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ORIGINAL ARTICLE

New species of *Cicadocoris* (Hemiptera: Coleorrhyncha: Progonocimicidae) from mid-Jurassic deposits in northeastern China

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Key words. Hemiptera, Coleorrhyncha, Progonocimicidae, *Cicadocoris parvus* sp. n., fossil, mid-Jurassic, Daohugou, China

Abstract. A new progonocimicid bug named *Cicadocoris parvus* sp. n. is described from the mid-Jurassic Haifanggou Formation at Daohugou, Ningcheng County, Inner Mongolia, northeastern China. It differs from other species by being distinctly smaller, veins dSc, R_1 and Rs run parallel to one another and are nearly evenly spaced on left tegmen, widest length of apical half/basal half of left tegmen is 1.1 and that of right tegmen is 1.0. Thus, there are at least three species of *Cicadocoris* (Progonocimicidae) described from Daohugou. All these species are relatively abundant in the Haifanggou Formation and are remarkable representatives of the early Yanliao biota.

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INTRODUCTION

Coleorrhyncha is a small suborder of Hemiptera comprised of three families: the extant Peloridiidae Breddin, 1897, the extinct Progonocimicidae Handlirsch, 1906 and Karabasiidae Popov, 1985 (Popov & Shcherbakov, 1991; Wang et al., 2009). Peloridiidae is a small family with currently a limited distribution in wet moss in temperate and sub-Antarctic rainforests in the Southern Hemisphere (e.g. Chile, Argentina, New Zealand, New Caledonia, southeastern Australia; Burckhardt, 2009; Burckhardt et al., 2011).

The fossil progonocimicids are recorded from the Upper Permian to the Lower Cretaceous and have a remote Gondwana origin. They were widely distributed, occurring in Permian deposits in Australia (Tillyard, 1926), Triassic in Kyrgyzstan (Becker-Migdisova, 1958; Popov & Shcherbakov, 1991), Australia (Evans, 1956, 1961, 1963; Wootton, 1963) and Argentina (Martins-Neto, 2003), Jurassic in Kyrgyzstan (Popov, 1982, 1985), United Kingdom (Popov et al., 1994), China (Hong, 1983; Dong et al., 2012, 2013, 2014), Russia (Popov, 1985, 1988), Germany (Handlirsch, 1939; Popov & Wootton, 1977), Luxembourg (Szwedo, 2011), and Cretaceous in Lebanon (Szwedo et al., 2011), United Kingdom (Handlirsch, 1906; Klimaszewski & Popov, 1993), Argentina (Martins-Neto, 2003), Mongolia (Popov, 1986) and Russia (Popov, 1988). Based on our recent unpublished data it also occurs in mid-Cretaceous Burmese amber. Karabasiids are reported from the Lower Jurassic to the Lower Cretaceous, including Jurassic in Mongolia (Popov, 1989), Russia (Popov & Shcherbakov, 1991; Becker-Migdisova, 1958; Popov, 1985), Kyrgyzstan (Martynov, 1926) and China (Lin, 1986; Wang et al., 2011), and Cretaceous in Russia (Popov & Shcherbakov, 1991).

The genera in Progonocimicidae are complicated. *Olgamartynovia* Becker-Migdisova, 1958, *Mesoscytina* Hong, 1983, *Mesocimex* Hong, 1983, and *Asianisca* Popov, 1985 were synonymized with *Cicadocoris* Becker-Migdisova, 1958. Popov & Shcherbakov (1991) transferred 10 species of *Olgamartynovia* to *Mesoscytina* and 10 to *Cicadocoris*, two species of *Asianisca* to *Mesoscytina* and one to *Cicadocoris*. They also proposed that *Mesocimex* is a synonym of *Mesoscytina*. Wang et al. (2009) found that the generic name *Mesoscytina* had already been used and the valid generic name should be *Mesocimex*. However, *Mesocimex* was very similar to *Cicadocoris* and a species named *Cicadocoris assimilis* Dong, Yao & Ren, 2013 had characters typical of both *Mesocimex* and *Cicadocoris*. The two genera were discussed and considered synonymous (Dong et al., 2012, 2013). Thus, *Cicadocoris* is currently the larg-

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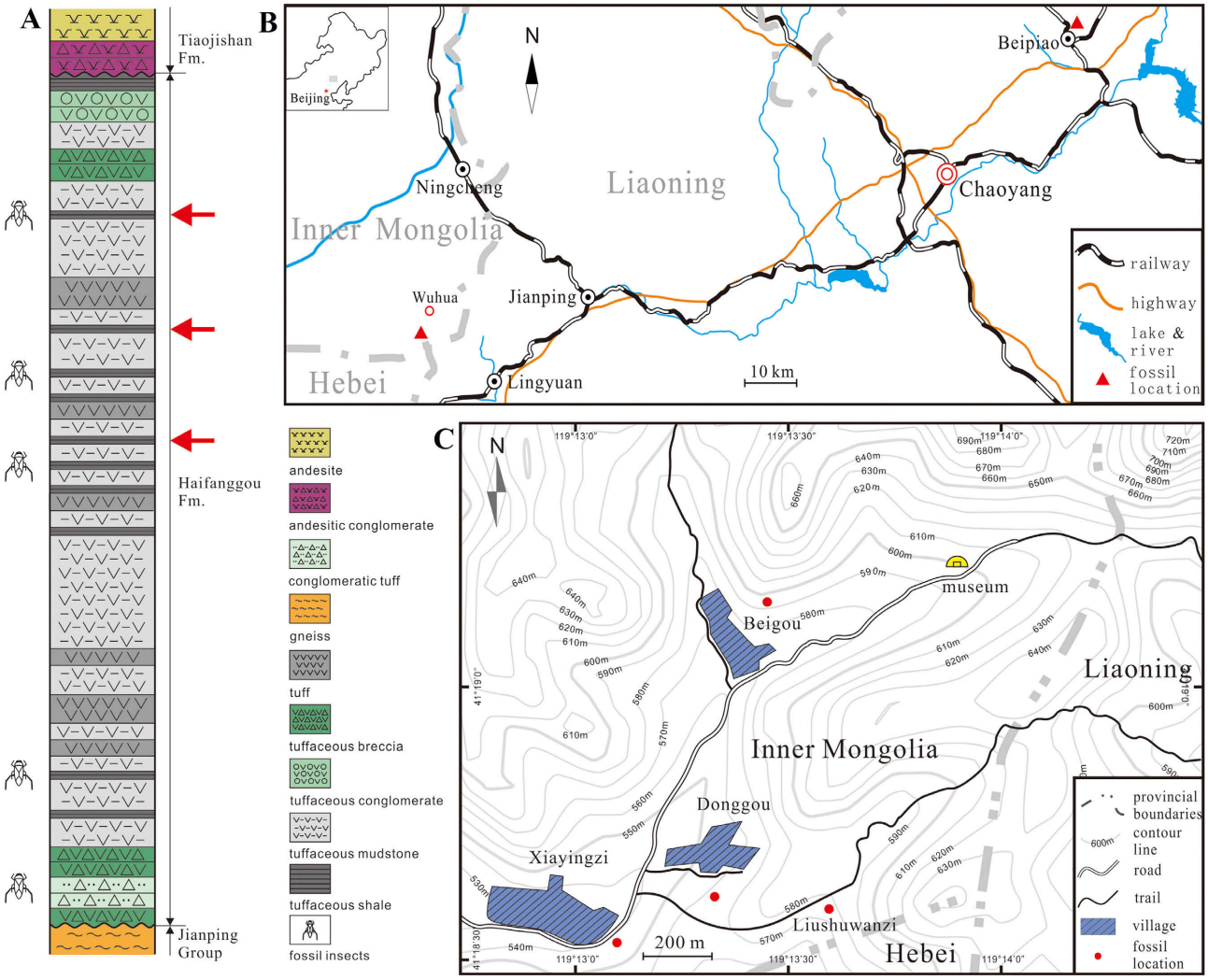

Fig. 1. A – stratigraphic column for the Haifanggou Fm. near Daohugou, Ningcheng County, Inner Mongolia, NE China (red arrows indicate the fossil layers that yielded new species); B – map showing the location of Daohugou and Yujiagou (red triangles); C – map showing locations near Daohugou (red spots).

est of the 23 genera currently considered valid in the Progonocimicidae, and is reported from the Late Triassic to Middle Jurassic (Becker-Migdisova, 1958; Popov, 1982, 1985; Hong, 1983; Dong et al., 2013).

The fossil progonocimicids are easily collected from the mid-Jurassic Haifanggou Formation (Daohugou beds) in Ningcheng County, Inner Mongolia (Wang et al., 2009; Dong et al., 2012, 2013, 2014) and localities near Haifeng, Beipiao, Liaoning Province (Hong, 1983; Jiang et al., 2016) (Fig. 1B). The Daohugou beds mainly occur at Wuhua near the border between the Inner Mongolia, Hebei and Liaoning provinces. The lacustrine deposits have yielded hundreds of progonocimicid specimens and other abundant fossil insects of more than 20 orders (Huang, 2015). The age of this fauna seems very close to the middle and late Jurassic boundary (163.5 Ma) (Huang, 2016).

MATERIAL AND METHODS

The material studied includes a total of 40 individuals (21 males, 12 females and 7 undetermined); most of them are complete or nearly complete, and 16 of them are with counterparts. Most specimens (39) were collected from several localities near Daohugou and Wuhua, Ningcheng County, Inner Mongolia, northeastern China (Fig. 1C). They are preserved in whitish or greyish fine laminated tuffaceous shale (Xiayingzi, Donggou and Beigou) or strongly weathered yellowish muddy shale (Liushuwanzi). Only one specimen was collected from the yellow-brownish shale at Yujiagou near Haifeng, Sanbao and Beipiao, Liaoning Province. All these fossils are from the Haifanggou Formation with a geological age close to the middle–late Jurassic boundary.

Some specimens were carefully prepared using a sharp knife. All fossils were studied using a Leica MZ16A dissecting microscope. Maps and line drawings were drawn with CorelDRAW X6 graphic software. Photographs were taken with a digital camera attached to a Leica MZ16A microscope. Specimens in a few photographs were moistened with 70% ethanol to show the fine details (e.g. teeth-bearing structure of hind tibia and tarsi). All type material is deposited in the Nanjing Institute of Geology and Palaeontology. We follow the wing venation nomenclature as amended by Popov & Shcherbakov (1991).

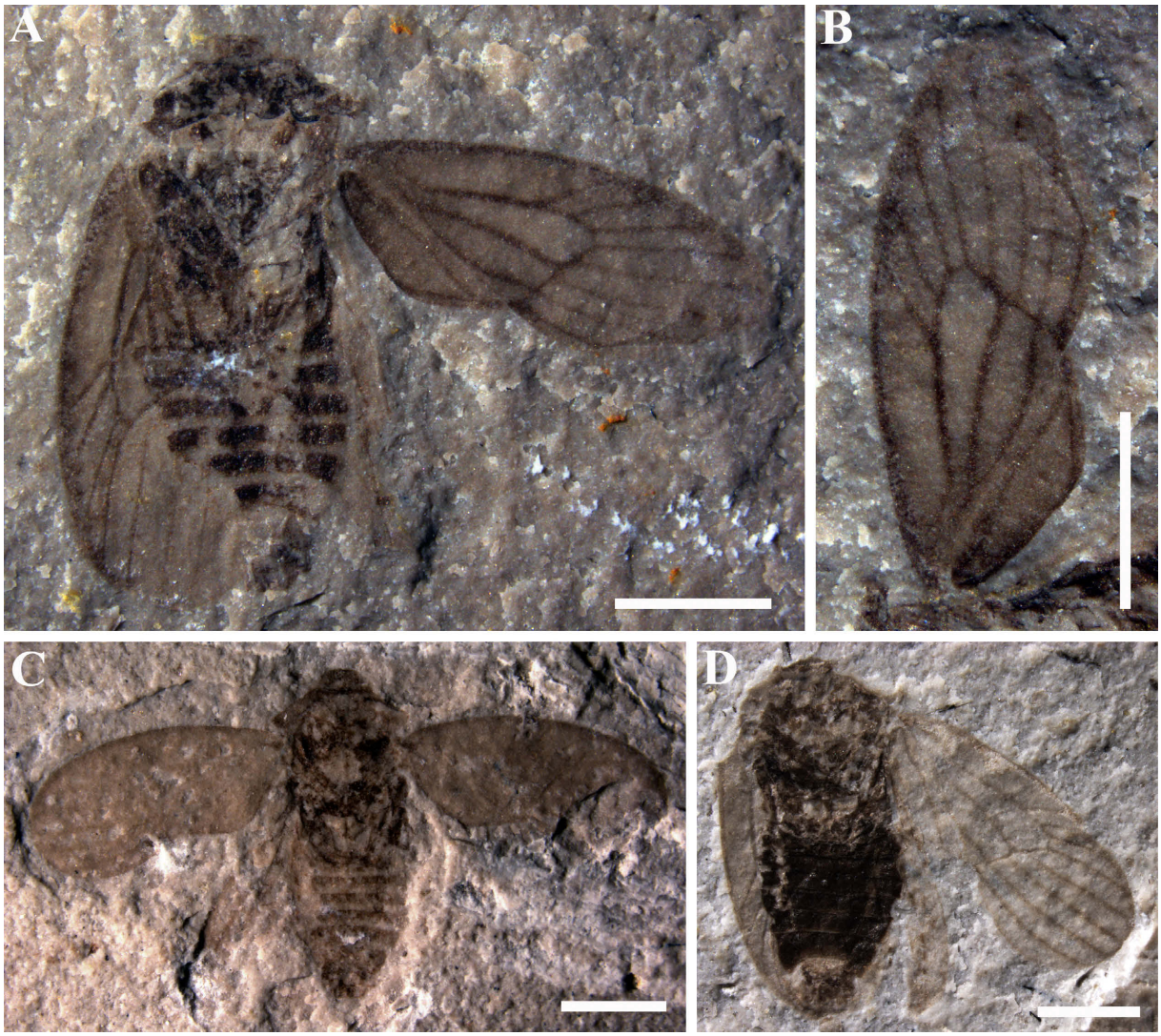

Fig. 2. Males of *Cicadocoris parvus* sp. n. with tegmina extended. A – holotype, (NIGP165304), a complete male, showing general habitus; B – left tegmen, showing venation; C – complete male (NIGP165305), showing general habitus and venation; D – complete male (NIGP165306), showing general habitus and venation. Scale bars: 1 mm.

SYSTEMATIC PALEONTOLOGY

Order Hemiptera Linnaeus, 1758

Suborder Coleorrhyncha Myers et China, 1929

Family Progonocimicidae Handlirsch, 1906

Subfamily Cicadocorinae Becker-Migdisova, 1958

Genus *Cicadocoris* Becker-Migdisova, 1958

Type species. *Cicadocoris kuliki* Becker-Migdisova, 1958 (original designation).

Olgamartynovia Becker-Migdisova, 1958: 62. Type species: *O. turanica* Becker-Migdisova, 1958 (original designation). Synonymized by Popov & Shcherbakov, 1991.

Liadoscytina Popov, 1982: 81. Nomen nudum.

Mesocimex Hong, 1983: 65. Type species: *M. sinensis* Hong, 1983 (original designation). Synonymized by Dong et al., 2013.

Mesoscytina Hong, 1983: 66 (nec Tillyard, 1919; Scytinopteridae). Type species: *M. brunnea* Hong, 1983 (original designation). Synonymized by Popov & Shcherbakov, 1991.

Asianisca Popov, 1985: 33 (*A. ambigua*; *A. incompleta*; *A. modesta*). Type species: *A. modesta* Popov, 1985 (original designation). Synonymized by Popov & Shcherbakov, 1991.

Genus diagnosis. Head small; eyes oval; antennae clavate; rostrum thin, extends to basal hind coxae; pronotum trapezoidal; hind tibia with two large movable conical spurs; hind tarsi three-segmented, apex of hind tibia and tarsomeres bear tiny teeth; costal margin arcuate; precostal carina narrow nearly horizontal; abdomen roughly oval, longer than wide with sternite 4 broadest, sternite 9 short, ovipositor extends slightly beyond sternite 9.

Cicadocoris parvus sp. n.

(Figs 2–7)

ZooBank taxon LSID:
937376DA-5BD4-4CFF-9379-1B0B3A0DEAEB

Etymology. Derived from the Latin parvus meaning "small", or "little" to indicate the small size of this new species.

Type material. Holotype NIGP165304, male, a well-preserved complete specimen with one extended tegmen, without counterpart. It was collected from the Xiayingzi locality. Paratypes. Males: NIGP165305–NIGP165313, NIGP166188–NIGP166198; females: NIGP165314–NIGP165319, NIGP165325–NIGP165326,

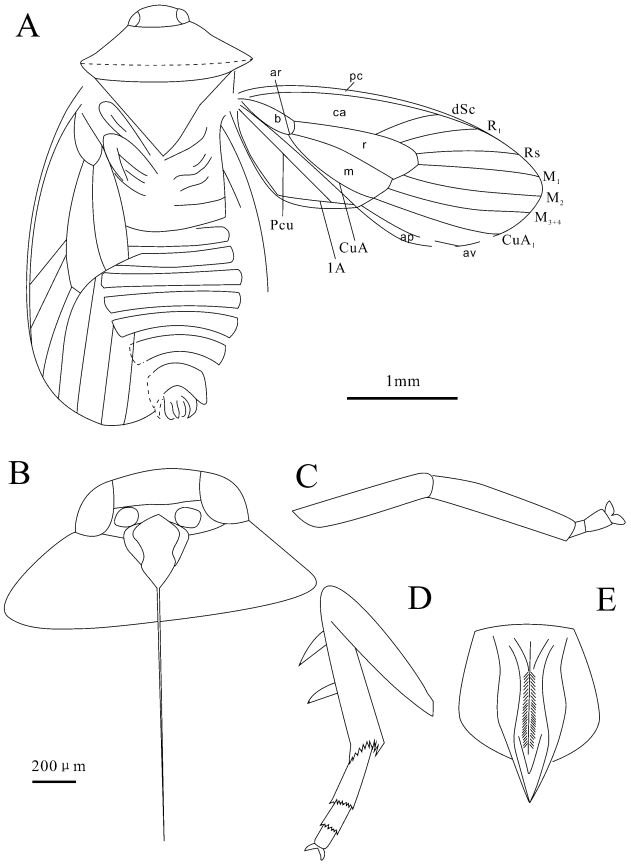

Fig. 3. Line drawings of *Cicadocoris parvus* sp. n. A – holotype (NIGP165304); B – head (NIGP165313); C – fore leg (NIGP166190); D – hind leg (NIGP165315); E – ovipositor (NIGP165319). Scale bars: 1 mm in A, 200 μm in B–E. ap – appendix, ar – arculus, av – ambient vein, b – basal cell, ca – costal area, dSc – apex of Sc, m – medial cell, pc – precostal carina, Cua – cubitus anterior Pcu – postcubitus.

NIGP166189–NIGP166202; unknown sexes: NIGP166203–NIGP166209.

Type locality, formation and age. Daohugou, Ningcheng County, Inner Mongolia, China; Haifanggou Formation; mid-Jurassic.

Diagnosis. Small size, differs from other species by its distinctly smaller body size (2.8–3.9 mm); veins dSc, R1 and Rs sub-parallel and nearly evenly spaced on left tegmen; left tegmen, widest length of apical half/basal half is1.1 and that of right tegmen is 1.0; 21 visible ridges along median section of female ovipositor; wing length/body length is 0.83 in male, 0.92 in female.

Description. Body 2.8–3.9 mm long, tegmen 2.5–3.8 mm long. Small insect, oval to round in outline. Head small, without areolae. Compound eyes oval. Antennae four segmented, antennal socket closer to postclypeus than eyes (Figs 3B, 5B, H). Anteclypeus subtriangular, laterally indented to postclypeus (Fig. 5B). Postclypeus rounded and slightly convex. Lora semicircular and completely separated. Rostrum thin, directed caudad, reaching base of hind coxae (Figs 5B, 6D).

Pronotum trapeziform, 1.8–2.2 times as wide as head, with weakly concave fore edge, lateral edges curled, slightly arcuate, posterior angles blunted, 3.8 times as wide as long. Scutellum medium-sized, triangular, 1.5–1.8 times as wide as long. Legs slight increasing in size from fore to hind legs, femur as long as tibia. Fore and middle tarsi two-segmented, hind tarsi three-segmented (Figs 3C, D, 4F, 5E, 6G, 7G). Hind coxae enlarged and transverse. Hind tibia bear two large lateral movable spurs that are 0.3 times shorter than length of tibia, one near the base and the other near the middle (Figs 3D, 4E, 5E, 6F, G, 7G), apex of hind tibia and tarsomeres bear tiny teeth (Figs 4F, 6G). Hind tibia armed with at least 10 visible apical tiny teeth (Figs 3D, 4E, J, 5C, 6I, J). Basal tarsomere distinctly longer than second and third tarsomeres together, basal tarsomere 2.0–2.2 times length of second tarsomere, apex of basal tarsomere and second tarsomere armed with at least 8 tiny teeth (Figs 3D, 5C, 6I, J, 7J).

Tegmen (Figs 2, 3) length-width ratio 2.5, with widest part 3/4 along the length of wing. Anterior margin weakly arcuate, with apex at apex of vein M_{3+4}. Precostal carina narrow and horizontal. Costal area narrow, not widening towards dSc, dSc straight. Stem of R slightly convex at point of dSc origin, dividing into R_1 and Rs halfway between the fork in M and costal margin, slightly beyond basal forking of M. Arculus short and sub transverse. M_{1+2} dividing before r-m, M_{3+4} longer than stem M. Stem CuA beyond arculus curved. CuA_2 transverse. Length of radial cell 0.36 times as long as tegmen, length of medial cell 0.34 times as long as tegmen. Right tegmen cu-a, m-cu, base of M_{3+4}, M_{1+2} and M_1 form distinct and continuous transverse arc, distance from dSc origin to that of R_1 1.1–1.5 times longer than that from the origin of R_1 to that of Rs, veins dSc, R_1 and Rs sub-parallel, M_1 arcuate and closer to Rs than M_2, width of apical half 1.0 times that of basal half. Left tegmen without arc, origin of R_1 in the middle of that of dSc and Rs, veins dSc, R_1 and Rs parallel and evenly spaced, M_1 on left tegmen straight, equals Rs and M_2, width of apical half 1.1 times that of basal half. Hindwing rounded apically, with apex at apex of vein M_{1+2}. Vein Rs connected to M_{1+2} by a sub transverse cross vein r-m a little distal of the origin of M_{1+2}. Stem M forks into M_{1+2} and M_{3+4} little beyond middle of wing. Vein M_{3+4} fused with vein CuA_1. Stem of CuA bifurcates into veins CuA_1 and CuA_2 at same level as the stem of M branches.

Abdomen slightly longer than wide. Lateral tergites 4–6 4.0 times narrower than sternites. Sternite IV broadest, sternite VIII curved, sternite IX small and blunt apically. Ovipositor 0.8 times as wide as long, extends slightly beyond apex of sternite 9, shorter than apex of tegmina, consisting of three pairs of valvulae and narrows anteriorly, with 24 visible ridges along its median section(Figs 3E, 6C, D, 7H, I). Male pygophore barrel-shaped, 0.92 times as wide as long (Figs 4B, G, H, 5A, E, H).

Measurements (in mm). The average value of the body length (head to apex of genitalia) of *Cicadocoris parvus* is 3.50 mm, wing length is 2.99 mm; the median length of the body is 3.51 mm, wing length is 3.00 mm (Table 1). Holotype, NIGP165304 (male): body length 3.68, body width 1.29; head length 0.20, width 0.53; pronotum length 0.50, width 1.57; left tegmen: length 3.02, width 1.18; arculus 0.02; dSc 0.69; R1 0.78, Rs 0.93; M_1

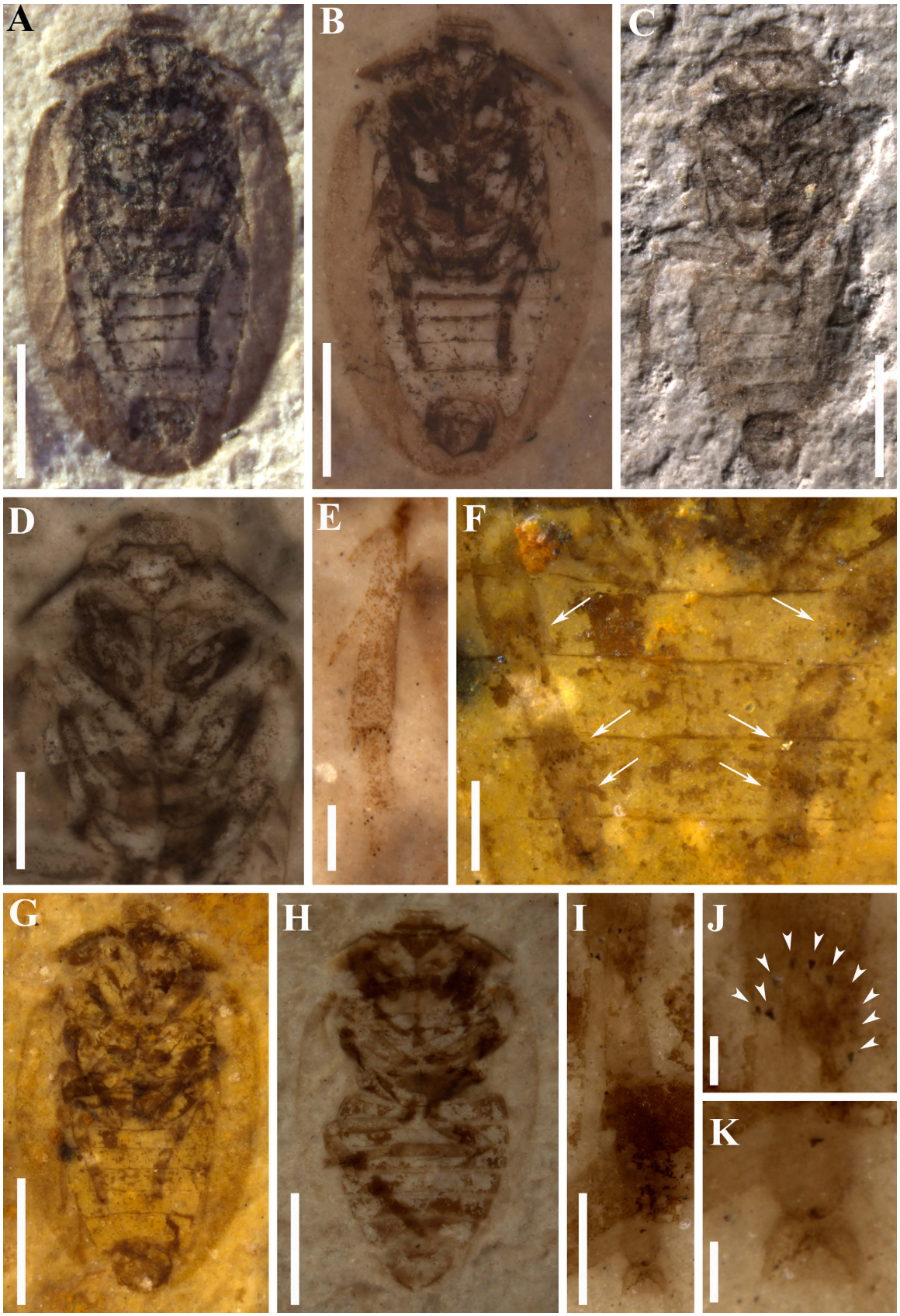

Fig. 4. *Cicadocoris parvus* sp. n., males, from the Haifanggou Formation at Daohuguo. A – NIGP165307, general habitus; B – NIGP165307(A), general habitus and body structures; C – NIGP165308, general habitus with tegmina under rock; D – enlargement of C, showing the details of rostrum and legs; E – enlargement of C, showing details of hind leg; F – enlargement of G, showing the tiny teeth on the apices of the tibia and tarsi (indicated by white arrows); G – NIGP165309, general habitus; H – NIGP165310, general habitus; I – enlargement of H, showing details of the tiny teeth on the apices of tibia and tarsi; J – enlargement of H, showing the apical teeth on hind tibia (white arrows); K – enlargement of H, details of claws. B, D, E, F, G, H, I, J, K moistened with 70% ethanol. Scale bars represent 1 mm in A, B, C, G, H; 0.5 mm in D; 0.2 mm in E, F, I; 50 μm in J, K.

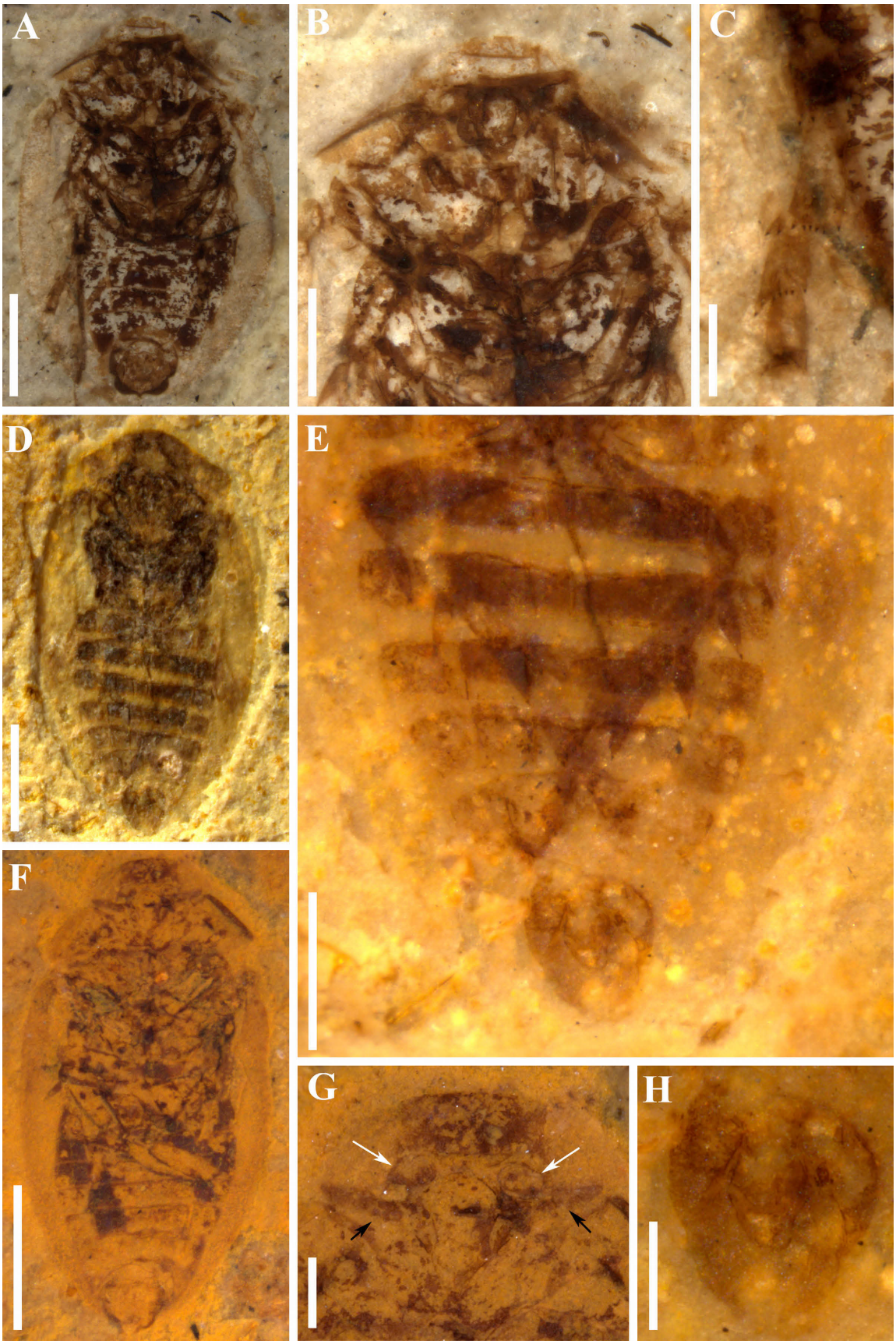

Fig. 5. Photographs of males of *Cicadocoris parvus* sp. n., from the Haifanggou Formation at Daohugou. A – NIGP165311, general habitus; B – enlargement of A, showing details of mouthparts and antennal socket; C – enlargement of A, showing the tiny teeth on the apices of tibia and tarsi; D – NIGP165312, general habitus; E – enlargement of D, showing the details of hind legs and pygophore; F – NIGP165313, general habitus; G – enlargement of F, showing the details of antennae (indicated by black arrows) and antennal socket (indicated by white arrows); H – enlargement of d, showing the details of pygophore. A, B, C, E, F, G, H moistened with 70% ethanol. Scale bars represent 1 mm in A, D, F; 0.5 mm in B, E; 0.2 mm in G, H, C.

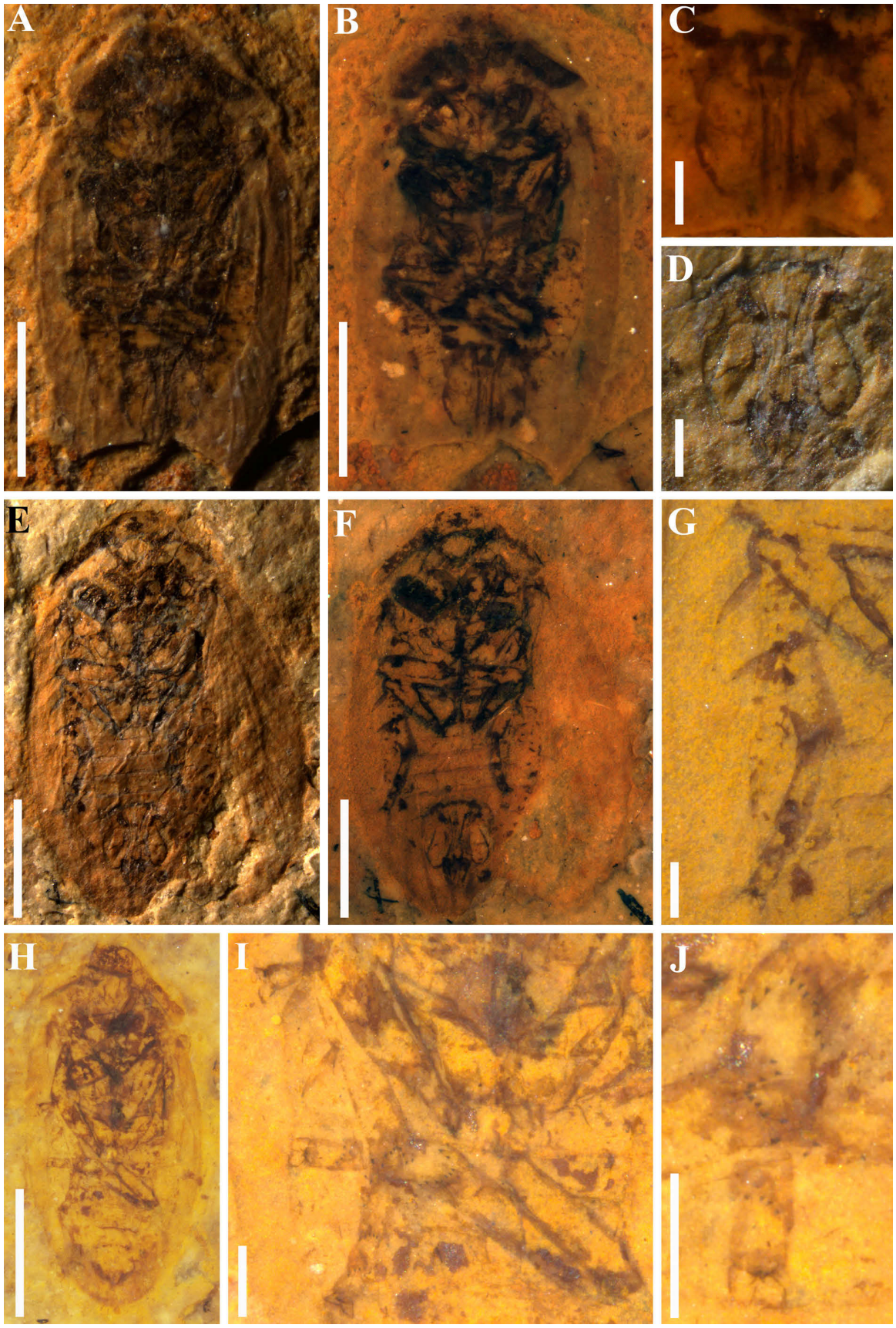

Fig. 6. Photographs of females of *Cicadocoris parvus* sp. n., from the Haifanggou Formation at Daohugou. A – NIGP165314, general habitus; B – NIGP165314(A), general habitus; C – enlargement of A, showing the details of ovipositor; D – enlargement of E, showing the details of ovipositor; E – NIGP165315, general habitus; F – NIGP165315 (E), general habitus and body structures; G – enlargement of A, showing the details of hind leg; H – NIGP165316, general habitus; I – enlargement of H, showing the details of hind legs; J – enlargement of H, showing the tiny teeth on the apices of the tibia and tarsi. B, C, F, G, H, I , J moistened with 70% ethanol. Scale bars represent 1 mm in A, B, E, F, H; 0.2 mm in C, D, G, I, J.

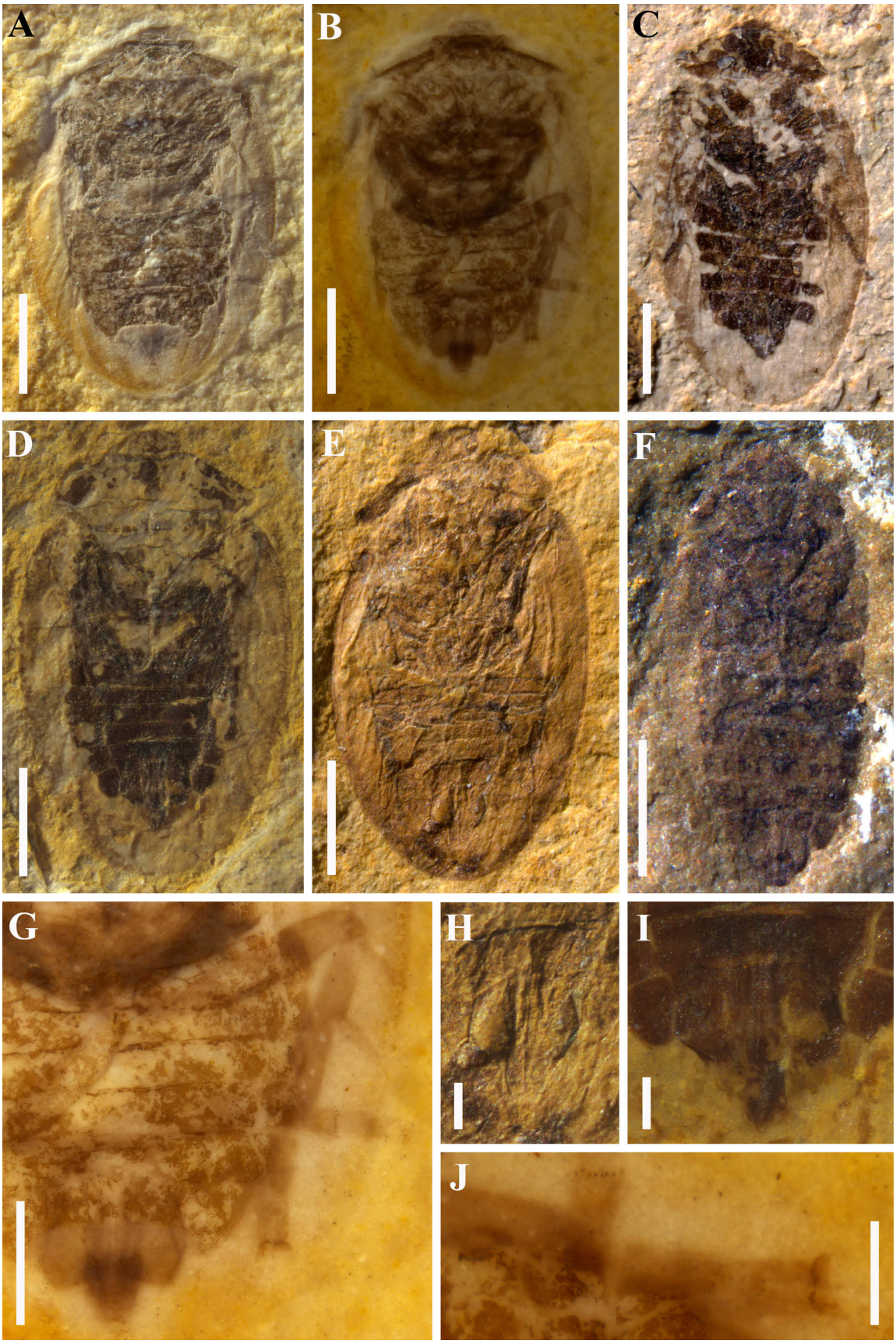

Fig. 7. Photographs of females of *Cicadocoris parvus* sp. n., from the Haifanggou Formation at Daohugou (A–E, G–J) and Yujiagou (F). A – NIGP165317, general habitus; B – NIGP165317(A), showing general habitus; C – NIGP165318, showing general habitus; D – NIGP165319, the details of ovipositor; E – NIGP165325, general habitus; F – NIGP165326, general habitus; G – enlargement of B, showing details of hind legs and ovipositor; H – enlargement of E, showing details of ovipositor; I – enlargement of D, showing details of ovipositor; J – enlargement of B, showing the tiny teeth on apices of tarsomere and claws. B, G, I, J moistened with 70% ethanol. Scale bars represent 1 mm in A, B, C, D, E, F; 0.5 mm in G; 0.2 mm in H, I, J.

Table 1. Measurements of *Cicadocoris parvus.*

Cicadocoris parvus (M)	165304	165305	165306	165307	165308	165309	165310	165311	165312	165313	166188	166189	166190
body length	3.68	3.21	3.52	3.35	3.82	3.32	3.54	3.77	3.54	3.78	3.58	3.41	3.8
body width	1.29	1.08	1.39	1.34	1.38	1.24	1.37	1.37	1.36	1.25	1.25	1.38	1.66
wing length	3.02	2.55	3.24	2.86		2.74	3.04	3.11	2.93	3.26	2.88	2.89	3.29
head width	0.53	0.54	0.64	0.81	0.68	0.64	0.83	0.73		0.84	0.75	0.71	
pronotum length	0.50	0.42	0.46	0.38	0.38	0.21	0.33	0.43		0.34	0.46	0.48	0.59
pronotum width	1.57	1.29		1.62	1.41	1.48	1.7	1.73	1.43	1.44	1.54	1.64	

Cicadocoris parvus (M)	166191	166192	166193	166194	166195	166196	166197	166198	Average (M)
body length	3.26	3.54	3.47	3.85	3.77	3.62	3.7	3.53	3.57
body width	1.29	1.38	1.29	1.33	1.4	1.55	1.44	1.44	1.36
wing length	2.45	2.99	2.8		3		3.24	3.01	2.96
head width	0.61	0.59	0.65		0.65	0.64	0.89	0.61	0.69
pronotum length	0.39	0.41	0.48	0.43	0.41	0.42	0.38	0.41	0.42
pronotum width	1.58	1.35	1.5	1.37	1.61	1.61	1.32	1.53	1.51

Cicadocoris parvus (F)	165314	165315	165316	165317	165318	165319	165325	165326	166199	166200	166201	166202	Average (F)
body length	2.85	3.42	3.1	3.36	3.86	3.77	3.7	3.35	3.34	3.2	3.65	3.74	3.44
body width	1.4	1.27	1.06	1.7	1.56	1.58	1.55	1.19	1.25	1.21	1.53	1.67	1.41
wing length	2.55	2.96	2.7	3.27	3.8	3.45	3.4		3.2	2.51	3.17	3.68	3.15
head width	0.8	0.84	0.58	0.7	0.68	0.77	0.78	0.69	0.65	0.62	0.76		0.72
pronotum length	0.4	0.39	0.33	0.3	0.52	0.46	0.56	0.35	0.52	0.37	0.4		0.42
pronotum width	1.5	1.54	1.33	1.83	1.72	1.81	1.78	1.27	1.59	1.2	1.91		1.59

Cicadocoris parvus (U)	166203	166204	166205	166206	166207	166208	166209
body length	3.6		3.43	2.98	3.44	3.36	
body width	1.44	1.32	1.61	1.31	1.31		1.43
wing length	2.18	2.76	3.04	2.66	3.18	2.99	
head width	0.64		0.97		0.56	0.57	0.65
pronotum length	0.39		0.32	0.36	0.44	0.4	0.38
pronotum width	1.44		1.84	1.52	1.54	1.35	1.47

Note: M – male; F – female; U – unknown sex; all the values are in mm.

1.11, M_2 1.32, M_{1+2} 0.11, M_{3+4} 1.30; CuA_1 1.16, CuA_2 0.14, 1A 0.68, Pcu 1.22. Paratype, NIGP165315 (female): body length 3.42, body width 1.27; head length 0.32, width 0.84; pronotum length 0.39, width 1.54; length of hind coxa 0.46, hind femur 0.65, hind tibia 0.60, hind tarsomeres I–III: 0.28, 0.14, 0.12.

DISCUSSION

This new species is assigned to *Cicadocoris* based on the following constitutive characters: small head; clavate antennae; rostrum thin, extends to base of hind coxae; trapezoidal pronotum; hind tibia with two large movable conical spurs; hind tarsi three-segmented; tegmen at claval apex wider than 1/3 of full length; costal margin arcuate; precostal carina narrow; M_{3+4} longer than stem of M.

Cicadocoris parvus sp. n. shares several critical characters with *C. sinensis* (Hong 1983), such as costal area not widening toward dSc, stem of M shorter than M_{3+4}, and the ratio of the widest length of apical half/basal half of the left tegmen larger than the right tegmen. In addition, the body length of this new species ranges from 2.8–3.9 mm and that of *C. sinensis* is 3.7–5.4 mm, with an overlapping region. Thus the body sizes of these two species are not strictly different. However, the new species differs from *C. sinensis* in the following characters: (1) veins dSc, R_1 and Rs sub-parallel; (2) normal distance from dSc origin to R_1 origin 1.1–1.5 times longer than R_1 origin to Rs origin on right tegmen (1.5–2.5 times in *C. sinensis*); (3) the ratio of the widest length of apical half is 1.1 times that of the basal half on left tegmen and 1.0 times on right tegmen (1.2 times and 1.1 times for *C. sinensis,* respectively); ovipositor has 24 visible ridges along its median section, 8–9 ridges /100 μm (13 visible ridges, 3–4 ridges /100 μm).

C. parvus closely resembles *C. brunneus* (Hong, 1983) in its venation. The body length of *C. brunneus* is 5.2–7.0 mm, circa twice as large as the new species. *C. parvus* sp. n., *C. sinensis* and *C. brunneus* always co-occur in the major fossil layers in the Daohugou beds, which excludes the possibility that the new species and *C. brunneus* are the same species.

C. parvus differs from the type species *Cicadocoris kuliki* Becker-Migdisova, 1958 in its body length 2.8–3.9mm (vs. 2.8–5.8 mm in *C. kuliki*); M_2 does not have a common stalk with M_1 (vs. M_2 has a common stalk with M_1); costal area does not widen towards dSc (vs. costal area much wider toward dSc).

Five species of *Cicadocoris* are so far described from the Daohugou beds. Two species namely *C. varians* and *C. assimilis* erected based on a single specimen (Dong et al., 2012, 2013). Among them, at least *C. varians* is probably a junior synonym of *C. sinensis* because of taphonomic deformation. Three of them (*C. sinensis C. brunneus* and *C. parvus*) are abundant in the Daohugou beds at Ningcheng, Inner Mogolia and localities near Haifeng (type section of the Haifanggou Fm.), Beipiao, Liaoning Province (Jiang et al., 2016). This is convincing evidence of the stratigraphic similarity of the Daohugou beds and the type locality of the Haifanggou Formation. *Cicadocoris* are distinct representatives of an early assemblage of the famous Yanliao biota that became extinct, probably due to a great tectonic movement and volcanic explosion (Huang, 2015; Jiang et al., 2016).

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