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On the validity of the *Macrochorobates scalabrinii* Biozone (early Huayquerian Stage/Age, Late Miocene). Multi-proxy analysis of the enigmatic Arenas Blancas site (Buenos Aires Province, Argentina)

***Rodrigo L. Tomassini[1], Claudia I. Montalvo[2], Elisa Beilinson[3], Daniel Barasoain[4], Gabriela I. Schmidt[5], Esperanza Cerdeño[6], Alfredo E. Zurita[4], Ricardo A. Bonini[7], Ángel R. Miño-Boilini[4], Luciano L. Rasia[8], Germán M. Gasparini[9]**

[1] *Instituto Geológico del Sur, Departamento de Geología Universidad Nacional del Sur (UNS)-CONICET. Avda. Alem 1253, 8000 Bahía Blanca, Argentina.*
rodrigo.tomassini@yahoo.com.ar

[2] *Facultad de Ciencias Exactas y Naturales, Universidad Nacional de La Pampa, Uruguay 151, 6300 Santa Rosa, Argentina.*
cmontalvolp@yahoo.com.ar

[3] *Centro de Investigaciones Geológicas, CONICET-UNLP, Diagonal 113-275, 1900 La Plata, Argentina.*
elisabeilinson@gmail.com

[4] *Laboratorio de Evolución de Vertebrados y Ambientes Cenozoicos-Centro de Ecología Aplicada del Litoral (CECOAL-CONICET) y Universidad Nacional del Nordeste, Ruta 5, km 2.5, 3400 Corrientes, Argentina.*
danielbarasoain@gmail.com; aezurita74@yahoo.com.ar; angelmioboilini@yahoo.com.ar

[5] *Laboratorio de Paleontología de Vertebrados, Centro de Investigación Científica y de Transferencia Tecnológica a la Producción (CONICET-Prov. ER-UADER), España 149, 3105 Diamante, Argentina.*
gabyschmidt2@hotmail.com

[6] *Paleobiología y Paleoecología, Instituto Argentino de Nivología, Glaciología y Ciencias Ambientales, CCT-CONICET-Mendoza, Avda. Ruiz Leal s/n, 5500 Mendoza, Argentina.*
espe@mendoza-conicet.gob.ar

[7] *Instituto de Investigaciones Arqueológicas y Paleontológicas del Cuaternario Pampeano (INCUAPACONICET), Facultad de Ciencias Sociales, Universidad Nacional del Centro de la Provincia de Buenos Aires, Avda. Del Valle 5737, 7400 Olavarría, Argentina.*
juniorito7@hotmail.com

[8] *CONICET, División Paleontología Vertebrados, Museo de La Plata, Facultad de Ciencias Naturales y Museo, Universidad Nacional de La Plata, Paseo del Bosque s/n, 1900 La Plata, Argentina.*
lucianorasia@hotmail.com

[9] *CONICET, División Paleontología Vertebrados, Unidades de Investigación Anexo Museo de La Plata, Facultad de Ciencias Naturales y Museo, Universidad Nacional de La Plata, 122 y 60, 1900 La Plata, Argentina.*
germanmgasparini@gmail.com

* *Corresponding author: rodrigo.tomassini@yahoo.com.ar*

ABSTRACT. Arenas Blancas is a poorly known fossiliferous site located in the lower reach of the Chasicó creek (Buenos Aires Province, Argentina), with great relevance from a biostratigraphic viewpoint. The *Macrochorobates scalabrinii* Biozone was defined in this site, proposed as the biostratigraphic basis of the early Huayquerian Stage/Age (Late Miocene); however, the geological context and faunal record of this site have never been studied in detail. In this work, we perform a multi-proxy analysis of the Arenas Blancas site, as well as a nearby site here called Curva de la Vaca, and provide new interpretations on their origin, age, and biostratigraphy. Sedimentological, stratigraphic, and geomorphological characteristics of both sites suggest that the sequences include fluvial/alluvial deposits that represent Quaternary terraces. The taxonomic analysis of the Arenas Blancas faunal assemblage evidences the presence of 14 mammal taxa, together with some fishes, reptiles, and birds; the assemblage is correlated with the assemblage from the Cerro Azul Formation assigned to the Chasicoan Stage/Age (Late Miocene), also recovered from the lower reach of the Chasicó creek. The use of the taxa proposed in previous works to characterize the *Macrochorobates scalabrinii* Biozone (including this species) is not supported due to their taxonomic status and/or temporal distribution. Taphonomic evaluation indicates that the assemblage is constituted by reworked specimens; in this frame, it is proposed that fluvio/alluvial events, occurred during the Late Pleistocene-Holocene, eroded the Upper Miocene substrate and reworked fossil remains. Based on the present evidence, the *Macrochorobates scalabrinii* Biozone is here rejected as a valid biostratigraphic unit.

Keywords: Mammals, Taphonomy, Reworking, Late Miocene, Pampean region, Biostratigraphy.

RESUMEN. Sobre la validez de la Biozona *Macrochorobates scalabrinii* (Huayqueriense temprano, Mioceno tardío). Análisis multi-proxy del enigmático sitio Arenas Blancas (provincia de Buenos Aires, Argentina). Arenas Blancas es una localidad fosilífera poco conocida, ubicada en el curso inferior del arroyo Chasicó (provincia de Buenos Aires, Argentina), pero con gran relevancia desde el punto de vista bioestratigráfico. La Biozona *Macrochorobates scalabrinii*, propuesta como base bioestratigráfica del Piso/Edad Huayqueriense temprano (Mioceno tardío) fue definida en este sitio, aunque su contexto geológico y registro faunístico nunca han sido estudiados en detalle. En este trabajo analizamos el sitio Arenas Blancas desde diferentes perspectivas, como así también un sitio cercano aquí denominado Curva de la Vaca, a fin de aportar nuevas interpretaciones sobre su origen, edad y bioestratigrafía. Las características sedimentológicas, estratigráficas y geomorfológicas de ambos sitios sugieren que las secuencias aflorantes corresponden a depósitos fluviales/aluviales que representan terrazas cuaternarias. El análisis taxonómico de la asociación faunística de Arenas Blancas permitió reconocer 14 taxones de mamíferos, como así también peces, reptiles y aves. Esta asociación muestra una clara correlación con la asociación de la Formación Cerro Azul asignada al Piso/Edad Chasiquense (Mioceno tardío), también registrada en el curso inferior del arroyo Chasicó. Por otra parte, se considera que el uso de los taxones que caracterizan la Biozona *Macrochorobates scalabrinii* (incluyendo esta especie) no está avalado por su estatus taxonómico y/o su distribución temporal. El estudio tafonómico muestra que la asociación está constituida por especímenes retrabajados; en este contexto, se propone que los eventos fluviales/aluviales ocurridos durante el Pleistoceno tardío-Holoceno erosionaron el sustrato del Mioceno tardío y retrabajaron los restos fósiles. Sobre la base de la evidencia disponible, se rechaza la validez de la Biozona *Macrochorobates scalabrinii* como unidad bioestratigráfica.

Palabras clave: Mamíferos, Tafonomía, Retrabajo, Mioceno Tardío, Región Pampeana, Bioestratigrafía.

1. Introduction

The Pampean region of Argentina includes several fossiliferous localities in Buenos Aires and La Pampa provinces with continental deposits bearing an abundant and diverse vertebrate fauna that corresponds to the Late Miocene-Holocene lapse. Mammal assemblages recovered from this area are of great importance because they have been used as the basis of the biochronostratigraphic schemes applied in different regions of South America (Cione and Tonni, 2005; Verzi *et al*., 2008; Montalvo *et al*., 2008, 2017, 2019; Tomassini *et al*., 2013; Cione *et al*., 2015; Deschamps and Tomassini, 2016; Gasparini and Tonni, 2016; Piñero *et al*., 2021).

The lower reach of the Chasicó creek, in southwestern Buenos Aires Province (Fig. 1), is a classical Neogene fossiliferous area. It includes several sites (*e.g.,* El Vivero, Bajada de Los Toros, Estancia Norma Alicia) where Late Miocene fluvial deposits crop out (Zárate *et al*., 2007) (Fig. 1). These deposits were traditionally assigned to the Arroyo Chasicó Formation (ACF), although Folguera and Zárate (2009) proposed that they are part of the

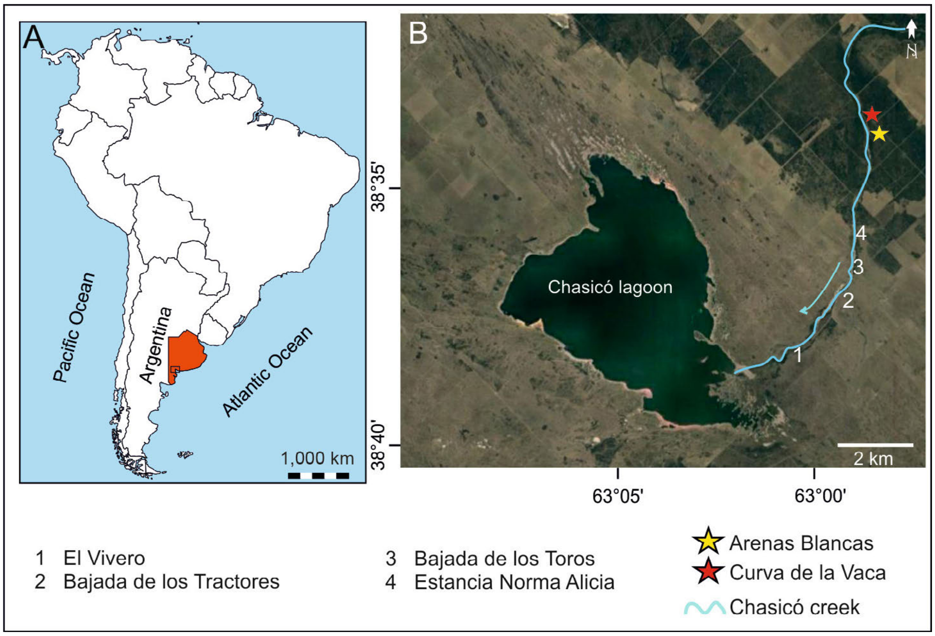

FIG. 1. Geographical setting of the study area. **A.** General map of South America, showing the location of the study area at the southwestern region of Buenos Aires Province (Argentina). **B.** Detail of the lower reach of the Chasicó creek, showing the distribution of the Arenas Blancas and Curva de la Vaca sites, and other classical paleontological sites considered in this work.

Cerro Azul Formation (CAF; *sensu* Linares *et al*., 1980). Vertebrate assemblage from these levels was assigned to the Chasicoan Stage/Age (*e.g.,* Pascual, 1961; Fidalgo *et al*., 1978, 1987; Bondesio *et al*., 1980; Verzi *et al*., 2008; Piñero *et al*., 2021).

Also located in the lower reach of the Chasicó creek (Fig. 1), Arenas Blancas is a poorly known site with great relevance for the Pampean biostratigraphy. Originally, Tonni *et al*. (1998) mentioned deposits belonging to an innominate lithostratigraphic unit overlying the CAF (as Arroyo Chasicó Formation in this previous work) in erosive discontinuity, but without any more detail, and made reference to the presence there of several Cingulata (Xenarthra) taxa (Table 1). Based on the record of an euphractine armadillo, these authors defined the *Macrochorobates scalabrinii* Biozone for these levels, proposed as the biostratigraphic basis of the early Huayquerian Stage/Age (Late Miocene) (Cione and Tonni, 2005). Later, in a preliminary analysis of a collection from this site, hosted in the Museo Municipal de Ciencias Naturales "Vicente Di Martino" (Monte Hermoso, Buenos Aires Province), Oliva *et al*. (2011) provided the first geographic information from Arenas Blancas locality (without sedimentological and stratigraphic details) and mentioned an assemblage constituted by 24 mammal taxa (Table 1), assigned to the Early Huayquerian Stage/Age, following Tonni *et al*. (1998). The only taxonomic studies performed on this assemblage concern a mylodontine (cf. *Simomylodon*) and an armored catfish (Loricariidae indet.), studied by Oliva and Brandoni (2012) and Bogan and Agnolin (2019), respectively. Beyond these contributions, the geological context and faunal record of this site were never studied in detail. In the frame of this work, a new outcrop, herein called Curva de la Vaca, has been discovered near the Arenas Blancas site, and can be correlated with the latter from a sedimentological and stratigraphic viewpoint.

The main goal of this contribution is to provide new geological and paleontological interpretations on the Arenas Blancas site, based on the sedimentological, stratigraphic, and geomorphological features of the outcrops, and the taxonomic and taphonomic analyses of the recovered vertebrate assemblage. This approach allows us to discuss the origin of the site, the temporal relationship between fossil-bearing deposits and faunal assemblage, the biostratigraphy, and the validity of the *Macrochorobates scalabrinii* Biozone.

TABLE 1. UPDATED TAXONOMIC REPRESENTATION FROM THE ARENAS BLANCAS SITE, COMPARED WITH PREVIOUS LISTS.

Taxa	Tonni *et al*. (1998)	Oliva *et al*. (2011)	This work
Order Cingulata			
Family Chlamyphoridae	-	-	-
Macrochorobates scalabrinii	X	X	X
Vetelia perforata	X	X	X
Chasicotatus ameghinoi	-	X	X
Chorobates cf. *C. villosissimus*	-	X	-
Proeuphractus sp.	X	X	X
Family Pampatheriidae	-	-	-
Kraglievichia paranensis	-	-	X
Kraglievichia sp.	X	X	-
Scirrotherium sp.	-	X	-
Vassalia sp.	-	X	-
Family Glyptodontidae	-	-	-
Plohophorus paranensis	-	X	-
Eosclerocalyptus cf. *E. tapinocephalus*	-	X	-
Eosclerocalyptus sp.	X	-	-
Hoplophractus sp.	X	-	-
Neuryurini gen. et sp. nov.	X	-	-
Palaehoplophorini indet.	-	X	-
Lomaphorini indet.	-	X	-
Glyptodontidae indet.	-	-	X
Order Pilosa			
Family Mylodontidae	-	-	-
cf. *Simomylodon*	-	X	-
Mylodontinae indet.	-	-	X
Family Nothrotheriidae	-	-	-
Nothrotheriinae indet.	-	-	X
Family Megalonychidae	-	-	-
?Megalonychidae indet.	-	-	X
Order Litopterna			
Family Proterotheriidae	-	-	-
Neobrachytherium cf. *N. ullumense*	-	X	-
Neobrachytherium ullumense	-	-	X
Proterotheriidae indet.	-	-	X
Family Macraucheniidae	-	-	-
Oxyodontherium zeballosi	-	X	-
Scalabrinitherium bravardi	-	-	X
Macraucheniidae indet.	-	-	X
Order Notoungulata			
Family Hegetotheriidae	-	-	-
Paedotherium minor	-	X	X
Family Mesotheriidae	-	-	-
Pseudotypotherium subinsigne	-	X	-
Typotheriopsis sp.	-	X	-

table 1 continued.

Taxa	Tonni *et al.* (1998)	Oliva *et al.* (2011)	This work
Order Notoungulata			
Typotheriopsis chasicoensis	-	-	X
Family Toxodontidae	-	-	-
Hemixotodon cf. *H. chasicoensis*	-	X	-
Calchaquitherium sp.	-	X	-
Calchaquitherium mixtum	-	-	X
Pisanodon nazari	-	-	X
Dinotoxodon paranensis	-	-	X
Order Rodentia			
Family Caviidae	-	-	-
Cardiatherium chasicoense	-	X	X
Cardiatherium sp.	-	-	X
Orthomyctera sp.	-	X	-
Prodolichotis sp.	-	X	-
Family Chinchillidae	-	-	-
Lagostomus sp.	-	X	X
Family Dinomyidae	-	-	-
Dinomyidae indet.	-	-	X
Eumegamyinae indet.	-	-	X

2. Geological and paleontological setting of the Chasicó creek area

In the extra-Andean region of central Argentina, continental deposits from the Late Miocene-Pliocene accumulated after the withdrawal of the Paranense Sea (Hernández *et al.*, 2005; Del Río *et al.*, 2018). These deposits exhibit a vast geographical extension and can be attributed to the southeastern Pampean Plain, a back-bulge basin related to the Andean foreland dynamics between ~34° and 41° S (Folguera *et al.*, 2015). In this area, two different depocenters have been described: the Late Miocene Southern Pampa basin (~34°-38° S) and the Pliocene Northern Patagonian basin (38°-41° S). Due to their distance to the orogenic front (between 600 and 800 km), the deposits have been interpreted as distal, low-energy, fluvio-alluvial systems in a distal fan/apron context (Folguera and Zárate, 2009, 2011; Folguera *et al.*, 2015). These levels are regionally covered by Quaternary sequences, which are represented by fluvial and eolian deposits (Folguera and Zárate, 2009; Deschamps and Tomassini, 2016).

The lower reach of the Chasicó creek (Fig. 1) can be considered as part of the Southern Pampa basin. This area was established by Pascual (1961) as the type locality of the ACF. A detailed sedimentological study of the ACF performed by Zárate *et al.* (2007) concluded that the accumulation of this sequence was the result of episodic sedimentation in a fluvial environment of a mixed-load stream under progressively decreasing energy. Based on a radiometric age of 9.23±0.09 Ma and high-resolution magnetostratigraphic profiles, they proposed that the lower part of the exposed formation was accumulated between 9.43 and 9.07 Ma, while the upper section is younger than 9.02 Ma; in this context, the total duration of sedimentation remains unconstrained and could have extended up to 8.7 Ma (Zárate *et al.*, 2007).

Folguera and Zárate (2009) proposed that different Late Miocene units cropping out in the southwestern Buenos Aires Province, including Arroyo Chasicó, Epecuén, and Saldungaray formations, should be referred to the CAF, which is widely extended in La Pampa Province and was defined on lithostratigraphic criteria (Folguera *et al.*, 2017). This proposal was considered in several recent paleontological works (*e.g.,* Deschamps and Tomassini, 2016; Montalvo *et al.*, 2019; Piñero *et al.*, 2021; Schmidt *et al.*, 2022) and it is also accepted for this study.

From a biostratigraphic viewpoint, two Late Miocene biozones were defined in the lower reach of the Chasicó creek: *Chasicotherium rothi* Biozone (early Chasicoan Stage/Age) and *Chasicotatus ameghinoi* Biozone (late Chasicoan Stage/Age) (Cione and Tonni, 2005; Cione *et al*., 2015). However, based on a large sample of mammal remains, all of them with precise geographic and stratigraphic provenance, Tomassini *et al*. (2017) concluded that these Upper Miocene levels do not show significant faunal differences, thus rejecting the validity of the biozones previously proposed and, therefore, the differentiation between early and late Chasicoan.

Concerning the Arenas Blancas site, different authors (*e.g.,* Tonni *et al*., 1998; Cione and Tonni, 2005; Oliva and Brandoni, 2012) recognized small and discontinuous deposits formed by fluvial sabulitic sands and matrix-supported conglomerates, within an innominate lithostratigraphic unit that overlies in erosive discontinuity the CAF (Arroyo Chasicó Formation in these previous works). As said above, the vertebrate assemblage of this unit was assigned to the *Macrochorobates scalabrinii* Biozone, biostratigraphic base of the early Huayquerian Stage/Age, Late Miocene (Tonni *et al*., 1998; Cione and Tonni, 2005). This biozone is based on the first record of *M. scalabrinii*, *Hoplophractus*, and *Eosclerocalyptus*, the last record of *Proeuphractus* and *Vetelia perforata*, and the presence of a Neuryurini "more primitive" than *Urotherium* (Tonni *et al*., 1998).

The Quaternary of the Chasicó creek is represented by Late Pleistocene and Holocene deposits represented by the in-fill of a fluvial valley incised in the Upper Miocene substrate. First, Fidalgo *et al*. (1987) recognized several informal units overlying this substrate: **1)** the *Grava Arenosa Salinas Chicas*, constituted by sandy gravels cemented by calcium carbonate; **2)** the *Conglomerado Bajada de Los Toros*, represented by fine to medium gravels of rounded white and pink quartzites from the Ventania basement, and sandy siltstones intraclasts of the Upper Miocene substrate cemented by calcium carbonate; **3)** the "*Grava Arenosa y Limo Sanquilcó*", characterized by layers of brown to gray sandy gravel that alternates with sands, silts, and even clays; the gravel clasts are made up of rounded white and pink quartzites from the Ventania basement; **4)** finally, in some cases, these coarse levels are capped by silty sands sediments, assigned to eolian deposits of the Holocene Estancia La Aurora Formation (Fidalgo *et al*., 1987), from which scarce Quaternary fossils were recovered: *Rhea americana*, *Ozotoceros bezoarticus*, *Dolichotis patagonum*, *Lama guanicoe*, and *Ctenomys* sp.

In turn, Folguera *et al*. (2017) made reference to deposits assigned to the three members of the Agua Blanca Formation (*sensu* Rabassa, 1989): **1)** the lower Psefítico Member, characterized by brown coarse sands, with well-rounded psefitic clasts of paleozoic rocks coming from the Ventania basement; **2)** the middle Arenoso Member, characterized by brown, well stratified silty sands and sands with occasional psefitic lenses; these two members have been interpreted as fluvial facies; and **3)** the upper Limo-Arenoso Member, composed of massive, gray silty sands that represent palustrine facies. Folguera *et al*. (2017) also mentioned the presence of informal units in the area: the *Depósitos aluviales antiguos*, including unconsolidated, light brown to gray, medium sands, and gravels with little silt content, which were interpreted as alluvial plains that represent a terrace within the valley of the Chasicó creek; and the *Arenas limosas eólicas*, represented by massive silty sand with carbonate and evidence of bioturbation, possibly correlatable with the Estancia La Aurora Formation.

3. Geomorphology, stratigraphy, and sedimentology of the Arenas Blancas and Curva de la Vaca sites

The Arenas Blancas fossiliferous site is located in the lower reach of the Chasicó creek, approximately 9.5 km from the mouth of the homonymous lagoon. It was discovered in the 1980s by Vicente Di Martino (former director of the Museo Municipal de Ciencias Naturales "Vicente Di Martino" of Monte Hermoso), who made a single rich collection of Late Miocene vertebrate remains (see below Material and methods section). According to Di Martino (personal communication, 2009), the bearing level had an extension of ~200 m and was 1 m-thick. The first geographic information of this site (38°34´25´´ S, 62°58´2´´ W) was provided by Oliva *et al*. (2011) and posteriorly by Oliva and Brandoni (2012).

In the frame of this study, this geographic point was visited four times between 2016 and 2019. In these opportunities, we identified small and discontinuous outcrops. The sequence at this point includes 0.3-1 m of whitish brown coarse sands, with pockets of well-rounded, very coarse gravel and cobbles of metasedimentites and quarzitic rocks from the Ventania basement and a brownish-gray sandy matrix (Fig. 2A), disposed in erosive discontinuity over the CAF. Rolled blocks with similar lithology to those registered in the outcrops were observed in the surroundings and even several kilometers downstream from this site (Fig. 2B).

The extension and thickness of these deposits make it difficult to evaluate their origin, age, and stratigraphic relationship with the underlying CAF.

FIG. 2. Outcrops of the studied sites in the lower reach of the Chasicó creek. **A.** Small cliff in the Arenas Blancas site formed by coarse deposits overlying the Cerro Azul Formation in erosive discontinuity. **B.** Rolled block with similar coarse lithology to those from the Arenas Blancas site, located several kilometers downstream. **C-D.** Sedimentary sequence in the Curva de la Vaca site. Note the coarse deposits in the lower and middle portions, and the silty sands in the upper portion. **E-F.** Detail of the coarse-grained deposits, showing well-stratified sands and gravels. Scale in E and F=1 m.

This situation is reflected in the scarce contributions made since the discovery of the Arenas Blancas site (Tonni *et al*., 1998; Oliva *et al*., 2011; Oliva and Brandoni, 2012).

In a nearby point, here called Curva de la Vaca (38°33´31.2´´ S, 62°58´36.2´´ W; Figs. 1, 2C), ~1.7 km upstream from Arenas Blancas site, we identified a more extensive outcrop (~500 m) with deposits that also overlie the CAF in erosive discontinuity. The sequence at this point is thicker, 2-2.5 m-thick, and includes grayish brown, well-stratified sands and gravels (Fig. 2D-F); sandy siltstones intraclasts of the CAF, cemented by calcium carbonate, are common. Coarse deposits are similar to those described for the Arenas Blancas site. Overlaying these coarse levels, gray silty sands crop out (Fig. 2D). Vertebrate fossils were not recovered from this site.

The information obtained in this study allows proposing new geological interpretations for this area. The sedimentological characteristics of the coarse deposits cropping out at both sites, overlying the Upper Miocene levels, are here interpreted as fluvio/alluvial deposits (Fig. 3A). From a geomorphological viewpoint, these sequences represent a terrace within the Chasicó creek valley (Fig. 3B). Their petrological nature and position in the sequence suggest a strong correlation with other deposits recognized in the lower reach of the Chasicó creek, such as the lower and middle members of the Agua Blanca Formation (Rabassa, 1989) and the informal units "*Grava Arenosa Salinas Chicas*", "*Conglomerado Bajada de Los Toros*" (Fidalgo *et al*., 1987), and "*Depósitos aluviales antiguos*" (Folguera *et al*., 2017). These levels are capped by a thin layer (less than 2 m) of eolian sediments (Fig. 3A), which could be correlated with the loessic deposits of the Estancia La Aurora Formation (Fidalgo *et al*., 1987; or "*Arenas limosas eólicas*" *sensu* Folguera *et al*., 2017). Based on the available evidence, sedimentary sequences of Arenas Blancas and Curva de la Vaca sites are here assigned to the Late Pleistocene-Holocene interval. Additionally, it is important to note that all these deposits show a completely different sedimentological nature and geomorphological distribution from the Neogene units cropping out in the area.

4. Material and methods

A rich vertebrate paleontological collection from Arenas Blancas site is evaluated in this work (Table 1, Supplementary Material 1) Materials recovered by Di Martino during the 1980s are housed in the Museo Municipal de Ciencias Naturales "Vicente

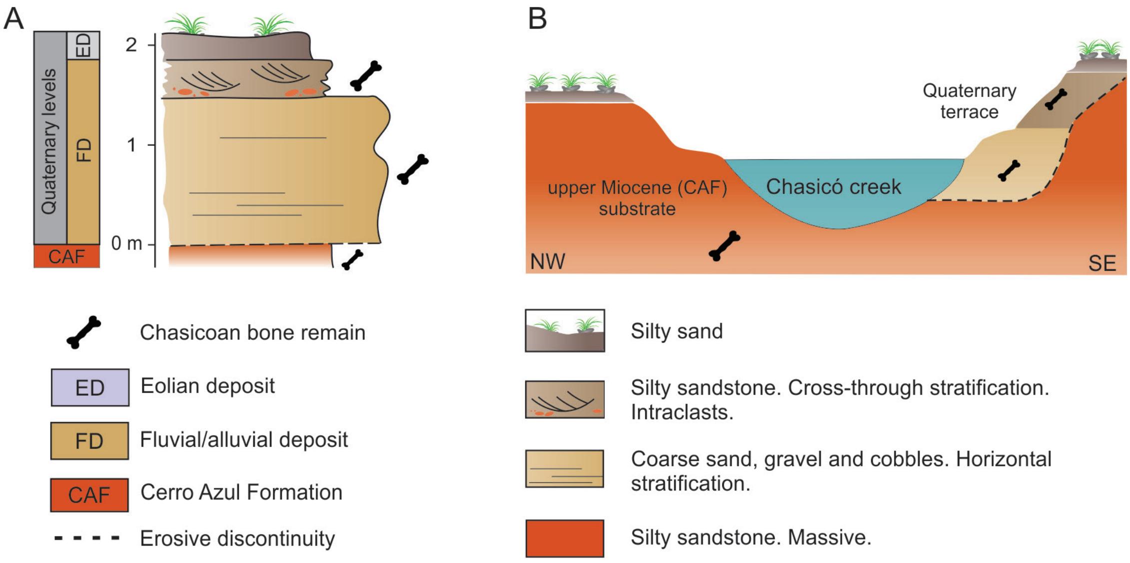

FIG. 3. Stratigraphy, sedimentology, and geomorphology of the Chasicó creek lower reach. **A.** Sequence showing the Late Miocene and Quaternary units. **B.** Schematic cross section (not to scale) showing the geomorphological features of the terraces and the lateral relation between units.

Di Martino" (Monte Hermoso, Buenos Aires Province, Argentina). As it was mentioned, part of this collection was previously studied by other authors from a taxonomic viewpoint (*e.g.,* Tonni *et al*., 1998; Oliva *et al*., 2011; Oliva and Brandoni, 2012; Bogan and Agnolin, 2019); with respect to this, we provide here new interpretations for some specimens.

For their taxonomic assignment, specimens have been compared with referential specimens from the Late Miocene-Pliocene of Argentina, which are housed in the following Argentinean institutions: Museo Argentino de Ciencias Naturales "Bernardino Rivadavia" (MACN Pv), Buenos Aires; Museo de Ciencias Naturales y Antropológicas "Profesor Antonio Serrano", Paraná; Museo de La Plata (MLP), La Plata; Museo Municipal de Ciencias Naturales "Vicente Di Martino" (MMH-CH), Monte Hermoso; Museo Municipal de Ciencias Naturales "Carlos Darwin", Punta Alta; Departamento de Geología, Universidad Nacional del Sur (PV-UNS), Bahía Blanca; and Facultad de Ciencias Exactas y Naturales, Universidad Nacional de La Pampa, Santa Rosa.

A systematic paleontology section is not included in this work, as most taxa from the Arenas Blancas site have been previously described. Details of remains and taxonomy of the vertebrate taxa (mammals, birds, fishes, and reptiles) are included in the Supplementary Material 1. However, we provide some additional information, particularly for those specimens identified at species or genus level (and occasionally also at family level).

In order to adjust its age and biostratigraphy, the fauna from the Arenas Blancas site is compared with classical Late Miocene assemblages assigned to the Chasicoan and Huayquerian stages/ages from Buenos Aires and La Pampa provinces, because they are the best represented from a taxonomic viewpoint for this period (Table 2); other assemblages assigned to different lapses of the Huayquerian Stage/Age (*e.g.,* Deschamps, 2005; Deschamps and Tomassini, 2016; Bonini *et al*., 2017) are not considered here because of the low number of taxa recorded from each locality.

We follow and discuss the biostratigraphic schemes proposed by Cione and Tonni (2005), Verzi *et al*. (2008, 2011), Sostillo *et al*. (2014), Deschamps and Tomassini (2016), Tomassini *et al*. (2017), Montalvo *et al*. (2019), and Piñero *et al*. (2021). We use the terms Chasicoan and Huayquerian to make reference to the assemblages (*e.g.,* Chasicoan assemblage) represented in each stage/age of the different sites studied.

The anatomical representation of the sample is evaluated based on the minimal number of elements (MNE) of each recovered skeletal element, following Badgley (1986). Taphonomic features of the specimens were observed with both the naked eye and a binocular light microscope Leica MS 5 in order to determine the processes and agents involved in the formation of the assemblage and to interpret the possible taphonomic histories. We consider: articulation, breakage, type of fractures, weathering, abrasion, bioerosion marks, soil corrosion, root traces, and impregnation (*e.g.,* Tomassini *et al*., 2010, 2020; Tomassini and Montalvo, 2013; Montalvo *et al*., 2022). For this taphonomic analysis, only mammals are considered, because this is the only vertebrate group that includes a considerable number of specimens.

Hydrodynamic sorting is evaluated based on Voorhies (1969), who defined groups according to the susceptibility of the different skeletal elements to be transported by water flows. Group I include elements with high susceptibility (rib, vertebra, sacrum, and sternum), Group II gathers elements with moderate susceptibility (femur, tibia, humerus, metapodial, pelvis, and radius), and Group III, those with low susceptibility (mandible and skull). Groups I/II (scapula, phalange, and ulna) and II/III (hemimandibles) include elements with intermediate characteristics. Behrensmeyer (1975) also considered isolated teeth in Group III, due to their high density. Some elements represented in the Arenas Blancas assemblage, such as scaphoid, astragalus, and calcaneus, were not present in Voorhies' (1969) experimentation.

The isolated teeth/vertebrae index proposed by Behrensmeyer (1975) considers the different structural density between these two elements to evaluate the hydrodynamic sorting degree of an assemblage. An index of 1 represents absence of sorting, values close to 1 indicate low sorting, and higher values indicate high sorting.

5. Results and discussion

5.1. Taxonomic and biostratigraphic analyses

A preliminary taxonomic list of the collection hosted in the Museo Municipal de Ciencias Naturales "Vicente Di Martino" was published by Oliva *et al*. (2011) (Table 1). We found 357 specimens within this

TABLE 2. LIST OF TAXA FROM THE ARENAS BLANCAS SITE COMPARED WITH OTHER SITES OF THE PAMPEAN REGION (BUENOS AIRES AND LA PAMPA PROVINCES), WHICH INCLUDE WELL-KNOWN ASSEMBLAGES ASSIGNED TO THE CHASICOAN (1 AND 2), EARLY (3), AND LATE (4) HUAYQUERIAN STAGES/AGES.

	Buenos Aires Province	**La Pampa Province**		
Arenas Blancas	**Chasicoan[1]**	**Chasicoan[2]**	**early Huayquerian[3]**	**late Huayquerian[4]**
Macrochorobates scalabrinii	X	X	X	-
Vetelia perforata	X	X	X	-
Chasicotatus ameghinoi	X	X	X	X
Proeuphractus sp.	X	X	X	X
Kraglievichia paranensis	X	-	-	-
Cardiatherium chasicoense	X	-	-	-
Lagostomus sp.	X	X	X	X
Calchaquitherium mixtum	-	-	-	-
Pisanodon nazari	X	-	X	-
Dinotoxodon paranensis	-	-	-	-
Paedotherium minor	X	X	X	X
Typotheriopsis chasicoensis	X	X	X	-
Scalabrinitherium bravardi	-	-	X	X
Neobrachytherium ullumense	X	-	-	-

1. Chasicó creek. **2.** Cerro La Bota and Cerro Patagua. **3.** Laguna Chillhué, Salinas Grandes de Hidalgo, Telén, and Quehué. **4.** Bajo Giuliani, Barrancas Coloradas, El Guanaco, and Caleufú. After Fidalgo *et al.* (1978, 1987), Bondesio *et al.* (1980), Montalvo *et al.* (2008; 2019), Verzi and Montalvo (2008), and Tomassini *et al.* (2017).

collection. Out of these, 347 correspond to mammals, including the orders Cingulata (MNE=234), Pilosa (MNE=13), Rodentia (MNE=11), Notoungulata (MNE=39), and Litopterna (MNE=14), with a total of 15 recognized families (Figs. 4-8; Table 1; Supplementary Material 1). Specimens assigned to Mammalia indet. mostly include fragmentary cranial and postcranial elements (MNE=36). There are 14 taxa identified at genus or species level (Table 1). Remaining vertebrates are represented by nine specimens of fishes (Siluriformes, Loricariidae indet.), reptiles (Testudines, *Chelonoidis* sp.), and birds (Cathartiformes, cf. Cathartidae) (Fig. 9A-D; Supplementary Material 1). Some taxa mentioned in previous lists (Tonni *et al.*, 1998; Oliva *et al.*, 2011) are not found within the studied sample, and no information on the collection number was previously provided; therefore, their presence cannot be confirmed.

Cingulates are clearly the most abundant group, mostly represented by glyptodonts and, to a lesser extent, by chlamyphorids and pampatheriids. Their abundance is fundamentally related to the high number of dorsal carapace osteoderms.

Unlike previous works that mentioned a wide diversity of glyptodonts from Arenas Blancas site (Tonni *et al.*, 1998; Oliva *et al.*, 2011), the large revised sample of isolated osteoderms and

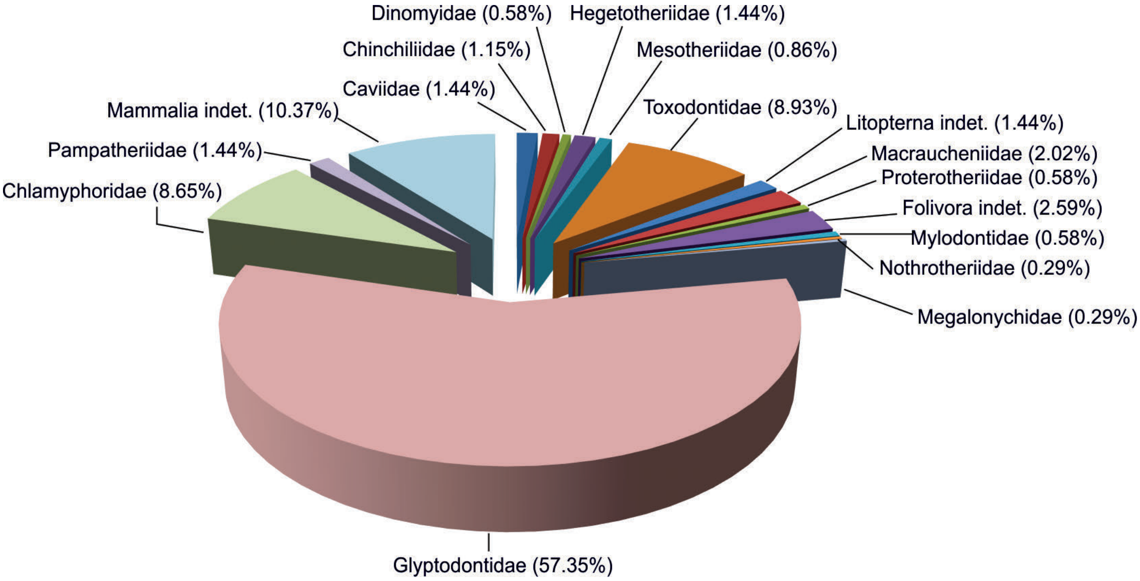

FIG. 4. Taxonomic representation of mammal groups identified in the studied sample from the Arenas Blancas site.

some small carapace fragments suggest otherwise. Specimens are represented by a single morphotype that includes dorsal carapace osteoderms with a "rosette" ornamentation pattern (Fig. 5A, B); shape and size of the central figure and number of peripheral figures varies according to the position of the osteoderm in the dorsal carapace. The scarce and fragmentary remains of caudal rings and caudal tubes (Fig. 5C) also show a "rosette" ornamentation pattern. This pattern is identified in all specimens and is similar to that described by Barasoain *et al*. (2022) for glyptodonts from CAF levels cropping out in the Chasicó creek (*e.g.,* PV-UNS-260). These authors suggested the existence of a single morphotype for the Chasicoan assemblages from central Argentina, which corresponds to *Kelenkura castroi*, recently described and not linkable with any of the known Glyptodontidae tribes (Barasoain *et al*., 2022). The slight variations in the ornamentation of osteoderms probably led to the identification of several taxa in previous works, but it would be the result of taphonomic processes (*e.g.,* abrasion, weathering, soil corrosion), that modified their external surface. This phenomenon has been observed to commonly affect these osteoderms with "rosette" ornamentation pattern in different Neogene taxa (Zurita *et al*., 2016, 2017). Therefore, the presence of *Hoplophractus*, *Eosclerocalyptus*, and a new Neuryurini at Arenas Blancas (Tonni *et al*., 1998; Table 1), as well as the taxa mentioned by Oliva *et al*. (2011; Table 1), is rejected.

Chlamyphorids from Arenas Blancas site are represented by isolated osteoderms identified as: Euphractinae Eutatini *Chasicotatus ameghinoi* (Fig. 5D, E), Euphractini *Macrochorobates scalabrinii* (Fig. 5F, G) and *Proeuphractus* sp. (Fig. 5H), and the Tolypeutinae Priodontini *Vetelia perforata* (Fig. 5I). The holotypes and several referred specimens of *C. ameghinoi* and *V. perforata* come from the Chasicoan assemblage of the Chasicó creek. For each taxon, there are not differences in the size and ornamentation pattern between the Arenas Blancas specimens and those from Chasicoan and Huayquerian assemblages from Buenos Aires and La Pampa provinces (Scillato-Yané, 1982; Esteban *et al*., 2001; Urrutia *et al*., 2008; Scillato-Yané *et al*., 2010). The presence of *Chorobates* cf. *C. villosissimus* mentioned by Oliva *et al*. (2011; Table 1) cannot be corroborated.

Macrochorobates scalabrinii is a very common species in Huayquerian assemblages from Buenos Aires and La Pampa provinces (*e.g.,* Scillato-Yané, 1982; Esteban *et al*., 2001; Urrutia *et al*., 2008). Besides, recent studies also confirmed its presence

FIG. 5. Xenarthrans from the Arenas Blancas site. **A.** Glyptodontidae indet., MMH-CH-10-4-22, fragment of dorsal carapace. **B.** Glyptodontidae indet., MMH-CH-88-6-95, three articulated osteoderms of the dorsal carapace. **C.** Glyptodontidae indet., MMH-CH-84-4-46, fragment of caudal tube. **D.** *Chasicotatus ameghinoi*, MMH-CH-87-7-65, fixed osteoderm. **E.** *Chasicotatus ameghinoi*, MMH-CH-84-4-71, mobile osteoderm. **F.** *Macrochorobates scalabrinii*, MMH-CH-88-6-15, fixed osteoderm. **G.** *Macrochorobates scalabrinii*, MMH-CH-87-7-69, mobile osteoderm. **H.** *Proeuphractus* sp., MMH-CH-87-7-70, mobile osteoderm. **I.** *Vetelia perforata*, MMH-CH-84-4-58, mobile osteoderm. **J.** *Kraglievichia paranensis*, MMH-CH-85-4-105, fixed osteoderm. **K.** *Kraglievichia paranensis*, MMH-CH-85-4-116, mobile osteoderm. **L-M.** Mylodontidae indet., MMH-CH-86-9-24, incomplete right hemimandible with m1-m3, in labial (L) and occlusal (M) views. **N-O.** Nothrotheriinae indet., MMH-CH-10-4-40, ?M2 fragment, in labial (N) and occlusal (O) views. **P-Q.** ?Megalonychidae indet., MMH-CH-84-4-40, left hemimandible fragment with remnants of caniniform, m1, and m2, in labial (P) and occlusal (Q) views.

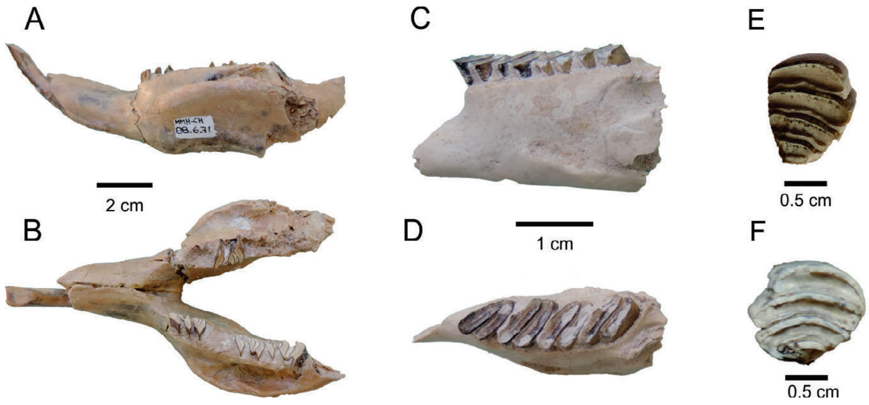

FIG. 6. Rodents from the Arenas Blancas site. **A-B.** *Cardiatherium chasicoense*, MMH-CH-88-6-71, incomplete mandible with left p4, m2-3 and right m1, in labial (A) and occlusal (B) views. **C-D.** *Lagostomus pretrichodactyla*, MMH-CH-87-7-68a, left hemimandible fragment with p4-m3, in labial (C) and occlusal (D) views. **E.** Eumegamyinae indet., MMH-CH-88-6-19, ?M1-M2 fragment, in occlusal view. **F.** Dinomyidae indet., MMH-CH-87-7-67a, ?M1 fragment, in occlusal view.

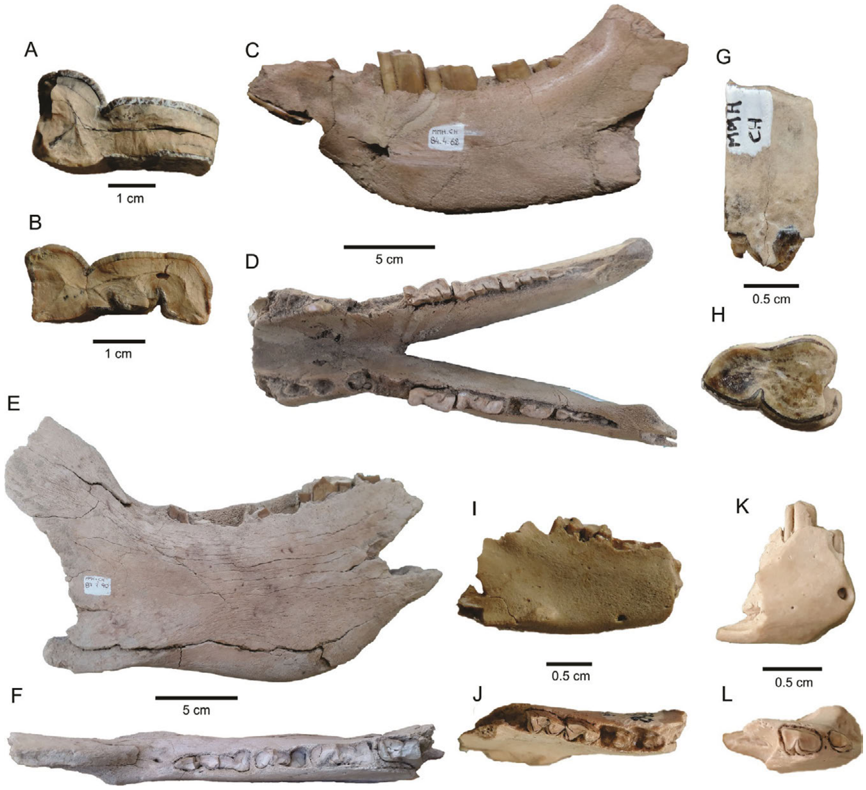

FIG. 7. Notoungulates from the Arenas Blancas site. **A.** *Calchaquitherium mixtum*, MMH-CH-83-3-58, m3, in occlusal view. **B.** *Calchaquitherium mixtum*, MMH-CH-84-4-1, m1 or m2, in occlusal view. **C-D.** *Pisanodon nazari*, MMH-CH 84-4-62, incomplete juvenile mandible with right i2, p1?, dp4-m3 and left i2, dp4-m3, in left labial (C) and occlusal (D) views. **E-F.** *Dinotoxodon paranensis*, MMH-CH-87-7-90, incomplete right hemimandible with p4-m3, in labial (E) and occlusal (F) views. **G-H.** *Typotheriopsis chasicoensis*, MMH-CH-87-7-72, left p4, in labial (G) and occlusal (H) views. **I-J.** *Paedotherium minor*, MMH-CH-84-4-57, right hemimandible fragment with m1-m2 and remnants of p3-4, in labial (I) and occlusal (J) views. **K-L.** *Paedotherium minor*, MMH-CH-86-9-27, right hemimandible fragment with p2-p3 in labial (K) and occlusal (L) views.

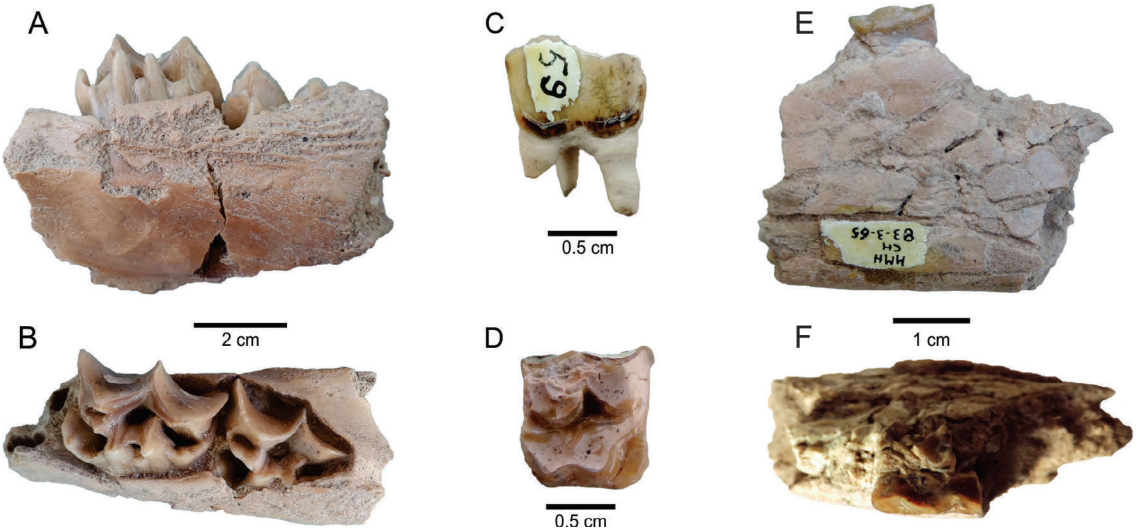

FIG. 8. Litopterns from the Arenas Blancas site. **A-B.** *Scalabrinitherium bravardi*, MMH-CH 84-4-45, left maxillary fragment with M2 and erupting M3, in lingual (A) and occlusal (B) views. **C-D.** *Neobrachytherium* sp., MMH-CH 83-3-59, right P3 or P4, in labial (C) and occlusal (D) views. **E-F.** *Neobrachytherium ullumense*, MMH-CH-83-3-65, right hemimandible fragment with lingual portion of m1 or m2, in lingual (E) and occlusal (F) views.

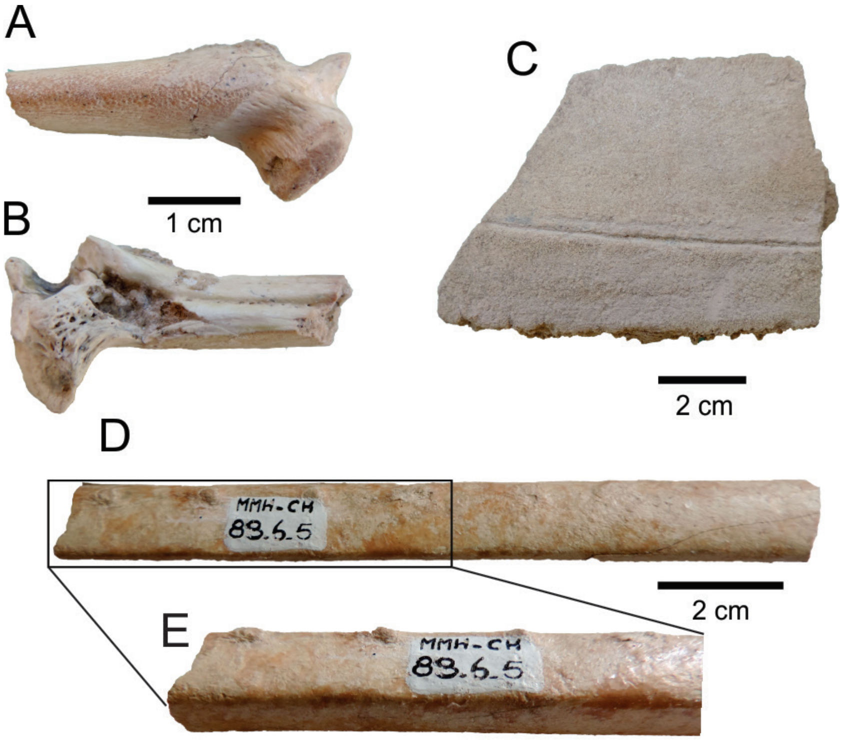

FIG. 9. Fish, tortoise, and bird remains from the Arenas Blancas site. **A-B.** Loricariidae indet. (Siluriformes), (MMH-CH-85-4-140), proximal end of pectoral spine. **C.** *Chelonoidis* sp. (Testudines), (MMH-CH-10-4-13), dorsal carapace osteoderm. **D-E.** cf. Cathartidae (Cathartiformes), (MMH-CH-88-6-5), ulna fragment. Note the detail (E) of the prominent papillae in the bone surface.

in Chasicoan assemblages from the Chasicó creek (*e.g.,* Estancia Norma Alicia site, Fig. 1; Barasoain *et al*., 2020) and La Pampa Province (Cerro La Bota site; Montalvo *et al*., 2019). These findings indicate that, at least in the Pampean region, the first record of this species is older than Huayquerian, contrary to previous proposal (Tonni *et al*., 1998; Cione and Tonni, 2005; Contreras *et al*., 2013).

Chasicotatus ameghinoi is the most abundant chlamyphorid in Chasicoan and Huayquerian assemblages from Buenos Aires and La Pampa provinces (Scillato-Yané, 1977; Urrutia *et al*., 2008). This species was used to define a biozone within the Chasicoan Stage/Age in the CAF cropping out in the Chasicó creek (*Chasicotatus ameghinoi* Biozone *sensu* Cione and Tonni, 2005, but see Tomassini *et al*., 2017). Additionally, Bonini *et al*. (2017) mentioned the presence of *Chasicotatus* cf. *C. ameghinoi* in the Laguna El Venado site (Buenos Aires Province). *Vetelia perforata* is a very common chlamyphorid in Chasicoan and early Huayquerian assemblages from Buenos Aires and La Pampa provinces (Scillato-Yané, 1977; Esteban *et al*., 2001; Urrutia *et al*., 2008; Montalvo *et al*., 2019; Barasoain *et al*., 2021). Remains belonging to *Proeuphractus* sp. do not show differences with the specimens of *P. limpidus* recovered in Chasicoan and Huayquerian assemblages from the Chasicó creek (Barasoain *et al*., 2018) and localities of La Pampa Province (Esteban *et al*., 2001; Urrutia *et al*., 2008; Montalvo *et al*., 2019). However, taking into account that different authors have mentioned the possible presence of a distinct species in Upper Miocene deposits (Esteban *et al*., 2001, 2003; Tauber, 2005), we prefer not to identify the remains from Arenas Blancas at species level until a comprehensive revision of the genus is achieved. The most recent records of *Proeuphractus* sp. come from a late Huayquerian assemblage (Caleufú, La Pampa Province, Late Miocene/Early Pliocene; Urrutia *et al*., 2008), which reject the previous proposal of last record in the early Huayquerian Stage/Age (Cione and Tonni, 2005).

Pampatheriids from Arenas Blancas site include some isolated osteoderms of *Kraglievichia paranensis* (Fig. 5J, K). They are comparable in size and ornamentation pattern to other referred specimens from the Chasicoan assemblage of the Chasicó creek. The presence of *Vassalia* sp. and *Scirrotherium* sp. mentioned by Oliva *et al*. (2011; Table 1) cannot be corroborated. Therefore, *K. paranensis* is the only pampatheriid species identified at Arenas Blancas, as it happens in the Chasicoan assemblage from the Chasicó creek (Góis Lima, 2013). Osteoderms assigned to *Kraglievichia* sp. were recovered from Chasicoan (Cerro La Bota site) and early Huayquerian (Salinas Grandes de Hidalgo site) assemblages of La Pampa Province (Montalvo *et al*., 2019).

Folivoran xenarthrans from Arenas Blancas site include scarce cranial elements of undetermined mylodontines, nothrotheriines, and megalonychids. Oliva and Brandoni (2012) mentioned the presence of the mylodontine cf. *Simomylodon*, based on the specimen MMH-CH 86-9-24 (Fig. 5L, M; see Oliva and Brandoni, 2012 for the description); however, Boscaini *et al*. (2019) recognized it as a juvenile individual just identifiable as Mylodontinae indet., assignment that we follow herein. There is no mention of other mylodontines from the Late Miocene of the Pampean region. Nothrotheriines are only represented by a molar fragment (M2?), subrectangular in outline (Fig. 5N, O), which was assigned to Nothrotheriinae indet. The species *Chasicobradys intermedius* and "*Mcdonaldocnus*" *bondesioi* were identified in the Chasicoan assemblage from the Chasicó creek and Sanquilcó Chico creek (Scillato-Yané, 1979, Scillato-Yané *et al*., 1987; Brandoni, 2014; Gaudin *et al*., 2022; 2022; Miño-Boilini *et al*., 2021). Representatives of "*Mcdonaldocnus*" sp. were reported for Chasicó creek and early Huayquerian assemblages from La Pampa Province (Miño-Boilini *et al*., 2022). A mandibular fragment, with remnants of a caniniform and m1-m2 (Fig. 5P, Q), presents some features (*i.e*., short horizontal ramus, convex ventral border, symphysis at the level of m1, very hypsodont molariforms, and m1 oval in section) that allow its assignment to ?Megalonychidae indet. The only well identified representative of this family in the Late Miocene of the Pampean region is *Protomegalonyx chasicoensis* (taxon based on postcranial materials) from the the Chasicoan assemblage of the Chasicó creek (Scillato-Yané, 1977; Brandoni, 2009). The remaining identified specimens from Arenas Blancas site correspond to postcranial elements that can only be assigned to Folivora indet. (Supplementary Material 1).

Rodents are represented in Arenas Blancas site by cranial elements belonging to representatives of Caviidae, Chinchillidae, and Dinomyidae. The presence of *Orthomyctera* sp. and *Prodolichotis* sp., mentioned by Oliva *et al*. (2011; Table 1), cannot be corroborated.

The almost complete mandible MMH-CH-88-6-71 assigned to the caviid *Cardiatherium chasicoense* (Fig. 6A, B) was previously referred to this species and described in detail by Deschamps *et al*. (2007). Isolated molariforms are assigned to *Cardiatherium* sp., based on their morphology and size. The species *C. chasicoense* is the oldest known capybara and it is considered characteristic of the Chasicoan Stage/Age (Deschamps *et al*., 2007, 2009, 2013; Vucetich *et al*., 2014). Deschamps *et al*. (2009) mentioned the presence of this species in levels of the Loma de Las Tapias Formation (San Juan Province) correlated with the Chasicoan Stage/Age, which represents the only known record out of the Pampean region, which allows extending this stage/age up to near 8 Ma (Deschamps *et al*., 2013). *Cardiatherium* aff. *C. orientalis* was mentioned for early and late Huayquerian assemblages from La Pampa Province (Deschamps *et al*., 2013).

Chinchillid specimens correspond to *Lagostomus*. This is a very common Late Miocene-Pliocene taxon from the Pampean region (Rasia, 2016). Based on shape, size, and cheek tooth proportions, two species were defined for levels of CAF, *L. telenkechanum* from the Chasicoan assemblage of the Chasicó creek (Rasia and Candela, 2017) and *L. pretrichodactyla* from the early Huayquerian assemblage of Salinas Grandes de Hidalgo site, La Pampa Province (Rasia *et al*., 2020), although both species overlap (Rasia and Candela, 2017; Rasia *et al*., 2020). A review of the chinchillids from CAF is needed in order to analyze the diversity of *Lagostomus* during the Chasicoan-Huayquerian lapse. In this frame, we consider that the most parsimonious option is to identify the specimens from the Arenas Blancas site as *Lagostomus* sp.

Dinomyids are only represented by two isolated molars. One of them (MMH-CH-88-6-19; Fig. 6E) presents features (euhypsodont, pentalophodont, and without change of the occlusal pattern with wear) that allow its assignment to Eumegamyinae indet., showing affinities with different taxa (*e.g., Isostylomys laurillardii*, *Arazamys castiglionii*, *Eumegamysops praependens*, *Pentastylodon racedi*). The second specimen (MMH-CH-87-7-67; Fig. 6F), assigned to Dinomyidae indet., has features (euhypsodont, tetralophodont, with the first two lophs labially joined and the last two lingually joined) that closely resemble *Gyriabrus*. Late Miocene dinomyids from the Chasicoan assemblage of the Chasicó creek include *Carlesia* sp., cf. *C. pendolai*, and ?*Tetrastylus*, and with doubts *Diaphoromys* and *Potamarchus* (Bondesio *et al*., 1980; Cione *et al*., 2000). Recently, Sostillo *et al*. (2022) reviewed the dinomyids from the Chasicoan and Huayquerian assemblages of La Pampa Province, identifying the Tetrastilinae *Tetrastylus laevigatus*, *T. intermedius*, *T. araucanus*, and *Tetrastylus* sp., and the Eumegamyinae *Diaphoromys gamayensis*. At present, the dinomyids from Arenas Blancas do not present similarities with those from Chasicoan and Huayquerian assemblages of the Pampean region; however, a comprehensive review of the representatives of this family from the CAF levels in Buenos Aires Province is necessary.

Notoungulates from Arenas Blancas site include cranial and postcranial elements of representatives of three families. Toxodontidae constitute the most abundant group, represented by 31 specimens (Fig. 4; Supplementary Material 1), mostly incomplete. Two isolated molars, MMH-CH 83-3-58 (Fig. 7A) and MMH-CH 84-4-1 (Fig. 7B), present a much wider trigonid than talonid, lingual grooves barely inclined and subparallel, the labial groove widely open, and the posterolingual angle of the m1-2 rather straight. Both their morphology and size are concordant with those of *Calchaquitherium mixtum*. This species is only known from the Playa del Zorro Alloformation (Late Miocene, Huayquerian Stage/Age, Catamarca Province; Nasif *et al*., 2000); thus, its presence at Arenas Blancas increases its paleobiogeographic distribution.

MMH-CH 84-4-62 (Fig. 7C, D) is a mandibular fragment of a juvenile individual, preserving dp4 and erupting m3, which resembles MLP 60-VI-18-63 recovered from the Chasicoan assemblage of the Chasicó creek and identified as *Palaeotoxodon*? *nazari* by Pascual (1965). Posteriorly, Zetti (1972) defined the genus *Pisanodon* for this species in his unpublished doctoral thesis, an informal nomenclatural act followed by posterior authors (*e.g.,* Bondesio *et al*., 1980; Sostillo *et al*., 2021). Other specimens referred to *P. nazari* also come from the Chasicoan assemblage of the Chasicó creek and the early Huayquerian assemblages of La Pampa Province (Sostillo *et al*., 2021).

The teeth (p4-m3) of the hemimandible MMH-CH 87-7-90 (Fig. 7E, F) differ from the specimen assigned to *Pisanodon nazari* MMH-CH 84-4-62 in the greater length of the ento-hypoconid groove, the longer entoconid, and the shorter hypoconulid, being closer to the morphology of *Dinotoxodon paranensis* (*e.g.,* MACN Pv 3812, MLP 58-IX-3-44), a taxon only known from the Lower Member of the Ituzaingó Formation (Late Miocene, Entre Ríos Province), also sharing the mandibular expansion of the horizontal ramus (MLP 39-XII-2-8, Schmidt, 2013; Ferrero *et al*., 2022). The presence of *D. paranensis* at Arenas Blancas site enlarges the geographical distribution of this species.

Several fragments of isolated incisors and molariforms, and a tibia-fibula cannot be presently determined beyond Toxodontidae indet. (Supplementary Material 1). The presence of *Hemixotodon* cf. *H. chasicoensis* mentioned by Oliva *et al*. (2011; Table 1) cannot be corroborated or even know whether or not he based on any of these revised specimens.

Mesotheriids are represented by an incomplete upper molar (MMH-CH 84-4-55) and a p4 (MMH-CH 87-7-72; Fig. 7G, H). The p4 is similar to that of MLP 12-1666, the holotype of *Typotheriopsis chasicoensis*, which comes from the Chasicoan assemblage of the Chasicó creek; so, we tentatively recognize this species at Arenas Blancas. *Typotheriopsis chasicoensis* is also present in Chasicoan and early Huayquerian assemblages from La Pampa Province (Cerdeño and Montalvo, 2001; Montalvo *et al*., 2019; Sostillo *et al*., 2021). We cannot confirm the presence of a second mesotheriid species, *Pseudotypotherium subinsigne*, as mentioned by Oliva *et al*. (2011).

Hegetotheriids include five specimens (four mandibular fragments; Supplementary Material 1) that can be assigned to the genus *Paedotherium* (Fig. 7I-L). The morphology of the p3 in MMH-CH 86-9-27 (Fig. 7K, L), with very short talonid and narrow labial groove, coincides with both *P. minor* and *P. typicum*, whose size overlaps (Cerdeño and Bond, 1998). Measurements of the studied remains are below the mean values of both species (Cerdeño and Bond, 1998), even below or close to the minimum value of *P. minor* in the case of premolars (p2-3); the width of molars is close to that of juvenile specimens from the CAF of La Pampa Province (Cerdeño *et al*., 2017). Previously, Oliva *et al*. (2011) mentioned the species *P. minor*, but without further justification. *Paedotherium minor* is very abundant and the only species of *Paedotherium* identified in Chasicoan and Huayquerian (Late Miocene-Early Pliocene) assemblages from the Pampean region (Cerdeño and Bond, 1998; Verzi and Montalvo, 2008; Deschamps and Tomassini, 2016; Cerdeño *et al*., 2017; Montalvo *et al*., 2016, 2019; Sostillo *et al*., 2021; and references therein); the holotype and several referred specimens come from the Chasicoan assemblage of the Chasicó creek (Cerdeño and Bond, 1998); therefore, it is reasonable to consider that this is the species recorded in the Arenas Blancas site.

Litopterns from Arenas Blancas site are represented by cranial and postcranial elements of two families. Macraucheniidae includes a maxillary fragment (MMH-CH 84-4-45; Fig. 8A, B) of a subadult individual. Its dental morphology coincides with the holotype MACN Pv 4414 of *Scalabrinitherium bravardi* and other referred specimens from the Lower Member of the Ituzaingó Formation (Late Miocene). According to C. Oliva (personal communication, 2011), the former was based on MMH-CH 84-4-45 to determine the presence of *Oxyodontherium zeballosi* at Arenas Blancas site (Oliva *et al*., 2011; Table 1). Consequently, the present identification of the specimen allows us to establish the presence of *S. bravardi* at Arenas Blancas site and reject that of *O. zeballosi*. Recently, *S. bravardi* has also been recognized in Huayquerian assemblages from several localities of La Pampa and Buenos Aires provinces, including Telén, Salinas Grandes de Hidalgo (early Huayquerian Stage/Age), Guatraché (late Huayquerian Stage/Age), and Laguna Epecuén (Huayquerian Stage/Age *sensu lato*) (Schmidt *et al*., 2022). Isolated lower teeth and some postcranial elements are identified as Macraucheniidae indet. (Supplementary Material 1).

Proterotheriids are represented by two specimens. The isolated P3 or P4 MMH-CH 83-3-59 (Fig. 8C, D) shares morphological features with *Neobrachytherium* sp. (Brandoni *et al*., 2012), but with more developed anterolingual cingulum, more lingually placed hypocone, and lophoid metaconule. The lophoid metaconule is present in *N. intermedium* (Soria, 2001). The lack of a confident specific match led us to consider MMH-CH 83-03-59 as *Neobrachytherium* sp. The mandibular fragment MMH-CH 83-3-65 (Fig. 8E, F) presents a molar with a well-developed lingual cingulum, coincident with *N. ullumense*; this specimen was probably the basis for the preliminary mention of *Neobrachytherium* cf. *N. ullumense* by Oliva *et al*. (2011; Table 1), and we now confirm the presence of this species. *Neobrachytherium ullumense* was mentioned for the Chasicoan assemblage of the Chasicó creek (Cerdeño, 2003), and *Neobrachytherium* sp. for Huayquerian assemblages from several localities of La Pampa and Buenos Aires provinces, such as Salinas Grandes de Hidalgo, Telén (early Huayquerian Stage/Age), Bajo Giuliani (late Huayquerian Stage/Age), Laguna Epecuén, and Laguna La Paraguaya (Huayquerian Stage/Age *sensu lato*) (Schmidt *et al*., 2022).

In summary, most of the taxa identified in the Arenas Blancas assemblage are also present in other assemblages of the Pampean region with Upper Miocene deposits of the CAF (Table 2). The highest taxonomic similarity is with the Chasicoan assemblage of the Chasicó creek and, to a lesser extent, with Chasicoan and early Huayquerian assemblages of La Pampa Province (Table 2). The main aspects to highlight are: **1)** the chlamyphorid *Macrochorobates scalabrinii*, used to define a biozone for the early Huayquerian Stage/Age, is present in different assemblages assigned to both Chasicoan and Huayquerian stages/ages; **2)** the caviid *Cardiatherium chasicoense* is also present in the Chasicoan assemblage of the Chasicó creek. This species was considered as biostratigraphic indicator of this stage/age; **3)** the notoungulates *Calchaquitherium mixtum* and *Dinotoxodon paranensis* are absent from all the other assemblages, and their identification in Arenas Blancas site represents the first record of both species in the Pampean region; **4)** the litoptern *Scalabrinitherium bravardi* and the toxodontid *Pisanodon nazari* are absent, up to now, from other Chasicoan assemblages, but they are present in Huayquerian assemblages; and **5)** the pampatheriid *Kraglievichia paranensis* and the litoptern *Neobrachytherium ullumense* are also present in the Chasicoan assemblage of the Chasicó creek.

5.2. Taphonomic analysis

Most of the recovered specimens correspond to osteoderms of the dorsal carapace, caudal rings, and caudal tube fragments of xenarthran cingulates (67.44%; MNE=234); this predominance is related to its great preservation potential due to the high number of osteoderms present in a single dorsal carapace (Gillette and Ray, 1981; Montalvo *et al*., 2016). This characteristic was reported in several late Cenozoic deposits of the Pampean region (Montalvo, 2004; Tomassini *et al*., 2013; Sostillo, 2016; Montalvo *et al*., 2016, 2022), including the Chasicoan levels of the CAF in the Chasicó creek (Barasoain *et al*., 2022). The remaining specimens (32.56%; MNE=113) include cranial and postcranial elements corresponding to other mammal groups.

Osteoderms show attributes that can be linked with different processes that affect their integrity and original features of the exposed surface. Scarce specimens (4.7%) are articulated, represented by osteoderms from the dorsal carapace (Fig. 5A, B) and caudal ring fragments; the remaining materials are isolated. Most of the specimens (59.2%) are complete; the incomplete ones have smooth transverse fractures, which would be related to the fossil-diagenetic stage. Only five specimens (2.1%) show alterations that could be interpreted as weathering, represented by slight splitting and chipping of the outer surface (Fig. 10A). Fluvial abrasion signs, including rounding (54%; Fig. 10B) and polishing (3.4%; Fig. 10C), are present in several specimens; these alterations are superimposed to other modifications, such as fossil-diagenetic fractures (Fig. 10D) and soil corrosion. There are specimens (5.1%) with their surface partially (dendritic aspect) or totally impregnated with Mn oxides, which results in a dark coloration. One specimen shows root traces, which are superimposed to the impregnation of the outer surface (Fig. 10E). Signs of soil corrosion are represented by degradation of the outer surface (5.5%; Fig. 10F), in some cases associated to color change. Pecking of the outer surface (15.4%; Fig. 10G) is other alteration that, at the moment, could not be related to a particular taphonomic process. These last two types of modifications modify the original ornamentation pattern of the osteoderms; in some cases, they appear combined (Fig. 10H).

The remaining skeletal elements are mainly represented by isolated teeth and, to a lesser extent, metapodials, mandibles, vertebrae, and phalanges (Table 3). The evaluation of the hydrodynamic sorting reflects that all the groups established by Voorhies (1969) are represented in the sample, with a predominance of Group III due the high number of isolated teeth (incorporated into this group by Behrensmeyer, 1975). It is important to remark that this analysis is partially biased, because the actualistic experiments of Voorhies (1969) used here to compare were developed with complete skeletal elements belonging to taxa with different body mass regarding the Arenas Blancas assemblage. The isolated teeth/vertebrae index is 4. The results of these two analyses suggest some degree of hydrodynamic sorting towards skeletal

FIG. 10. Taphonomic features of the specimens from the Arenas Blancas site. **A.** Dorsal carapace osteoderm of Glyptodontidae indet., MMH-CH-10-4-57, with slight splitting by weathering. **B.** Dorsal carapace osteoderm of Glyptodontidae indet., MMH-CH-87-7-13, with slight rounding by abrasion. **C.** Dorsal carapace osteoderm of Glyptodontidae indet., MMH-CH-84-4-32, with rounding and polishing by abrasion. **D.** Dorsal carapace osteoderm of Glyptodontidae indet., MMH-CH-88-6-4, with rounding by abrasion affecting a transversal fossil-diagenetic fracture. **E.** Mobile dorsal carapace osteoderm of *Vetelia perforata*, MMH-CH-83-3-64, with root traces superimposed to the Mn oxide impregnation. **F.** Dorsal carapace osteoderm of Glyptodontidae indet., MMH-CH-87-7-84, with degradation of the outer surface by soil corrosion, which modified the original ornamentation pattern. **G.** Dorsal carapace osteoderm of Glyptodontidae indet., MMH-CH-86-9-43, with pecking, which modified the original ornamentation pattern. **H.** Dorsal carapace articulated fragment of Glyptodontidae indet., MMH-CH-83-3-115, with degradation of the outer surface by soil corrosion and pecking. **I.** Undetermined long bone of Mammalia indet., MMH-CH-83-3-70, with slight splitting by weathering. **J.** Hemimandible of *Dinotoxodon paranensis*, MMH-CH-87-7-90, with deep splitting and flaking by weathering. **K.** Vertebra of Mammalia indet., MMH-CH-10-4-44, with slight rounding by abrasion. **L.** Hemimandible fragment of *Paedotherium minor*, MMH-CH-86-9-27, with rounding (and polishing) by abrasion affecting a transversal fossil-diagenetic fracture. **M.** I phalange of Folivora indet., MMH-CH-86-6-99, partially impregnated with Mn oxide. **N.** Incisor fragment of Toxodontidae indet., MMH-CH-88-6-25), with root traces. **O.** Femur fragment of Mammalia indet., MMH-CH-86-9-94, with soil corrosion represented by degradation of the outer surface.

TABLE 3. MINIMUM NUMBER OF ELEMENTS (MNE) FOR THE MAMMAL SKELETAL ELEMENTS (EXCEPT OSTEODERMS AND CAUDAL ARMOR OF CINGULATES) FROM THE ARENAS BLANCAS SITE.

Skeletal element	MNE
Isolated tooth	48
Mandible	13
Maxilla	2
Humerus	1
Femur	1
Tibia	3
Tibia-fibula	1
Astragalus	4
Calcaneus	2
Metapodial	14
Scaphoid	1
Phalange	10
Vertebra	12
Undetermined diaphysis	1
Total	113

elements with high density and low susceptibility to being mobilized. The mandibles of *Cardiatherium chasicoense* (Fig. 6A, B) and *Pisanodon nazari* (Fig. 7C, D) represent the only articulated specimens; the remaining specimens are disarticulated and isolated. Complete specimens (33.9%) are represented by isolated teeth, astragali, calcanei, metapodials, and phalanges, all of them with high structural density. Incomplete long bones show longitudinal and stepped fractures, linked to the biostratinomic stage, and smooth transverse fractures, related to the fossil-diagenetic stage (Marshall, 1989); in some cases, these types of fractures appear combined. Most of the other incomplete skeletal elements also show smooth transverse fractures, which can also be associated to the fossil-diagenetic stage. Most of the specimens with signs of weathering (8.6%) have slight splitting (Fig. 10I); only a toxodontid hemimandible has deeper splitting and flaking (Fig. 10J). Fluvial abrasion evidence includes rounding (17.3%; Fig. 10K) and polishing (3.4%); these alterations are superimposed to other modifications, such as biostratinomic and fossil-diagenetic fractures (Fig. 10L). Several specimens (19.1%) show their surface partially (dendritic aspect) impregnated with Mn oxides, which results in a dark coloration of some portions (Fig. 10M). Evidence of traces produced by root growth is present in scarce specimens (5.2%; Fig. 10N), in some cases superimposed to the impregnation. Modifications by soil corrosion (6.1%; Fig. 10O) are represented by degradation of the surface associated to color change.

As it was previously indicated, beyond some scarce taxonomic contributions, little is known on the vertebrate assemblage from Arenas Blancas site and its relationship with the bearing levels. Now, the detailed study of the taphonomic features, plus the information obtained from the taxonomic and geological analyses, allows us to interpret different aspects related to the origin, age, and preservation history of the specimens of this assemblage.

The weathering signs, mainly represented by slight splitting, high degree of disarticulation, and identification of longitudinal and stepped fractures, suggest that bone remains were exposed in the surface (probably for a variable time according to the different weathering degrees) before primary burial, subject to the action of different destructive processes (*e.g.,* weathering, trampling, predators/scavengers activity). The predominance of disarticulated/isolated and incomplete specimens, the signs of abrasion (intense in many cases), which can be linked to transport and/or interaction with moving sedimentary particles, and the hydrodynamic sorting are taphonomic features concordant with the fluvio/alluvial environment proposed for the bearing level. Predominance of fossil-diagenetic fractures reflects that, in most cases, the breakage occurred once the remains were mineralized. Alterations by corrosion, root traces, and impregnation are linked to the characteristics of the substrate where the remains were primarily buried.

A key point to consider in the interpretation of the taphonomic history of the Arenas Blancas assemblage is the identification of abrasion signs superimposed to post-burial modifications, such as fractures and soil corrosion. This aspect allows inferring that transport and/or interaction with moving sedimentary particles were posterior to the original burial of the bones. Based on this fact, we consider that this assemblage is constituted by reworked specimens (*sensu* Behrensmeyer, 1982). Several of the mentioned taphonomic features (*e.g.,* predominance of disarticulated/isolated specimens, high percentage of specimens with abrasion -many of them with intense degree-, high percentage of broken specimens -with predominance of smooth transverse fractures-) are consistent with the development of fluvial reworking (Behrensmeyer, 1982; Tomassini and Montalvo, 2013; Montalvo *et al*., 2022). This proposal is, in turn, consistent with the interpretation of the Quaternary fluvial/alluvial origin proposed for the bearing levels.

Based on the available evidence, it is proposed here that fluvio/alluvial events, occurred during the Late Pleistocene-Holocene, eroded the Upper Miocene substrate (CAF) cropping out in the Chasicó creek valley and reworked fossil remains (Fig. 3A, B). This interpretation is also supported by the presence of intraclasts from the CAF in the fossil-bearing levels and the Chasicoan affinities of the revised assemblage. Reworking processes would explain the accumulation in a small area of hundreds of skeletal remains belonging to diverse vertebrate taxa, which show very different types of preservation. Vertebrate assemblages formed by reworked specimens were reported for other Neogene fluvial deposits in the Pampean region, such as Cerro La Bota site (Cerro Azul Formation, Chasicoan Stage/Age, Late Miocene; Montalvo *et al*., 2022) and Farola Monte Hermoso site (Monte Hermoso Formation, Montehermosan Stage/Age, Early Pliocene; Tomassini and Montalvo, 2013).

6. Conclusions

Arenas Blancas and Curva de la Vaca are sites of the Chasicó creek lower reach (Buenos Aires Province), herein evaluated from different geological (stratigraphy, sedimentology, geomorphology) and paleontological (taxonomy and taphonomy) perspectives. The obtained information and the comparisons with other sites from the Pampean region lead to a different interpretation on the origin, age, and biostratigraphy of the Arenas Blancas assemblage. Evidence from this multi-proxy analysis allows us to conclude that: **1)** sedimentary sequences cropping out at Arenas Blancas and Curva de la Vaca sites represent Quaternary terraces, which include fluvial/alluvial and eolian deposits; **2)** there is a significant temporal difference between the sedimentation of the deposits and the fossil content of Arenas Blancas site; this vertebrate assemblage is constituted by Late Miocene specimens that were reworked by alluvial/fluvial processes during the Late Pleistocene-Holocene; **3)** most of the identified taxa from Arenas Blancas site are also recorded in levels of the CAF cropping out in the lower reach of Chasicó creek, even being very abundant (*e.g., Chasicotatus ameghinoi*, *Vetelia perforata*, *Typotheriopsis chasicoensis*) and one of them (*Cardiatherium chasicoense*) considered as typical of the Chasicoan Stage/Age in the Pampean region; **4)** the taxonomic status and/or temporal distribution do not support the use of some taxa considered in previous works to characterize the *Macrochorobates scalabrinii* Biozone (Late Miocene, early Huayquerian Stage/Age); and **5)** based on points 1-4, the *Macrochorobates scalabrinii* Biozone is rejected as a valid biostratigraphic unit.

This type of comprehensive study, involving multiple lines of evidence, is totally necessary to make integral evaluations of the vertebrate assemblages preserved in fluvial environments. Particularly, the identification of reworking, a common process in different fluvial/alluvial systems, is essential to propose biochronological and/or biostratigraphic interpretations.

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Supplemetary material S1

Specimen (MMH-CH)	Anatomical assignment	Taxonomic assignment
ORDER RODENTIA		
Family Caviidae		
83-3-24	m1 or m2 fragment	*Cardiatherium* sp.
87-7-64	m1 or m2 fragment	*Cardiatherium* sp.
87-7-66b	m1 or m2 fragment	*Cardiatherium* sp.
87-7-68b	m3	*Cardiatherium* sp.
88-6-71	Mandible fragment with left p4, m2-3 and right m1	*Cardiatherium chasicoense*
Family Chinchillidae		
85-4-101	Right maxilla fragment without teeth	*Lagostomus* sp.
86-9-29	Molariform fragment	*Lagostomus* sp.
87-7-68a	Left hemimandible fragment with p4-m3	*Lagostomus* sp.
87-7-71	m3	*Lagostomus* sp.
Family Dinomyidae		
87-7-67a	?M1 fragment	Dinomyidae indet.
88-6-19	?M1-M2 fragment	Eumegamyinae indet.
ORDER NOTOUNGULATA		
Family Hegetotheriidae		
84-4-68	Right hemimandible fragment with m1-m2	*Paedotherium minor*
84-4-57	Right hemimandible fragment with m1-m2 and remnants of p3-4	*Paedotherium minor*
85-4-110	M3	*Paedotherium minor*
85-4-112	Left hemimandible fragment with m1-m2	*Paedotherium minor*
86-9-27	Right hemimandible fragment with p2-m3	*Paedotherium minor*
Family Mesotheriidae		
83-3-56	Molariform fragment	Mesotheriidae indet.
84-4-55	Left M1 or M2 fragment	?*Typotheriopsis*
87-7-72	Left p4	*Typotheriopsis chasicoensis*
Family Toxodontidae		
83-3-52	Molariform fragment	Toxodontidae indet.
83-3-53	Molariform fragment	Toxodontidae indet.
83-3-55	Incisor fragment	Toxodontidae indet.
83-3-57	Molariform fragment	Toxodontidae indet.
83-3-58	Right m3	*Calchaquitherium mixtum*
84-4-1	Right m1 or m2	*Calchaquitherium mixtum*
84-4-2	Molariform fragment	Toxodontidae indet.
84-4-42	Molariform fragment	Toxodontidae indet.
84-4-44	Incisor fragment	Toxodontidae indet.
84-4-62	Juvenile mandibular fragment with right i2, p1?, dp4-m3 and left i2, dp4-m3	*Pisanodon nazari*
84-4-67	Incisor fragment	Toxodontidae indet.
84-4-109	Tibia-fibula	Toxodontidae indet.
85-4-111	Molariform fragment	Toxodontidae indet.

table S1 coninued.

Specimen (MMH-CH)	Anatomical assignment	Taxonomic assignment
86-9-25	Incisor fragment	Toxodontidae indet.
86-9-33	Molariform fragment	Toxodontidae indet.
86-9-93	Incisor fragment	Toxodontidae indet.
86-9-117	Molariform fragment	Toxodontidae indet.
87-7-2	Incisor fragment	Toxodontidae indet.
87-7-4	Incisor fragment	Toxodontidae indet.
87-7-6	Molariform fragment	Toxodontidae indet.
87-7-7	Incisor fragment	Toxodontidae indet.
87-7-8	Molariform fragment	Toxodontidae indet.
87-7-9	Incisor fragment	Toxodontidae indet.
87-7-10	Molariform fragment	Toxodontidae indet.
87-7-11	Molariform fragment	Toxodontidae indet.
87-7-12	Incisor fragment	Toxodontidae indet.
87-7-14	Molariform fragment	Toxodontidae indet.
87-7-15	Molariform fragment	Toxodontidae indet.
87-7-90	Right hemimandible with p4-m3	*Dinotoxodon paranensis*
88-4-44	Incisor fragment	Toxodontidae indet.
88-6-25	Incisor fragment	Toxodontidae indet.
ORDER LITOPTERNA		
83-3-60	Molariform fragment	Litopterna indet.
85-4-92	Left hemimandible fragment without teeth	Litopterna indet.
86-9-89	Metapodial	Litopterna indet.
86-9-99	Phalange	Litopterna indet.
10-4-67	Calcaneus fragment	Litopterna indet.
Family Proterotheriidae		
83-3-59	P3 or p4 fragment	*Neobrachytherium* sp.
83-3-65	Right hemimandible fragment with lingual portion of m1 or m2	*Neobrachytherium ullumense*
Family Macraucheniidae		
83-3-62	?p3 fragment	Macraucheniidae indet.
83-3-63	Incisor fragment	Macraucheniidae indet.
84-4-45	Left maxillae fragment with M2-M3	*Scalabrinitherium bravardi*
84-4-106	Calcaneus	Macraucheniidae indet.
86-9-23	Metapodial (?Mt III)	Macraucheniidae indet.
86-9-103	Phalange	Macraucheniidae indet.
86-9-106	I lateral phalange	Macraucheniidae indet.
ORDER PILOSA		
84-4-33	I Phalange	Folivora indet.
84-4-61	Metapodial	Folivora indet.
85-4-74	II Phalange	Folivora indet.
85-4-81	III Phalange	Folivora indet.
85-4-83	I Phalange	Folivora indet.

table S1 coninued.

Specimen (MMH-CH)	Anatomical assignment	Taxonomic assignment
86-6-99	I Phalange	Folivora indet.
86-9-89	Metapodial	Folivora indet.
87-7-72	Metapodial	Folivora indet.
87-7-74	Scaphoid	Folivora indet.
Family Mylodontidae		
83-3-54	Caniniform fragment	Mylodontinae indet.
86-9-24	Right hemimandible fragment with m1-m3	Mylodontinae indet.
Family Nothrotheriidae		
10-4-40	?M2 fragment	Nothrotheriinae indet.
Family Megalonychidae		
84-4-40	Left hemimandible fragment with remnants of caniniform, m1, and m2	?Megalonychidae indet.
ORDER CINGULATA		
Family Glyptodontidae		
83-3-66	Molariform fragment	Glyptodontidae indet.
83-3-67	Dorsal carapace osteoderm	Glyptodontidae indet.
83-6-68	Dorsal carapace osteoderm	Glyptodontidae indet.
83-3-69	Caudal ring osteoderm	Glyptodontidae indet.
83-3-71	Dorsal carapace osteoderm	Glyptodontidae indet.
83-3-72	Caudal ring osteoderm	Glyptodontidae indet.
83-3-73	Caudal ring osteoderm	Glyptodontidae indet.
83-3-74	Dorsal carapace osteoderm	Glyptodontidae indet.
83-3-75	Dorsal carapace osteoderm	Glyptodontidae indet.
83-3-76a	Caudal ring osteoderm	Glyptodontidae indet.
83-3-78	Dorsal carapace osteoderm	Glyptodontidae indet.
83-3-78	Dorsal carapace osteoderm	Glyptodontidae indet.
83-3-79	Dorsal carapace osteoderm	Glyptodontidae indet.
83-3-80	Dorsal carapace osteoderm	Glyptodontidae indet.
83-3-81	Caudal ring osteoderm	Glyptodontidae indet.
83-3-82	Dorsal carapace osteoderm	Glyptodontidae indet.
83-3-83	Dorsal carapace osteoderm	Glyptodontidae indet.
83-3-84	Dorsal carapace osteoderm	Glyptodontidae indet.
83-3-85	Dorsal carapace osteoderm	Glyptodontidae indet.
83-3-86	Caudal ring osteoderm	Glyptodontidae indet.
83-3-115	Dorsal carapace fragments (six articulated osteoderms)	Glyptodontidae indet.
84-4-3	Dorsal carapace osteoderm	Glyptodontidae indet.
84-4-4	Dorsal carapace osteoderm	Glyptodontidae indet.
84-4-5	Dorsal carapace osteoderm	Glyptodontidae indet.
84-4-6	Dorsal carapace osteoderm	Glyptodontidae indet.
84-4-7	Dorsal carapace osteoderm	Glyptodontidae indet.
84-4-8	Dorsal carapace osteoderm	Glyptodontidae indet.
84-4-9	Dorsal carapace osteoderm	Glyptodontidae indet.
84-4-10	Dorsal carapace osteoderm	Glyptodontidae indet.

table S1 coninued.

Specimen (MMH-CH)	Anatomical assignment	Taxonomic assignment
84-4-11	Dorsal carapace osteoderm	Glyptodontidae indet.
84-4-12	Dorsal carapace osteoderm	Glyptodontidae indet.
84-4-14	Dorsal carapace osteoderm	Glyptodontidae indet.
84-4-15	Dorsal carapace osteoderm	Glyptodontidae indet.
84-4-16	Dorsal carapace osteoderm	Glyptodontidae indet.
84-4-17	Dorsal carapace osteoderm	Glyptodontidae indet.
84-4-18	Dorsal carapace osteoderm	Glyptodontidae indet.
84-4-19	Dorsal carapace osteoderm	Glyptodontidae indet.
84-4-20	Dorsal carapace osteoderm	Glyptodontidae indet.
84-4-21	Dorsal carapace osteoderm	Glyptodontidae indet.
84-4-23	Dorsal carapace osteoderm	Glyptodontidae indet.
84-4-24	Dorsal carapace osteoderm	Glyptodontidae indet.
84-4-25	Dorsal carapace osteoderm	Glyptodontidae indet.
84-4-26	Caudal ring osteoderm	Glyptodontidae indet.
84-4-27	Dorsal carapace osteoderm	Glyptodontidae indet.
84-4-28	Dorsal carapace osteoderm	Glyptodontidae indet.
84-4-29	Caudal ring osteoderm	Glyptodontidae indet.
84-4-30	Dorsal carapace osteoderm	Glyptodontidae indet.
84-4-31	Dorsal carapace osteoderm	Glyptodontidae indet.
84-4-32	Dorsal carapace osteoderm	Glyptodontidae indet.
84-4-34	Dorsal carapace osteoderm	Glyptodontidae indet.
84-4-35	Dorsal carapace osteoderm	Glyptodontidae indet.
84-4-36	Dorsal carapace osteoderm	Glyptodontidae indet.
84-4-37	Dorsal carapace osteoderm	Glyptodontidae indet.
84-4-38	Dorsal carapace osteoderm	Glyptodontidae indet.
84-4-39	Dorsal carapace osteoderm	Glyptodontidae indet.
84-4-41	Dorsal carapace osteoderm	Glyptodontidae indet.
84-4-46	Caudal tube fragment	Glyptodontidae indet.
84-4-47	Caudal ring osteoderm	Glyptodontidae indet.
84-4-48	Dorsal carapace osteoderm	Glyptodontidae indet.
84-4-50	Caudal ring fragment (two articulated osteoderms)	Glyptodontidae indet.
84-4-51	Dorsal carapace osteoderm	Glyptodontidae indet.
84-4-53	Dorsal carapace osteoderm	Glyptodontidae indet.
84-4-108	Caudal ring	Glyptodontidae indet.
85-4-75	Dorsal carapace osteoderm	Glyptodontidae indet.
85-4-76	Dorsal carapace osteoderm	Glyptodontidae indet.
85-4-77	Dorsal carapace osteoderm	Glyptodontidae indet.
85-4-78	Dorsal carapace osteoderm	Glyptodontidae indet.
85-4-79	Dorsal carapace osteoderm	Glyptodontidae indet.
85-4-80	Dorsal carapace osteoderm	Glyptodontidae indet.
85-4-82	Dorsal carapace osteoderm	Glyptodontidae indet.
85-4-84	Dorsal carapace osteoderm	Glyptodontidae indet.
85-4-85	Caudal ring osteoderm	Glyptodontidae indet.
85-4-86	Dorsal carapace osteoderm	Glyptodontidae indet.

table S1 coninued.

Specimen (MMH-CH)	Anatomical assignment	Taxonomic assignment
85-4-87	Dorsal carapace osteoderm	Glyptodontidae indet.
85-4-88	Dorsal carapace osteoderm	Glyptodontidae indet.
85-4-94	Caudal ring osteoderm	Glyptodontidae indet.
85-4-95	Dorsal carapace osteoderm	Glyptodontidae indet.
85-4-96	Caudal ring osteoderm	Glyptodontidae indet.
85-4-97	Dorsal carapace osteoderm	Glyptodontidae indet.
85-4-98	Dorsal carapace osteoderm	Glyptodontidae indet.
85-4-99	Caudal ring osteoderm	Glyptodontidae indet.
85-4-100	Dorsal carapace osteoderm	Glyptodontidae indet.
85-4-102	Caudal ring osteoderm	Glyptodontidae indet.
85-4-104	Dorsal carapace osteoderm	Glyptodontidae indet.
85-4-107	Dorsal carapace osteoderm	Glyptodontidae indet.
85-4-115	Dorsal carapace osteoderm	Glyptodontidae indet.
86-9-3	Dorsal carapace osteoderm	Glyptodontidae indet.
86-9-4	Dorsal carapace osteoderm	Glyptodontidae indet.
86-9-5	Dorsal carapace osteoderm	Glyptodontidae indet.
86-9-7	Dorsal carapace osteoderm	Glyptodontidae indet.
86-9-8	Dorsal carapace osteoderm	Glyptodontidae indet.
86-9-9	Dorsal carapace osteoderm	Glyptodontidae indet.
86-9-10	Dorsal carapace osteoderm	Glyptodontidae indet.
86-9-11	Dorsal carapace osteoderm	Glyptodontidae indet.
86-9-12	Dorsal carapace osteoderm	Glyptodontidae indet.
86-9-13	Caudal ring osteoderm	Glyptodontidae indet.
86-9-14	Dorsal carapace osteoderm	Glyptodontidae indet.
86-9-15	Caudal ring osteoderm	Glyptodontidae indet.
86-9-17	Dorsal carapace osteoderm	Glyptodontidae indet.
86-9-18	Dorsal carapace osteoderm	Glyptodontidae indet.
86-9-19	Caudal ring osteoderm	Glyptodontidae indet.
86-9-20	Dorsal carapace osteoderm	Glyptodontidae indet.
86-9-21	Dorsal carapace osteoderm	Glyptodontidae indet.
86-9-22	Dorsal carapace osteoderm	Glyptodontidae indet.
86-9-36	Dorsal carapace osteoderm	Glyptodontidae indet.
86-9-37	Dorsal carapace osteoderm	Glyptodontidae indet.
86-9-38	Dorsal carapace osteoderm	Glyptodontidae indet.
86-9-39	Dorsal carapace osteoderm	Glyptodontidae indet.
86-9-40	Dorsal carapace osteoderm	Glyptodontidae indet.
86-9-41	Dorsal carapace osteoderm	Glyptodontidae indet.
86-9-42	Dorsal carapace osteoderm	Glyptodontidae indet.
86-9-43	Dorsal carapace osteoderm	Glyptodontidae indet.
86-9-44	Dorsal carapace osteoderm	Glyptodontidae indet.
86-9-45	Dorsal carapace osteoderm	Glyptodontidae indet.
86-9-90	Dorsal carapace osteoderm	Glyptodontidae indet.
86-9-91	Dorsal carapace osteoderm	Glyptodontidae indet.
86-9-92	Dorsal carapace osteoderm	Glyptodontidae indet.

table S1 coninued.

Specimen (MMH-CH)	Anatomical assignment	Taxonomic assignment
86-9-96	Dorsal carapace osteoderm	Glyptodontidae indet.
86-9-98	Dorsal carapace osteoderm	Glyptodontidae indet.
86-9-100	Dorsal carapace osteoderm	Glyptodontidae indet.
86-9-101	Dorsal carapace osteoderm	Glyptodontidae indet.
86-9-102	Dorsal carapace osteoderm	Glyptodontidae indet.
86-9-104	Dorsal carapace osteoderm	Glyptodontidae indet.
86-9-106	Dorsal carapace fragment (two articulated osteoderms)	Glyptodontidae indet.
86-9-108	Dorsal carapace osteoderm	Glyptodontidae indet.
86-9-109	Dorsal carapace osteoderm	Glyptodontidae indet.
86-9-110	Dorsal carapace osteoderm	Glyptodontidae indet.
86-9-111	Dorsal carapace osteoderm	Glyptodontidae indet.
86-9-112	Dorsal carapace osteoderm	Glyptodontidae indet.
86-9-114	Dorsal carapace osteoderm	Glyptodontidae indet.
86-9-115	Dorsal carapace osteoderm	Glyptodontidae indet.
86-9-116	Dorsal carapace osteoderm	Glyptodontidae indet.
87-7-13	Dorsal carapace osteoderm	Glyptodontidae indet.
87-7-15	Three dorsal carapace and three caudal ring osteoderms	Glyptodontidae indet.
87-7-17	Dorsal carapace fragment (two articulated osteoderms)	Glyptodontidae indet.
87-7-73a	Dorsal carapace osteoderm	Glyptodontidae indet.
87-7-73b	Molariform fragment	Glyptodontidae indet.
87-7-76	Caudal ring osteoderm	Glyptodontidae indet.
87-7-77	Caudal ring fragment (two articulated osteoderms)	Glyptodontidae indet.
87-7-78	Dorsal carapace osteoderm	Glyptodontidae indet.
87-7-79	Dorsal carapace osteoderm	Glyptodontidae indet.
87-7-80	Dorsal carapace osteoderm	Glyptodontidae indet.
87-7-81	Dorsal carapace osteoderm	Glyptodontidae indet.
87-7-82	Dorsal carapace osteoderm	Glyptodontidae indet.
87-7-84	Dorsal carapace osteoderm	Glyptodontidae indet.
87-7-85	Dorsal carapace osteoderm	Glyptodontidae indet.
87-7-86	Dorsal carapace osteoderm	Glyptodontidae indet.
87-7-87	Dorsal carapace osteoderm	Glyptodontidae indet.
87-7-88	Dorsal carapace osteoderm	Glyptodontidae indet.
88-6-3	Dorsal carapace osteoderm	Glyptodontidae indet.
88-6-4	Dorsal carapace osteoderm	Glyptodontidae indet.
88-6-7	Dorsal carapace osteoderm	Glyptodontidae indet.
88-6-8	Dorsal carapace osteoderm	Glyptodontidae indet.
88-6-9	Dorsal carapace osteoderm	Glyptodontidae indet.
88-6-10	Dorsal carapace osteoderm	Glyptodontidae indet.
88-6-11	Dorsal carapace osteoderm	Glyptodontidae indet.
88-6-12	Dorsal carapace osteoderm	Glyptodontidae indet.
88-6-14	Caudal ring osteoderm	Glyptodontidae indet.
88-6-16	Dorsal carapace osteoderm	Glyptodontidae indet.
88-6-17	Dorsal carapace osteoderm	Glyptodontidae indet.
88-6-18	Dorsal carapace osteoderm	Glyptodontidae indet.

table S1 coninued.

Specimen (MMH-CH)	Anatomical assignment	Taxonomic assignment
88-6-20	Caudal ring osteoderm	Glyptodontidae indet.
88-6-21	Dorsal carapace osteoderm	Glyptodontidae indet.
88-6-22	Dorsal carapace osteoderm	Glyptodontidae indet.
88-6-23	Caudal ring osteoderm	Glyptodontidae indet.
88-6-95	Dorsal carapace fragment (three articulated osteoderms)	Glyptodontidae indet.
10-4-22	Dorsal carapace fragment (16 articulated osteoderms)	Glyptodontidae indet.
10-4-24	Dorsal carapace osteoderm	Glyptodontidae indet.
10-4-25	Dorsal carapace osteoderm	Glyptodontidae indet.
10-4-26	Dorsal carapace osteoderm	Glyptodontidae indet.
10-4-27	Dorsal carapace osteoderm	Glyptodontidae indet.
10-4-28	Dorsal carapace osteoderm	Glyptodontidae indet.
10-4-31	Caudal ring osteoderm	Glyptodontidae indet.
10-4-32	Caudal ring fragment (two articulated osteoderms)	Glyptodontidae indet.
10-4-33	Caudal ring osteoderm	Glyptodontidae indet.
10-4-34	Caudal ring fragment (two articulated osteoderms)	Glyptodontidae indet.
10-4-35	Caudal ring osteoderm	Glyptodontidae indet.
10-4-36	Dorsal carapace osteoderm	Glyptodontidae indet.
10-4-37	Dorsal carapace osteoderm	Glyptodontidae indet.
10-4-38	Dorsal carapace osteoderm	Glyptodontidae indet.
10-4-39	Dorsal carapace osteoderm	Glyptodontidae indet.
10-4-40	Dorsal carapace osteoderm	Glyptodontidae indet.
10-4-41	Dorsal carapace osteoderm	Glyptodontidae indet.
10-4-42	Dorsal carapace osteoderm	Glyptodontidae indet.
10-4-43	Dorsal carapace osteoderm	Glyptodontidae indet.
10-4-51	Dorsal carapace osteoderm	Glyptodontidae indet.
10-4-52	Dorsal carapace osteoderm	Glyptodontidae indet.
10-4-53	Dorsal carapace osteoderm	Glyptodontidae indet.
10-4-54	Dorsal carapace osteoderm	Glyptodontidae indet.
10-4-55	Dorsal carapace osteoderm	Glyptodontidae indet.
10-4-56	Dorsal carapace osteoderm	Glyptodontidae indet.
10-4-57	Caudal ring osteoderm	Glyptodontidae indet.
10-4-58	Dorsal carapace osteoderm	Glyptodontidae indet.
10-4-59	Caudal ring osteoderm	Glyptodontidae indet.
10-4-60	Caudal ring osteoderm	Glyptodontidae indet.
10-4-62	Dorsal carapace osteoderm	Glyptodontidae indet.
10-4-63	Dorsal carapace osteoderm	Glyptodontidae indet.
10-4-64	Dorsal carapace osteoderm	Glyptodontidae indet.
10-4-65	Caudal ring osteoderm	Glyptodontidae indet.
Family Chlamyphoridae		
83-3-64	Mobile dorsal carapace osteoderm	*Vetelia perforata*
84-4-13	Cephalic osteoderm	*Vetelia perforata*
84-4-49	Mobile dorsal carapace osteoderm	*Vetelia perforata*
84-4-52	Dorsal carapace osteoderm	Dasypodidae indet.
84-4-54	Mobile dorsal carapace osteoderm	*Vetelia perforata*

table S1 coninued.

Specimen (MMH-CH)	Anatomical assignment	Taxonomic assignment
84-4-56	Mobile dorsal carapace osteoderm	?*Macrochorobates*
84-4-58	Mobile dorsal carapace osteoderm	*Vetelia perforata*
84-4-60	Dorsal carapace osteoderm	Dasypodidae indet.
84-4-63	Mobile dorsal carapace osteoderm	*Vetelia perforata*
84-4-64	Dorsal carapace osteoderm	Dasypodidae indet.
84-4-66	Semimobile dorsal carapace osteoderm	*Macrochorobates scalabrinii*
84-4-69	Dorsal carapace osteoderm	Dasypodidae indet.
84-4-70	Semimobile dorsal carapace osteoderm	*Proeuphractus* sp.
84-4-71	Mobile dorsal carapace osteoderm	*Chasicotatus ameghinoi*
85-4-113	Fixed dorsal carapace osteoderm	*Macrochorobates scalabrinii*
85-4-114	Mobile dorsal carapace osteoderm	*Proeuphractus* sp.
86-9-30	Mobile dorsal carapace osteoderm	*Chasicotatus ameghinoi*
86-9-32	Mobile dorsal carapace osteoderm	*Proeuphractus* sp.
87-7-6	Mobile dorsal carapace osteoderm	*Macrochorobates scalabrinii*
87-7-65	Fixed dorsal carapace osteoderm	*Chasicotatus ameghinoi*
87-7-69	Mobile dorsal carapace osteoderm	*Macrochorobates scalabrinii*
87-7-70	Mobile dorsal carapace osteoderm	*Proeuphractus* sp.
87-7-71	Mobile dorsal carapace osteoderm	*Chasicotatus ameghinoi*
88-6-6	Fixed dorsal carapace osteoderm	*Macrochorobates scalabrinii*
88-6-13	Fixed dorsal carapace osteoderm	*Macrochorobates scalabrinii*
88-6-15	Fixed dorsal carapace osteoderm	*Macrochorobates scalabrinii*
10-4-22	Mobile dorsal carapace osteoderm	*Chasicotatus ameghinoi*
10-4-46	Mobile dorsal carapace osteoderm	*Chasicotatus ameghinoi*
10-4-50	Semimobile dorsal carapace osteoderm	*Chasicotatus ameghinoi*
10-4-66	Mobile dorsal carapace osteoderm	*Macrochorobates scalabrinii*
Family Pampatheriidae		
85-4-93	Mobile dorsal carapace osteoderm	*Kraglievichia paranense*
85-4-105	Fixed dorsal carapace osteoderm	*Kraglievichia paranense*
85-4-106	Mobile dorsal carapace osteoderm	*Kraglievichia paranense*
85-4-116	Mobile dorsal carapace osteoderm	*Kraglievichia paranense*
10-4-22	Mobile dorsal carapace osteoderm	*Kraglievichia paranense*
Other mammal specimens		
83-3-61	Astragalus	Mammalia indet.
83-3-70	Undetermined long bone	Mammalia indet.
84-4-43	Tibia fragment	Mammalia indet.
84-4-59	Astragalus	Mammalia indet.
84-4-107	Vertebra fragment	Mammalia indet.
85-04-72	Vertebra fragment	Mammalia indet.
85-4-73	Vertebra fragment	Mammalia indet.
85-4-91	Vertebra fragment	Mammalia indet.
85-4-92	Left hemimandible fragment without teeth	Mammalia indet.
86-9-1	Metapodial	Mammalia indet.

table S1 coninued.

Specimen (MMH-CH)	Anatomical assignment	Taxonomic assignment
86-9-2	Vertebra fragment	Mammalia indet.
86-9-6	Phalange	Mammalia indet.
86-9-16	Vertebra fragment	Mammalia indet.
86-9-28	Molariform fragment	Mammalia indet.
86-9-31	Phalange	Mammalia indet.
86-9-34	Astragalus	Mammalia indet.
86-9-35	Humerus fragment	Mammalia indet.
86-9-94	Femur fragment	Mammalia indet.
86-9-95	Tibia fragment	Mammalia indet.
86-9-97	Vertebra fragment	Mammalia indet.
86-9-107	Vertebra fragment	Mammalia indet.
87-7-5	Vertebra fragment	Mammalia indet.
87-7-18	Metapodial	Mammalia indet.
87-7-65	Molariform fragment	Mammalia indet.
87-7-69	Astragalus	Mammalia indet.
87-7-70	Tibia fragment	Mammalia indet.
87-7-72	Metapodial	Mammalia indet.
87-7-74	Metapodial	Mammalia indet.
87-7-75	Vertebra fragment	Mammalia indet.
87-7-82	Metapodial	Mammalia indet.
88-6-24	Vertebra fragment	Mammalia indet.
10-4-29	Metapodial	Mammalia indet.
10-4-40	Metapodial	Mammalia indet.
10-4-44	Vertebra fragment	Mammalia indet.
10-4-48	Metapodial	Mammalia indet.
10-4-49	Metapodial	Mammalia indet.
ORDER SILURIFORMES		
Family Loricariidae		
85-4-140	Proximal end of pectoral spine	Loricariidae indet.
ORDER TESTUDINES		
Family Testudinae		
85-4-90	Dorsal carapace osteoderm	*Chelonoidis* sp.
85-4-109	Dorsal carapace osteoderm	*Chelonoidis* sp.
87-7-3	Dorsal carapace osteoderm	*Chelonoidis* sp.
87-7-16	Dorsal carapace osteoderm	*Chelonoidis* sp.
87-7-67b	Dorsal carapace osteoderm	*Chelonoidis* sp.
88-6-94	Dorsal carapace osteoderm	*Chelonoidis* sp.
10-4-13	Dorsal carapace osteoderm	*Chelonoidis* sp.
ORDER CATHARTIFORMES		
88-6-5	Ulna fragment	cf. Cathartidae