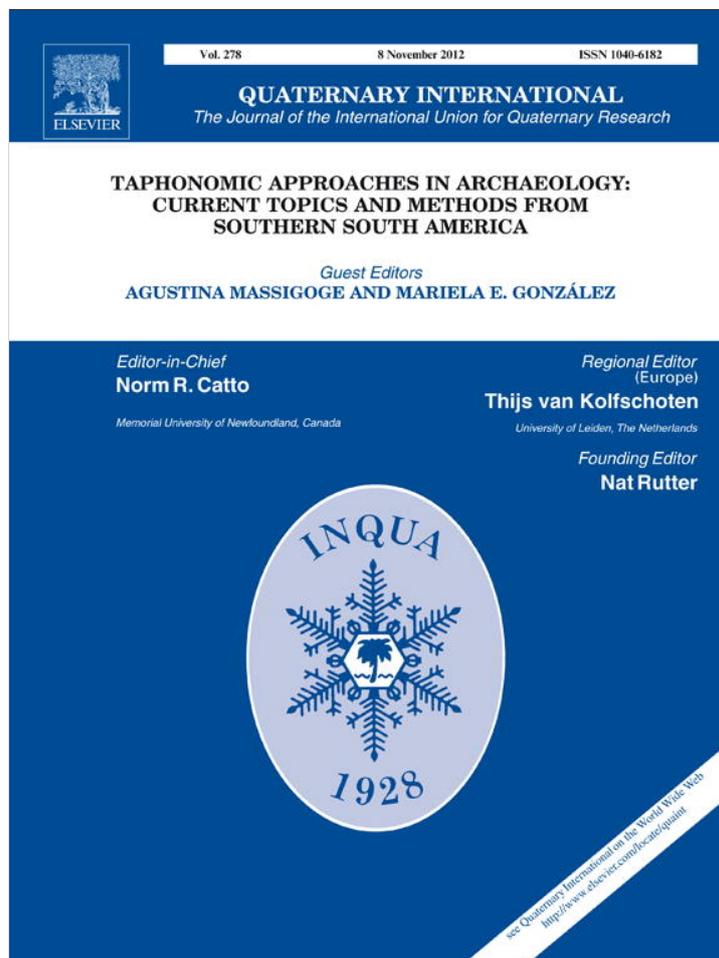


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## Small mammal remains from Cueva Huenul 1, northern Patagonia, Argentina: Taphonomy and paleoenvironments since the Late Pleistocene

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## ABSTRACT

Small mammal samples from the archaeological sequence of Cueva Huenul 1 (CH1, 36°56'45"S, 69°47'32"W, Neuquén Province, Argentina) are described, and taphonomic and paleoenvironmental conditions assessed. This site is located near the steppe-monte ecotone in the northernmost Patagonia. Small mammal remains (NISP = 1426, MNE = 1409, MNI = 87) were recovered from Late Pleistocene (13,800–11,800 <sup>14</sup>C BP), Early Holocene (9500 <sup>14</sup>C BP) and Late Holocene layers (1400 <sup>14</sup>C BP). Taphonomic analysis indicates that the CH1 assemblage is an archaeofaunistic owl pellet accumulation. It has a good post-depositional preservation since it was rapidly incorporated in the sedimentary matrix, although it previously experienced trampling action. From latest Pleistocene to Late Holocene, the assemblages are mainly composed by the sigmodontines *Eligmodontia* spp. and *Phyllotis xanthopygus*, and the caviomorphs *Microcavia australis* and *Ctenomys* sp., suggesting in overall terms a marked ecological stability. CH1 is one of the few sites where the Pleistocene–Holocene transition is represented by faunal evidence. The latest Pleistocene sample spanning 13,800 and 11,800 <sup>14</sup>C BP indicate scrub steppe with substantial open ground and rocky exposition; one Early Holocene sample (9500 <sup>14</sup>C BP) suggests a more heterogeneous environment as evidenced by the first occurrence of *Akodon iniscatus* and *Euneomys chinchilloides*. In this context, CH1 assemblages do not reflect the small mammal community reworking that putatively accompanied the Pleistocene–Holocene transition.

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### 1. Introduction

Patagonian sequences of small mammals have been the focus of several studies during the last decade. Most of these contributions were centered on the paleoenvironmental and paleoclimatic meaning of these assemblages (e.g., Pardiñas, 1998, 1999a; Teta et al., 2005, 2009; Pardiñas and Teta, 2008; Fernández, 2010; Fernández et al., 2011a). In turn, and with some exceptions taphonomic aspects were minimally addressed. The few studies available for the region proposed different kinds of accumulators of fossil micro-mammals, such as humans, owls and carnivore mammals (Pardiñas, 1999a,b; Teta et al., 2005; Fernández et al., 2011a). As in many places around the world, nocturnal birds can be identified as the main contributors to the formation of archaeological and paleontological small mammal assemblages in Patagonia (e.g., Andrews, 1990; Pardiñas, 1999a,b; Teta et al., 2005).

Data on the composition of Late Pleistocene small mammal assemblages is scarce and widely scattered across Patagonia (Pardiñas and Teta, 2008; Teta et al., 2009; Pardiñas et al., 2011). The same is true for the Early and Middle Holocene, with an increase in the number of samples only for the Late Holocene (Pardiñas et al., 2011). In any case, none of the available faunal sequences cover the Pleistocene–Holocene transition, a segment that encompassed the most significant changes in climatic conditions (e.g., Clapperton, 1993; Whitlock et al., 2006). This is not a minor issue, considering that this period is characterized by a deep restructuration in faunal composition, with the extinction of several large species throughout the Americas (Haynes, 2009; Barnosky and Lindsey, 2010). Small mammals were also subject to this intense ecological reworking (Blois et al., 2010). The Pleistocene–Holocene transition includes significant shifts in range distributions and local extinctions of several small mammal species in temperate ecosystems of the Pampean region (Pardiñas and Teta, 2010). Zoarchaeological records for the northern end of Patagonia are scarce [Cueva Haichol (Massoia et al., 1981; Massoia, 1992);

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Tromen Locality (Pastore, 1974; Goñi et al., 1996), Cueva Epullán Grande (Crivelli Montero et al., 1996; Pardiñas, 1999a; Cordero, 2010); Cueva Traful (Cordero, in press); and El Trébol Rockshelter (Hajduk et al., 2006; Lezcano et al., 2010)].

This contribution stems from new projects intended to fill this gap by developing ecological, paleontological and archaeological research in northern Neuquén Province, Argentina (Fig. 1). In particular, research being conducted at the Cueva Huenul 1 site provided stratified sequences of archaeological and paleontological remains spanning the Late Pleistocene–Late Holocene (Barberena et al., 2010). The main subject of this study is to present an exhaustive analysis of the taphonomic and paleoenvironmental significance of the micro-mammal remains obtained in CH1, and to assess human involvement in their deposition by expanding upon an earlier preliminary study (Fernández et al., in press). Since both Late Pleistocene and Early Holocene layers were recognized, CH1 provides a unique opportunity to explore the composition of micro-mammal communities at the time of the major climatic changes in the Late Quaternary.

## 2. Regional setting

Cueva Huenul 1 site (CH1; 36°56'45"S, 69°47'32"W, 1008 masl) is located east of the Andes mountain range, near the southern margin of the Colorado River (Fig. 1). The site is emplaced within the Tromen volcanic complex in the Andean back-arc, with numerous vents, basaltic, andesitic and rhyolitic lava flows and domes that originated between the Late Pliocene and the Holocene, even during historical times (Galland et al., 2007; Folguera et al., 2008). The region is surrounded by two other extensive volcanic fields: the Domuyo complex, westwards in the Andean arc, with dacitic lava domes of Late Pleistocene or possibly Holocene age (Gonzalez-Ferran, 1995), and the Payún Matrú complex (northward) in the Andean back-arc, with more than 300 eruptive centers, numerous trachyandesitic lava domes and basaltic lava flows, chronologically bracketed between the Late Pleistocene and the Middle Holocene (Germa et al., 2010).

CH1 is located near the western limit of the South American Arid Diagonal, which covers a large part of the subcontinent, from northern Peru, along the Andes to southern Neuquén, and continuing across Patagonia to reach the Atlantic coast near the mouth of the Chubut River (Bruniard, 1982). The southern portion of the Arid Diagonal is mainly associated with the Monte phytogeographic province, Monte Austral district (*sensu* León et al., 1998; see also Páez et al., 2004; Abraham et al., 2009). This is one of the most arid biomes of Argentina, with mean annual precipitation <200 mm producing a poor plant cover (10–40%). The vegetation is characterized by xerophytic shrubs, and contains a generally sparse herbaceous layer. CH1 site is near the ecotone of the Monte province with the Patagonia phytogeographic province (*sensu* León et al., 1998), the latter being characterized by higher mean annual precipitations and lower temperatures, and dominated by steppes and grasslands.

This area is characterised by the presence of strigiform birds such as *Tyto alba* (barn owl), *Bubo magellanicus* (magellanic horned owl), *Asio flammeus* (short-eared owl), and *Athene cucularia* (burrowing owl) and the falconiforms *Geranoaetus melanoleucus* (black-chested buzzard-eagle), *Buteo polyosoma* (red-backed hawk), *Caracara plancus* (crested caracara) and *Falco peregrinus* (peregrine falcon).

The recent assemblages of small mammals registered in the area of CH1 mainly consist of species associated with the xeric environments of the Monte desert and the South American Arid Diagonal and Patagonian elements, widely distributed (Pardiñas et al., 2003, 2011). Within the former are the marsupial *Thylamys pallidior* (mouse opossum) and the sigmodontine rodents *Akodon neocenus*

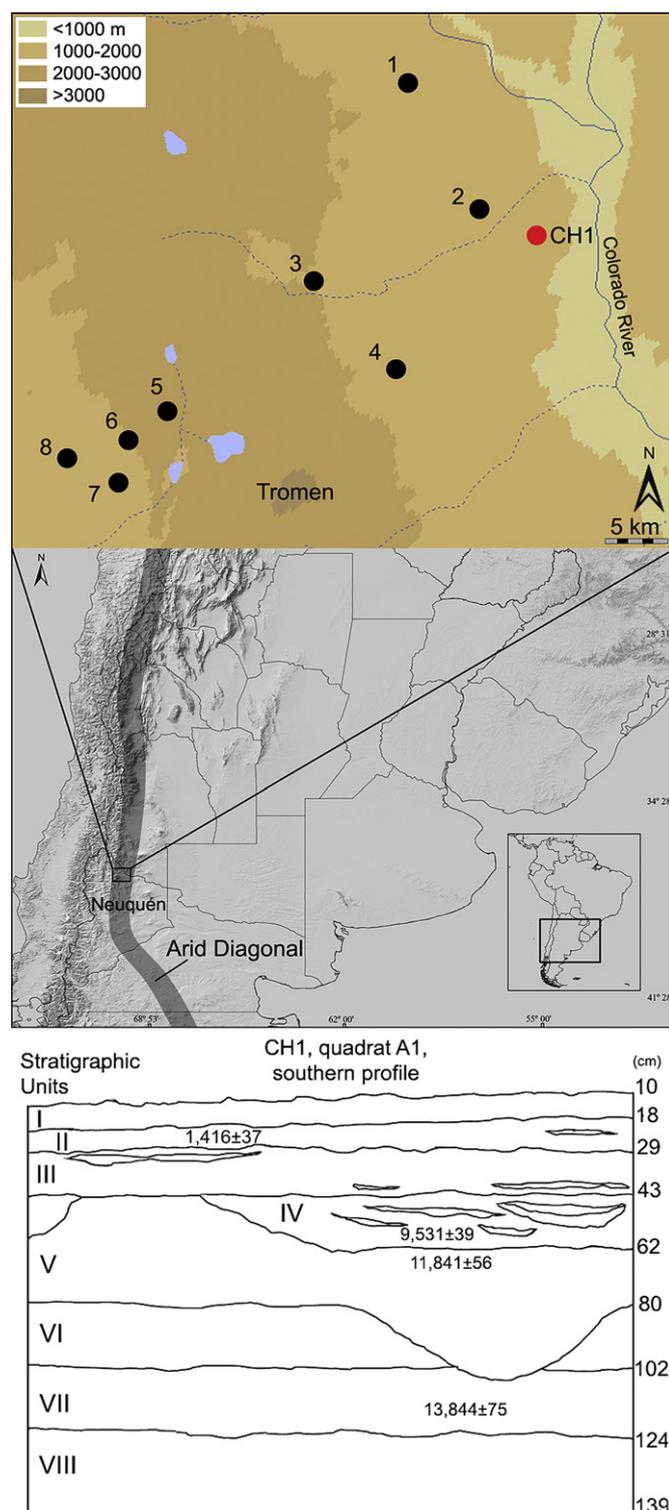


Fig. 1. Map of the study area (above and middle), northern Patagonia, Argentina, showing the emplacement of Cueva Huenul 1 (CH1) and stratigraphic profile (below); numbers in the map correspond to recent owl pellets samples: 1, Barrancas. 2, Buta-Co. 3, P.P. Tromen, Arroyo Buta-Co. 4, 5.5 km W Buta Ranquil. 5, P.P. Tromen. 6, 12 km NW refugio P.P. Tromen. 7, 4 km SW Laguna Tromen. 8, Cerro Wayle.

(Neuquén grass mouse), *Akodon iniscatus* (Patagonian grass mouse), *Eligmodontia typus* (silky-desert mouse), and *Graomys griseoflavus* (gray leaf-eared mouse); Patagonian taxa are the abrotrichines *Abrothrix longipilis* (long-haired grass mouse) and *Abrothrix olivacea* (olive grass mouse), plus the larger sigmodontines *Euneomys*

*chinchilloides* (chinchilla rat), *Phyllotis xanthopygus* (yellow-rumped pericote), and *Reithrodon auritus* (bunny rat).

### 3. Materials and methods

#### 3.1. Materials

CH1 archaeological site is a large cave originated by erosive processes acting along the contact of two different volcanic lithologies: the underlying ignimbrites of the Tilhué Fm. and the basaltic flow that corresponds to El Puente Fm. (Narciso et al., 2004). Recent excavations retrieved a sedimentary sequence spanning the Late Pleistocene–Early Holocene and reaching the Late Holocene. The archaeological and paleontological materials include lithic artifacts, combustion features (hearths), coprolites of megafaunal taxa, and small mammal remains (see Barberena et al., 2010, 2011; Fernández et al., in press).

The materials analyzed here come from quadrat A1, emplaced near the bottom of the cave, with a dimension of  $2 \times 1$  m and a depth of 1.4 m ( $2.8 \text{ m}^3$  of excavated sediment). The sedimentary sequence is composed by two sets of litho-stratigraphic units with contrasting physical and chemical properties. The basal units (VIII, VII, VI, and V) have high percentages of organic matter and poor granulometric selection. These units presented abundant coprolites and decomposed macrobotanical remains. Two radiocarbon dates on coprolites allow bracketing this stratigraphic set:  $13,844 \pm 75 \text{ }^{14}\text{C}$  BP (AA-85722) for unit VII (100–110 cm), and  $11,841 \pm 56 \text{ }^{14}\text{C}$  BP (AA-85720) for unit V (55–60 cm). On this basis, it can be stated that units VIII–V correspond to the latest Pleistocene. This stratigraphic set is bounded by an erosional unconformity affecting Unit V, and in direct contact with the second set of stratigraphic units: IV, III, II, I. These units present lower percentages of organic matter and unimodal granulometric curves indicating a better selection. Unit IV has the earliest evidences of human occupation of the site and is dated at  $9531 \pm 39 \text{ }^{14}\text{C}$  BP (AA-85718). Finally, unit II is dated at  $1416 \pm 37 \text{ }^{14}\text{C}$  BP (AA-85721) (Fig. 1). The sequence is not continuous and the presence of temporal gaps is assumed, and more dates are in progress in order to assess this issue. On the basis of the chrono-stratigraphic analysis, bones and teeth of rodents and marsupials [number of identified specimens (NISP) = 1426; minimum number of elements (MNE) = 1409; minimum number of individuals (MNI) = 87] are assigned to the following temporal units: Late Pleistocene layers (units VIII–V), Early Holocene (unit IV), and Late Holocene units (III, II, I).

Current small mammal communities in the surroundings of CH1 (Fig. 1) were assessed through the analysis of eight samples of *T. alba* (Strigiformes, Tytonidae) fresh pellets. The studied samples are: 1) Barrancas ( $36^{\circ}51'28.6''\text{S}$ ,  $69^{\circ}55'29.9''\text{W}$ ; housed at Museo de Historia Natural de San Rafael collection [San Rafael, Mendoza, Argentina], under the number MHNSR 0092); 2) Buta Co ( $36^{\circ}56'12.12''\text{S}$ ,  $69^{\circ}51'54.21''\text{W}$ ; housed at Colección de Material de Egagrópilas y Afines “Elio Massoia” del Centro Nacional Patagónico [Puerto Madryn, Chubut, Argentina], under the number CNP-E 624); 3) P.P. Tromen, Arroyo Buta-Co ( $36^{\circ}59'23.7''\text{S}$ ,  $69^{\circ}59'56.8''\text{W}$ ; CNP-E 457); 4) 5.5 km W Buta Ranquil ( $37^{\circ}03'0.52''\text{S}$ ,  $69^{\circ}56'0.05''\text{W}$ ; CNP-E 591); 5) P.P. Tromen ( $37^{\circ}04'43.2''\text{S}$ ,  $70^{\circ}07'06.6''\text{W}$ ; CNP-E 453); 6) 12 km NW refugio P.P. Tromen ( $37^{\circ}05'59.28''\text{S}$ ,  $70^{\circ}08'58.95''\text{W}$ ; CNP-E 529); 7) 4 km SW Laguna Tromen ( $37^{\circ}07'40.10''\text{S}$ ,  $70^{\circ}09'27.34''\text{W}$ ; CNP-E 563, CNP-E 561); 8) Cerro Wayle ( $37^{\circ}06'38.42''\text{S}$ ,  $70^{\circ}11'54.03''\text{W}$ ; CNP-E 541).

#### 3.2. Methods

Remains of bones and teeth from CH1 site were recovered with a 2.5 mm-sized screen mesh and examined with a stereomicroscope.

Taxonomic identifications were made exclusively based on cranial and dental remains by comparison with reference materials from the Colección de Mamíferos del Centro Nacional Patagónico (Puerto Madryn), as well as with bibliographic sources (e.g., Pearson, 1995; Pardiñas, 2009; Fernández et al., 2011b). In addition, fragmentary remains of small specimens of *Ctenomys* (tuco-tuco), and *Eli-gmodontia* are difficult to identify to species level, and therefore an open taxonomy was used.

The taphonomic approach followed the methodology used by Andrews (1990) and Fernández-Jalvo and Andrews (1992). The relative abundances of skeletal elements were evaluated with the representation of each element in the sample, calculated (MNEi) on the basis of the expected number for each skeletal element per individual (Ei) and the minimum number of individuals (MNI) by using the following formula:  $\text{MNEi}/(\text{Ei} \times \text{MNI}) \times 100$ . In order to assess the relationships between cranial and post-cranial elements, two indices were calculated:  $[(\text{femur} + \text{tibia} + \text{humerus} + \text{radius} + \text{ulna}) \times 16 / (\text{mandible} + \text{maxilla} + \text{molars}) \times 10] \times 100$ , and  $[(\text{humerus} + \text{femur}) / (\text{mandible} + \text{maxilla})] \times 100$ . In order to assess the proportions between distal and proximal elements of the limbs, the following index was calculated:  $[(\text{tibia} + \text{radius}) / (\text{femur} + \text{humerus})] \times 100$ . Two other indices were calculated to evaluate the proportions of individual teeth  $[(\text{premaxillary alveoli} + \text{mandibular alveoli}) / (\text{incisors})] \times 100$ , and  $[(\text{maxillary alveoli} + \text{mandibular alveoli}) / (\text{molars})] \times 100$ .

The paleoenvironmental analysis is based upon the use of small mammals as indicators of environmental conditions, which allows developing paleoecological inferences based on the presence or absence of several species in conjunction with their environmental requirements (e.g., Andrews, 1995; Pardiñas, 1999a). Recent owl pellet samples are compared with fossil samples in the theoretical framework of the modern analog method (Overpeck et al., 1985). A principal component analysis (PCA) was performed in order to explore the multivariate relationship between fossil and modern micro-mammal samples. The PCA worked over a data matrix composed by species abundances (MNI%) per sample. Principal components were extracted from a correlation matrix and computed using the MNI% after transformation through the octave scale (Gauch, 1982). Statistical analyses were made with the program *Statistica* (StatSoft, Inc. 2001).

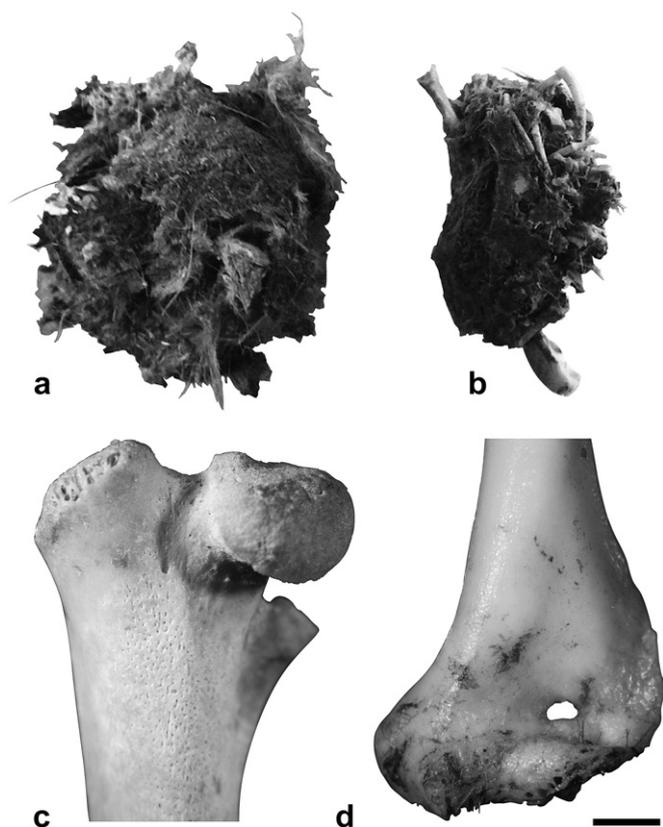
## 4. Results

#### 4.1. Taphonomic analysis

Three fragmented owl pellets were recovered from Units I–III, and two from Units V–VIII (Fig. 2a and b). Of the analyzed bones and teeth, 31% showed signs of alteration by digestive action (Table 1) with minor variations per unit (Units I–III: 28.3%, Unit IV: 41.5%, Unit V–VIII: 39.4%). Observed corrosion is categorized mainly as light (sensu Andrews, 1990). Some proximal portions of the femurs and distal portions of the humeri showed light pitting (Fig. 2c and d); in several incisors the corrosion was concentrated on the edges, and some cusps of molars showed a more rounded shape. In all of units, isolated teeth were more affected than those found *in situ*, due to their larger surface exposed to digestive acids (Andrews, 1990).

The average relative abundance was low in all the units, with the most represented elements being mandibles, maxillas, vertebrae, humeri, pelvis, femurs, and tibias (Fig. 3). The relative abundance patterns of skeletal parts could be affected by sieve-mesh size. However, the use of 2.5 mm sized screen in this study suggests adequate recovery of the elements.

Table 2 summarizes the extent of cranial, dental, and postcranial breakage. Almost all the revised skulls were found fractured, most



**Fig. 2.** Examples of raptor evidence at different units of Cueva Huenul 1. A, pellet (Unit II; major diameter ~40 mm). B, pellet (Unit V; major diameter ~20 mm). C, femur showing light digestive corrosion on the proximal epiphysis (Unit VIII). D, humerus showing light digestive corrosion on the distal epiphysis (Unit IV). Scale in C and D = 1 mm.

of them showing maxillas without zygomatic arches (Fig. 4). Most of the molars were lost from the maxillas, although a high frequency of incisors remained in the premaxillas. The mandibles presented different categories of breakage throughout the sequence, which the highest proportion possessing the ascending ramus broke. With the exception of Unit IV, a high proportion of molars were lost from the mandibles. Most of the incisors were retained on the mandibles.

The percentage of fractured molars was low in all units, whereas for incisors it was low in Units I–III and moderate in Units IV and Units V–VIII. As mentioned, the teeth found *in situ* showed minor breakage extent than those found isolated. The proportion of fractures in femurs, humeri, tibiae, and ulnas was 21% for Units I–III, 15.7% for Units IV and 41.5% for Units V–VIII. In all cases, the femurs and ulnas showed higher proportions of proximal segments, whereas distal segments were predominant in the humeri. Otherwise, ribs, scapulae, and pelvises were highly fractured and most of the vertebrae, radii, calcanea, astragalus, metapodia, and phalanges were complete (Table 3). Most of the broken bones presented sharp edges and rough surfaces and only a few of them had rounded edges and smooth surfaces.

The values obtained for the indices are presented in Table 4. The first index displays the relations between postcranial and cranial elements, indicating an overall better preservation of postcranial elements. However the second index, intended to analyze the relationship between postcranial and cranial elements, shows better preservation of the latter, with the exception of the Late Pleistocene Units V–VIII. The index that estimates the relationship between distal and proximal elements of the limbs indicates a loss

**Table 1**

Representation of the various categories of digestive corrosion for the small mammal assemblages from CH1 archaeological site.

	Digestion classes <i>sensu</i> Andrews (1990)									
	Absent		Light		Moderate		Heavy		Extreme	
	(N)	%	(N)	%	(N)	%	(N)	%	(N)	%
<b>Units I–III</b>										
Digestion of teeth										
Incisors <i>in situ</i>	43	70.5	18	29.5	0	0	0	0	0	0
Isolated incisors	6	46.2	7	53.8	0	0	0	0	0	0
Incisors Total	49	66.2	25	33.8	0	0	0	0	0	0
Molars <i>in situ</i>	134	79.3	32	18.9	3	1.8	0	0	0	0
Isolated molars	1	14.3	6	85.7	0	0	0	0	0	0
Molars Total	135	76.7	38	21.6	3	1.7	0	0	0	0
Digestion in postcranials										
Proximal femur	19	50	15	39.5	4	10.5	0	0	0	0
Distal humerus	20	87	2	8.7	1	4.3	0	0	0	0
<b>Unit IV</b>										
Digestion of teeth										
Incisors <i>in situ</i>	16	64	8	32	1	4	0	0	0	0
Isolated incisors	7	38.9	11	61.1	0	0	0	0	0	0
Incisors total	23	53.5	19	44.2	1	2.3	0	0	0	0
Molars <i>in situ</i>	73	61.9	41	34.7	4	3.4	0	0	0	0
Isolated molars	4	57.1	3	42.9	0	0	0	0	0	0
Molars total	77	61.6	44	35.2	4	3.2	0	0	0	0
Digestion in postcranials										
Proximal femur	14	58.3	8	33.3	2	8.3	0	0	0	0
Distal humerus	7	46.7	6	40	2	13.3	0	0	0	0
<b>Units V–VIII</b>										
Digestion of teeth										
Incisors <i>in situ</i>	12	70.6	5	29.4	0	0	0	0	0	0
Isolated incisors	7	29.2	9	37.5	7	29.2	1	4.1	0	0
Incisors total	19	46.3	14	34.1	7	17.1	1	2.4	0	0
Molars <i>in situ</i>	48	78.7	13	21.3	0	0	0	0	0	0
Isolated molars	1	12.5	6	75	1	12.5	0	0	0	0
Molars total	49	71	19	27.5	1	1.4	0	0	0	0
Digestion in postcranials										
Proximal femur	11	39.3	12	42.9	4	14.3	1	3.5	0	0
Distal humerus	24	75	7	21.9	1	3.1	0	0	0	0

of distal elements throughout the sequence, whereas the index measuring the relative proportion of isolated teeth shows that the greater part of the molars and incisors were retained on the maxillaries and mandibles. Finally, no evidence of anthropic cut-marks was recorded, while only seven burned specimens were found, not necessarily being an evidence of human consumption.

Taking into account the post-depositional processes, no evidence of weathering, rodent marks, hydraulic transport, root action, or diagenesis were found. Neutral pH values were measured for all the units composing the sequence (Barberena et al., 2010), favoring a good preservation of organic materials. Only two specimens showed evidence of sedimentary corrosion in Units I–III and IV.

#### 4.2. Paleoenvironmental analysis

The abundances of the small mammals recovered at the CH1 are detailed in Table 5. Recorded taxa include the didelphid marsupial *T. pallidior*, several sigmodontine rodents and two caviomorphs, the fossorial *Ctenomys* sp. and the cavy *Microcavia australis* (southern mountain cavy) (Figs. 4 and 5). Most of these mammals are registered throughout the stratigraphical sequence. The sigmodontine *A. niscatus* is exclusive for Holocene units and the sigmodontine *E. chinchilloides* is restricted to the Unit IV. The codominance of *Ctenomys* sp., *Eligmodontia* spp., *M. australis*, and *P. xanthopygus* characterizes the three analytical units studied and also the recent assemblages close to the site.

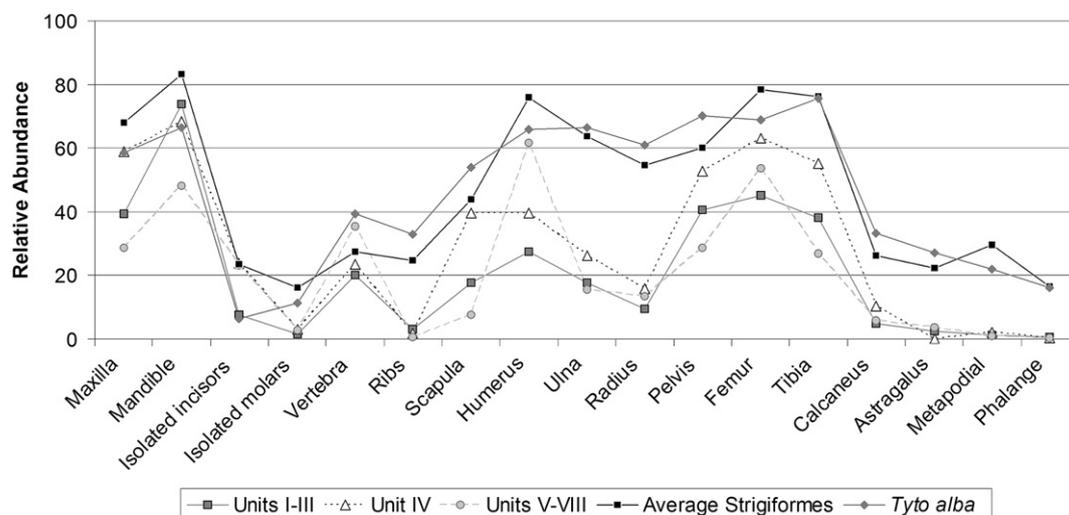


Fig. 3. Relative abundance values for the various anatomical elements from Cueva Huenul 1, compared with small mammal assemblages generated by average of *Tyto alba* (Andrews, 1990), and average by strigiform (Andrews, 1990).

Table 2  
Fracturing in cranial, dental, and post-cranial elements for small mammals from the CH1 archaeological site.

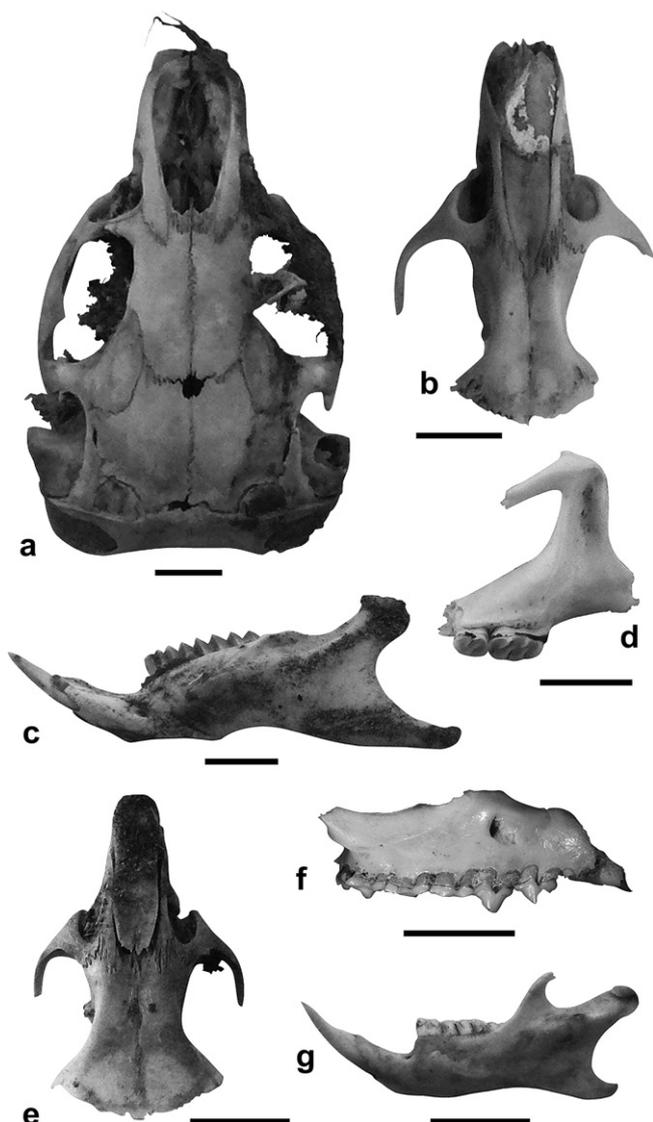
	Units I–III		Unit IV		Units V–VIII	
	N	%	N	%	N	%
<b>Breakage of skulls</b>						
Complete skull	1	3	0	0	0	0
Maxillary with zygomatic	3	9.1	1	4.5	1	6.7
Maxillary without zygomatic	29	87.8	21	95.5	14	93.3
Molars missing from maxillary	24	26.4	20	27.8	16	3.8
Incisors missing from premaxillary	0	0	0	0	0	0
<b>Breakage of mandible</b>						
Complete mandible	21	33.9	6	23.1	6	24
Ascendant ramus broken	23	37.1	18	69.2	12	48
Without ascendant ramus	14	22.6	1	3.8	5	20
Without ascendant ramus and inferior edge broken	4	6.4	1	3.8	2	8
Molars missing from mandible	78	43.3	15	18.5	46	64.8
Incisors missing from mandible	3	5	2	8	2	11.8
<b>Breakage of teeth</b>						
Broken molars <i>in situ</i>	0	0	1	0.8	0	0
Broken isolated molars	3	42.8	7	100	5	62.4
Total broken molars	3	1.7	8	6.4	5	7.3
Broken incisors <i>in situ</i>	3	4.9	1	4	0	0
Broken isolated incisors	7	53.8	12	66.7	18	75
Total broken incisors	10	13.5	13	30.2	18	43.9
<b>Breakage of postcranial elements</b>						
<b>Femur</b>						
Complete	32	84.2	20	83.3	12	42.9
Proximal	6	15.8	4	16.7	16	57.1
Shaft	0	0	0	0	0	0
Distal	0	0	0	0	0	0
<b>Humerus</b>						
Complete	19	82.6	14	100	23	71.9
Proximal	0	0	0	0	2	6.2
Shaft	0	0	0	0	0	0
Distal	4	17.4	0	0	7	21.9
<b>Tibia</b>						
Complete	27	81.8	16	76.2	11	78.6
Proximal	5	15.2	0	0	3	21.4
Shaft	0	0	0	0	0	0
Distal	1	3	5	23.8	0	0
<b>Ulna</b>						
Complete	8	53.3	8	80	2	25
Proximal	7	46.7	2	20	6	75
Shaft	0	0	0	0	0	0
Distal	0	0	0	0	0	0

The complex topographic pattern of northern Neuquén Province determines abrupt changes in small mammal assemblages, even in relatively short distances (Fig. 6). At the latitude of CH1, along <30 linear kilometers the altitude ranges from 850 to 3900 m asl. Micro-mammal communities at low elevations are mostly composed by the phyllotine rodents *Eligmodontia* spp. and *P. xanthopygus*; with lower frequencies are also present the sigmodontines *A. iniscatus*, *G. griseoflavus* and *R. auritus*. Other micro-mammal taxa included hystricognath rodents such as *Ctenomys* sp. and *M. australis* and the didelphid marsupial *T. pallidior*. In turn, small mammal communities at higher elevations are mostly composed by typical Patagonian elements, such as the large rat *E. chinchilloides* and the abrotrichine rodents *A. longipilis*, *A. olivacea* and *Chelemys macronyx* (Andean long-clawed mouse) (Pardiñas et al., 2003, 2011). This replacement of species occurs more or less gradually along the altitude gradient, involving changes in taxonomic composition and relative frequencies. For example, *Eligmodontia* spp. and *P. xanthopygus* are most abundant at lowland areas, decreasing its participation in the communities with increasing altitude, whereas *Abrothrix* or *Euneomys* have its first records at intermediate elevations, becoming dominant at the highlands. Within this context, some species completely disappear at high elevations (e.g., *Thylamys*), while others only occur above 2000 m asl (e.g., *Chelemys*). Finally, some taxa are patchily represented, occurring across this altitudinal range, such as *Oligoryzomys longicaudatus* (long-tailed pygmy rice rat), whereas others are homogeneously distributed, such as *R. auritus*.

PCA results (Fig. 7) showed that recent samples are geographically arranged along the first principal component (50.02% of the variance); this axis shows a contrast between assemblages – including the CH1 fossil samples – composed by small mammals typically allied with the Arid Diagonal to the right, and those associated with the Patagonian steppes to the left.

### 4.3. Archaeological evidence

Archaeological research at CH1 provides the context for the micro-mammal faunal data presented here (Barberena et al., 2010, 2011; Pompei et al., in press). Fig. 8 shows frequencies of lithic artifacts, carnivore scats (measured by weight), micro and macro faunal remains (measured by NISP%), suggesting a number of important trends.



**Fig. 4.** Small mammals recovered at Cueva Huenul 1, showing different pattern of breakage. A, *Ctenomys* sp., skull in dorsal view (Unit II). B, *Phyllotis xanthopygus*, anterior fragment of skull in dorsal view (Unit IV). C, *Microcavia australis*, left dentary in labial view (Unit VI). D, *Euneomys chinchilloides*, right maxillary in lateral view (Unit IV). E, *Eligmodontia* spp., anterior fragment of skull in dorsal view (Unit II). F, *Thylamys pallidior*, right maxillary in lateral view (Unit II). G, *Akodon iniscatus*, left dentary in labial view (Unit IV). Scales = 5 mm.

**Table 3**  
Fracturing in others post-cranial elements for small mammals from the CH1 archaeological site.

	Units		Unit		Units		V–VIII	
	N	%	N	%	N	%	N	%
Vertebra	0	0	0	0	0	0	0	0
Ribs	29	65.9	7	87.5	0	0	0	0
Scapula	14	93.3	13	86.7	4	100		
Radius	0	0	0	0	1	14.3		
Pelvis	30	83.3	20	100	15	100		
Calcaneus	0	0	0	0	0	0		
Astragalus	0	0	0	0	0	0		
Metapodial	0	0	4	50	0	0		
Phalange	0	0	0	0	0	0		

**Table 4**

Values of the indices calculated for the CH1 archaeological site: f = femur; t = tibia; h = humerus; r = radius; c = ulna; mx = maxilla; mb = mandible; m = molar.

	Units I–III	Unit IV	Units V–VIII
<i>Postcranial/cranial</i>			
f + t + h + r + u/mx + mb + m	113.7	221.1	185.4
h + f/mx + mb	64.2	81.3	150
<i>Distal/proximal elements</i>			
t + r/f + h	65.6	69.2	31.8
<i>% Isolated teeth</i>			
% Isolated molars	60.4	29.7	101.6
% Isolated incisors	4.9	8	11.8

There is a positive and significant correlation value for the abundance of macro and microfaunal remains ( $r=0.70$ ,  $p. 0.05$ ). The macro faunal specimens are dominated by *Lama guanicoe* (guanaco), the largest herbivore inhabiting the area, and display an excellent preservation state and systematic evidences of human consumption. This co-occurrence, on the other hand, does not imply deposition by the same agent (see taphonomic discussion below). Correlation between micro-mammal bones and lithic artifacts is also positive and relatively high, but non significant ( $r=0.56$ ,  $p. 0.14$ ). The locally available *Huenul* obsidians (Durán et al., 2004; Barberena et al., 2011) mostly compose the lithic assemblage. Interestingly, both lithics and macro-faunal remains are negatively correlated with the abundance of carnivore scats through time ( $r=-0.53$ ,  $p. 0.17$ ; and  $r=-0.56$ ,  $p. 0.14$ ). Finally, micro-mammal remains and carnivore scats present a weak and non-significant correlation value ( $r=-0.27$ ,  $p. 0.51$ ).

## 5. Discussion

### 5.1. Taphonomic interpretation

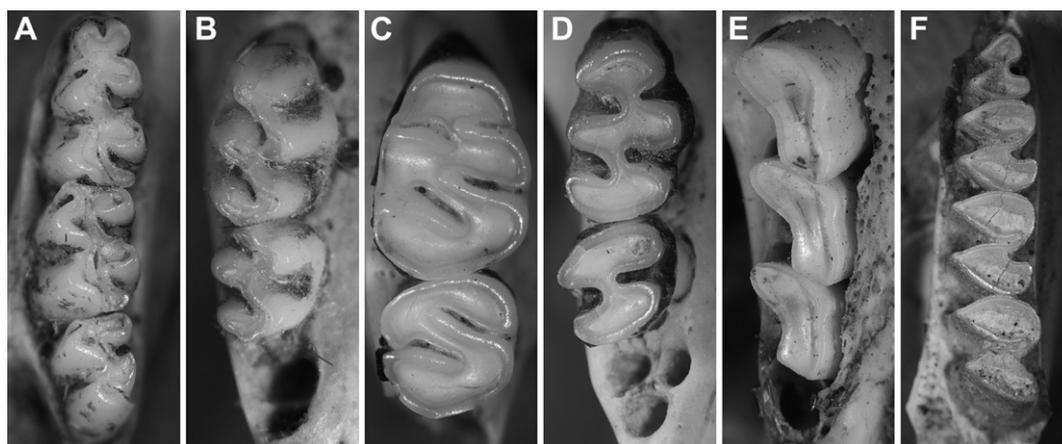
The absence of cut-marks, presence of few burned remains, and low abundance of some large (>200 g), mostly diurnal, gregarious or colonial rodents recovered from the CH1 site, would indicate non-human deposition (cf. Pardiñas, 1999b). Moreover, the finding of pellets preserved in stratigraphy, light digestive marks on some teeth and postcranial bones, relative abundance patterns of skeletal parts, molars and incisors retained into alveoli, and loss of

**Table 5**

Taxonomic composition of the small mammal sample from the CH1 archaeological site (expressed NISP, MNE, MNI).

Chronology (ka)	1.4			9.5			11.8–14		
	Units			Units			Units		
	NISP	MNE	MNI	NISP	MNE	MNI	NISP	MNE	MNI
<b>Mammalia</b>									
<b>Didelphimorphia</b>									
<i>Thylamys pallidior</i>	14	14	5	1	1	1	2	2	2
<b>Rodentia</b>									
<b>Ctenomyidae</b>									
<i>Ctenomys</i> sp.	31	31	4	17	17	2	27	27	4
Caviidae indet. <sup>a</sup>	5	5	–	0	0	–	0	0	–
<i>Microcavia australis</i>	5	5	3	1	1	1	7	7	5
Cricetidae/	479	462	–	278	278	–	412	412	–
<b>Sigmodontinae indet.<sup>a</sup></b>									
<i>Akodon iniscatus</i>	2	2	1	2	2	1	0	0	0
<i>Phyllotis xanthopygus</i>	2	2	1	4	4	3	3	3	3
<i>Eligmodontia</i> spp.	72	72	28	36	36	10	25	25	12
<i>Euneomys chinchilloides</i>	0	0	0	1	1	1	0	0	0
<b>Total</b>	<b>610</b>	<b>593</b>	<b>42</b>	<b>340</b>	<b>340</b>	<b>19</b>	<b>476</b>	<b>476</b>	<b>26</b>

<sup>a</sup> Only postcranial elements, possibly corresponding to identified taxa.



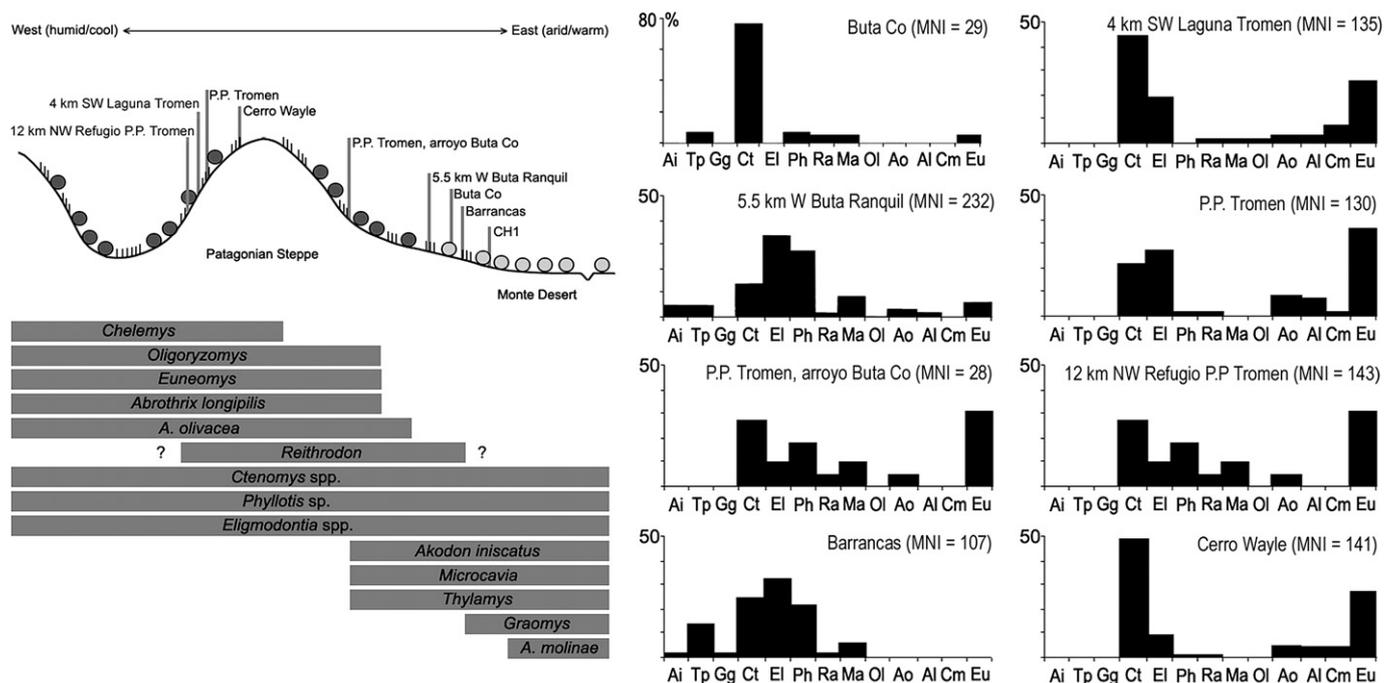
**Fig. 5.** Molar tooththrows in occlusal view for small mammals recovered at Cueva Huenul 1. A. *Akodon iniscatus*, left m1-3 (m1 length: 2.18 mm). B. *Eligmodontia* spp., right M1-2 (M1 length: 1.68 mm). C. *Euneomys chinchilloides*, right M1-2 (M1 length: 3.03 mm). D. *Phyllotis xanthopygus*, right M1-2 (M1 length: 2.59 mm). E. *Ctenomys* sp., right P4-M2 (M1 length: 3.08 mm). F. *Microcavia australis*, left P4-M3 (M1 length: 2.44 mm).

distal elements, agree with actualistic studies of strigifoms with a light destructive capacity, such as *T. alba* (Andrews, 1990; Gómez, 2007). Nevertheless, CH1 assemblages differ taphonomically from those produced by other birds of prey that inhabit northern Neuquén, such as *B. polysoma*, *C. plancus*, *F. peregrinus*, *B. magellanicus*, and *A. cunicularia*, all of which produce moderate and heavy modification in the small mammals' remains (Andrews, 1990; Gómez, 2007; Iglesias, 2009; Montalvo and Tallade, 2009, 2010; Montalvo and Tejerina, 2009).

*T. alba* is a common owl that usually inhabits open landscapes and displays an opportunistic behavior, feeding mostly on nocturnal small mammals within a foraging area of about 1–5 km (Taylor, 2004, and references therein). This owl has been

considered the main accumulator of micro-vertebrate bones in caves and rockshelters (e.g., Andrews, 1990; Saavedra and Simonetti, 1998). Moreover, the taxonomic structure recorded at CH1 coincides with the *T. alba* trophic activity known in Argentina (see Bellocq, 2000, and references therein). This ensures an adequate comparison with the recent owl pellet samples in the vicinities of the archaeological site, in order to carry out paleoenvironmental interpretations (e.g., Andrews, 1990, 1995).

Pardiñas (1999a,b) and Teta et al. (2005) reviewed the micro-mammal sequences of several archaeological sites in the Pampean and Patagonian regions, recognizing that owls and humans were the main accumulator agents of bone remains. The Patagonian owl assemblages were characterized by high taxonomic



**Fig. 6.** Distribution of small mammal species in a west-east gradient in northeastern Neuquén Province (at the latitude of the Huenul area) and histograms showing the small mammal abundance (expressed as percentage of the minimum number of individuals [MNI]) of the recent samples. Abbreviations: *Abrothrix longipilis* (Ai); *Abrothrix olivacea* (Ao); *Akodon iniscatus* (Ai); *Chelemys macronyx* (Cm); *Ctenomys* sp. (Ct); *Eligmodontia* spp. (El); *Euneomys chinchilloides* (Eu); *Graomys griseoflavus* (Gg); *Microcavia australis* (Ma); *Oligoryzomys longicaudatus* (Ol); *Phyllotis xanthopygus* (Ph); *Reithrodon auritus* (Ra); *Thylamys pallidior* (Tp).

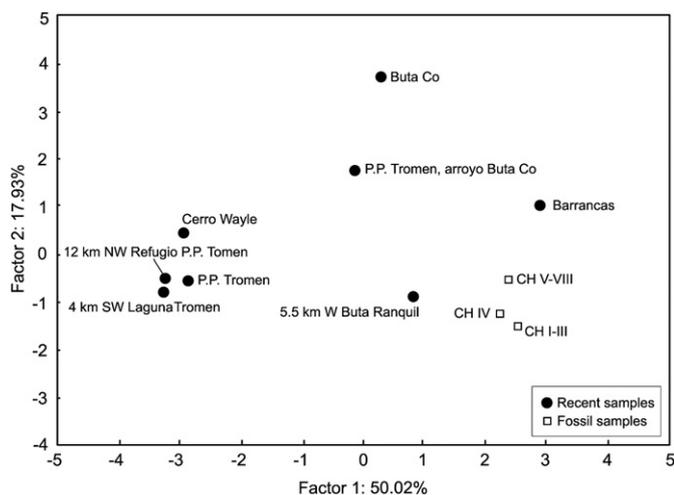


Fig. 7. Representation of recent and archaeological (CH1) micromammal samples on the plane defined by axes 1 and 2 of a principal component analysis.

diversity, low levels of digestive traces and predominance of nocturnal micro-mammals weighting <300 g (Pardiñas, 1999a,b; Teta et al., 2005). Finally, Fernández et al. (2011a) demonstrated the participation of mammalian carnivores and humans in the genesis of small mammal assemblages from two archaeological sites in Negro River valley, southwards from CH1.

In the case of CH1, the absence of weathering, rodent marks, hydraulic transport, root action, and diagenesis, as well as the very low frequency of bones with sedimentary corrosion, suggest a good preservation and a rapid incorporation of the material in the stratigraphic context (Korth, 1979; Andrews, 1990; Fernández-Jalvo and Andrews, 2003). However, the high proportion of breakage of cranial elements, ribs, pelvis, and scapulas with sharp edges and rough surfaces indicate a poorer preservation of small elements such as vertebrae, calcaneus, astragalus, metapodials, and phalanges (Tables 2 and 3), indicating some trampling action (Andrews, 1990). This is very common at cave sites with restricted circulation areas (Andrews, 1990; Pardiñas, 1999b). The circulation of mega-mammals (possibly *Phyllophaga* indet.) within the cave during the Late Pleistocene is indicated by the dung content recorded in the layers VIII–V.

## 5.2. Paleoenvironments

CH1 samples are characterized by low MNI values, probably biasing specific richness. In this context, paleoenvironmental

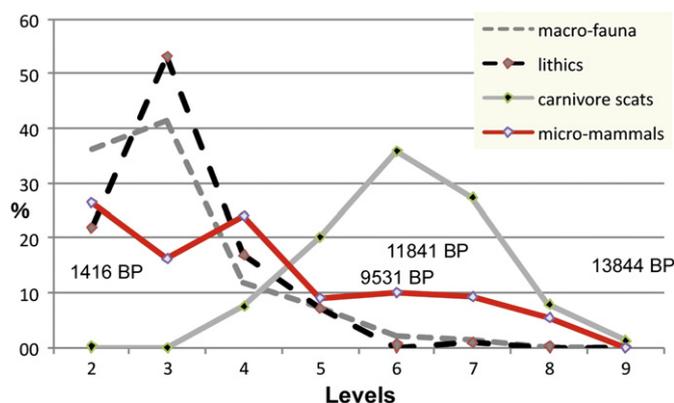


Fig. 8. Stratigraphic frequencies of micro and macro mammal remains, lithics and carnivore scats based on Nisp.

inferences must be cautionary. Fossil samples are dominated by *Eligmodontia* spp., *P. xanthopygus*, *M. australis* and *Ctenomys* sp. Holocene assemblages are richer than those from the Late Pleistocene, including the sigmodontine *A. iniscatus*, typically associated with the Monte Desert and *E. chinchilloides*, frequent in open and rocky areas of the Patagonian steppe (Pardiñas et al., 2003, 2011). These occurrences are suggestive of a smooth change towards a more heterogeneous environment since ca. 9500 <sup>14</sup>C BP and up to the Late Holocene, including a mosaic of shrubby steppes, open bare areas and large rocky outcrops. However, it is important to highlight that the basic signature (i.e., the codominance of *Ctenomys* sp., *Eligmodontia* spp., *M. australis*, and *P. xanthopygus*) of the small mammal assemblages of CH1 remained basically unchanged during the Pleistocene–Holocene transition and up to the Late Holocene.

Paleoecological research in CH1 is complemented by pollen analysis (being conducted by M. Eugenia de Porras, CEAZA, La Serena). Preliminary results (Pompei et al., in press) suggest that shrub and grass-shrub communities were present around the cave since 13,800 <sup>14</sup>C BP. Even though the pollen assemblages show no major plant community changes since then, some minor differences are evident. Between ca. 13,800 and 9500 <sup>14</sup>C BP the pollen assemblages point out the presence of a Patagonian grass-shrub steppe integrated by shrubs (*Schinus*, *Lycium*), dwarf shrubs (*Nassauvia*, *Ephedra*), and grasses which currently lies between 2000 and 2200 masl, well above CH1 (1100 m asl). This suggests local cooler conditions. The current conditions, with dominance of a Monte-Patagonian transition shrub steppe, were established during the last 1500 <sup>14</sup>C years.

A few kilometers west of CH1, under cooler and wetter conditions, recent assemblages are composed by several abrotichines (*A. longipilis*, *A. olivacea*, *C. macronyx*), as well as by high proportions of *E. chinchilloides* and *R. auritus*. In accordance with the preserved record, this faunal assemblage never reached CH1 vicinities; an expectable situation if cooling events had a major local ecological effect on the micro-mammal communities (Pardiñas and Teta, 2008). The general faunal stability of CH1 can be explained by two alternative but non-exclusional hypotheses: (1) the climate pulses experienced were not enough to trigger large modifications in the small mammal assemblage composition near CH1; (2) the fluvial valley environment which is very close to CH1 and the main foraging area for a raptor living inside the cave has a remarkable ecological resilience to environmental change. Larger samples are needed to refine the paleoecological perception of the CH1 area since the Late Pleistocene. However, the general faunal stability of CH1 is in agreement with the environmental stability inferred on the basis of pollen data from the segment 14,800–8900 <sup>14</sup>C BP of Mallín Vaca Lauquen (Markgraf et al., 2009), and also with preliminary data from rodent middens in Central Neuquén Province (Hofreiter et al., 2003). On the other hand, available micro-mammalian sequences for most of the Patagonian Holocene are remarkably stable, with minor changes in relative species abundance and short-distance distributional shifts (e.g., Pearson and Pearson, 1993; Pardiñas, 1998; Teta et al., 2005). Additionally, small mammals of CH1 do not reflect the occurrence of the Huelmo/Mascardi Cold Reversal (HMCR) (Hajdas et al., 2003). The HMCR is broadly coincident with an erosive unconformity recorded at CH1 that is bracketed between the ages of 11,800 and 9500 <sup>14</sup>C BP (Barberena et al., 2010).

## 5.3. Archaeological record and human occupational history

The first undoubted human presence at CH1 occurred in the Early Holocene, established indicated by a radiocarbon date on charcoal from a hearth (9531 ± 39 <sup>14</sup>C BP). Integrating the

taphonomic evidences presented here, humans were not involved to any extent in the deposition of the Late Pleistocene small mammal assemblage. The Early Holocene archaeological context suggests a very brief human use of the cave, in coincidence with the peak recorded for the abundance of carnivore scats. This is likely associated with an instance of human exploration of the region (sensu Borrero, 1999) and broadly coincident with the data available for northern Patagonia east of the Andes, clustering right after 10,000 <sup>14</sup>C BP. This includes sites located in the steppe (Cueva Epullán Grande in Neuquén and Arroyo Malo 3 in southern Mendoza), and in the forest-steppe ecotone (Cueva Trafal and Cuyín Manzano sites, both in southern Neuquén) (Ceballos, 1982; Crivelli Montero et al., 1993, 1996; Diéguez and Neme, 2003; Cordero, 2010, in press).

The supra regional dataset shows a brief temporal pulse in the Early Holocene during which human occupations are first recorded at a number of distant places. This can be explained as human radiation to ecologically marginal regions from areas that were colonized earlier (probably associated with the local establishment of a more heterogeneous environment than was characteristic of the Early Holocene as shown by the CH1 small mammals record).

More dates are needed in order to assess the archaeological signature of the Middle Holocene in CH1, as in northern Neuquén as a whole. This is a key period characterized by persistently arid conditions and low human demographics in neighbor regions (Neme and Gil, 2009). Finally, the Late Holocene layers at CH1 denote recurrent human occupations, although in a discontinuous fashion, in compass with an effective occupation of the region (sensu Borrero, 1999, 2005). Nonetheless, Cueva Huenul 1 and the region as a whole may have occupied a marginal position within human home ranges, such as suggested for the Payunia volcanic field in southern Mendoza (Gil, 2006). Small mammal remains are relatively abundant in these layers, while carnivore scats are not, probably indicating a difference in the use of the cave by avian and mammal predators.

## 6. Conclusions

Taphonomic analysis indicates that the assemblage from CH1 is an archaeofaunistic owl pellet accumulation showing a good post-depositional preservation and rapid incorporation in the sedimentary matrix, although previously exposed to trampling action. CH1 is one of the few sites where the Pleistocene–Holocene transition is represented by faunal evidence. Despite sample size limitations, the studied small mammal assemblages display only smooth changes towards a more heterogeneous and perhaps drier environment during the Late Holocene.

The paleoecological data presented provides a necessary context for archaeological investigations studying the past geographic distribution and subsistence of mobile human societies. The taphonomic analysis presented allows suggesting a largely natural deposition of the small mammal remains, contributing to assess the dietary breadth of northern Patagonian hunter-gatherer populations. In the near future, this research will be expanded by the palynological and paleobotanical study of rodent middens (cf., Hofreiter et al., 2003; Latorre et al., 2006), providing an unexplored local record of the paleoecological history of northern Neuquén.

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