Radiocarbon date on megafauna from the late Pleistocene-early Holocene of Córdoba province, Argentina: stratigraphic and paleoclimatic significance

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ABSTRACT

A radiocarbon date (7550 ± 60 yr ^{14}C BP) was obtained from bone collagen of an extinct ground sloth (Scelidotherium leptocephalum) from the locality of Río Cuarto (Córdoba province, Argentina). The fossil remains were recovered from the La Invernada Formation (late Pleistocene- Holocene). The date presented in this paper is the first radiocarbon date obtained from megafauna in Córdoba province, Argentina. It supports the temporal assignation of the La Invernada Formation to the late Pleistocene-early Holocene, and it will allow correlation of these sediments with climatic events that took place during this time. Moreover, it is the youngest radiocarbon date from megamammals recorded in central Argentina.

Key words: geochronology, radiocarbon date, Scelidotherium, ground sloth, late Pleistocene-early Holocene, Córdoba, Argentina.

RESUMEN

Se presenta el primer fechamiento por radiocarbono (7550 ± 60 yr ^{14}C AP) para la provincia de Córdoba, obtenido a partir de colagéno presente en huesos de Scelidotherium leptocephalum, un perezoso terrestre extinto. Los materiales fósiles fueron exhumados de sedimentos asignados a la Formación La Invernada, en el Departamento de Río Cuarto, provincia de Córdoba, Argentina. La fecha aquí presentada soporta la asignación temporal de la Formación La Invernada al Pleistoceno tardío-Holoceno temprano y permite la correlación de estos sedimentos con los eventos climáticos que tuvieron lugar durante ese periodo. Asimismo, es uno de los fechamientos por radiocarbono más jóvenes de megamamíferos de Argentina.

Palabras clave: geocronología, fechado radiocarbónico, Scelidotherium, perezoso terrestre, Pleistoceno tardío-Holoceno temprano, Córdoba, Argentina.

Cruz, L.E., Bargo, M. S., Tonni, E.P., Figini A.J., 2010, Radiocarbon date on megafauna from the late Pleistocene-early Holocene of Córdoba province, Argentina: stratigraphic and paleoclimatic significance: Revista Mexicana de Ciencias Geológicas, v. 27, núm. 3, p. 470-476.

INTRODUCTION

The Quaternary sediments of Río Cuarto area (Córdoba province, Argentina, Figure 1) are part of the loess deposits of South America, which extend from 23ºS to 38ºS (Zárate, 2003). These sediments have been extensively studied by several authors due to their palaeosoil development which results from the pedogenesis of loessoid sediments (Cantú *et al.,* 2004; Kemp *et al.,* 2006; and references therein). Particularly, the sediments of Río Cuarto area are primarily aeolian sediments (silt and sandy silt), and secondarily fluvial sediments, which were defined and characterized by Cantú (1992, 1998). This author named, from oldest to youngest, the following units: "Pampiano Formation", Chocancharava Formation, La Invernada Formation, Las Lajas Formation and Laguna Oscura Formation, and assigned them to the late Pleistocene – Holocene. This paper will only refer to the first three units, which are associated with the late Pleistocene-early Holocene period. See Table 1, modified of Carignano (1999), for the correlation of this unit with others of the Buenos Aires and Córdoba provinces.

The "Pampiano Formation" is composed of two types of sediments: (1) alluvial, integrated with brown reddish silt and very fine sandy silt, with several levels containing iron and silica nodules, and (2) aeolian, composed of reddish brown to yellowish brown silt, with a high content of dispersed calcium carbonate and levels of calcretes. The Chocancharava Formation is composed of alluvial materials, including clasts of basement rocks, mainly of granitic origin, that are supported in a sandy matrix and cemented by calcium carbonate. Finally, the La Invernada Formation is composed of aeolian sediments comprising yellowish brown very fine sandy silt without visible structure (Cantú, 1998).

The La Invernada Formation has been studied not only by its palaeosoil development, age and mammals assem-

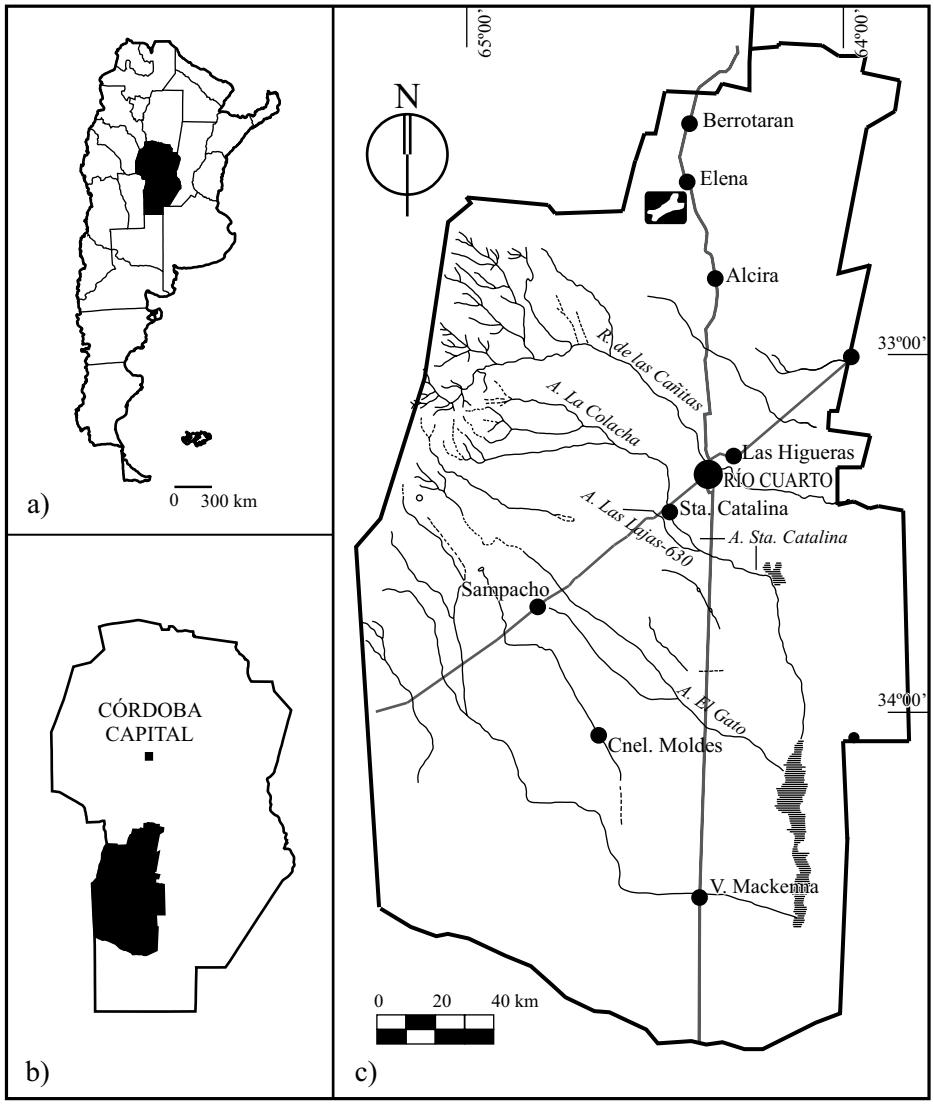


Figure 1. Location map. a) Argentine Republic, b) Córdoba province, c) Río Cuarto Department.

blages, but also because it includes structures that have been interpreted either as craters produced by impacts of meteors (Schultz and Lianza, 1992; Schultz *et al.* 1994), or as great systems of deflation/accumulation landforms (Cione *et al.* 2002 and references therein; see also Bland *et al.* 2002). At the base of these structures, described by Schultz and Lianza (1992), some fossils remains (osteoderms of a Mylodontidae ground sloth housed at the Museo de La Plata, Argentina; MLP 99-XI-2-1) have been discovered, which supports that these structures do not correspond to craters (Cione *et al.* 2002). However, Schultz *et al.* (2004) suggest that two different impact glasses from the area of Río Cuarto yield two different dates, the younger at about 3 – 6 ka.

The vertebrate fossil remains recovered from the units throughout the area of Río Cuarto are scarce, and thus they provide little stratigraphic information. Moreover, no absolute age has been obtained previously from bone collagen in Córdoba province. Although there are some radiocarbon dates from the area of Río Cuarto, they have been obtained from calcium carbonate (see Cantú, 1998). This fact contrasts strongly with the chronological information available for Buenos Aires province, which is the basis of the biostratigraphic profile that is currently in use in Argentina (Cione and Tonni, 1999, 2001, 2005). In this context, other dates from bone collagen are available from Buenos Aires province, but these are slightly younger than 10 ka (Politis and Messineo, 2008), except for a date reported by Rosello *et al.* (1999), which was questioned by Cione *et al.* (2001).

The aim of this contribution is to present the results of the first radiocarbon date from bone collagen of a ground sloth *Scelidotherium leptocephalum* Owen, 1840 (Xenartha, Tardigrada, Mylodontidae) (Figure 2) from the La Invernada Formation, Córdoba province, Argentina.

GEOGRAPHIC LOCATION AND GEOLOGY

The fossil remains were found at Elena locality, Río Cuarto Department, Córdoba province (Figure 1). The site is located in a natural open crevasse corresponding to a rural road, about 2.5 km from National Highway N° 36, where sandy silts containing the ground sloth remains are exposed. Figure 3 provides a schematic profile of this site. The sediments of level A are composed of yellowish brown sandy silt loess, that is referred to the La Invernada Formation. The level B is referred to the Laguna Oscura Formation.

Cantú (1992, 1998) described La Invernada Formation as composed of silty and sandy silt loess, overlain by the Las Tapias paleosoil. This formation was partially correlated by Cantú (1992, 1998) with the Last Glacial Maximum (LGM). Evidence of this climatic event is also found in the neighbouring provinces of San Luis, Buenos Aires, and Santa Fé (Carignano, 1999 and references therein). Later results of thermoluminiscence (TL) obtained by Cantú *et al.* (2004) for the La Invernada Formation showed an age between 85700 ± 11500 and 12800 ± 1500 yrs. BP. Until now, these were the only dates for these sediments. The upper limit of this formation was coincident with a climatic amelioration period (Hypsithermal) (Cantú 1992, 1998 p. 109: *"Edad: de acuerdo con la correlación existente entre el clima interpluvial y las glaciaciones, en este caso con el último stadial de la glaciación Wisconsin o Máximo glacial, Cantú (1992) llega a establecer que estos materiales comenzaron a depositarse al inicio de la denominada Glaciación Vallecito I (Wayne, 1984), 18000 a 20000 a. A.P., culminando tal vez a principio del Holoceno (9500 a 8200 B.P.) cuando se establece un mejoramiento generalizado del clima (Optimum Climaticum)"*).

The Las Tapias paleosoil was referred to the Hypsithermal (7–5 ky BP) by Cantú (1992, 1998) and Cantú *et al.* (2004), and correlated with other paleosoils identified in several locations in Córdoba province by Carignano (1999). Additional information about its composition and age has been recently provided by Cantú *et al.* (2004). In this work, about the paleosoils of southern Córdoba Province, the authors were able to make a correlation between the studied paleosoils and climatic events.

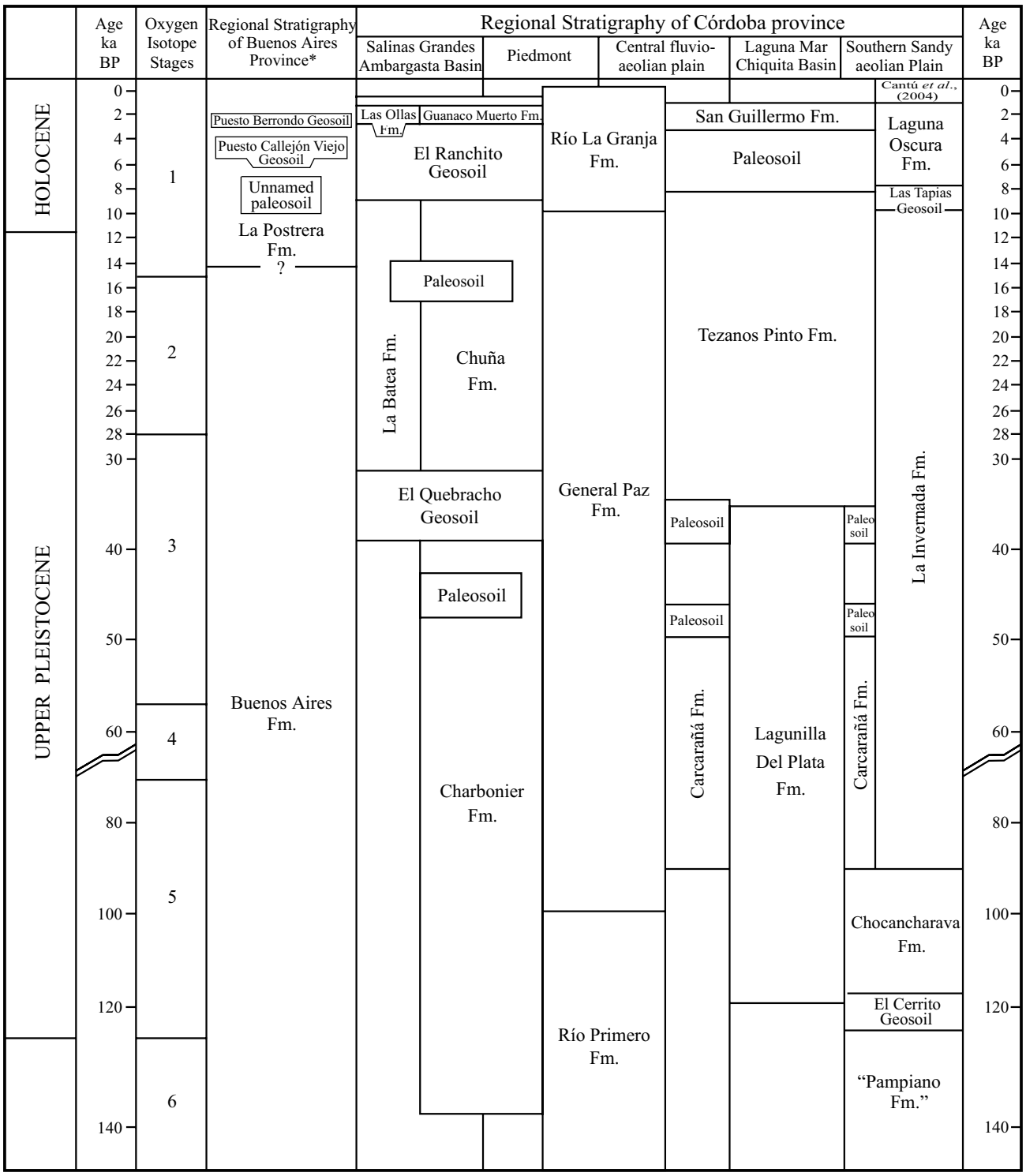
Additionally, the alternation of soils with fluvio-aeolian and loess sediments is a typical feature of the late Quaternary deposits in the Pampean Region. Iriondo (1999) analyzed climatic evolution in the "Pampean Sand Sea", and explained that the stratigraphic column is an excellent record for palaeoclimatic reconstruction. In this context, Carignano (1999) correlated the different stratigraphic units of Córdoba with Oxygen Isotope Stages and glacier fluctuations in South America, so he correlated the Chocancharava Formation with the OIS 5, OIS 4 and OIS 3 in part, the El Cerrito Paleosoil with the upper OIS 3 and lower OIS2, the La Invernada Formation with OIS 2 and upper OIS 1 and the Las Tapias Paleosoil with OIS 1 (see Table 1).

MATERIAL AND METHODS

The fossil specimen under study here is an almost complete, partially articulated skeleton of *Scelidotherium leptocephalum*. This form of preservation suggests a burial event that prevented the action of scavengers and dispersion of the remains. Some ribs and fragments of the post-cranial skeleton were selected for dating. The specimen is housed in the Department of Geology at the Universidad Nacional de Río Cuarto (UNRC PV 001, see Figure 2). It is interesting to note that a number of other fossil mammals (*i.e.* glyptodonts and other ground sloths) have been found in equivalent levels of the Chocancharava and the La Invernada formations at other localities in the same province (Cruz, 2003, 2007).

The radiocarbon date was obtained at the Laboratorio de Tritio y Radiocarbono (LATYR, CONICET-UNLP). Age calculations on the Libby half-life of ^{14}C before 1950 are reported to be 5568 yr. Reliable ^{14}C dating using fossil

Table 1. Correlation between late Pleistocene – Holocene glacier fluctuations, Oxygen Isotope Stages and regional stratigraphy of Córdoba province, modified from Carignano (1999) and Cantú *et al*. (2004), and * Stratigraphic scheme of Cuenca del Río Salado, south of Buenos Aires province, *sensu* Tonni *et al*. (2001) and Zárate (2005).



bones (Hedges and Van Klinken, 1992) should be based on samples with an adequate collagen fraction. The bones of *Scelidotherium leptocephalum* analyzed here are well preserved and they have 4% collagen content. The original carbon of the bone collagen was extracted following the method of Longin (1971). Carbonates were eliminated with HCl. Collagen was extracted as gelatin treated with water acidified (pH = 3) and heated to 90º for several hours. Impurity was eliminated by centrifugation. The gelatin obtained contains 1.34% N, and the relation C/N = 2.985.

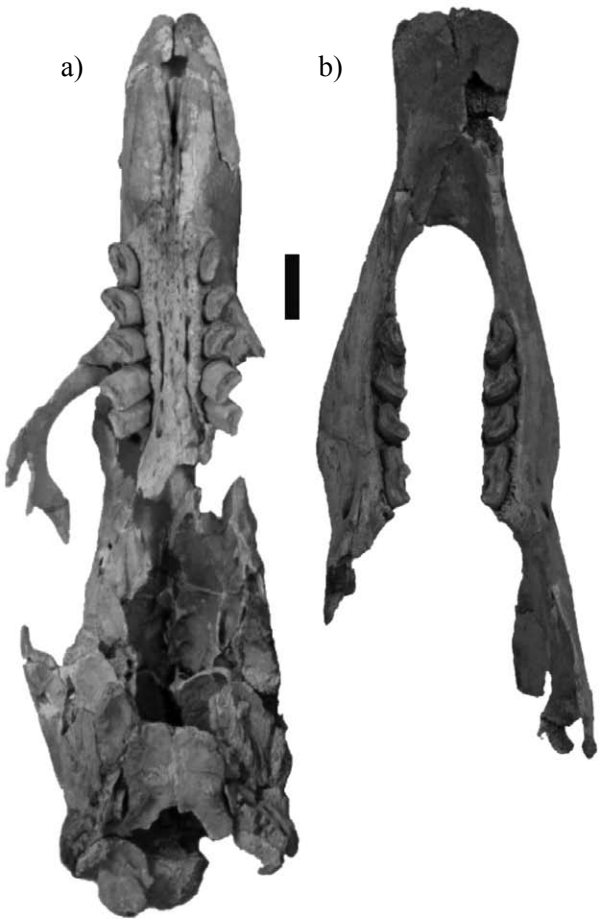


Figure 2. *Scelidotherium leptocephalum*. a) Skull. b) Mandible. Scale bar: 10 cm.

The gelatin was oxidized by quantitative combustion and transformed in benzene and measurement was made by liquid scintillation counting of synthesized benzene (see Huarte and Figini, 1988). Conventional age values were calculated at the ± 1σ level for overall analytical confidence, in compliance with the definition given by Stuiver and Polach (1977). To transform the ^{14}C years to calibrated years, the SHCAL04 software was used (see McCormac *et al*., 2004).

RESULTS AND DISCUSSION

The radiocarbon date obtained for *Scelidotherium leptocephalum* (LP-1407) is 7550 ± 60 yr ^{14}C BP; this supports the temporal assignation proposed by Cantú (1998) and Cantú *et al.* (2004) for the La Invernada Formation, that is late Pleistocene (about the LGM) to early Holocene. The range for the calibrated years with a probability of 68% (± 1σ sigma) is 8335 – 8394 cal yr BP.

According to Cione and Tonni (1999, 2001, 2005), the middle Pleistocene to early Holocene in the pampean region of Argentina, are represented by the stages/ages Bonaerian and Lujanian.

Cruz (2003, 2007) concluded that the sediments of the La Invernada Formation and the upper and middle part of Chocancharava Formation may correspond to the Lujanian (late Pleistocene-early Holocene), whilst the lower part of the latter formation may correspond to the Bonaerian (middle Pleistocene). This proposal is partially corroborated by Cantú *et al.* (2004) who reported new thermoluminiscence dates on sediments of the La Invernada and Las Oscuras formations. The dates of La Invernada Formation (85700 ± 11500 and 12800 ± 1500 yrs BP) are older than those previously proposed by Cantú (1998) on the basis of radiocarbon dates on carbonates, and permitted with the new date to extend this formation from 85700 to 7500 yrs BP.

In Buenos Aires province, radiocarbon dates were taken from extinct fauna from aeolian sediments (see Tonni *et al.* 1999 and references therein). The date reported in this contribution coincides with those dates, and with the temporal assignment (*i.e.*, Lujanian) of the upper part of the Chocancharava Formation and the La Invernada Formation.

The great extent and relative young age of these aeolian sediments allow their correlation with climatic events that took place during the late Pleistocene and early Holocene, namely increase in aridity and decrease in temperature. Between 13 and 11 ka, the Antarctic Cold Reversal (ACR), and the Younger Dryas (YD) occurred; these events clearly mark a pause (reversal) in the deglaciation process (Blunier *et al.* 1998). Later, at approximately 8000 years BP, a new cold event occurred (see Alley *et al.,* 2003).

Correlations of the stratigraphic sections of the Pampean Sand Sea, with local and global climatic changes had been postulated by Iriondo (1999) and Cantú *et al.* (2004). The large sandy plains covering the Pampean Region originated during the LGM and were partially reworked later during desertic and semidesertic episodes of the late Pleistocene (ACR and YD) and the early Holocene. The

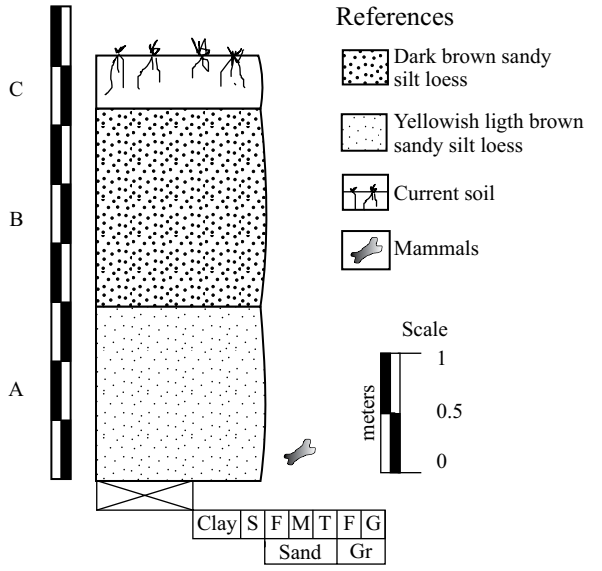


Figure 3. Schematic profile of the sediments in the study locality.

humid climatic phases marked by paleosoils are intercalated with the aeolian beds (Iriondo, 1999), and the soils of the late Pleistocene and Holocene of Río Cuarto respond to global climatic changes (Cantú *et al.,* 2004). These paleosoils may be correlated with those exposed in Buenos Aires province (Tonni *et al.,* 2001, see Table 1).

To sum up, the vast exposures of aeolian sediments of Córdoba, San Luis, Santa Fe, and Buenos Aires provinces can be correlated with the climatic events of the late Pleistocene and early Holocene, including biogeographic changes in the mammalian fauna and the extinction process verified *ca.* 8 ka BP (Cione *et al.,* 2009). The date here published support the idea proposed by Borrero (2008) and Politis and Messineo (2008) that the megafauna and humans have coexisted, although it is necessary more information for evaluate these hypothesis.

ACKNOWLEDGMENTS

The authors gratefully acknowledge the invaluable help and discussions of Mario Cantú and Fernando Cañas; Juan J. Moly was very helpful with the preparation of the material, and Alejandro Kramarz (Museo Argentino de Ciencias Naturales), Marcelo Reguero and Lucas Pomi (Museo de La Plata) are thanked for their help with the collections under their care. Finally, we are grateful to Eduardo Jiménez Hidalgo and an anonymous reviewer, whose critical reviews improved the manuscript. The Agencia Nacional de Promoción Científica y Tecnológica PICT 38171 (E. P. Tonni), the Comisión de Investigaciones Científicas (CIC) de la Provincia de Buenos Aires, CONICET, and the Universidad Nacional de La Plata provided financial support.

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Manuscript received: April 23, 2010
Corrected manuscript received: July 26, 2010
Manuscript accepted: August 9, 2010