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Article

New material of *Equus (Amerhippus) neogeus* (Mammalia, Perissodactyla) from the late Pleistocene of Olavarría (Argentina)

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With 5 figures and 2 tables

Abstract: The fossil mammal locality from the El Polvorín limestone Quarry in Calera Avellaneda (Olavarría, Argentina) is known for its Quaternary mammals. This paper describes new specimens of equids. The comparative study with other horses, from different localities of South America, mostly Argentina and Brazil, allowed identifying the specimen as *Equus (Amerhippus) neogeus* Lund. This represents a new locality for this species, assigned to the late Pleistocene (Lujanian Stage/Age, c. 130-12 ka BP). The fauna associated with this stratigraphic level is consistent with a lapse of time dominated by fauna adapted to arid and cold conditions.

Key words: Taxonomy, *Equus*, late Pleistocene, Buenos Aires Province, Argentina.

1. Introduction

The South American Equidae fossil record is one of the best known of vertebrate palaeontology (Simpson 1951). This group originated in North America during the Eocene, where they had an extraordinary adaptive radiation. The study of this group in South America began in the mid-nineteenth century, when Darwin found a molar of a fossil horse in Argentina (Owen 1840). Since this publication, notes and articles proliferated, which in most cases do not reflect the global diversity of this group. Recent papers on the Equidae in South America (Alberdi 1987; Alberdi & Prado 1992, 1993, 2004; Prado & Alberdi 1994, 2008, 2012; Alberdi et al. 1989, 2003; Prado et al. 2005; among others) recognize two genera: *Equus* (*Amerhippus*) and *Hippidion*. Both genera share common features such as a large skull in relationship to body size. However, each genus has distinct dental morphology, with a certain intraspecific variability. *Hippidion* has a more primitive morphology than *Equus*, and its body structure are more robust in comparison with *Equus*. The former have three different species and the latter five species (see Alberdi & Prado 1993; Prado & Alberdi 1994).

In 1950, the French palaeontologist Robert Hoffstetter created the subgenus *Equus(Amerhippus)* to include all species of genus *Equus* from South America. The author justified this subgenus by a single character: the absence of the infundibulum marked on the surface of the lower incisors and, therefore, the loss of enamel on the occlusal surface. Several articles have been published to systematise the knowledge of the species of *Equus*. Prado & Alberdi (1994) reviewed this group and recognised five species: *E. (A.) andium* Branco, *E. (A.) insulatus* Ameghino, *E. (A.) neo-*

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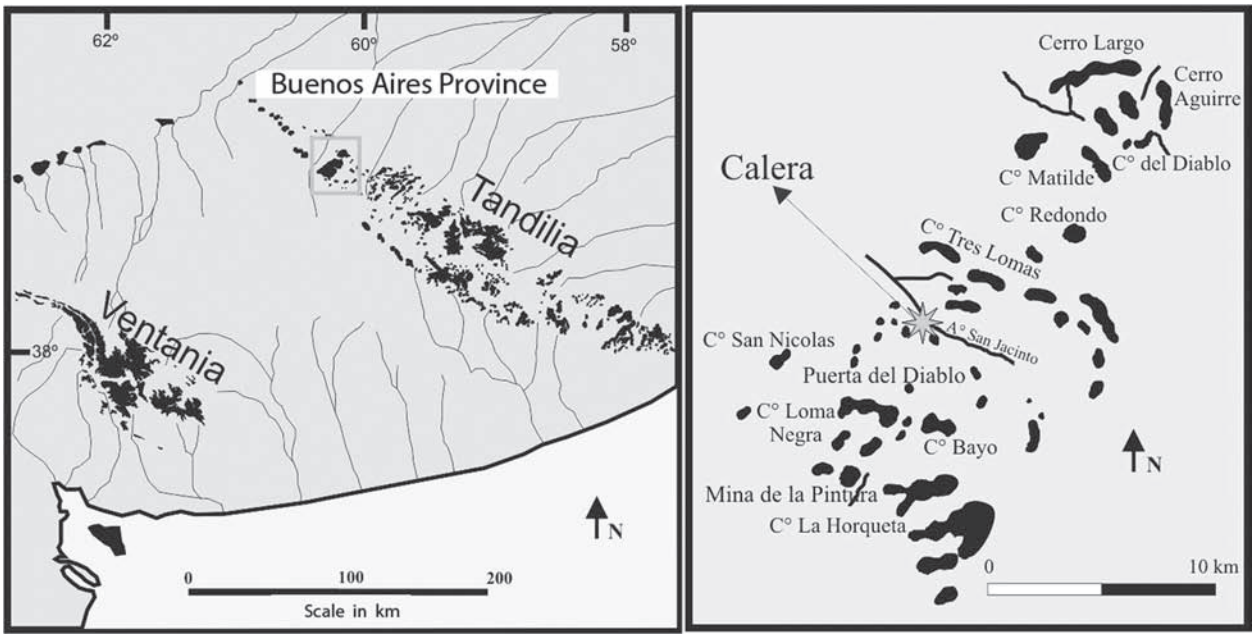

Fig. 1. Geographic location of the commercial exploitation of the El Polvorín limestone Quarry in Calera Avellaneda (Olavarría, Buenos Aires Province, Argentina).

geus (Lund), *E. (A.) santaeelenae* (Spillmann) and *E. (A.) lasallei* Daniel. This review is based largely on findings from Argentina, Bolivia, Ecuador, and Brazil. The earliest appointed *Equus* corresponds to the middle Pleistocene Ensenadan Stage/Age in Tarija (Bolivia), dated by MacFadden et al. (1983) and MacFadden (2013) to around 1.0 to 0.8 Ma, which has been recently questioned by Tonni et al. (2009).

The new remains of horse analysed here come from the fossiliferous locality called El Polvorín limestone Quarry Calera Avellaneda near the city of Olavarría in the Buenos Aires Province. These fossils were recovered during a palaeontological rescue work performed by one of the authors (MR). This specimen constitutes a new record of horses in South America that completes the description of the species. The aim of this paper is to present a detailed description of this material, its precise taxonomic status and stratigraphic location.

2. Physiographical and geological setting

The Sierra of Tandilia is a NW-trending hill range, 350 km long, which rises 50-250 m above the surrounding Pampa grasslands. The valleys or the undulating plain separates the ranges (González-Bonorino 1965). According to Teruggi & Kilmurray (1980), the Sierra of Tandilia is divided into three main sectors from NW to SE: (a) the Sierra de Olavarría, (b) Sierra de Azul and Tandil, and (c) the Sierra de Lobería and Mar del Plata.

Upper Tertiary/Quaternary sedimentary covers are overlaying the previous geological record showing a conglomerate, sandstone and loessic deposits bearing abundant fossil vertebrates (Poiré et al. 2007; De los Reyes et al. 2007; Poiré 2012a).

Commercial exploitation of the El Polvorín limestone Quarry in Calera Avellaneda uncovered several years ago the presence of a Mio-Pliocene unit called El Polvorín Formation and above one unit designated as informal quaternary sediments (Poiré et al. 2007; De los Reyes et al. 2007). The extraction of limestone from this quarry has allowed to distinguish in the latter, the presence of two distinct units with several fossil remains. This site is located in the central area of the so-called Sierras Bayas at 36°58'05'' S and 60°14'02'' W (Fig. 1). This area is known for its hills, valleys and plains along the Tapalqué River.

The profile sequence in the area is referred to the upper Cenozoic and presents a wide distribution. They

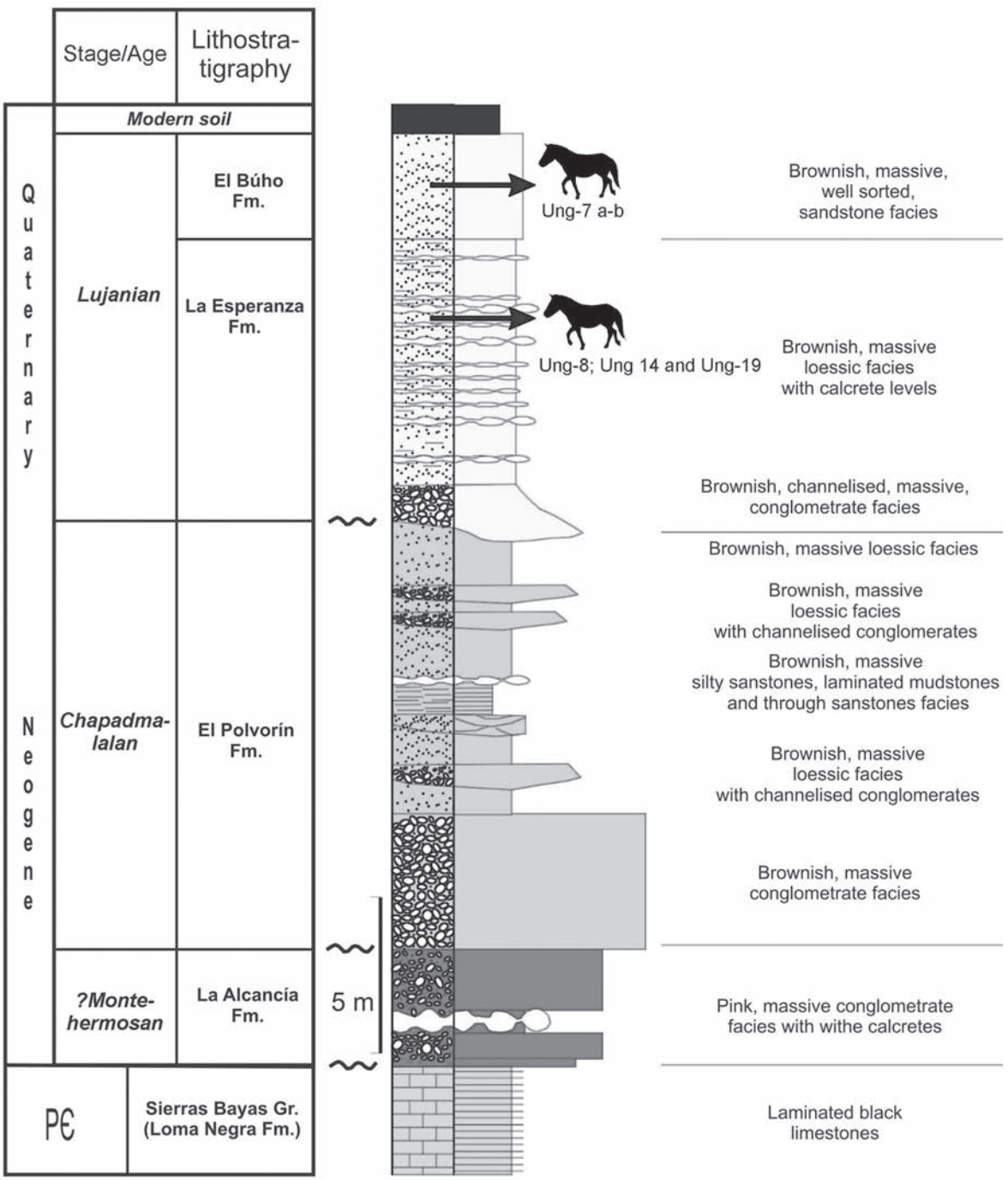

Fig. 2. Detailed stratigraphy of the El Polvorín Formation, Buenos Aires Province, Argentina (modified from Poiré 2012b).

are sedimentary rocks, mainly caused by wind and fluvial processes, and in addition to materials produced by landslides and pyroclastic events from eolian and fluvial sediments developed by weathering processes. These sequences whose oldest sediments in the area was referred to as late Miocene and Pliocene (Zárate

et al. 2007) have great development in the profile where they can register thicknesses of over 100 meters. Deposits generated by wind processes correspond to sediments carried by wind from distant areas and then accumulated and remobilised under drier climatic conditions than today. The most representative are mainly fine-grain loess. The extensive plains in the province of Buenos Aires contain extensive formations of superficial sand and loess that are known as the Pampean Formation (Teruggi 1957). Palaeomagnetic stratigraphy and radiometric data suggest that most of this formation was deposited over the last 3.3 Ma (Schultz et al. 1998). The stratigraphy of Pampean loess typically consists of superposed beds, 1-2 m thick, separated by either erosional discontinuities or palaeosols. The majority of these palaeo-aeolian features lie in areas presently supporting vegetation communities dominated by grassland.

At present, the Pampean grasslands have a subtropical climate, which varies from humid in the east to arid in the west. This climatic pattern reflects the dominant effects of the ocean in the southern half of South America (Iriondo & García 1993). The mean annual temperature is approximately 17°C and the mean annual precipitation is around 800 mm.

The El Polvorín Formation present facies with conglomerates alternate with fine sandstones and mudstones (loess facies). The first is divided into two levels up to 4 m thick (Fig. 2), discontinuous, located at the base and top of the unit, marking its limits, and smaller lenses within the loess materials. The loessic facies exists between the two main bodies of psephitic, net contacts. Its thickness reaches 7 m higher with tabular geometry, which is wedged in approaching the quartzite counters. This level supports vertebrate fossils assignable to the Montehermosan Stage/Age (Prado et al. 1998; Tonni et al. 1992) dating around 5.28 to 4.5 Ma. Recently, Deschamps et al. (2012) suggests a new interpretation for the age of this formation extending it to the Chapadmalal Stage/Age. Overlying the El Polvorin Formation appears a level up to 4 m thick with sedimentary sandy brown loam, moderately compact, and characterized by a tufa horizontal level (calcareous concretions). This level is identified by the presence of gullies and palaeo-caves, and abundant fossils with poor mineralization and carbonate bonded. The fossil find was assigned to this level, which corresponds to the late Pleistocene (Lujanian Stage/Age, around 0.13 to 0.012 Ma). Finally, a strong erosive discordance develops above the deposition of loess, up to 5 m thick, partly friable. Poiré et al. (2007) proposed the name "El Búho" for this unit, which is also assigned to the late Pleistocene. In general, these sedimentary units have strong erosional surfaces, are framed as a predominantly mountainous area, with concomitant signs of tectonic uplift.

3. Material and methods

The remains recovered from El Polvorín limestone quarry in Calera Avellaneda are stored at the palaeontological collection of the UE INCUAPA (CONICET-UNICEN) in Olavarría.

For morphometric and comparative analysis, we used data on South American horses described by Prado & Alberdi (1994, 2008, 2012), Alberdi et al. (2003), Alberdi & Prado (2004), Alberdi & Frassinetti (2000), Prado et al. (2005), and Rincón et al. (2006). The nomenclature and measurements are based on the recommendations and rules elaborated by the "*Hipparion* Conference" (Eisenmann et al. 1988). All dimensions are in millimetres.

We describe one maxilla symphysis with large canines and incisive (UNG-19); one left M1-2 (UNG-14); a left p3-4 (UNG-08); a left metacarpal III (UNG-07b); and the first phalanx of the third digit (UNG-07a).

For comparative analysis, new remains are incorporated into the large database already used in previous works (Prado et al. 2013). The discriminate analysis (DA) was performed over 60 MCIII and 130 1PHIII. On each within-group variance-covariance matrix, the first three functions were extracted. The character function loadings were used to calculate the operational unit function scores, or projections, in the two function spaces. DA is a linear function of the original variable weighed by coefficients. It can also be used to evaluate whether the centroids differ significantly or not, and to identify specimens not included in the original analysis, which established the groups (Marcus 1990; Reyment 1991). The computational work was performed using SPSS version 15.0 (SPSS Inc.).

Fig. 3. Remains of *Equus (Amerhippus) neogeus* Lund, 1840 from El Polvorín, Calera Avellaneda (Olavarría, Buenos Aires Province, Argentina). **A** – Anterior view of left MCIII; **B** – occlusal view of upper symphysis; **C** – occlusal view of left p3-4; **D** – the same in labial view; **E** – occlusal view of left P3-4 or M1-2; **F** – anterior view of 1PHIII. All scales equal 3 cm.

Fig. 3.

Table 1. Measurements of the remains of *Equus (Amerhippus) neogeus* Lund, 1840 from El Polvorín, Calera Avellaneda (Buenos Aires Province). Numbers following Eisenmann et al. (1988). All dimensions are expressed in millimeters.

Collection number	Specimen	Formation	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	IG
Ung-7b	MCIII izq	Buho Fm	215	205	37.3	29.18	54.19	36.23	46.43	13.65	7.97	50.3	48.81	34.95	28.06	30.85		17.35
Ung-7a	1FIII	Buho Fm	85.8	78.84	36.01	55.05	37.3	44.2	42.94	26.48	58.26							

Collection number	Tooth	Formation	Ls	Bs	Lb	Bb	H	Lpr
Ung-14	M1-2 left	Esperanza Fm	27.2	30.5	24.5	28	50	11.1
Ung-08	p3-4 left	Esperanza Fm	29.88	16.32			15.97	

Table 2. Percentage of correct classification by cross-validation techniques of the MCIII and 1PHIII from El Polvorín, Calera Avellaneda (Buenos Aires Province, Argentina).

	Original	N	1	2	3	4
McIII	1	20	100%	0%	0%	0%
	2	8	0%	100% (2)	0%	0%
	3	30	0%	0%	100%	0%
	4	2	0%	50%	0%	50%
	ungrouped	1	100%	0%	0%	0%
First	1	28	85.7%	3.6%	0%	10.7%
phalanx	2	31	0%	93.5%	0%	6.5%
	3	61	0%	0%	98.4%	1.6%
	4	10	10%	10%	0%	80%
	ungrouped	1	100%	0%	0%	0%

4. Systematic palaeontology

Order Perissodactyla Owen, 1848
Family Equidae Gray, 1821
Subfamily Equinae Gray, 1821

Equus (*Amerhippus*) *neogeus* Lund, 1840
Fig. 3

Material: An upper symphysis of the skull (UNG-19); a left M1-2 (UNG-14); a left p3-4 (UNG-08); the left metacarpal of the third digit (UNG-07b); and the first phalanx of the third digit (UNG-07a) (Fig. 3).

Description: The symphysis preserves all incisive and canines but they are very worn and broken. It corresponds to a very old individual large in size, a possible male. We could take only two dimensions 14 = 63.7 and 15 = 78.4, following Eisenmann et al. (1988). M1-2 is slightly broken, lack the mesostyle and metacone, protocone has a characteristic triangular form with one caballine pli and the fosettes folders are 1/6 7/2 respectively. The lower tooth, isolated p3-4, shows little degree of wear. Occlusal morphology is not complicated, with a rounded subtriangular double-knot. Linguaflexid is shallow. Ectoflexids are slightly developed without crosses in the isthmus. The measurements of the different teeth are presented in Table 1. The left MCIII is complete and conserves the lateral metacarpal, MCII and MCIV. The gracility index of MCIII1 vs. MCIII3 is 17.35 (Table 1). The first phalanx of the third digit conserves sediment remains on the proximal articulation. The DA based on MCIII provides a correct identification of the 98.3% of the original prediction, and 91.7% by cross tabulation. The MCIII from El Polvorín place among the remains of *Equus (A.) neogeus* previously classified. The DA for the 1PHIII also reproduces the same results, provides a correct identification of the 93.1% of the original prediction and 84.6% by cross tabulation (Fig. 4; Table 2).

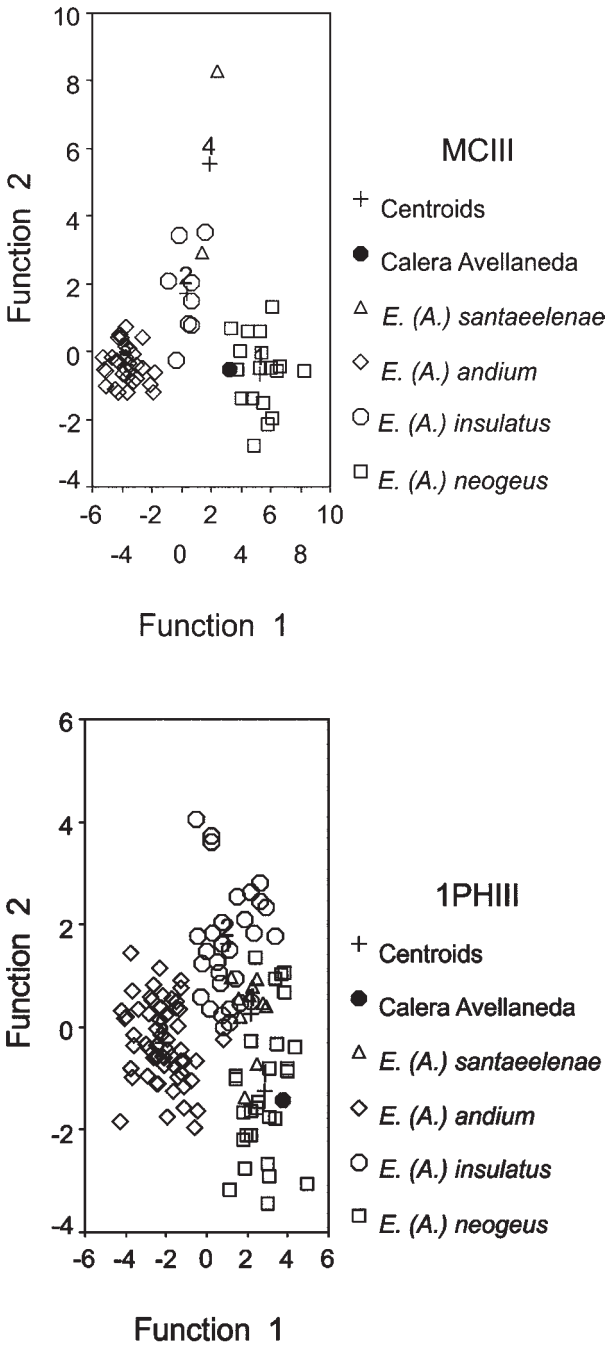

Fig. 4. *Equus (Amerhippus) neogeus* Lund, 1840 MCIII and 1PHIII discriminant analysis from El Polvorín, Calera Avellaneda (Buenos Aires Province, Argentina) compared with other *Equus (Amerhippus)* species from South America. 1, 2, 3 and 4 are centroids.

Discussion: The measurements and description of these teeth remains indicate the general tooth pattern as a subtriangular protocone, a reduced caballine pli, a few plis at the fossettes, large parastyle and mesostyle, an oval, strangulated and large hypocone are all morphological features characteristic of *Equus* (*Amerhippus*) *neogeus.* The DA of MCIII and 1PHIII present high percentages of correct classification of original prediction and both specimens are placed among the remains previously classified as *Equus* (*Amerhippus*) *neogeus.*

5. Remarks and conclusions

Although the horse remains from El Polvorin profile are scarce, they are enough distinctive in morphology and size to be assigned unequivocally to *Equus* (*Amerhippus*) *neogeus*, comparable to other specimens from the Pampean Region of Argentina and other South American localities.

Equus (*Amerhippus*) *neogeus* is the largest and most slender morphotype of the South American horses, and appears to have predominated at middle and lower latitudes in eastern South America (Argentina, Uruguay and Brazil). This species occupied savannas or xerophytic pastures, and consequently would have been better adapted to open and arid landscapes (Prado & Alberdi 1994). The record of this species diminished from North to South, particularly during the latest Pleistocene and this locality represents one of the southern records for this species.

Equus (*Amerhippus*) *neogeus* was found in association with other large mammals such as *Megatherium americanum*, *Glyptodon reticulatus*, and *Neosclerocalyptus* sp. This association, composed basically by taxa adapted to a cold and arid environment present during the late Pleistocene, is compatible with a glacial period, involving possibly the last glacial stage, which also includes the last glacial maximum (Prado et al. 2001).

From a biostratigraphic point of view, both *Equus* (*Amerhippus*) *neogeus* and *Neosclerocalyptus* sp. are taxa limited to the Lujanian Age (c. 130-13 ka BP; Alberdi et al. 2003; Zurita et al. 2005; Cione & Tonni 2005). In the Pampean region, Cione et al. (2009) proposed the *E.* (*A.*) *neogeus* biozone based on the "Piso Lujanense" (Fig. 5). More recently, Toledo (2011) reinterpreted the "*Piso Lujanense*" based on a sequence stratigraphy analysis and AMS, OSL and ESR dating in the Lujan section. This author proposed that the Pleistocene Pampean valley fill spans from OIS 4 to OIS 2 with sequence boundaries at 75, 55, 30, 17 and 13 ka BP.

All taxa present at this locality are compatible with Lujanian mammal assemblage in the inter hill sector of the Pampean Region, fundamentally composed

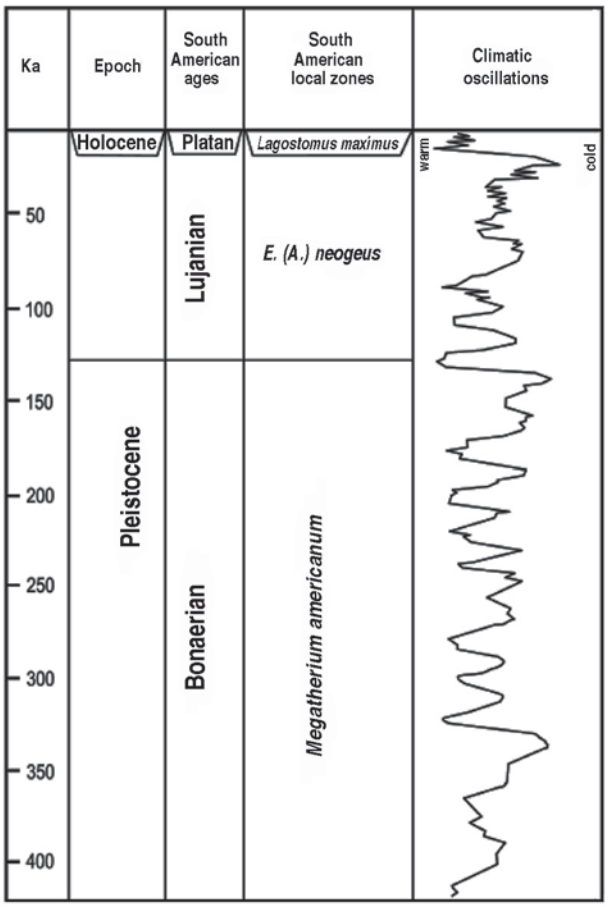

Fig. 5. Chronological chart of the middle Pleistocene to present day in Southern South America depicting mammal zones and South America ages (modified from Cione et al. 2009). The climatic oscillations represented by ^{18}O of Vostok, Antarctica (Petit et al. 1999).

by mammals from the Pampa and Patagonian area, adapted to cold environments and arid conditions during most of the late Pleistocene (see Tonni et al. 1999; Prado et al. 2001). Hence, this association is consistent with a glacial period, possibly involving the last glacial stage, which also includes the last glacial maximum (c. 18 ka BP).

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