

First record of the fossil bee nest *Elipsoideichnus meyeri* from Argentina (Colón, Entre Ríos province)

Carlos CÓNSOLE-GONELLA^{“†”a,b}; Mariano VERDE^c; Silvina DE VALAIS^{a,d*}; Sebastián APESTEGUÍA^{a,c}; Ignacio DÍAZ-MARTÍNEZ^{a,d}; Pablo A. GALLINA^{a,c}; Federico A. GIANECHINI^{a,f}; Paolo CITTON^{a,d} and Florencio Gilberto ACENÓLAZA^b

Resumen: *PRIMER REGISTRO DEL NIDO DE ABEJA FÓSIL ELIPSOIDEICHNUS MEYERI DE ARGENTINA (COLÓN, PROVINCIA DE ENTRE RÍOS).* Se presenta el primer registro de la traza fósil *Elipsoideichnus meyeri* Roselli, 1987, de afloramientos de la cantera Prefectura Naval Argentina, Parque Nacional El Palmar, Colón (provincia de Entre Ríos), Argentina. *E. meyeri* consiste en un nido de abeja fósil helicoidal, hasta la fecha solo registrado en la Formación Asencio (Cuenca Norte) del suroeste de Uruguay. El nuevo espécimen fue encontrado en rocas tradicionalmente asignadas a la Formación Puerto Yerúa (Cuenca Chaco Paraná), consideradas del Cretácico Superior sobre la base del contenido paleontológico de estratos correlativos en el área, conformado por restos de dinosaurios y plantas. Sin embargo, el marco estratigráfico más confiable para la localidad de estudio debería mantener los nombres litoestratigráficos de la Cuenca Norte de Uruguay, siendo el principal argumento para la presencia de una discordancia regional entre las formaciones Guichón y Mercedes, lo que imposibilita la asignación de este nuevo registro a la Formación Puerto Yerúa. Las facies observadas y este nuevo registro en sí permitieron la asignación preliminar de los estratos portadores de *E. meyeri* de la Prefectura Naval Argentina a la Formación Asencio, reforzado por el registro que aquí se presenta ya que no existe evidencia tafonómica que apoye un transporte significativo horizontal o vertical del mismo. Sobre la asignación cronoestratigráfica de este registro, no existen elementos concluyentes para ubicarlo dentro del Cretácico Superior o Eoceno, siendo un hecho aún en análisis. Este registro amplía la distribución geográfica de este icnotaxón, permitiendo el desarrollo de nuevas investigaciones en el área, reabriendo interrogantes relacionados con la paleobiología y la cronoestratigrafía de abejas antiguas en esta zona del sur de América del Sur.

Abstract: We present the first record of the trace fossil *Elipsoideichnus meyeri* Roselli, 1987, from outcrops of the Prefectura Naval Argentina quarry, Parque Nacional El Palmar, Colón (Entre Ríos province), Argentina. *E. meyeri* consists of a singular helicoidal fossil bee nest, to date only recorded from the Asencio Formation (Norte Basin) of southwestern Uruguay. The new specimen came from rocks traditionally assigned to the Puerto Yerúa Formation (Chaco Paraná Basin), considered Upper Cretaceous

^a CONICET (Consejo Nacional de Investigaciones Científicas y Tecnológicas), ^b Instituto Superior de Correlación Geológica (INSUGEO; Universidad Nacional de Tucumán-CONICET), Miguel Lillo 205 (4000), Tucumán, Argentina. ^c Departamento de Paleontología, Instituto de Ciencias Geológicas, Facultad de Ciencias, Universidad de la República, SNI-ANII, PEDECIBA Geociencias, Iguá 4225 (11400), Montevideo, Uruguay. E-mail: verde@fcien.edu.uy, ^d Instituto de Investigación en Paleobiología y Geología (IIPG; Universidad Nacional de Río Negro-CONICET), Av. Roca 1424 (8332), General Roca, Río Negro province, Argentina. Email: sdevalais@yahoo.com.ar; inaportu@hotmail.com; pcitton@unrn.edu.ar, ^e Departamento de Paleontología, CCNAA (Fundación Azara - Universidad Maimónides), Hidalgo 775, C1405BCK, Buenos Aires, Argentina. E-mail: sapestegui@caece.edu.ar, pablogallina@gmail.com, ^f Instituto Multidisciplinario de Investigaciones Biológicas de San Luis (IMIBIO-SL; CONICET-Universidad Nacional de San Luis), Ejército de los Andes 950, D5700HHV, San Luis, Argentina, E-mail: fgianechini@email.unsl.edu.ar

* Corresponding author: Silvina de Valais, sdevalais@yahoo.com.ar

* Carlos CÓNSOLE-GONELLA^{“†”}

in age based on paleontological content of correlative strata in the area, composed of dinosaur and plant remains. However, the most reliable stratigraphic framework for the studied locality should keep the lithostratigraphic names of the Norte Basin of Uruguay, being the main argument for the presence of a regional unconformity between Guichón and Mercedes formations, which precludes the assignment of this new record to the Puerto Yeruá Formation. Observed facies and this new record itself allowed the preliminary assignation of Prefectura Naval Argentina *E. meyeri*-hosting strata to the Asencio Formation, which is reinforced by the record presented here itself due to there are no taphonomic evidence supporting significant transport horizontally or vertically. About the chronostratigraphic assignment of this record, there are no concluding elements to locate it within the Upper Cretaceous or Eocene, being a matter of fact and still in flux. This record expands the geographical distribution of this ichnotaxon, allowing the development of further research in this area and, re-opening questions related to the palaeobiology and chronostratigraphy of ancient bees in this area of southern South America.

Palabras clave: *Elipsoideichnus meyeri*. Nido de abeja fósil. Icnología. Formación Asencio. Argentina.

Key words: *Elipsoideichnus meyeri*. Fossil bee nest. Ichnology. Asencio Formation. Argentina.

Introduction

Fossil bees first appear in the geological record during the Cretaceous, both as body- and ichnofossils (Genise, 2016, 2020). Within the ichnological record, *Elipsoideichnus meyeri* Roselli, 1987 represents an uncommon and significant ichnotaxon, showing the highest observed complexity and bringing together rare examples of helicoidal invertebrate trace fossils (Verde and Genise, 2014). After the first description, *Elipsoideichnus meyeri* remained as a single specimen until the contribution by Verde and Genise (2014). In addition to the holotype, eight more specimens assigned to *Elipsoideichnus* were recovered from localities near Nueva Palmira, Dolores and Mercedes cities, all in southwest Uruguay (Verde and Genise, 2014), and one from a museum collection, expanding its distribution and enriching our knowledge about the ichnotaxon. All these discoveries came from the Asencio Formation (Norte Basin, Uruguay), a lithostratigraphic unit traditionally considered Upper Cretaceous (Maastrichtian) in age (see Veroslavsky *et al.*, 2019 and references therein), but for which an Eocene age has also been suggested according to different approaches (see Genise, 2016 and references therein).

Recently, during fieldworks at Prefectura Nacional Argentina quarry (Parque Nacional El Palmar, Entre Ríos province, Argentina), a new specimen assigned to *Elipsoideichnus meyeri*, the first outside Uruguay about 150 km north of the northernmost locality bearing the ichnotaxon known to date, was found (Figure 1). The main goals of this work are to present and describe this new record and discuss the lithostratigraphic assignment of the trace-bearing unit, its chronostratigraphy and geological correlations.

Geological and Stratigraphic Setting

The ichnological locality is situated in the Prefectura Nacional Argentina (hereafter PNA) quarry, which is located at the western margin of the Uruguay River, few meters from the coast, 35 km north Colón city, Entre Ríos province, Argentina (Figure 1).

The exposed stratigraphic framework of the Mesopotamia geological province comprises units ranging between Upper Jurassic/Lower Cretaceous and Miocene (Aceñolaza, 2007 and references therein). Although Chaco-Paraná Basin from Argentina and Norte Ba-

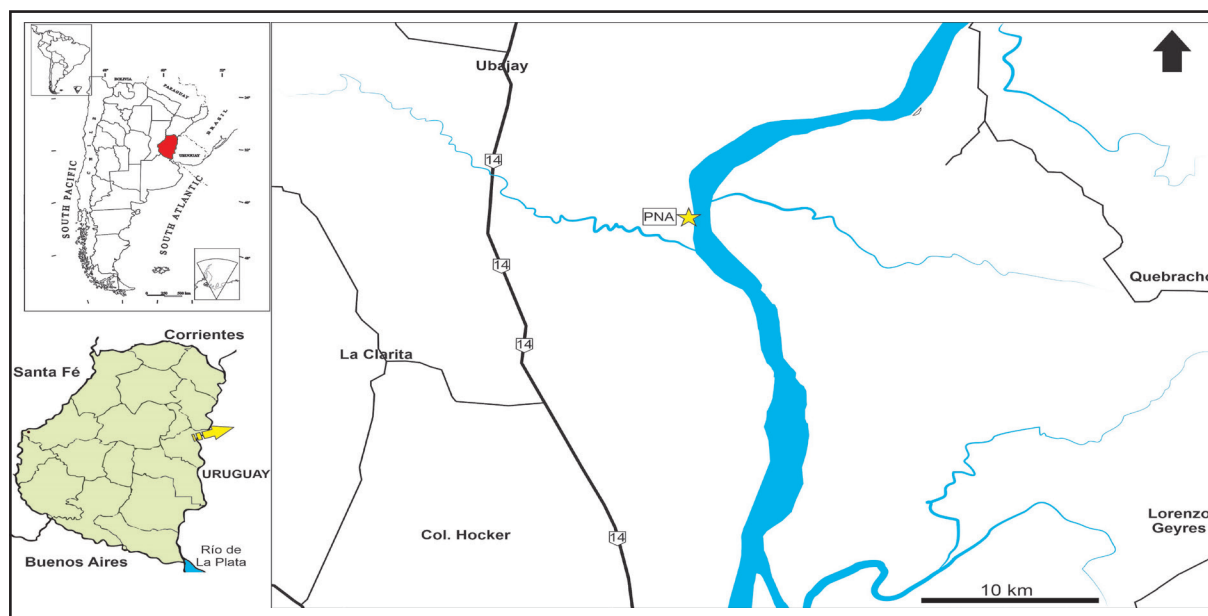


Figure 1. Location map of the Prefectura Naval Argentina quarry (PNA) within the Parque Nacional El Palmar of the Entre Ríos province (Argentina). The yellow star indicates the ichnofossiliferous location. Coordinates are: $31^{\circ}53'25,85''$ S – $58^{\circ}12'15,44''$ W. / **Figura 1.** Mapa de la ubicación de la cantera de la Prefectura Naval Argentina (PNA) dentro del Parque Nacional El Palmar de la provincia de Entre Ríos (Argentina). La estrella amarilla indica el sitio icnofosilífero. Coordenadas: $31^{\circ}53'25,85''$ S – $58^{\circ}12'15,44''$ O.

sin from Uruguay shared an overall common geological history, there are some differences related to different geological processes, besides disparities in nomenclature and also lithostratigraphic and/or genetic interpretations (e.g. Tófaló, 1986; Chebli *et al.*, 1989; Pazos *et al.*, 1998; Tófaló and Pazos, 2002; Bellosi and Genise, 2004, 2016; Goso and Perea, 2004; Aceñolaza, 2007; Morrás *et al.*, 2010; Tófaló *et al.*, 2008; Alonso-Zarza *et al.*, 2011; Genise, 2016; Veroslavsky *et al.*, 2019). Even if a comprehensive analysis of the whole regional stratigraphic framework is beyond the scope of this contribution, a brief description of more accepted backgrounds is needed in order to evaluate the significance of the new material in disentangling pending issues. A summary of regionally distributed units and their chronostratigraphical positions and relationships between Entre Ríos province and Uruguay is provided in Figure 2, which is our interpretation of more accepted schemes suggested by the literature. In Entre Ríos province, the two main stratigraphic discrepancies are related to the Upper Cretaceous-Eocene lapse. Figure 2.A displays

the first alternative, which suggests for Entre Ríos that the Upper Cretaceous-Danian lapse is represented by a single unit, the Puerto Yeruá Formation, which would be correlated in Uruguay with three units from bottom to the top: Guichón, Mercedes and Asencio formations, each one lying unconformably. At the right of the scheme, in Figure 2.B, the second alternative is observed, displaying these same units for Entre Ríos province, thus replacing the Puerto Yeruá Formation.

Trace fossil-bearing unit

Outcrops of the *Elipsoideichnus*-bearing unit from Argentina are distributed from the right margin of Uruguay River at Colón city and the Parque Nacional El Palmar, near Concordia city (Aceñolaza, 2007). Trace fossil-bearing strata at PNA section are made up of an averaging 15 m thick succession, with a 18 m maximum (see Tófaló, 1986; Figure 3). This succession is composed of about 10 m of alternated oxidized wackes and shales, with less proportion of wackestones, and wackestones dominance up to

gested by Genise (2000, 2016) and Verde and Genise (2014). High-resolution digital photogrammetry was undertaken to achieve a detailed representation of trace three-dimensional morphology. To model the studied specimen, the software package Agisoft Metashape Pro (Educational License), which enables creating 3D dense clouds and meshes by means of semi-automatic processing of images (Mallison and Wings, 2014), was used. The 60 images selected for the photogrammetric process were acquired using a digital camera, with 1.8 focal length and 4.032×3.024 pixels of resolution.

Ichnotaxonomy

CELLIFORMIDAE Genise, 2000

Elipsoideichnus Roselli, 1987

Diagnosis

Helicoidal tunnel, circular in cross section, with its main axis vertically oriented. Each whorl bears internally two cells, arising from opposite sides of the whorl and connected to it by means of short, elbowed, lateral tunnels. Openings of lateral tunnels are also helically arranged along the main tunnel. Cells are club-shaped, thick lined, and show spiral closures (after Verde and Genise, 2014: 27, modified from Genise, 2000).

Remarks

This ichnogenus is comparable to *Cellicalichnus* Genise, 2000, in showing cells connected by tunnels. Nevertheless, *Cellicalichnus* has

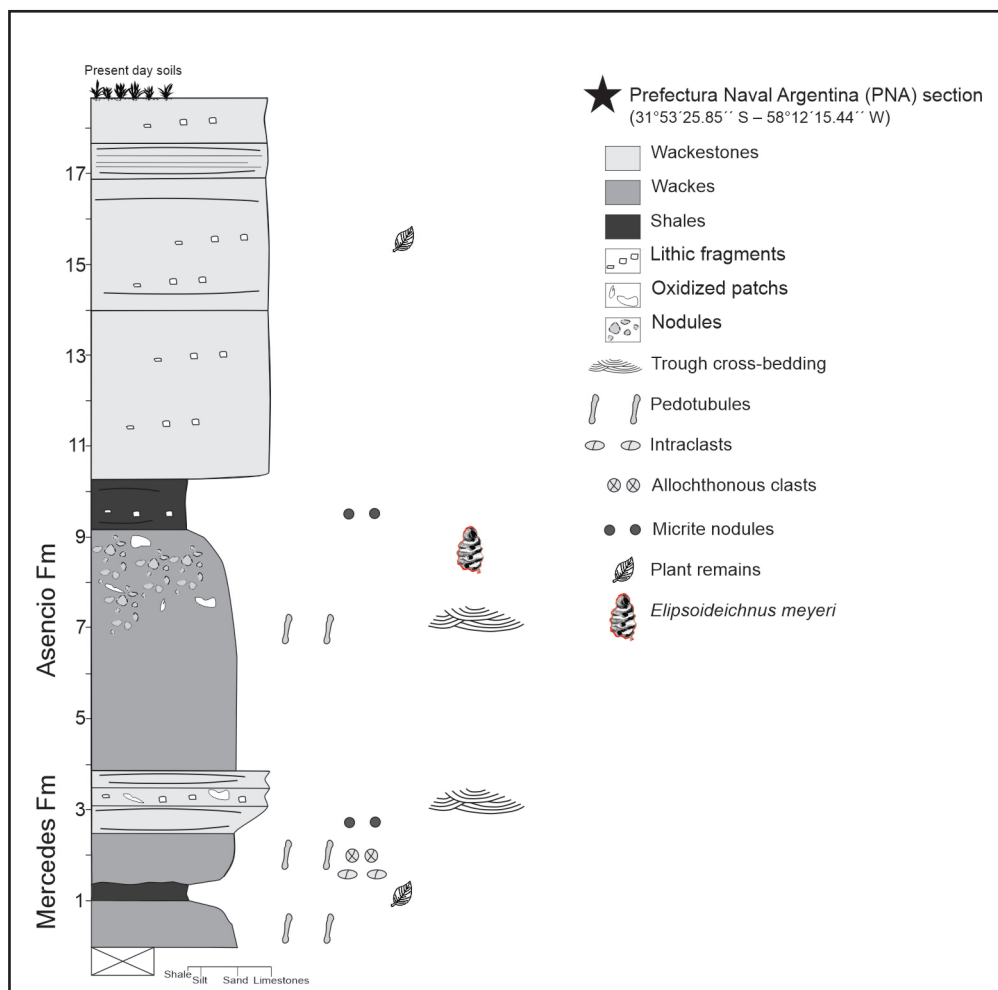


Figure 3. Integrated section of the Prefectura Naval Argentina quarry (PNA) in the Parque Nacional El Palmar of the Entre Ríos province (Argentina). Based on Tófaló (1986) and field data. / **Figura 3.** Sección integrada de la cantera de la Prefectura Naval Argentina (PNA) en del Parque Nacional El Palmar de la provincia de Entre Ríos (Argentina). Basado en Tófaló (1986) y datos de campo.

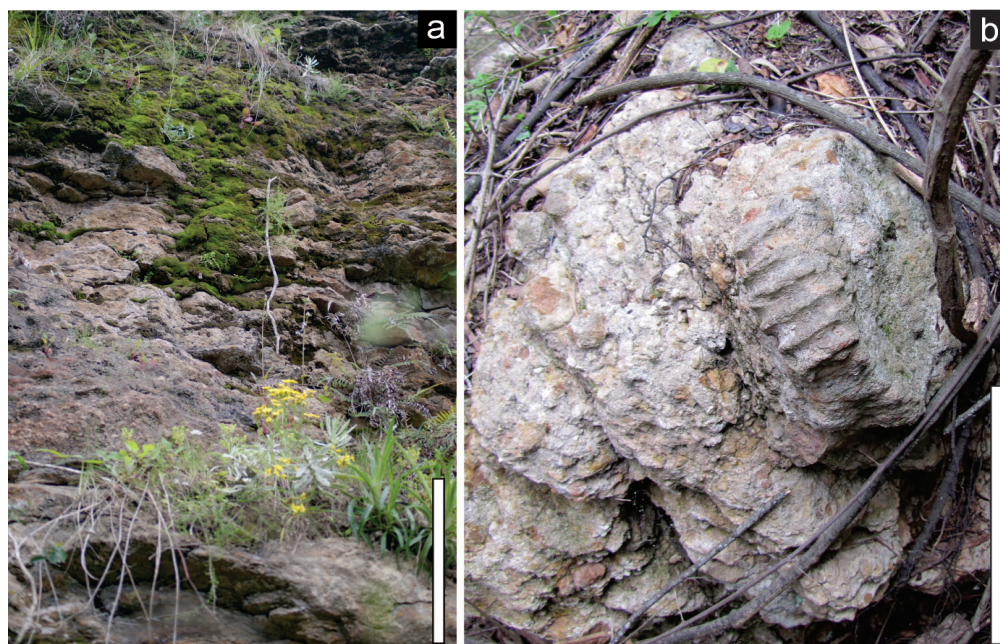


Figure 4. Outcrop views. **A.** Overall outcrop view. Scale bar: 50 cm. **B.** *E. meyeri* in situ. Scale bar: 10 cm. / **Figura 4.** Vistas del afloramiento. **A.** Vista general del afloramiento. Escala: 50 cm. **B.** *E. meyeri* in situ. Escala: 10 cm.

straight to slightly sinuous tunnels, whereas *Elipsoideichnus* has helicoidal ones (Verde and Genise, 2014). Verde and Genise (2014) made a detailed and extensive revision of the ichnogenus *Elipsoideichnus* and so it is not necessary to offer further comments here.

Elipsoideichnus meyeri Roselli, 1987

Type ichnospecies

Elipsoideichnus meyeri Roselli, 1987 by monotypy.

Provenance

PNA quarry, Parque Nacional El Palmar, Colón, Entre Ríos province, Argentina.

Coordinates: 31°53'25.85'' S – 58°12'15.44'' W; Figure 1).

Horizon

Asencio Formation (Upper Cretaceous or Eocene) (Bossi, 1966, after Pazos *et al.*, 1998).

Description

The specimen MAS-Pi-1007 consists of

one tridimensional structure (Figure 5), with a dominant cylindrical shape, slightly decreasing in diameter at both endings. It preserves the internal half of a helical tunnel formed of five whorls, each one having a diameter averaging 7.5 mm (Figure 5). The tunnel is 70 mm. long.

The structure is made up of fine grey (10Y 8/2, Munsell, 2009), yellowish (5Y 8/4, Munsell, 2009) and reddish (5R 6/6, Munsell, 2009) sandstone, slightly darker in colour and with finer texture (fine- to medium-grained sand) than host rock (coarse-grained sand to pebbles) (Figures 4, 5 and 6). The internal surface of the tunnel shows a smooth polished surface made of fine material (Figure 5), which is typical of previously recorded *E. meyeri* specimens.

Unfortunately, as occurs in all other recorded specimens (Verde and Genise, 2014), the external part of the helix lacks in the new material, precluding observation of the presence and possible features of external cells.

Discussion

Taphonomic and paleoenvironmental considerations

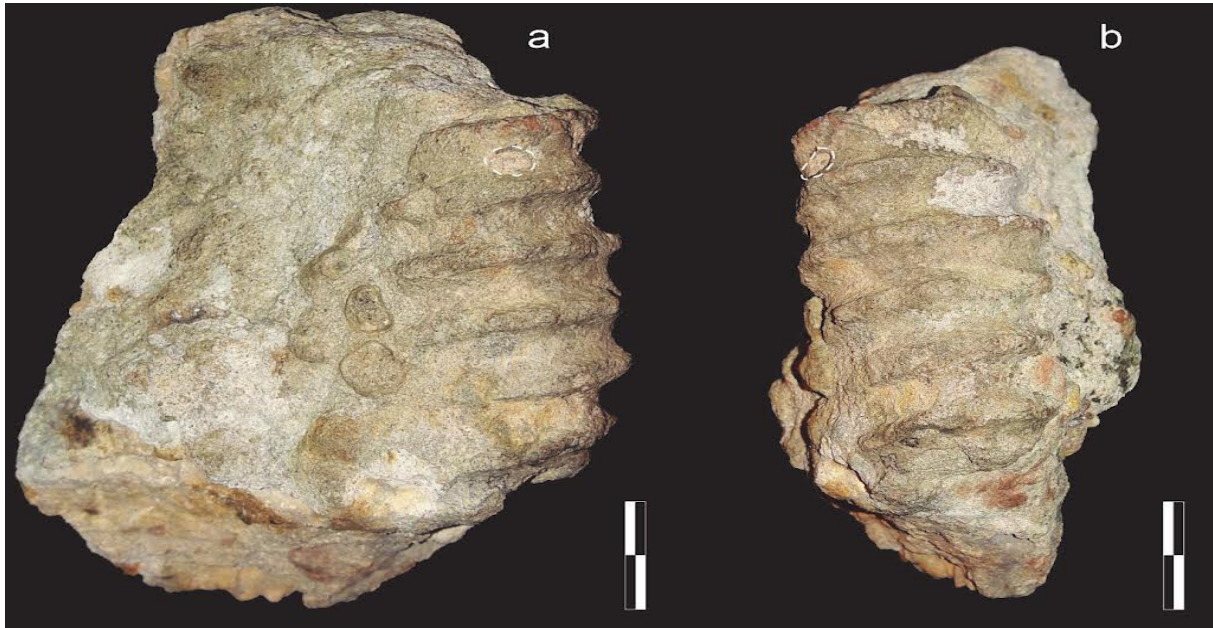


Figure 5. Specimen MAS-Pi-1007, *Elipsoideichnus meyeri*, from PNA quarry. **A.** Front view showing the helical tunnel and a tunnel entrance (dashed line). **B.** Lateral view showing the helical tunnel and a tunnel entrance (dashed line). Scale bars: 2 cm. / **Figura 5.** Especimen MAS-Pi1007, *Elipsoideichnus meyeri*, de la cantera de la PNA. **A.** Vista frontal que muestra el túnel helicoidal y la entrada del túnel (línea discontinua). **B.** Vista lateral que muestra el túnel helicoidal y la entrada del túnel (línea discontinua). Escala: 2 cm.

As mentioned above, *E. meyeri*-hosting facies are made up of reddish nodular edaphized wackes, with slightly trough cross bedding structures, oxidized patches and pedotubules (Figure 4). MAS-Pi-1007 is one of the most complete specimen of *E. meyeri* recorded until now. It was found in an almost vertical position (Figure 4), supporting the assumption that the construction position locates the helix axis oriented perpendicular to the bedding plane, as in the other specimens (see Genise and Hazeldine, 1998; Verde and Genise, 2014). However, some preservational features suggest some minor degree of rotation within the paleosol substrate after the construction of the nest. It is possible to distinguish vertically oriented, syn-depositional, or early post-depositional fractures, and two different patterns of diagenetic oxidation (Figure 6).

Interpretation

Observed symsedimentary features are probably related to the seasonal alternation and calcretization of floodplain soils (e.g. Tófaló, 1986; Tófaló and Pazos, 2002, 2010; Tófaló *et*

al., 2011; Tófaló and Morrás, 2009; Veroslavsky *et al.*, 2019). This process is sustained by paleoenvironmental data, suggesting a warm and humid to seasonally dry paleoclimate, in agreement with paleobotanical record (Franco *et al.*, 2015). Interestingly, taphonomic process proposed here can be likely related to those described by Bellosi *et al.* (2004, 2016) for the facies of Asencio Formation. *E. meyeri*-hosting facies at the PNA quarry strongly resembles nodular beds (NB) defined by Bellosi *et al.* (2004), who further developed these concepts, strengthening original assumptions and redefining the cycle (Asencio cycle) of facies development and ichnoassociations establishment during the Early Eocene Climatic Optimum (ECO). Each cycle included sedimentation, pedogenesis, ferricretization and dismantling, according to changes in accommodation space and precipitation, which have been recognized in quantities up to three in the Asencio Formation (Bellosi *et al.*, 2016). On this subject, a different approach was carried out by analyzing the contact between the Mercedes and Asencio formations, focusing on weathering processes between both units (Mo-

rrás *et al.*, 2010). Regarding the origin of nodular beds, the same authors proposed that nodular strata at the base of the Asencio Formation were originated by weathering that affected greyish sandstones of the Mercedes Formation, instead that by dismantling of duricrust (see in detail in Bellosi *et al.*, 2016; Figure 3).

Lithostratigraphical and chronostratigraphical provenance of *E. meyeri* and geological correlation

As mentioned before, there is not a single consensus about the regional stratigraphic framework. The assignment to the Puerto Yerúa Formation (e.g. Tófalo, 1986; Aceñolaza, 2007 and references therein) needs to be ruled out due to the existence of the regional unconformity between Guichón and Mercedes formations, which has been identified both in Uruguay and Argentina (Tófalo *et al.*, 2008) (see Figure 3 for comparisons). The most reliable alternative sus-

tains the stratigraphic scheme divided into these two units (e.g. Herbst, 1980; Chebly *et al.*, 1989). This approach is supported by the Stratigraphic Code of Argentina (see points 18.3, p. 15 and 28.c, p. 26; Comité Argentino de Estratigrafía, 1992).

A first possibility is to assign the *E. meyeri*-bearing strata to the Upper Cretaceous Mercedes Formation, or instead, to propose the belonging of these levels to the Eocene Asencio Formation. The background suggests both possibilities with about equal strength, beyond some discrepancies in the naming designation of units, already mentioned. Thus, a brief discussion should be appropriated.

Background supporting an Upper Cretaceous age

Several authors suggested a Cretaceous age for the succession exposed at PNA quarry, although following different stratigraphic

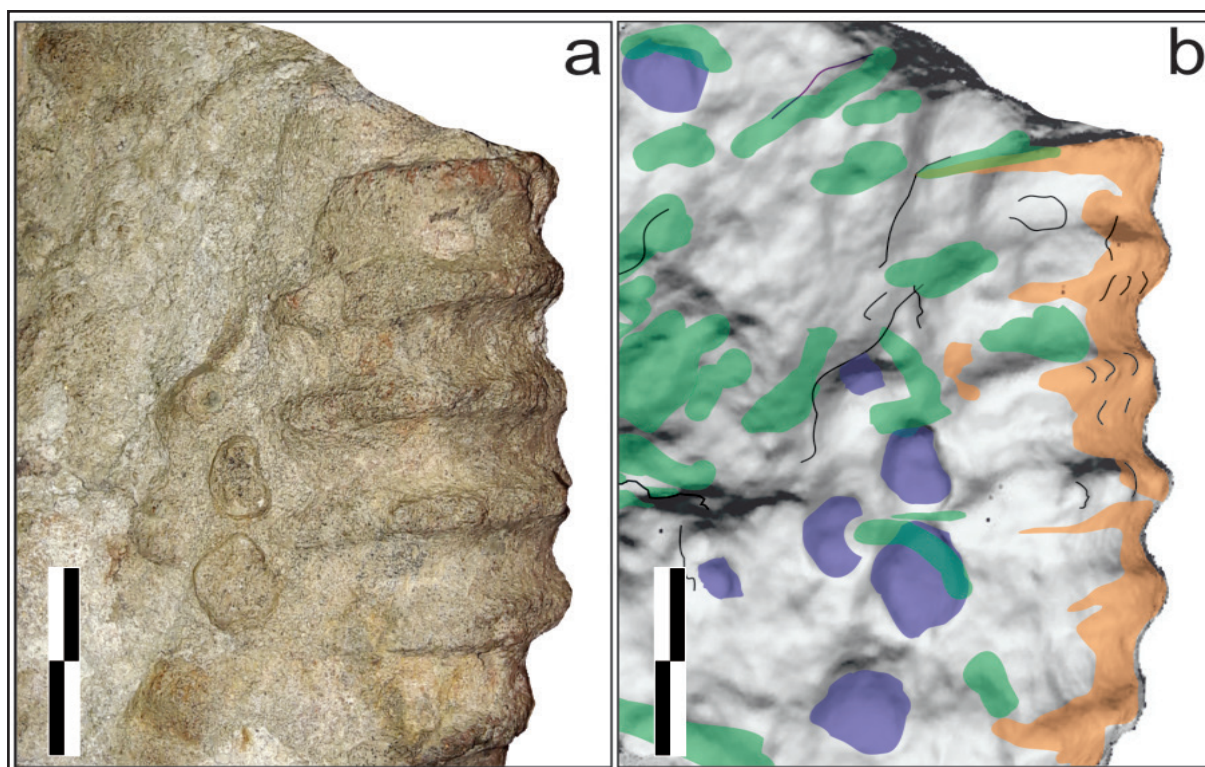


Figure 6. Taphonomic analysis of MAS-Pi-1007. **A.** Best preserved lateral view used to 3D digital modelling. **B.** Digital model. Orange: high level of weathering/oxidation. Green: moderate to low level of weathering/oxidation. Blue: lithified blocky soil (nodules) aggregates. Black lines: synsedimentary fractures. / **Figura 6.** Análisis tafonómico de MAS-Pi-1007. **A.** Vista lateral mejor conservada utilizada para modelado digital 3D. **B.** Modelo digital. Naranja: alto nivel de meteorización/oxidación. Verde: nivel moderado a bajo de meteorización/oxidación. Azul: agregados de suelo en bloques litificados (nódulos). Líneas negras: fracturas sinsedimentarias.

schemes and names of units. Alonso-Zarza *et al.* (2011) claimed that nodular and mottled limestones with rhizoliths inferred as pond deposits, assigned to the Upper Cretaceous Pay Ubre Formation, were identified at the same locality, one kilometer to the north of the present record locality (Alonso-Zarza *et al.*, 2011). The Pay Ubre Formation was defined by Herbst (1980) to include limestones outcropping in the Corrientes province, Argentina, and also in the Parque Nacional El Palmar area, Entre Ríos province, including specifically the Calera Barquín quarry, a dinosaur remain-bearing site (von Huene, 1929; Mannion and Otero, 2012), thus replacing the original assignment (i.e. Puerto Yeruá Formation). However, and taking into account the already-mentioned regional unconformity between Guichón and Mercedes formations, it should prevail the correlation of these levels with the Campanian Mercedes Formation (e.g. Herbst, 1980; Chebli *et al.*, 1989; G. Veroslavsky, pers.comm. 2020), or with the Asencio Formation but conferring it an Upper Cretaceous age (Cónsole-Gonella *et al.*, 2018).

From a paleontological point of view, a left humerus referred to an indeterminate titanosaur, recorded in the Calera Barquín quarry (Huene, 1929; Mannion and Otero, 2012), supports an Upper Cretaceous age (Aceñolaza, 2007). Moreover, de Valais *et al.* (2003) described some other dinosaur remains (i.e. one thoracic ankylosaur osteoderm, a theropod tooth and one titanosaurid egg fragment) from this unit, in the Ita-i-Corá and Arroyo Mármol localities, around 20 km and 10 km to the northwest respectively from the location reported in this contribution. The record of ankylosaurs in Argentina is restricted to Campanian-Maastrichtian (see Leanza *et al.*, 2004; Arbour and Currie, 2015). Interestingly, de Valais *et al.* (2003) also mentioned the record of another isolated dinosaur egg with similar features to the previous finding about 5 km north but lacking a stratigraphic position. Finally, a Lauraceae fossil wood assigned to *Paraperseoxylon septatum* Franco *et al.*, 2015, has been recovered near Puerto Yeruá vi-

llage, about 50 km to northeast of PNA quarry, mentioned as Cretaceous age.

Background supporting an Eocene age

A key approach to understanding this chronological assignment can be assessed properly after a brief review of the latest sedimentological/pedogenetic/ichnological background of the Asencio Formation (Bossi, 1966) in Uruguay. As mentioned above, the Asencio Formation is the unit hosting all the known *E. meyeri* specimens from Norte Basin.

Despite several contributions supporting an Upper Cretaceous age for the unit, or even Upper Cretaceous–Paleocene (e.g. Bossi *et al.*, 1975; Genise and Bown, 1996; Veroslavsky and Martínez, 1996; Veroslavsky *et al.*, 1997, 2019 and references therein), there are updated strong background suggesting an Eocene age. Bossi (1966) divided the Asencio Formation into two members, namely Yapeyú and Palacio, being the first lying transitionally over the Mercedes Formation. After Pazos *et al.* (1998), the Asencio Formation was restricted to the Palacio Member, due to the recognition of the Yapeyú Paleosurface, which is a regional unconformity involving two sedimentary cycles and an intensive edaphization process, under warm humid tropical weather. Genise and Bown (1996), Veroslavsky and Martínez (1996) and Pazos *et al.* (1998) recognized that levels belonging to the “Palacio Section” (sensu Pazos *et al.*, 1998) should represent paleosols development, instead that fluvial deposition as proposed by Ford (1988). More recently, Bellosi *et al.* (2004) elucidated the process related to the origin of the Asencio Formation facies. These authors established two interfingering facies, namely ferruginized duricrusts and nodular beds, exhibiting transitional to sharp contacts (Bellosi *et al.*, 2004). Necessary climatic conditions to allow this process are inferred as produced during the Paleogene Climate Optimum, thus an Eocene age was proposed (Bellosi *et al.*, 2004, 2016), and supported later by Morrás *et al.* (2010). Despite criticism of this age assignment

(see review in Veroslavsky *et al.*, 2019), the bulk of sedimentological/pedogenetic data seems to support an Eocene age.

Geological correlation

As mentioned before, within the Chaco-Paraná Basin, the Puerto Yeruá Formation has been traditionally assigned to the chronostratigraphic range comprising the Cenomanian-Maastrichtian (Upper Cretaceous) lapse (see reviews in Veroslavsky *et al.*, 2019; Tófaló and Pazos, 2002). Tófaló (1986), Tófaló *et al.* (2011) and Veroslavsky *et al.* (2019) claimed that the Guichón, Mercedes and Asencio formations, which belong to the Norte Basin in Uruguay, should be correlated with the Puerto Yeruá Formation of Argentina (see also Apesteuguía *et al.*, 2005). Goso and Perea (2004) correlated the Puerto Yeruá Formation (De Alba y Serra, 1959) with Guichón Formation (Lambert, 1939), both units from Argentina. In the same sense, Aceñolaza (2007) synonymised the Upper Cretaceous–Paleogene Puerto Unzué Formation (Gentili and Rimoldi, 1979) from the Norte Basin with the Guichón Formation and Puerto Yeruá Formation. With less strength in literature, an alternative possibility was to include PNA quarry within the also Cretaceous Pay Ubre Formation (e.g. Herbst, 1980; Alonso-Zarza *et al.*, 2011). As already mentioned, the assignment of trace fossil-bearing rocks at PNA quarry to the Puerto Yeruá Formation is questioned due to the existence of a regional unconformity between Guichón and Mercedes formations, which has been identified both in Uruguay and Argentina (Tófaló *et al.*, 2008, see Figure 2). Thus, following Tófaló *et al.* (2008), it would be more appropriate to correlate these units with those of Norte Basin, keeping the designation and division in between- Guichón and Mercedes formations (see Figure 2.B). This scheme has been already proposed by Herbst (1980) and later by Chebly *et al.* (1989) and agrees with the Stratigraphic Code of Argentina (see points 18.3, p. 15 and 28.c, p. 26; Comité Argentino de Estratigrafía, 1992). Thus, a more possible assignment for PNA

quarry would be to confer these strata to the Upper Cretaceous Mercedes Formation (Bossi, 1966), as a continuity with the Norte Basin of Uruguay, with a final Late Cretaceous–Early Cenozoic deposit of the calcareous Queguay Formation, as also occurs with the end of the Neuquen Group in Patagonia with the Roca Formation (see Apesteuguía *et al.*, 2015). However, as commented before, a further possibility is the assignment of *E. meyeri* PNA-hosting levels to the Eocene Asencio Formation (after Pazos *et al.*, 1998), which has been preliminarily proposed by Genise and Zelich (2001), and more recently by Cónsole-Gonella *et al.* (2018). Genise and Zelich (2001), based on the paleoichnological record, proposed a correlation between the Puerto Unzué Formation in Argentina with the Asencio Formation in Uruguay. These authors reported the record of *Teisseirei barattinia* Roselli, 1939, *Uruguay rivasi* Roselli, 1939, and *Palmirai-chnus castellanosi* Roselli, 1939 from two outcrops near the International Bridge General Artigas, which connects the Colón and Paysandú cities, about 65 km to the southeast of Parque Nacional El Palmar, Entre Ríos province (Genise and Zelich, 2001). In this sense, The ichnoassociation of the Asencio Formation seems to be indicative of Eocene age, due to the abundance and nature of associated dung beetle brood ball ichnotaxa, which are related to Eocene large-sized mammals (see review in Genise, 2016). Besides, from a sedimentological and edaphological standpoint, the presence of laterites in the Asencio Formation is only compatible for this latitude with the Early Eocene Climatic Optimum (Belloussi *et al.*, 2016).

Interestingly, Souza Carvalho *et al.* (2009) have described a single specimen of *Coprinisphaera* from the Adamantina Formation in Brazil (Bauru Basin), whose age is Upper Cretaceous (Turonian–Santonian). In this sense, Verde (2012) reported the presence of four individuals of *Coprinisphaera murguiai* in levels of the Upper Cretaceous Mercedes Formation of Uruguay. More recently, Sedorko *et al.* (2019) found structures assigned to *Coprinisphaera* from the Upper Cretaceous Capacete Formation

(Sanfranciscana Basin), also in Brazil. However, until the present date, there are no reliable records older than Eocene age in Argentina and Uruguay (see review in Genise, 2016).

Keeping into account the overall background, it seems clear that the chronostratigraphy and genesis of the Asencio Formation and its relationship with the counterpart in Argentina are not totally solved, being a topic still in development that exceeds the aims of this contribution.

Concluding remarks

A new record of *E. meyeri* reinforces the validity of this rare ichnotaxon, besides opening a new window to further research on insect trace fossils and providing new elements about the chronostratigraphy, geological correlation and sedimentary environments between Chaco Paraná and Norte basins and related areas in South America. Based on the bulk of stratigraphic, sedimentological, and paleopedogenetic data in the literature, the most reliable stratigraphic framework for the studied area should keep the nomenclature adopted in the Norte Basin of Uruguay. This has been stressed by several contributions, being the main argument the presence of a regional unconformity between Guichón and Mercedes formations, which precludes the assignment of this new record of *E. meyeri* to the Puerto Yeruá Formation. Thus, there are two remaining possibilities: 1- the assignment to the Mercedes Formation, and 2- the assignment to the Asencio Formation. Observed facies similarities of hosting strata between studied trace-bearing outcrops and those of the Asencio Formation in Uruguay, allow the preliminary assignation of PNA strata to this unit. This is reinforced by the record presented here, and due to taphonomic elements supporting the lack of significant horizontal or vertical transport. Regarding the chronostratigraphic assignment of this record, there are no concluding elements to locate it within the Upper Cretaceous or Eocene, being as matter

of fact an issue still in flux. There are some elements suggesting that *Elipsoideichnus*-bearing deposits in Entre Ríos are Upper Cretaceous in age, as some laterally correlatable strata hosting dinosaur remains. At the same time, the ichnological record and some paleopedogenetic/paleoenvironmental interpretations suggests an Eocene age. Further research is needed to solve this geological/stratigraphic riddle. For the time being the new specimen, which represents the first record of *Elipsoideichnus meyeri* from Argentina, enriches the scarce record of the ichnotaxon and improves our knowledge of fossil bee nests.

Acknowledgements

The authors thank to authorities of the Museo de Ciencias Naturales y Antropológicas Prof. A. Serrano (Paraná, Entre Ríos province) for allowing the permits to explore the area under the projects (to S. Apesteuguía) “Los tetrápodos del Cretácico de Entre Ríos: Una aproximación faunística e icnológica” of 2012 to 2014 (decreto N° 187 MCyC), extended to 2017 (decreto N° 760 MCyC), and “Estudio geopaleontológico del Cretácico de Entre Ríos” of 2017 (decreto N° 3164 MCyC del 25 de septiembre de 2017), extended to 2020. Authorities of the Parque Nacional El Palmar also allowed the corresponding permits and guards of Prefectura Naval Argentina allowed the access to the coastal cliffs. To A. Ernst for field support and to the community of Colón, Villa Elisa and El Palmar for their kindness and support. Finally, to G. Veroslavsky (Udelar, Uruguay) for his fruitful comments during the course of this work and two anonymous reviewers who improved the original version of this work. Fieldworks were financial and logistic supported by Fundación Azara.

References

- Aceñolaza, F.G. 2007. Geología y Recursos Naturales de la Mesopotamia Argentina. *Serie Correlación Geoló-*

- gica, 22, 160 pp.
- Alonso-Zarza, A.M., Genise, J.F. and Verde, M. 2011. Sedimentology, diagenesis and ichnology of Cretaceous and Palaeogene calcretes and palustrine carbonates from Uruguay. *Sedimentary Geology*, 236: 45-61.
- Apesteuguía, S., Gallina, P. A., Gianechini, F. A., Soto, M. y Perea, D. 2015. Dinosaurios cretácicos del Triángulo Minero (Grupo Baurú, Brasil), el Grupo Paysandú (Uruguay Occidental) y la Cuenca Neuquina (Grupo Neuquén, Argentina). In *Fósiles de Vertebrados e Plantas do Período dos Dinossauros da Região do Triângulo Mineiro (C.R.A. Candeiro y L.S. Avilla, Eds.)*. Letra Capital: 185-241.
- Arbour, V.M. and Currie, Ph.J. 2015. Systematics, phylogeny and palaeobiogeography of the ankylosaurid dinosaurs. *Journal of Systematic Palaeontology*, 14: 385-44.
- Belosi, E.S., Genise, J.F. and González, M.G. 2004. Origen y desmantelamiento de lateritas paleógenas del sudoeste del Uruguay (Formación Asencio). *Revista del Museo Argentino de Ciencias Naturales*, 6: 25-40.
- Belosi, E.S., Genise, J.F., González, M.G. and Verde, M. 2016. Paleogene laterites bearing the highest insect ichnodiversity in paleosols. *Geology*, 44: 119-122.
- Bossi, J. 1966. Geología del Uruguay. *Departamento de Publicaciones de la Universidad de la República*, Montevideo, 469 pp.
- Bossi, J., Ferrando, L., Fernández, A., Elizalde, G., Morales, H., Ledesma, J., Carballo, E., Medina, E., Ford, I. and Montaña, J. 1975. Carta geológica del Uruguay, a escala 1:1.000.000. Dirección de Suelos y Fertilizantes, Montevideo.
- Brown, R.W. 1934. *Celliforma spirifer* the fossil larval chambers of mining bees. *Journal of the Washington Academy of Sciences*, 24: 532-539.
- Chebli, G., Tófaló, O.R. and Turazzini, G. 1989. "Mesopotamia", Simposio de Cuencas Sedimentarias Argentinas. Argentina. *Serie Correlación Geológica*, 6: 79-100.
- Comité Argentino de Estratigrafía. 1992. *Código Argentino de Estratigráfica*. Asociación Geológica Argentina, Serie B (Didáctica y Complementaria), 20: 1-64, Buenos Aires.
- Cónsole-Gonella, C., Verde, M., Aceñolaza, F.G., de Valais, S. and Apesteuguía, S. 2018. Primer registro en Argentina de *Ellipsoideichnus meyeri* Roselli 1987 (Formación Puerto Yerúa o Asencio?: Cretácico superior – Eoceno), Colón, Entre Ríos. Problemas geológicos y cronoestratigráficos. *I Simposio del Cretácico del río Uruguay* (Colón, Entre Ríos, Argentina), Abstracts: 5 p.
- De Alba, E. and Serra, N. 1959. Aprovechamiento del Río Uruguay en la zona de Salto Grande. Informe sobre las condiciones y características geológicas. *Anales de la Dirección Nacional de Geología*, 11, 35 pp.
- De Valais, S., Apesteuguía, S. and Udrizar Sauthier, D. 2003. Nuevas evidencias de dinosaurios de la Formación Puerto Yerúa (Cretácico), Provincia de Entre Ríos, Argentina. *Ameghiniana*, 40: 631-635.
- Ford, I. 1988. Conglomerados con nidos de insectos fósiles: Formación Palmitas (Provisorio) – Terciario inferior (Tentativo). *6° Panel de geología del litoral and 1° Reunión de geología del Uruguay* (Salto, Uruguay), Abstracts: 47-49 p.
- Franco, J.M., Brea, M., Passeggi, E. and Pérez, L.M. 2015. The first record of Lauraceae fossil woods from the Cretaceous Puerto Yerúa Formation of eastern Argentina and palaeobiogeographic implications. *Cretaceous Research*, 56: 388-398.
- Genise, J.F. 2000. The ichnofamily Celliformidae for *Celliforma* and allied ichnogenera. *Ichnos*, 7: 267-282.
- Genise, J.F., Belosi E.S., Sarzetti, L.C., Krause, J.M., Dinghi, P.A., Sánchez, M.V., Umazano, A.M., Puerta, P., Cantil, L.F. and Jich, B.R. 2020. 100 Ma sweat bee nests: Early and rapid co-diversification of crown bees and flowering plants. *PLoS ONE*, 15(1): e0227789. <https://doi.org/10.1371/journal.pone.0227789>.
- Genise, J.F. 2016. *Ichnoentomology. Insect traces in soils and paleosols*. Topics in Geobiology, 37. Springer International Publishing Switzerland, 695 pp.
- Genise, J.F. and Bown, T.M. 1996. *Uruguay Roselli* 1938 and *Rosellichnus*, n. ichnogenus: two ichno genera for cluster of fossil bee cells. *Ichnos*, 4: 199-217.
- Genise, J.F. and Hazeldine, P.L. 1998. 3D-Reconstruction of insect trace fossils: *Ellipsoideichnus meyeri* Roselli. *Ichnos*, 5: 167-175.
- Genise, J.F. and Zelic, M.R. 2001. Trazas fósiles de insectos de la Formación Puerto Unzué (Cretácico Superior-Paleógeno) de Entre Ríos. *4° Reunión Argentina de Icnología and 2° Reunión de Icnología del Mervosur* (Tucumán), Abstracts: 44.
- Gentili, C.A. and Rimoldi, H.V. 1979. Mesopotamia. In: Academia Nacional de Ciencias en Córdoba (ed.), *Geología Regional Argentina*, Abstracts 1: 185-224.
- Goso, C.A. and Perea, D. 2004. El Cretácico post-basáltico de la Cuenca Litoral del Río Uruguay: geología y paleontología. In: Veroslavsky, G., Ubilla, M. and Martínez, S. (eds.), *Cuencas sedimentarias de Uruguay: geología, paleontología y recursos minerales – Mesozoico*. DIRAC, Facultad de Ciencias, Montevideo, pp. 141-169.
- Herbst, R. 1980. Consideraciones estratigráficas y litológicas sobre la Formación Fray Bentos (Oligoceno inferior-medio) de Argentina y Uruguay. *Revista de la Asociación Geológica Argentina*, 35: 308-317.
- Huene, F. von. 1929. Los saurisquios y ornitisquios del Cretácico argentino. *Anales del Museo de La Plata*, 196 pp.
- Lambert, R. 1939. *Memoria explicativa de la Carta Geológica de los terrenos sedimentarios y las rocas efusivas del de-*

- partamento de Durazno. Instituto Geológico del Uruguay, Boletín N°25: 1-37.
- Leanza, H.A., Apesteguía, S., Novas, F.E. and de la Fuente, M.S. 2004. Cretaceous terrestrial beds from the Neuquén basin (Argentina) and their tetrapod assemblages. *Cretaceous Research*, 25: 1-96.
- Mallison, H. and Wings, O. 2014. Photogrammetry in Paleontology - A practical guide. *Journal of Paleontological Techniques*, 12: 1-31.
- Mannion, P.D. and Otero, A. 2012. A reappraisal of the Late Cretaceous Argentinean sauropod dinosaur *Argyrosaurus superbus*, with a description of a new titanosaur genus. *Journal of Vertebrate Paleontology*, 32: 614-638.
- Morrás, H., Tófaló, O.R. and Sánchez Betucci, L. 2010. Weathering processes at the boundary between the Mercedes (Cretaceous) and Asencio (Eocene) formations, Southwestern Uruguay. *Revista de Geociencias de Río Claro*, 4: 487-500.
- Munsell Color Co., Inc. 2009. *Revised Munsell Geological Rock-Color chart: Baltimore*. 12 pp.
- Pazos, P., Tófaló, O.R. and González, M. 1998. La Paleosuperficie Yapeyú: significado estratigráfico y paleoambiental en la evolución del Cretácico Superior del Uruguay. 2° Congreso Uruguayo de Geología, Abstracts (Punta del Este), pp. 59-63.
- Roselli, F.L. 1987. Paleoicnología: nidos de insectos fósiles de la cubierta Mesozoica del Uruguay. *Publicaciones del Museo Municipal de Nueva Palmira*, 1: 1-56.
- Sedorko, D., Alessandretti, L., Rangel, C.C., Verissimo Warren, L. and Silva Ramos, K. 2019. Late Cretaceous insect trace fossils from the Capacete Formation, Sanfranciscana Basin, Brazil. *3rd International Conference of Continental Ichnology*, Abstract Volume & Field Trip Guide, pp. 90.
- Souza Carvalho, I., Gracioso, D.E. and Sequeira Fernandes, A.C. 2009. Uma camara de coleóptero (*Coprinisphaera*) do Cretaceo Superior, Bacia Bauru. *Brazilian Journal of Geology*, 39: 679-684.
- Tófaló, O.R. 1986. Caracterización sedimentológica y estratigrafía de las formaciones Puerto Yerúa y Arroyo Ávalos, provincias de Entre Ríos y Corrientes. *Doctoral Thesis*, Facultad de Ciencias Exactas y Naturales, Universidad de Buenos Aires, 363 pp.
- Tófaló, O.R. and Morrás, H. 2009. Evidencias paleoclimáticas en sedimentitas continentales del Cenozoico de Uruguay. *Revista de la Asociación Geológica Argentina*, 65: 674-686.
- Tófaló, O.R. and Pazos, P.J. 2002. Caracterización de calcretes de la Formación Puerto Yerúa (Cretácico), en base a su micromorfología (Entre Ríos, Argentina). *Latin American Journal of Sedimentology and Basin Analysis*, 9: 127-134.
- Tófaló, O.R. and Pazos, P.J. 2010. Paleoclimatic implications (Late Cretaceous-Paleogene) from micromorphology of calcretes, palustrine limestones and silcretes, southern Paraná Basin, Uruguay. *Journal of South American Earth Sciences*, 29: 665-675.
- Tófaló, R.O., Marengo, H. and Wilson, C. 2008. Las formaciones Guichón y Mercedes (Cretácico), en la provincia de Corrientes. 12° Reunión Argentina de Sedimentología (Buenos Aires), Abstracts CDR: 173.
- Tófaló, O.R., Pazos, P.J. and Sánchez Bettucci, L. 2011. Estudio composicional de sedimentitas silico-clásticas y paleosuelos de la Formación Mercedes (Cretácico Superior), Uruguay. *Revista de la Asociación Geológica Argentina*, 68: 615-626.
- Verde, M. 2012. Icnología de la Formación Asencio y las "Calizas del Queguay" (Cretácico Tardío – Terciario temprano). *Doctoral Thesis*, Universidad de la República, Uruguay, 204 pp.
- Verde, M. and Genise, J.F. 2014. *Elipsoideichnus meyeri* Roselli 1987 revisited: A helicoidal fossil bee nest from the Paleogene of Uruguay. *Spanish Journal of Palaeontology*, 29: 25-32.
- Veroslavsky, G. and Martínez, S. 1996. Registros no depositacionales del Paleoceno-Eoceno del Uruguay: nuevo enfoque para viejos problemas. *Revista Universidade Guarulhos Geociencias*, 1: 32-41.
- Veroslavsky, G., de Santa Ana, H., Goso, C. and González, S. 1997. Calcretas y silcretas de la región Oeste del Uruguay (Queguay), Cuenca de Paraná (Cretácico Superior – Terciario Inferior). *Geociencias*, 16: 205-224.
- Veroslavsky, G., Aubet, N., Martínez, S.A., Heaman, L.M., Cabrera, F. and Mesa, V. 2019. Late Cretaceous stratigraphy of the southeastern Chaco - Paraná Basin ("Norte basin" - Uruguay): the Maastrichtian Age of the calcretization process. *Geociencias*, 38: 427- 449.

Received : August 28, 2022

Accepted : November 23, 2022