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First Late Triassic Record of a Paleoentomofauna from South America (Malargüe Basin, Mendoza Province, Argentina)

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Abstract: Late Middle Triassic to early Late Triassic insects from Argentina have been previously described from the Bermejo and Cuyana Basins where they have been recovered from the Ischichuca–Los Rastros and Potrerillos–Cacheuta Formations, respectively. The insect fauna discussed herein was collected during field studies in 1986/1987 from the Llantenes section (Norian to Rhaetian? Late Triassic), which is situated in the Malargüe Basin in southern Mendoza province. The insect remains were found in the upper part of the Llantenes section (Llantenes Formation), which is built up of two coarsening-upwards cycles reflecting a deltaic progradation of a fluvial into a lacustrine environment (lower part), succeeded by repeated progradations into a floodplain-dominated environment (upper part; with finds of insects, conchostracans, fish remains, plant fragments, and drifted logs). The new finds represent the youngest Triassic insect records described from Argentina and even from South America in its entirety. There is only one contemporaneous fossil assemblage in Gondwana: in the Clarence/Moreton Basin (Aberdare Conglomerate; Late Norian) in Australia. The new Triassic insects include an impression of an isolated Mecopterida-like wing (*Mendozachorista volkheimeri* gen. et sp. nov.; Mendozachoristidae fam. nov.), coleopteran elytra of the Permosynidae (*Ademosyne rosenfeldi* sp. nov. and *Ademosyne llantenesensis* sp. nov.) and other isolated body fragments. This new Late Triassic entomofauna from Argentina is of considerable importance in the reconstruction of the biotic recovery of continental environments in Gondwana after the catastrophic mass extinction at the P/T boundary.

Key words: Mecopterida, Coleoptera, Late Triassic, Llantenes Formation, Malargüe Basin, Argentina

1 Introduction

Triassic insect faunas from the Southern Hemisphere are known to be from different localities (e.g. Schlüter 1990, 2003). Their presence has been documented since the 19th century; the first record from South America was published by Kurtz (1921). An overview of insects from Argentina was given by Martins-Neto et al. (2003). Knowledge of the South American Triassic insect fauna has increased noticeably during recent years through the studies of our research team. This permits us to recognize the real insect diversity, the probable relationships of the Gondwanan Triassic insect biota, and their recovery after the drastic end-Permian extinction.

The history of research and the previously-described Triassic insect species from southern South America were discussed by Gallego (1997), Gallego and Martins-Neto (1999), Gallego et al. (2005), Martins-Neto and Gallego (1999, 2001, 2006, 2009), and Martins-Neto et al. (2003, 2005, 2006a,b, 2007). They were mainly collected from several levels of the Ischichuca and Los Rastros Formations (Bermejo Basin, Argentina), Potrerillos and Cacheuta Formations (Cuyana Basin, Argentina), Santa Maria Formation (Brazil), and Santa Juana Formation (Chile). Still unpublished is the record of new coleopteran levels from the Cortaderita Formation (Barreal–Sorocayense Basin, San Juan province, Argentina).

From the uppermost part of the Rincón Blanco section (Casa de Piedra Formation, also the Cuyana Basin) Hauschke (1988a, 1991) mentioned for the first time a coleopteran elytron, which unfortunately, is now lost.

In this contribution, we describe the first insect remains from the Late Triassic (Norian to Rhaetian?) upper section of the Llantenes Formation of the Arroyo Llantenes locality within the Malargüe Basin (Mendoza province, western Argentina). They were collected during field work in different continental Triassic

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outcrops within the Malargüe Basin in 1986/1987 by one of the authors (NH). Until now, this Triassic insect fauna had only been mentioned in context with the sedimentary sequence of the Llantenes section and the interpretation of the depositional environment by Hauschke (1988a, 1988b, 1989, 1991).

The new record presents the first insect association of Late Triassic (Norian to Rhaetian?) age in the Southern Hemisphere. The only other record from the Norian is a single nymph (*Samarura* sp., Odonata: Zygoptera; Rozefelds, 1985) from the Late Norian Aberdare Conglomerate in the Clarence/Moreton Basin in Australia.

2 Geological Setting, Facies, and Sedimentary Environment

During Triassic times, southern South America was part of the south–western margin of Gondwana. When Proterozoic to Paleozoic accretion processes came to an end, numerous rift basins evolved (e.g. Ramos, 1988, Spalletti, 2001, Jenchen and Rosenfeld, 2002), particularly in the western part of Argentina. Most of these basins form elongated depressions, which are directed north–west to south–east (Fig. 1). The Malargüe Basin is interpreted as a half-graben structure (Spalletti, 2001).

The basement of the Malargüe Basin consists of Choiyoi volcanics, which are overlain by unconformable siliciclastic Triassic deposits (Fig. 2). The sequence can be subdivided into two formations (Stipanicic and Marsicano, 2002), reflecting different stages of the Triassic rift. Sedimentation of the lower Chiuido Formation (lower facies unit; Fig. 3, left), which was controlled by subsidence, is interpreted as the early rift stage of the basin, whereas subsidence of the upper Llantenes Formation (upper facies unit; Fig. 3, right) was probably thermally controlled and is assigned to the late synrift to early postrift stage (Spalletti, 1997). Early studies on the sedimentary sequence were published by Stipanicic (1949) and Menéndez (1951). Systematic investigations taking into account the facies development and the sedimentary environment of the Triassic sequence in the Malargüe Basin were carried out for the first time by Hauschke (1988a,b, 1989). Hauschke et al. (1988) discussed sedimentological, geochemical, and palynological aspects, and in this context, palynological results from the Malargüe Basin could be presented for the first time. In detail, the microflora of the Chiuido Formation, which was determined as the youngest Triassic example from Argentina, was published by Volkheimer and Papú (1993). More recent investigations dealing with the Triassic of the Malargüe Basin were carried out by Spalletti and Morel (1992), and Artabe et al. (1995, 1998). In a broader context, the Malargüe Basin was discussed in terms of the relationship between tectonic activity, basin development, facies, and sedimentary environment of Triassic basins in Argentina (e.g. Spalletti, 2001; Jenchen and Rosenfeld, 2002).

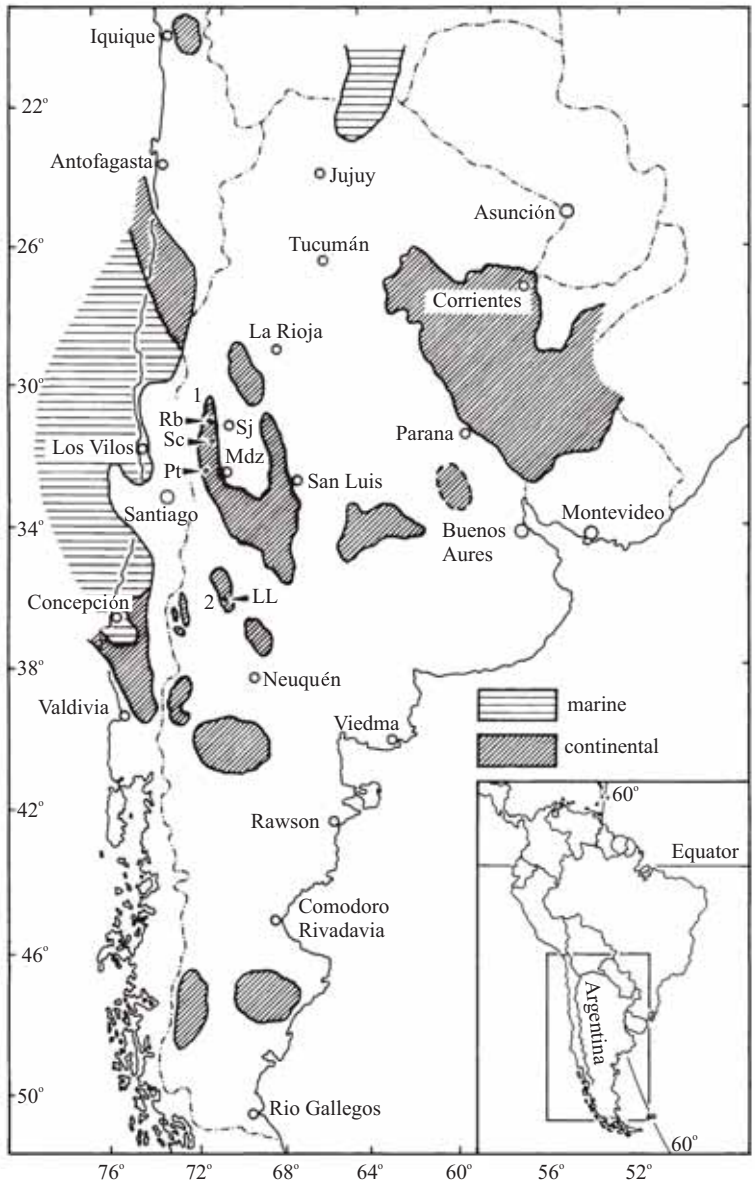

Fig. 1. Triassic sedimentary basins in southern South America (redrawn from Stipanicic, 1983, Rosenfeld and Volkheimer, 1986, and Hauschke, 1988a, b). In the northwestern part of the Cuyo Basin, the insect-bearing sections of Rincón Blanco (RB), and Potrerillos (PT) are marked (see arrows). Further south, the small Malargüe Basin with the Llantenes section (LL; see arrow) is visible. MDZ, Mendoza; SC, Santa Clara; SJ, San Juan.

Within the Malargüe Basin (Fig. 2), the Triassic sedimentary sequence can best be studied in the Llantenes section. The predominantly coarse-grained lower facies unit (Chiuido Formation) consists of a conglomeratic sedimentary unit, partly with intercalated logs, which is interpreted as proximal volcaniclastic deposits of a braided river or braid plain system. Repeatedly, breccias are intercalated. These breccias can laterally increase up to 60 m (Fig. 3, left), and are interpreted as alluvial fan deposits in more marginal parts of the basin (Hauschke 1988a,

1988b, 1989; Volkheimer and Papú, 1993; Spalletti, 1997).

The focus of the present paper is the upper facies unit (Llantenes Formation; Fig. 3, right). The characteristics for this part of the profile are two coarsening-upwards cycles, which were first published by Hauschke (1988a). All the insect remains, which are described here in greater detail, were found in the basal part of the upper cycle. The facies development of these two coarsening-upwards cycles shows considerable differences. With 56 m, the lower coarsening-upwards cycle measures half the thickness of the upper cycle. The lower cycle starts with gray, laminated pelitic sediments. Interstratified are fine-grained sandstone beds, usually without visible erosive basal contact (Fig. 4a). Some of these sandstone beds show deformation structures. Concentrations of plant debris are frequent in particular intervals of this unit. Above, a succession of coarsening-upwards sedimentary cycles follows, starting with siltstone and fine sandstone layers, which frequently contain plant debris, and ending with coarse-grained sandstones. This sedimentary unit is superimposed by coarse-grained, tabular cross-bedded, and lenticular, channel-like sandstones with conglomeratic intercalations (Fig. 4c). At the base of this sandstone body, mud pebbles are visible, which point to erosive processes. However, there is no convincing evidence for basal erosive contact. Deformational structures below the sandstone body point instead to penecontemporaneous gravitational processes (Fig. 4b). For the uppermost, deposition into erosion channels cannot be completely disregarded. However, for the uppermost unit of the lower coarsening-upwards cycle, which is a coarse conglomerate, an erosive contact is proven. Large tree trunks are intercalated (Fig. 4d). The lower coarsening-upwards cycle reflects a deltaic progradation of a fluvial into a lacustrine environment (Fig. 5; Hauschke, 1988a, b, 1989; Hauschke et al., 1988; Spalletti, 1997).

The upper coarsening-upwards cycle also shows a general increase in grain size from base to top, but a number of characteristics point to different paleoenvironments. This cycle also starts with gray shales and mudstones. Where the content of silt and fine sand increases, plant debris is frequent, whereas well-preserved leaves and other plant fragments appear only in distinct layers. In pelitic intervals, spinicaudatans are frequent. In one sediment layer, fish scales occur, and in another, some insects could be found (Figs. 6–8). Characteristics are a few calcareous layers and lenses, which are probably stromatolites. Intercalated in these fine-grained sediments are sandstone channels, which have an erosive base. At the base, mud pebbles frequently are concentrated. To the higher parts of this cycle, the content of sandstone increases, and also conglomeratic intercalations are more frequent. In individual sedimentary units, fining-upwards and coarsening-upwards trends could be observed. The upper coarsening-upwards cycle ends with an erosive channel with a coarse conglomeratic fill. This second coarsening-upwards cycle is interpreted as a fluvial system, which progrades into a floodplain-dominated environment or delta plain (Fig. 5; Hauschke, 1988a, b, 1989; Hauschke et al., 1988; Spalletti, 1997).

Fig. 2. Overview of the Llantenes region.
In the foreground, red pelites of the Jurassic Puchenque Formation are visible. Middle part of the photograph is occupied by the outcropping Triassic strata. In the background, the granitic complex of Cerro Chiuido is to be seen together with young volcanics. View from west to east. Distance between the position of the photographer and the Cerro Chiuido (at left-upper corner of the figure), about 5 km.

The Llantenes Formation is well known for its excellently preserved finds of plant fossils (Böhm, 1937; Stipanicic, 1949; Menéndez, 1951; Groeber and Stipanicic, 1953; Stipanicic, 1957, 1983; Stipanicic and Bonetti, 1969; Artabe and Morel, 1983, Artabe et al., 1995, 1998). Also, wood fragments could be found in some coarser-grained horizons. It is surprising that rooted sediments could not be found in the Triassic of Llantenes. However, rooted sedimentary sequences are extensively documented from other Triassic localities in Argentina; for example, from the Cuyana Basin (localities: Quebrada de Santa Clara and Rincón Blanco), as described and discussed by Hauschke (1991). Apart from this, the environmental situation in the upper part of the Llantenes Formation (upper coarsening-upwards cycle) seems to be very similar to that of the Casa de Piedra Formation of the Rincón Blanco section (Cuyana Basin).

The age of the Llantenes Formation was recently referred to by Morel et al. (2002) as upper Late Triassic, which corresponds to the paleofloristic Florian stage (Spalletti et al., 1999).

3 Material and Methods

The insect remains from the Llantenes section (Malargüe Basin) described in this paper were collected during field work in various Triassic Basins with continental sedimentary fill in 1986 and 1987 (Hauschke, 1988, 1989). The material will be deposited in the Paleoinvertebrate Collection (MCNAM–PI Nº 24527–MCNAM–PI Nº 24530) of the Museum of Natural and Anthropological Sciences “Juan Cornelio Moyano”, Mendoza, Argentina.

The morphological terminology adopted here for mecopteroid wing veins follows Kukalova-Peck (1991): ScP, posterior subcosta; RA, anterior radius; RP, posterior radius; MA, anterior

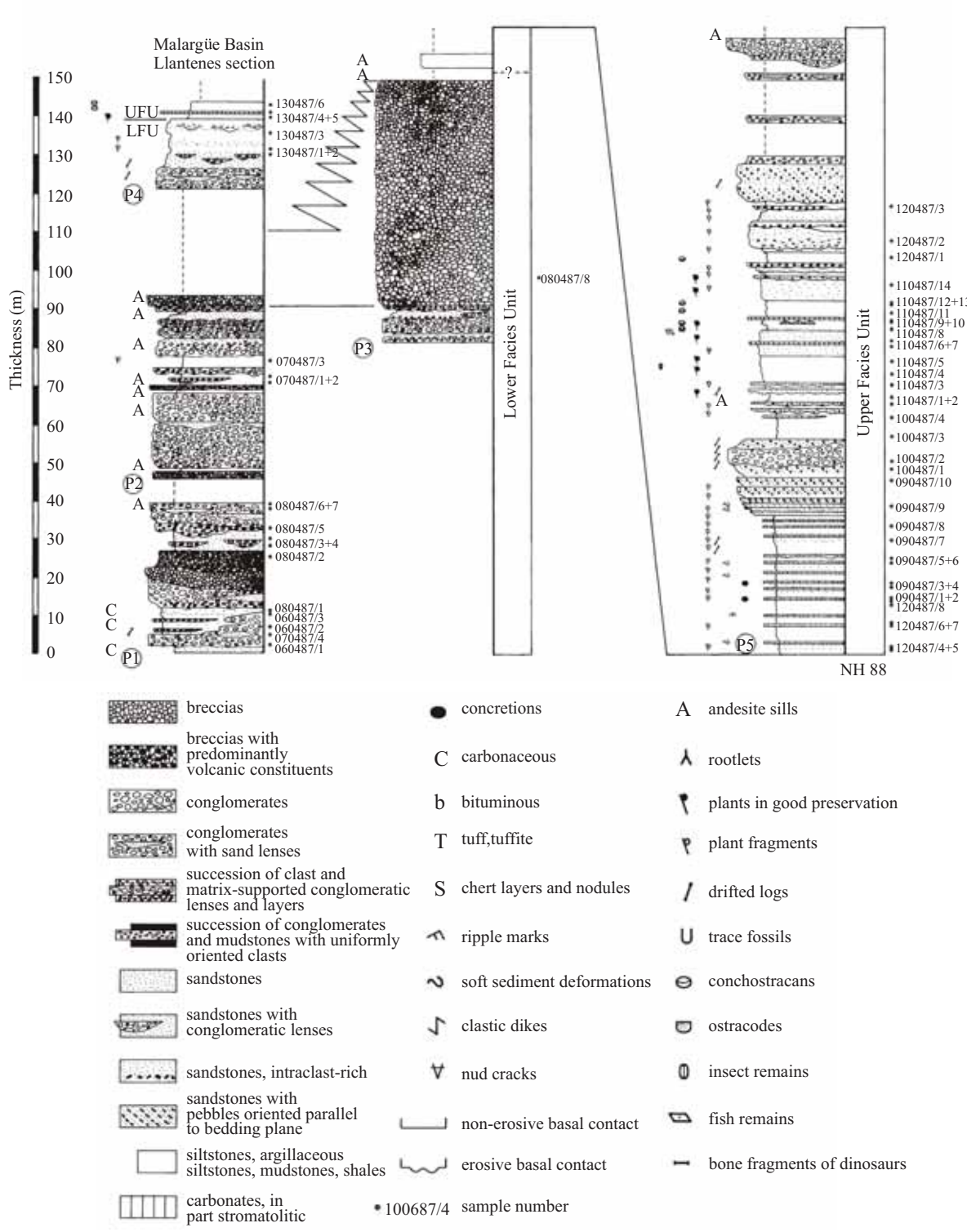

Fig. 3. Lower facies unit (Chiuido Formation) and upper facies unit (Llantenes Formation) in outcrops in the Llantenes section, the latter of which is built up of two coarsening-upwards cycles.
The insect-bearing horizon is in the middle part of the upper coarsening-upwards cycle. P1–P5 mark the individual studied sections, which were joined to the figured combined profile. Redrawn from Hauschke (1988a, b).

media; MP, posterior media; CuA, anterior cubitus; CuP, posterior cubitus; f, height from the main CuP curvature to d, in relation to the tegmen base; and d, anal area diagonal from CuP origin at CuP distal extremity, at the anal margin. The terminology used here for Coleoptera elytron follows Ponomarenko (1969) and Martins-Neto et al. (2006b).

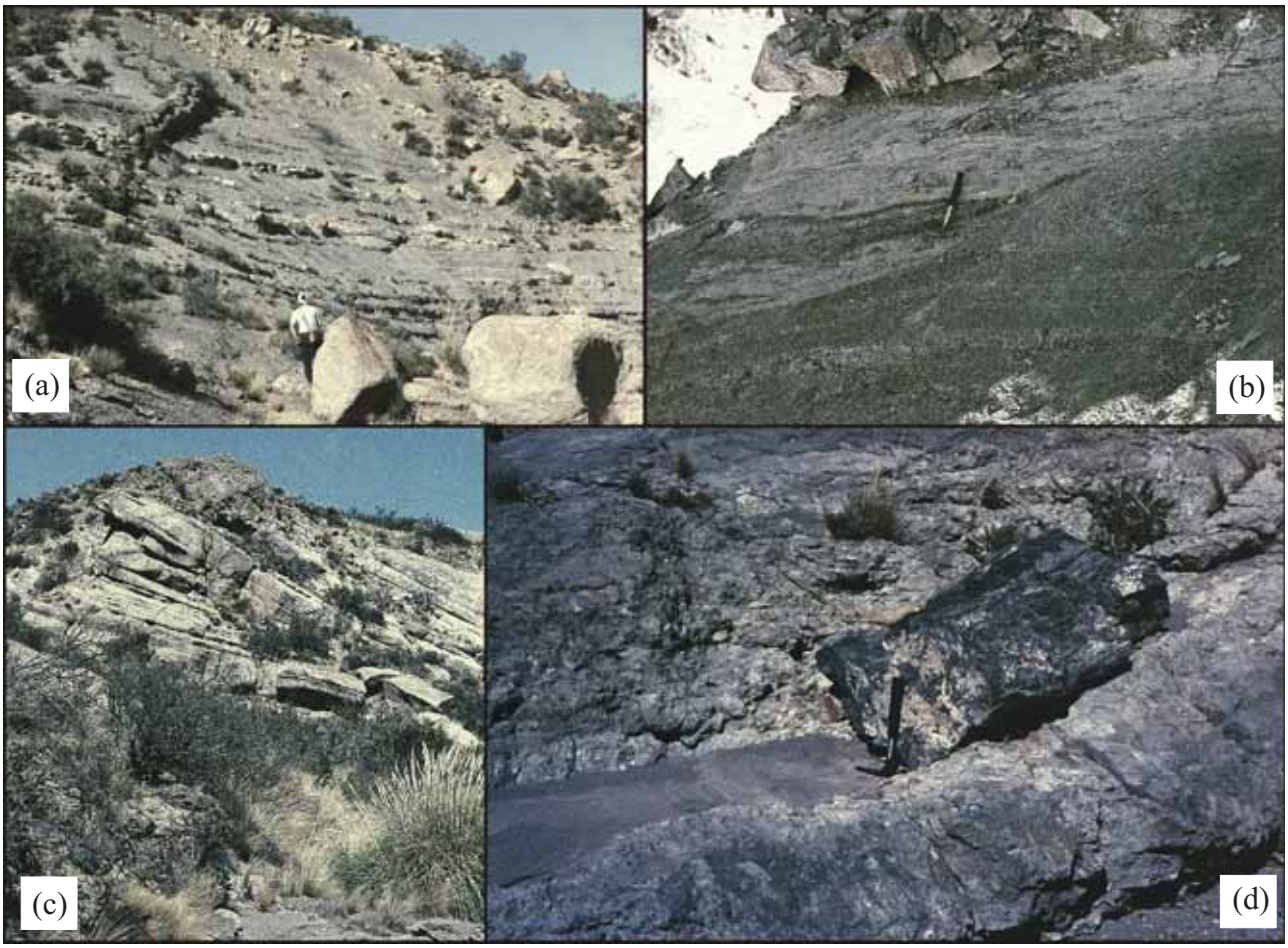

Fig. 4. Upper facies unit (Llantenes Formation) of the Llantenes section. Four photographs show different aspects of the facies development of the lower coarsening-upwards cycle.

(a) Basal part of the deltaic sequence, built up of predominantly pelitic sediments. Within the pelitic complex, fine-grained sandstone beds are intercalated. These sediments are interpreted as prodelta deposits. On the left side, an andesitic sill obliquely cuts the sedimentary sequence. (b) Predominantly gray and laminated pelites of the deltaic sequence, overlain by sandstones. Characteristics are syndepositional fault and slumping structures, which were probably produced by a high rate of sedimentation and the instability of the sediments. These sediments, which overlay the prodelta deposits, are interpreted as distal delta-front deposits. Hammer for scale. (c) Upper and predominantly sandy part of the deltaic sequence, showing a channel-like sedimentary body, which is in part, tabular cross-bedded. In the uppermost part of the sequence, the coarse-grained sandstone is cut by small channels, which are filled with conglomerates. This part of the lower coarsening-upwards cycle is interpreted as proximal delta-front deposits. (d) In the conglomeratic uppermost part of this cycle, drifted logs are intercalated. Hammer for scale.

4 Systematic Paleontology

?Stem group of Hymenoptera+Mecopterida or ?Trichoptera

Mendozachoristidae fam. nov.

Type (and only known) genus: *Mendozachorista* gen. nov.

Locality and horizon: "Arroyo" Llantenes locality, Llantenes section, Mendoza province, western Argentina; upper section of the Llantenes Formation (Tronquimalal Group, Malargüe Basin), Late Triassic (Norian to Rhaetian?).

Diagnosis: RP reduced (with only two distal branches); R, M, and Cu distally fused.

Discussion: Mendozachoristidae combine several plesiomorphic characteristics (e.g. anal veins without Y-shaped branches) with some conspicuous autapomorphies (reduced RP, distally fused R, M, and Cu). Therefore, we prefer to establish a separate family (probably endemic to Gondwana) closely related to the Permian Protomeropidae Tillyard (Carpenter, 1992). Several similar Mecoptera-like Permian and Triassic Endopterygota, like the Protomeropidae, are interpreted as a probable stem group of Hymenoptera+Mecopterida by Kukalová-Peck (1991). However, Ivanov and Sukatsheva (2002) assigned the Protomeropidae to the Trichoptera. The new material does not contribute a clear resolution to this debate.

Genus *Mendozachorista* nov.

Etymology: Mendoza+-chorista, a common name for Mecopterida and similar insects.

Type (and only known) species: *Mendozachorista volkheimeri* gen. et sp. nov.

Diagnosis: As for the family.

Discussion: As for the family.

Mendozachorista volkheimeri sp. nov. (Fig. 6a, b)

Etymology: The species name is dedicated to Wolfgang Volkheimer, Buenos Aires/Mendoza (Argentina) for his outstanding contributions to investigations of the Triassic in

Argentina.

Holotype (and only known) specimen: Forewing MCNAM–PI Nº 24527, to be deposited in the Paleoinvertebrate Collection of the Museum of Natural and Anthropological Sciences "Juan Cornelio Moyano", Mendoza, Argentina.

Type locality: "Arroyo" Llantenes locality, Llantenes section, Mendoza province, western Argentina.

Type stratum: Upper section of the Llantenes Formation (Tronquimalal Group).

Age: Late Triassic (Norian to Rhaetian?).

Diagnosis: As for the family and genus. Length of wing approximately 26 mm.

Preservation: Nearly completely preserved wing; from its general shape, most probably the forewing.

Measurements (in mm): Preserved length =25; total length (estimated) =26; maximal width =7.

Description: Shape narrow, oval anterior and posterior margin nearly symmetrical, apex rounded, anterior margin convex, posterior margin similar, but with smooth indentation slightly distally from anal area; ScA short, with two distal branches ending in anterior margin; ScP of moderate length, also ending in anterior margin; RA forked into only two branches, close to proximal fifth of wing length; origin of RP close to base of wing, with two branches, both fusing close to anterior margin; MA dichotomous, proximal fork close to base of wing, second forking close to mid-wing, further branching close to apex, several distal branches fusing around apex; MP simple, its origin at wing base; CuA forking shortly proximal of mid-wing, far distally with further branches, fusing close to posterior margin; CuP with three forkings and five distal branches ending in posterior margin between distal two-thirds of wing and close to wing base; Analis simple, very short; more prominent cross-veins mainly concentrated to precubital area (=area between MP and CuA).

Discussion: As for the family. This particular combination of plesiomorphies and apomorphies appears to be unique. For this reason, we establish a separate family, which seems to be close to Protomeropidae.

Coleoptera Linnaeus, 1758

Remarks: The new Triassic Coleoptera from the Llantenes section consists of three isolated elytra of the Permosynidae (MCNAM–PI Nº 24528–MCNAM–PI Nº 24530). Two of them are rather well preserved and are described here.

Permosynidae Tillyard, 1924 (including Ademosynidae Ponomarenko, 1969)

Remarks: For the relationships of the Permosynidae and Ademosynidae, and the authors´ position on this matter, see Martins-Neto and Gallego (2009) and Martins-Neto et al. (2007).

Genus Ademosyne Handlirsch, 1906

Type species: *Ademosyne major* Handlirsch, 1906, plate 39, fig. 14, from the Australian Triassic.

Ademosyne llantenesensis sp. nov. (Fig. 7a, b)

Etymology: The name of the species is allusive to the Llantenes Formation where the holotype comes from.

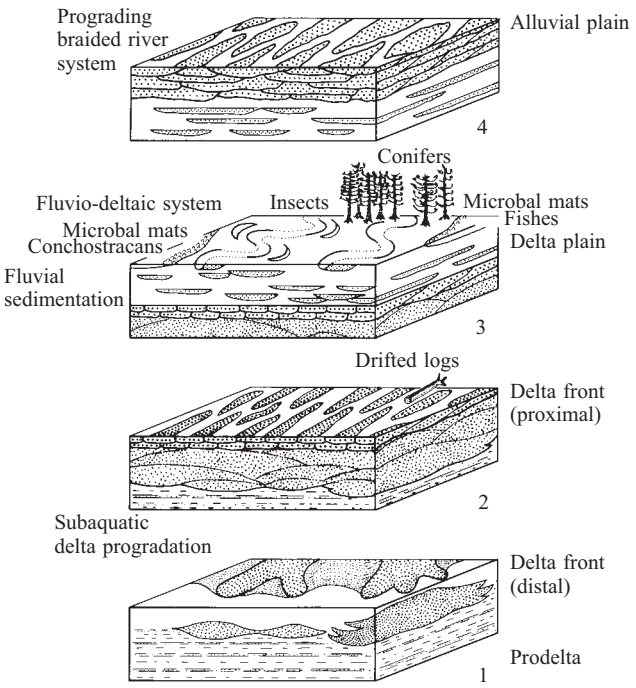

Fig. 5. Facies development and environment as interpreted from the two coarsening-upwards cycles (1 and 2 = lower cycle; 3 and 4 = upper cycle), which characterize the Llantenes Formation. Redrawn from Hauschke (1989).

Holotype (and only known) specimen: Incomplete right elytron MCNAM–PI Nº 24528, to be deposited in the Paleoinvertebrate Collection of the Museum of Natural and Anthropological Sciences "Juan Cornelio Moyano", Mendoza, Argentina.

Type locality: "Arroyo" Llantenes locality, Llantenes section, Mendoza province, western Argentina.

Type stratum: Upper section of the Llantenes Formation (Tronquimalal Group).

Age: Late Triassic (Norian to Rhaetian?).

Diagnosis: Very small, subtriangular elytron (ratio length/width =2.57), with 10 smooth and convergent costae, apex acute (rounded), sutural margin slightly convex, lateral margin strongly convex; ornamentation: small granules along the right side of the costae over the whole elytron surface, barely evident and poorly pronounced, regularly distributed.

Measurements (in mm): Preserved length =4.5, total length (estimated) =4.9, width =1.9 (ratio length/width =2.58).

Description: Right elytron with the characteristics shown in the diagnosis; proximal part irregularly broken off.

Discussion: *Ademosyne llantenesensis* sp. nov. differs from previously-described related species (i.e. *Ademosyne arcucciae*, *Ademosyne elongata*, *Ademosyne hexacostata*, *Ademosyne punctuada*, authors of all species: Martins-Neto and Gallego in Martins-Neto et al., 2006b, and *Ademosyne umutu* Martins-Neto and Gallego, 2009) by the following characteristics: ratio length/width: =2.58 (2 in *Ademosyne umutu*, 2.47 in *Ademosyne punctuada*, 2.72 in *Ademosyne hexacostata*, and 2.65 in

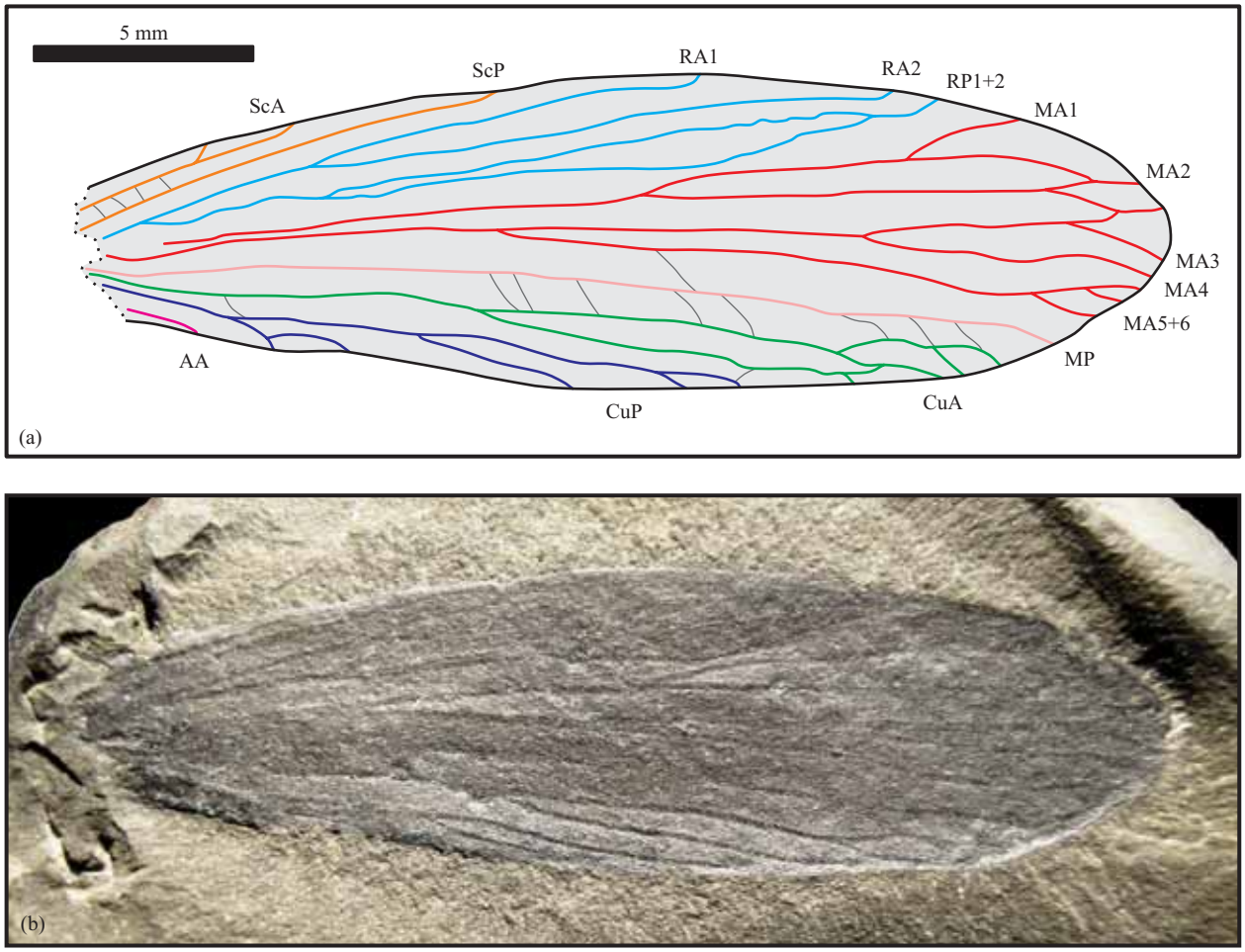

Fig. 6. *Mendozachorista volkheimeri* gen. et sp. nov., holotype specimen MCNAM–PI Nº 24527, isolated forewing; Late Triassic (Norian to Rhaetian), Llantenes Formation; Llantenes section, Malargüe Basin, Mendoza province, Argentina. (a) Drawing (Jan-Michael Ilger); (b) photograph.

Ademosyne arcucciae); number of costae =10 (11 in *Ademosyne elongata*, 9 in *Ademosyne arcucciae*, 6 in *Ademosyne hexacostata*, 6–9 in *Ademosyne punctuada*, and 7–8 in *Ademosyne umutu*); convergent costae (similar in *Ademosyne umutu*, but non-convergent in *Ademosyne arcucciae*, *Ademosyne elongata*, and *Ademosyne punctuada*, and subparallel in *Ademosyne hexacostata*); particular ornamentation: space between costae bearing small, homogeneously-distributed granules (not present in other previously-described species). The presence of this granular ornamentation is unique for *Ademosyne llantenesensis* sp. nov. and supports the erection of a new species.

Ademosyne rosenfeldi sp. nov. (Fig. 8a, b)

Etymology: The species name is dedicated to Ulrich Rosenfeld, Münster (Germany) for his outstanding contributions to investigations of the Triassic in Argentina.

Holotype (and only known) specimen: Right elytron MCNAM–PI Nº 24529, to be deposited in the Paleoinvertebrate Collection of the Museum of Natural and Anthropological Sciences "Juan Cornelio Moyano", Mendoza, Argentina.

Type locality: "Arroyo" Llantenes locality, Llantenes section, Mendoza province, western Argentina.

Type stratum: Upper section of the Llantenes Formation (Tronquimalal Group).

Age: Late Triassic (Norian to Rhaetian?).

Diagnosis: Small elytron of boat-like shape (ratio length/width =2.5), with 11 costae, convergent in the apical area, sutural and lateral margins with slight concavity ("shoulder"), lateral margin wide; lateral margin slightly convex at second proximal third and strongly convex apically; sutural margin slightly convex (more markedly in the terminal third part). Smooth costae and space between them.

Measurements (in mm): Total length =4.5, width = 1.8 (ratio length/width =2.5).

Description: Completely preserved right elytron with characteristics as shown in the diagnosis.

Discussion: In the diagnosis of *Ademosyne* by Dunstan (1923), the elytra are costate without abnormally-wide borders, while the number of costae or intervals, together with size, shape, and other features provide specific differences. The number of costae or intervals varies from eight to eleven, with nine generally present, and the variation in the length of the elytra varies between 1.8 and 6.2 mm. *Ademosyne rosenfeldi* sp. nov. has all the generic characteristics mentioned earlier. In this respect, it is more similar to *Ademosyne prisca* Riek (Molteno Formation, Late Triassic,

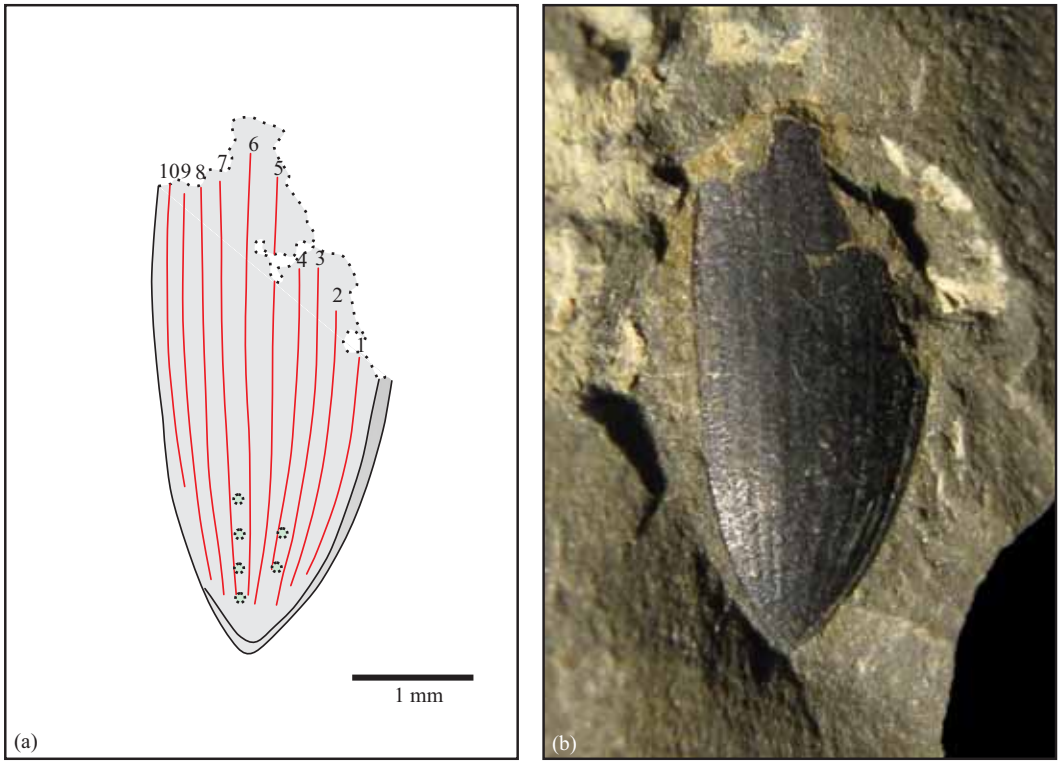

Fig. 7. *Ademosyne llantenesensis* sp. nov., specimen MCNAM–PI Nº 24528, isolated right elytron; Late Triassic (Norian to Rhaetian?), Llantenes Formation; Llantenes section, Malargüe Basin, Mendoza province, Argentina. (a) Drawing (Jan-Michael Ilger); (b) photograph.

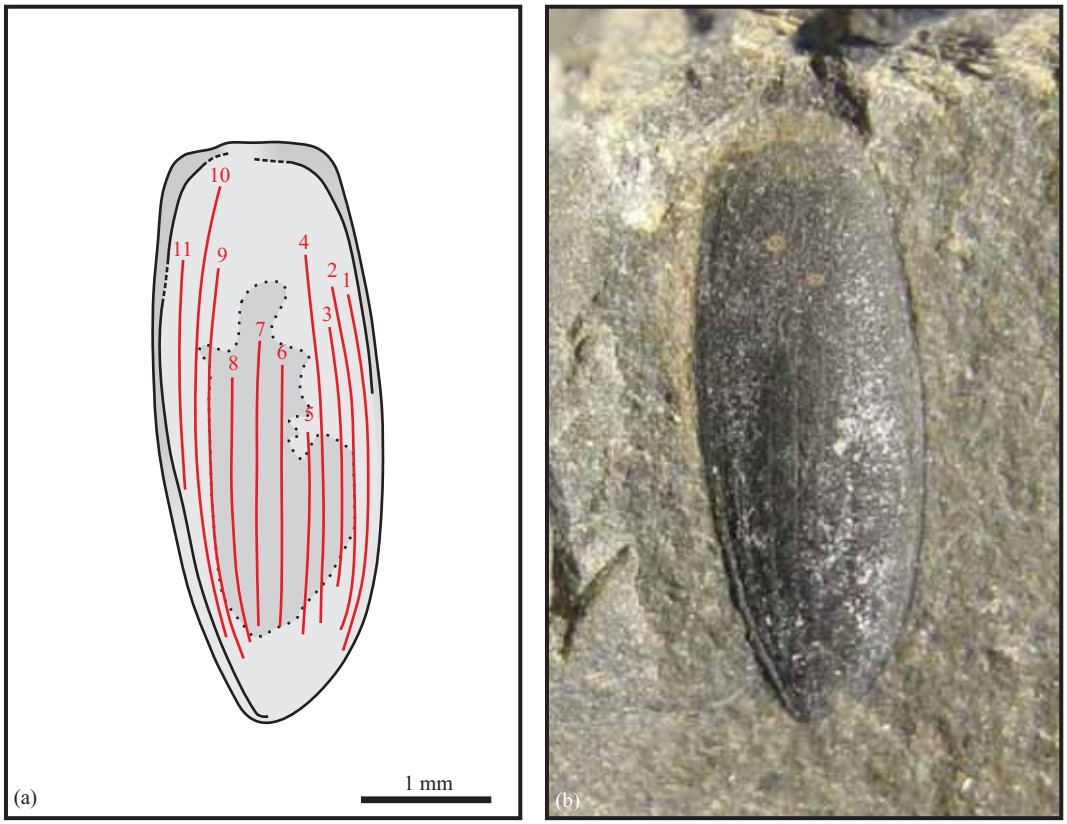

Fig. 8. *Ademosyne rosenfeldi* sp. nov., specimen MCNAM–PI Nº 24529, isolated right elytron; Late Triassic (Norian to Rhaetian?), Llantenes Formation; Llantenes section, Malargüe Basin, Mendoza province, Argentina. (a) Drawing (Jan-Michael Ilger); (b) photograph.

South Africa) in the general outline of the apical area and wide border of the lateral and sutural margins, but it differs in the basal area; the rounded basal lateral angle is continuously joined from the lateral to the basal margins. The new species also differs from *Ademosyne arcucciae*, the most frequent Triassic species from Argentina, in the number of costae (nine in *Ademosyne arcucciae*) and the presence of concavities in both the marginal and sutural margins. It shares with *Ademosyne elongata* the number of costae, but also differs by lacking the marginal and sutural concavities, its larger size, elliptical shape, and presence of square ornamentation between the costae.

5 Conclusions

The new records permit the first description of a Mecopterida-like wing from the Late Triassic of southern South America.

The presence of the new Coleoptera coincides with the record of other Triassic sequences in Argentina: Ischichuca–Los Rastros (Bermejo Basin) and Potrerillos–Cacheuta, each with great diversity and low density in the insect-yielding bed and with the fragmentary preservation of most of the elytra.

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