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Redescription and commentary on the Chinese mayfly *Vietnamella sinensis* (Ephemeroptera: Vietnamellidae)

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Abstract

The genus *Vietnamella* Tshernova, 1972 is reviewed and 3 valid species are confirmed. They are *V. ornata* (Tshernova, 1972), *V. sinensis* (Hsu, 1936) (=*V. dabieshanensis* You & Su, 1987, new synonym; =*V. qingyuanensis* Zhou & Su, 1995, new synonym; =*V. guadunensis* Zhou & Su, 1995, new synonym) and *V. thani* Tshernova, 1972. The nymphal and key imaginal characters of *V. sinensis* are described and figured. The monogeneric family Vietnamellidae has long series of autapomorphies (two pairs of projections on head, modified mandibles, slender maxillae with few setae, round hindwings, and half of egg covered with single cap) and some plesiomorphies (seven pairs of gills, large hindwings, few marginal intercalaries on forewings). The structures of mouthparts, head and forefemora suggest that nymphs of *Vietnamella* may be able to move substrates and scrape food from them. Morphological evidences show that the family Vietnamellidae is a basal clade of Ephemerelloidea.

Key words: *Vietnamella*, new synonyms, phylogeny, biology, morphology

Introduction

The genus *Vietnamella* was established by Tshernova (1972) for the species *V. thani* Tshernova, 1972 from Vietnam. The genus now includes six recognized species and the remaining five species were originally described from China in the genus *Ephemerellina* Lestage, 1924 (Wang & McCafferty 1995; McCafferty & Wang 1997). You & Gui (1995) misspelled *Ephemerella xiasimaensis* You, 1987 as *Ephemerellina xiasimaensis*. This species is not considered in this paper. However, two species (*V. qingyuanensis* Zhou & Su, 1995 and *V. guadunensis* Zhou & Su, 1995) were based only on nymphs and two, *V. ornata* (Tshernova, 1972) and *V. sinensis* (Hsu, 1936), were described only from adults; only *V. dabieshanensis* You & Su, 1987 is known at both imaginal and nymphal stages. Unfortunately, all previous original descriptions are very brief and sometimes inaccurate. For instance, both Tshernova (1972) and You & Su (1987) reported that nymphs of *Vietnamella* have six pairs of gills, but Zhou & Su (1995), McCafferty & Wang (2000), Kluge (2004) and Jacobus *et al.* (2005) argued that there is an additional pair of gills on abdominal segment 1. Further, the imaginal genitalia and wing venation are not clear in the papers by Hsu (1936) and You & Su (1987), and a better description is clearly needed.

The phylogenetic position of the genus *Vietnamella* has been discussed in several different publications. It was regarded as belonging to Ephemerellidae (Tshernova 1972; Allen 1980, 1984), or a tribe within Teloganodidae (Edmunds & Murvosh 1995; McCafferty & Wang 1997), or, together with *Austremerella* Riek, 1963, a genus of the family Austremerellidae (McCafferty & Wang 2000) renamed later Vietnamellidae by Hubbard (2002), and finally as belonging to the monotypic family Vietnamellidae by Jacobus & McCafferty (2006), *Austremerella* forming the monotypic family Austremerellidae. *Vietnamella* was regarded as closely related to the Australian genus *Austremerella* by McCafferty & Wang (1997, 2000) but not by Kluge (2004) and Jacobus & McCafferty (2006). The nymphs and adults of the latter genus were described by Riek (1963) and Suter & Mynott (2013).

Specimens of *Vietnamella* have been collected frequently in China. We have examined all species and compared them to the types. As a result, three species of *Vietnamella* are now recognized. These are *V. ornata*, *V.*

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thani and *V. sinensis*. Tshernova (1972) and Kluge (2004) provided key characters for the former two species. Here we redescribe and illustrate *V. sinensis* and its new synonyms.

Material and methods

The nymphs were collected by hand net and adults were attracted by ultraviolet light trap. Some adults were reared from mature nymphs in the lab. The materials were stored into ethanol (more than 75%) immediately.

All specimens were photographed with a digital camera (Single Lens Reflex) and examined under a stereomicroscope. Some small structures, like mouthparts, claws and gills were observed and photographed with a microscope camera.

Eggs were dissected from females. Before placed on the stage of the SEM (scanning electron microscope) for photographs, they were prepared with a standard protocol: fixed in 4% glutaraldehyde for 4–8 hours, rinsed with PBS (physiological saline) 2–3 times (10–15 minutes each), dehydrated in concentration gradient acetone (30%, 50%, 70%, 80%, 90%, 100%, 10 to 15 minutes each), and coated with gold film in a vacuum.

All specimens are deposited in the Institute of Genetic Resources, College of Life Sciences, Nanjing Normal University, P. R. China.

Vietnamella sinensis (Hsu, 1936)

Ephemerella sinensis Hsu, 1936: 325. Holotype: male imago, from Shang Jao (=Shangrao), Jiangxi Province, China.
Ephemerella sinensis: Gui, 1985: 89.
Ephemerellina sinensis: Allen & Edmunds, 1963: 15; Tshernova, 1972: 614; You & Gui, 1995: 138.
Vietnamella sinensis: Wang & McCafferty, 1995: 194; McCafferty & Wang, 1997: 395.
Vietnamella dabieshanensis You & Su, 1987: 176. Syntypes: male and female adults, nymphs, from Anhui and Fujian Provinces, NEW SYNONYM.
Vietnamella dabieshanensis: Edmunds & Murvosh, 1995: 159; McCafferty & Wang, 1997: 395; Su & Zhou, 1998: 28.
Cincticostella (*Vietnamella*) *dabieshanensis*: You & Gui, 1995:140; Gui *et al.*, 1999: 341.
Vietnamella qingyuanensis Zhou & Su, 1995: 47. Holotype: nymph; paratypes: nymphs, from Zhejiang Province, NEW SYNONYM.
Vietnamella qingyuanensis McCafferty & Wang, 1997: 395.
Vietnamella guadunensis Zhou & Su, 1995: 48. Holotype: nymph; paratypes: nymphs, from Fujian Province, NEW SYNONYM.
Vietnamella qingyuanensis McCafferty & Wang, 1997: 395.

Description. Nymph (in alcohol): body length 13.0–16.0 mm, cerci 6.0–9.5 mm, terminal filament 8.0–11.0 mm. body greenish brown to dark brown, with dense setae laterally and on free margins of head.

Head (Figs 1A–C): two pairs of projections below eyes near slightly concave anterior margin of head capsule; inner pair of projections small, spine-like and sharp, outer pair large, triangular, cone-shaped with length slightly less than width of head capsule; antenna length more than half width of head and positioned between projections; ocelli elevated on small tubercles; vertex of head rough; compound eyes large, dark.

Mouthparts: Labrum (Figs 2A, 3A): anterior half of dorsal surface and margins with relatively long setae, ventral surface with shorter setae but those near margins longer and denser, two setal tufts near anteromedian corners. Left mandible (Figs 2D, 3D): slender, with very thin setae on lateral surface; outer incisor totally fused, spoon-like, inner incisor transformed into two tufts of spines with common base; prostheca stouter than inner incisor, consisting of numerous spines; molar block-like with rough surface, additional small tuft of spine-like setae on mesal apex. Right mandible (Figs 2E, 2G, 3E): similar to left but molar with apparent independent tooth and larger tuft of spine-like setae. Maxilla (Figs 2F, 2H, 3F): slender, apex with 3 fused medio-apical teeth or canines, 2 dentisetae and an additional spine-like seta at apex; a small tuft of setae located dorsally (Fig 2H); a median seta on inner margin; maxillary palpi 3-segmented, with tiny setae, length ratio from basal to apical 1: 1.6: 1, tip of apical segment sclerotized; cardo with setae. Labium (Figs 2C, 3C): glossae and paraglossae almost fused, with dense setae on surface, setae on dorsal surface and margins longer; labial palpi 3-segmented, basal segment broader and longer than the second, apical segment very small; palpi with tiny setae; submentum broad. Hypopharynx (Figs 2B, 3B): lingua and superlinguae nearly round, with setae on surface, those near margins longer.

Thorax (Figs 1A–E): pronotum with sharp anterolateral projections and small, slightly rounded protuberances mesal to anterolateral projection. *Forelegs*: coxae with setae on dorsal surface but trochanters without setae; length ratio of femora: tibiae: tarsi = 3: 3: 1; femora strongly expanded except at base, expansion forming distinct transverse ridge dorsally, leading margin of forefemora serrated with projections or teeth progressively smaller distally; inner, outer, basal margins and ridge with a row of setae; tibiae with small spines on surface, inner margin with dense setal row; tarsi with very sparse setae. *Midlegs*: Length ratio of femora: tibiae: tarsi = 3: 2.5: 1; coxae with obvious dorsal projection and setae; trochanters with setae; femora wider and flatter than tibiae and tarsi, inner, outer and basal margin with setae. *Hindlegs*: Setal pattern similar to midleg; length ratio of femora: tibiae: tarsi = 4: 3: 1; tarsi of all legs dark brown; all claws similar, with basal projection and several tiny apical setae (Figs 1D, 1E).

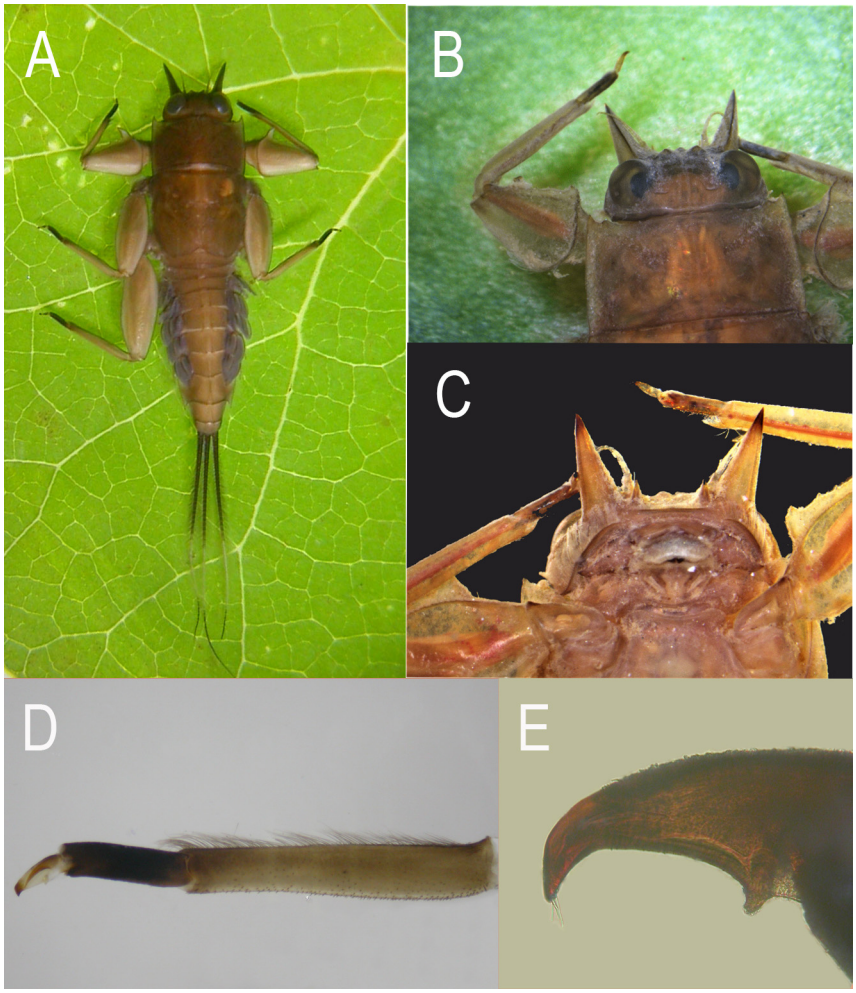

FIGURE 1. Nymphal habitus and structures of *Vietnamella sinensis* (digital photos): A. Nymphal habitus, dorsal view; B. Head and foreleg of nymph (dorsal); C. Head of nymph (ventral); D. Apical part of foreleg; E. Foreclaw (enlarged)

Abdomen (Fig 1A): terga 1–10 with a pair of median ridges or tubercles progressively larger posteriorly; posterolateral angles of terga 1–9 extended into sharp projections, lateral margins of terga with dense setae; sterna with a pair of short dark submedian stripes. Gills on terga 1–7; gills 1 long, finger-like, with setae (Fig 2I); gills 2–6 similar in structure, with dorsal and ventral lamellae, the latter further divided into 2 clusters, each with several smaller lobes; gills 7 smaller, usually covered by gills 6, also with 2 lamellae but ventral lamella divided into 3 lobes only (Fig 2J). Caudal filaments dark brown to black with broad median pale band, with dense lateral setae on inner and outer margins (Fig 1A).

Male imago (in alcohol, Figs 4, 5): stigmatic area of forewing divided by a thin longitudinal vein into upper and lower series of cells. MA forked near middle of wing, MP forked basally, 3–4 long intercalaries between MP_1 and MP_2; CuA and CuP adjacent at base; independent marginal intercalaries present (Figs 4A, 5A). Hind wing nearly round, leading margin slightly concave, with clear crossveins (Figs 4B, 5B). Genitalia (Figs 4C, 5C):

forceps 3-segmented, basal segment a little longer and broader than second, apical segment small, nearly round; penes totally fused with a shallow median cleft; subgenital plate slightly convex.

Egg (Figs 6A–C, dissected from females collected in 2006): Length 0.223 mm, width 0.15 mm; oval, chorionic surface without distinct structure but with small protuberances. Half of egg covered with helmet-shaped polar cap.

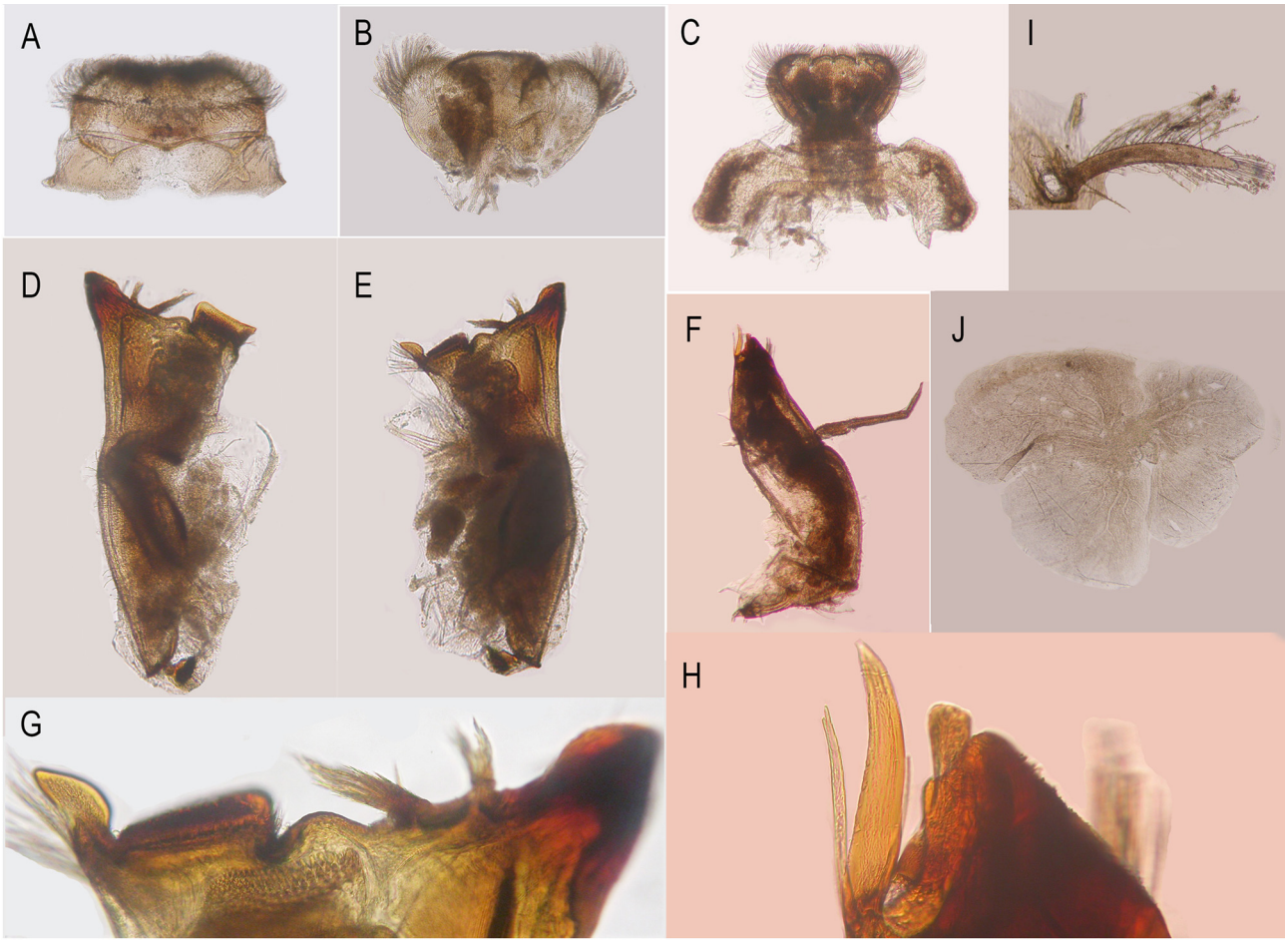

FIGURE 2. Nymphal structures of *Vietnamella sinensis* (digital photos): A. Labrum; B. Hypopharynx; C. Labium; D. Left mandible; E. Right mandible; F. Maxilla; G. Partial enlarged detail of right mandible; H. Partial enlarged detail of maxilla; I. Gill 1; J. Gill 7

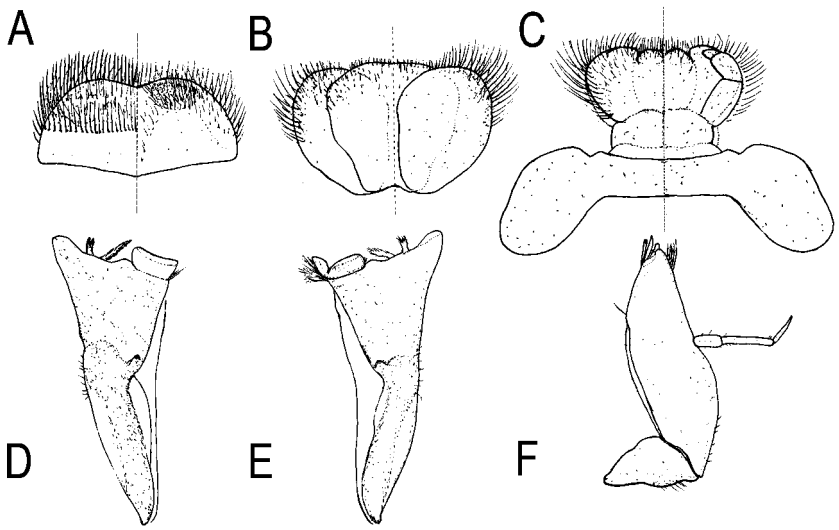

FIGURE 3. Mouthparts of *Vietnamella sinensis* nymph: A. Labrum (dorsal view, left; ventral view, right); B. Hypopharynx (dorsal view, left; ventral view, right); C. Labium (dorsal view, left; ventral view, right); D. Left mandible; E. Right mandible; F. Maxilla

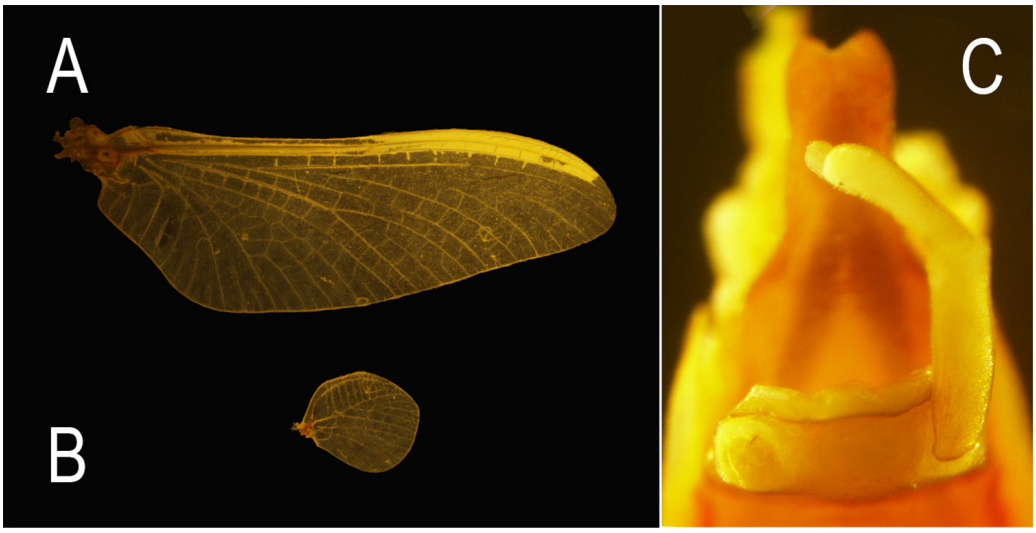

FIGURE 4. Imaginal structures of *Vietnamella sinensis* (digital photos): A. Forewing; B. Hindwing; C. Genitalia

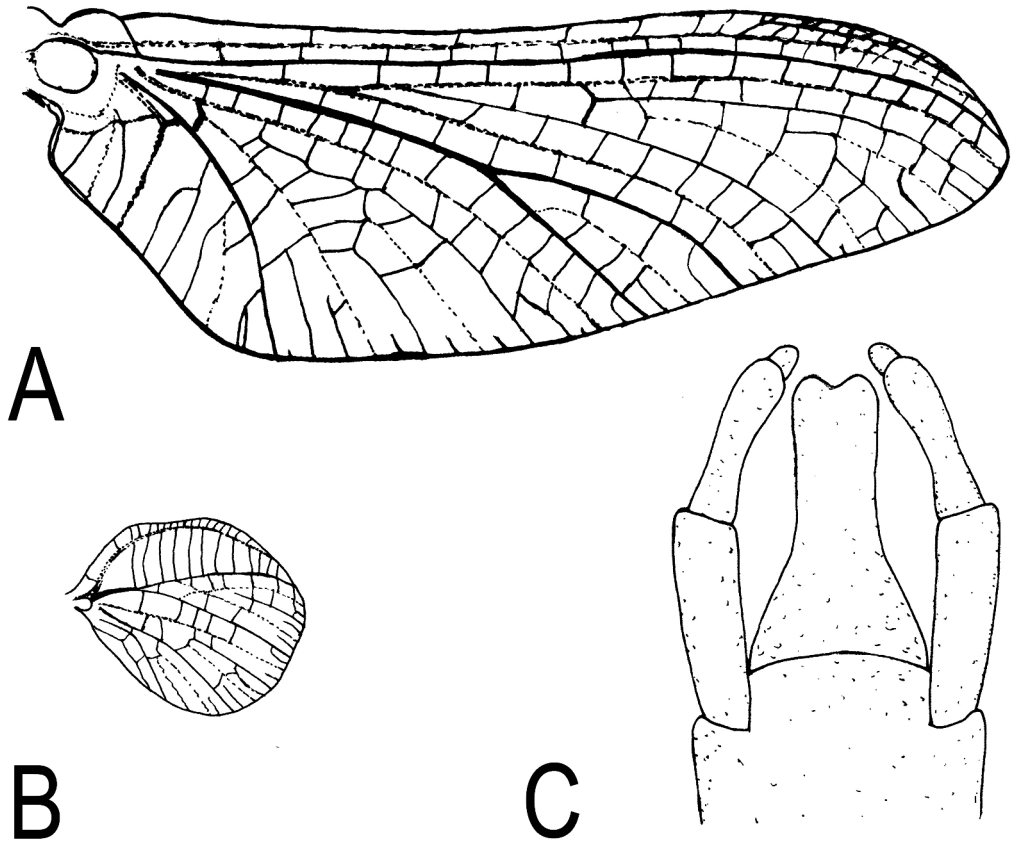

FIGURE 5. Imaginal structures of *Vietnamella sinensis*: A. Forewing; B. Hindwing; C. Genitalia

Material

Vietnamella sinensis (Hsu, 1936)

CHINA: **Anhui Province:** Huoshan County, Zhufoan village, lectotype ♂ of *Vietnamella dabieshanensis*, 14.vi.1983; 5♂♂, 1♀, 1 nymph (paratypes of *V. dabieshanensis*), same data. Additional material: Qilin village,

4♀♀, 8♂♂, 16 nymphs, 9.vi.1983; Zhufoan village, 27♂♂, 41♀♀, 40♂♂ subimagos, 40♀♀ subimagos, 400 nymphs, 15.vi.1983; Dahuaping village, 5♂♂, 6♀♀, 4♂♂ subimagos, 3♀♀ subimagos, 16.vii.1983; Manshuihe village, 30♀♀, 2♂♂, 50♀♀ subimagos, 8♂♂ subimagos, 25 nymphs, 18.vi.1983; Qingshan village, 8♂♂ subimagos, 8♀♀ subimagos, 3 nymphs, 19.vii.1983 (all material collected by Xing-Yong WU). Tiantangzhai village (475 m alt., 115.48062°E, 12.257°N), Dabieshan Mountain, 8♂♂ subimagos, 5♀♀ subimagos, 50 nymphs, 19–24.viii.2006, leg. Dong LIU.

Fujian Province: Shangguadun village, 1 nymph (holotype of *Vietnamella guadunensis*), 15.vii.1995, leg. Chang-Fa ZHOU and Ning YIN; 20 nymphs (paratypes of *V. guadunensis*), same data. Sangang village, 5♂♂, 1 nymph, 18.v.1981; 4♀♀, 2♀♀ subimagos, 10 nymphs, 10.vi.1982; 4♀♀, 2♂♂ subimagos, 26–28.vi.1982, leg. Cui-Rong SU (paratypes of *V. dabieshanensis*); 4♀♀, 3♀♀ subimagos, 2♂♂ subimagos, 4.viii.1982, leg. Huan-Guang ZOU.

Jiangxi Province: Jiulianshan Mt., Longnan County, Daqiutian village, 5 nymphs, 1.vi.2005, leg. Chang-Fa ZHOU and Chang-Hai SUN; Xiagongtang River (519 m alt., 114.2654°E, 24.3151°N), 1♀ subimago 1 nymph, 8.vi.2005, leg. Lian-Fang Yang and C. Geraci; Unknown tributary of Tongmu River (1790 m alt., 117.75736°E, 27.83820°N), 4 nymphs, 2.vi.2005, leg. Xin Zhou and C. Geraci. These collecting localities are in the Shangrao municipality, where is the type locality of *V. sinensis*.

Zhejiang Province: Houguan town, Qingyuan County, 1 nymph (holotype of *Vietnamella qingyuanensis*), 10.vii.1994, leg. Chang-Fa ZHOU and Chao-Dong ZHU; 30 nymphs (paratypes of *V. qingyuanensis*), same data. Heping town, Jiangshan City, (395 m alt., 118.6°E, 28.333°N), 20 nymphs, 11.viii.2016, leg. Ze HU, Chang-Hai SUN and JI-Hua XU.

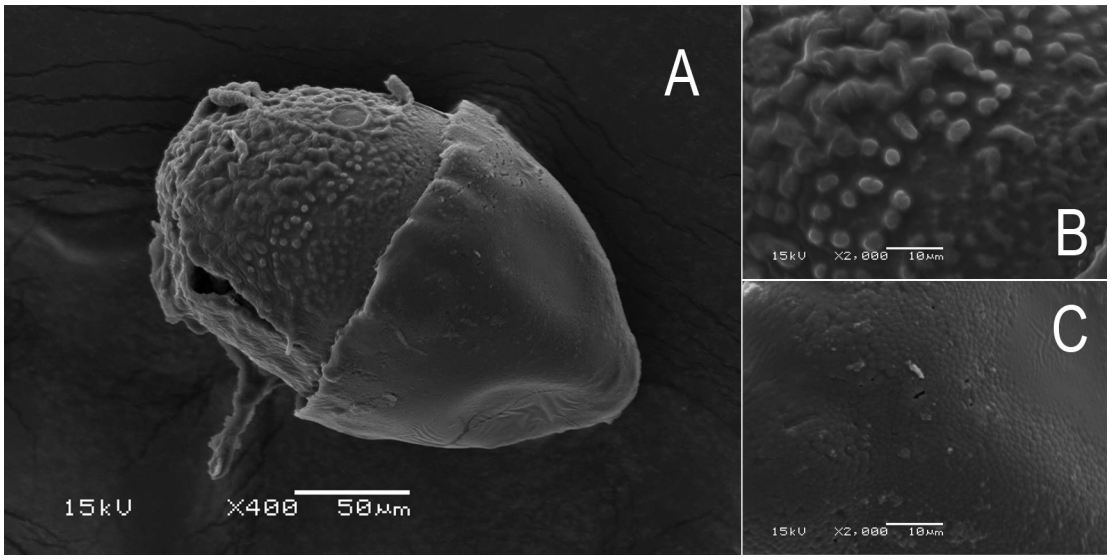

FIGURE 6. Egg of *Vietnamella sinensis* (SEM photo): A. Egg structure; B. Partial enlarged detail of the surface; C. Partial enlarged detail of the cap

Vietnamella thani Tshernova, 1972

CHINA: **Guangxi Province:** Guilin City, Qingshitang town, Bojitang village, 12 nymphs, iii.2008, leg. Bei-Xin WANG.

Remarks. Originally described from Shangrao, Jiangxi Province, by Hsu (1936) as *Ephemerella sinensis*, this species was transferred to *Vietnamella* by Wang and McCafferty (1995). You and Su (1987) then described another species *V. dabieshanensis* from Anhui and Fujian Province, China. Zhou and Su (1995) described two more species from Zhejiang Province (*Vietnamella qingyuanensis*) and Fujian Province (*Vietnamella guadunensis*). These two species were described on different nymphal stages, and the dissimilarities proposed are in fact link to ontogenic stages rather than interspecific variation. The type localities of these species are from same or adjacent provinces and very close. In addition, our specimens from these localities cannot be morphologically distinguished from *V. sinensis* and are here considered synonyms of *V. sinensis.*

Diagnosis. Compared to characters provided by Tshernova (1972), Kluge (2004) and materials in our

collection of *Vietnamella thani* (Fig 7), the nymphs of *V. sinensis* have relatively slender legs (Figs 1A, 1D), especially the femora of mid- and hind-legs. Further, the projections on the head of *V. sinensis* are smaller than those of *V. thani*, especially the inner pair (Figs 1A–C, 7A–B), and the second segment of the maxillary palpi of *V. sinensis* is longer than that of *V. thani* (Figs 2F, 3F, 7C).

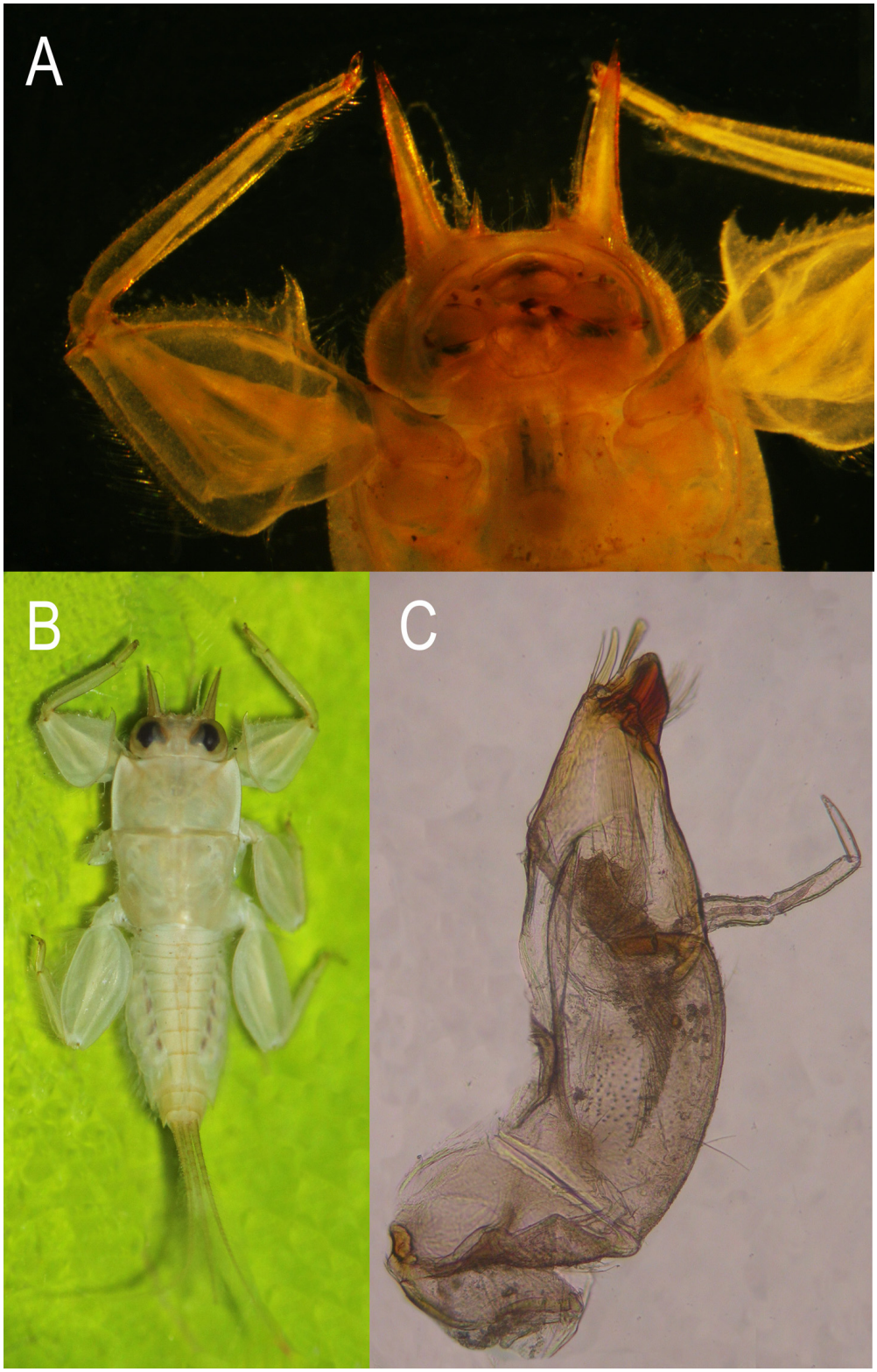

FIGURE 7. Nymphal habitus and structure of *Vietnamella thani* (digital photos): A. Head and foreleg of nymph (ventral); B. Nymphal habitus, dorsal view; C. Maxilla

Discussion

Several characters are unique to Vietnamellidae in the superfamily Ephemerelloidea sensu Jacobus & McCafferty (2006). They include: in nymph: 1) two pairs of horns on head; 2) very slender mandibles with modified incisors (fused, spoon-like outer incisor, spine-tuft like inner incisor), prostheca (shorter base of spines) and molar (smooth and large); 3) maxillae with few apical and mesal setae; 4) gills present on abdominal segments 1–7; 5) very stout and enlarged forefemora; 6) simple claw without subapical denticle. In imago: 7) relatively large round hindwings without costal projection; 8) basal segment of forceps slightly longer than the second segment; 9) forewings with few free marginal intercalaries. In short, the Austremerellidae and Ephemerellidae appear more similar to each other in these structures than to Vietnamellidae, especially their similar nymphal heads, mouthparts, and imaginal wings and genitalia.

Among above mentioned characters, most are autapomorphies of the family Vietnamellidae, like the head horns, mouthparts and round hindwings. Some characters are plesiomorphies, such as 7 pairs of gills, no teeth on claws, few marginal intercalaries in forewings and large hindwings (Jacobus & McCafferty 2006). Because of these autapomorphies and plesiomorphies, the Vietnamellidae may be a basal detached clade of Ephemerelloidea. This suggestion has been already proposed by Jacobus & McCafferty (2006). Kluge (2004) placed the *Vietnamella* into *Tricorythus*-group (Pantricorythi, a derived clade from the Ephemerelloidea) based on setal pattern of legs. In our view, the Vietnamellidae seems to be not a derived lineage but a basal one of Ephemerelloidea or Ephemerelloidea + Tricorythoidea (Furcatergaliae-Ephemerella/fg1 sensu Kluge 2004).

In Ephemerellidae, *Drunella* Needham, 1905 nymphs also have enlarged forefemora and obvious subantennal projections, but those characters are not similar to counterparts of *Vietnamella*. The femora of *Drunella* are expanded and sclerotized and usually have obvious tubercles on surface, making the inner margin of femora serrated (see Allen 1971; Allen & Edmunds 1962; Jacobus & McCafferty 2008). Only a few species (such as *Drunella ishiyamana* Matsumura 1931, see Zhou *et al.* 2015) have transverse and longitudinal ridges on forefemora. The spines or projections on head of *Drunella* are usually small, curved and flat or cone-shaped. In contrast, the projections on the *Vietnamella* head are very large, straight, triangular. Further, the femora have no tubercles and their inner margins are serrated more deeply. Remarkably, the base of femora is not expanded. This leaves an obvious transverse ridge on femoral surface (Figs 1A–B, 7A–B). In addition, *Drunella* nymphs have a distinct apical projection on tibiae while this structure is missing in *Vietnamella* (Fig 1D). To sum up, the forelegs of *Drunella* and *Vietnamella* are fundamentally different.

Biologically, the typical ephemerellid nymphs are scrapers, filters or shredders. Kluge (2004) suggested *Drunella* nymphs are carnivorous and they can use their strong forelegs to grasp prey. Riek (1963) show the nymphs of Austremerellidae have enlarged forelegs and carnivorous mouthparts (elongated mandibles, long apical canines on maxillae and long labial palpi). The exact biology of *Vietnamella sinensis* is not known but they possibly can use their horns and forelegs to move gravel or pebbles (like potamanthid and ephemerid nymphs use their mandibular tusks and bifurcated frons) and scrape on substrate surface with their modified mandibles. The presence of a fused outer incisor seems to confirm this function (see Arens 1990). Morphological and presumed biological evidences show the Vietnamellidae diverged from other lineages of Ephemerelloidea (in broad view) very early.

Generally, the morphological pattern of the *Vietnamella* egg is similar to that of Ephemerellidae with one polar cap (Koss 1968; Jacobus & McCafferty 2008); however, the cap of *Vietnamella* is much larger covering almost half the egg. The egg of Austremerellidae is still unknown.

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