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New Neuroptera (Insecta, Osmylidae and Mesochrysopidae) from the Santana Formation, Lower Cretaceous of northeast Brazil

Rafael Gioia Martins-Neto
Sociedade Brasileira de Paleoartropodologia – SBPr. Centro de Ensino Superior de Juiz de Fora – CES/JF. Programa de Pós-Graduação em Ecologia, Universidade Federal de Juiz de Fora – UFJF, Campus Universitário Martelos, 36036-900, Juiz de Fora, MG, Brazil. martinsneto@terra.com.br.
Viviane Zeringóta Rodrigues
Sociedade Brasileira de Paleoartropodologia – SBPr.

ABSTRACT

This work presents the results of a taxonomic study of two specimens of fossil Neuroptera from the Crato Member laminated limestone, (Santana Formation, Lower Cretaceous), of the Araripe Basin, northeastern Brazil. The following new taxa are proposed: *Cratovoluptia criptoneura* n. gen. et n. sp. (Osmylidae), and *Dryellina placida* n. gen. et n. sp. (*Mesochrysopidae*). Additionally, new remarks on the taxonomy of *Araripe neuropterofauna* were maid, with comments about their paleoecology and paleoethology.

Key words: Neuroptera, Santana Formation, Araripe Basin, Lower Cretaceous, Brazil.

RESUMO

NOVOS NEUROPTERA (INSECTA, OSMYLIDAE AND MESOCHRYSOPIDAE) DA FORMAÇÃO SANTANA, CRETÁCEO INFERIOR DO NORDESTE DO BRASIL. Este trabalho apresenta o estudo taxonômico de duas novas formas de insetos neurópteros, provenientes dos níveis de calcários laminados do Membro Crato (Formação Santana, Cretáceo Inferior), da bacia do Araripe. Os novos táxons propostos são *Cratovoluptia criptoneura* n. gen. et n. sp. (Osmylidae) e *Dryellina placida* n. gen. et n. sp. (Mesochrysopiidae). Adicionalmente são discutidos sua implicação e os novos enfoques filogenéticos que envolvem os Neuropteros na bacia e comentadas suas implicações etológicas e paleoecológicas.

Palavras-chave: Neuroptera, Formação Santana, bacia do Araripe, Cretáceo inferior, Brasil.

INTRODUCTION

The Neuropterans are among the commonest orders of fossil insects from the Araripe Basin in terms of named species (Martins-Neto, 2006), represented mainly by Chrysopoidea, and Araripeneuridae among the Myrmeleontoidea. Some groups are especially rare such as Nemopteroidea, Makarkiniidae, Nymphidae, Berothidae, Osmylidae, and Babinskaiidae. Recently, several new taxa were proposed, focusing especially on chrysopid-like neuropterans (Nel *et al.*, 2005a; Makarkin and Menon, 2005; Menon and Makarkin, 2008), but also Rafaelids (Nel *et al.*, 2005b, 2006), Myrmeleontoidea (Martins-Neto, 2005; Heads *et al.*, 2005), Nymphidae (Martins-Neto, 2005; Menon *et al.*, 2005), and Ithonidae (Makarkin and Menon, 2007). The present study is a contribution and addition to previous research by the author (Martins-Neto, 1992, 1994, 1997, 1998, 2005, 2006; Martins-Neto and Vulcano, 1989, 1997), and reveals new forms of neuropterans.

MATERIAL AND METHODS

The samples here focused consists of two selected slabs collected in the expositions along Nova Olinda-Santana do Cariri road, 4 km from the municipal district of Nova Olinda, and were originated from the laminated limestone from the Crato Member, lowermost unit of the Santana Formation, Araripe Basin (Ponte and Appi, 1990), Upper Aptian in age (Ponte and Ponte-Filho, 1996; Coimbra *et al.*, 2002). Martill and Wilby (1993) and Martill (2007) elevate the Crato Member to a status of a geological formation and proposed the inclusion of the limestone interval in the Nova Olinda Member, the lowermost unit of their new geological unit. Based in Pons *et al.* (1990) and Batten (2007), they also proposed an Upper Albian to early Albian age to those levels.

The terminology used here is based on Martins-Neto (2002). The abbreviations cited in the text are: MA, anterior media; MP, posterior media; RA, anterior radial; RP, posterior radial; rp-ma, cross vein connecting RP with MA and ScP, posterior subcosta.

SYSTEMATIC PALEONTOLOGY

Order NEUROPTERA Olivier, 1789
Family OSMYLIDAE Leach, 1815
Cratovoluptia n. gen.

Type species. *Cratovoluptia criptoneura*, n. sp. here designated.
Etymology. From Crato, the name of the stratigraphic unit which the material came from, and *voluptia*, alluding to the rich venation pattern.
Diagnosis. Midsized neuropteran with fore and hind wings twice as long as wide, broad costal area broad, apex wide and rounded; ScP distally fused with RA. Hipostigmal cell inconspicuous; RP origin close to the wing base with seven secondary branches, distally dichotomous. Fore wing with ScP sigmoid at the wing base; MA short, distally fused with RP7. Hind wing with ScP quite parallel with RA; MA long, three-branched; MP unbranched. Both fore and hind wings with intense cross veins, forming mosaics of heterogeneous cells. No zigzag patterns in the longitudinal veins. Cryptic color pattern in both wings.
Discussion. The closest genus, *Cretosmylus* Makarkin, 1990, was based on a very fragmented fore wing from the Lower Cretaceous of East Siberia, sharing some plesiomorphic characters including a wide costal area, broad wings and the CuA fork close to the wing base, as well as a conspicuous color pattern. Although similar in general appearance, *Cratovoluptia* n. gen. differs of *Cretosmylus* in all diagnostic characters noted by Makarkin (1990): *Cratovoluptia* n. gen. exhibits costal veinlets forked (unforked in *Cretosmylus*); area between ScP and RA as wide as the RA and RP (narrow in *Cretosmylus*); first fork of MP close to origin of RP (far distal to origin of RP in *Cretosmylus*). *Cratovoluptia* n. gen. differs from *Cretosmylus*, apart the characters listed above by having MA short distally fused with RP7.

Cratovoluptia criptoneura n. sp.
(Figures 1A-B and 3A)

Etymology. Alluding to the wing venation pattern: cryptic.
Holotype. Sample CPCA 3562, housed at Centro de Pesquisas da Chapada do Araripe – CPCA/DNPM, Crato municipality, Ceará State, Northeast Brazil.
Type locality. Road between Nova Olinda and Santana do Cariri, 4 km from the town of Nova Olinda, Ceará State, Brazil.
Type stratum. Laminated limestone level, Crato Member, Santana Formation.
Age. Aptian (Lower Cretaceous).
Diagnosis. As for the genus.
Description. Medium-sized neuropteran, fore wing with length around 30 mm and 15 mm wide, with broad costal area filled by long, sinuous and dichotomously cross veined, with small veinlets forming a mosaic of heterogeneous cells. ScP sigmoid, distally fused with RA. RP origin close to the wing base. Space between ScP and RA, and RA and RP, relatively wide, filled with several cross veins (at least 18 preserved), some are Y-shaped. Seven secondary branches of RP, forming a wide radial area; M origin at RP base, forking close to the wing base; MA short, distally fused to RP7; MP long. CuA two-branched; CuP forking far from the wing base. Hind wing with similar venation pattern, except for M and Cu; M origin at RA, close to the wing base; MA two-branched and MP unbranched. Conspicuous color pattern in both wings and an intense number of Y-shaped cross veins in whole wings.

Family MESOCHRYSOPIDAE Handlirsh, 1906
Dryellina n. gen.

Type species. *Dryellina especiosa* n. sp. here designated.
Etymology. Little Dryelle, a mythological forest princess.
Diagnosis. Prothorax twice as long as wide. Fore wing twice as long and almost as wide as hind wing. Fore wing with MP touching CuA; presectorial basal cell smaller than the premedial one. Hind wing triangular, without tornus, apical margin curved, slightly acuminated; rp-ma at distal part of the radial basal cell; CuA linked to MP through a small cross vein.
Discussion. *Dryellina*, the new genus here proposed, is closely related with

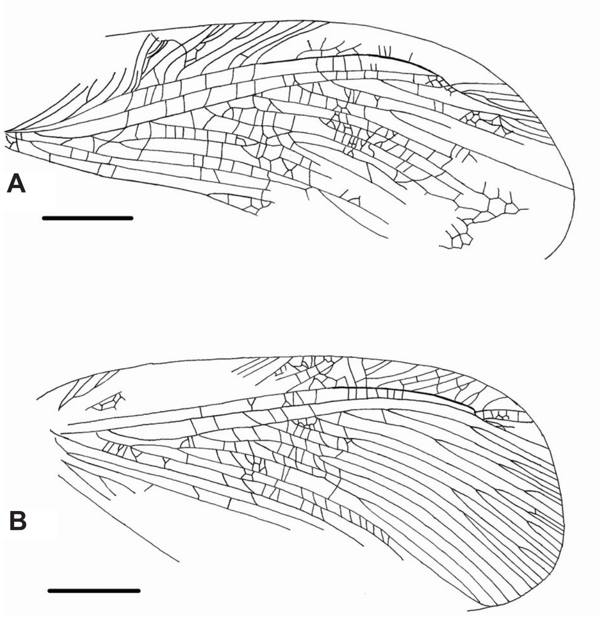

Figure 1. *Cratovoluptia criptoneura* Martins-Neto, n. sp., drawn from holotype (CPCA 3562). **A.** Fore wing; **B.** Hind wing. Scale bars = 5 mm.

Karenina Martins-Neto, 1997 and *Triangulochrysopa* Nel *et al*., 2005a, both genera with species known from the Crato Member. *Dryellina* n. gen. shares with *Triangulochrysopa* MP touching CuA in the fore wing and a triangular hind wing (connected by a small cross vein, and a rather elongate hind wing, respectively, in *Karenina*, see details in the Figure 2E). Also shares similarity with *Allopterus* Zhang, 1991, another mesochrysopid came from the Lower Cretaceous of China, in the rp-ma close to the radial basal cell in the fore wing, notably distinct from that seen in *Karenina* (Figure 2G), and *Triangulochrysopa* (Figure 2F), but this conective cross vein is situated directly on the basal radial cell in *Dryellina* n. gen., and on the last secondary RP branch in *Allopterus* (Figure 2H).

Dryellina n. gen. exhibits a small presectorial basal cell, smaller than the premedial one (greater in *Karenina*, *Allopterus* and *Triangulocrhysopa*).

Dryellina placida n. sp.

(Figures 2 A-D and 3B)

Etymology. In honour to Dr. Placido Cidade Nuvens, Chancellor of the Universidade Regional do Cariri (URCA).

Holotype. Sample MPSC I 1204, housed at Paleontological Museum from Universidade Regional do Cariri (URCA), at Santana do Cariri municipality, Ceará, Brazil.

Type locality, type stratum, and age. As for *Cratovoluptia criptoneura* n. sp.

Diagnosis. As for the genus, fore wing 30 mm long and 8 mm wide; hind wing 16 mm long and 6 mm wide. Hind wing/fore wing ratio 0.5.

Description. Transverse head in dorsal view, with prominent compound eyes. Filiform antenna with scape as long as wide. Pronotum 4 mm long and 2 mm wide. Thin and delicate forelegs, with fore wing 30 mm long and 8 mm wide (width/length rate 3.7); apex slightly acuminate. ScP distally fused with RA. Pterostigma occupying six subcostal cells. Humeral vein simple (Fig. 2D). RP origin close to the wing base and M forking at the mid length of the radial basal cell: space between RP and MA filled with three basal cross veins; rp-ma at the radial basal cell; MP transverse to the anal margin, CuA directly touching MP. Hind wing triangular, 16 mm long and 6 mm wide (W/L rate 2.6), without tornus. Costal and anal margins quite straight, divergent; anal margin rounded; apex acuminate. ScP distally fused with RA which its extension deflecting toward the apex. Subcostal narrow margin with 23 small cells preceding the pterostigma, two after, and four encompassing it, all without branches. RP origin close to the wing base; radial area filled with nine radial cells, the basal one greater. The six RP zigzag-like secondary branches form a mosaic of relatively homogeneous cells. M forking before the RP origin level: MA arising from MP in a quite right angle, curved initially and follow in a zigzag-pattern toward the apical margin; two secondary branches also with this same pattern, indistinctly rising from MA or, more probably, from MP; MP slightly sigmoid; rp-ma at distal part of the radial basal cell. CuA distally

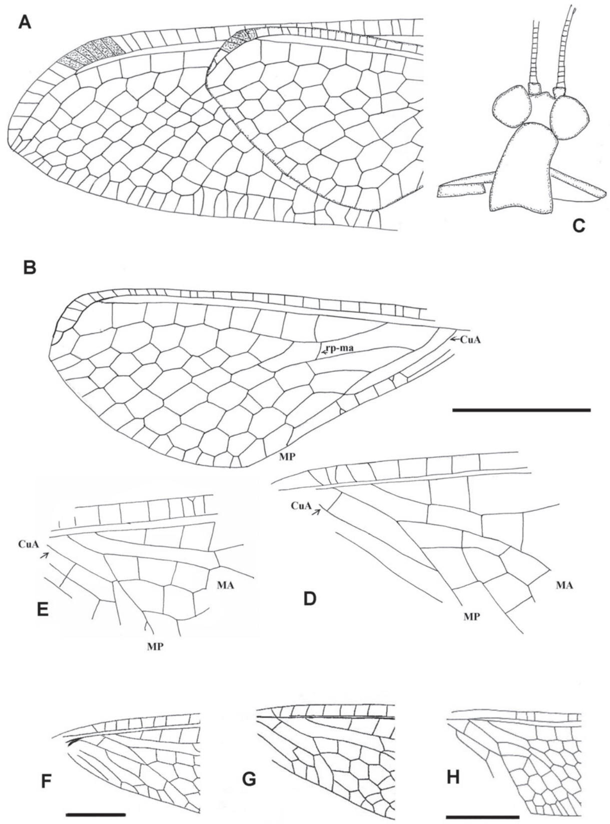

Figure 2. **A-D**, *Dryellina placida* Martins-Neto n. sp. (drawn from the holotype, sample MPSC I 1204) and their comparatives (**E-H**). **A.** *D. placida*, detail of the left fore and hind wing; **B.** isolated left hind wing; **C.** head detail; **D.** basal part of the right fore wing; **E.** *Karenina breviptera* Martins-Neto, detail from the basal part of the right fore wing (holotype); **F.** *Triangulochrysopa formosa* Makarkin & Menon, basal part of the fore wing (modified from Makarkin and Menon, 2008); **G.** *Karenina longicollis* Makarkin & Menon, basal part of the fore wing (from Makarkin and Menon, 2005); **H.** *Allopterus mayorgai* Nel, Delclòs & Hutin, basal part of the fore wing (modified from Nel *et al.,* 2005a). Scale bars = 5 mm.

touch MP through a small cross vein. A short CuP is connected at the mid length of CuA trough a small cross vein. Hind wing/fore wing ratio: 0.5.

TAXONOMIC NOTES ABOUT THE NEUROPTERA

The new forms here described and the new taxonomic information about the Araripe neuropterofauna acquired in the last years, with several new species being proposed, enormously contributes to the recent phylogenetic analyses made to this insects.

Some groups as Mesochrysopidae and Allopteridae are still problematic and at least one Brazilian genus has been the focus of considerable attention: *Karenina* Martins-Neto, 1997. Initially assigned to Ascalaphidae (Martins-Neto, 1997) was further removed to Allopteridae (Martins-Neto, 2002, 2005). Nel *et al*. (2005a) confirm this last attribution through a phylogenetical approach. Makarkin and Menon (2005) also discussing its relations, consider *Karenina* as Mesochrysopidae, a posture adopted here.

However, Nel *et al.* (2005a) omitted some important taxa from their phylogentic analysis, like the newly complete *Caririchrysa* species (Martins-Neto, 2002), who had removed from Mesypochrysa. In the work is accepted the peculiar genus, *Cratochrysa* Martins-Neto, 1992, but a new species created to this genus by Nel *et al*. (2005a) was include in a probable new family, Chrysopoidea incertae sedis. With this the new subfamily Cratochrysinae created by Martins-Neto (2002, 2005) was ignored, but in our opinion and by the inclusion of *Cratocrysia*, the proper name to the new family must be Cratochrysidae.

Heads *et al*. (2005) describe a well-preserved Palaeoleontidae which includes color patterns that they interpret as belonging to the Asiatic genus *Baissopardus* Ponomarenko, and propose *Neurastenyx* as a new synonym. To this last genus Martins-Neto and Vulcano (1997) designed the form *"Palaeoleon" araripensis* Martins-Neto, 1992, like the type of a new species *Neurastenyx gigas* Martins-Neto and Vulcano (1997), and also proposed the inclusion of *Neurastenyx polyhymnia* Martins-Neto (1997). Apparently in this work Heads *et al.* (2005) do not pay attention to the discussion about those genera (*Baissopardus* and *Neurastenyx*) made by Martins-Neto (1998) that shows *Baissopardus* like having more plesiomorphic venation when compared with *Neurastenyx* (Martins-Neto, 1998). Additionally, the peculiar elongated abdomen of *Neurastenyx* and the recently discovery of a conspicuous color pattern to *Baissopardus* made by Heads *et al.* (2005), could furnish enough arguments to separate *Baissopardus* and *Neurastenyx* as valid generic names, which is also confirmed by Menon and Makarkin (2008).

MORPHOLOGIC, PALEOETOLOGIC AND PALEOECOLOGICAL ASPECTS OF THE ARARIPE NEUROPTEROFAUNA

A relatively expressive number of Araripe neuropterans specimens clearly exhibit a conspicuous color pattern in its

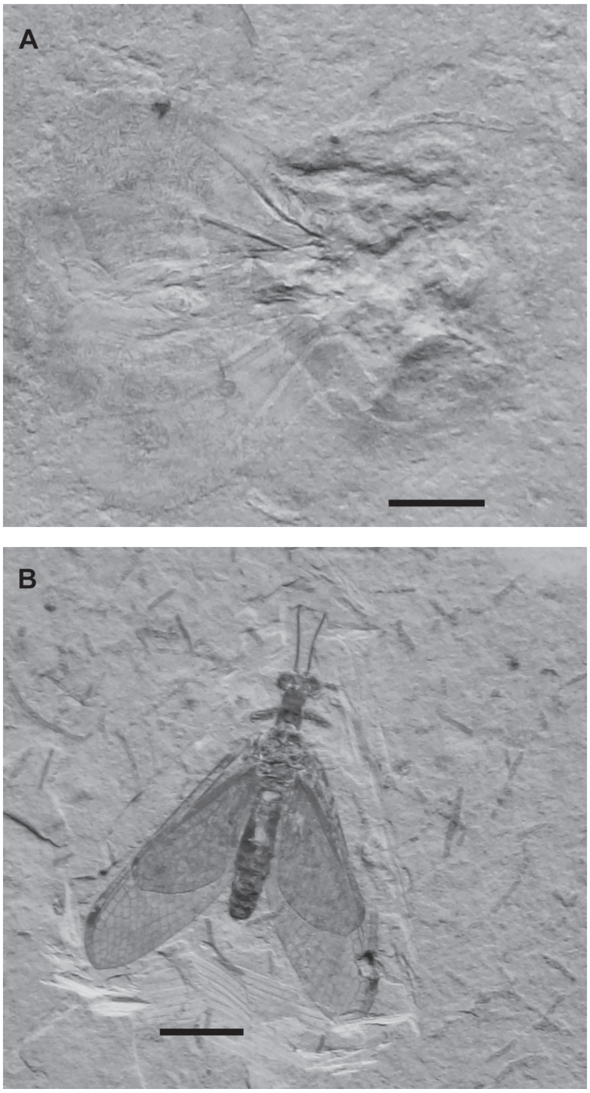

Figure 3. New Neuroptera from Santana Formation. **A.** *Cratovoluptia criptoneura* Martins-Neto, n. sp., holotype. **B.** *Dryellina placida* Martins-Neto n. sp., holotype. Scale bars = 1 cm.

wings. It is the case, e.g. for *Babinskaia pulchra* (Martins-Neto and Vulcano, 1989), *Neliana maculata* (Martins-Neto, 1994), *Blittersdorffia pulcherrima* (Martins-Neto and Vulcano, 1997) and *Baissopardus cryptohymen* (Heads *et al*., 2005). This is a relatively common case today evolving several insect species, as for example Batesian mimetism in butterflies. *Karenina longicollis* is other interesting case of this process, being virtually mimetic with Raphidioptera species. The new cryptic neuropteran described in this paper, *Cratovoluptia criptoneurta*, also shares this character.

With respect of wing-span, the Araripe neuropterans are also diverse, with the wing length varying since 5 mm (e.g. *Pseudonymphes zamboni* Martins-Neto, 2001), but also including giant forms as *Makarkinia adamsi* Martins-Neto 1995, where the wing-span could attain the incredible mark of 50 cm (Martins-Neto, 1992). Probably letting thunderstruck several birds, it surely must be a banquet for big-sized and hungry pterosaurs.

Confronting the extant biogeographic distribution of Nemopteridae (one of the represented Neuropteroidea at Araripe times) against vegetation, climate and raining rate we can note that they are rather distributed at desert areas, fields and steppes, savannas and tropical forest, with high temperatures and low annual precipitation index.

Those modern appeals suggest that Nemopteridae must be autochthonous to the boundary of the Araripe paleolake and could occupy the same niche of some kind of Elcanidae grasshoppers and crickets, very common in the taphocenosis, and associated to desertic vegetation, under warm climate.

For otherwise the Raphidioptera are today restrict to high altitudes, submitted to warm summer and cold winters, low rates of annual precipitation, and linked to distinct vegetations, since tundra to more closed mountain forests. Their abundance and diversity at Araripe basin in the beginning of Cretaceous suggest the presence of vegetated uplands, probably covered by gymnosperms and some Gnetales. Their complete extinction in the Southern Hemisphere at the end of Cretaceous seems to indicate a change of those conditions and their migration to higher areas or latitudes.

Quite all neuropteran families known for the Santana Formation are still represented at Brazil today. It is the case of Chrysopidae, Myrmeleontidae and Ascalaphidae among others. In warm belts they normally occur in winter times (as is the case of extant forms collected in Araripe plateau today). The conspicuous size variation of the fossil specimens indicates seasonal changes (winter or humid season more or less prolonged), that causes also seasonal mass mortality. By the other hand, big-sized neuropterans as Makarkiniidae, Palaeoleontidae, and Osmyloidea could represent those periods were the aridity and high temperatures characterize the climate in the area. Curiously, both groups are totally extinct today, or the last, together with Nemopteridae, Raphidioptera, and Nymphidae absent from the Brazilian faunas, although occurring in other South American areas, like Argentina, Amazonian Peru, Bolivia and Venezuela.

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