



## New Limaiinae (Neuroptera: Chrysopidae) from the early Eocene Fur Formation, Denmark, including an unexpected finding of a Mesozoic genus

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### Abstract

Two species of Limaiinae (Chrysopidae) are described from the early Eocene Fur Formation of Denmark: *Mesypochrysa nielseni* **sp. nov.** and Limaiinae gen. et sp. A. All forewing character states of *M. nielseni* **sp. nov.** are similar to those of the widely distributed Mesozoic genus *Mesypochrysa* Martynov, 1927, which was formerly known from the Middle Jurassic to mid-Cretaceous. Limaiinae gen. et sp. A is represented by an incomplete forewing. Although it differs from other species known from the formation, we refrained to name it pending a more complete specimen. The relatively high diversity of Limaiinae in the early Eocene of Denmark, with at least by two genera and four or five species is surprising. This diversity in the Fur Formation is nearly equal to that of Nothochrysininae.

**Key words:** Neuroptera; Chrysopidae; Limaiinae; Fur Formation; Denmark; early Eocene

### Introduction

The family Chrysopidae (green lacewings) is widely accepted to consist of four subfamilies, the Apochrysininae, Nothochrysininae, Chrysopinae, and Limaiinae (e.g., Archibald *et al.* 2014; Winterton *et al.* 2019). Its fossils are known to occur from the Middle Jurassic to the Pliocene. In the Mesozoic, they are represented by the Limaiinae and unclassified genera similar to that subfamily, while Nothochrysininae and Chrysopinae dominate fossil chrysopids in the Cenozoic. Only one species of Nothochrysininae is known from the Paleocene (Huang *et al.* 2022), while the Eocene chrysopids are numerous and diverse, predominantly belonging also to Nothochrysininae (see Makarkin & Archibald 2013; Makarkin 2014; Makarkin *et al.* 2018, 2022).

Chrysopidae are known from the earliest Eocene Fur Formation in northern Jutland of Denmark (Region Nordjylland). A general account of this well-known Lagerstätte may be found elsewhere (e.g., Larsson 1975; Rust & Ansoerge 1996; Archibald & Makarkin 2006; Rasmussen *et al.* 2016; Dietrich & Perkovsky 2023). In general, Neuroptera are numerous there, represented by four families: Polystoechotidae, Osmylidae, Hemerobiidae and Chrysopidae (Henriksen 1922; Schlüter 1982; Willmann & Brooks 1991; Willmann 1993; Rust 1999; Andersen 2001; Archibald & Makarkin 2006); all undescribed specimens known to us belong to them.

Four valid species in four genera of Chrysopidae have been described from the Fur Formation: *Protochrysa aphrodite* Willmann & Brooks, 1991 (Limaiinae), and *Cimbrochrysa moleriensis* Schlüter, 1982, *Danochrysa madseni* Willmann, 1993 and *Stephenbrooksia multifurcata* Willmann, 1993 (all Nothochrysininae). Rust (1999) described two other species (*Protochrysa athene* and *Brooksiochrysa jutlandica*) but these are invalid as they appeared in a dissertation and so their names are unavailable (ICZN, 1999, Articles 8.1.2 and 8.1.3).

Here, we describe two species of Limaiinae, one of which we assign to the widely distributed Mesozoic genus *Mesypochrysa* Martynov, 1927, the other remaining unnamed pending a more complete specimen.

were previously assigned to *Lembochrysa*) by the forked A1 and A1, and RA entering the margin slightly before the wing apex. Zhang *et al.* (2020b) described *Protochrysa brevinervis* Zhang *et al.*, 2020 from the Yixian Formation. All of its character states are similar to those of species of *Lembochrysa*, except the forked veinlets of RA. Finally, Chen *et al.* (2022) described *Mesypochrysa coadnata* Chen *et al.*, 2022 from the Burmese amber. RA in this species is probably shortest of the genus, entering the margin much proximad the wing apex.

Therefore, 37 species are currently known in this subfamily. Eight genera (*Mesypochrysa*, *Limaia*, *Baisochrysa*, *Parabaisochrysa*, *Drakochrysa*, *Aberrantochrysa*, *Cretachrysa* and *Protochrysa*) are considered valid, two others (*Caririchrysa* and *Lembochrysa*) as synonyms of *Mesypochrysa*, and the limaiine affinities of *Araripechrysa* and *Paralembochrysa* are questioned.

The forewing venation of *Araripechrysa*, *Cretachrysa*, *Baisochrysa*, *Parabaisochrysa*, *Paralembochrysa* and *Protochrysa* are very dissimilar to that of the new species and not considered further.

The venation of other limaiine genera is more or less similar to that of each other and the new species, differing only in small details. *Mesypochrysa* is the most speciose genus of the subfamily, containing 23 Mesozoic species (if the synonymy of *Caririchrysa* and *Lembochrysa* with *Mesypochrysa* is accepted). However, *Mesypochrysa* is probably a heterogeneous genus, and this synonymy may be questioned. Indeed, RA does not reach the wing apex, and A1 and A2 are forked in the species of *Lembochrysa* and *Mesypochrysa* from the Chinese Yixian Formation, whereas RA ends on the margin at or slightly after the wing apex, and A1 and A2 are simple in all Jurassic and the Early Cretaceous Baissa species of *Mesypochrysa*. Similarly, RA ends on the margin at or slightly after the wing apex in the Crato *Caririchrysa* and *Limaia*, but the configuration of anal veins is not clearly discernible in any specimen of these genera. Also, the hind wing MA is connected by a crossvein with RP in some species of *Mesypochrysa* (e.g., Panfilov 1980: Fig. 113; Chen *et al.* 2021: Fig. 3B), while MA originates on RP in other genera (e.g., Makarkin 1997: Figs 5, 14, 16, 18; Jepson *et al.* 2012: Fig. 15). The genus *Drakochrysa* was inadequately described, but examination of the photograph of *D. sinica* C. Yang & Hong, 1990 (the type and only species the genus) shows that its venation is very similar to that of *Lembochrysa*, especially *L. miniscula* Ren & Guo, 1996, in particular by the shorter RA that does not reach the wing apex. These genera are probably synonymous, taking into account that they are found in nearly contemporaneous nearby formations.

Therefore, while a revision of *Mesypochrysa* is needed, it is currently the only possible generic attribution for the new species. All forewing characters of *Mesypochrysa nielseni* **sp. nov.** are well concordant those of the genus, except the forked anterior branch of CuP. It is most similar to the single mid-Cretaceous species *Mesypochrysa coadnata*, which has an RA that does not reach the wing apex and A1 and A2 are simple. But RA is much shorter in this species than in *M. nielseni* **sp. nov.**

## Conclusions

The discovery of *Mesypochrysa nielseni* **sp. nov.** in the early Eocene is very important, as it shows that some genera may survive across the K-Pg event. The total number of species of Limaiinae known from the Fur Formation is now five (if “*Protochrysa athene*” is a distinct species), taking into account that at least one more species remains undescribed (VNM, pers. data). Such a relatively high diversity of Limaiinae in the early Eocene of Denmark, represented at least by two genera, is surprising, nearly equaling the Nothochrysinæ in this formation.

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