, X., 1998. A revision of the fossil petalurid dragonflies (Insecta: Odonata: Anisoptera: Petalurida). Paleontologia Lombarda, (N.S.) 10: 1–68.

Nel, A., Bechly, G., Martínez-Delclòs, X., 2001. A new fossil dragonfly from the Upper Jurassic of Germany (Odonata: Anisoptera: Protolindeniidae). Revue Francaise d'Entomologie 23: 257–261.

Nel, A., Bechly, G., 2009. The Third Petalurid Dragonfly from the Lower Cretaceous of Brazil (Odonata: Cretapetaluridae). Annales Zoologici 59: 281–285.

Petrulevičius, J.F., Nel, A., 2003. Oldest petalurid dragonfly (Odonata: Insecta): a Lower Cretaceous specimen from south Patagonia, Argentina. Cretaceous Research 24: 31–34.

Pritykina, L. N., 1968. Strekozy Karatau (Odonata). Dragonflies from Karatau (Odonata). pp. 26–55. In: Panfilov, D.V. (coord.), Yurskie Nasekomye Karatau. Fossil insects from Karatau. Academy of Sciences of the S.S.S.R., Nauka, Moscow, p. 252 (in Russian).

Riek, E.F., 1976. A new collection of insects from the Upper Triassic of South Africa. Annals of the Natal Museum 22: 791–820.

Riek, E.F., Kukalová-Peck, J., 1984. A new interpretation of dragonfly wing venation based upon early Carboniferous fossils from Argentina (Insecta: Odonatoidea) and basic characters states in pterygote wings. Canadian Journal of Zoology 62: 1150–1166.

Wang, B., Zhang, H.C., Ponomarenko, A.G., 2012. Mesozoic Trachypachidae (Insecta: Coleoptera) from China. Palaeontology 55: 341–353.

Zhang, H.C., Wang, B., Fang, Y., 2010. Evolution of insect diversity in the Jehol biota. Science China Earth Sciences 53: 1894–1907.

Fig. 1. Geographic sketch map of Chifeng City, Inner Mongolia, China, showing the locality of the Liutiaogou outcrop.

Fig. 2. *Sinaktassia tangi* Lin et al., 2010, specimen NIGP 161882, photograph of hind wing. Scale bar = 10 mm.

Fig. 3. *Sinaktassia tangi* Lin et al., 2010, specimen NIGP 161882, line drawing showing venation of hind wing. Scale bar = 10 mm.

Fig. 4. *Sinaktassia tangi* Lin et al., 2010, holotype, NIGP 148316, forewing. A. Photograph of forewing; B. Line drawing of forewing (modified from Lin et al., 2010). Scale bar = 10 mm.

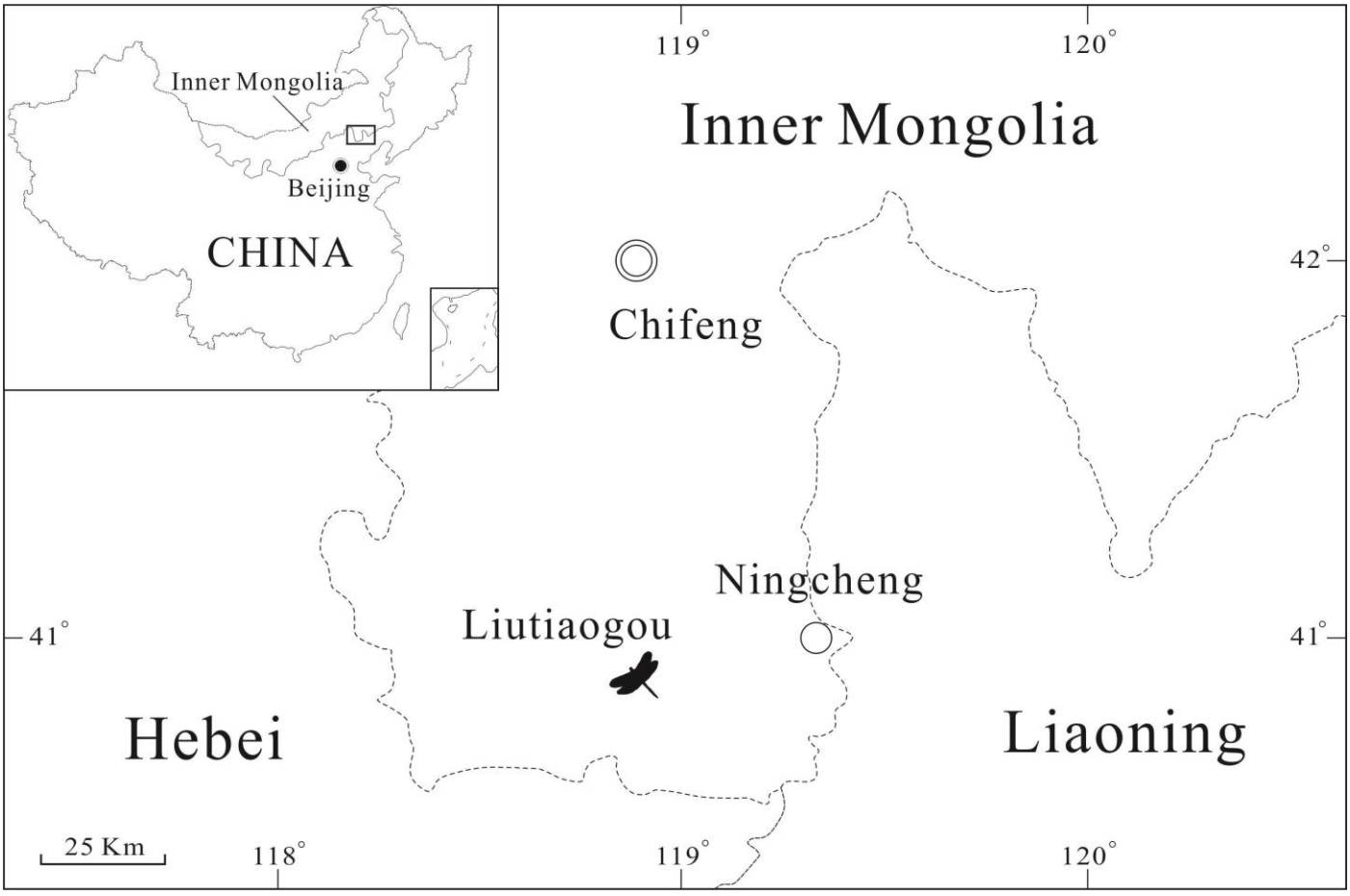
Inner Mongolia
Beijing
CHINA
119°
120°
Inner Mongolia
42°
Chifeng
Ningcheng
Liutiaogou
41°
41°
Hebei
Liaoning
25 Km
118°
119°
120°

Figure 1

Figure 2

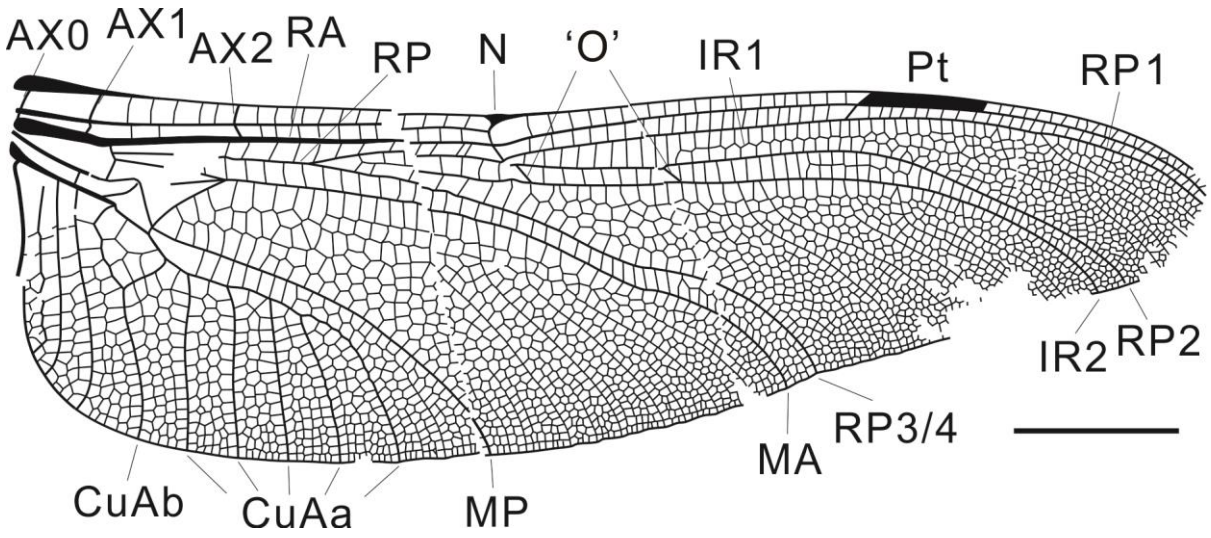

Figure 3

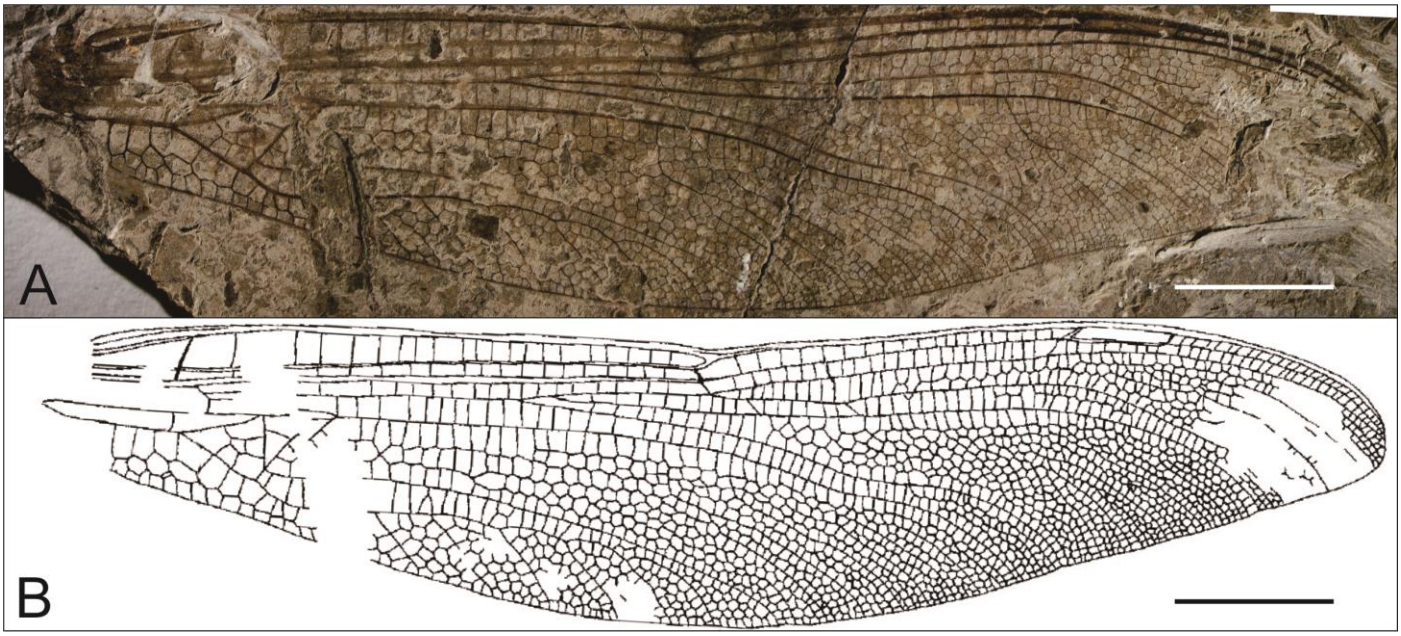

Figure 4