



**A New Fossil Stick Grasshopper
(Proscopioidea: Proscopiidae) from the Crato Formation of Brazil**
Um Novo Fossil de Falso Bicho-Pau
(Proscopioidea: Proscopiidae) da Formação Crato, Brasil

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Abstract

A new specimen of a stick grasshopper (Orthoptera: Proscopioidea: Proscopiidae) is described from the Early Cretaceous (Late Aptian – Early Albian) Crato Formation of southern Ceará, northeastern Brazil. This is only the second formal description of Proscopiidae in the fossil Record. Unfortunately, LP/UFC CRT 2698 is poorly preserved as a faint impression due to post-diagenetic processes. However, the discovery of this new taxon enhances the diversity of Proscopiidae in the Gondwana, and it confirms the South America as a dispersion zone for this family.

Keywords: Orthoptera; Proscopiidae; Crato Formation

Resumo

Um novo espécime de falso bicho-pau (Orthoptera: Proscopioidea: Proscopiidae) é descrito na Formação Crato, Cretáceo Inferior (Aptiano superior – Albiano inferior), sul do Ceará, Nordeste do Brasil. Essa é apenas a segunda descrição formal de Proscopiidae no registro fossilífero. Infelizmente, LP/UFC CRT 2698 apresenta-se pobremente preservado como uma impressão. Contudo, a descoberta de um novo táxon aumenta a diversidade de Proscopiidae no Gondwana, e confirma a América do Sul como zona de dispersão dessa família.

Palavras-chave: Orthoptera; Proscopiidae; Formação Crato

1 Introduction

Proscopiidae, also known as stick grasshoppers, is a distinctive family often confused with a stick insect than any other grasshopper. These enigmatic orthopterans are characterised by their elongated head, slender body, short antennae and the extremely short or absent wings. Proscopiids are flightless and wingless (though they are able to jump considerable distances) and rely on their ability to camouflage as protection. This family shows pronounced sexual dimorphism, sometimes females are much more than twice the size of males and much more robust. In proscopiids an abdominal tympanal organ is absent. The proscopiids are herbivores and are able to thrive in a wide variety of environmental conditions, being ecological generalists feeding on a variety of plants. They also are of great economic importance, because they cause significant damage to agricultural crops, such as *Stiphra robusta* Mello-Leitão (1939) which is considered a sporadic pest in north-eastern Brazil (Lima & Andrade, 2002).

The family comprises 219 species distributed throughout Central and South America (Cigliano *et al.*, 2019). According to Liana (1980), the Proscopiidae family is subdivided into three subfamilies: Hybusinae having only one genus, *Hybusa*, with four species; Proscopiinae constituting the most speciose subfamily, with 196 species distributed between the tribes Proscopiini and Tetanorhynchini; and Xeninae with 16 species in three genera. Apart from those, there are seven genera that are not yet distributed in the three families (Cigliano *et al.*, 2019). The proscopiids have seem to have had a complex evolutionary history reflecting the great number of authors who have relocated species in different genera constantly. Jago (1989) presented a comprehensive review of the family, establishing the male genitalia as the main criterion for the characterization and description of the species. But the taxonomy of the group remains unclear, since most of the species descriptions were based upon only the external morphology. The placement of Proscopiidae within Eumastacoidea has always been a reason for much debate. Descamps (1973a, 1973b) suggested separating them into two superfamilies, elevating Proscopiidae to the Proscopioidea (a superfamily comprising

a single family). However, other authors have placed the proscopiids as a family within Eumastacoidea (Dirsh, 1973; Otte *et al.*, 2003). Eades (2000) proposed to move the Proscopiidae family from the Proscopioidea superfamily to the Eumastacoidea superfamily. Matt *et al.* (2008), based on molecular analysis, is quite ambiguous regarding the removal of the Proscopiidae family from the Proscopioidea and its placement in the Eumastacoidea. Although these grasshoppers have sometimes been considered as a member of Eumastacoidea, because their close affinity (Roberts, 1941), we consider it here as a separate superfamily based on their basal features that do not clearly link proscopiids to eumastacoids (Song *et al.*, 2015).

The Early Cretaceous Crato Formation is a worldwide fossil locality known for storing a well-preserved fauna of insects. The fossils are preserved exceptionally well, with details visible at the micrometer scale. Several recent studies have demonstrated that Crato Formation insects have been preserved by iron oxides after framboidal pyrite (Delgado *et al.*, 2014; Barling *et al.*, 2015; Osés *et al.*, 2016). The high quality of preservation of Crato insects is often reported in species descriptions. This exceptional quality of fossils represents an extremely valuable source of data concerning diversification and biogeography of insects during the Gondwana.

The fossil record of this family is extremely rare. Indeed, Proscopiidae are known mainly for their extant fauna. As an example of the significance of the Crato Formation, the single formally described species *Eoproscopia martilli* Heads (2008), is the only fossil record of Proscopiidae so far. In this paper we describe a second species of Proscopiidae from the Crato Formation, *Eoproscopia reliquum* sp. nov., based on the specimen LP/UFC CRT 2698. The new fossil is quite distinct and differs from the other previously described by presenting modifications, both in terms of overall body size and in the proportions and in the length of antennae.

2 Geological Setting

The Araripe Basin is the most extensive of the Brazilian Northeastern Interior Basins, occupying

an area of proximally 9,000 km². This fault-bounded Basin lies on the borders of Ceará, Pernambuco and Piauí states. Its tectonic evolution was strongly controlled by extensional tectonics accompanying the opening of the South Atlantic rift system (Heimhofer *et al.*, 2010; Matos, 1999). In the paleontological context, the principal lithostratigraphy unit is the Santana Group (Assine *et al.*, 2014) which represents Barbalha, Crato, Ipubi and Romualdo formations, highlighting the Crato and Romualdo formations, considered as two of the most important Cretaceous *fossil-Lagerstätte* deposits in Gondwana (Selden & Nudds, 2012). The Crato Formation consists of several units of laminated limestones interbedded with a series of claystones, siltstones and sandstones (Martill & Heimhofer, 2007). Overall, Crato limestones outcropping in quarries or in river margins, from Santana do Cariri-CE until near the Porteiras-CE. Based on ostracode assemblages and terrestrial palynomorphs, the Crato Formation is part of the *Sergipea variverrucata* palynozone implying an Aptian age, Early Cretaceous (Coimbra *et al.*, 2002). According to Castro *et al.* (2006), Crato Formation comprises four cycles of facies: lacustrine limestone and bituminous shale; deltaic shale and sigmoidal sandstones; lacustrine marginal marl and sandy siltite; and, fluvio-lacustrine sandstone with cross-stratification. Neumann *et al.* (2003) distinguish between two types of laminated carbonate facies: clay-carbonate rhythmites (CCR); and, Laminated Limestone (LL). The CCR is characterized by couplets of light-dark micritic laminae. The calcite crystals are idiomorphic associated with framboidal pyrite, phyllosilicates and high inter-grain porosity (Heimhofer *et al.*, 2010). The LL facies is composed by calcite microspar with disseminated pyrite and show less inter-grain porosity (Heimhofer *et al.*, 2010). In the CCR, the content of Corg (Organic Carbon) is less than 4% while LL has less than 1% (Neumann *et al.*, 2003).

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3 Material & Methods

The new fossil has been housed in the scientific collection of the Laboratory of Paleontology (Laboratório de Paleontologia) of the Federal University of Ceará (Universidade Federal do Ceará), Brazil.

LP/UFC CRT 2698 was collected in the Triunfo quarry, Nova Olinda city, Ceará state, Brazil. The fossil was prepared using a fine needle to remove overlying pieces of host matrix. The specimen was studied and drawn using Olympus C011 microscope with camera lucida drawing attachment.

4 Systematic Paleontology

Order ORTHOPTERA Olivier, 1789

Suborder CAELIFERA Ander, 1936

Superfamily PROSCOPIOIDEA Serville, 1838

Family PROSCOPIIDAE Audinet-Serville, 1839

Genus EOPROSCOPIA Heads 2008

Eoproscopia reliquum sp. nov.

Figures 1 and 2

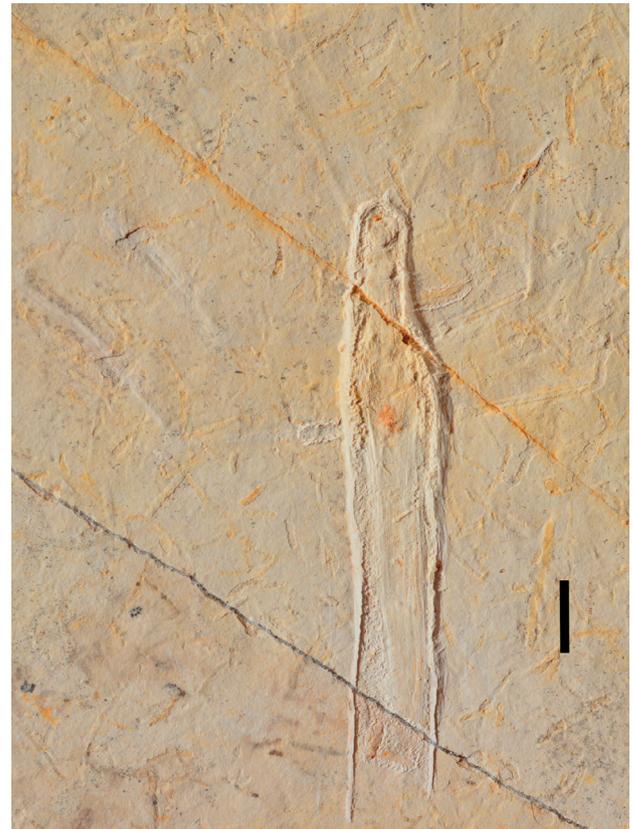


Figure 1 *Eoproscopia reliquum* sp. nov. from Crato Formation (Lower Cretaceous, Aptian) of Ceará, Brazil. Holotype, sex indeterminate, LP/UFC CRT 2698. Scale bar represent 10 mm.

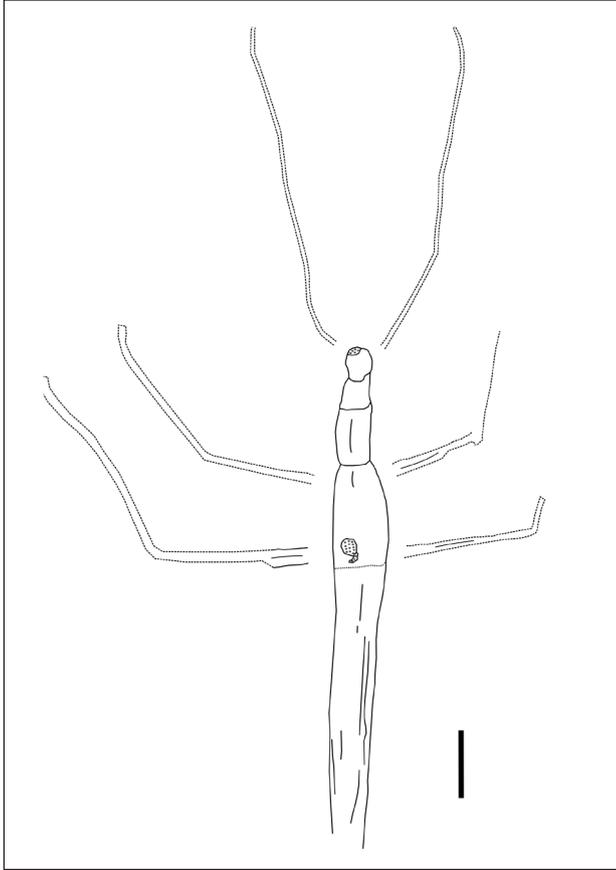


Figure 2 Camera lucida drawing of *Eoproscopia reliquum* sp. nov. Holotype, sex indeterminate, LP/UFC CRT 2698. Scale bar represent 10 mm.

Diagnosis. Adult. Slightly oval head with 9.0 mm in length, antennae with more than 45.0 mm. Mesothoracic legs with at least 33.0 mm and metathoracic legs with approximately 50.0 mm. Total body length over 80.0 mm without antennae.

Description. Adult specimen, sex indeterminate (fig. 2). Head, slightly oval preserved in dorsal view, with 9.0 mm in length; width 8.0 mm at widest point. Antennae probably filiform expanded distally, 45 mm in length. Pronotum and postnotum well developed displaying visible longitudinal carinae. Legs elongate and slender with longitudinal sulci. Mesothoracic legs, 42.0 mm in length; femur 15.0 mm; tibia 27.0 mm without spines; tarsus not preserved. Metathoracic legs, 54.0 mm in length; femur 18.0 mm; tibia 36.0 mm without spines; tarsus not preserved. Wings poorly preserved, most of the venation is not visible. Wings length at least 61.0 mm.

Occurrence. Laminated limestone Crato Formation, Santana Group, Araripe Basin, Lower Cretaceous, Aptian. Specimen LP/UFC CRT 2698 was located at the quarry Triunfo, Nova Olinda city, Ceará state, northeastern Brazil.

Type material. Holotype (LP/UFC CRT 2698) is preserved as an impression in dorsal view. The specimen is housed in the scientific collection of the Laboratório de Paleontologia, Federal University of Ceará, Fortaleza, Ceará state, Brazil.

Etymology. The specific epithet is derived from “rest” (Latin). The name refers to poor preservation condition of the specimen.

Discussion. Our new fossil preserves characters which are consistent with Proscopiidae, such as short head, antennae longer than the prothorax, pronotum and postnotum with longitudinal carina, and visible wings. LP/UFC CRT 2698 differs from *Eoproscopia martilli* by presenting larger body length, larger head and antennae at least three times longer. Mesothoracic legs twice larger and Metathoracic legs slightly larger.

5 Discussion

The external morphological characteristics of Proscopiidae are very peculiar. The eyes of the proscopiids vary notably in correlation with the environment in which they inhabit (Uvarov, 1966; Bentos-Pereira, 2003). The first pair of legs divides the prothorax into two distinct parts. The legs are extremely homogeneous, varying only in presence or absence of well developed spines at the distal part of the femur. The medial dorsal carina is extremely fine (Bentos-Pereira, 2003). According to Heads (2008), *Eoproscopia* genus is a convergence of plesiomorphic and apomorphic characters. Developed wings and short head would represent plesiomorphs, whereas the absence of spines in the metathoracic tibia could be recognized as apomorphy. LP/UFC CRT 2698, as described here, fits into this genus. So far, the only fossil species of Proscopiidae is *Eoproscopia martilli* described by Heads (2008). The previous fossil Proscopiidae and our new specimen appear quite different, both in terms of overall body size and in the proportions of the antennae and head.

The antennae of *E. martilli* are 12 mm in length, where the last two antinomers are expanded distally. The antennae of LP/UFC CRT 2698 reach 40 mm in length, being much longer. The elongated head and fastigium are remarkable characters in most modern members of Proscopiidae. *Eoproscopia* differs somewhat from the extant proscopiids by having shorter head and fastigium (Heads, 2008). Due to post-diagenetic damage, it is not possible to visualize such characters in our fossil. Although, it is notable the head of LP/UFC CRT 2698 is larger than the previously described specimen. The third feature of note is a quite strongly distinct, and it is the most important factor that in determining our fossil as a new species. In overall size of body the new fossil reaches at least 80 mm in length, referring to the visible preserved portion, while *E. martilli* is approximately 50.5 mm, being considerably smaller. Overall, most Proscopiids exhibit marked sexual dimorphism, where females are larger than males (Domenico & Bentos-Pereira, 2011). The holotype of *E. martilli* is recognized as a female, thus the hypothesis that the LP/UFC CRT 2698 is a male of the same species is rejected.

Beyond to the typical laminated limestone, the Crato Formation is characterized by presenting several rupture structures. They strongly influence the development of discontinuities that often impart a well-developed break-induced permeability to rock. Miranda *et al.* (2012) identified fractures, joints (partially filled) and veins (filled by the recrystallized calcite) as the most often rupture structures in the Crato Formation. These extensional structures occur preferably in two main directions NNW e NE (Miranda *et al.*, 2012). Regarding the preservation mode, most of Crato insects are commonly encountered displaying orange to brown color. This style of preservation occurs in weathered limestone (Menon & Martill, 2007), sometimes associated with rupture structures (Miranda *et al.*, 2012). The orange-color insets are composed by spherical to sub-spherical microcrystals often regular in shape and size, interpreted as pyrite pseudomorphs replaced by goethite and/or limonite mineral later (Delgado *et al.*, 2014, Barling *et al.*, 2015, Osés *et al.*, 2016). Besides those goethite-replaced, Crato fossils also occur as black carbonaceous compressions (Osés *et al.*, 2017). Apparently, no taxonomic bias influences the Crato

insect preservation. The LP/UFC CRT 2698 is preserved on a single slab superimposed by two deformational structures (a vein is filled by recrystallized calcite), and both structures are parallel to each other.

The uplift of the Araripe plateau in the Upper Cretaceous and during the Oligocene or later (Moraes-Neto *et al.*, 2005-2006) promoted the establishment of fractures/faults facilitating the underground percolation of meteoric waters. The Fe-rich mineralization and sulfur-depleted phase suggests that sulfur-phase has probably been lost through limestone weathering. The preservational mode of LP/UFC CRT 2698 seems to represent a later version of the oxidized fossils. This fossil preservation style stands out as worst preservation type in the Crato Formation, when all fossil material is removed leaving only the fossil outline impression. It is possible to identify in some dispersed punctuations displaying orange color over LP/UFC CRT 2698. These punctuations represent remnants of fossil material that survived the intense process of dissolution. Undoubtedly, these structures contributed negatively to poor preservation of our fossil.

The phylogenetic position of the family has always been much discussed. Baum *et al.* (2007) tried unsuccessfully to support a sister relationship between Proscopiidae and Morabinae. Proscopiids have been considered as members of Eumastacoidea (Dirsh, 1961), although recent studies have positioned Proscopioidea within Proscopioidea (Matt *et al.*, 2008; Song *et al.*, 2015). According to Heads (2008), *Eoproscopia* represents the stem-group to extant Proscopiids. In any case, the presence of this phasmid-looking grasshopper family in the Crato Formation, attests that they were already established in South America even during the Lower Cretaceous. Heads (2008) suggested that proscopiids would be able to disperse throughout the tropical belt of northern Gondwana (African and South American continents). However, no Proscopioidea fossil has been found on the African continent to date, and the modern distribution of this family is restricting entirely to the Central and South America. Finally, the discovery of a new fossil species of Proscopiidae contributes to increase the diversity of this family in the fossil record. In addition, it confirms the South America as a dispersion zone for this group.

6 Conclusions

Most of the Proscopiidae representatives are restricted to living specimens. Here we describe the second fossil species of this family. The new species, *Eoprosopia reliquum* sp. nov., is assigned to Proscopiidae based mainly on the body size and in the proportions and in the *length of antennae*. *Eoprosopia reliquum* sp. nov., is poorly preserved (only identified in outline as an impression) due to a range of post-depositional events that did not favor the observation of taxonomic details with clarity. This discovery provides us new information about this family of orthoptera, especially regarding future phylogenetic and biogeographic analyses.

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