

# New Miocene mammal assemblages from Neogene Manantiales basin, Cordillera Frontal, San Juan, Argentina

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## ABSTRACT

The discovery of abundant fossil mammals from two different levels of the lowest third of the Chinchas Formation (Manantiales basin) located in Cordillera Frontal of San Juan, between 32°30' and 33°S, is reported. These synorogenic Miocene deposits were deposited by the structural evolution of Cordón de La Ramada fold and thrust belt. Two diverse fossil mammal assemblages have been recognized, one from the lowest bearing horizon, informally named «Chinchas bearing level» (CBL), and other, stratigraphically higher, informally named «Las Hornillas bearing level» (LHBL). Marsupials, Xenarthra (Cingulata and Tardigrada), Notoungulates (four families), Litopterns and six groups of rodents are represented in both mammal assemblages. The presence of *Eocardia montana*, *E. excavata* and *Nesodon conspurcatus* strongly suggests that the bearing levels may be referred to the Santacrucian SALMA (South American Land Mammal Age), late early Miocene in age. The morphology of *Stenotatus* sp., *Hapalops* sp., *Protypotherium* sp., *Neoreomys cf N. australis*, and the mesotheriines is comparable to that of Santacrucian species. Although both assemblages are referred to the Santacrucian SALMA, differences in composition among them suggest slight differences in age. This temporal reference matches with studies of fission-track and magnetostratigraphy, and sedimentological data of this sequence. The latitudinal intermediate location together with the particular taxonomic composition of these assemblages may provide the clue to understand the differences between Miocene faunas from Patagonia and the Altiplano (Chile and Bolivia). As well, these assemblages are a new important source of information for the comprehension of the phyletic and geographic relationships of several taxa, and the paleoenvironmental changes associated with the uplift of the Andes.

**Keywords:** Argentina - Andes - Miocene - Santacrucian - Fossil Mammals

## RESUMEN

En este trabajo se da a conocer el hallazgo de abundantes restos de mamíferos fósiles en dos niveles estratigráficos diferentes del tercio inferior de la Formación Chinchas (Cuenca Manantiales). Esta formación aflora en el ámbito de Cordillera Frontal (entre los 32°30' y 33°S), a lo largo del valle del río Los Patos, entre Las Hornillas y El Horcajo (Departamento de Calingasta, Provincia de San Juan). La Formación Chinchas está representada por sedimentos sinorogénicos miocénicos que fueron depositados durante la evolución estructural de la faja plegada y corrida de La Ramada. Los fósiles que se presentan fueron recolectados en dos niveles fosilíferos diferentes que, informalmente aquí se denominan como «nivel portador Chinchas» (CBL) al inferior y «nivel portador Las Hornillas» (LHBL) al superior. Restos referidos a marsupiales, xenartros (Cingulata y Tardigrada), cuatro familias de notoungulados, Litopterna (Macraucheniidae y Proterotheriidae) y seis grupos de roedores fueron recolectados en estos dos niveles. La presencia de *Eocardia montana*, *E. excavata* y *Nesodon conspurcatus* sugiere que los niveles portadores pueden referirse a SALMA (South American land Mammal Age) Santacrucense (Mioceno temprano tardío). Por otro lado, la morfología presente en *Stenotatus* sp., *Hapalops* sp., *Protypotherium* sp., *Neoreomys cf N. australis*, y los mesoterinos registrados es comparable a la de las especies santacrucenses. A pesar de que los dos niveles portadores son referidos a la SALMA Santacrucense, diferencias en su composición podrían sugerir diferencias temporales entre ellos. Esta referencia temporal es concordante con estudios previos de

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trazas de fisión, magnetoestratigráficos y de destejado realizados en esta secuencia. Por la posición latitudinal y la particular composición taxonómica, estos conjuntos faunísticos pueden contribuir a comprender mejor las diferencias existentes entre las faunas del Mioceno de Patagonia y las del Altiplano (Chile y Bolivia). Además constituyen una importante fuente de información para la comprensión de las relaciones filéticas y geográficas de varios taxa y los cambios ambientales asociados a la orogénia andina. **Palabras clave:** Argentina - Andes - Mioceno - Santacrucense - Mamíferos fósiles

## INTRODUCTION

Early to middle Miocene South American mammals are well known mostly from Patagonia. Contrarily, mammals of this lapse from outside Patagonia come from isolated localities and are only poorly known, with the exception of those well described from the middle Miocene of La Venta (Colombia). Recently, Miocene mammals have been described from different localities of southern South America, especially from the new fossil locality of Chucal in northern Chile (Flynn et al. 2002). Mammal assemblages from Patagonia and Chucal present several discrepancies hard to be explained, but that could be understood when more records of mammals from areas between Chucal and Patagonia are available. In fact, the existence of early to middle Miocene mammals from this intermediate area has been known for almost eighty years, but only through brief reports. The first fossil mammal in this area was reported by Windhausen (1931, p. 380) who mentioned for the Paso del Espinacito a material referred as *Theosodon*(?) (Litopterna, Macraucheniiidae). Rusconi (1946) described isolated glyptodontid osteoderms (*Asterostema barrealense*) and post-riental materials referred as *?Hegetotherium arctum* (Notoungulata, Hegetotheriidae) collected in the Las Hornillas area. Later, Contreras (1989) mentioned the specimens of Rusconi and added a fragmentary mandible referred to *Theosodon* sp. In 1996, a joint expedition of the Museo de La Plata (Argentina) and Duke University Medical Center (USA) recovered a few fossil mammals in the lower levels of the Chinchas Formation (Manantiales basin) in San Juan Province and a preliminary taxonomic list was presented by Carlini et al. (1996). Geological, radiometrical, magnetostratigraphical and paleontological studies suggested that the deposition of the Chinchas Formation should have taken place in the Miocene from 20-10 Ma, thus representing one of the most complete Miocene sequences outside Patagonia (Pérez 2001a).

In the last few years abundant fossil mammals were recovered from two different levels of the lowest third of the Chinchas Formation by the staff of the División Paleontología Vertebrados of the Museo de La Plata during three brief field-trip seasons (2005, 2007 and 2008) in the Las Hornillas area. Las Hornillas (32°00'S

and 69° 45'W), at the Puesto de Gendarmería «Álvarez Condarco», is located 65 km southwest from the village of Barreal (Calingasta Department, San Juan Province; Fig. 1).

Two diverse fossil mammal assemblages have been recognized along the Los Patos valley, in this area (Table 1). One of them found mostly at the right margin of the Los Patos river in the lowest bearing horizon is informally named «Chinchas bearing level» (CBL). The other, stratigraphically higher and exposed at the left margin of the river, is informally named «Las Hornillas bearing level» (LHBL) (Fig. 2).

The main goal of this paper is to report these new mammal assemblages. Detailed anatomical and systematic studies of these mammals will be accomplished elsewhere. All specimens will receive Museo de Ciencias Naturales (San Juan province) collection numbers at the completion of this project. In this paper the field numbers are reported.

## GEOGRAPHIC AND GEOLOGICAL SETTING

The Manantiales basin is located in Los Patos valley, between the Cordón del Espinacito and Cordillera del Tigre, at 32°00'S and 69°45'W, in the Cordillera Frontal. The basin measures approximately 65 km in north-south length and about 20 km in width. Tertiary deposits pinch out between the Cordón del Espinacito and Cordillera del Tigre ranges in the southern portion of the basin, exposed in the river bank west of the Tigre creek. Uplift of La Ramada system would have produced a tectonic subsidence of the crust, developing the Manantiales foredeep where materials of the Cordillera Principal were deposited (Pérez 1995).

Mirré (1966) defined the Chinchas Formation for a sedimentary succession more than 2000 m thick exposed along the Los Patos river, between the Hornillas and Horcajo, overlying the volcanic rocks of the Horcajo Formation, and divided the Chinchas Formation into three members, from bottom to top: Areniscas Chocolate, Brecha andesítica and Areniscas Conglomerádicas. Iglesias Llanos (1995) described in the eastern slope of Cordón del Espinacito, between the Hornillas and Las Leñas rivers, more than 2000-meter-thick of coarsen-

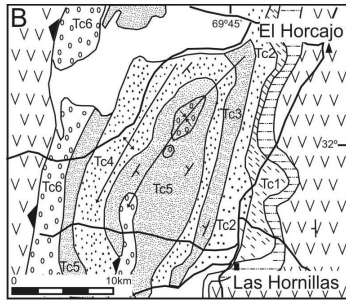
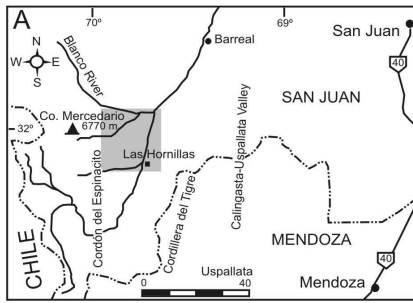


Figure 1. Geography and geology of the Chinchas Formation. (A) Location map; (B) schematic geologic map of the area between Hornillas and Horcajo (from Pérez, 2001a). Tc0-Tc6: Tertiary deposits of Manantiales foreland basin (see Figure 2).

ing-up sandstones, which she correlated with the Areniscas Conglomerádicas member of the Chinchas Formation (Mirr  1966). P rez and Ramos (1996) and P rez (2001a) gave results of an unroofing study, supplemented with the radiometric data and magnetostratigraphic study of the Tertiary sequences by Jordan et al. (1996) (Fig. 3).

The Manantiales basin deposits unconformably overlie the Permotriassic volcanic rocks of the Choiyoi Group. This relationship is observed in the Horcajo region and along the western slope of the Cordillera del Tigre to the Quebrada de Los Indios river. The upper boundary of the Tertiary deposits is tectonic. The Choiyoi Group volcanic rocks are the hanging wall and are thrust over the sedimentary rocks of the Chinchas Formation footwall. This relationship is observed from the Blanco river to exposures south of Los Patos river (P rez 2001a). The Tertiary sequences in the Manantiales basin represented by the Chinchas Formation, have been divided into seven members (TC0 to TC6), and their integration allowed a reconstruction of the development over the whole Manantiales basin (P rez 2001a) (Fig. 2).

TC0 is equivalent to the Areniscas Chocolate of Mirr  (1966), and unconformably overlies the pyroclastic rocks of the Choiyoi Group. It is characterized by yellow, red and violet shale, and red, medium grained

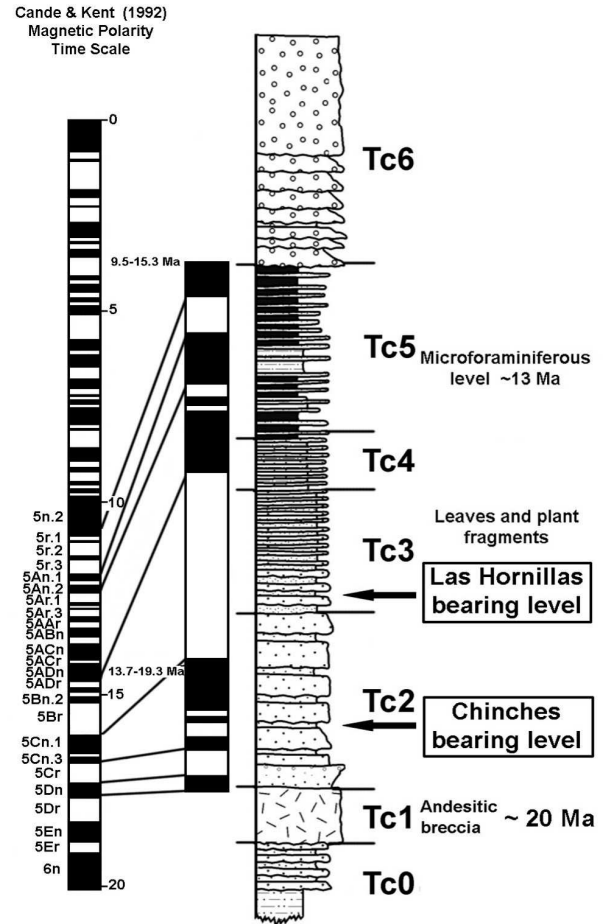


Figure 2. Stratigraphic section of the Chinchas Formation, indicating members, fossil bearing levels (right) and correlations between local magnetic polarity column and Magnetic Polarity Time Scale (left). The stratigraphy is based on P rez (2001a), and the magnetic polarity column on Jordan et al. (1996).

sandstone. They are probably eolian, and maybe indicate conditions of aridity (Mirr  1966).

TC1 corresponds to the andesitic breccia widely exposed, e.g. north of the Blanco river up to the Las Casitas creek (P rez 2001a). The geochemistry corresponds to a typical retroarc sequence assigned to the Lower Miocene (P rez and Ramos 1996; P rez 2001a). This member was recognized by Mirr  (1966) as Brecha andes tica.

TC2 to TC4 are characterized by medium to coarse-grained, massive, parallel-stratified sandstones interfingering with lenticular conglomerates (Figs. 1b and 2). Clast composition mainly consists in rhyolites and volcanic breccia derived from the Choiyoi Group. Shales interfinger toward the top (TC4). These levels represent fluvial meandering environments whose energy dimin-

CHINCHES BEARING LEVEL	LAS HORNILLAS BEARING LEVEL
Order Cingulata	Supercohort Marsupialia
Family Dasypodidae	Family Palaeothentidae
<i>Stenotatus</i> sp.	<i>Palaeothentes</i> sp.
Family Peltephilidae	Order Cingulata
<i>Peltephilus</i> sp.	Family Dasypodidae
Order Tardigrada	<i>Prozaedyus</i> sp.
Family Notrotheriidae	Order Tardigrada
cf. <i>Hapalops</i>	Family Prepotheriidae
Order Notoungulata	Gen. et sp. indet.
Family Interatheriidae	Order Notoungulata
<i>Protypotherium</i> sp. 1	Family Interatheriidae
<i>Protypotherium</i> sp. 2	<i>Protypotherium</i> sp. 1
Family Interatheriidae ?	<i>Protypotherium</i> sp. 2
Gen. et sp. nov 1	Family Hegetotheriidae
Family Hegetotheriidae	Subfamily Hegetotheriinae
Subfamily Hegetotheriinae	Gen. et sp. indet.
<i>Hegetotherium</i> cf. <i>H. mirabile</i>	Subfamily Pachyrukhinae
Family Mesotheriidae	Gen. et sp. indet.
cf. <i>Altitypotherium</i>	Family Toxodontidae
Order Litopterna	<i>Nesodon conspurcatus</i>
Family Macraucheniiidae	Family Mesotheriidae
Gen. et sp. indet.	Gen. et sp. nov 2
Family Protheroheriidae	Order Litopterna
Gen. et sp. indet.	Family Macraucheniiidae
Order Rodentia	Gen. et sp. indet.
Family Dasyproctidae	Order Rodentia
<i>Neoreomys</i> cf. <i>N. australis</i>	Family Eocardiidae
Family Dinomyidae	<i>Eocardia montana</i>
<i>Scleromys</i> sp. nov.?	<i>Eocardia excavata</i>
	Family Chinchillidae
	<i>Prolagostomus</i> sp.
	Family Cephalomyidae
	<i>Cephalomyopsis</i> ?
	Superfamily Octodontoidea
	Gen. et sp. indet. 1
	Gen. et sp. indet. 2

Table 1. Preliminary faunal list of the «Chinches bearing level» (CBL) and «Las Hornillas bearing level» (LHBL).

ishes upward in the section (Pérez 2001a).

TC5 is composed of shales, siltstone, and medium to coarse sandstone with lenses of medium to fine conglomerate and several tuff levels (Figs. 1b and 2). Palynological studies identified herbaceous and shrubby elements together with chlorococcaleans, scarce microforaminifera and dinoflagellate cysts (Ottone et al. 1998). These deposits indicate a shallow lake of relatively dry climate. The presence of planispiral microforaminifera characteristic of marine environment, suggests some short lived marine transgression for part of this member TC5 (Pérez et al. 1996; Pérez 2001a).

TC6 is composed of coarsening upward sequences of chaotic and poorly sorted conglomerates, cross-stratified coarse sandstones and lenses of conglomerates (Figs. 1b and 2). This member is related to a braided fluvial system in a proximal environment, which quickly changes to fans and talus dominated environments, close to an active thrust active system.

Members TC2 to TC6 correspond to the Areniscas

Conglomerádicas of Mirré (1966). The upper boundary of the Chinches Formation is a tectonic contact with the Choiyoi Group.

Fossils here reported were found in two levels of the sandstones of the TC2 and TC3 members.

#### PRELIMINARY TAXONOMIC ANALYSIS

Supercohort Marsupialia Illiger, 1811  
 Order Paucituberculata Ameghino, 1894  
 Family Palaeothentidae (Sinclair 1906) Osgood, 1921  
 Subfamily Palaeothentinae Sinclair, 1906  
 cf. *Palaeothentes* Ameghino, 1887b

The single marsupial remain found is a skull fragment with the lower teeth in occlusion coming from LHBL (Ar-96-40). The hypertrophied I1 followed by a series of vestigial teeth (I2-P2), P3/p3 which although broken, are enlarged and compressed, and the m1 with elongate trigonid with developed metaconid, suggest it may be referred



Figure 3. Southwest-northeast view across the Los Patos river valley in Las Hornillas area. In the foreground the sedimentary sequence of the Chinchas Formation and in the background the volcanic rocks of the Cordón del Espinacito (the Horcajo Formation).

to the Palaeothentinae Palaeothentidae. This material has not been completely prepared yet, but both in cheek teeth morphology and in size is recognized as closely related to *Palaeothentes*. This genus has nine recognized species from Deseadan to Santacrucian levels (Oligocene-early Miocene; Bown and Fleagle 1993).

Order Cingulata Illiger, 1811  
 Family Dasypodidae Gray, 1821  
 Subfamily Euphractinae Winge, 1923  
 Tribe Euphractini Winge, 1923  
*Prozaedyus* Ameghino, 1891a  
*Prozaedyus* sp.

Associated osteoderms, mostly disarticulated (LH-07-23, LH-08-52) were found in LHBL (Fig. 4a). They undoubtedly belong to *Prozaedyus*, because of the small size, elongate, straight and narrow central figure surrounded by peripheral anterior and posterior lateral figures, and with very small and scarce piliferous foramina. However, it is difficult to assign them to any of the known species because they have some particular features (e.g. 1, furrows dividing lateral figures of mobile osteoderm superficial, almost imperceptible; 2, mobile osteoderms with piliferous foramina in the posterior lateral margins, in addition to those of the posterior margin; these foramina, two to three posteriors and up to three poste-

rolaterals, are small), that in turn, and with more specimens, could justify the recognition of a new species. Fixed osteoderms are 4 to 5.5 mm wide, 5.5 to 6 mm long and 2 mm thick, and mobile ones are 4.5 to 5 mm wide and 12 to 13 mm long. This genus has six described species from Deseadan to «Friasian» s.l. levels (Oligocene-middle Miocene) (Scillato-Yané 1980).

Tribe Eutatini Bordas, 1933  
*Stenotatus* Ameghino, 1891c  
*Stenotatus* sp.

The specimen AR-96-61, recovered from the CBL and assigned to this taxon, is a very damaged skull, fragments of both hemimandibles, some vertebrae, fragments of limbs (fragments of humerus, radius, femur and tibia-fibula), and several fixed and mobile osteoderms (Fig. 4b).

The left mandible has seven molariforms (the anteriormost ones are missing, probably three), anterior teeth are laterally very compressed and toward the posterior ones, they become circular in section, as in *Stenotatus patagonicus*. Fixed osteoderms bear an elongate central figure surrounded by four or six peripheral figures. On the anterior portion of the central figure, there are small foramina on the surrounding furrow. All the figures are convex and well defined. On the posterior margin, there are three or four large piliferous

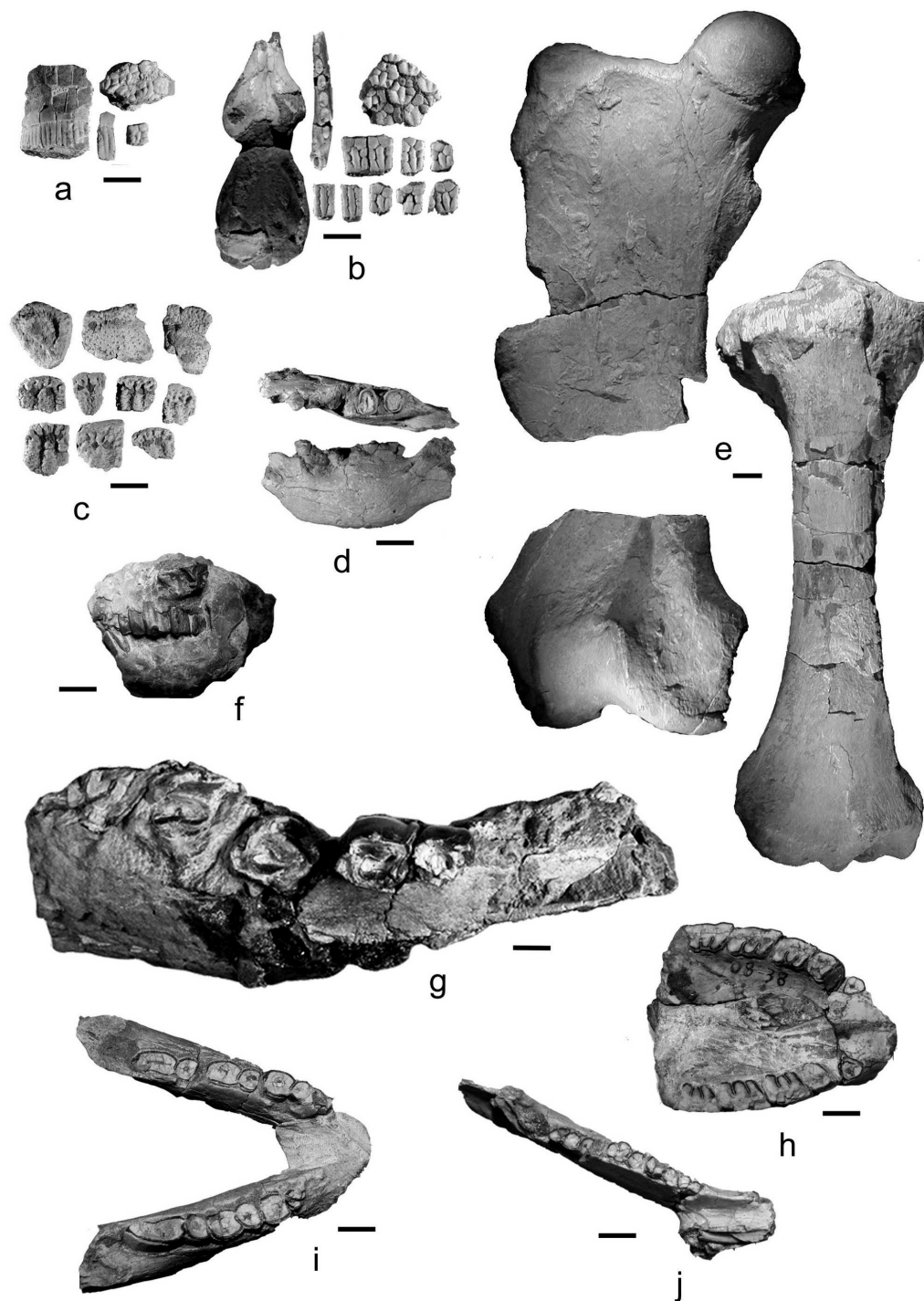


Figure 4. (a) *Prozaedyus* sp., LH-07-23, associated osteoderms; (b) *Stenotatus* sp., AR-96-61, damaged skull, left mandible and fixed and mobile osteoderms; (c) *Peltephilus* sp., AR-96-54, associated osteoderms; (d) cf. *Hapalops*, AR 07-02, fragment of left mandible with C1, M2-3 and the alveolus of M1 in occlusal and labial view; (e) Preprotheriidae gen et sp. indet., LH-07-41, fragments of right femur and right tibia in anterior view; (f) Interatheriinae gen et sp. nov.1, LH-07-03, skull with the mandible in occlusion; (g) *Nesodon conspurcatus*, LH-07-17, incomplete right maxilar with P2-P3, Dp4 and M1; (h-i) cf. *Altityotherium*, (h), LH-08-38, maxilar remain with left and right P3-M3, (i), LH-08-32, mandible with left p4-m3 and right m1-m3; (j) Mesotheriinae gen et sp. nov.2, Ar-96-49, mandibular fragment with left i1-i2 and p4-m3 and right i1. Scale bar: 1cm.

foramina, and in some cases some small ones are intercalated between them. Fixed osteoderms are 5 to 7 mm wide, 8 to 11 mm long and 2 to 3 mm thick. Morphological features of these osteoderms match with those of *S. patagonicus*; however, they are smaller, even considering the range size recorded in *S. patagonicus* (6.5 to 9.5 mm, 9 to 13 mm and 3 to 5 mm respectively). In addition, the skull and post-cranial measurements are also smaller than those of *S. patagonicus*. This specimen, both in osteoderm morphology and in size is closely related to *Stenotatus* sp. nov. described by Croft et al. (2007), from the early Miocene of Chucal (northern Chile), and with *Stenotatus* cf. *S. patagonicus* described by Kramarz et al. (2010) for the early Miocene of Gran Barranca (Chubut, Argentina). This genus has five described species from Deseadan to «Friasian» s.l. levels (Oligocene-middle Miocene) (Scillato-Yané 1980; Scillato-Yané and Carlini 1998).

Family Peltephilidae Ameghino, 1894  
*Peltephilus* Ameghino, 1887b  
*Peltephilus* sp.

Several associated osteoderms (AR-96-54) and an isolated one (LH-08-19) recovered from the basal levels of the Chinchas Formation (CBL) are assigned to *Peltephilus* (Fig. 4c).

Among the osteoderms there are some belonging to the cephalic shield and some to the dorsal carapace. Not any of the dorsal carapaces is complete. They are middle sized (12 mm wide and ~15 mm long), with a very rugose surface, numerous tubercles on the exposed surface, and a very developed central medial keel. At both sides of the anterior portion of the central keel there are two large foramina. The general morphology is similar to that of *P. pumilus*, but differs because the central keel is narrow anteriorly and becomes wider posteriorly, while in *P. pumilus* the keel is always narrow and higher. This genus has seven described species from Deseadan to Santacrucian levels (Oligocene-early Miocene) (Scillato-Yané 1980).

Order Tardigrada (=Phyllophaga) Latham and Davies, 1795  
 Family Nothrotheriidae Kraglievich, 1923  
*Hapalops* Ameghino, 1887b  
 cf. *Hapalops*

Mandibular, dental and postcranial remains from the CBL match with the morphology of the small species of the Santacrucian *Hapalops*, slightly smaller than

*H. longiceps*, comparable to *H. rostratus* and slightly larger than *H. rutimeyeri*. The specimen AR 07-02 is a fragment of mandible with C1, M2-3 and the alveolus of M1 (Fig. 4d). As in most of the *Hapalops* species, the first two molariforms are subquadrangular in section, but the third is subrounded with a slight posterior concavity, the caniniform is subtrapezoidal in section, separated from the first molariform by a distance equivalent to twice the length of the first molariform. The mandibular body is high, externally and ventrally convex, and prolonged anteriorly by a subvertical, short symphyseal zone, similar to that of *H. rectangularis*. The alveolar foramen is postero-external, located on the base of the coronoid process.

Postcranial fragmentary remains (AR 08-46) are tentatively assigned to the same taxon as the mandible, since the skeletal proportions of associated specimens of the Santacrucian suggest no contradiction, and so far it is the most parsimonious option. The femur, dorsoventrally flattened, is similar to that of *H. longiceps*, but smaller. The tibia is similar to those of *H. longipes*, but also smaller. Remains AR 07-02 and AR 08-46 belong to adult specimens. The numerous species described for the genus *Hapalops* are recorded certainly in the Santacrucian → «Friasian» s.l. lapse. *Hapalops? antistis* Ameghino 1887b has been described for the Deseadan (Oligocene), but surely these remains do not belong to *Hapalops* (Carlini and Scillato-Yané 2004).

Family Prepotheriidae Ameghino, 1891a  
 (=Planopidae Ameghino, 1887b)  
 Gen. et sp. indet.

Postcranial remains of an adult specimen were collected in the LHBL: fragments of both femuri, tibiae, fibula, astragalus, metacarpals, metatarsals, ulna, radius, humerus, vertebrae and ribs (LH-07-41). The femur is anteroposteriorly flattened (Fig. 4e), similar to those described for *Planops* and *Prepothierium* (see Hoffstetter 1961). The head is hemispheric, with the fossa for the insertion of the round ligament displaced posteriorly and continued in a furrow, unlike in *Planops* and *Prepothierium*, in which it is isolated. The neck is shorter than in *Planops*. The trochanter major has a deep digital fossette and the trochanter minor is acute. The third trochanter is approximately at the middle of the external side of the diaphysis. The facets for the external, internal and patellar condyles are continuous, as in *Planops* and *Prepothierium*. The diaphysis of the tibia is more gracile than in *Planops*, with two well marked furrows for the flexors of the foot, a net facet for the proximal articulation of the fibula di-

rected downward and anteriorly; a distal facet for the articulation with the fibula directed downward and posteriorly (Fig. 4e). The astragalus is proportionally small, with a sessile *caput* and the articulation with the navicular is concave-convex; the astragalian facets are asymmetric, the external larger than the internal, which tends to form an odontoid process. The calcaneus is large with the proximal process more developed than in *Preprotherium* and *Planops*. An articulate forelimb of this specimen was recovered but has not been completely prepared yet.

This family is recorded in the Santacrucian - «Friasian» s.l. (at least to the «Colloncuran»).

Order Notoungulata Roth, 1903  
 Family Interatheriidae Ameghino, 1887a  
 Subfamily Interatheriinae Ameghino, 1887a  
 Genus *Protypotherium* Ameghino, 1885

Interatheriinae remains are the most abundant mammals present in both mammal assemblages from the Chinchas Formation, and approximately one-fourth of the identified specimens are referable to this group.

Most of these remains could be referred to *Protypotherium*, because of the presence of cement, upper premolars with unequal lobes, posterior projection of the M3, and lower p3-p4 with reduced trigonid. These two latter allow differentiation from *Cochilius*. The more transverse upper molars with less developed parastylus and smaller size differentiate them from *Miocochilius*. Likewise, the less «octodontiform» shape of their cheek teeth, and descendent zygomatic process less developed allow differentiation from *Interatherium*. Among these remains, two morphotypes are tentatively recognized on the basis of morphological differences of premolars and molars and their size.

*Protypotherium* sp. 1

Several specimens (LH-08-39 from CBL, and Ar-96-41, Ar-96-48, LH-08-21 and LH-08-51 from LHBL) represent this taxon which is the smallest morphotype. Its size is smaller than that of the Santacrucian species such as *Protypotherium australe* and *P. praerutilum*, being somewhat smaller than *P. attenuatum* and near in size to some specimens referred to *P. minor* from the Colhuehuapian of Gaiman. The imbrication of the upper molars, less than in *P. australe*, resembles that of *P. attenuatum*.

*Protypotherium* sp. 2

Several remains (LH-08-14, LH-08-15, LH-08-33/

34, and Ar-96-60 from CBL, and Ar-96-42, Ar-96-52, LH-07-39, and PVSJ-5-507 from LHBL) represent a morphotype larger than the previous one, comparable in size to *Protypotherium australe* and *P. praerutilum*. Two specimens are complete skulls with the mandible in occlusion (PVSJ-5-507, Ar-96-60). Preparation of these materials will enable a more accurate comparison with Santacrucian species. This morphotype differs from the previous one by having P3-4 with less conspicuous parastylus, para- and metacone separated by a well defined labial furrow, and less evident labial furrow of m3. The genus *Protypotherium* is recorded in Patagonia from the Colhuehuapian (lower Miocene) to the Colloncuran (middle Miocene) ages, and in the «Mesopotamian» (Late Miocene) of Entre Ríos, Argentina.

Family Interatheriidae ?  
 Gen et sp. nov. 1

Among the collected remains, there are three specimens of associated crania and lower jaw from CBL (LH-07-03, LH-08-43, and LH-08-44) representing a notoungulate tyotherian with a high and very short rostrum, which curiously resemble more that of the Groeberiidae marsupials than any other rodent-like notoungulate. Although these remains have not been prepared yet, one specimen partially disarticulated shows the occlusal figure of the lower molars which is similar to the one observed in the Interatheriidae. Despite the similarity observed in the lower molars, this taxon has hypertrophied and very high crowned I1, probably hypsodont as the two lower incisors; the other upper incisors are very small. The canines and premolars are very short and strongly imbricated and very probably there is reduction of the antemolar dental formula. In ventral view the symphysis has a peculiar flat area, different from any other structure observed in the remaining tyotheres. These characters clearly distinguish this taxon from the other known Interatheriidae, and clearly represent a different lineage within the tyotheres, and novel even within notoungulates (Fig. 4f).

Family Hegetotheriidae Ameghino, 1894  
 Subfamily Hegetotheriinae Ameghino, 1894  
*Hegetotherium* Ameghino, 1887b

An incomplete right mandibular fragment with broken p2-m3 (PVSJ 05-0500) recovered in the lower levels (CBL) is referred to *Hegetotherium* cf. *H. mirabile*. Although the dentition of this mandibular fragment is eroded, its morphology and size suggest it is closely re-

lated to the Santacrucian species *H. mirabile* Ameghino 1887b. The poor preservation of this remain impedes a sure assignment to this species.

Gen. et sp. indet.

One left mandibular fragment with m2-m3 and one right fragment with talonid of p3, p4 and trigonid of m1 of a single individual (LH-07-32) were found in LHBL. These fragments are clearly referable to the hegetotheriinae but they are 30% smaller than the materials referred to *Hegetotherium* cf. *H. mirabile*, being probably a different taxon.

Subfamily Pachyrukhinae Kraglievich, 1934

Gen. et sp. indet.

One incomplete left mandibular fragment (LH-07-33) with p2-m1? was collected in LHBL. The assignment to Pachyrukhinae is based on the morphology of the cheek teeth and minute size. Premolars and molars have subequal trigonids and talonids and straight lingual wall, and in molars the metaconids are not protruding. Unfortunately, because of the bad preservation, a more accurate taxonomic assignment is difficult.

Family Toxodontidae Gervais, 1847

Subfamily Nesodontinae Murray, 1866

*Nesodon* Owen, 1847

*Nesodon conspurcatus* Ameghino, 1887b

Some remains found in LHBL (LH-07-17, LH-07-42, and PVSJ-5-517) are referred to the genus *Nesodon*. One of the most diagnostic (LH-07-17) is an incomplete anterior portion of skull with I1 and I2 in eruption, and right P2-P3, Dp4 and M1, and left P1-P3, Dp4 and M1 (Fig. 4g).

The presence of a spatular hypertrophied I1 and a subtriangular I2 (in eruption in this specimen), together with the hypsodonty and molars with a Y-shaped lingual valley, and with at least one posterolingual fossette, suggest this remain belongs to the Toxodontidae Nesodontinae. The marked hypsodonty of upper cheek teeth differentiates it from the *Proadinothorium*, whereas its large size, discards its reference to the Santacrucian *Adinothorium*. The morphology and size of upper cheek teeth instead, are similar to *Nesodon*, and especially to the Santacrucian *N. conspurcatus* Ameghino 1887b.

Family Mesotheriidae Alston, 1876

Subfamily Mesotheriinae Simpson, 1945

cf. *Altitypothorium* Croft et al., 2004

Several mesotheriine remains, among which there are very complete palates (PVSJ-5-504; LH-07-13; LH-08-32; LH-08-38) and mandibles (PVSJ-5-527; LH-08-32) were collected in the right margin of the Los Patos river (CBL) (Fig. 4h-i). Based on the morphology of the diastema (short and with divergent rami) and cheek teeth (e.g. P4 subtriangular, without central fossa, shape and development of molar lobes, relation i1/i2, m2 not shortened), these remains may be assigned to a taxon related to *Altitypothorium* Croft et al. 2004. However, some differences suggest it belongs to a species different from those recognized for the Santacrucian levels of the Chucal Formation of northern Chile (*Altitypothorium paucidens* and *A. chucalensis*).

Gen. et sp. nov 2

Only two mesotheriid remains have been recovered from LHBL, and are clearly different from those found in lower levels of this unit (CBL). One of them (Ar-96-49) is a mandibular fragment with left i1-i2 and p4-m3 and right i1 (Fig. 4j); the other is a right maxillary fragment with incomplete M1 and much damaged M2-M3, associated with a fragment of right mandible with m2-m3 (LH-08-48). The absence of p3 and fossettids in lower molars justify its inclusion within the Mesotheriinae (Reguero et al. 2005), although the elongate and low mandibular body and the subequal i1/i2 resemble to the Trachytheriinae. Among the distinctive features of this taxon are the small size (comparable to *Eotypotheium chico* Croft et al. 2004), the absence of middle furrow on the lingual side of the talonid of the m3, and a band without enamel along the whole crown in the postero lingual sector of the last molar. Because of its particular morphology, it is separated as a new taxon clearly different from the three species of mesotheriines recognized for the Chucal Formation from northern Chile (Croft et al. 2004).

Order Litopterna Ameghino, 1889

Family Macraucheniiidae Gervais, 1855

Gen. et sp. indet.

Numerous postcranial fragments of a single specimen (LH-08-10) have been recovered from LHBL being outstanding a right astragalus and right and left calcani. These tarsal elements are similar to those referred to

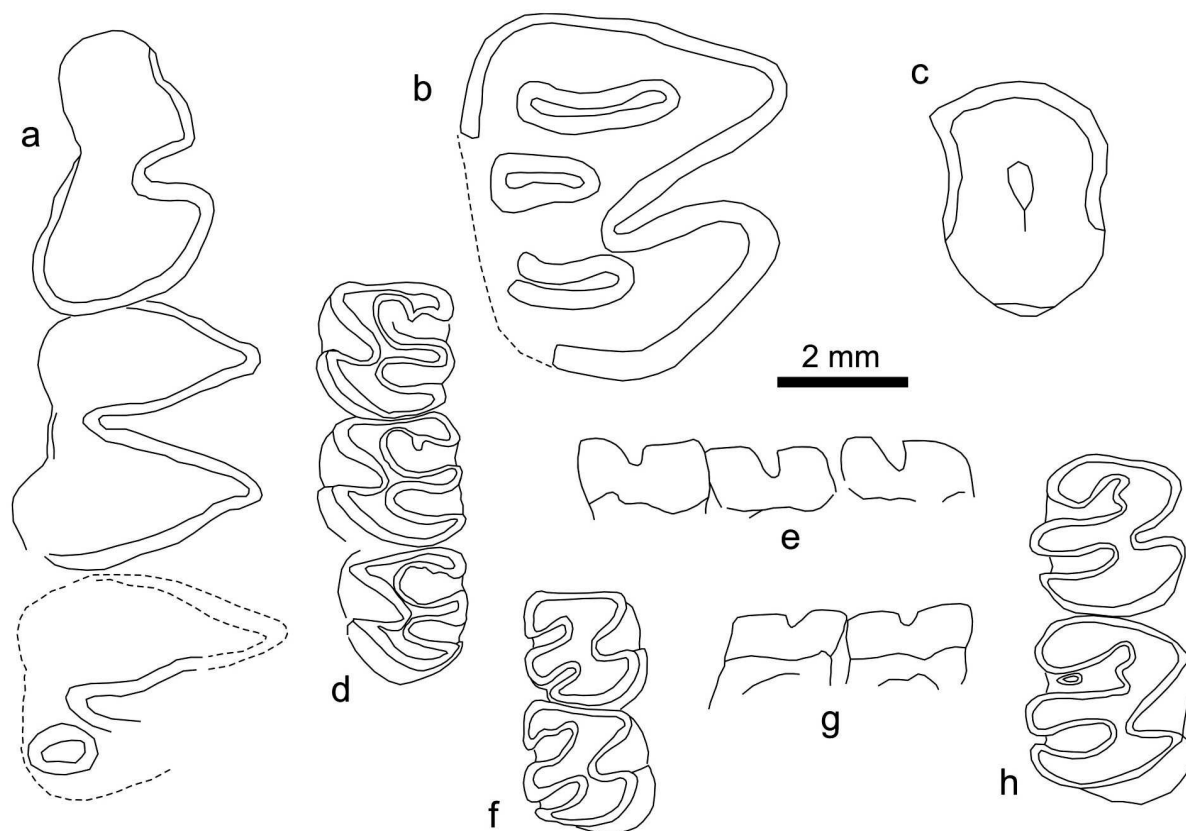


Figure 5. (a) *Eocardia montana*, LH-07-40, right p4-m2; (b) *Neoreomys*, Ar. 96-55, right m1 or m2; (c) Cephalomyidae indet., LH 07-44, right M3; (d-g) Octodontoidea indet. Gen. et sp. indet. 1, (d-e), LH-07-25, left m1-m3, (d, occlusal view, e, external view), (f-g) LH-08-47, right m1-m2, (f, occlusal view, g, external view); (h) Octodontoidea indet. Gen. et sp. indet. 2, LH-07-47, right m1-m2, occlusal view. Scale bar: 2 mm.

*Theosodon* sp. from Santacrucian levels of Patagonia. Some small differences such as a smaller and shallower maleolar facet and a longer and more robust neck in the calcaneus, as well as a shallower subtentacular facet in the astragalus, impede a precise generic reference. The genus *Theosodon* was mentioned for the Paso del Espinacito by Windhausen (1931) and for Las Hornillas area by Contreras (1989). Other macraucheniid remains found in this level (Ar-96-53, Ar-96-57) are poorly diagnostic.

In CBL levels, Macraucheniiidae are represented by much damaged dental remains included in two mandibular fragments a left one with the talonid of p3 and p4-m1, and a right one with p4-m3 (Ar-96-39), one isolated left calcaneus (LH-08-45) and a lot of foot bones among which there is a right astragalus (LH-07-51). The calcaneus and astragalus show differences with those described above from the LHBL, suggesting it may be one or more different taxa. The calcaneus (LH-08-45) is smaller, with a slight difference in the orientation of the

tuber calcis, a smaller cuboid facet and a wider ectal facet. The astragalus (LH-07-51) is somewhat smaller but morphologically similar to those recorded in LHBL.

Family Protheroheriidae Ameghino, 1887b  
Gen. et sp. indet.

Postcranial and non-diagnostic dental protheroheriid remains were recovered from CBL. Some of them, postcranials (with right astragalus and calcaneus) associated with a left mandibular fragment with m1-m2 (LH-08-13), and another with welded left calcaneus and astragalus and part of a right calcaneus (LH-08-17). Astragali are gracile, elongated, with a well defined troclea. Unlike macraucheniiids, calcanii are proportionally more compressed. Unfortunately, the strong wear of the dental elements impedes the generic assignment.

Order Rodentia Bowdich, 1821  
Suborder Hystricognathi Tullberg, 1899  
Eocardiidae Ameghino, 1891b  
*Eocardia* Ameghino, 1887b  
*Eocardia montana* Ameghino, 1887b

This species is represented by three damaged mandibular fragments collected in LHBL, a juvenile left jaw with m1-m2 (LH-07 34), a juvenile right jaw with incisor and p4-m2 with the metafossetid still present in m2 (LH-07-40, Fig. 5 a), and LH-07 45, a left jaw with incisor and m1. These specimens are assigned to *E. montana* because they have a robust mandible with alveolar protuberances, heart shaped check teeth and p4 with subequal lobules.

*Eocardia excavata* Ameghino, 1891b

Another mandibular fragment also coming from LHBL, is referred to *Eocardia excavata* (LH-07-18, left jaw with p4-m2 and isolated right m3). This specimen is assigned to *E. excavata* because the mandible has not alveolar protuberances, anterior lobe of p4 smaller than the posterior one, and the external apex of the anterior lobe of m1-m2 strongly forwardly directed. Both, *E. montana* and *E. excavata* have been described so far only from sediments referred to the Santacrucian (late early Miocene) from several localities of the Santa Cruz province.

Family Dasyproctidae Gray, 1825.  
*Neoreomys* Ameghino, 1887b  
*Neoreomys* cf. *N. australis* Ameghino, 1887b

One isolated right m1 or m2 (Ar-96-55) found in CBL is referred to *Neoreomys* Ameghino 1887b (Fig. 5 b). This specimen is similar in size to the smallest specimens of *N. australis*, the Santacrucian species, and the relationship crown height-fossetid formation is also similar. The ectolophid is very long with respect to the mesolophid, as in *N. australis* (Kramarz 2006). Although it resembles *N. australis*, this specimen is only tentatively referred to this species, because it is difficult to determine a single tooth of *Neoreomys* at species level, due to the important morphological change they display during ontogeny. *Neoreomys* is represented in the «Pinturan», Santacrucian, «Colloncuran» and Laventan (early to middle Miocene), and the species *N. australis* in particular, is only known for the Santacrucian.

Family Dinomyidae Peters, 1873.  
*Scleromys* Ameghino, 1887b  
*Scleromys* sp. nov.?

*Scleromys* is represented by an excellently preserved mandibular fragment with right p4-m3 and left m2-3 (LH-08-42) found in CBL levels cropping out behind the Puesto de Gendarmería. This specimen is slightly smaller than those referred to the other species of *Scleromys* with a similar wear degree, and it also differs in some details of the tooth morphology (e.g. morphology of the hypolophid of m3, shortening of p4) suggesting it may represent a new species. *Scleromys* is represented in the «Pinturan», Santacrucian (early Miocene). This genus was mentioned for the Laventan but the assignment is dubious (Cerdeño and Vucetich 2007 and bibliography there).

Family Chinchillidae Bennett, 1833  
*Prolagostomus* Ameghino, 1887b  
*Prolagostomus* sp.

Chinchillids are represented exclusively by two fragments of *Prolagostomus* found in LHBL, a left palate with M1-2 (LH-08-09(A)), and a mandible with left and right p4-m3, some isolated upper teeth and parts of the tarsals (LH-08-02). These materials are referred to *Prolagostomus* because the teeth are bilaminar with scarce cement and the hypoflexi/ids are sinuous. *Prolagostomus* is recorded from the Santacrucian to the «Colloncuran», and a revision of its systematics is in need.

Family Cephalomyidae Ameghino, 1897  
*Cephalomyopsis*?

A damaged right M3 (LH 07-44; Fig. 5 c), included in a tiny portion of palate, found in LHBL, is assigned to this family. It is fairly kidney-shaped in outline, similar to those assigned to Cephalomyidae gen. et sp. indet., Morphotypes 1, 2 and 3 (Vucetich 1989), which possibly represent the upper teeth of *Cephalomyopsis*. LH 07-44 represents a fourth morphotype, larger and more robust than the other morphotypes, and more rectangular in outline than the M3 of Morphotype 1, (Vucetich 1989, Plate II, a; this tooth is not known for Morphotypes 2 and 3). *Cephalomyopsis* is recorded in the Colhuehuapian of Patagonia while the upper teeth come from the late Oligocene (Deseadan) of Patagonia (Morphotype 2) and Bolivia (Morphotype 3), and the early Miocene (Colhuehuapian) of Patagonia (Morphotype 1), but the family has been reported for the Laventan of Quebrada Honda (Bolivia) through the otherwise Deseadan *Cephalomys*

(Frailey 1980; Croft 2007).

Superfamily Octodontoidea Simpson, 1945  
 Octodontoidea indet.  
 Gen. et sp. indet. 1

Four mandible remains, one of them edentulous (LH-08-49), collected in LHBL represent this superfamily. They are small, with brachyodont and three-lophated cheek teeth. A left mandibular fragment with m1-m3 (LH-07-25; Fig. 5 d-e) has little wear; the hypolophid is transverse in m1 but slightly forwardly directed in m2 and m3, and there is a conspicuous spur in the anterolophid of m1 and m2. A right mandibular fragment with m1-m2 (LH-08-47; Fig. 5 f-g) is slightly smaller, and more deeply worn. The hypolophid is backwardly directed and only in m2 there is a small hint of the spur. In spite of these differences, both specimens share a straight anterior wall and the order of internal flexiid closure. Differences in size, hypolophid orientation and presence/absence of the spur could be due to the different degree of wear they display. Thus, we tentatively consider them as a single taxon. Alternatively, they could represent different but closely related species.

Gen. et sp. indet. 2

A right mandibular fragment with m1-m2 found in LHBL (LH-07-47; Fig. 5 h) is larger than the others, and has a somewhat different structure. The anterolophid is straight in m1 but curve in m2; there is not a spur in the anterolophid, but a large one in the ectolophid and an isolated column in the centre of the anteroflexid. In m1, with more wear, this column has already been incorporated to the anterolophid. The spur and the column would represent remnants of the meso or meta-lophid. This specimen clearly represents a taxon different from the other two. Systematics of the Oligocene - middle Miocene octodontoids is very controversial (Vucetich and Kramarz 2003; Vucetich and Vieytes 2006), so we prefer not to refer these specimens to family level.

## DISCUSSION

Schiller (1912) assigned the sequence of the Manantiales basin to the middle Tertiary. Groeber (1951) assigned beds in members TC2 to TC6 to the Agua de la Piedra Group of Oligocene age and the andesitic breccia to the Mollelitense of Oligocene-Miocene age. Clearly Groeber (1951) interpreted the andesitic breccia as an intrusive, as he assigned it a younger age than the beds

immediately above.

Chemical correlation of the TC1 andesitic breccia with some other Lower Miocene volcanics, suggests an approximate age of 20 Ma for the andesitic breccia (Pérez and Ramos 1996; Pérez 2001a). To the west of the Cordón del Espinacito, the andesitic lavas of the Cordón de La Ramada were deposited over the structures of the Mesozoic fold and thrust belt. These andesitic rocks have ages of 9.2, 10.7 and 12.7 Ma (Pérez and Ramos 1996; Pérez 2001a). According to these ages, the synorogenic deposits of the Chinchas Formation are synchronous with the uplift of the La Ramada fold and thrust belt, approximately between 20 and 10 Ma.

These ages are sustained by the fission-track studies of four tuff levels, from member TC5, which yielded ages between 17.1 and 11.5 Ma, complemented by the magnetostratigraphy carried out by Jordan et al. (1996) for this sequence (Fig. 2). Based on these data, sedimentation of the Chinchas Formation was constrained between 19 and 9.5 Ma. The study section by Jordan et al. (1996) does not include TC0, TC1 (Andesitic Breccia), and TC6.

The lithology and age of the Manantiales basin fill allow correlation with other Tertiary deposits. Toward the north, the deposits of the transported (*piggy-back*) basin of Iglesias (30°S) have ages ranging from 16 to 6 Ma (Beer et al. 1990), those of the Las Juntas sector range from 18 to 9 Ma and those of the Azul river from 16 to 9 Ma (Jordan and Damanti 1990). Toward the south (32°40'S) the Santa María Conglomerate has an age of 8 Ma at the top of the section (Ramos et al. 1990). In the Cacheuta and Tunuyán areas the Mariño Formation is 15.7-12.2 Ma, the La Pilona Formation ranges from 11.7 to 9 Ma and the ash-rich unit of Tobas Angostura Formation is 8.9 Ma (Irigoyen et al. 1998). However, further south in the cerro Duraznito area, the Tertiary deposits of the Tunuyán Conglomerate (34°S) would have an age older than 5.9 Ma (Pérez 2001b). This would indicate that the continental Tertiary deposits to the north and south of the Manantiales basin reflect uplift of the Cordillera Principal and Cordillera Frontal and were deposited diachronously during the early Miocene to the late Miocene.

Geochemical data of the member TC1 indicate that the High Andes were not yet structured and that it might be correlated with a part of Doña Ana Formation (Pérez and Ramos 1996; Pérez 2001a). These andesitic rocks interpreted as formed in a retroarc environment are equivalent to similar age rocks which crop out near Barral (Leveratto 1976), with ages between 18 and 20 Ma. This would indicate that the andesitic breccia of

Member TC1 could correspond to the beginning of the volcanism and the uplift of the Cordillera Principal in Manantiales region.

The fauna here reported, recovered from the basal levels of the Chinchas Formation (CBL and LHBL) in the area of Las Hornillas, is formed by about 25 taxa. Some of them are tentatively referred to genera and species already known for the Santacrucian, but there is also an important amount of new taxa. Probably due to sampling bias, marsupials are poorly represented, and only a single remain could be referred to this group (cf. *Palaeothentes*). On the contrary, Xenarthra, although not very abundant, are diverse. Cingulata is represented by dasypodids (Eutatini and Euphractini) and peltephilids, and Tardigrada by Nothrotheriidae (Cf. *Hapalops*) and one indetermined taxon of Preprotheriidae. Notoungulata is the best represented group (nine taxa) with members of the families Interatheriidae, Hegetotheriidae, Toxodontidae and Mesotheriidae. Interatheriinae remains are among the most abundant fossils recovered from both mammal assemblages of the Chinchas Formation, and approximately one-fourth of the identified specimens are referable to this group. Litopterna is mainly represented by badly preserved postcranial and dental remains which allow recognizing the presence of the indetermined macraucheniiids and protheriids. Rodents are also diverse, and six groups can be identified (Eocardiidae, Dasyproctidae, Dinomyidae, Chinchillidae, Cephalomyidae and Octodontoidea).

This composition is quite particular because both assemblages contain Mesotheriidae (present in Chucal but absent in Santacrucian faunas of Patagonia) as well as Interatheriidae (absent in Chucal but present in Patagonia).

The presence of *Eocardia montana*, *E. excavata* and *Nesodon conspurcatus* strongly suggests that the bearing levels may be referred to the Santacrucian SALMA. The remaining taxa do not contradict this hypothesis: (1) the morphology of *Stenotatus* sp., *Hapalops* sp., *Protyopotherium* sp., *Neoreomys* cf. *N. australis*, and the mesotheriines is comparable to that of Santacrucian species; (2) the rodents *Scleromys* and *Prolagostomus* have broad early to middle Miocene distributions, and (3) *Cephalomyopsis*? was known so far only through Deseadan-Colhuehupian species, but the material from Las Hornillas represents a new one.

Although both assemblages are referred to the Santacrucian SALMA, differences in composition among them (they only share Interatheriinae, with certain doubts) suggest slight differences in age. This correlation will certainly be improved when larger amount

of remains of CBL and LHBL are available, and systematic revisions of early Miocene taxa are accomplished.

The Santacrucian SALMA is late early Miocene in age. Based on geochronologic data from the Santa Cruz Formation of Patagonia, Marshall et al. (1986) and Marshall (1990) referred the Santacrucian SALMA to the span 15-18 Ma, and Flynn and Swisher (1995) to 16.3-17.5 Ma. The mammal assemblages, both in systematic composition and evolutionary degree of most of the taxa agree with the temporal assignment suggested by geological and micropaleontological studies.

The latitudinal intermediate location together with the particular taxonomic composition of these assemblages may provide the clue to understand the differences between Miocene faunas from Patagonia and the Altiplano (Chile and Bolivia). As well, these assemblages are a new important source of information for the comprehension of the phyletic and geographic relationships of several taxa, and the paleoenvironmental changes associated with the uplift of the Andes.

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