

New Isophlebioid Dragonflies from the Middle Jurassic of Inner Mongolia, China (Insecta: Odonata: Isophlebioptera: Campterophlebiidae)

ZHANG Binglan¹, REN Dong^{1, *} and PANG Hong^{2, *}

¹ College of Life Sciences, Capital Normal University, Beijing 100037

² State Key Laboratory of Biocontrol and Institute of Entomology, Sun Yat-sen University, Guangzhou, Guangdong 510275

Abstract: Three new species of fossil dragonflies assigned to *Sinokaratawia* Nel, Huang and Lin in family Campterophlebiidae, i.e. *S. daohugouica* sp. nov., *S. magica* sp. nov. and *S. gloriosa* sp. nov., and new materials of male *S. prokopi* Nel, Huang and Lin, 2007 are described from the Middle Jurassic of Daohugou, Inner Mongolia, China. An emended diagnosis of genus *Sinokaratawia* was proposed.

Key words: Odonata, Campterophlebiidae, new species, Middle Jurassic, Inner Mongolia, China

1 Introduction

Campterophlebiidae Handlirsch, 1920, the largest family of the “Anisozygoptera”, is an extinct group survived from Jurassic to Cretaceous (Pritykina and Rasnitsyn, 2002). Nel et al. (1993) firstly made a comprehensive revision of this family and gave a complete list of 23 genera and 38 species previously described. All of them were based mainly on isolated, even fragmentary fossil wings (Bode, 1905; Pritykina, 1968, 1970, 1980, 1985; Walley, 1985). All genera included in this family by Nel et al. (1993) were endorsed by Bechly (2005), except *Shurabiola* Pritykina, 1970. The latter was transferred to Cyclothemistidae Bechly, 1996 for its postdiscoidal space not distally narrowed and its space between RP3/4 and MA less expanded. A genus and species incertae sedis specimen was added to this family by Nel and Jarzembowski (1996) but finally transferred to Tarsophlebiidae (Fleck et al., 2004). After that, four new genera and five species were discovered, including *Bellabrunetia catherinae* Fleck and Nel, *Amnifleckia guttata* Zhang, Ren and Cheng, *A. splendida* Huang, Fleck, Nel and Lin, *Parabrunetia celinea* Huang, Fleck, Nel and Lin and *Sinokaratawia prokopi* Nel, Huang and Lin (Fleck and Nel, 2002; Zhang et al., 2006; Nel et al., 2007), with rather completed wings and body structures. All of them came from the Middle Jurassic Jiulongshan Formation in Daohugou Village, Ningcheng

County, Inner Mongolia, China. Recently we recovered some other specimens from the same location. Three new species and one old species are described herein.

This study is based on ten (two pairs of parts and six parts) adult specimens housed in the Key Lab of Insect Evolution and Environmental Changes, College of Life Science, Capital Normal University, Beijing, China (CNUB; Ren Dong, Curator).

The specimens were examined with the LEICA MZ 12.5 dissecting microscope and illustrated with the aid of a drawing tube attached to the microscope.

The geology and stratigraphy of the Jiulongshan Formation was extensively studied by Ren et al. (2002), Gao and Ren (2006) and Tan et al. (2007). In this work, we follow the wing venation nomenclature of Riek (1976), Riek and Kukalová-Peck (1984), amended by Kukalová-Peck (1991), Nel et al. (1993) and Bechly et al. (2001). The higher classification of fossil and extant Odonatoptera is based on the phylogenetic system of Bechly (1996).

2 Systematic Paleontology

Order Odonata Fabricius, 1793

Clade Isophlebioptera Bechly, 1996

Superfamily Isophlebioidea Handlirsch, 1906

Family Campterophlebiidae Handlirsch, 1920

Genus *Sinokaratawia* Nel, Huang and Lin, 2007

Type species: *Sinokaratawia prokopi* Nel, Huang and

* Corresponding author. E-mail: rendong@mail.cnu.edu.cn; lsshpang@mail.sysu.edu.cn

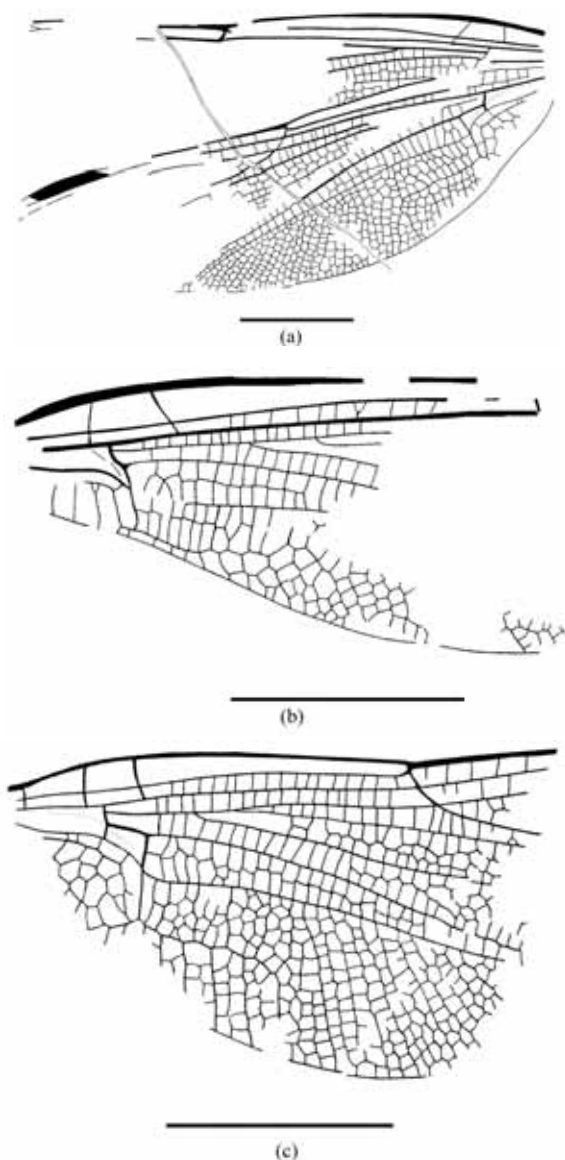


Fig. 1. *Sinokaratawia daohugouica* sp. nov., holotype CNU-OD-NN2004058.

(a) Left wings; (b) right fore wing; (c) right hind wing. Scale bars represent 10 mm.

Lin, 2007

Emended diagnosis: hind wing broader than fore wing; a very acute projecting anal angle in male hind wing; Ax2 in fore wing strongly oblique, much more oblique than that in hind wing; Ax2 in hind wings situated on the level of the distal side of discoidal space; subdiscoidal space posteriorly open in male but posteriorly closed in female; CuAa shortened in hind wing, reaching posterior margin before nodus; MP straight; MAa with a smooth bend, distally zigzagged; a constricted area between MAa and MP; CuAa very short; two rows of cells in fore wing basal part of postdiscoidal area and area between MP and CuA.

Species included: four species: *S. prokopi* Nel, Huang and Lin, 2007, *S. daohugouica* sp. nov., *S. magica* sp. nov. and

S. gloriosa sp. nov..

Remarks: the emended genus diagnosis is based on new materials collected from the same location the type species sampled.

***Sinokaratawia daohugouica* sp. nov.**

(Figs. 1–2, Plates 1–4)

Material. Holotype CNU-OD-NN2004058, paratypes CNU-OD-NN2004061, CNU-OD-NN2004064 and CNU-OD-NN2004063.

Etymology: The specific name is dedicated to the fossil site at Daohugou.

Species diagnosis: female wing characters only. Hind wing unique hexagonal subdiscoidal space longer than discoidal space; fore wing Ax2 much closer to arculus than to midfork.

Descriptions:

Holotype CNU-OD-NN2004058 Female. Wings attached with body. Parts of legs, distal parts of abdomen and wings not preserved. Fore wings and hind wings overlapped, as well as the basal parts of hind wings and abdomen. A great deal of little white round spots spread all over wings and body. Specimen fossilized with some conchostracans.

Fore wing: not petiolate; distance between base and arculus about 4.4 mm, between arculus and nodus 21.8 mm; two primary antenodal veins very strong, Ax1 0.9 mm basal of arculus; Ax2 3.0 mm distal of arculus; no secondary crossveins between C and ScP but at least ten between ScP and RA, distal of Ax2; eighteen antesubnodal crossveins preserved; median space and discoidal space free of crossveins, with oblique membranaceous pleats; discoidal space basally opened; base of RP and MA separated at arculus; postdiscoidal area with two rows of cells basally; midfork 6.0 mm distal of arculus, much closer to arculus than to nodus; base of IR2 very close to midfork, 3.0 mm distally, originating distinctly on RP; gaff very long; CuAa parallel to posterior margin closely before strongly humping up on the level of Ax2, with a single row of small cells in between, then bending to posterior margin midway between arculus and nodus, reaching posterior margin before nodus, zigzag distally; two rows of transverse elongate cells between CuAa and MP; three branches originated on CuAa, three bending to MP and three bending to posterior wing margin; anal area preserved not completely but big cells along AA recognizable.

Hind wing: not petiolate; 13.9 mm wide at nodus; distance between base and arculus about 5.6 mm, between arculus and nodus 13.8 mm, between nodus and pterostigma 16.4 mm; Ax0 visible; two primary antenodal veins very strong, Ax1 0.8 mm basal of arculus, Ax2 1.8 mm distal of arculus, with distance between them shorter

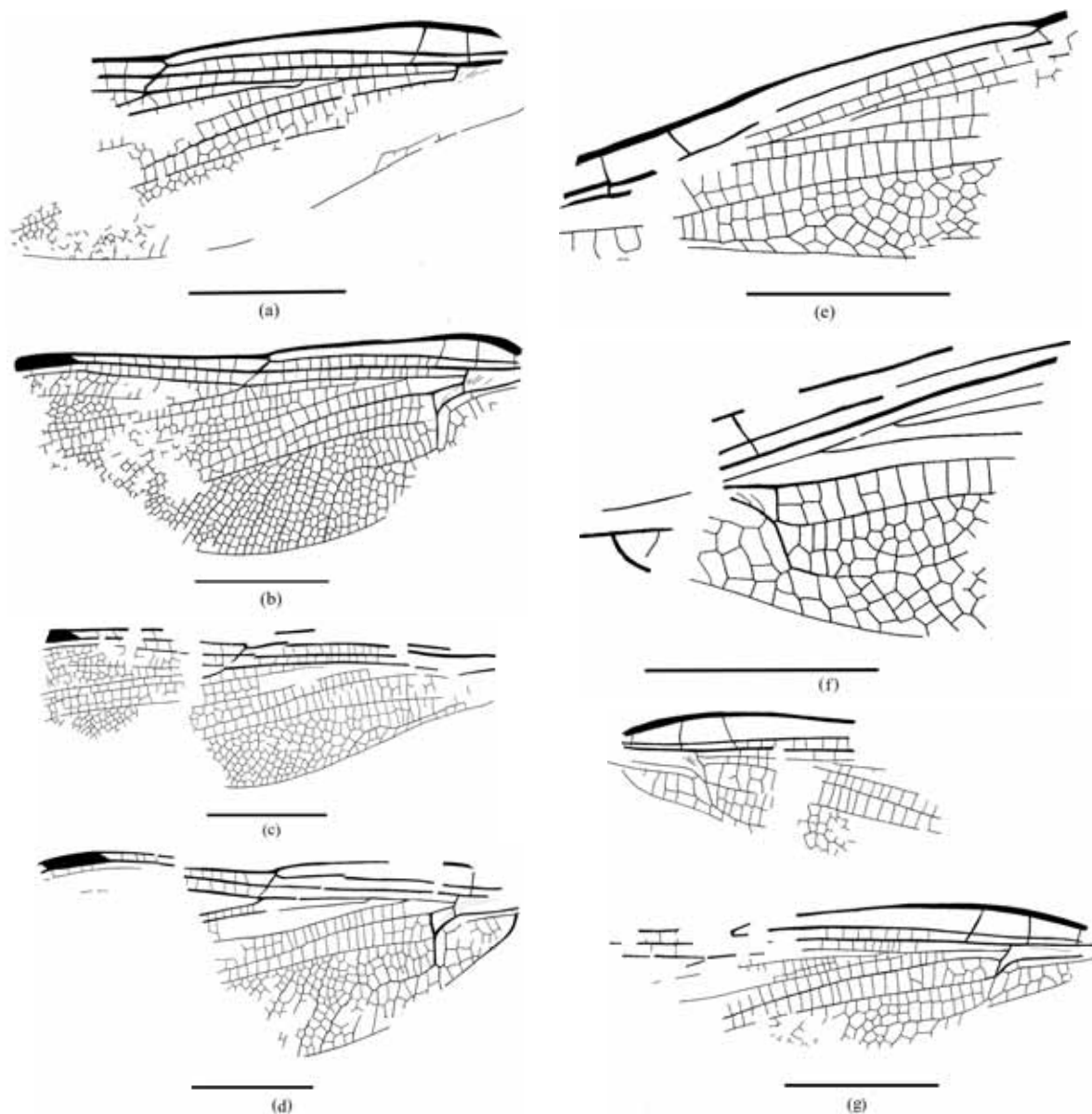


Fig. 2. *Sinokaratawia daohugouica* sp. nov., paratypes.

CNU-OD-NN2004061, (a) left fore wing; (b) left hind wing. CNU-OD-NN2004064; (c) left fore wing; (d) left hind wing; (e) right fore wing; (f) right hind wing. CNU-OD-NN2004063, (g) fore wings; (h) right hind wing. Scale bars represent 10 mm.

than that of fore wing; Ax1 situated midway of Ax0 and Ax2; Ax2 situated on the level of distal side of discoidal space, about midway of arculus and midfork; no secondary crossveins between C and ScP but seventeen visible between ScP and RA, distal of Ax2; eighteen antesubnodal crossveins visible; pterostigma 6.3 mm long, 1.1 mm wide, with basal side much more oblique than distal side; median space free of crossveins; submedian space traversed by CuP-crossing and other two crossveins; unique subdiscoidal space divided by one crossvein, longer than discoidal space; basally closed discoidal space free of crossveins, 2.3 mm long, basal side 0.5 mm long and distal side (MAb) 1.5 mm long; cells of anal area rather big and

equal in size; base of RP and MA separated at arculus; RP2 aligned with subnodus; eleven bridge crossveins visible; oblique vein "O" not preserved; base of IR2 1.8 mm distal of midfork, originating on RP; a single row of cells between IR2 and RP2 before nodus; midfork 4.0 mm distal of arculus, much closer to arculus than to nodus; postdiscoidal area with a maximal width of 2.0 mm, two rows of cells basally, distal part much narrower than basal part because of the converging of MAa and MP distally; MAa basally smooth and slightly zigzag after the level of nodus; MP reaching posterior margin far distal of nodus; area between MP and posterior margin broad, with ten zigzag intercalary veins; two to four rows of cells between CuAa and MP; gaff

strong and elongated; CuAa very short, bending to posterior margin midway between arculus and nodus, reaching posterior margin before nodus; five branches originated on CuAa.

Head: 7.1 mm long and 5.9 mm wide.

Thorax: stout, 8.6 mm long and 8.2 mm wide.

Paratypes have same venations as that of holotype. Some details were described as following:

Paratype CNU-OD-NN2004061 Gender uncertain, strong tendency to be female. Right wings, hind legs and distal of abdomen missing; left wings overlap partly, as well as the basal of hind wing and the abdomen, so that the hind part of fore wing and the basal part of hind wing unclear.

Fore wing: 12.7 mm wide at nodus; distance between arculus and nodus 19.5 mm; Ax1 0.7 mm basal of arculus; Ax2 oblique, 3.0 mm distal of arculus, closer to arculus than to midfork; no secondary crossveins between C and ScP but twelve between ScP and RA, distal of Ax2; seventeen antesubnodal crossveins visible; median space and discoidal space free; MP reaching posterior margin far distal of nodus; midfork 7.3 mm distal of arculus, closer to arculus than to nodus; base of IR2 very close to midfork, 2.4 mm distally, originating on RP; RP2 aligned with subnodus; five bridge crossveins visible; area between MA and RP3/4 rather narrow basally, with a single row of cells before nodus; area between MP and posterior margin broad.

Hind wing: broader than fore wing, 14.6 mm wide at nodus; distance between base and arculus 4.3 mm, between arculus and nodus 15.7 mm, between nodus and pterostigma 14.5 mm; Ax0 very close to wing base; two primary antenodal veins very strong, Ax1 0.5 mm basal of arculus, Ax2 not oblique like that of fore wing, situated on the level of distal side of discoidal space, 2.4 mm distal of arculus; no secondary crossveins between C and ScP but fourteen visible between ScP and RA, distal of Ax2; fifteen antesubnodal crossveins visible; nine postnodal crossveins, not aligned with the fourteen postsubnodal crossveins; pterostigma preserved incompletely, but distinctly long and thick, without brace vein, covers at least two crossveins; median space free of crossveins; submedian space only traversed by CuP-crossing; unique unicellular subdiscoidal space longer than discoidal space; discoidal space free of crossveins, basally closed, 2.4 mm long, basal side 0.5 mm long and distal side (MAb) 1.4 mm long; most part of anal area not preserved, only a single row of cells along AA are preserved; base of RP and MA separated at arculus; nine bridge crossveins visible; one oblique vein "O", five cells and 3.9 mm distal of subnodus; base of IR1, four cells (2.2 mm) distal of subnodus; IR1 parallel to RP1 more or less, with two rows of cells in between under the pterostigma;

area between IR1 and RP2 distally slightly expanded; IR2 originating distinctly on RP, with the base 3.6 mm distal of midfork; area between IR2 and RP2 with a single row of cells up to the base of pterostigma, then expanded distally; midfork 4.3 mm distal of arculus, much closer to arculus than to nodus; RP3/4 slightly undulate, with one to three rows of cells between it and IR2; area between RP3/4 and MA with only one row of cells before nodus, distally strongly expanded with more than four intercalary veins appear; postdiscoidal area with a maximal width of 2.1 mm; area between MP and posterior margin strong expanded, with about seven zigzag intercalary veins originated on MP; two to four rows of cells between CuAa and MP; gaff strong and elongated; about three branches originated on CuAa.

Head: about 8.7 mm long and 6.6 mm wide.

Thorax: stout; about 8.5 mm long and 8.1 mm wide.

Abdomen: rather stout; basal four segments preserved with 30.8 mm long.

Paratype CNU-OD-NN2004064 Female. Body not preserved. Fore wings and hind wings overlap partly, with most parts after nodus missing.

Fore wing: basal part not preserved well; distance between Ax1 and Ax2 4.2 mm; no secondary crossveins between C and ScP but eleven visible between ScP and RA, distal of Ax2; fourteen antesubnodal crossveins visible; pterostigma not preserved completely, at least 2.1 mm long, with basal side rather oblique; RP2 aligned with subnodus; six bridge crossveins visible; three rows of cells between RP1 and IR1, as well as between IR1 and RP2, beneath the pterostigma; RP2 parallel to IR2 up to the level of pterostigma, with only one rows of cells in between; two rows of cells between IR2 and RP3/4 up to the level of pterostigma; a single row of cells between MA and RP3/4 before nodus; postdiscoidal area with two rows of cells basally, then change to one row before midway between arculus and nodus, distal part much narrower than basal part; CuAa parallel to posterior margin closely, with a single row of small cells in between, before strongly humping up far distal of the level of Ax2; two rows of transverse elongate cells between CuAa and MP; area between MP and posterior margin broad, with at least five intercalary veins.

Hind wing: distance between base and arculus 4.7 mm, between arculus and nodus 14.7 mm; Ax1 1.0 mm basal of arculus; Ax2 situated on the level of distal side of discoidal space; no secondary antenodal crossveins and antesubnodal crossveins preserved; ten postnodal crossveins, not aligned with the visible six postsubnodal crossveins; pterostigma 4.7 mm long, 0.6 mm wide, with basal side more oblique than distal side, without brace vein, covers at least four crossveins; median space free of crossveins; unique

unicellular subdiscoidal space longer than discoidal space; discoidal space free of crossveins, basally closed, 1.9 mm long, basal side 0.7 mm long and distal side (MAb) 1.6 mm long; cells in anal area rather big and equal in size; bridge crossveins and oblique vein “O” not preserved; IR2 originating distinctly on RP, with the base 3.0 mm distal of midfork; midfork 4.0 mm distal of arculus, much closer to arculus than to nodus; area between RP3/4 and MA with only one row of cells before nodus; postdiscoidal area with a maximal width of 2.1 mm, two rows of cells basally, then change to one row before midway between arculus and nodus; area between MP and posterior margin broad, with at least four zigzag intercalary veins originated on MP; two to three rows of cells between CuAa and MP; four branches originated on CuAa.

Paratype CNU-OD-NN2004063 Gender uncertain. Fragments of one leg and thorax poorly preserved. Basal parts of fore wings and right hind wing still attached to the thorax. Specimen fossilized with some conchostracans.

Fore wing: distance between base and arculus 5.6 mm, from arculus to nodus 18.8 mm; Ax1 0.9 mm basal of arculus; Ax2 2.8 mm distal of arculus, closer to arculus than to midfork; at least eight antenodal crossveins between ScP and RA, distal of Ax2; at least eleven antesubnodal crossveins between arculus and subnodus; midfork 6.5 mm distal of arculus, closer to arculus than to nodus; base of IR2 close to midfork, 1.4 mm distally.

Hind wing: distance between base and arculus 4.8 mm; Ax1 0.8 mm basal of arculus; Ax2 1.9 mm distal of arculus; eleven antenodal crossveins between ScP and RA, distal of Ax2; at least ten antesubnodal crossveins between arculus and subnodus; discoidal space 2.1 mm long, basal side 0.6 mm long and distal side (MAb) 1.5 mm long; midfork 4.3 mm distal of arculus, much closer to arculus than to nodus; area between RP3/4 and MA with only one row of cells before nodus.

Remarks: specimens CNU-OD-NN2004064 and CNU-OD-NN2004063 show an interesting character differing from other materials: cells in postdiscoidal area change to one row before midway between arculus and nodus. We consider this as natural individual difference.

Sinokaratawia magica sp. nov.

(Fig. 3, Plates 5–6)

Holotype: female, part CNU-OD-NN2004041-1, counterpart CNU-OD-NN2004041-2. Specimen fossilized with some conchostracans.

Etymology: After the Latin “magicus”= magic.

Species diagnosis: female wing characters only. Hind wing unique quasi-pentagonal subdiscoidal space equal to discoidal space in length; cells of anal area in hind wing sizable; fore wing Ax2 on the level of midway between

arculus and midfork; vaulted arculus of fore wing strongly bulge.

Description:

Wings attached with thorax and basal two segments of abdomen; distal parts of nodus missing in all wings, but the pterostigma of right hind wing still preserved; right wings overlap.

Fore wing: not petiolate; distance between base and arculus about 5.2 mm, between arculus and nodus 20.8 mm; two primary antenodal veins very strong, Ax1 straight, 0.8 mm basal of arculus; Ax2 oblique, 3.8 mm distal of arculus, on the level of midway between arculus and midfork; no secondary antenodal crossveins between C and ScP but at least ten between ScP and RA, distal of Ax2; only four antesubnodal crossveins preserved; median space and discoidal space free of crossveins, with oblique membranaceous pleats; discoidal space basally opened; vaulted arculus strongly bulge; base of RP and MA separated at arculus; basal part of postdiscoidal area with two rows of cells; midfork 7.6 mm distal of arculus, much closer to arculus than to nodus; base of IR2 2.9 mm distal of midfork; RP2 aligned with subnodus; only two bridge crossveins preserved; MAb 1.2 mm long; two rows of large cells in the area between AA and posterior margin; CuAa terminate about the level of midway between arculus and nodus; about three branches originated on CuAa; two to three rows of cells between CuAa and MP; two zigzag branches originated on MP visible.

Hind wing: not petiolate; broader (by 15 percent) than fore wing, 13.6 mm wide at nodus; distance between base and arculus 5.5 mm, between arculus and nodus 16.7 mm, between nodus and pterostigma 14.6 mm; Ax0 close to wing base; two primary antenodal veins very strong, Ax1 0.7 mm basal of arculus, Ax2 2.3 mm distal of arculus; distance between Ax1 and Ax2 distinctly shorter than that of fore wing; Ax2 situated on the level of distal side of discoidal space, midway between arculus and midfork; no secondary crossveins between C and ScP but eighteen visible between ScP and RA, distal of Ax2; fifteen antesubnodal crossveins visible; ten postnodal crossveins preserved, not aligned with the six visible postsubnodal crossveins; pterostigma preserved incompletely, but distinctly rather long and thick, without brace vein, covers at least two crossveins; median space free of crossveins; submedian space only traversed by CuP-crossing; unique unicellular subdiscoidal space equal to discoidal space in length; discoidal space free of crossveins, basally closed, 2.4 mm long, basal side 0.2 mm long and distal side (MAb) 1.5 mm long; cells of anal area in hind wing sizable; oblique membranaceous pleats appear in median space and discoidal space; base of RP and MA separate at arculus; RP2 aligned with subnodus; twelve bridge crossveins

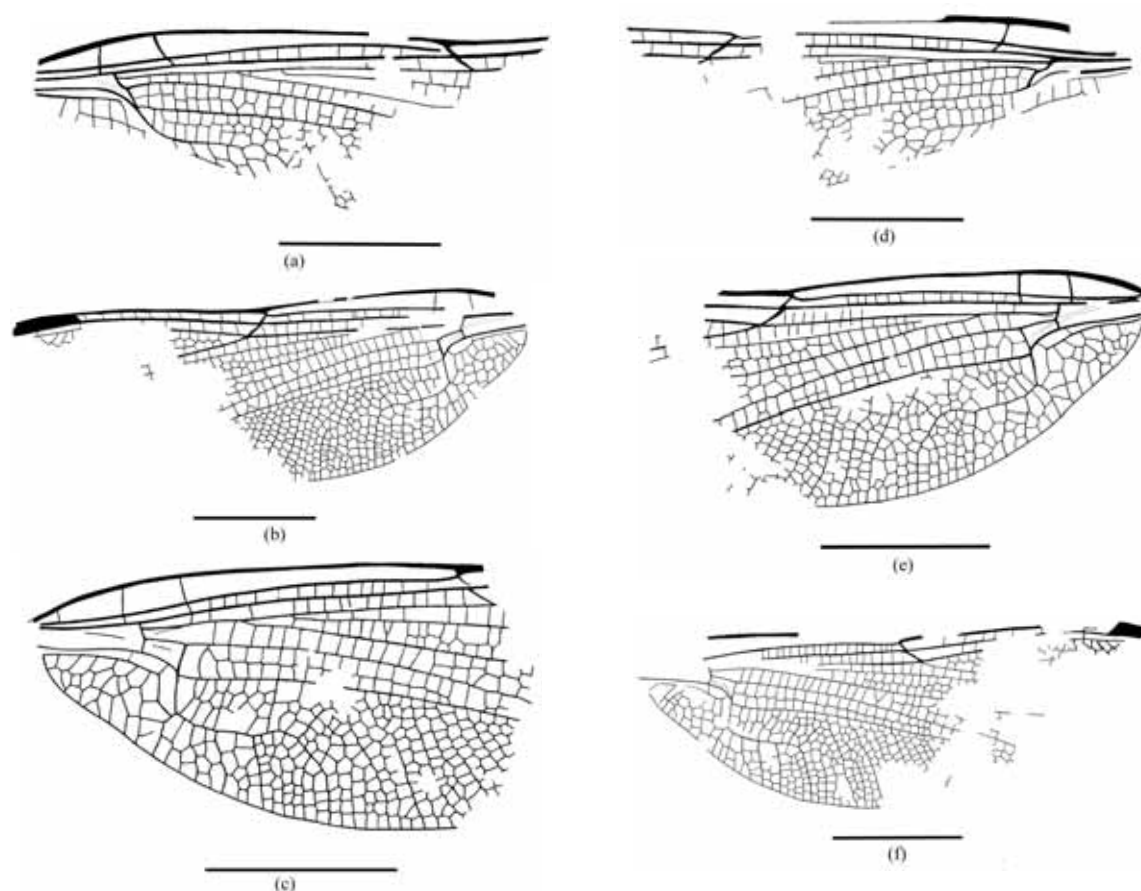


Fig. 3. *Sinokaratawia magica* sp. nov., holotype CNU-OD-NN2004041.

Part, CNU-OD-NN2004041-1 (a) right fore wing; (b) left hind wing; (c) right hind wing. Counterpart, CNU-OD-NN2004041-2 (d) left fore wing; (e) left hind wing; (f) right hind wing. Scale bars represent 10 mm.

visible; oblique vein "O" not preserved; IR2 originating distinctly on RP, with the base 2.7 mm distal of midfork; midfork 4.6 mm distal of arculus, much closer to arculus than to nodus; area between RP3/4 and MA with only one row of cells before nodus; postdiscoial area with a maximal width of 1.9 mm, two rows of cells before nodus, narrowed distally; MAa slightly zigzag after the level of nodus; area between MP and hind margin very large, with at least six zigzag intercalary veins originated on MP; two to four rows of cells between CuAa and MP; gaff strong and elongated; CuAa rather short, bending to posterior margin midway between arculus and nodus, reaching posterior margin before nodus, zigzag distally; about four branches originated on CuAa.

Thorax: not well preserved, jumbled and indistinct.

Abdomen: basal two segments very stout, with presence of a very distinct dorso-longitudinal carina. The first segment 6.0 mm long and 6.0 mm wide, the second segment 7.0 mm long and about 5.9 mm wide.

***Sinokaratawia gloriosa* sp. nov.**

(Fig. 4, Plates 7–8)

Holotype: female, part CNU-OD-NN2004040-1, counterpart CNU-OD-NN2004040-2. Specimen fossilized with some conchostracans.

Etymology: After the Latin "gloriosus"=wonderful.

Species diagnosis: female wing characters only. Hind wing subdiscoial space equal to discoial space in length; cells in anal area of hind wing different from each other in size and shape, those along the AA remarkable larger than others; fore wing Ax2 slightly closer to arculus than to midfork.

Description:

Basal wings, thorax, basal four segments of abdomen and part of pterostigma preserved; fore wings and hind wings overlap partially.

Fore wing: not petiolate; 11.0 mm wide at nodus; distance between base and arculus about 4.6 mm, between arculus and nodus 19.6 mm; two primary antenodal veins very strong, Ax1 0.6 mm basal of arculus; Ax2 oblique, 2.5 mm distal of arculus, midway between arculus and midfork; no secondary crossveins between C and ScP but thirteen between ScP and RA, distal of Ax2; twelve antesubnodal crossveins visible; at least twelve postnodal

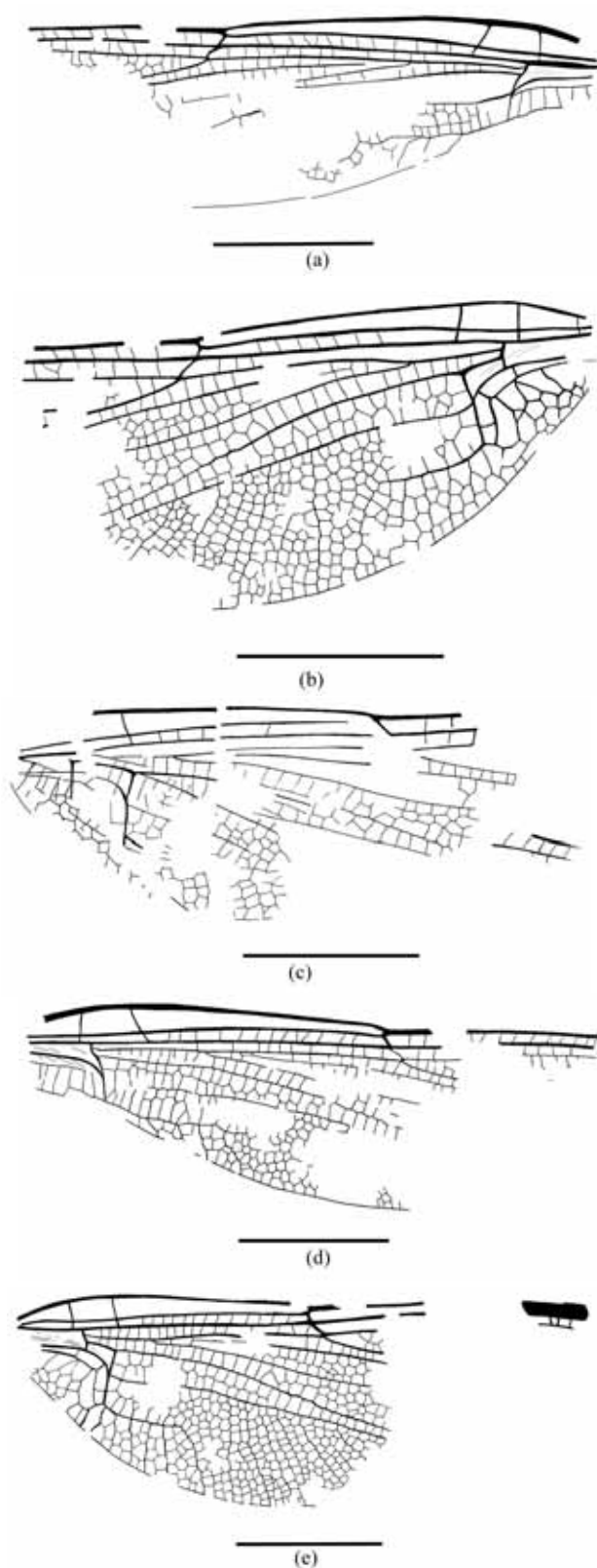


Fig. 4. *Sinokaratawia gloriosa* sp. nov., holotype CNU-OD-NN2004040.

Part, CNU-OD-NN2004040-1 (a) left fore wings; (b) left hind wing; (c) right wings. Counterpart, CNU-OD-NN2004040-2 (d) right fore wing; (e) right hind wing. Scale bars represent 10 mm.

crossveins and eight postsubnodal crossveins; median space and discoidal space free of crossveins, with oblique membranaceous pleats; discoidal space basally opened; base of RP and MA separated at arculus; postdiscoidal area with two rows of cells basally; midfork 7.5 mm distal of arculus, closer to arculus than to nodus; base of IR2 very close to midfork, 2.2 mm distally; RP2 aligned with subnodus; eight bridge crossveins preserved; area between MA and RP3/4 with a single row of cells before nodus; two rows of cells between AA and posterior margin, cells aligned along AA much larger than those aligned along the posterior margin; CuAa terminated about the level of midway between arculus and nodus, zigzag distally; at least three branches originated on CuAa; two to three rows of cells between CuAa and MP.

Hind wing: not petiolate; broader (by 20 percent) than fore wing, 13.2 mm wide at nodus; distance between base and arculus 4.7 mm, between arculus and nodus 15.2 mm, between nodus and pterostigma less than 14.3 mm; Ax0 close to wing base; two primary antenodal veins very strong, Ax1 0.6 mm basal of arculus, Ax2 2.3 mm distal of arculus, distance between them shorter than that of fore wing; Ax1 situated midway of Ax0 and Ax2; Ax2 situated on the level of distal side of discoidal space, midway of arculus and midfork; no secondary crossveins between C and ScP but thirteen visible between ScP and RA, distal of Ax2; eighteen antesubnodal crossveins visible; at least six postnodal crossveins, not aligned with the visible seven postsubnodal crossveins; pterostigma preserved incompletely, but distinctly rather long (at least 4.3 mm long) and thick, without brace vein, covers at least three crossveins; median space free of crossveins; submedian space only traversed by CuP-crossing; unique subdiscoidal space longer than discoidal space, traversed by one crossvein; discoidal space free of crossveins, basally closed, 2.1 mm long, basal side 0.5 mm long and distal side (MAb) 1.7 mm long; oblique membranaceous pleats appear in median space and discoidal space; cells in anal area of hind wing different from each other in size and shape, those along the AA much larger than others; base of RP and MA separated at arculus; RP2 aligned with subnodus; four bridge crossveins visible; oblique vein "O" not preserved; base of IR2 2.5 mm distal of midfork; midfork 4.6 mm distal of arculus, much closer to arculus than to nodus; area between RP3/4 and MAa with only one row of cells basally; postdiscoidal area with a maximal width of 2.0 mm, two rows of cells up to nodus, distal part much narrower than basal part because of the intensively converging of MAa and MP distally; MAa basally smooth and slightly zigzag after the level of nodus; area between MP and posterior margin very large, with about seven zigzag intercalary veins originated on MP; gaff strong and

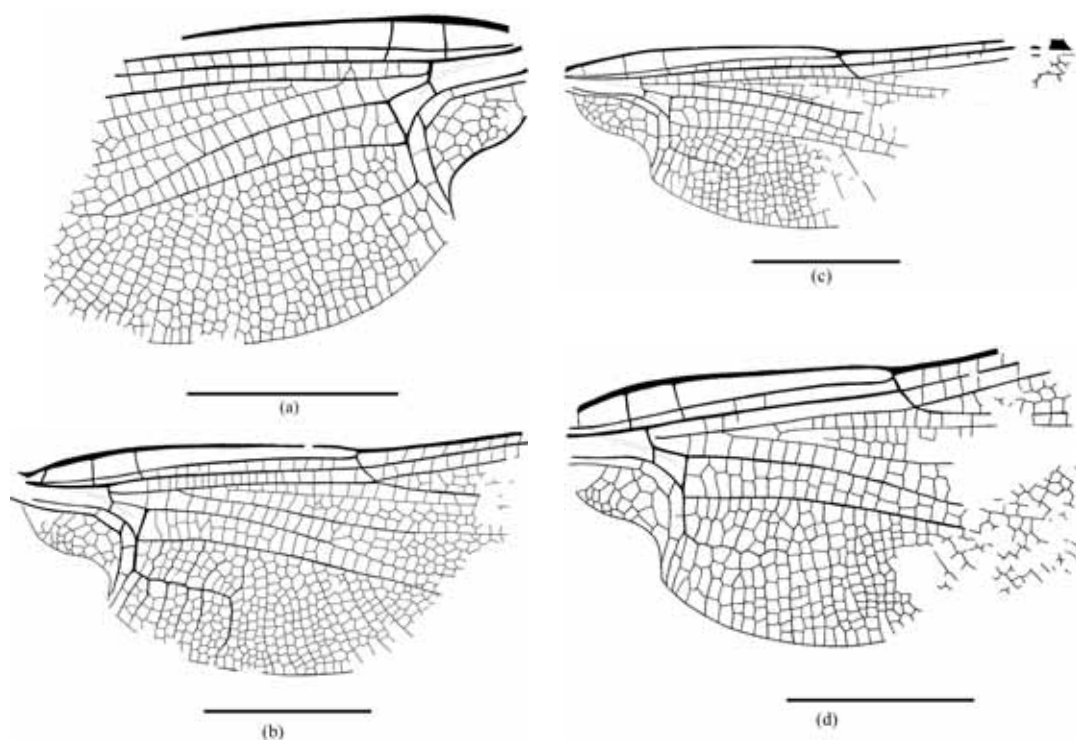


Fig. 5. *Sinokaratawia prokopi* Nel, Huang and Lin, 2007.

CNU-OD-NN2004042 (a) left hind wing; (b) right hind wing. CNU-OD-NN2004057 (c) left hind wing (reversal); (d) right hind wing. Scale bars represent 10 mm.

elongated; two to four rows of cells between CuAa and MP; CuAa very short, bending to posterior margin midway between arculus and nodus, reaching posterior margin before nodus, zigzag distally; about four branches originated on CuAa.

Thorax: not preserved completely but distinctly stout.

Abdomen: basal four segments preserved, with 25.1 mm long and 6.2 mm wide; each segment rectangular (width longer than length).

***Sinokaratawia prokopi* Nel, Huang and Lin, 2007.
(Fig. 5, Plates 9–10)**

Material: CNU-OD-NN2004042 and CNU-OD-NN2004057.

Descriptions:

CNU-OD-NN2004042. Male. Parts of hind wings, thorax and four segments of abdomen preserved.

Hind wing: not petiolate; 13.4 mm wide at nodus; distance between base and arculus 5.1 mm, between arculus and nodus 15.0 mm; Ax0 close to wing base; two primary antenodal veins very strong, rather straight; Ax1 0.8 mm basal of arculus; Ax2 2.1 mm distal of arculus, situated on the level of distal side of discoidal space, midway of arculus and midfork; no secondary crossveins between C and ScP but thirteen between ScP and RA, distal of Ax2; twenty one antesubnodal crossveins preserved; nine postnodal crossveins visible, not aligned with the ten

postsubnodal crossveins preserved; median space free of crossveins, with oblique membranaceous pleats; submedian space only traversed by CuP-crossing; AA reach posterior margin directly, without meeting CuAb, thus subdiscoidal space distally opened; subdiscoidal space divided by two crossveins, much longer than discoidal space; discoidal space free of crossveins, basally closed, 2.0 mm long, basal side 0.6 mm long and distal side (MAb) 1.8 mm long; very acute projecting anal angle present; cells in anal area different to each other in size and shape, those in basal and posterior part smaller than others; base of RP and MA separated at arculus; RP2 aligned with subnodus; ten bridge crossveins; oblique vein "O" indistinct; IR2 originating on RP, with the base 3.0 mm distal of midfork; midfork 4.1 mm distal of arculus, much closer to arculus than to nodus; area between RP3/4 and MA with only one row of cells before nodus, then strongly expanded; postdiscoidal area with a maximal width of 1.9 mm, two rows of cells before the level of nodus; MAa basally smooth and slightly zigzag after the level of nodus (left wing misshapen, MAa and MP fused before nodus); area between MP and posterior margin broad, with at least six zigzag intercalary veins originated on MP; two to five rows of cells between CuAa and MP; gaff strong and elongated; CuAa rather short, bending to posterior margin midway between arculus and nodus, reaching posterior margin before nodus, zigzag distally; five branches originated on

CuAa.

Thorax: stout; 10.3 mm wide and 11.3 mm long; detail characters indistinguishable.

Abdomen: basal four segments preserved. Copulatory apparatus jumbled and indistinct; the third and fourth segments with 4.3 mm wide and 6.7 mm (third) or 7.0 mm (fourth) long; dorso-longitudinal carina of the fourth segment distinct.

CNU-OD-NN2004057. Male. Parts of hind wings, thorax and four segments of abdomen preserved; left hind wing reversed. Both specimens fossilized with some conchostracans. This specimen has same hind wing venation as CNU-OD-NN2004042. Some details were described as following: 13.3 mm wide at nodus; distance between base and arculus 5.2 mm, between arculus and nodus 14.0 mm; Ax1 0.8 mm basal of arculus; Ax2 2.0 mm distal of arculus; fifteen antesubnodal crossveins visible; six postnodal crossveins visible, not aligned with the six postsubnodal crossveins; discoidal space 1.9 mm long, basal side 0.6 mm long and distal side (MAb) 1.5 mm long; IR2 originating on RP, with the base 2.9 mm distal of midfork; midfork 3.9 mm distal of arculus; postdiscoidal area with a maximal width of 2.0 mm; wings not misshapen, with natural MAa and MP.

Remarks: the most difference between our materials and holotype of *S. prokopi* is the divided hind wing discoidal space. It is also considered as natural individual difference.

3 Comparison and Discussion

These new species were attributed to Isophlebioptera: Isophlebiida: Isophlebioidea: Campterothlebiidae because of the following synapomorphies: arculus in a position between Ax1 and Ax2; all antenodal crossveins distal of Ax2 between the costal margin and ScP are suppressed; CuAa shortened, posterior-distally zigzagged, correlated with an distally strongly expanded area between MP and CuAa and the development of numerous convex parallel “secondary branches” of MP in the hind wing; hind wing subdiscoidal enlarged and transversely elongated, correlated with an very long and straight gaff; male hind wing with a very acute or even hook-like projecting anal angle; the hind wing longitudinal veins (especially RP3/4) are distinctly undulate (not distinct here for the incompletely preservation of our study materials); the space between MA and MP is distally constricted by an opposite curvature of these two veins.

Within the Campterothlebiidae, *Samarura* was not considered as it based on larval specimens; *Amnifleckia*, *Angaroneura*, *Bellabrunetia*, *Gampsophlebia*, *Hypsomelana*, *Hypsophlebia*, *Hypsothemis*, *Karatawia*,

Melanohypsa, *Olonkia*, *Parabrunetia*, *Pternopteron*, *Sibirioneura* can be easily excluded because of their single row of cells between MAa and MP basally; *Campterothlebia* with long CuAa reaching posterior margin on the level of nodus; *Oreophlebia* and *Sogdophlebia* have longer CuAa and remarkable transverse elongated cells in the posterior area of hind wing; *Adelophlebia* has a straighter arculus and a longer CuAa; *Sagulia* has much different subdiscoidal space and strongly undulated longitudinal veins; *Sarytashia* has much narrower areas between IR2 and RP2, IR2 and RP3/4, with much smaller size; *Bathmophlebia* has a strongly undulated MP with four rows of cells in maximum between it and MAa, and a much longer CuAa, which strongly hunching distally; *Xanthohypsa* with much less expanded area between MP and posterior margin, three rows of cells in maximum between MP and MAa, and a distinct longer CuAa; *Oshinia* was erected base on a wing apex with very small and dense cells under the pterostigma; *Dorsettia* has particular anal area and unique transverse subdiscoidal space; *Petrophlebia* has small and simple anal area, with Ax2 not situated on the level of the distal side discoidal space. All these genera appear to differ in above-mentioned characters from our specimens. According with all diagnosis proposed by Nel et al. (2007), our specimens can included in *Sinokaratawia*, which was just erected based on four specimens from Daohugou, the same location our materials collected from. Furthermore, we found that some other feathers appeared stably on all materials studied here, as well as on those specimens described by Nel et al. (2007), thus an emended diagnosis was proposed (see above).

Short petiole of *S. prokopi* described by Nel et al. (2007) seems indistinct. After working on our materials, we preferred to consider this genus as a no-petiole group.

As three new species coming out only based on female materials from the same location, the male and female partnership of *S. prokopi* became questionable. In fact, identification of conspecific male and female can be accurate only if the mating dragonflies were preserved as fossils fortunately. For this group, the big different venation of male and female make this work even harder. Well preserved specimens, especially those with body characters would be advantageous to resolve this problem.

Acknowledgements

We are grateful to Dr. Shih Chungkun (College of Life Sciences, Capital Normal University) and two anonymous reviewers for their useful comments on this manuscript. The research was supported by the National Natural Science Foundation of China (30430100, 40872022),

Beijing Natural Science Foundation (5082002), Key Project of Beijing Municipal Commission of Education, National Infrastructure of Natural Resources for Science and Technology (2005DKA21403) and China Postdoctoral Science Foundation (20060400479).

Manuscript received April 15, 2007

accepted Dec. 27, 2007

edited by Liu Xinzhu

References

- Bechly, G., 1996. Morphologische Untersuchungen am Flügelgeäder der rezenten Libellen und deren Stammgruppenvertreter (Insecta; Pterygota; Odonata) unter besonderer Berücksichtigung der Phylogenetischen Systematik und des Grundplanes der *Odonata. *Petalura* (Boblingen), spec., 2: 1–402 (in German).
- Bechly, G., 2005. *Phylogenetic systematics of "Anisozygoptera"*. Homepage on Internet: <http://www.bernstein.naturkundemuseum-bw.de/odonata/anisozyg.htm#campterothlebiidae>.
- Bechly, G., Nel, A., Martínez-Delclòs, X., Jarzembowski, E.A., Coram, R., Martill, D., Fleak, G., Escuillí, F., Wisshak, M.M., and Maisch, M., 2001. A revision and phylogenetic study of Mesozoic Aeshnoptera, with description of numerous taxa (Insecta: Odonata: Anisoptera). *Neue Paläontologische Abhandlungen*, 4: 1–219.
- Bode, A., 1905. Orthoptera und Neuroptera aus dem Oberen Lias von Braunschweig. *Jahrbuch der Königlich Preussischen Geologischen Landesanstalt und Bergakademie (Berlin)*, 25: 218–245 (in French).
- Fleck, G., and Nel, A., 2002. The first Isophlebioid dragonfly (Odonata: Isophlebioptera: Campterothlebiidae) from the Mesozoic of China. *Palaeontology*, 45: 1123–1136.
- Fleck, G., Bechly, G., Martínez-Delclòs, X., Jarzembowski, E.A., and Nel, A., 2004. A revision of the Upper Jurassic-Lower Cretaceous dragonfly family Tarsophlebiidae, with a discussion on the phylogenetic positions of the Tarsophlebiidae and Sieblosiidae (Insecta, Odonatoptera, Panodonata). *Geodiversitas*, 26(1): 33–60.
- Gao Keqin and Ren Dong, 2006. Radiometric dating of ignimbrite from Inner Mongolia Provides no indication of a post-Middle Jurassic age for the Daohugou Beds. *Acta Geologica Sinica* (English Edition), 80(1): 42–45.
- Kukalová-Peck, J., 1991. Chapter 6: Fossil history and the evolution of hexapod structures. In: Naumann, I.D. (ed.), *The Insects of Australia, A textbook for students and research workers*. Melbourne: Melbourne University Press, 1, 141–179.
- Nel, A., and Jarzembowski, E.A., 1996. Description and revision of some dragonflies ('Anisozygoptera') from the Lower Cretaceous of England (Odonata: Stenophlebiidae, Campterothlebiidae?, Epiophlebiidae, Euthemistidae). *Cretaceous Res.*, 17: 87–96.
- Nel, A., Huang, D.Y., and Lin, Q.B., 2007. A new genus of isophlebioid damsel-dragonflies (Odonata: Isophlebioptera: Campterothlebiidae) from the Middle Jurassic of China. *Zootaxa*, 1642: 13–22.
- Nel, A., Martínez-Delclòs, X., Paicheler, J.C., and Henrotay, M., 1993. Les "Anisozygoptera" fossiles Phylogénie et classification (Odonata). *Martinia (Numéro hors-série)*, 3: 1–311 (in French).
- Pritykina, L.N., 1968. Strekozy Karatau (Odonata). In: Panfilov, D.V. (ed.), *Yurskie Nasekomye Karatau*. Moscow: Academy of Science of the SSSR, Nauka, 26–55 (in Russian).
- Pritykina, L.N., 1970. Trassic and Jurassic dragonflies of the Liassophlebiidae from Soviet Central Asia. *Paleontol. J.*, 4: 104–117 (in Russian).
- Pritykina, L.N., 1980. New fossil Odonata from the Mesozoic of Central Asia. In: Dolin, V.G., Panfilov, D.V., Ponomarenko, A. G., and Pritykina, L.N. (eds.), *Mesozoic fossil insects*. Kiev: Naukova Dumka, 119–131 (in Russian).
- Pritykina, L.N., 1985. Fossila Odonata (Libellulida=Odonata) from Siberia and outer Mongolia. In: Pasnitsyn, A.P. (ed.), *Fossil Insects from Siberia and Mongolia*. Moscow: Trudy Paleontologicheskogo Instituta, 211: 120–138 (in Russian).
- Pritykina, L.N., and Rasnitsyn, A.P., 2002. Superorder Libellulidea Laicharting, 1781. Order Odonata Fabricius, 1792. The dragonflies. In: Rasnitsyn, A.P., and Quicke, D.L.J., (eds.), *History of Insects*. Dordrecht: Kluwer Academic Publishers, 97–103.
- Ren Dong, Gao Keqin, Guo Ziguang, Ji Shuan, Tan Jingjing and Song Zhuo, 2002. Stratigraphic division of the Jurassic in the Daohugou area, Ningcheng, Inner Mongolia. *Geol. Bull. China*, 21(8–9): 584–591.
- Riek, E.F., 1976. A new collection of insects from the Upper Triassic of South Africa. *Annals Natal Museum*, 22: 791–820.
- Riek, E.F., and 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 J. Zool.*, 62: 1150–1166.
- Tan Jingjing, Huang Diying and Ren Dong, 2007. First Record of Fossil Mesocopes from China (Coleoptera: Archostemata: Cupedidae). *Acta Geologica Sinica* (English edition), 81(5): 688–696.
- Whalley, P.E.S., 1985. The systematics and palaeogeography of the Lower Jurassic insects of Dorset, England. *Bull. British Museum Natural History (Geology)*, 39: 107–187.
- Zhang, B.L., Fleck, G., Huang D.Y., Nel, A., Ren, D., Cheng, X. D., and Lin, Q.B., 2006. New isophlebioid dragonflies (Odonata: Isophlebioptera: Campterothlebiidae) from the Middle Jurassic of China. *Zootaxa*, 1339: 51–68.

Explanation of plates:

1. *Sinokaratawia daohugouica* sp. nov., holotype CNU-OD-NN2004058.
2. *Sinokaratawia daohugouica* sp. nov., paratype CNU-OD-NN2004061.
3. *Sinokaratawia daohugouica* sp. nov., paratype CNU-OD-NN2004064.
4. *Sinokaratawia daohugouica* sp. nov., paratype CNU-OD-NN2004063.
5. *Sinokaratawia magica* sp. nov., holotype CNU-OD-NN2004041-1.
6. *Sinokaratawia magica* sp. nov., holotype CNU-OD-NN2004041-2.
7. *Sinokaratawia gloriosa* sp. nov., holotype CNU-OD-NN2004040-1.
8. *Sinokaratawia gloriosa* sp. nov., holotype CNU-OD-NN2004040-2.
9. *Sinokaratawia prokopi* Nel, Huang and Lin, 2007, CNU-OD-NN2004042.
10. *Sinokaratawia prokopi* Nel, Huang and Lin, 2007, CNU-OD-NN2004057.

Plate I