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Preliminar correlation of the Pleistocene sequences of the Tarija valley (Bolivia) with the Pampean chronological standard

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ABSTRACT

Most of the mammal collections of the Pleistocene from the Tarija valley (Bolivia) lack precise stratigraphic data. Some fossil collections were made under stratigraphic control but have not been described. However, mammals were used for correlation and comparison with the pattern established for the Pampean region of Argentina. The bearing units have been referred either to the Ensenadan and Bonaerian stages, the "Belgranan", the Ensenadan, or the Lujanian in a broad sense, corresponding to the middle-upper Pleistocene or the upper Pleistocene. Studies during the last twenty five years accomplished by American authors and based on magnetostratigraphy and absolute dating suggest that the Tarija sequence corresponds to the Ensenadan (early-middle Pleistocene) of the Pampean standard. Recently, Italian scientists, based on radiometric dating, discarded this age and considered that the whole sequence belongs to the late Pleistocene. New biostratigraphic and systematic studies allowed the recognition of *Glyptodon munizi*, *Arctotherium angustidens*, and *Hippidion devillei*, exclusive taxa of the *Mesotherium cristatum* Biozone, the biostratigraphic base for the Ensenadan of the Pampean region. However, collections include mostly putative endemic species or those characteristic of the *Equus* (*Amerhippus*) *neogaeus* Biozone, the biostratigraphic base for the Lujanian of the Pampean area. In sum, from a biostratigraphic point of view, the Tarija sequence has taxa from the lower to middle Pleistocene (Ensenadan) and the upper Pleistocene-lower Holocene (Lujanian) of the Pampean area. From a paleofaunistic standpoint, the association recovered from the Tarija valley shows significant differences with the typical Pampean association. The high frequency of remains of Gomphotheriidae and Equidae and, in lower proportion, of Hydrochoeriidae and Tapiridae, are noteworthy. Members of these two latter families are restricted today to warm and wet climates. Most Glyptodontidae records belong to *Glyptodon*, and in the Pampean region this family is much more diversified.

1. Introduction

The Tarija valley is located in southern Republic of Bolivia, 1000 km from La Paz city and some 140 km north from the border with Argentina (Tarija city, 21° 31′S –61° 44′W; Fig. 1). The Tarija fossil mammals rival in abundance similar aged faunas from the classic Pampean area of Argentina (MacFadden, 2000). Unfortunately, most collections of Pleistocene mammals from the Tarija valley have no precise published stratigraphic data, although they have been used for correlation and to establish chronologies in regard to the standard pattern of the Pampean region of Argentina. Taxa cited therein are in urgent need of revision, because most have not been studied recently (see Soibelzon et al., 2005; Prevosti, 2007; Zurita et al., 2009; Zurita et al., in press).

More than a century ago, Carles (1888) stated that the mammal-bearing sediments of the Tarija valley were referable to the "pampeano inferior" and the "pampeano superior", that is "ensenadense" and "bonaerense" respectively, of the pattern of Ameghino (1889; see below). This criterion is shared with Ameghino (1902) who, after examining the fossils, said that "me han convencido de que el autor [Carles] tiene razón" ("… they have convinced me that this author [Carles] is right…"; 1902: 838).

Boule and Thévenin (1920) refer the fauna from Tarija to "au Pléistocène inférieur" (Boule and Thévenin, 1920: 249). Kraglievich

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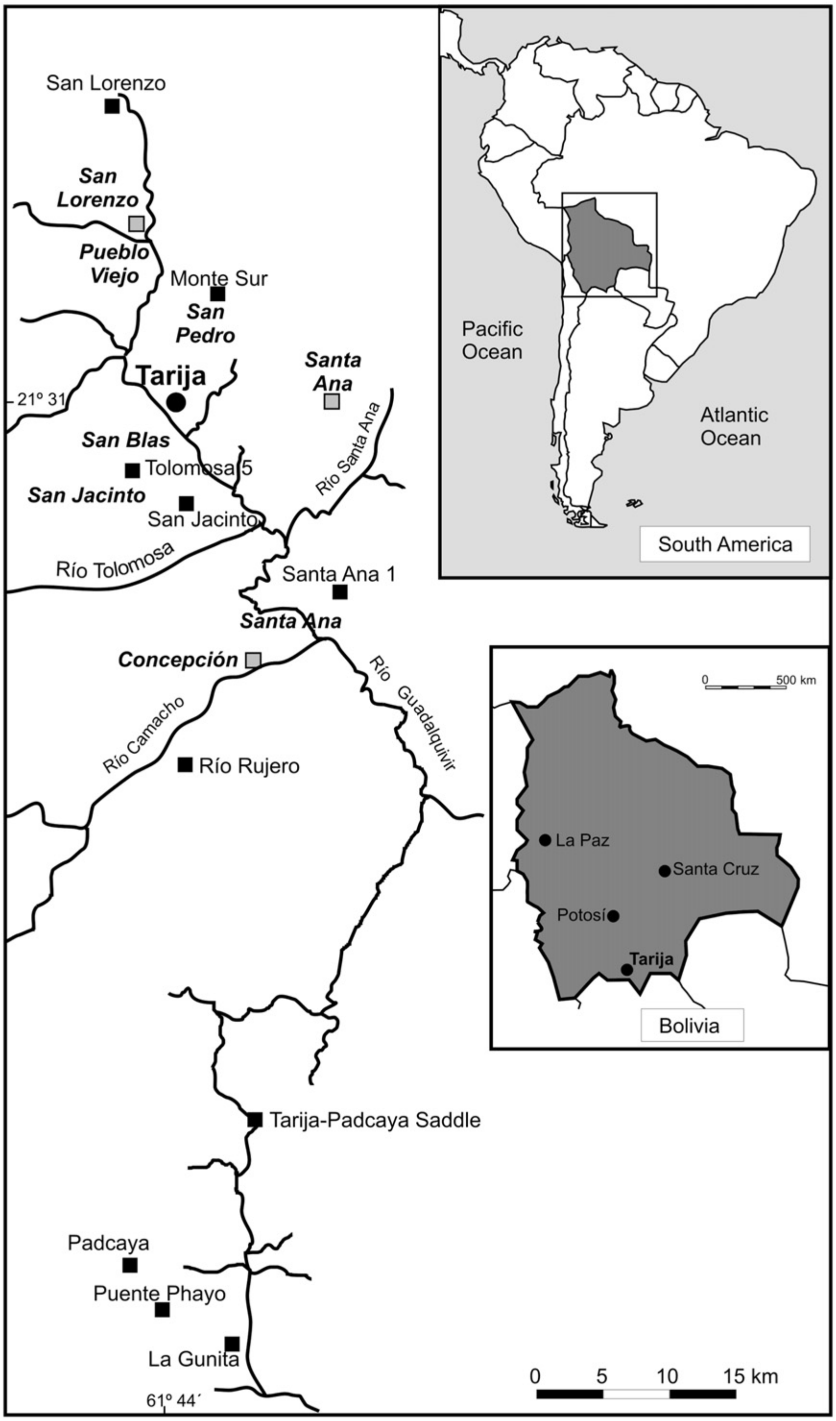

Fig. 1. Location map showing the localities studied by MacFadden et al. (1983; Bold and italic; grey squares) and Coltorti et al. (2007; regular; black squares).

(1934) states that “En su conjunto es una fauna más moderna que la ensenadense, y no más antigua, como lo ha dicho Rovereto… tomados en conjunto, los sedimentos de Tarija son más recientes que el ensenadense, y pueden lógicamente referirse al belgranense” (“As a whole, this is a more modern fauna than the Ensenadan, and not an older one, has Rovereto has said… taken as a unit, the Tarija sediments are more recent than the Ensenadan, and they may logically referred to the Belgranan; Kraglievich, 1934: 409). Oppenheim (1943) supports a younger age, middle to upper Pleistocene, a criterion shared later by Patterson and Pascual (1972). Noteworthy, in this moment, the Ensenadan and Lujanian (sensu Pascual et al., 1965; non Cione and Tonni, 1995a, 2005) of the Pampean region were referred to the middle-late Pleistocene.

More recently, studies including magnetostratigraphy and numerical dating suggest that the levels bearing the fossil mammals are exclusively Ensenadan (see MacFadden et al., 1983; MacFadden and Shockey, 1997; MacFadden, 2000) or late Pleistocene, Lujanian (see Coltorti et al., 2007), although neither the precise levels in which the remains were found are discriminated (except for some specimens), nor their relationships with the dated sediments. In addition, a large part of the analyses was made at generic level or with tentative specific assignments.

Despite discrepancies regarding the chronology of the bearing sediments, and especially the disparity between fossil-bearing localities and dated stratigraphic columns, Takai et al. (1982, 1984), Alberdi et al. (2003) and Alberdi and Prado (2004) assign the whole fauna exclusively to the Ensenadan of the Pampean standard. Accordingly, Marshall et al. (1984; see also MacFadden, 1997, 2000) had assigned the Tarija fauna to the "Ensenadan land-mammal Age", although they recognized that it "is possible that some fossils from this locality are younger" (Marshall et al., 1984: 33). Surprisingly, the possibility that the record of mammals suggesting different ages with respect to the Pampean pattern could be a consequence of latitudinal and climatic-environmental causes has never been analyzed.

Theoretical aspects under which the paradigm of "Land-mammal ages" was developed were analyzed by Cione and Tonni (1995a,b, 1996, 1999) in several papers. The authors consider that there is not an essential differentiation between "Land-mammal ages" and formal ages (c.f. Cione and Tonni, 1995a). South American "Land-mammal ages" are in fact stages poorly defined according to the modern requirements in geosystematics (Cione and Tonni, 1995b; see Woodburne, 1987, 2004, and Walsh, 1998 for a different point of view). Currently, some authors argue the convenience of establishing a single chronologic scale, discarding the difference between chronostratigraphic and geochronologic scale, using the category of stage but not age (Odin et al., 2004). One consequence of the paradigm of "Land-mammal ages" in South America was the lack of interest in developing biostratigraphic schemes.

Two of us (AEZ and ES) reexamined the fossil-bearing localities of Tarija and together with the rest of the authors re-studied materials from different collections. In this paper, the biostratigraphic and paleontological information of this significant site is preliminarily analyzed, resulting in different conclusions from those of preceding authors concerning the correlation and age of the sediments and the identity of fossil remains. It is hoped that the research in progress will produce an adequate amount of factual evidence for solving the problems presented here.

2. Chronologic scale and continental biostratigraphy of southern South America

Florentino Ameghino established the standard scale for the continental Cenozoic of southern South America in numerous papers (e.g. Ameghino, 1889, 1908). Later, this scale was simplified and extended with variable results for the rest of South America (e.g. Pascual et al., 1965, Marshall et al., 1983, 1984, 1992; Madden et al., 1996, and references therein).

Members of the staff of the Museo de La Plata and other institutions have been prospecting different exposures of the Pampean region, collecting new specimens of known and new taxa, with precise stratigraphic data. Likewise, the old collections of different institutions have been re-studied, improving the faunal lists, as well as establishing the levels of the first and last records. With all these data, a biostratigraphic pattern in sediments of the upper Miocene-Recent for the Pampean region was recognized that includes the biozones listed below (Tonni et al., 1992, Cione and Tonni, 1995a,b, 1996, 1999, 2005; Woodburne et al., 2006; Soibelzon et al., 2008). The units here considered are "assemblage zones" (NACSN, 1983; "biozonas de asociación" CAE, 1992) although some of them may represent interval biozones. It is noteworthy that in their stratotypes the biozones are not isolated but are in superposition or have underlying relationships to other biozones. The biozones of *Trigodon gaudryi*, *Neocavia depressidens*, *Paraglyptodon chapadmalensis*, *Platygonus scagliai, Akodon* (*Akodon*) *lorenzinii*, and *Ctenomys chapadmalensis*; and those of *Mesotherium cristatum, Megatherium americanum, Equus* (*Amerhippus*) *neogaeus*, and *Lagostomus maximus* are demonstrably superposed in the field. The scale of biozones supports the scheme of chronostratigraphic units named as Montehermosan, Chapadmalalan (lower and upper), Marplatan (lower, middle and upper), Ensenadan, Bonaerian (see also Verzi et al., 2004 in respect to the biozone of *Ctenomys kraglievichi* at the base of this Stage) Lujanian and Platan (Soibelzon et al., 2009: Fig. 1).

The local biozones may be recognized in other areas, within certain limits (e.g. middle Miocene of Colombia; Madden et al., 1996). The South American continent has very diverse climate and topography, and is very complex from a biogeographic point of view. Through the comparison with global events and magneto- and chronostratigraphic global scales, the Pampean scale has been partially correlated to the European one (Alberdi et al., 1995; Cione and Tonni, 2001).

3. History of paleontological findings in the Tarija valley

The first reference of fossils from the region of Tarija is very old, by Ávalos (1602). More than 150 years passed before the second mention of the finding of fossil bones and teeth in this locality was presented (more details in Marshall and Sempere, 1991).

In 1845, Weddell made the first significant fossil collection from Tarija, which was deposited in the Museum National d'Histoire Naturelle de Paris. This collection was later studied by Gervais (1855) and Gervais and Ameghino (1880). Between August 1886 and July 1887, Enrique de Carles, who had been sent by Hermann Burmeister, director of the Museo de Historia Natural de Buenos Aires (the present Museo Argentino de Ciencias Naturales "Bernardino Rivadavia"), collected a large amount of fossils at Tarija. Later, Burmeister published some papers concerning fossil horses and mastodons (see Burmeister, 1889). By the end of the 19th and beginning of the 20th centuries, E. Nordenskjöld made numerous prospecting trips to South America. During his second trip (1901–1902) he collected fossils from Tarija and sent them to Uppsala (Sweden). This collection was partially published by Nordenskjöld (1902) and Sefve (1912, 1915a, 1915b), and more recently by Werdelin (1991). According to Marshall and Sempere (1991), in 1903, Créqui-Montfort and Sénéchal de la Grange bought a large collection of fossils from Tarija to local people (the Echazú family) and gave it to the Museum National d'Histoire Naturelle of Paris. This collection was the basis for the paper of Boule and Thévenin (1920). Between 1894 and 1915, members of the Echazú family collected a large amount of fossil mammals at Tarija and surroundings (Echazú, 1905; Echazú, 1921) and sold it to different institutions. Later, during the 1930s, nearly 2600 specimens of this collection were sent to La Paz, some of which were returned to the Museo de la Universidad de Tarija in 1977. In 1924 and 1927, members of the Field Museum of Natural History of Chicago made an important collection and bought part of the fossils collected by the Echazú family. Since 1960, numerous researchers have worked at Tarija, among them, Hoffstetter (1963), the group from "The Research Institute of Evolutionary Biology" of Tokyo (see Takai et al., 1982, 1984), the staff of the Florida University at Gainesville (see MacFadden et al., 1983, 1994; MacFadden and Shockey, 1997; MacFadden, 2000) and groups of the universities of Siena, Florence and Parma (Coltorti et al., 2007).

4. Stratigraphy of the Tarija valley

From a geological standpoint, Tarija is located within a sedimentary basin, filled with fluvial sediments unconformably lying on the Paleozoic basement. The basin itself extends northwest - southeast in an area of 1000 km^2. It is deeply cut by dendritic drainage valleys, crossed by the Guadalquivir, Tolomosa, Camacho, and Santa Ana rivers and other minor watercourses (see MacFadden, 2000: Fig. 1; Coltorti et al., 2007: Fig. 1). The basin developed along a synclinal depression, the sides of which plunge toward an axis joining the lowest points, although no faults were recorded during surface survey. The ranges surrounding the basin have very sharp, denudated slopes, carved on the Paleozoic rocks. The outstanding features of the area are characteristic of badlands landscape with irregular relief caused by differential erosion of the sediments.

Carles (1888: 39) recognized a "Lower" level, formed by different greyish, yellowish and greenish strata with fossil remains, identified as "*Praopus*", *Scelidotherium*, "*Coelodon*", *Lestodon*, *Hoplophorus*, *Glyptodon*, "*Auchenia*", "*Cervus*", *Equus*, "*Hippidium*", *Macrauchenia*, *Felis*, "*Machaerodus*", "*Ursus*", "*Canis*", "*Mastodon*" and *Cavia*; and the "Upper" level, reddish, similar to the Pampean silts of Buenos Aires, Córdoba and San Luis, with *Glyptodon*, *Mylodon*, *Megatherium*, "*Dasypus*" (= "*Dasypus*" *tarijensis* Ameghino, 1902; probably *Chaetophractus*) *Ctenomys*, "*Auchenia*" and *Equus*, pointing out that no mastodon remains were found in this upper level. Ameghino (1902) referred these horizons to the "ensenadense" and "bonaerense" respectively. Boule and Thévenin (1920) did not find stratigraphic differences in the Tarija Formation and suggested that it belonged to the Early Pleistocene. Oppenheim (1943) divided the sediments of Tarija into two "Horizons" (see Oppenheim, 1943: 553): "A" (lower), without fossils and characterized as light grey to reddish brown clayey beds, 30 m thick, generally with a lignite bed, 5–30 cm thick at the top. This bed is composed of plant remains and fragments of partially decayed wood. The upper "Horizon" ("B") is composed of very fine sandy silts (loess) light grey to yellowish grey, not much consolidated, about 20 cm thick, with two conspicuous ferruginous beds at the top, with some gravel beds variable in thickness. This author pointed out that the most complete fossil mammals were found mainly in the upper part of this horizon, and they were generally associated with the ferruginous beds. The remains collected from the lower part of this horizon are less abundant and more eroded. In sum, this Horizon B (upper) may include both levels of Carles (1888). Finally, he pointed out that the whole sequence belongs to the middle to late Pleistocene.

During 1970 and 1980, paleontologists from the "Research Institute of Evolutionary Biology of Tokyo" prospected the area of Tarija (see Takai et al., 1982, 1984). They recognized three "members" (see Takai et al., 1982: 5) in their Tarija Formation, within the 150 m thickness:

Lower: 50 m thick, with alternation of gravel, reddish sands and tuffs. Fossils are very uncommonly found.

Middle: 20 m thick, alternation of medium-size grain, bluish grey sands. The upper part of this member has a tuffaceous bed, 1.5–2 m thick. Fossils are rare.

Upper: 70 m thick, more widely distributed. It shows alternation of greyish white silts and medium-size grain sands. This is the most fossiliferous member, in which they mention the record of the following taxa: *Smilodon ensenadensis*, "*Paleocyon*" *tarijensis*, *Arctotherium tarijense*, *Cuvieronius andium*, *Equus curvidens*, *Tapirus tarijensis*, *Lama mesolithica*, *Glyptodon reticulatus*, *Megatherium tarijense*, and *Hydrochoerus tarijense*. It has a tuff bed in its uppermost part. Takai et al. (1982) report the possible occurrence of *Glossotherium tarijense* and "*Scelidotherium*" *capellini* in the upper member (see Table 1 in Takai et al., 1982)

Takai et al. (1982, 1984) correlated the lower and middle members with the Horizon A of Oppenheim (1943), and the upper member with the Horizon B of this author. Based on the electron spin resonance method they suggest an age of 200–250 ka for the sequence (Takai et al., 1984).

Table 1
Mammals from Tarija valley and its biochrons in the Pampean Region.

Taxa	Temporal distribution in the Pampean Region		
	Ensenadan	Bonaerian	Lujanian
Didelphimorphia			
Lutreolina sp.	X	X	?
Xenarthra			
Chaetophractus tarijensis			
Propraopus sp.	X	X	X
Euphractus sp.		X	?
Pampatherium sp.	X	X	X
Glyptodon reticulatus		X	X
Glyptodon munizi	X		
Hoplophorus sp.			
Panochthus sp.	X	X	X
Nothropus tarijensis			
Megatherium tarijense			X
Megatherium americanum		X	X
Glossotherium tarijense			
Lestodon armatus	?	X	X
Catonyx tarijensis	?		
Carnivora			
Protocyon tarijensis			
Chrysocyon brachyurus			
Dusicyon gymnocercus			X
Canis dirus			X
Protocyon troglodytes		X	X
Arctotherium tarijense		X	X
Arctotherium brasiliense			
Arctotherium angustidens	X		
Conepatus chinga			
Eira sp.			
Smilodon populator	X	X	X
Panthera onca		X	X
Puma concolor	X	X	X
Felis (Herpailurus) yagouaroundi		X	
Rodentia			
Neochoerus tarijensis		X	
Litopterna			
Macrauchenia patachonica	?	X	X
Notoungulata			
Toxodon platensis			X
Proboscidea			
Cuvieronius hyodon			
Perissodactyla			
Hippidion principale		X	X
Hippidion devillei	X		
Equus (Amerhippus) insulatus			
Equus (Amerhippus) neogaeus			X
Tapirus tarijensis			
Artiodactyla			
Catagonus stenocephalus	X		
Palaeolama weddelli			
Vicugna provicugna			
Lama castelnaudi			
Palaeolama hoffstetteri			
Hippocamelus sp.		X	X
Agalmaceros tarijensis			

More recently, Suárez Montero (1996) included the sediments of the Tarija Formation of previous authors within the Tolomosa Group, recognizing the Santa Ana Formation at the base, and the San Lorenzo Formation above. Coltorti et al. (2007) included the whole sequence in the Tolomosa Formation, which is informally subdivided into two units: the Ancón Grande Unit (AG, lower) and the San Jacinto Unit (SJ, upper) (see Fig. 2). The Tolomosa Formation presents a morphology of badlands, with very flat alluvial terraces, piedmont alluvial fans, and wide alluvial plains mainly braided. The uppermost part is locally covered by coarse sands in alluvial

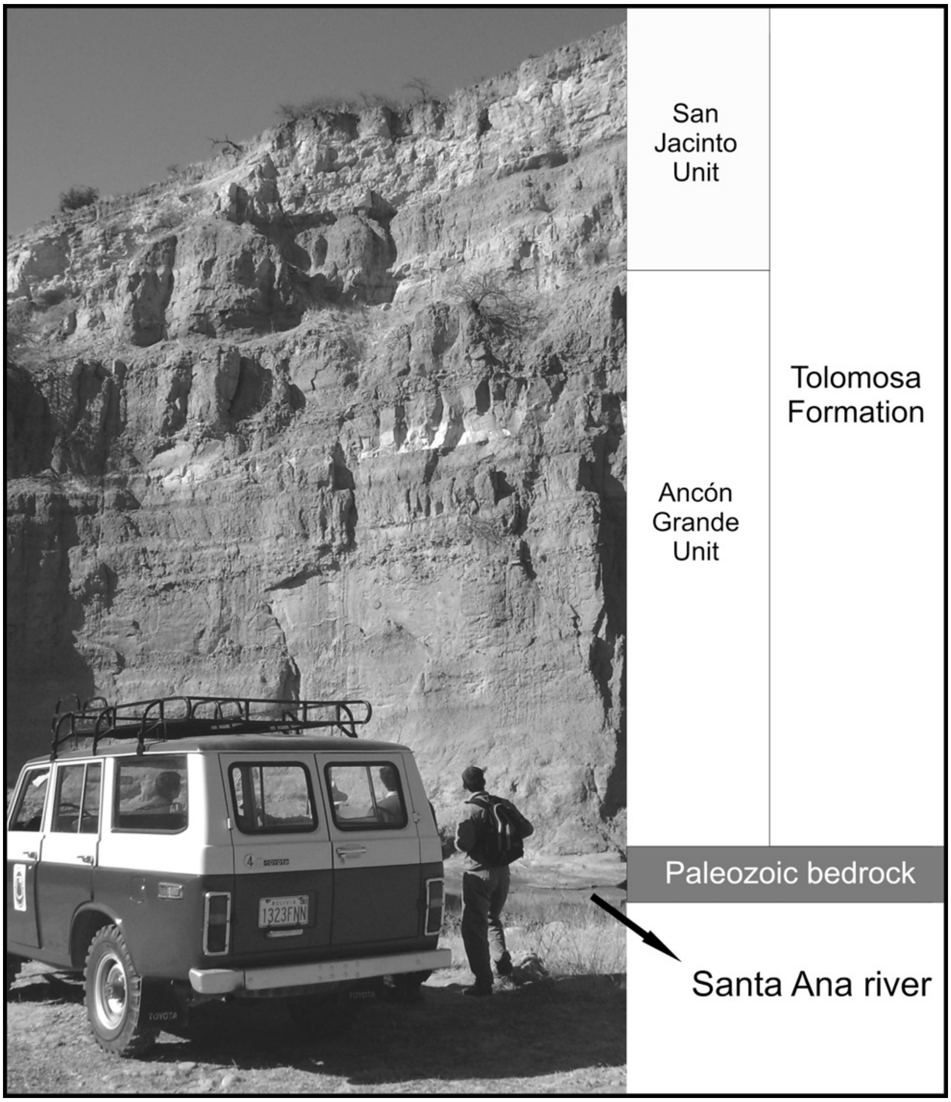

Fig. 2. Geological profile exposed at Santa Ana 1 locality.

terraces deposited during the valley cut in. The transition from Unit AG to Unit SJ is evident along most of the badlands.

The Ancón Grande Unit is reddish and coarse grained. The depositional environment is typical of a braided plain, transitional to a coarse alluvial fan near the slope, to finer grained toward the distal plain. The plain, shallow channels, and depressions were filled with gravels and sands, and the sediments were deposited by gravity flows. At the top of the unit there is a pedological sequence formed by several reddish illuvial horizons.

The San Jacinto Unit is greyish yellowish and fine grained. It was deposited by a meandering stream, and locally shows a high sedimentation rate (>2 cm/year). In the middle of the basin there is a cyclic repetition of channels filled with cross bedded sands and thin intercalations of gravels. At the top of the structureless channel sediments or of those slightly laminated ones, there are peat levels, calcium carbonate crusts and gypsum.

5. Numerical dating and magnetostratigraphy

According to MacFadden et al. (1983) the base of the profile exposed at San Blas is magnetically reversed, yielding a late Matuyama age, younger than the Jaramillo Subchron (older than 0.78 Ma and younger than 1.07 Ma; time scale of Cande and Kent, 1995). Likewise, these authors dated a tuffaceous level by fission track that yielded an age of 0.7 ± 0.2 Ma, congruent with the magnetostratigraphic information. The age of the upper boundary of the section is discussed below.

Recently, Coltorti et al. (2007) reported a series of radiocarbon dates of organic levels from these profiles. These datings were made in exposures of different localities along the Guadalquivir river: San Jacinto (= San Blas of MacFadden, 2000), Monte Sur (= approximately San Pedro of MacFadden), Santa Ana 1 (not exactly Santa Ana of MacFadden, 2000; see Fig. 1 of the respective papers), Tolomosa 5, Estancia La Gunita, Puente Phayo 2, Tarija-Padcaya Saddle and Río Rujero.

At San Jacinto, three dates were obtained in a profile located at the same coordinates reported by MacFadden (2000) for his locality of San Blas. From the middle, upwards, dating yielded 37,000 and 39,000 ^{14}C BP, whereas one date from the lower half is infinite (>40,000 ^{14}C BP, see Coltorti et al., 2007).

There are two dates for Santa Ana 1, one of 34,070 ± 940 ^{14}C BP and the other infinite (>44,000 ^{14}C BP), stratigraphically below. This locality is not the same as that reported by MacFadden et al. (1983) where they recorded reversed polarity including one normal polarity section attributed to the Jaramillo event. At Monte Sur, a sample from approximately the middle of the profile yielded an age of 27,180 ± 880 ^{14}C BP, and another one almost at the base, an infinite age (>39,880 ^{14}C BP).

6. Fauna from Tarija

The faunal list reported by Hoffstetter (1963) is the longest and certainly the most useful among the numerous lists of fossils of the Tarija valley, especially because of the wide knowledge of this author about the South American megafauna. However, the fauna from Tarija as a whole requires an exhaustive taxonomic revision, since more than 90 taxa have been reported, many of them supposedly endemic species. The considerably numerous recent revisions are only partial, encompassing a few taxa (see for example Frailey et al., 1980; Alberdi and Prado, 1992, 1993; Berman, 1994; MacFadden, 1997; Guérin and Faure, 1999; McDonald and Perea, 2002; Soibelzon, 2004; Pardiñas et al., 2002; Cione and Tonni, 2005; Deschamps, 2005; Prado et al., 2005; Scillato-Yané et al., 2005; Soibelzon et al., 2005; Prevosti, 2007; Miño Boilini and Carlini, 2007; Zurita et al., 2009; Zurita et al., in press; Gasparini et al., 2009); hence, it is necessary to deal with this issue in general (see Table 1).

7. Discussion

Taking into account the list of Hoffstetter (1963) and the revisions of Soibelzon (2004), Alberdi and Prado (1992, 1993), Scillato-Yané et al. (2005), Prevosti (2007), Zurita et al. (2009; Zurita et al., in press), and Gasparini et al. (2009), among others, the common taxa (excluded micromammals) with the Pampean region are *Lutreolina crassicaudata*, *Pampatherium typum*, *G. reticulatus*, *Glyptodon munizi*, *Panochthus* sp., *Lestodon armatus*, *M. americanum*, *Megatherium tarijense* (about the presence of this species in the Pampean region, see De Iuliis, 1996, 2006), *Arctotherium angustidens*, *A. tarijense*, *Chrysocyon brachyurus*, *Protocyon troglodytes*, *Canis dirus*, *Dusicyon gymnocercus* (= *Pseudalopex proplatensis* of Ameghino, 1889), *Smilodon populator* (= *S. ensenadensis* of Ameghino, 1889), *Panthera onca*, *Felis* (*Puma*) *concolor* (= *Felis platensis* Ameghino, 1889), *Equus* (*Amerhippus*), *Hippidion principale*, *Hippidion devillei*, *Platygonus* sp., *Catagonus stenocephalus*, *Macrauchenia patachonica*, and *Toxodon platensis*.

From a biostratigraphic standpoint, three taxa recorded at Tarija are exclusive of the *M. cristatum* Biozone of the Pampean region: the glyptodont *G. munizi* (MNPA-V 006118; Zurita et al., 2009), the ursid *A. angustidens* (AMNH 117433, L. Soibelzon, 2004; MNPA-V 006035, L. Soibelzon pers. com., 2007), and the equid *H. devillei* (MNHN TAR 687, 675; Alberdi and Prado, 1993). However, most of the fauna may be referred to younger biostratigraphic units (i.e.the *E.* (*Amerhippus*) *neogaeus* Biozone; see Table 1).

The glyptodont *Neothoracophorus* cf. *elevatus* was cited for Tarija (e.g. Hoffstetter, 1963; Marshall et al., 1984; Coltorti et al., 2007). However, the diagnostic characters mentioned originally by Nodot (1857) and Ameghino (1889) suggest that it could be a juvenile specimen. Thus, the records of *Neothoracophorus* belong to juvenile specimens of *Glyptodon* (see Fig. 3). In addition, the glyptodont *Hoplophorus* is shared with the upper Pleistocene of Brazil.

MacFadden (2000) states that *Equus* occurs throughout the entire Tarija sequence, including the putative Ensenadan levels. In the Pampean area, *Equus* is exclusive of the zone of *E.* (*Amerhippus*) *neogaeus*, which is the biostratigraphic basis for the Lujanian (sensu Cione and Tonni, 1999, 2005, non Pascual et al., 1965 or Flynn and

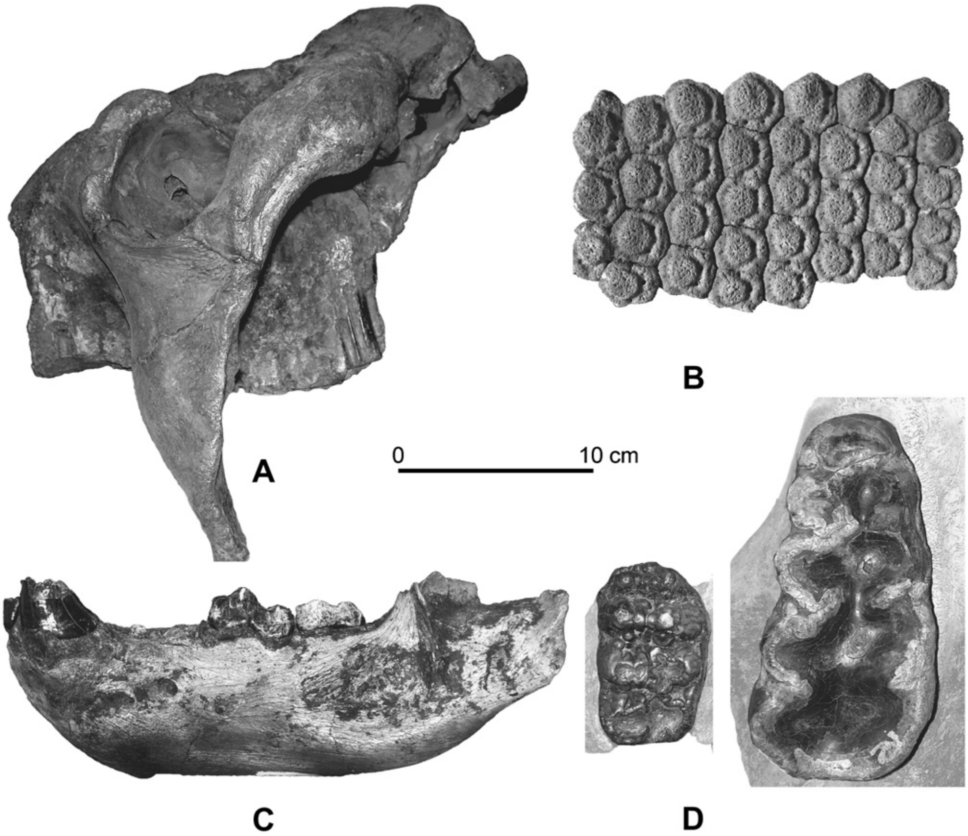

Fig. 3. Some fossil mammals from Tarija valley. A: *Glyptodon munizi* MNPA-V 006118; B: *Glyptodon* juvenile specimen MNPA-V without number; C: *Arctotherium angustidens* MNPA-V 006035; D: *Cuvieronius hyodon* MNPA-V without number.

Swisher, 1995). Cione and Tonni (2005) suggested that the Lujanian ranges from 0.125 to 0.075 Ma. *Equus* occur in many other sites in South America, but the only place where it was reported from putatively older beds than Lujanian is Tarija. Although there are no descriptions of the specimens attributed to *Equus* from the lower part of the Tolomosa Formation, MacFadden is a distinguished specialist in fossil horses. There are no Ensenadan beds to the north of Tarija in South America. So, it appears that this horse genus reached southern South America at a recent date. However, it still is a good indicator of Lujanian times in the standard of southern South America.

8. Conclusions

Contrary to the opinion of several authors, biostratigraphic data indicate that the mammal fauna of Tarija is neither exclusively Ensenadan nor late Pleistocene (Lujanian) in age. Although there are many putative endemic mammals that are in need of revision (e.g. *Chaetophractus tarijensis*, *Nothropus tarijensis*, *Tapirus tarijensis*, *Hydrochoerus tarijensis*; see Hoffstetter, 1963, Takai et al., 1982, 1984), several typical taxa of the Pampean area occur. An accurate revision is needed especially considering that several primitive species survive in tropical environments (see Carlini et al., 1997, 2006a,b,c, 2008a,b; Miño Boilini and Carlini, 2007). Notwithstanding this, there are in Tarija at least three exclusive species of the *M. cristatum* Biozone of the Pampean area (*G. munizi*, *A. angustidens* and *H. devillei*) and ten taxa typical of the *E.* (*Amerhippus*) *neogaeus* Biozone (*G. reticulatus*, *Lestodon armatus*, *M. americanum*, *A. tarijense*, *P. troglodytes*, *C. dirus*, *Equus* (*Amerhippus*) sp., *H. principale*, *M. patachonica*, and *T. platensis*. These biozones represent the typical Ensenadan and the Lujanian lapse and were calibrated between about 2 Ma and 0.4 Ma and about 0.13 Ma and 0.075 Ma respectively in Argentina (Cione and Tonni, 2005; E. Soibelzon et al., 2008). Besides, the extant species *C. brachyurus*, represented by a single remain in Tarija (MNHN TAR 761) was also recorded in the upper Pleistocene of Brazil and the Holocene of Argentina (Prevosti, 2007).

However, when analyzing the chorological history of several extinct and living taxa, it can be seen that the latitudinal position of the fossil localities is very important to establish continental correlations of faunas geographically apart. The Tarija valley is presently at about 2000 m a.s.l., thus representing a very different environment to that one present in the Pampean region then and now. It would be possible that the original faunas were different, as Tarija is at a lower latitude and higher altitude than the Pampean sites.

Moreover, latitudinal differences were seen in late Cenozoic (middle and late Miocene) faunas from northern and southern South America. In middle Miocene beds in Colombia and Venezuela, some mammal taxa appear to be in more primitive evolutionary stages than the other components of the fauna (e.g. McKenna, 1956; Carlini et al., 1997; Carlini et al., 2006a). Also, in late Miocene and younger beds some Megatheriinae from northern South America (*Proeremotherium*, *Urumaquia*, and *Eremotherium*), show a mix of characteristics, some very primitive and some derived (Carlini et al., 2006b, 2008b).

If the entire sequence of Tarija actually correlates with the Pampean Lujanian, the survival in this area of taxa recorded in the typical Ensenadan (i.e. *G. munizi* and *A. angustidens*) could be due to a local continued existence of these species. In short, the association of the Tarija Valley shows differences with the one typically Pampean, possibly due to ecological or historical causes.

From a paleofaunistic point of view, it is noteworthy the high frequency of remains of Gomphotheriidae, Equidae, Hydrochoeriidae and Tapiridae. These two latter taxa are restricted today to warm and humid climates. In turn, most records of Glyptodontidae are represented by *Glyptodon* remains, in contrast to what is seen in the Pampean region, where the Glyptodontidae are notably more diverse (Zurita et al., 2009; Zurita et al., in press).

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