Morphological conservatism in the foreleg structure of cicada hatchlings, *Novicicada burmanica* n. gen., n. sp. in Burmese amber, *N. youngi* n. gen., n. sp. in Dominican amber and the extant *Magicicada septendecim* (Fisher) (Hemiptera: Cicadidae)

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Abstract

Two new species of cicada hatchlings in Burmese and Dominican amber are described as *Novicicada burmanica* n. gen., n. sp. and *N. youngi* n. gen., n. sp. in the new collective genus *Novicicada* n. gen. (Hemiptera: Cicadidae). Diagnostic characters of the new genus are an elongate, flattened body, all antennomeres of subequal width, elongate procoxae, enlarged profemurs with spurs and spines, foretibiae with spurs and spines and the foretarsi subapically attached to the foretibiae. A comparison of the forelegs of the fossil hatchlings with an extant hatchling of the periodical cicada, *Magicicada septendecim* (Fisher) reveals a remarkable degree of morphological conservatism over 100 million years. A brief review of fossil cicadas is presented.

Keywords: Burmese amber, Dominican amber, *Novicicada* n. gen., cicada hatchlings, morphological conservatism, periodical cicada, *Magicicada septendecim*

Introduction

The cicadas (Hemiptera: Cicadidae) represent a large, worldwide family of hemipterans that are mostly known for their distinctive sounds during the mating season. Immature cicadas are identifiable to family based on their enlarged forelegs with the protarsus attached subapically to the protibia (Stahr 1991). Using their sharp ovipositors, the adults insert eggs into branches and stems of woody plants. After eclosion, the hatchlings climb or drop to the ground and enter the soil in search of roots that will sustain them, often for a number of years, until they are ready to emerge and molt to the adult stage. Cicada hatchlings have been little studied but are equipped with enlarged forelegs at the time of eclosion. The present study describes two cicada hatchlings separated by 70-80 million years with an extant hatchling of *Magicicada septendecim* (Fisher). A remarkable degree of conservatism in the arrangement of setae, spines and a foliose appendage on the profemora is documented. A brief review of fossil cicadas is presented.

Materials and methods

The Burmese amber specimen is in a piece of amber 12 mm long by 4 mm wide by 1 mm deep. The amber was obtained from a mine in the Hukawng Valley, southwest of Maingkhwan in Kachin State (26º20´N, 96º36´E) in Burma (Myanmar). This amber site, known as the Noije Bum 2001 Summit Site, was assigned to the Early Cretaceous, Upper

Albian, on the basis of paleontological evidence (Cruickshank and Ko 2003), placing the age at 97 to 110 mya. Nuclear magnetic resonance (NMR) spectra and the presence of araucaroid wood fibers in amber samples from the Noije Bum 2001 Summit site indicate an araucarian (possibly *Agathis*) tree source for the amber (Poinar et al. 2007).

The Dominican amber specimen is in a piece of amber 13 mm long by 6 mm wide by 2 mm deep. It was obtained from mines in the Cordillera Septentrional of the Dominican Republic. Dating of Dominican amber is still controversial with the latest purposed age of 20-15 mya based on foraminifera (Iturralde-Vinent and MacPhee 1996) and the earliest as 45-30 mya based on coccoliths (Cêpek in Schlee 1990). In addition, Dominican amber is secondarily deposited in sedimentary rocks, which makes a definite age determination difficult (Poinar and Mastalerz 2000). A range of ages for Dominican amber is possible since the amber is associated with turbiditic sandstones of the Upper Eocene to Lower Miocene Mamey Group (Draper et al. 1994). Dominican amber was produced by the leguminous tree, *Hymenaea protera* Poinar and a re-construction of the Dominican amber forest based on amber fossils indicated that the environment was similar to that of a present day tropical moist forest (Poinar and Poinar 1999).

Observations, drawings, and photographs were made with a Nikon SMZ-10 R stereoscopic microscope and Nikon Optiphot compound microscope with magnifications up to 600X. The SEM photo of a one-minute-old hatchling periodical cicada nymph, *Magicicada septendecim* (Fisher), was obtained from the files of the late Dr. Frank Young.

Description

For taxonomic convenience, animals lacking diagnostic characters can be described in collective group genera, as defined in Article 42.2.1 of the International Code of Zoological Nomenclature. If and when more complete specimens are recovered, the taxon can be transferred to an extant genus or re-described in a new genus. Fossil collective genera, such as *Carabites* Cockerell (1908), fall under the same guidelines as extant collective genera. Collective genera are independent of the nomenclatural classification system used for extant forms, but are useful in establishing the presence of certain lineages at particular time periods and locations.

Both specimens are well preserved and complete with the beak arising from the caudal portion of the head and the protarsus attached before the apex of the protibia.

Hemiptera

Cicadomorpha

Cicadoidea

Cicadidae

Novicicada Poinar and Kritsky n. gen.

This is a collective group genus erected for fossil hatchlings of the family Cicadidae.

Diagnosis: minute size; elongate, flattened body; simple eye spots, eight antennomeres, all of subequal width; elongate procoxae; enlarged profemurs armed with spurs, spines, setae and foliose appendage; femoral comb absent; swollen protibae armed with spurs and spines; protarsi elongate, 2-segmented, subapically attached to protibiae; nine abdominal segments.

Etymology: from the Latin “novis” = new, referring to a hatchling, the Latin “cicada”=

cicada.

Comments: According to Stehr (1991), extant immature cicadas can have 1, 2 or 3 tarsal segments, however both fossil specimens have 2-segmented tarsi. While some Cixidae (Hemiptera) immatures also have fossorial front legs, the tarsi are attached to the tip of the tibiae, not subapical as in cicada immatures (Stehr 1991).

Type species: *Novicicada burmanica*

Novicicada burmanica Poinar and Kritsky n. sp.

With characters listed under generic diagnosis.

Antennae 8-segmented; terminal antennomere bearing forked process; beak 2 segmented; profemur with large upturned tooth protruding from base of inner (ventral) side; foliose appendage attached to base of anterior edge of tooth; two short spurs positioned near middle of profemoral tooth;two protrusions on inner (ventral) side of profemur; lower protrusion seta-like; upper protrusion cyclindrical (tubular), rounded at apex; protibia greatly enlarged with downturned pointed tip; inner (ventral) surface bearing tooth adjacent to spine-like seta; second tooth on inside surfacee of protibia just proximal to insertion of protarsus; protarsus 2-segmented, attached subapically; first protarsomere short, approximatedly $1/5^{th}$ length of second protarsomere; claws paired, nearly straight; arolium absent or greatly reduced; femora and tibia on mid and hind legs not modified; abdomen with 9 segments.

Measurements. Total length, 1.26 mm; antenna length, 547 µm; length of forked process on terminal antennomere, 30 µm; profemur length, 210 µm; profemur greatest width, 150 µm; length profemoral tooth, 178 µm; protibial length, 277 µm; protarsal length, 123 µm;

claw length, 40 µm;

Type. Holotype deposited in the Poinar amber collection (accession # B-HE-23) maintained at Oregon State University, Corvallis, Oregon.

Type locality. Amber mine at the Noije Bum 2001 Summit Site in the Hukawng Valley, southwest of Maingkhwan in Kachin State (26º20´N, 96º36´E) in Burma (Myanmar).

Etymology. The specific name refers to the geographical location of the fossil.

Novicicada youngi Poinar and Kritsky n. sp.

With characters listed under generic diagnosis.

Antennae 8-segmented; terminal antennomere bearing single seta; beak two segmented; profemur with large upturned tooth protruding from base of inner (ventral) side; foliose appendage attached to base of anterior edge of tooth; two protrusions on inner (ventral) edge of profemur; lower protrusion setal-like; upper protrusion spine-like, pointed at apex;protibia greatly enlarged with downturned tip, bearing small tooth at base; inner (ventral) surface bearing two teeth separated by setal spine; medium-sized tooth on inner side of protibia just proximal to insertion of protarsus; protarsus 2 segmented, attached subapically; first protarsomere short, approximately 1/3 rd length of second protarsomere; claws paired, nearly straight, arolium absent or greatly reduced; femora and tibia on mid and hind legs not modified; abdomen with 9 segments.

Measurements: total length, 1.4 mm; profemur length, 270 µm; profemur greatest width, 180 µm; length profemora tooth, 180 µm; protibial length, 315 µm; protarsus length, 135 µm; claw length, 63 µm;

Type. Holotype deposited in the Poinar amber collection (accession # HO-4-16) maintained at Oregon State University, Corvallis, Oregon.

Type locality. Amber mines in the northern portion of the Dominican Republic.

Etymology. The specimen is named in honor of the late Dr. Frank N. Young, Jr. from Indiana University in Bloomington, who worked on periodical cicadas for over 30 years.

Hatchling of the periodical cicada, *Magicicada septendecim* (Fisher). The following description is based on a SEM photograph taken of a specimen collected in 1991 by Frank N. Young, Jr.

Antenna 7-segmented, terminal antennomere bearing single seta, beak two segmented; profemur with large upturned tooth protruding from base of inner (ventral) side; foliose appendage attached to base of anterior edge of tooth; single spine-like protrusion positioned on inner (ventral) side of profemur; protibia greatly enlarged with downturned pointed tip; protibia bearing medium-sized tooth at base; inner surface with single spine positioned about midlength; protarsus 2-segmented, attached subapically; first protarsomere short, approximately $1/5^{th}$ length of second protarsomere; claws paired, wide at base; ariolium absent of greatly reduced; femora and tibia on mid and hind legs not modified; abdomen with 9 segments.

Measurements: total length, 1.8 mm; length antenna, 590 µm; length profemur, 330 µm; greatest width profemur, 240 µm; length profemoral tooth, 190 µm; length protibia, 350 µm; length protarsus, 160 µm; length claws, 50 µm; length abdomen, 820 µm.

Comments. There is a surprising degree of morphological similarity in the fossil and extant cicada hatchlings. The major differences are the number of antennal segments, the process at the tip of the antennae (simple in *N. youngi* and *M. septendecim* but forked in *N. burmanica*), the position and size of teeth, spines and setae on the profemora and protibia, the shape and size of the upper protrusion on the inner side of the profemur (cylindrical in *N. burmanica* and spine-like in *N. youngi* and *M. septendecim*).

Discussion

The armature on the profemora and protarsi of these cicada hatchlings has remained remarkably conserved over the past 100 million years. The foliose appendage at the base of the profemoral tooth is remarkably similar in form and position in all three specimens. More unique structures (femoral comb, etc.) in the forelegs appear in later instars (Marlatt 1907; Gerhard 1923).

The biology of the fossil species is of course unknown. Extant cicadas oviposit in various hardwoods and palms, which appear to serve as host plants for the nymphs (Young, 1980). There was a variety of hardwoods and palms in the Dominican amber forest that could have provided ovipositional sites and plant hosts (Poinar 2002a,b ; Poinar and Poinar 1999). Five extant genera of cicadas occur in the Dominican Republic (Perez-Gelabert 2008), but hatchlings of these are unknown.

The tree that produced the Burmese amber was a conifer (Poinar et al. 2007), and if the cicada nymph hatched from eggs laid in the conifer itself, this makes the Burmese specimen even more remarkable. Cicada oviposition wounds the tree, releasing resin that

can entomb the eggs. White et al. (1982) found that fewer than 10% of the eggs in white pine (*Pinus strobus)* and 27% of the eggs laid in hemlock successfully hatched, compared to angiosperm hatch rates between 77-95%. The one conifer exception was juniper (*Juniperus virginiana*), from which 73-92% of the eggs hatched. Their dissections of egg nests in junipers showed that juniper resin was thinner than pine resin, which they postulated resulted in higher hatch rates. Several angiosperm lineages have been found in Burmese amber, and it is also possible these could have served as ovipositional and host plants (Chambers et al. 2009).

The previous record of fossil cicadas (Cicadidae) is ambiguous. While there is mention of cicadas in Baltic amber, none have been described (Spahr 1988). Bode (1953) described *Liassocicada antecedens* Bode from the Jurassic of Germany based on a forewing fragment. However there is some confusion over the position of both *L. antecedens* and the Triassic *Liassocicada ignotatus* (Brodie 1845), which was originally described as a dipteran (Brodie 1845). Whalley (1983) re-described *L. ignotatus* and considered both *Liassocicada* fossils as possible cicadas, however Carpenter (1992) felt they were too fragmentary to be certain of family status. Partial limbs of a cicada nymph in Late Cretaceous New Jersey amber were depicted by Grimaldi and Engel (2005). However it is difficult to equate the legs to a modern group since the leg portion labeled as tarsus is actually the tarsus and a portion of the tibia. Although no measurements are provided, the presence of a femoral comb shows that the specimen is an older nymph and not a first instar nymph.

A number of Tertiary fossils have been assigned to the Cicidadae but only 11 are uncontested (Table 1). Cooper (1941) and Carpenter (1992) provide reasons why many

of these have been dismissed. The British Eocene *Eotettigarcta scotica* Zeuner, 1944, which was redescribed by Whalley (1983), was placed in the related family Tettigarctidae Distant, 1905 by Carpenter (1992). While *Novicicada burmanica* in Burmese amber would be the oldest uncontested fossil cicadid, the group obviously had a much earlier origin, possibly dating back to the Permian.

Acknowledgments

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Figures

Figure 1**.** *Novicicada burmanica* in Burmese amber. Bar = 278 µm.

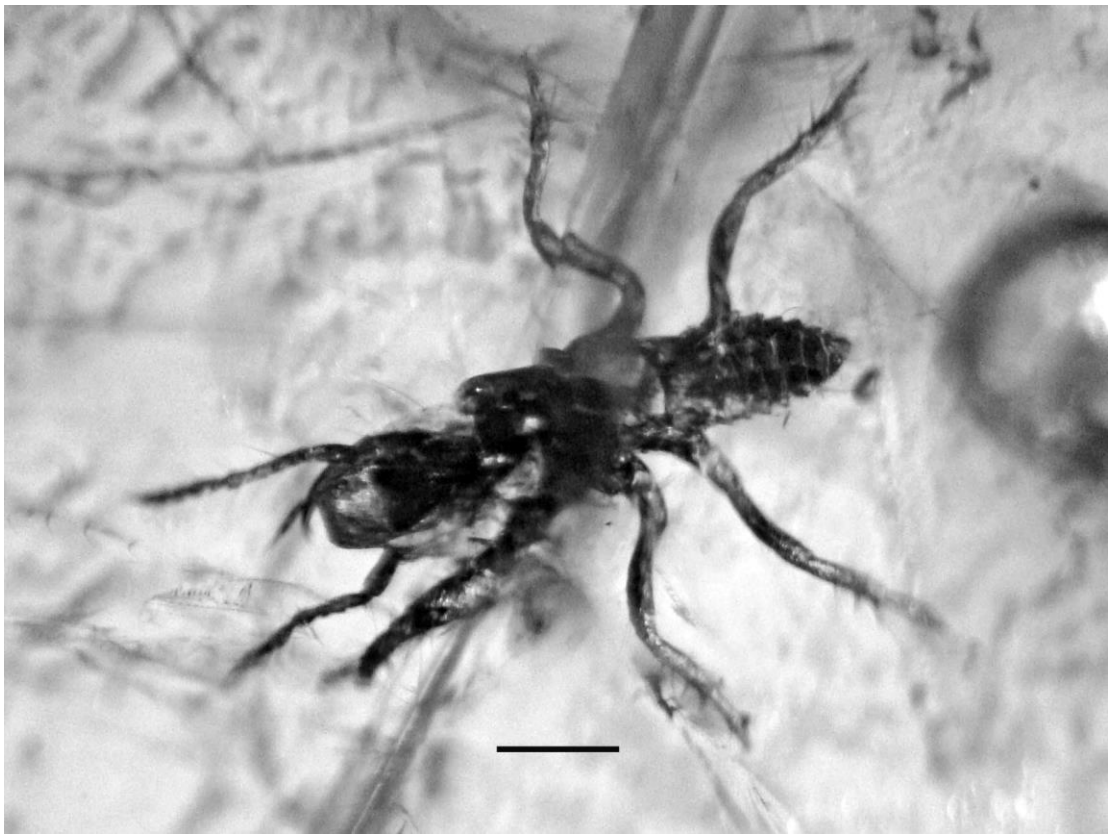

Figure 2. Foliose appendage (arrow) on profemur of *Novicicada burmanica*. Bar = 53 µm.

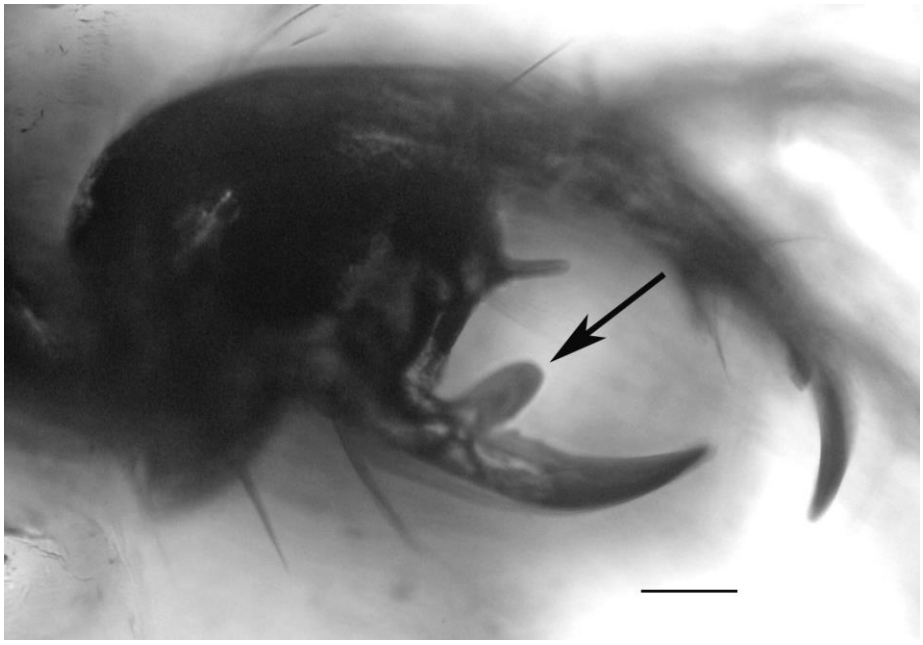

Figure 3. Preapical attachment of basal protarsomere (arrow) to protibia of *Novicicada burmanica*. Bar = 14 µm.

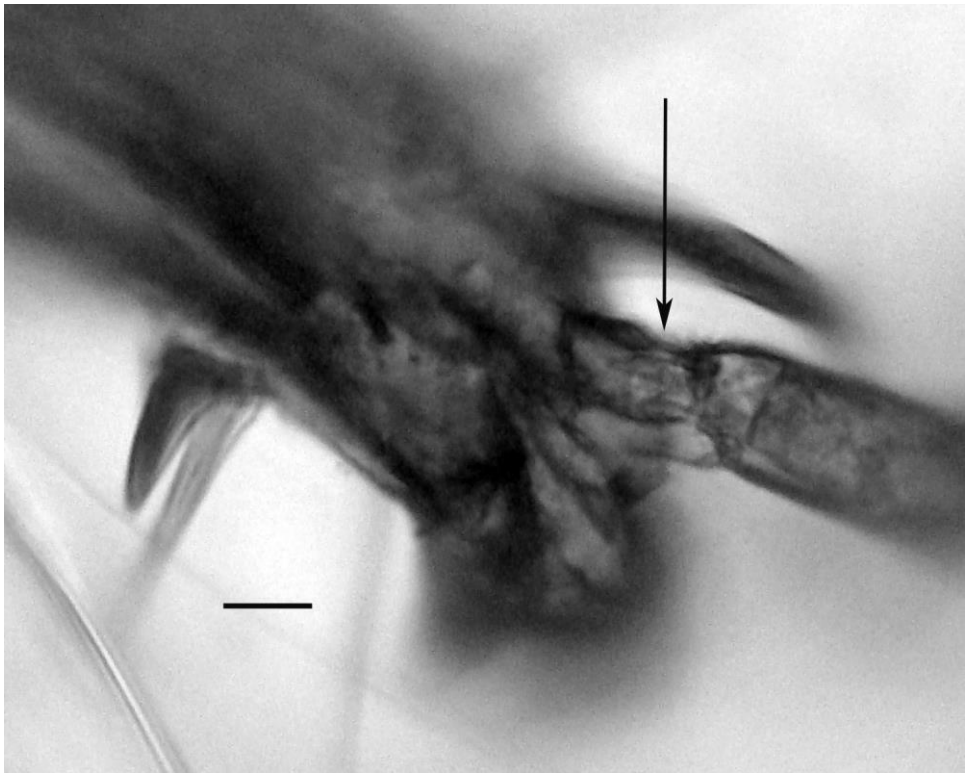

Figure 4. Antenna of *Novicicada burmanica*. Bar = 60 µm.

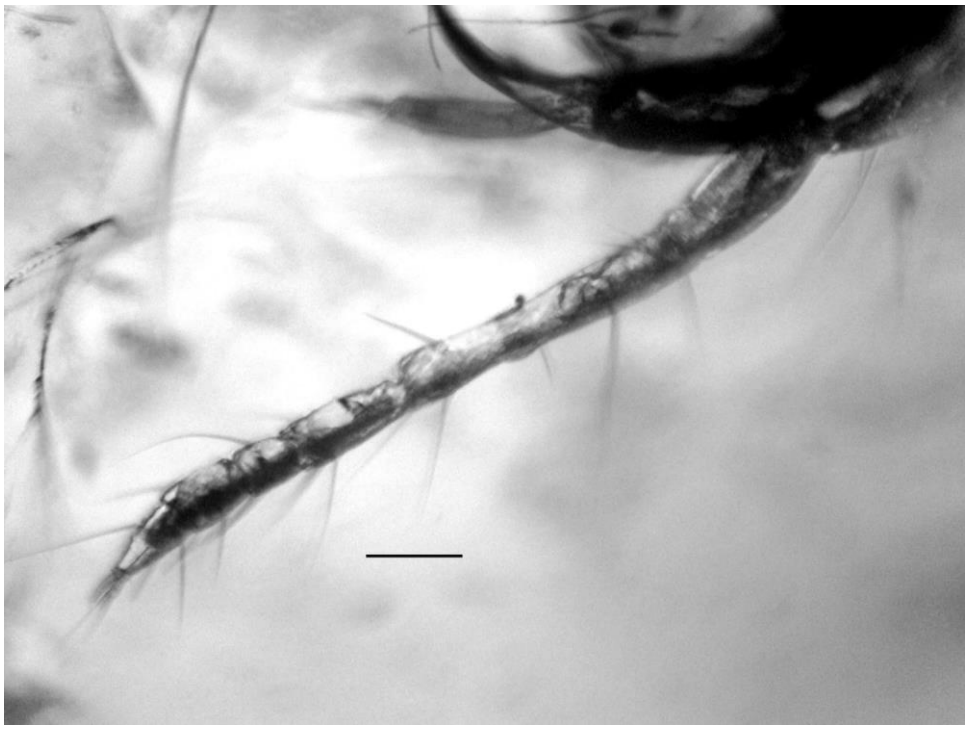

Figure 5. Forked structure (arrow) on terminal antennomere of *Novicicada burmanica*. Bar = 23 µm.

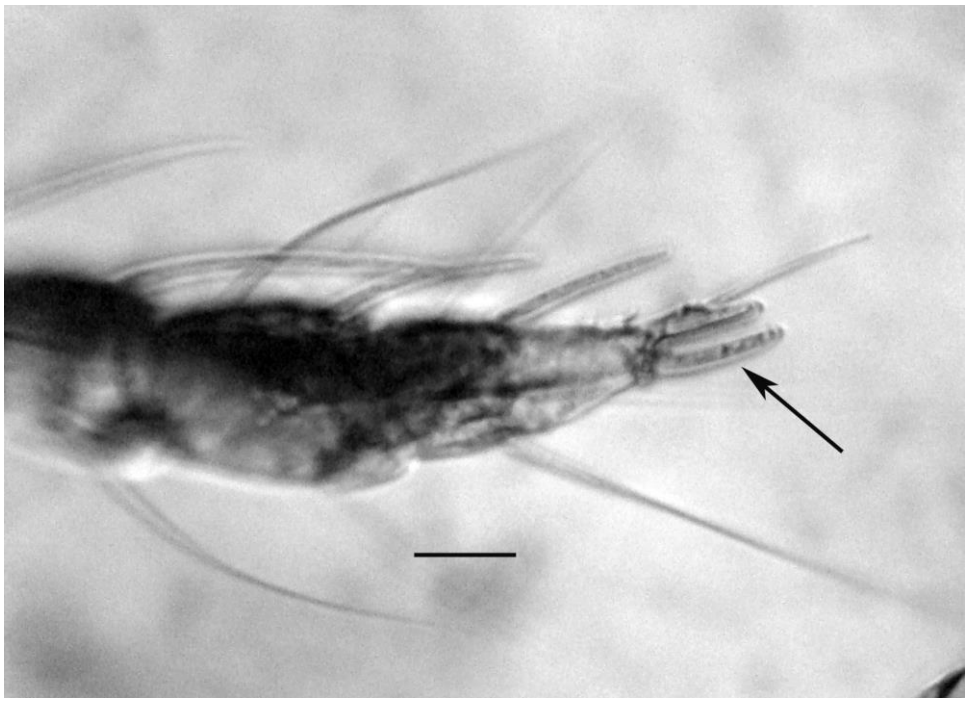

Figure 6. *Novicicada youngi* in Dominican amber. Bar = 237 µm.

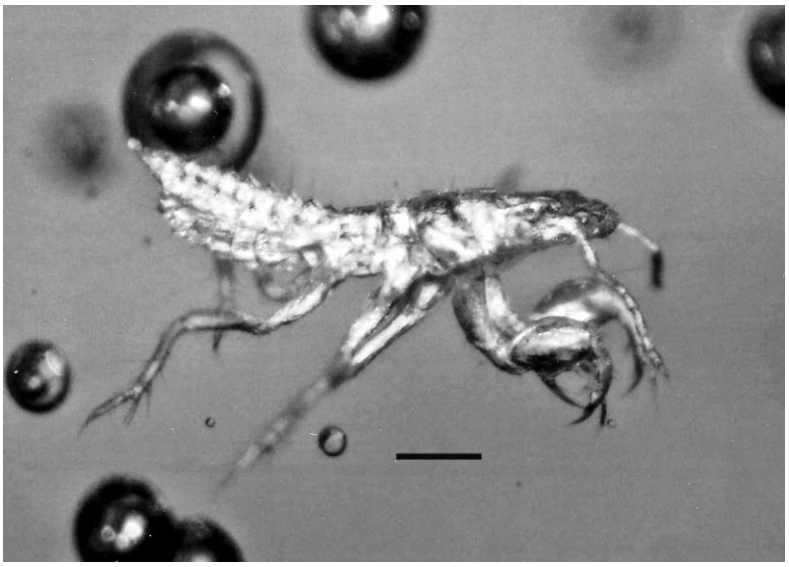

Figure 7. SEM of the foreleg of a hatchling of the periodical cicada, *Magicicada septendecim* (Fisher). Arrow shows foliose appendage on femoral tooth. Bar = 80 µm.

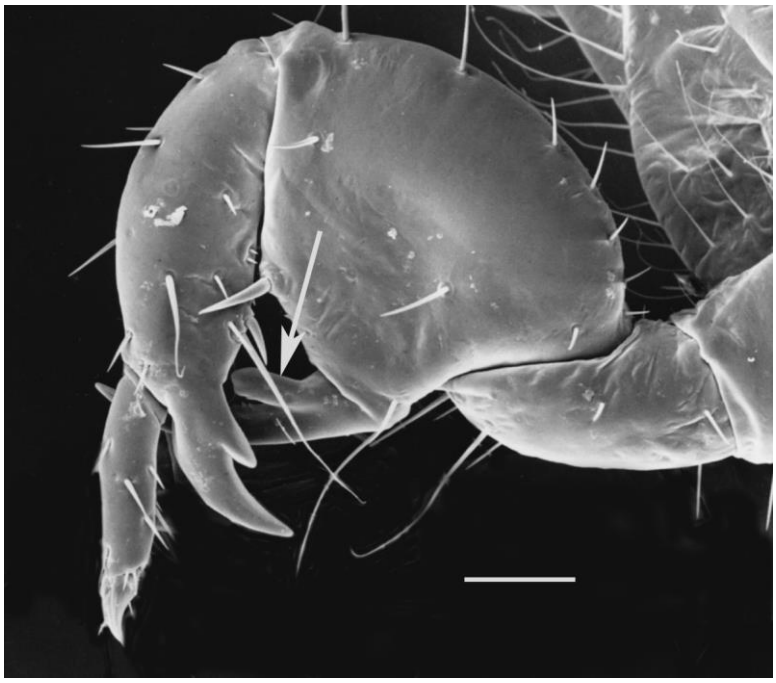

Figure 8. Forelegs of *Novicicada burmanica* (A), *Novicicada youngi* (B) and *Magicicada septendecim* (C) showing trochanters, femurs (stippled) with foliose appendage (arrow), tibiae and tarsi. Bars: A = 80 µm; B = 90 µm; C= 114 µm.

Table 1. Species, age and locality of described, uncontested, fossil Cicadidae

Species	Age	Locality
Cicada aichhornia Heer, 1853	Miocene	Europe
Cicada bifasciata Heer, 1853	Miocene	Europe
Cicada emathion Heer, 1853	Miocene	Europe
Cicada serresi Meunier, 1915	Oligocene	Europe
Cicada ungeri Heer, 1853	Miocene	Europe
Davispia bearcreekensis Cooper,1940	Palaeocene	North America
Lithocicada perita Cockerell, 1906	Eocene	North America
Meuniera haupti Piton, 1936	Eocene	Europe
Novicicada burmanica Poinar & Kritsky *	Early Cretaceous	Myanmar
Novicicada youngi Poinar & Kritsky*	Miocene- Oligocene	Dominican Republic
Platypedia primigenia Cockerell, 1908	Eocene	North America
Tibicen grandiosa (Scudder), 1892	Eocene Florissant	North America
Tibicina gigantea Boulard & Riou,1988	Miocene	Europe

* present study