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Distinguishing between cultural and natural depositional agents: Micromammal taphonomy from the archaeological site Cueva y Paredón Loncomán (Patagonia, Argentina)

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ABSTRACT

This paper presents the research achievements to understand the formation processes of north Patagonia archaeological sites through the study of small mammal's assemblages. Our research area is an arid and central region; in particular, our work is focused on Cueva y Paredón Loncomán, a rock shelter used by hunter–gatherer societies through the last 2000 years BP. Small mammal's assemblages were employed to differentiate cultural and natural deposition agents. The analysis included bone patterns of cranial and post-cranial remains which were performed separately for Caviomorpha and Cricetidae rodents. The taphonomic analysis included the estimation of the MNE and MNI, the relative abundance, the breakage degree and the representation of skeletal elements. Heat alteration of bone surface and the presence of cut marks and digestion traces were also included in our research. The disintegration of pellets regurgitated by owls was the main cause of accumulation of the small mammal's assemblages. The overrepresentation of skull bones and distal elements of the limbs, the high degree of fragmentation, and a defined pattern of thermal alteration – mostly affecting distal segments of the long bones, especially tibias, incisors, premaxillaes and mandibles – suggested human consumption of some Caviomorpha rodents inside the cave. Two new species, the rodents *Ctenomys* sp. and *Microcavia australis* were incorporated into the list of species exploited by hunter–gatherers from the northern Patagonian steppes.

1. Introduction

Archaeological sites often show complex formation histories. Traces of different agents of accumulation on bone remains are overimposed and affected by burial processes (biostratinomy) and diagenesis stages, and are also affected by the excavation techniques employed (Andrews, 1990; Fernández-Jalvo and Andrews, 1992; Shaffer, 1992; Lyman, 1994; Stahl, 1996; Dauphin et al., 1999; Kos, 2003; Smoke and Stahl, 2004; amongst others). Taphonomic researches play a key role for interpreting formation processes of paleontological and archaeological sites. Moreover, taphonomy allows discrimination between cultural and natural bone assemblages, necessary to be considered in zooarchaeological studies. Small mammals are consumed by a wide range of predators. Mammalian carnivores, owls and even humans produce a singular small mammal assemblage with a particular signature in archaeological and paleontological sequences (Dodson and Wexlar, 1979; Korth, 1979; Kusmer, 1990; Stahl, 1996; Saavedra and Simonetti, 1998; Andrews, 1990; Andrews and Nesbit Evans, 1983; Crandall and Stahl, 1995; Fernández-Jalvo et al., 1999; Henshilwood, 1997; Simonetti and Cornejo, 1991; Saavedra and Simonetti, 1998; Lyman et al., 2003; amongst others). Defining the role played by predators, animals and humans involved in the genesis of the small mammal deposits in the archaeological sites help to determine possible hiatus in human settlements and to propose hypotheses related with human subsistence practices, among others. As well, taphonomic interpretations are essential for an accurate paleoecological and paleoenvironmental reconstruction based on small mammals as proxy data (Fernández-Jalvo, 1995, 1996; Andrews, 1995; Fernández-Jalvo et al., 1998; Avery, 2001; amongst others).

Caves and stone outcroppings in Patagonia are inhabited by rodents and marsupials and used as refuge for many species of aerial and ground predators. Small mammals died from natural causes at the site and may eventually incorporate into the sediment. Meanwhile, predators deposited pellets or feces into the site, which contain the bones of the prey consumed. Particularly, the raptor *Tyto alba* is considered as the major accumulator of small mammals found in caves and stone outcroppings all over the world (Andrews, 1990). Carnivores like pumas (*Puma concolor*), foxes (*Lycalopex culpaeus* and *Lycalopex gymnocercus*), cats (*Leopardus geoffroyi* and *Leopardus colocolo*) and skunks (*Conepatus chinga*), Falconiforms and Strigiforms are between the potential small mammal bone accumulators in extra-Andean Patagonia. These factors, combined with the eventual human consumption, determine multiple causes of origin of the small mammal's bone remains in these archaeological sites. While in Patagonia, the proportions of rodent remains in

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zooarchaeological contexts are, in many cases, higher than those of other taxa, few specific taphonomic analyses were conducted oriented to determine the deposition agent of those bone remains. Generally, rodents were considered as intrusive into the archaeological sequences. Specifically for the case of fossorial rodents, they were treated as bioturbation agents of the archaeological deposits because of their burrowing behavior. Displacements of archaeological buried remains by faunalturbation associated with subterranean rodents were documented (Erlandson, 1984; Bocek, 1986; Duran, 1991; amongst others). Despite not having detailed taphonomic descriptions for Patagonian archaeological sites, some paleoenvironmental hypotheses were proposed based on the small mammal faunas (Pardiñas, 1998; Pardiñas et al., 2000; Andrade and Teta, 2003; Teta et al., 2005; Pearson and Pearson, 1993).

Cueva y Paredón Loncomán (CLO) is an archaeological site located in the western semiarid steppes of northern Patagonia. Human occupations in the site are dated since 2000 years BP. Small mammals' assemblages of CLO were studied at a regional scale to propose paleoenvironmental hypotheses for the extra-Andean steppes (Teta et al., 2005). Also, small mammals were included into a general zooarchaeological research of this site (Andrade et al., 1999). In these studies, owls and humans were proposed as possible agents of deposition of the small mammal's bone assemblages, based on stratigraphic and qualitative evidence emerging from direct observation of bones. However, these hypotheses have not been yet tested by the taphonomic evidence. In this work we carried out a detailed taphonomic analysis of the micromammal assemblages from CLO, in order to test these hypotheses and to determine the main agents of deposition that participate in the formation of this archaeological site.

2. The archaeological site

The archaeological site Cueva y Paredón Loncomán (CLO, 40° 47′ S; 70° 10′ W; 900 MASL) is a rock shelter located in Northern Patagonia (Río Negro province, Fig. 1). The cave is at the top of an isolated hill conformed of tuffaceous rocks from Collón Curá Formation (Mid-Tertiary). The entrance of the cave opens to the north. The opening is 9.5 m wide and 2.15 m high. The surface of the site is 30 m^2. The archaeological site was excavated and the evidence was recovered using the microstratigraphy methodology. The small bone remains were retained from the sediments extracted from CLO using a 2 mm mesh. This allowed recovering almost all of the small mammal's remains. Even those smaller like vertebrae, ribs and metapodia were registered. Site singularities and descriptions are detailed in Boschin (2009).

It was excavated eight grids (1 m^2 each one) from the top down to bedrock. The archaeological sequence extends from 1960 ± 30 BP to recent times. Three components were identified: inferior, medium and superior. The inferior component (IC) is characterized by two human occupations that correspond to hunter–gatherers. Between them, a hiatus conformed by an important deposit of small mammals bone remains was recognized. The medium component (MC) is separated from the IC by a second hiatus marked by a carnivore den, inferred by the presence of bones of *Lama guanicoe* (guanaco) with tooth pitting marks. MC supports only one human occupation that corresponds also to hunter–gatherers. The superior component (SC) is constituted by three human occupations. The first two occupations are from hunter–gatherers but the most recent one corresponds to indigenous people who frequented the shelter during the nineteenth and twentieth centuries, as was verified by a radiocarbon date, by the presence of horse bones and feces at the top of SC and by ethnographical evidences (Boschin, 2009, personal communication).

CLO is an important archaeological site, highlighted by its diversity and abundance of rock art motifs. The archaeological materials recovered on the sequence include lithic artifacts, ceramic shreds, mineral pigments, and instruments made of guanaco bones. As well as bone remains from the species *L. guanicoe* (guanaco), *Pterocnemia pennata* (choique), *Chaetophractus villosus* (peludo), *Zaedyus pichiy* (piche), *Lagidium viscacia* (pilquín), *Conepatus* sp. (zorrino), *L. gymnocercus*

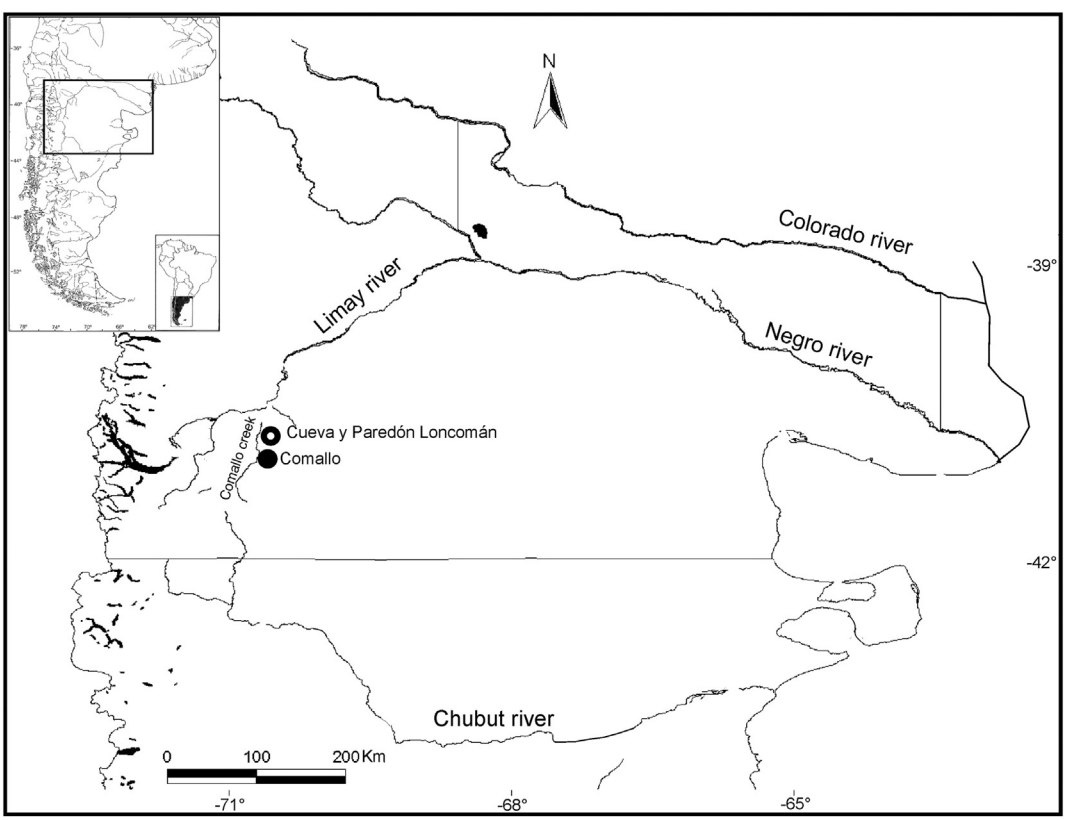

Fig. 1. Location of the archaeological site Cueva y Paredón Loncomán.

(zorro gris), *L. culpaeus* (zorro colorado), *P. concolor* (puma) and *Leopardus* sp. were found (Andrade et al., 1999; Boschin, 2009; Cordero, 2011).

3. Materials and methods

A taphonomic analysis was performed for the small mammal's assemblages recovered from the inferior, medium, and superior components of CLO. All the small mammal's remains were included, both cranial and post-cranial. Bones belong to Sigmodontinae rodents (family Cricetidae, subfamily Sigmodontinae), Caviomorpha rodents (families Caviidae and Ctenomyidae) and opossums (family Didelphidae). Anatomical and taxonomical identifications of bone remains were made using reference materials housed at the *Centro Nacional Patagónico* (CENPAT-CONICET, Puerto Madryn, Chubut, Argentina).

The taphonomic analysis employed here follows the proposal of Andrews (1990) and Fernández-Jalvo and Andrews (1992). Because Caviomorpha and Cricetidae rodents show clear differences in size and ecological habits, the analyses of bone patterns were performed distinguishing both taxonomic groups. Each bone was assigned to one anatomical and taxonomical category. Post-cranial elements – impossible to be assigned to a particular species – were classified into major taxonomic groups: Caviomorpha, Cricetidae and Didelphidae, according to their size and morphology. Anatomical and taxonomical quantifications were based on the standard counting units of zooarchaeological research: NISP (Number of Identified Specimens), MNE (Minimum Number of Elements) and MNI (Minimum Number of Individuals). The MNI counts were based on cranial elements (jaws and crania), because they are the only taxonomic identification elements. We also included in the analysis the proportions of the main taxonomic groups as an indicator of the general taxonomic structure in samples.

Breakage pattern was investigated through categories defined according to bone type. Complete or fragmented bones were quantified separately. Long bones were defined as proximal and distal epiphyses, and diaphysis. Relative abundance of skeletal elements (*Ri*) was calculated (Dodson and Wexlar, 1979) in order to evaluate losses of skeletal units in the sample, according to the equation $Ri = [Ni/MNI * Ei] * 100$ where *Ri* is the relative frequency of element *i*; *Ni* is the minimum number of observed elements for element *i* and *Ei* is the number of times element *i* occurs in the complete skeleton.

To evaluate agent selectivity, two indexes of representation of the skeletal elements were calculated (Andrews, 1990; Fernández-Jalvo and Andrews, 1992): Post-crania/crania relationship (PC/C = femur + humerus/mandible + maxilla) and distal/proximal relationship (D/P = tibia + radius/femur + humerus). Values close to 1 for both indexes are expected when sections of the skeleton were equally represented in samples. Digestion traces were investigated for molars and incisors of Caviomorpha and Sigmodontinae separately to determinate the kind of predator according to categories proposed by Andrews (1990).

Heat alteration of bone surface and the presence of cut marks were investigated. Heat alteration was determined by naked eye following color criteria, considering completely burned (blackened), partially burned and not burned. It was also determined which of the anatomical sections were burned. Bone surface modifications like cut and percussion marks, and digestion traces, were observed with an 8× and 10× binocular lenses. Skeletal modification, including weathering was registered with stages defined by Andrews (1990) and Fernández-Jalvo and Andrews (1992).

To test the hypothesis that owls were one of the potential agents of deposition, a sample of 40 pellets regurgitated by *T. alba* was included as an actual correlate. This sample was incorporated into the analysis to follow the same criteria as for the archaeological samples. The taphonomic analysis was developed individually for Caviomorpha and Cricetidae rodents to investigate if predation behavior is the same for these two taxa. Other potential predators, including diurnal raptor birds and carnivores were evaluated, based upon the evidence found in the assemblages and compared with reference data (Andrews, 1990; Andrews and Nesbit Evans, 1983; Gómez, 2005; Reed, 2005; Gómez and Kaufmann, 2007; Mondini and Munoz, 2008; Montalvo et al., 2007, 2008, 2012, amongst others).

4. Results

4.1. CLO archaeological samples

4.1.1. Taxonomy and MNI counts

A total of 179 individuals were recovered from the whole archaeological sequence. The species defined were 11: seven Sigmodontinae rodents, *Abrothrix longipilis*, *Abrothrix olivaceus*, *Eligmodontia* sp., *Euneomys chinchilloides*, *Loxodontomys micropus*, *Phyllotis xanthopygus* and *Reithrodon auritus*, three Caviomorpha rodents, *Ctenomys* sp., *Galea leucoblephara* and *Microcavia australis* and one Didelphidae opossum *Lestodelphys halli* (Table 1).

Considering the MNI counts, Sigmodontinae and Didelphidae altogether dominate the IC sample (69.4%, Table 1). Towards the MC these differences are less marked and both taxa are equally represented (57.1% for Sigmodontinae and Didelphidae and 42.9% for Caviomorpha rodents). The pattern is opposite for SC where the Caviomorpha rodents are predominant (58.5%, Table 1).

4.1.2. Representation of skeletal elements

A total of 1.529 small mammal's bones (NISP) were recovered from the CLO archaeological sequence, 952 from post-cranial section, 570 from crania and only seven were indeterminate. These are the identified bone representations (MNE = 1.125): 75.9% were from Cricetidae (MNE = 567) and 24.1% from Caviomorpha rodents (MNE = 180) in IC; 63% belong to the first (MNE = 48) and 37% to the second (MNE = 28) in MC and values are 50% for each category in SC (MNE = 107 and 108 respectively) (Table 2). For the entire sequence, only 87 post-cranial remains could not be assigned to any taxonomical category.

Table 1
Weight (grams), ecological habits (N = nocturnal; D = diurnal; S = solitary and C = colonial) and Minimum Number of Individuals (MNI) of the species recovered from the Inferior (IC), Medium (MC) and Superior (SC) components of Cueva y Paredón Loncomán and from the pellet sample (PS).

	Weight (g)	Habits	MNI IC	MNI MC	MNI SC	MNI PS
Rodentia						
Cricetidae						
Sigmodontinae						
Abrothrix longipilis	30	N/D–S	1		1	22
Abrothrix olivaceus	19	N/D–S	10	2	1	37
Chelemys macronyx	67	N/D–S				1
Eligmodontia sp.	17	N–S	24	2	4	22
Euneomys chinchilloides	45	N–S	4			24
Loxodontomys micropus	58	N–S	1	1	2	
Notiomys edwardsii	20	N–S				31
Phyllotis xanthopygus	43	N–S	18	4	5	4
Reithrodon auritus	81	N–S	8	7	8	
Ctenomyidae						
Ctenomys sp.	164	D–C	21	4	18	4
Caviidae						
Galea leucoblephara	193	D–C	1	1	2	
Microcavia australis	259	D–C	8	7	11	1
Didelphimorphia						
Didelphidae						
Lestodelphys halli	87	N–S	2		1	
MNI Sigmodontinae–Didelphidae			68	16	22	141
MNI Caviomorpha			30	12	31	5
% Sigmodontinae–Didelphidae			69.4	57.1	41.5	96.6
% Caviomorpha			30.6	42.9	58.5	3.4

Mandibles were the most represented elements, both for Sigmodontinae (IC = 80.1%; MC = 50%; SC = 63.6%) and for Caviomorpha rodents (IC = 93.8%; MC = 66.7%; SC = 90.3%). Between post-cranial elements, femora were the most frequent bones in IC (55.1% for Sigmodontinae and 70.8% for Caviomorpha rodents). In the case of MC and SC, the most represented elements for Sigmodontinae were the femora (25% and 29.5% respectively) and the tibias for Caviomorpha rodents (16.7% and 28.3% respectively) (Table 2 and Fig. 2). No fibulas were found in samples and only two phalanges were registered in IC.

The values obtained for the indices that evaluate the relationship between appendicular and cranial elements shows that in IC there is no differential preservation between these sections, for Sigmodontinae (PC/C = 0.78) and for Caviomorpha rodents (PC/C = 1.04). For the case of MC and SC, the pattern is quite different. This index suggests a better representation of cranial elements, for Sigmodontinae (PC/C = 0.59 for MC and 0.54 for SC) and for Caviomorpha, representing a marked difference for this taxon (0.22 for MC and 0.24 for SC). The relationship between distal and proximal elements of the limbs shows different patterns according to the component and taxonomic group. For Sigmodontinae this index assumes values lower than one for the three units (D/P = 0.39 for IC, 0.46 for MC and 0.52 for SC). These results indicate a loss of distal bones. Similar results were obtained for Caviomorpha rodents in IC (D/P = 0.41). At MC and SC the pattern is opposite, with a better representation of distal bones in comparison with proximal ones (D/P = 1.25 for MC and 1.20 for SC).

4.1.3. Breakage pattern

The degree of fracture of the cranial and post-cranial elements recovered in CLO is moderate. An average of 57% of bones from Sigmodontinae and 50% from Caviomorpha were complete in the sequence. Best conserved elements throughout the sequence correspond to those of the appendicular skeleton (femur, humerus, tibia and radius). Considering post-cranial elements, 60% of long bones of Sigmodontinae and 55% of Caviomorpha were complete at the IC. These values are 63% and 55% for the MC and 68% and 28% for the SC respectively. Bones with higher degree of fracture are the ribs and scapulas. No complete skulls were found and all the maxillaries and mandibles were broken (Fig. 3). Mandibles lacked one, two or three of the processes and in some cases only the isolated molar row was found.

4.1.4. Bone surface modifications

Almost all of the bone remains from CLO show no signs of a long aerial exposure. More than 90% of them belong to the lowest weathering category proposed by Andrews (1990). Furthermore, no traces of bone surface modifications like cut and percussion marks were observed.

Incisors digestion was not frequent and affected only the enamel surface at the edge of the incisors (Fig. 4). For the IC, 6% of Caviomorpha and 14% of Sigmodontinae showed digestion traces. Only one incisive of Sigmodontinae was digested at the MC. Percentages of teeth affected were higher for SC (40% for Caviomorpha and 9% for Sigmodontinae), although the pattern and degree of digestion were similar as for the IC. Incidence of digestion on molars was minimal. For the IC, 6% of Caviomorpha and 5% of Sigmodontinae remains showed digestion traces. For the SC, those values were 3% and 2% respectively.

Heat alteration was low at the three components of CLO (Fig. 4). Almost all remains were not burned. Only 1% of bones were partially burned (NISP = 6) and 3% were blackened (NISP = 40) in the IC. Most of the partially and completely burned bones were from the MC (3%, NISP = 3 and 10%, NISP = 9, respectively). For the SC, these values were 1% (NISP = 3) and 2% (NISP = 6) respectively. However, considering altogether the remains partially and completely burned, a clear pattern was observed. Thermal altered bones belong almost exclusively to Caviomorpha rodents (67% in IC, 83% in MC and 89% in SC).

At the IC, a tympanic bulla, a right mandible and a tibia of an indeterminate Caviomorpha were partially burned. Blackened bones correspond to six right and seven left mandibles and a piece of crania of *Ctenomys* sp., one left and right mandible, a tympanic bulla and three pieces of crania of an indeterminate Caviidae, three tibias, two femora, one humerus and two vertebraes of an indeterminate Caviomorpha. In the case of Sigmodontinae rodents, thermo-altered bones are a maxillary of *R. auritus*, a mandible of *A. olivaceus* and two mandibles, a tympanic bulla, five femora and two vertebraes of an indeterminate Sigmodontine. Also an ileum and a piece of crania of an indeterminate taxon were registered.

At the MC, a right mandible of *Ctenomys* sp. and a tibia of an indeterminate Caviomorpha were partially burned. Blackened bones are two left and one right mandible of *M. australis*, two right and one left mandible of *Ctenomys* sp., two tibias of an indeterminate Caviomorpha and a tibia of an indeterminate taxon. For Sigmodontines, only a femur was burned.

At the SC, only one femur of an indeterminate Sigmodontinae was burned. The remaining bones were all of Caviomorpha rodents: two right mandibles of *M. australis* and a piece of crania of an indeterminate Caviidae were partially burned. A right mandible of *Ctenomys* sp., a left mandible of *M. australis*, and a maxillary, a femur and a humerus of an indeterminate Caviidae were blackened.

Table 2
Minimum Number of Elements (MNEs) and relative abundances (R*i*) of skeletal elements of small mammals from the three components of Cueva y Paredón Loncomán.

	Inferior component				Medium component				Superior component			
	Sigmodontinae		Caviomorpha		Sigmodontinae		Caviomorpha		Sigmodontinae		Caviomorpha	
	MNE	R*i*	MNE	R*i*	MNE	R*i*	MNE	R*i*	MNE	R*i*	MNE	R*i*
Humerus	51	37.5	17	35.4	5	15.6	1	4.2	12	27.3	6	13.0
Femur	75	55.1	34	70.8	8	25.0	3	12.5	13	29.5	9	19.6
Tibia	45	33.1	16	33.3	6	18.8	4	16.7	12	27.3	13	28.3
Fibula	–	–	–	–	–	–	–	–	–	–	–	–
Ulna	14	10.3	7	14.6	–	–	–	–	2	4.5	–	–
Radius	4	2.9	5	10.4	–	–	1	4.2	1	2.3	5	10.9
Metapodial	17	1.3	6	1.3	–	–	–	–	–	–	–	–
Phalange	2	0.1	–	–	–	–	–	–	–	–	–	–
Scapula	3	2.2	7	14.6	–	–	–	–	1	2.3	3	6.5
Rib	4	0.2	3	0.5	–	–	–	–	–	–	1	0.2
Vertebra	173	7.5	23	2.8	2	0.4	–	–	17	2.3	3	0.4
Pelvis	18	13.2	13	27.1	5	15.6	1	4.2	3	6.8	5	10.9
Maxillary	52	38.2	4	8.3	6	18.8	2	8.3	18	40.9	7	11.3
Mandible	109	80.1	45	93.8	16	50.0	16	66.7	28	63.6	56	90.3
Total	567		180		48		28		107		108	

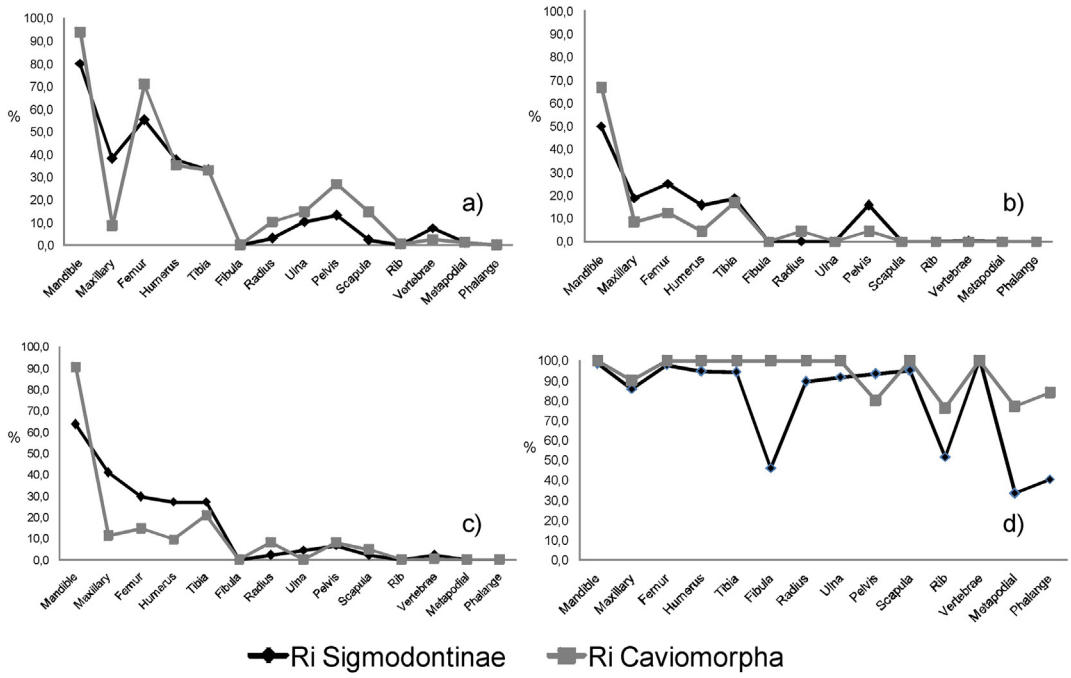

Fig. 2. Relative abundances of skeletal elements (Ri) for Sigmodontinae and Caviomorpha rodents from a) the inferior component, b) the medium component, c) the superior component of Cueva y Paredón Loncomán archaeological site and d) the actual pellet sample.

4.2. Actual owl pellet sample

4.2.1. Taxonomy and MNI counts

Seven species of Sigmodontinae rodents and two species of Caviomorpha rodents were recovered from *T. alba*'s pellets (Table 1). Beyond the representation of particular species, considering the MNI counts, the sample was composed almost exclusively by Sigmodontinae rodents (97% of determined specimens). The bibliographic research about the diet of *T. alba* in Patagonia (Andrade, 2007; Andrade and Teta, 2002; Andrade et al., 2002; Bellocq, 2000; Pillado and Trejo, 2000; Travaini et al., 1997; Trejo and Ojeda, 2004; Trejo and Lambertucci, 2007; amongst others), showed that this owl feeds mainly on Sigmodontinae rodents. Proportions of this taxon in samples are between 78% and 100%.

4.2.2. Representation of skeletal elements

A total of 15,968 small mammal's bones (NISP) were identified from Barn owl's pellet sample, 15,518 post-cranial and 450 cranial remains representing 146 individuals. Both segments of the skeleton were practically complete, for Sigmodontinae and Caviomorpha rodents, as can be deduced by the MNE counts and the relative abundances of each bone in sample (Table 3 and Fig. 2). Metapodials, phalanges, and ribs were underrepresented. In addition, for Sigmodontinae rodents, fibulas were scarce while for Caviomorpha the pelvis bone was also underrepresented.

Values obtained for the indices that evaluate the relationship between appendicular and cranial elements and between distal and proximal elements of the limbs shows that there is no differential preservation between these sections, for both Sigmodontinae (PC/C = 1.04 and D/P = 0.95) and Caviomorpha rodents (PC/C = 1.05 and D/P = 1). However, a slight tendency to underestimate the distal limbs (tibia and radius) was observed for Sigmodontinae rodents.

4.2.3. Breakage pattern and bone surface modifications

Fracture of cranial and post-cranial elements was low. Completeness frequencies of bones were 73.5% for Sigmodontinae and 78% for Caviomorpha in the pellet sample. Almost all of the long bones were unbroken (91% for Sigmodontinae and 94% for Caviomorpha) whereas those more fragile were the scapulas, ribs and pelvis. No complete skulls were found and all the maxillaries and mandibles were broken (Fig. 3).

Digestion pattern on teeth was similar to the one reported by Andrews (1990) although percentages of teeth with digestion traces were higher for Patagonian owls. Digestion affected only the enamel surface at the tip of the incisors. Mean value for the Barn owl pellet sample was 20%. Percentage of incisors with traces was higher for Caviomorpha rodents compared with Sigmodontinae (33.3% and 19.7% respectively). No molars showed digestion traces. Considering the pattern and the percentages of incisors digested, Barn owls from Patagonia can be considered as category 2 predators.

5. Taphonomic history of small mammals from Cueva y Paredón Loncomán archaeological site

The detailed taphonomic analysis developed in this study allows the identification of some general patterns in the small mammals' assemblages of CLO and reveals the depositional agents along the archaeological sequence. Diverse evidences enabled the taphonomic reconstruction and give support to the hypotheses that the bulk of the small mammals' remains were accumulated by the disintegration of pellets regurgitated by the raptor *T. alba*. However, human activities related with the subsistence would have deposited some specific pieces of rodents into this archaeological site. These taphonomic signatures are considered and discussed below for the case of the three CLO components. Based on the evidences observed, the general processes that occur inside the cave were considered and discussed, although other specific and restricted processes, like other predators and even natural death are not rejected.

5.1. Deposition agent at inferior component of CLO

Small mammal's assemblage from the IC is composed mainly by Sigmodontinae rodents. However, bone representation pattern is similar for both Sigmodontinae and Caviomorpha rodents. There is no differential preservation between the appendicular and cranial elements in the sample, and contrasting the representativeness of distal and

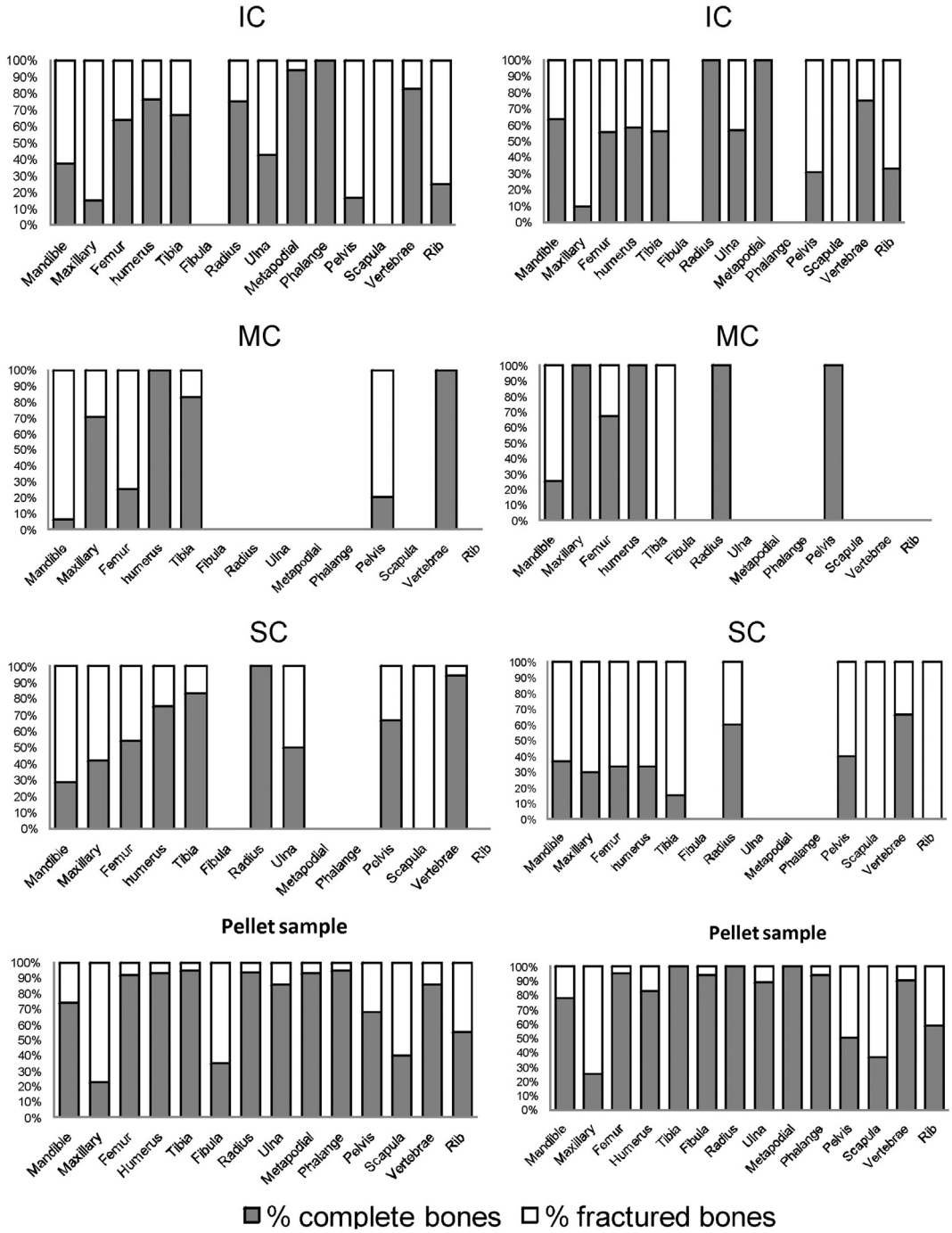

Fig. 3. Proportion of complete and fractured bones, for Sigmodontinae (left) and Caviomorpha rodents (right) at the inferior component (IC), medium component (MC), superior component (SC) of Cueva y Paredón Loncomán archaeological site and the actual pellet sample.

proximal limb bones, values show a better proportion of the second ones mentioned. The degree of bone fracture was relatively low; the pattern observed showed that most affected bones were those of the axial section and those of the appendicular skeleton were the most preserved. Comparing the digestion pattern in the incisors with the one observed in the actual pellet sample, both for Caviomorpha and Cricetidae rodents, reveals that digestion affected only slightly to the edge of the teeth. Percentages from IC were even lower than those of the actual sample. In this sense, based on the pattern and frequency of altered teeth, small mammals from the IC could be accumulated by the same kind of predator. Patagonian Barn owls seem to be more destructive than African and European owls and could be proposed as a predator category 2.

Besides digestion evidences, similar patterns in the taxonomic structure and the skeletal representation could be tracked between the archaeological sample and the Barn owl pellet sample, and could be considered as a framework of reference to compare with the patterns recognized in diverse experimental and archaeological taphonomic analysis. The taxonomic structure of the pellet sample reveals that this owl preyed almost exclusively upon Sigmodontinae rodents. Only few remains of Caviomorpha rodents were obtained. The bibliographic research about the diet of *T. alba* in Patagonia and Argentina shows that this owl consumes Sigmodontines and Caviomorphs at most in a ratio of 4:1. Even Caviomorpha rodents were absent in some Barn owl's diets (Andrade, 2007; Trejo and Lambertucci, 2007). As was expected, there was no taphonomic agent selectivity regarding the anatomical

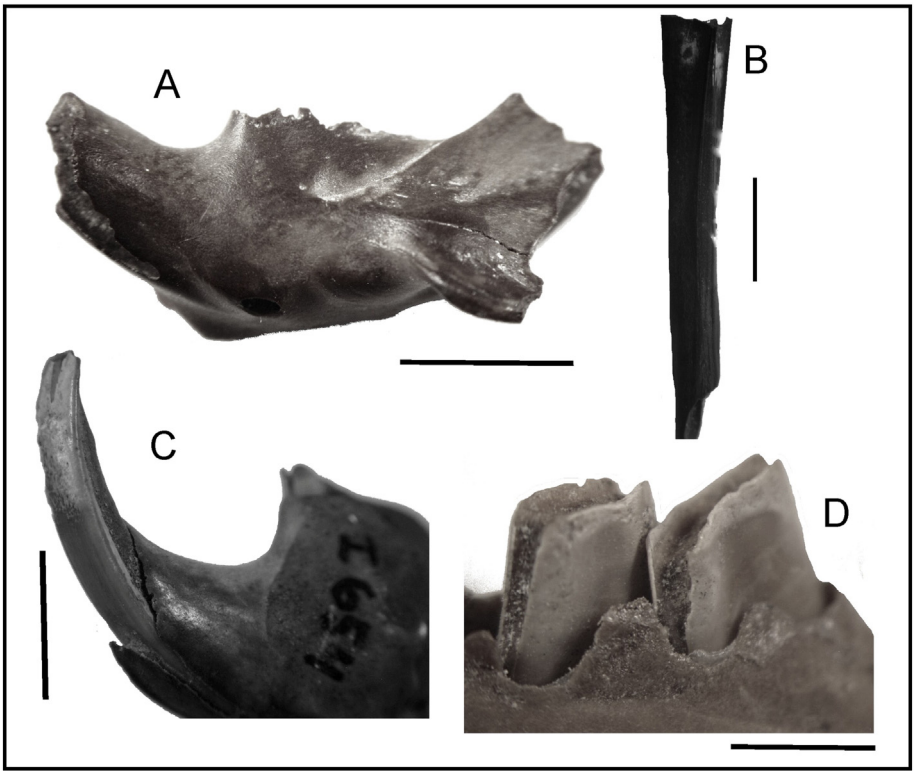

Fig. 4. Mandible of *Ctenomys* sp. burned (A); tibia of Caviomorpha completely blackened (B); incisive of *Ctenomys* sp. with digestion traces (C); molar of *Ctenomys* sp. with digestion traces (D). Scale bars = 5 mm.

unit. As was extensively documented, Barn owls consume the whole prey and regurgitate their bones and hairs without any selection (see Andrews, 1990 for a discussion). There was no differential preservation between skeletal elements in the pellet sample. Cranial and post-cranial sections were practically complete, and equally represented both for Sigmodontinae and Caviomorpha rodents. Metapodials, phalanges and ribs were the underrepresented bones in pellets as in the archaeological sample, may be because of their small size. Weissbrod et al. (2005) notice high survival of body remains and low frequencies of phalanges and metapodials in the assemblages accumulated by Barn owls. More fractured bones, and so more fragile elements, were the maxillaries and mandibles, scapulas, ribs and pelvis, a pattern that also was observed both for pellets and for the archaeological sample. Because digestive processes are not so destructive, archaeological signals of this behavior are low levels of bone fracture and loss of skeletal parts of the prey consumed; more affected bones are ribs, scapulas and pelvis (Dodson and Wexlar, 1979). Pattern observed for the relation between distal and proximal portions of the appendicular skeleton was dissimilar. For the actual pellet sample, those sections were equally represented, although in the case of Sigmodontines, a slight tendency to underestimate the distal limbs (tibia and radius) was observed. For the archaeological sample, the loss of distal elements is more marked.

Table 3
Minimum Number of Elements (MNEs) and relative abundances (R*i*) of skeletal units of small mammals from the actual *Tyto alba* pellet sample.

	Pellet sample			
	Sigmodontinae		Caviomorpha	
	MNE	R*i*	MNE	R*i*
Humerus	267	94.7	10	100.0
Femur	276	97.9	10	100.0
Tibia	266	94.3	10	100.0
Fibula	130	46.1	10	100.0
Ulna	259	91.8	10	100.0
Radius	252	89.4	10	100.0
Metapodial	942	33.4	77	77.0
Phalange	3.194	40.5	235	83.9
Scapula	268	95.0	10	100.0
Rib	1.894	51.7	99	76.2
Vertebra	4.806	100.0	170	100.0
Pelvis	263	93.3	8	80.0
Maxillary	242	85.8	9	90.0
Mandible	278	98.6	10	100.0

Some other evidences, like the presence of avian droppings in a cliff above the excavated area, the finding of some complete pellets preserved in the sedimentary sequence and the location of the bones in a concentrated bulk in one of the layers support the hypothesis of owls as primary agents of deposition of the small mammal's remains into the IC. This unique faunal concentration was associated with a specimen of *Leopardus* sp. (Geoffroy's cat), incorporated into the sequence seemingly by natural death (Andrade et al., 1999), and with a low density of cultural remains.

We discard the possibility that small mammal's remains from IC could be accumulated by the Great Horned Owl (*Bubo magellanicus*). This owl is more destructive than *T. alba*. It was categorized for Argentinean populations as predator type 2 or 3 and produces assemblages with 50% of molars and 32% of incisors with signs of digestion (Gómez, 2005). Those values, especially for molars, are much higher than those from IC. Besides, other species from the *Bubo* genus, like the Spotted Eagle owl (*Bubo africanus*) showed to segregate the roosting habit with Barn owl, occupying preferably the ground or tree crowns in open habitats (Reed, 2005). This roosting behavior was also observed in the extra-Andean Patagonia, where individuals of the Great Horned Owl were seen to roost in shrubs and concentrate their pellets below (Andrade, 2009). We also discard the hypothesis that small mammal's remains from IC could be accumulated by a Falconiforme and/or a mammalian carnivore. Falconiforms show moderate to heavy digestion on bones (Andrews, 1990; Montalvo and Tallade, 2009). Contrary to the pattern observed in CLO, the assemblages produced by mammalian

carnivores have a great number of fractured and altered bones, with a high proportion of unidentified items. These predators produce heavy digestion on the structure of the incisors and molars and are classed as category 4 or 5 (Andrews, 1990). Carnivores from the study area, such as pumas, foxes, cats and skunks were classified in those categories (Gómez and Kaufmann, 2007; Montalvo et al., 2007, 2008, 2012).

The pattern of thermal alteration found in some skeletal remains from IC is quite remarkable. Thermal altered bones belong mainly to Caviomorpha rodents and mostly affect distal segments of long bones and the crania. This evidence, although scarce, suggests the possibility that some individuals were accumulated into the site due to practices related with human consumption. This hypothesis will be discussed deeply for the MC and SC.

Although some animals could have died inside the cave, natural death was discarded as a general pattern because no evidences support this hypothesis. If the animal died on the site by natural causes, individuals with the skeleton articulated are expected and the bone assemblage would be composed by a small number of remains, relatively unbroken and with no signs of digestion (Stahl, 1996).

5.2. Deposition agent at medium and superior components of CLO

Although MC and SC samples are small, some specific features give clues about the potential predators that could have participated in the genesis of these assemblages. Caviomorpha rodents become more important towards the MC and SC. In contrast to IC, patterns of bone fracture and skeletal representation differ for Sigmodontinae and Caviomorpha rodents. Bones of the skull and distal elements of the limbs were overrepresented for Caviomorphs while for Sigmodontines proximal elements are best preserved. Fractured bones were relatively scarce for the MC, but no more inferences can be made because of the small sample size. For the SC, fragmentation degree was preponderantly higher for Caviomorpha than for Sigmodontinae. Although fragmentation is not a variable that could link an assemblage with a specific predator, the fact that values were clearly different is another indication that both assemblages were accumulated by different agents, since the same post-depositional alterations are expected for both taxa in the same component.

A well defined pattern of thermal alteration was observed for the assemblages of MC and SC. Burned bones were mainly from Caviomorpha rodents and thermal alteration mostly affects distal segments of the long bones, especially tibias, the superior and inferior incisors, premaxillaes, and mandibles. In MC, burned remains belong to at least three individuals of *Ctenomys* sp. and two of *M. australis*. In SC, at least one *M. australis*, one *Ctenomys* sp. and one indeterminate Caviidae (probably another individual of *M. australis*) were burned. Although a very low proportion of Sigmodontines bones were thermo-altered, no specific pattern was detected. The absence of a definite pattern suggests that remains could have been accidentally burned and prevents to relate these species with human consumption.

Considering all the evidences provided by MC and SC small mammal's assemblages, a different taphonomic history could be deduced for the Sigmodontinae and Caviomorpha rodents. A different skeletal representativeness, a dissimilar completeness percentage of bones, and a definite pattern of thermal alteration, suggest that at least two agents accumulated the small mammal's assemblages, owls and humans.

Digestion traces on molars and incisors are striking. Although high percentages of incisors of Caviomorpha showed signs of digestion in SU, the degree of alteration was slow and restricted only to the tip of the teeth. The pattern is similar to the observed in IC and in the actual Barn owl pellet sample. Besides, as was previously discussed, percentages of teeth affected in the pellet sample were higher than those previously reported by Andrews (1990) and placed *T. alba*, at least in Patagonia, as a predator moderately destructive specially for Caviomorpha rodents. In consequence, *T. alba* could be proposed as the main agent of accumulation of small mammals in SC. Andrews (1990) suggests that sometimes predators could provoke more heavy digestion than expected for the category when juveniles are involved. It is possible that this could be the case in CLO sequence. Another explanation to the higher values of digested incisors compared with the actual pellet sample could be related with preservation problems associated with mixed assemblages. The destruction of bones by cultural causes (like the way these specimens were prepared by humans for consumption) could alter the Caviomorpha proportions in the sequence; therefore the reduction of total bones overestimates the proportion of teeth affected by digestion.

The high abundance of Caviomorpha rodents in the sequence, the specific pattern of thermal alteration, and the overrepresentation of bones of the skull and distal elements of the limbs support the conclusion that some remains have also been incorporated by cultural causes. Small mammals' assemblages deposited by human refuse are generally constituted by large, diurnal and fossorial-colonial species. Humans tend to focus on these particular species because they are conspicuous and predictable in space (Simonetti and Cornejo, 1991). Rodent species found in CLO with signs of human consumption are *M. australis* and at least one species of the genus *Ctenomys* sp. The species of the genus *Ctenomys* sp. are gregarious, active day and night and are restricted entirely to its underground burrows (Pearson, 1995). *M. australis* is a large, colonial and diurnal species. The high population densities around the burrow systems (Contreras and Roig, 1978) become this species a conspicuous and easy resource to exploit by the hunter–gatherers.

The bone pattern of thermal modification and the differential representativeness of skeletal sections found in the sequence of MC and SC could be related to the way in which these animals were processed to their intake. Cranial elements and tibias were the most frequent bones for Caviomorpha rodents. Additionally, they were partially or completely burned. Only an intentional discard of some bone pieces could provoke this kind of assemblage. It could be proposed that heads and distal bones of the limbs could have been put aside after roast and before consumption stages. An overrepresentation of mandibles, maxillae and isolated molars was interpreted for some archaeological sites as evidence of human discarded activities (Simonetti and Cornejo, 1991; Shaffer, 1992; Dewar and Jerardino, 2007; amongst others). Shaffer (1992) associated the disparity in the recovery of skulls and mandibles in archaeological sites in New Mexico with cultural evidences and points out that this could be due to the removal of heads before consumption, as was normal practice for these prehistoric groups. Hesse (1985) proposed, based on bone types found in the archaeological sequence and ethnographical data that in the Atacama Desert (northern Chile) decapitation would be realized during the butchering and preparation of these animals. Heads tend to be preserved differently because of this activity while post-cranial bones, softened by cooking, are lost. This kind of preparation and consumption could also be the cause of the high rate of fragmented bones in SC, and also could explain the low representativeness of burned bones in CLO. Distinguishable burning pattern was observed on the incisors, premaxillae and mandibles of Mole-rats (*Bathyergus suillus*) from South African archaeological sites. This pattern resembles the ethnographical evidences of modern Mole-rats cooked in coals by farmworkers in the area (Henshilwood, 1997). A recent experimental cooking of Caviomorph rodents by open fire (Medina et al., 2012) suggested that thermo alteration was mostly restricted to the distal portions of un-meaty long bones such us tibias and radios, because of the retraction of the proximal muscular masses of the limb bones during cooking. Cooking by fire increased the susceptibility to fragmentation of the damaged bones, biasing its representation. We think that it is also likely that post-cranial bones, especially those from the axial skeleton, could be consumed directly with the meat. Their small size tenders them during cooking. The finding of an assemblage composed exclusively of post-cranial bones collected from the stomach area of a human burial in South Africa, complemented by

the high abundance of cranial remains recovered from an archaeological sequence of a nearby site reaffirm this conclusion (Dewar and Jerardino, 2007). Some historical evidences from Patagonia point out that sometimes rodents were even completely eaten without any special preparation. Antonio Pigafetta (1520), the Italian explorer Magellan's assistant of the voyage to the Indies, refers that Patagonian people ("Patagones" from southern Santa Cruz province) ate rats uncooked without skinning. Numerous evidences from the ethno-historical record show that rodents were a very important item in the diet of Patagones and Selknam people from Patagonia and Tierra del Fuego provinces (Andrade and Boschín, 2015). Recent ethnographic data notes that rodents were consumed by humans in the area around CLO even until 1950 (Andrade and Boschín, 2015). The absence of cut marks on rodent's bones reveals no butchering related to processing techniques in CLO sequence, as was proposed for other areas (Quintana, 2005; Medina et al., 2011).

The possibility that rodents have been consumed by Patagonian populations was suggested in some studies (Bond et al., 1981; Ceballos, 1982, 1987; Fernández, 1988–1990; Sanguinetti de Bórmida and Curzio, 1996; Silveira and Massoia, 1996; Hajduk and Albornoz, 1999; Teta et al., 2005), but the hypothesis (except in Pardiñas, 1999) was formulated as opposed to post-depositional or accidental intrusion by the lack of evidences to support them. The absence of taphonomic studies specifically on the small mammal's assemblages made impossible to test the hypothesis of human consumption. Based on the results obtained in this study, two new species, the rodents *Ctenomys* sp. and *M. australis* could be incorporated into the list of species exploited by hunter–gatherers from northern Patagonian steppes.

5.3. Biostratinomic and burial processes in CLO

Taphonomic analysis suggests different deposition agents in IC, MC, and SC of CLO but similar post-depositional processes. The low frequencies of bones with signs of weathering at the three components suggest a rapid rate of burial of the small mammal assemblages. The low time of exposure to sub-aerial weathering and the arid environmental conditions in extra-Andean Patagonia provided a high-quality setting for a good integrity of the archaeological record of small mammals. In the case of CLO, good preservation of this dry rock-shelter allowed even the preservation of intact pellets in the sequence. Pellet structures protect bone remains from weathering during the deposition and burial stages. The disintegration of pellets over time exposed them to physical and chemical processes and/or to bioturbation, increasing the fragmentation and loss of skeletal bones, especially for those smaller and fragile items (Andrews, 1990; Dodson and Wexlar, 1979). The high proportions of complete bones in the sequence show that not only biostratinomic processes (and depositional process related with the kind of predator as was already explained) were moderate but also those deal with the burial stage. Bones of the appendicular skeleton were the best preserved in the sequence of CLO and could be related with their great density, which makes them more resistant to the taphonomic processes. On the other hand, those of the axial skeleton, which are more susceptible to damage and therefore to be lost of the record (Dodson and Wexlar, 1979) were the least represented elements in CLO. However, estimations of total numbers of individuals for Caviomorpha and Sigmodontinae rodents based on post-crania and crania counts were similar. So, there is not a distinct size preservation of bones or an intentional selection during excavation. Methodologies of recovery during excavation and transport should be specific and careful in the case of the small mammal's bones from archaeological sites because the collection, handling, and transport of samples could increase the fragmentation of the assemblages (Stahl, 1982). Excavations techniques at CLO allowed to recovering even the smaller skeletal remains of the small mammals, so we estimate that biases introduced during this final stage of sampling have been scarce.

6. Conclusions

The detailed taphonomic analysis realized in this study allowed for distinguishing between cultural and natural vestiges of small mammals from the archaeological sequence of Cueva y Paredón Loncomán. Sigmodontinae and Caviomorpha rodents were predated by the raptor *T. alba* and bones accumulated into the site by the disintegration of its pellets. Some Caviomorpha remains were also incorporated by humans during and after their consumption. This study reveals some important features, both for local and regional archaeological studies. First, small mammals enabled to corroborate the abandonment of the cave by humans during a period in which owls occupied it. Taphonomical evidences reinforce the stratigraphical traces of this hiatus in human occupations. Second, two new species, the rodents *Ctenomys* sp. and *M. australis* were incorporated into the list of species exploited by hunter-gatherers from northern Patagonian steppes. Human populations have consumed those species at least over the last 2000 years. Patagonian researches underestimated the consumption of small vertebrates by prehistoric societies. These recent studies allow us to think that it is higher the probability that rodent consumption has been a widespread practice among Patagonian hunter–gatherers than it was previously believed. Finally, a methodology of analysis which separately evaluate the taphonomic histories of major taxonomic groups (Sigmodontinae and Caviomorpha rodents) and that include all the small mammals' remains – not only the cranial as was usually but also the post-cranial – highlight new lines of evidences for archaeological studies.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at http://dx.doi.org/10.1016/j.jasrep.2015.06.012.

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