First caddisflies (Trichoptera) in Lower Cretaceous Lebanese amber

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ABSTRACT: Lebanese amber contains a diverse biota from the Lower Cretaceous, and more than 150 families of arthropods have been reported as inclusions. Amongst these, caddisflies (Trichoptera) are very scarce inclusions, consisting of a few indeterminate fragments and only two inclusions that permit clear descriptions of new species. We describe the first two Trichoptera species from Lebanese amber, belonging respectively to Dipseudopsidae (*Phylocentropus succinolebanensis* n. sp.) and Ecnomidae (*Ecnomus cretacia* n. sp.). Previously, the oldest fossil representatives of both families were known from the Upper Cretaceous amber of New Jersey for Dipseudopsidae and from the Eocene Baltic amber for Ecnomidae.

KEY WORDS: Ecnomidae, *Ecnomus*, Dipseudopsidae, fossil insects, *Phylocentropus*.

The Trichoptera are an order of insects with approximately 15,000 extant and about 700 known fossil species (Morse 2016). They are small moth-like insects, having two pairs of hairy membranous wings. They are closely related to Lepidoptera and together they constitute the superorder Amphiesmenoptera. Trichopteran have aquatic larvae, where many species use silk to make protective cases of gravel, sand, or other debris.

The Cretaceous is one of the most interesting and important periods in the history of life on Earth. It is largely admitted that the angiosperms appeared and radiated during this critical period, which witnesses the emergence of most of the recent insect families. Amber is famous for being a superb material for the preservation of biological inclusions in minute three-dimensional detail. The oldest amber containing diverse biological inclusions is Lebanese amber. More than 400 localities have recently been discovered, including 23 that have yielded a high diversity of biological inclusions. Until now, more than 15,000 biological inclusions (mainly insects) have been found in the amber from the different localities, with more than 190 species distributed in nearly 150 families. The age of Lebanese amber ranges from Late Jurassic (Azar *et al*. 2010; Nohra *et al*. 2013) to Albian. Information about the age of the fossiliferous amber outcrops in Lebanon has been updated recently (Maksoud *et al.* 2014, 2016), and they are now considered to be early Barremian in age (Granier *et al.* 2016). Herein, we describe *Phylocentropus succinolebanensis* n. sp. and *Ecnomus cretacia* n. sp., the first two Trichoptera species from Lebanese amber, belonging respectively to Dipseudopsidae and Ecnomidae. These fossils constitute the earliest representatives of both families.

1. Material and methods

The *Ecnomus* specimen was cut, ground and polished, then placed between two cover slips using Canada balsam as a medium, as described by Azar *et al.* (2003). The *Phylocentropus* specimen is in a small and very fractured piece of amber, but as a precaution was embedded in synthetic resin, as described by Hoffeins (2001).

The specimens were examined under a Leica M5 or MZ12.5 dissecting microscope (Leica, Wetzlar, Germany). Photographs were taken using a Leica stereomicroscope M 420 Apozoom in combination with Canon EOS 600D, EOS utility software and the Zerene Stacker software; incident and transmitted light were used simultaneously. All images were edited with Adobe Photoshop CS4.

The studied material was collected from the Hammana Mdeirij amber outcrop, Baabda District, Mount Lebanon Governerate, Central Lebanon. The specimens were deposited in the Natural History Museum of the Lebanese University, Faculty of Sciences II, Fanar, Lebanon.

2. Systematic palaeontology

Order Trichoptera Kirby, 1815
Suborder Annulipalpia Martynov, 1924
Family Ecnomidae Ulmer, 1903
Genus: *Ecnomus* McLachlan, 1864

Type species. *Philopotamus tenellus* Rambur, 1842.

Diagnosis (modified from Botosaneanu 1992). Small or medium-sized extant insects and very small fossil insects. Maxillary palps five-segmented, first segment very short, second and fourth longer and similar, third longer again, fifth as long as second, third and fourth together, fifth terminal segment secondarily annulated and flexible. In forewings, R1 forked; apical forks I, II, III, IV, and V present; discoidal, median and thyridial cells present. In hindwings, R1 unbranched, forks II and V present; discoidal, median and thyridial cells absent. Tibial spurs 3/4/4, but in some species 2/4/4. Some African species belong to the *natalensis*-group of *Ecnomus*, which possesses inferior appendages (claspers) with an apical finger-like lobe and does not possess preapical spurs of the tibial prolegs: tibial spurs 2/4/4 (Scott 1968; Barnard & Clark 1986).

 doi:10.1017/S1755691017000354

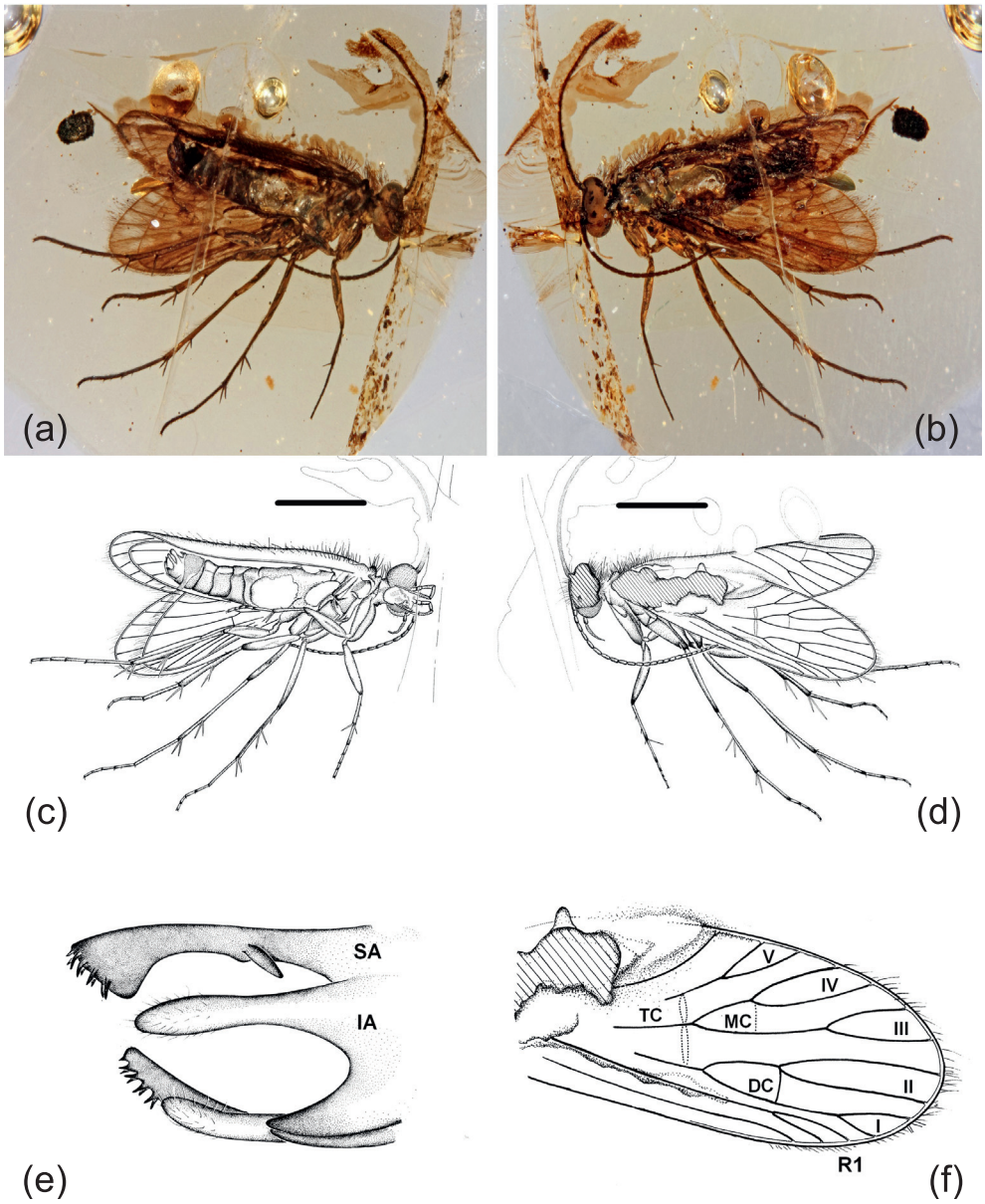

Figure 1 *Ecnomus cretacia* n. sp.: (a) male, laterovental view, forewing length 3 mm; (b) male in dorsal view; (c) male, drawing in ventral view; (d) male, drawing in dorsal view; (e) male genitalia, drawing in ventrolateral view; (f) left forewing, upside down. Scale bars = 1 mm.

Remarks. *Ecnomus* is the largest of eight genera in the Family Ecnomidae (Johanson & Espeland 2010), including the extinct genus *Archaeotinodes* Ulmer, 1912 from Eocene Baltic amber. *Ecnomus* is represented by more than 275 species worldwide, distributed in the Oceanian/Australian (61 species), Afrotropical (68), Oriental (135) and Palearctic (15) regions, except in the New World (Johanson & Espeland 2010). The larvae of *Ecnomus* construct tubes of silk and fine sand grains and live in running and standing water on rocks and submerged vegetation.

Ecnomus cretacia n. sp.
(Fig. 1)

Etymology. The species *cretacia* is named after the geological age (Cretaceous) of Lebanese amber.

Holotype. Male, in Lebanese amber, from the Azar collection (no. 574-C), deposited in the Natural History Museum of the Lebanese University.

Diagnosis. The new fossil species belongs to the *natalensis*-group of *Ecnomus*, indicated by the absence of preapical spurs of the tibial prolegs (tibial spurs: 2/4/4) and by the presence of the paired inferior appendages, each with an apical finger-like lobe in male genitalia. The extinct species differs from the extant species of the *natalensis*-group by the male genitalia. The superior appendages bear a small mesal projection and the basoventral process of the inferior appendages is subtriangular-shaped.

Description. Small caddisfly with forewing length of 3 mm. Ocelli absent. Antennae consisting of 23 flagellomeres plus scapus and pedicellus, not reaching the lengths of the forewings. Maxillary palps five-segmented, basal segment shorter than all others; its second segment longer than first but shorter than third and fourth; third segment originates from the apex of second segment; terminal fifth segment longest, about as long as all other segments together, secondarily annulated and flexible. Labial palps three3-segmented; basal first segment slightly longer than second segment and shorter than terminal segment. Third labial segment annulated and flexible. The dorsal part of head damaged, as well as the thorax and the basal part of the wings. However, the apical forewings well preserved, with R1 typically subdivided into two branches near wing margin, with the small and petiolate fork I, fork II sessile, fork III petiolate, as

https://doi.org/10.1017/S1755691017000354 Published online by Cambridge University Press

long as the stem, fork IV sessile, and fork V petiolate. The cross-veins closing the slightly elongated discoidal cell; cross-vein m closing the median cell, not well preserved, and cross-vein m–cu closing the thyridial cell indicated by a light oval mark. The hindwings covered dorsally by the forewings; ventrally the apical hindwings indicate the absence of the discoidal cell and the loss of fork I, III and IV, but the presence of forks II and V. In ventral view, all six legs well preserved; each tibiae of the legs bearing a pair of apical spurs and, additionally, tibiae of middle and hind legs bearing two additonal preapical spurs (spurs formula: 2/4/4). Male genitalia solely visible in ventrolateral view allows a tentative description. Superior appendages (SA) long and slender, with a small mesal projection and a field of spiny setae restricted to the dilated apex. Inferior appendages (IA) with two branches, the lateral one elongate, finger-like lobe, apex rounded, the shorter ventral one (basoventral process) subtriangular, apically tapered and slightly curved mediad.

Remarks. *Ecnomus cretacia* n. sp. belongs to the African *natalensis*-group of *Ecnomus*, as indicated by the tibial spurs (2/4/4) and in male genitalia by inferior appendages (claspers) with an apical elongate finger-like lobe. The *natalensis*-group of *Ecnomus* includes more than 23 extant species (Barnard & Clark 1986), ranging from South Africa (e.g., *E. forbesi* Scott, 1968) via central Africa (e.g., *E. mennellli* Barnard & Clark, 1986) to the Ethiopian region and northwards up to Palestine, and to the Galilee of northern Israel, where *E. galilaeus* Tjeder, 1946 occurs (Botosaneanu 1992). *Ecnomus galilaeus* is probably an endemic element of the Levantine fauna (Botosaneanu 1992), but lives relatively close to the location where the extinct *Ecnomus cretacia* was found.

Family Dipseudopsidae Ulmer, 1904
Genus: *Phylocentropus* Banks, 1907

Type species. *Holocentropus placidus* Banks, 1905 (original designation) and *Polycentropus lucidus* Hagen, 1861 included.

Diagnosis (modified from Ross 1965; Schuster & Hamilton 1984). Medium-sized extant insects and small fossil insects. Ocelli absent. Antennae about as long as forewings. Maxillary palps five-segmented; first and second segments short, third segment originating from the apex of second segment; third segment longer than the first and second segments together, fourth segment shorter than third, terminal fifth segment longest, secondarily annulated and flexible. Labial palps three-segmented; first segment slightly longer than second and shorter than terminal segment; third terminal labial segment annulated and flexible. Forewings with complete wing venation, the discoidal, median and thyridial cells closed, the apical forks I, II, III, IV and V present; in hindwing fork IV absent, discoidal and thyridial cells closed. Fork I and II sessile or subsessile in both wings. Tibial spurs: 3/4/4.

Remarks. Betten (1934) placed *Phylocentropus* in the subfamily Polycentropodinae of the family Polycentropodidae. Ross (1965) suggested that *Phylocentropus* was "an extremely archaic member of the subfamily Polycentropodinae." Ross & Gibbs (1973) placed *Phylocentropus* in the polycentropodid subfamily Dipseudopsinae, indicated by some larval characters. The Dispeudopsinae was given family status by Weaver & Morse (1986) and Frania & Wiggins (1997). Kjer *et al.* (2001) suggested that Dipseudopsidae are closely related to Polycentropodidae and Ecnomidae. Dipseudopsidae is a relatively small family, with five genera and about 120 species (Holzenthal *et al.* 2010). Extant species of *Phylocentropus* are found in eastern North America, southeast Asia and Japan. Extinct species were described from Cretaceous New Jersey amber (Wichard & Bölling 2000; Wichard & Luer 2003) and Eocene Baltic amber (Ulmer 1912). The new extinct species described below belongs to the genus *Phylocentropus* Banks, 1907, which differs from the closely-related Polycentropodidae by the sessil fork I in the fore- and hindwings (Ross 1965; Schuster & Hamilton 1984).

Phylocentropus succinolebanensis n. sp.
(Fig. 2)

Etymology. The species *succinolebanensis* is named after the amber (= succinum (lat.)) of Lebanon.

Holotype. Male, in Lebanese amber, from the Azar collection (no. 500), deposited in the Natural History Museum of the Lebanese University.

Diagnosis. *Phylocentropus succinolebanensis* n. sp. differs from the other extinct species by the structures of the outer male genitalia. Inferior appendage one-segmented, sclerotised, in ventral view triangular, slightly elongated and slightly rotated, its inside area bearing two dark strong spiny setae.

Description. Male embedded in a small amber piece. Apical parts of the wings, of the legs and of maxillary palps preserved incomplete. Adult with forewing length probably 4 mm. Antennae consisting of 35 flagellomeres plus scapus and pedicellus, not reaching the lengths of the forewings. Maxillary palps probably five-segmented, terminal segment absent; labial palps three-segmented, terminal segment secondarily annulated, little longer than first and second segment together. The forewing venation complete, fork I and fork II sessile, fork III petiolate, probably as long as the stem, fork IV sessile, and fork V petiolate. Discoidal cells closed and small; median and thyridial cells closed, longer than the discoidal cells, crossveins adelomorphic. Hindwings not visible, covered by forewings. Legs apically cut, but tibial spurs reconstructed: 3/4/4. Male genitalia so far as visible in ventral view and from behind. Inferior appendage (IA) one-segmented, sclerotised, in ventral view triangular, slightly elongated and slightly rotated, its inside area bearing two dark strong spiny setae. Preanal appendages (?) elongate filiform in posterior views. Phallic apparatus simple, aedeagus membranous at base, probably accompanied by two filiform parameres.

3. Discussion

The first two Trichoptera species are herein described from Lower Cretaceous Lebanese Amber: *Phylocentropus succinolebanensis* n. sp. and *Ecnomus cretacia* n. sp. They represent the earliest evidence of the families Dipseudopsidae and Ecnomidae. Both families belong to the superfamily Psychomyoidea, which probably originated in the Early/Middle Jurassic (Ivanov & Sukatsheva 2002).

The origin of the family Ecnomidae was proposed as Middle/Late Jurassic (Ivanov & Sukatsheva 2002; Grimaldi & Engel 2005). Previously, the oldest records of this family were known from Eocene Baltic amber. Ulmer (1912) erected the extinct genus *Archaeotinodes* (forewings with R1 simple and apical forks IV absent, in hindwings fork III present) and described 13 fossil species; further species were described by Melinitsky & Ivanov (2013) and Melinitsky (2009, 2013). The new species from Lebanese amber, belonging to the extant genus *Ecnomus*, is about 80 Ma older than extinct *Archaeotinodes* and thus greatly extends the known geological range of this family.

Fossil species of genus *Phylocentropus* are known from Eocene Baltic amber. Ulmer (1912) described four species: *P. antiquus, P. ligulatus, P. simplex* and *P. spiniger*. Three further species are known from Upper Cretaceous (Turonian) amber of New Jersey: *Phylocentropus cretaceous* and *P. swolenskyi*, as well as *Veteropsyche gelhausi* Botosaneanu,

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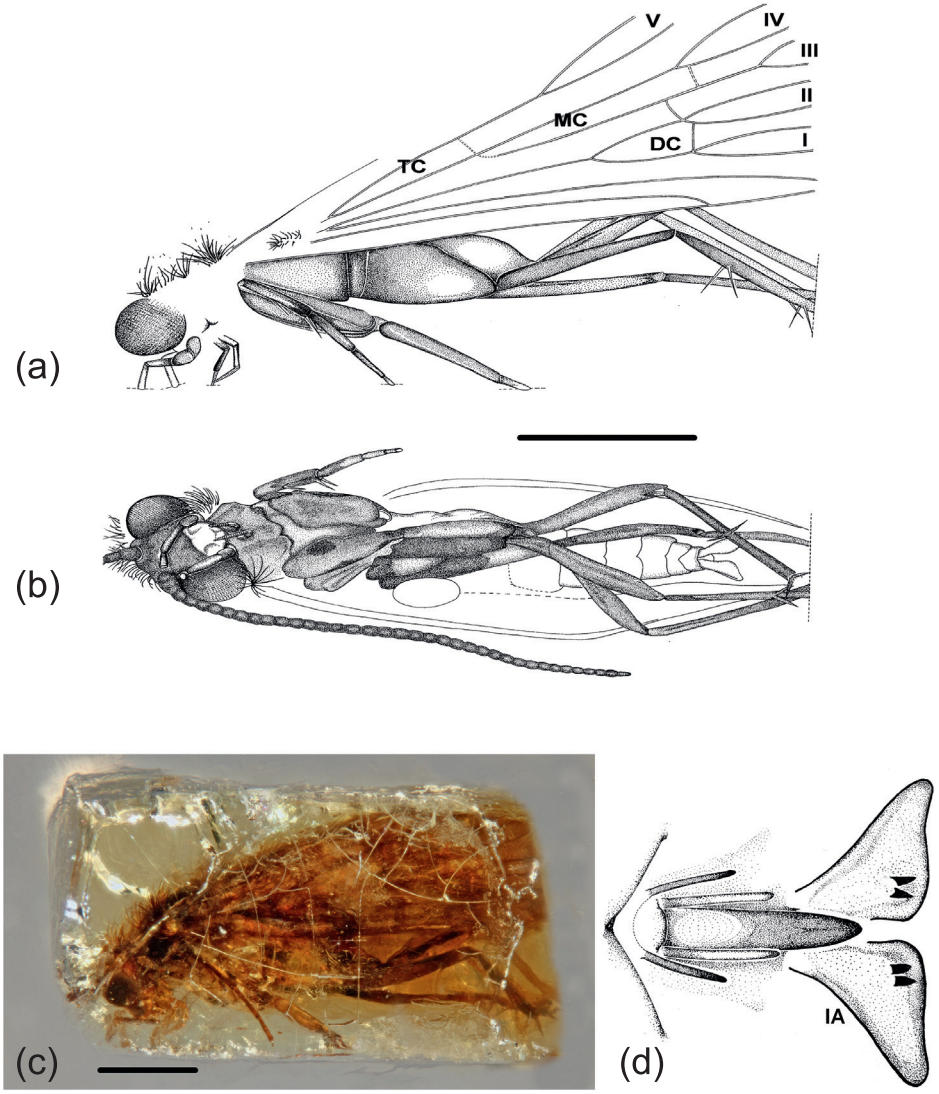

Figure 2 *Phylocentropus succinolebanensis* n. sp.: (a) male, drawing in lateral view, preserved forewing, length 4 mm; (b) male, drawing in ventral view; (c) male in fractured amber; (d) male genitalia, drawing in posterior view. Scale bars = 1 mm.

Johnson & Dillon, 1998, which was transferred to the genus *Phylocentropus* (Wichard & Luer 2003). The newly described *Phylocentropus succinolebanensis* n. sp. from Lebanese amber is the oldest known *Phylocentropus* species so far, with an age of about 130 Ma.

Sukatsheva (1993) described the "oldest Polycentropodidae (Trichoptera) from Mongolia", dating to the Upper Jurassic–Lower Cretaceous, and established two fossil genera *Eoclipsis* (type species *E. mongolica*) and *Plectrocentropu*s (type species *P. sulis*). The descriptions, based on compression fossils of a forewing (*Eoclipsis*) and of fore- and hindwings (*Plectrocentropus*), are unfortunately without any other necessary characters for a convincing placement in the family Polycentropodidae, so their placement is tentative. The forewing venation of *Eoclipsis* conforms to the forewing venation of *Phylocentropus* with the sessile forks I and II and differs only by sessile fork III, instead of petiolate fork III in *Phylocentropus*. The fore- and hindwing venations of *Plectrocentropus* and *Phylocentropus* are largely similar, but differ in the presence (*Plectrocentropus*) and absence (*Phylocentropus*) of fork IV in the hindwing. If the presence of sessile or subsessile forks I and II in fore- and hindwings are significant (apomorphic) and predominant characters of *Phylocentropus* Banks, 1907, then *Eoclipsis* Sukatsheva, 1993 and *Plectrocentropus* Sukatsheva, 1993 belong to *Phylocentropus* (or to narrowly related taxa) within the family Dipseudopsidae. Old fossil material of insects preserved as compression fossils consisting only of wings, without any other necessary characters, can lead to misinterpretations (Wichard 2016).

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https://doi.org/10.1017/S1755691017000354 Published online by Cambridge University Press

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MS received 30 May 2016. Accepted for publication 22 December 2016.