Remarks on the neuropterofauna (Insecta, Neuroptera) from the Brazilian Cretaceous, with keys for the identification of the known taxa

R.G. MARTINS-NETO

Laboratório de Paleontologia, Departamento de Biologia, Faculdade de Filosofia Ciências e Letras
USP, campus de Ribeirão Preto Av. Bandeirantes, 3900, 14040-901, Ribeirão Preto-SP, Brasil.
E-mail: mtnsneto @ ffclrp.usp.br

ABSTRACT

This paper reviews all previous knowledge about neuropterans from the Santana Formation (Lower Cretaceous, northeastern Brazil) involving a decade of research in this group. The neuropterofauna from Santana Formation is one of the most complete and diverse known, formed by 50 species distributed in 28 genera, representing 11 families: Ascalaphidae, Myrmeleontidae, Psychopsidae, Chrysopidae, Berothidae, Sisyridae, Nemopteridae, Roeslerianidae, Babinskaiidae, Paleoleontidae and Makarkiniidae. All the known material is from the laminated limestone, tip of the Crato Member, lowest unit of the Santana Formation, Lower Cretaceous, Ceará State, northeastern Brazil. This research have the objective to furnish the keys for the identification of all known Brazilian fossil neuropterans and 16 Figures containing the drafts of all Brazilian neuropterans holotypes.

Keywords: Neuroptera. Keys. Lower Cretaceous. Santana Formation. Brazil.

RESUMO

O principal objetivo deste trabalho é o de sintetizar uma década sobre o conhecimento dos neurópteros da Formação Santana, fornecendo-se um guia prático de identificação, útil a estudantes, pesquisadores e iniciados em paleontologia.

A neuropterofauna da Formação Santana vem demonstrando ser uma das mais completas e diversificadas que se tem conhecimento. Ela é composta por 50 espécies distribuídas em 28 gêneros, representando 11 famílias: Ascalaphidae, Myrmeleontidae, Psychopsidae, Chrysopidae, Berothidae, Sisyridae, Nemopteridae, Roeslerianidae, Babinskaiidae, Paleoleontidae e Makarkiniidae, que com exceção destas quatro últimas, todas possuem representação atual. Todo o material conhecido é proveniente do nível de calcário laminado, topo do Membro Crato, unidade inferior da Formação Santana, Bacia do Araripe, Cretáceo Inferior do Estado do Ceará, nordeste do Brasil. A terminologia empregada segue a de trabalhos anteriores da série sobre neurópteros.

Figure 1. A) Geographical situation  B) Araripe geological map. C) Outcrops of Crato Member. D) Position of the collected specimens.
INTRODUCTION

This paper reviews all previous knowledge about neuropterans from the Santana Formation (Lower Cretaceous, northeastern Brazil) involving a decade of research in this group (Fig. 1).

The neuropterofauna from Santana Formation is one of the most complete and diverse known, formed by 50 species distributed in 28 genera, representing 11 families: Ascalaphidae, Myrmeleontidae, Psychopsidae, Chrysopidae, Berothidae, Sisyridae, Nemopteroidea (Roeslerianidae and Nemopteridae), Babinskaiidae, Paleoleontidae and Makarkiniidae (after Martins-Neto, 1992 a, b, 1994, 1997, 1998; Martins-Neto and Vulcano, 1989 a, b, c, 1990 a, b, 1997).

The Neuroptera fauna from the Brazilian Cretaceous is unique in several aspects as for example the fact that, until this moment, just a single genus, Mesyphochrysa Martynov 1927, is known outside Brazil, exhibiting a high grade of endemism. Babinskaiidae, Roeslerianidae, Paleoleontidae and Makarkiniidae are families totally extinct, but during Cretaceous, paleoleontids are represented by five species, distributed in two families: Nemopteridae and Roeslerianidae.


All the known material came from the laminated limestone, tip of the Crato Member, lower unit of the Santana Formation, Lower Cretaceous, Ceará State, northeastern Brazil (Fig. 1). The terminology adopted here follows previous papers of the Neuroptera series (Martins-Neto, 1998). The systematic and taxonomic summary is available in Martins-Neto (1997).

TERMINOLOGY (Fig. 2)

Main venation: AA - anterior anal; CuA, CuP - respectively, anterior and posterior cubital vein; CuA2 - the most proximal secondary branch of CuA; MA, MP - respectively, anterior and posterior median vein; RA, RP - respectively, anterior and posterior radial vein; ScP - posterior subcostal vein.

Special areas: 1. Anal area (AAN): small area between A1 and the anal margin. 2. Costal area (AC): area between the costal margin and ScP, filled by several Pectinated cross veins. 3. Cubital area (ACU): triangular area between MP2+CuA1, CuA2 and the posterior margin. 4. Posterior Cubital area (ACP): triangular area between CuP and A1. 5. Pre setorial area (APS): area between the wing base and the posterior radius (RP); above by ScP below by MP1. This area is occasionally filled by pre setorial subcostal cross veins. 6. Radial area (AR): relatively narrow area between the apex and the RP origin, bordered below by RA. 7. Setorial area (AS): area between the RP secondary branches. 8. Subcostal area (ASC): area between ScP and RA.

Cells: 9. Cubital cells (ccu): cells from the cubital area, since CuA2, until the posterior margin, forming a triangular area between CuA2, MP2+CuA1 and the posterior margin. 10. Posterior cubital cells (ccup): cells of the posterior cubital area formed by the CuP secondary
branches. 11. Hypostigmal cell (h): long cell placed below the ScP/RA fusion point. 12. Infra radial cells (cir): cell space between oma and the first cross vein of the medial area. 13. Radial cells (cr): radial area cells formed by the radial cross veins. cr1 - basal radial cells. cr2 - the subsequent one. 14. Pre cubital cells (cpcu): pre cubital area cells. cpcu1 - basal pre cubital cell. 15. Pre medial (cpm): cells anterior of the medial area. cpm1 - first pre medial cell. 16. Pre setorial (cps): pre setorial area cells formed by radial cross veins after the RP origin. cps1 - basal pre setorial cell.

Special cross veins: 17. Humeral (hu): basal cross vein of the subcostal area. 18. Oblique vein (o): oblique cross vein between MP1 and MP2. 19. Pre cubital cross veins (pcu): cross veins of the pre cubital area. 20. Pre setorial cross veins (ps): cross veins of the pre setorial area. 21. Pseudomedia (psm): cross veins forming a continuous line looking like a median vein. This is a common character in chrysopids, very rare in other insects. 22. Pseudocubitus (psc): similar to the pseudomedia, but in the cubital region. 23. r-m : cross vein which links R to M.


Others: 28. an - antenna. 29. pro - pronotum.

KEYS FOR IDENTIFICATION OF THE SANTANA FORMATION NEUROPTERA

Key for the families (valid only for the Araripe fauna)

(1) Fore wing with oblique vein (o) .......................... 2
   - Fore wing without oblique vein (o) .................. 5

(2) Hind wing as long as fore wing .......................... 3
   - Hind wing at least twice longer than fore wing... NEMOPTEROIDEA ........................................ 4

(3) Fore wing with RP branches not fused .................. 11
   - Fore wing with RP branches partially fused .... 20

(4) Fore wing with the costal cross veins dichotomous. h without cross veins. CuP secondary branches dichotomous...ROESLERIANIDAE ........................................ 21
   - Fore wing with the costal vein dichotomous only after fsr. h with at least, one cross vein. CuP secondary branches without dichotomies...NEMOPTERIDAE: (1 gen. Cratonemopteryx; 3 sp.) ........ 28

(5) Fore wing with ScP distally fused with RA ........ 6
   - Fore wing with ScP and RA unfused .............. 8

(6) Fore wing with de AC narrower than the AR. ASC without cross veins ..................................... 7
   - Fore wing with the AC four times wider than the AR. ASC with more than 60 cross veins… MAKARKINIIDAE: Makarkinia (1 sp. Makarkinia adamsi, Fig. 13 A).

(7) Fore wing with the RP origin at one third or less from the wing base. More than 10 cr. h absent… ASCALPHIDAE ........................................ 22
   - Fore wing with the RP origin at one-forth to one and half from the wing base. Four cr. h present ........ 23

(8) Fore wing elongated, with at least two cr. MA+MP origin at RA+RP. M secondary branches with only marginal dichotomies .................................................. 9
   - Fore wing triangular, wider in the mid length, without cr. oma at RP M secondary branches multi branched… PSYCHOPSIDAE: Pulchrop pilonia (1 sp. Pulchropilonia espatifata , Fig. 12).

(9) Fore wing with costal cross veins distally multi branched .................................................. 10
   - Fore wing with costal cross veins unbranched… CHRYSOPIDAE ............................................ 24

(10) Fore wing elongated, three and half times longer than wide… BEROTHIDAE .......................... 27
    - For wing ovated, two and half times longer than wide… SISYRIDAE: Cratosisyrops (1 sp. Cratosisyrops gonzagai, Fig. 10C).

Key to the genera

(11) Fore wing with a long h. More than three branches of RP ........................................ 12
    - Fore wing without h. RP with only one secondary branch… Bleyeria (1 sp. Bleyeria nordestina, Fig. 8F).

(12) Fore wing with a very long cir ........................... 13
    - Fore wing with a small cir .......................... 16

(13) Fore wing with oma after cr1 .......................... 14
    - Fore wing with oma at cr1 .......................... 15
Figure 2. Terminology, mainly of the wing veins. See details in pages 99 and 100.
Figure 4. A, B, H, and I) Caririneura damianii MARTINS-NETO 1992a, respectively fore wing, hind wing, antenna detail and body detail, of the holotype. C, D, and J) Caririneura microcephala MARTINS-NETO AND VULCANO 1989a, respectively fore wing, hind wing and body detail, of the holotype. E-G) Caririneura crassatella MARTINS-NETO AND VULCANO 1997, respectively fore wing, hind wing and body detail, of the holotype. K and L) Paracaririneura priscila MARTINS-NETO AND VULCANO 1997, respectively fore wing and body detail, of the holotype.
Figure 6. A, B, and F) Cratoalloneura acuminata MARTINS-NETO 1992a., respectively fore wing, body detail and hind wing, of the holotype. C and H) Cratoneura dividens MARTINS-NETO 1994, respectively body detail and fore wing, of the holotype. D and I) Cratoneura longissima MARTINS-NETO 1992b, respectively body detail and fore wing, of the holotype. E and G) Cratoneura pulchella MARTINS-NETO 1992b, respectively body detail and fore wing, of the holotype.
Figure 8. A, D, and E) *Neliana maculata* MARTINS-NETO 1992b. A) holotype, D and E) additional material. B and C) *Neliana impolluta* MARTINS-NETO 1997; B) fore wing reconstruction, based on the holotype; C) fore wing and hind wing, of the holotype (F) *Bleyeria nordestina* MARTINS-NETO 1992 a., holotype.
Figure 9. A and G) Babinskaia formosa MARTINS-NETO AND VULCANO 1989a., respectively fore wing detail and body detail, of the holotype. B-F, H, and I) Babinskaia pulchra MARTINS-NETO AND VULCANO 1989a., respectively forewing, hind wing, anterior member, middle member, posterior member, head detail and general view, of the holotype.
Figure 10. A) Caririberotha martinsi MARTINS-NETO AND VULCANO 1990b, general view of the holotype. B) Araripeberotha fairchildi MARTINS-NETO AND VULCANO 1990b, general view of the holotype. C) Cratosisyrops gonzagai MARTINS-NETO 1997, general view of the holotype. D) Cratochrysa wilmanni MARTINS-NETO 1994, respectively fore wing (D1) and hind wing (D2), of the holotype. E) Cratochrysa sublapsa MARTINS-NETO 1997, respectively fore wing (E1) and hind wing (E2), of the holotype.
Figure 11. A, B, D, and J) Limaia conspicua MARTINS-NETO AND VULCANO 1989b, respectively fore wing, hind wing and body details, of the holotype. J) fore wing drawing of additional material. C and E) Araripechrysa magnifica MARTINS-NETO AND VULCANO 1989b, respectively body and fore wing details. F, G, L, and M) Mesypochrysa criptovenata MARTINS-NETO 1992a: F and L) respectively fore wing and hind wing, drawing of additional material; G) fore wing, of the holotype; M) fore wing of another specimen; H and I) Limaia adicotomica MARTINS-NETO 1997, respectively fore wing and hind wing, of the holotype; K) Mesypochrysa confusa MARTINS-NETO 1992a, fore wing and hind wing overlapped, of the holotype.
Figure 12. *Pulchoptilonia espatifata* MARTINS-NETO 1997, respectively fore wing and hind wing left, overlapped; right hind wing reversed by convenience, ScP and RA fusion point and general view; drawing of the holotype.
Figure 13. A) *Makarkinia adamsi* MARTINS-NETO 1997, fore wing of the holotype; B and C) *Karenina breviptera* MARTINS-NETO 1997, respectively left fore wing apical detail and right fore wing, of the holotype; D) *Cratoscalapha electroneura* MARTINS-NETO AND VULCANO 1997, fore wing, of the holotype.
Figure 14. *Roesleriana exotica* MARTINS-NETO AND VULCANO 1989c, general view, drawing of additional material.
Figure 15. A-C) *Roesleriana exotica* MARTINS-NETO AND VULCANO 1989c. A) fore wing, of the holotype; B and C) respectively fore wing and hind wing, drawing of additional material. D-F) *Krika pilosa* MARTINS-NETO 1992b. D) fore wing, of the holotype; E and F) respectively forewing and body detail, drawing of additional material.
Figure 16. A-C, H) Cratonemopteryx robusta MARTINS-NETO 1992a, A-C) respectively fore wing, hind wing and body detail, of the holotype; H) fore wing, drawing of additional material. D and E) Cratonemopteryx audax MARTINS-NETO 1992a, respectively fore wing and body detail, of the holotype. F and G) Cratonemopteryx speciosa MARTINS-NETO AND VULCANO 1997, respectively fore wing and hind wing, of the holotype.
(14) Fore wing base as wide as the apical margin. Less than 10 cr. Banksian-line absent… Araripeneura (2 sp.) … 30
- Fore wing leaf-like shaped with acuminated apex. More than 15 cr. Banksian-line present at least in AS. Cratoneura (3 sp.) … 31

(15) Fore wing apical margin wider than the wing base. Banksian-line absent. Caririneura (3 sp.) … 33
- Fore wing leaf-like shaped with acuminated apex. Continuous banksian-line in both ACU and AS. Cratoalloneura (1 sp. Cratoalloneura acuminata, Figs. 6A, B, F).

(16) Fore wing with less than five cr … 17
- Fore wing with more than ten cr … 18

(17) Antenna short, as long as the thorax… Pseudonympha (3 sp.) … 35
- Antenna long, longer than the thorax… Cratopteryx (1 sp. Cratopteryx Robertosantos, Figs. 5D, E, I).

(18) Fore wing with MA multi branched. oma after the mid length of the wing … 19
- Fore wing with MA unbranched. oma at one-third of the wing base… Blittersdorffia (5 sp.) … 38

(19) Fore wing three times longer than wide… Paracaririneura (1 sp. Paracaririneura priscilla, Figs. 4K, L).
- Fore wing five times longer than wide… Caldasia (1 sp. Caldasia cretacea, Figs. 7F, G).

(20) Fore wing with more than 50 cr… Neurastenyx (3 sp.) … 42
- Fore wing with less than 20 cr… Paraneurastenyx (1 sp. Paraneurastenyx ascalaphix, Fig. 7E).

(21) Fore wing without ps… Roessleriana (1 sp. Roessleriana exota, Figs. 14, 15A-C).
- Fore wing with at least two ps… Krika (1 sp. Krika pilosa, Fig. 15D-F).

(22) Fore wing without pterostigma. More than 16 cr… Cratoscalapha (1 sp. Cratoscalapha electroneura, Figs. 13D).
- Fore wing with pterostigma. Less than 14 cr… Karrenina (1 sp. Karrenina breviberta, Figs. 13B, C).

(23) Fore wing with four ps… Babinskaia (2 sp.) … 44
- Fore wing with seven ps… Neliana (2 sp.) … 45

(24) Fore wing with less than 10 cr. Both psm and psc absent … 25
- Fore wing with more than 10 cr. Both psm and psc present… Mesopochrysa (2 sp.) … 46

(25) Fore wing with seven to ten cr … 26
- Fore wing with two to three cr… Cratochrysa (2 sp.) … 7

(26) Fore wing c1 as long as c2… Limaia (2 sp.) … 48
- Fore wing with c1 at least twice longer than c2… Araripechrysa (1 sp. Araripechrysa magnifica, Figs. 11C, E).

(27) Fore wing with the AC wider than ASC. Head longer than wide… Caririberotha (1 sp. Caririberotha martinsi, Fig. 10 A).
- Forewing with the AC as wide as ASC. Head rounded, as long as wide… Araripeberotha (1 sp. Araripeberotha fairchildi, Fig. 10B).

**Key to the species**

(28) Fore wing with two ps … 29
- Fore wing with one ps… Cratonomopteryx speciosa, Fig. 16F).

(29) Fore wing with one pcu… Cratonomopteryx robusta, Figs. 16A-C, H.
- Fore wing with three pcu… Cratonomopteryx audax, Figs. 16E-G.

(30) Fore wing around 19 mm long and relatively wide. Body short, around 14 mm long. Anal margin curved. CuP with long secondary branches. Apex acute… Araripeneura regia, Figs. 3F-G, M, N, P.
- Fore wing around 15 mm long, relatively narrow. Body elongated, around 17 mm long. Anal margin straight. CuP with short secondary branches. Apex rounded… Araripeneura gracilis, Figs. 3E, H-I, O.

(31) Fore wing with MA with less than five distal secondary branches … 32
- Fore wing with MA with more than eight distal secondary branches… Cratoneura longissima, Figs. 6D, I.

(32) Fore wing with h without cross veins… Cratoneura pulchella, Figs. 6E, G.
- Fore wing with h with at least one cross vein… Cratoneura dividens, Figs. 6C, H.
(33) Head smaller than the thorax… *Caririneura microcephala*, Figs. 4C-D, J.
   - Head greater than the thorax .......................... 34

(34) Great eyes, occupying 2/3 of the head area… *Caririneura crassatella*, Figs. 4E-G.
   - Small eyes, occupying less than 1/5 of the head area… *Caririneura damianii*, Figs. 4 A, B, H-I.

(35) Fore wing around 15 mm long
   - Fore wing around 6 mm long… *Pseudonymphes zamponii*, Fig. 5F.

(36) Mesothorax anterior margin rounded and little wider than the posterior margin …… 37
   - Mesothorax anterior margin quite straight and two times wider than the posterior margin… *Pseudonymphes araripensis*, Figs. 5 A-C, K.

(37) Abdomen robust as wide as thorax… *Pseudonymphes brunnerottae*, Figs. 5I, M.
   - Abdomen thin, narrower than thorax… *Pseudonymphes pononarenkoi*, Figs. 5G, H, L.

(38) Fore wing with CuA2 distally branched …… 39
   - Fore wing with CuA2 unbranched …… 41

(39) Fore wing with o after ocua. Apex acuminated. Collor pattern… *Blitteardoelia pulcherrima*, Fig. 3K.
   - Fore wing with o at ocua. Apex rounded. Without collor pattern… *Blitteardoelia pleoneura*, Figs. 3 A, C.

(40) Fore wing with CuP long, reaching the anal margin at 1/3 from the wing base …… 41
   - Fore wing with CuP short, reaching the anal margin near of the wing base… *Blitteardoelia dicotomica*, Fig. 3J.

(41) Fore wing with AAN as narrow as ACU… *Blitteardoelia volkheimeri*, Fig. 3B.
   - Fore wing with AAN wider than ACU… *Blitteardoelia polyplusia*, Figs. 3D, L.

(42) Fore wing around 90 mm long. *Neurastenyx gigas*, Fig. 7D.
   - Fore wing with 40 to 60 mm long …… 43

(43) Fore wing around 60 mm long… *Neurastenyx araripensis*, Figs. 7 A, B.
   - Fore wing around 40 mm long… *Neurastenyx polyhymnia*, Fig. 7C.

(44) Fore wing with cr1 smaller than cr2. Five CuP secondary branches… *Babinskaia pulchra*, Figs. 9B-F, H, I.
   - Fore wing with cr1 greater than cr2. Four CuP secondary branches… *Babinskaia formosa*, Figs. 9 A, G.

(45) Fore wing with five to six cp. and color pattern… *Neliana maculata*, Figs. 8 A, D, E.
   - Fore wing with only one cp cell. Without color pattern… *Neliana impolluta*, Figs. 8B, C.

(46) Fore wing around 20 mm long… *Mesophyrsis criptovenata*, Figs. 11F-G, L-M.
   - Fore wing around 10 mm long… *Mesophyrsis confusa*, Fig. 11K.

(47) Fore wing with MA distally unbranched… *Cratochrysa sublapsa*, Fig. 10E.
   - Fore wing with MA distally branched… *Cratochrysa willmanni*, Fig. 10D.

(48) Hind wing with four marginal dichotomies… *Limaia conspicua*, Figs. 11A, B, D, I.
   - Hind wing with two marginal dichotomies… *Limaia adicotomica*, Figs. 11H, I.

REFERENCES


