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Taphonomic and archeological aspects of massive mortality processes in guanaco (*Lama guanicoe*) caused by winter stress in Southern Patagonia

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Abstract

The taphonomic and archeological implications of massive mortality patterns of guanaco (*Lama guanicoe*) populations due to winter stress are discussed, considering both local and regional scales. The presentation has its focus in the Lake Cardiel basin, Southern Patagonia, Argentina. Winter stress is not an unusual event in Patagonian ecosystems and it produces a seasonal and predictable output: a huge number of dead guanacos in certain loci.

Five faunal assemblages formed in 2000 are discussed, three in rock shelters and two at open-air settings, considering guanaco individuals/bone preservation, age and sex structure, death positions, degree of interment, carnivore damages, trampling marks, and the association between guanaco individuals/bones and archeological material (mainly lithic artifacts). Conditions exist for the commingling of naturally formed guanaco bone assemblages and archeological materials. The taphonomic signature of this mortality pattern is analysed, and criteria developed that allow identification of the potential mixture between archeological material and modern guanaco bones. From an archeological point of view, the potential scavenging opportunities brought by these guanaco mortality events to hunter-gatherer populations are explored.

In sum, the results of this study are twofold. First, it brings new data on the regional taphonomy of guanacos and its implications for the archeological record. Second, it invites consideration of these mass mortality events in the context of strategies employed by hunter-gatherer populations to cope with their environment.

1. Introduction

The study of bone assemblages generated by mass mortality processes, among which are those caused by winter stress, has a great tradition in taphonomic literature since the beginning of this discipline (Weigelt, 1989). At the same time different research works have examined winter stress mortality in several species of mammals, such as pronghorn antelope (*Antilocapra americana*) (Martinka, 1967), wild horses (*Equus caballus*) (Berger, 1983) and Tibet antelope (*Pantholops hodgsoni*) (Schaller and Jun-rang, 1988).

Intense snowfalls in Patagonia generate important mortality events in guanaco (*Lama guanicoe*). Given the fact that these ungulates have been the main prey for hunter-gatherer populations (Borrero, 1990; Mengoni Goñalons, 1995) it is relevant to study and discuss the mortality caused by winter stress as a process that generates a synchronic deposit of a high frequency of guanaco carcasses at a regional range. This interest has at least two aspects that will be dealt with in this work: first, the taphonomic aspect, related to the information about potential commingle of archeological sites due to the natural bone deposition that this kind of mortality causes and the paleoecological information provided by their characteristics, and the second, archeological, related to the potential scavenging niche that it offers to human populations.

Five faunal assemblages are discussed in this research work. They were deposited in two different situations, both related to a catastrophic mortality episode of guanacos caused by winter stress in the year 2000 in the Cardiel Lake

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basin, province of Santa Cruz, Patagonia Argentina. Three of these assemblages have been formed under the protection of rockshelters and two in the open air.

The discussion focuses on the different signature that this kind of events generate from other processes and agents that are capable of causing guanaco carcass accumulations; the preservation potential of the different deposit situations; the potential mixture with archeological remains; the possibilities of burial; and the ecologic conditions that promote the probability of this kind of mortality event to take place. The hunter-gatherer populations profit from these deaths at a low cost and risk (Borrero et al., 2005). The dead animals usually show good physical condition (Cajal and Ojeda, 1994). The deposit follows a pattern in space and the event happens under strict seasonal conditions. All the above-mentioned characteristics illustrate the importance of the deaths caused by winter stress in terms of the generation of a scavenging niche.

2. Mortality of guanacos caused by winter stress in Patagonia

The most commonly mentioned causes of death among the South American camelids are predation, hunting, diseases, drought, accidents, lightning bolts and winter stress. Several authors identify winter stress as an important cause of fluctuation in guanaco populations (Raedeke, 1976; Merino and Cajal, 1993; Cajal and Ojeda, 1994; Borrero, 2001). Judging by the literature of voyagers and explorers that traveled across Patagonia at the end of XIXth century and the beginning of the XXth, episodes of catastrophic guanaco mortality take place very often. There are references to these episodes in Casamiquela (1983), Darwin (1951), Fitz Roy (1839), González (1965), Hatcher (2003), Madsen (1998), Moreno (1969), Musters (1997) and Prichard (2003).

The ecological conditions capable of generating these assemblages are the result of normal parameters in southern Patagonia ecosystems. These episodes of mass mortality are not exceptional, as in years of severe winters thousands of animals die. Thus, heterogeneity and unpredictability are characteristics that define the weather of southern Patagonia (Endlicher and Santana Aguila, 1997, 1988; Sturzenbaum and Borrelli, 2001). The characteristic of the tropic chains in the area is a low diversity of species in each microenvironment (Pisano, 1989–1990), according to the ecological expectancy that predicts the decrease in biodiversity with the increase in latitude, better known as the Rapoport Rule (Dynesius and Jansson, 2000; Sax 2001). This low diversity has, as a consequence, a low functional redundancy (*sensu* Waide et al., 1999): the available niches are occupied by one or at the most two species. One implication of this is that any fluctuation in one specie's productivity has an amplified effect in the whole ecosystem (Pisano, 1989–1990). The oscillations in vegetation productivity are reflected in animal populations. So, the region's carrying capacity may vary enormously from year to year. There are two factors that cause fluctuations in the ungulate populations. On one side the quality of summer pastures, regulated by winter and spring precipitation that, in case of not being the optimum, contributes to a low winter survival and a larger predisposition to parasitism and disease (Sturzenbaum and Borrelli, 2001), and, on the other side, reduced winter forage. Long drought periods, very common in the study area (Endlicher and Santana Aguila, 1988), generate proper conditions for this kind of phenomena. Finally, the amount and quality of winter forage, even without fluctuations in summer pastures, affects certain parameters of population productivity, such as age of maturity, conception and survival of the young animals, average longevity, and resistance to disease, parasites and predators. It has been observed that, in the case of guanaco, the mortality conditions of the young are higher during the first 7 months of life, and that in winter mortality increases 6% approximately with every centimeter of fallen snow (Sarno et al., 1999, p. 937). Censuses carried out in different environments of Tierra del Fuego after a winter with heavy snowfalls (1995) have calculated almost 26% mortality associated with these extreme climatic factors (Montes et al., 2000).

3. Population structure of guanaco

The guanaco is a generalist herbivore, basically a grazer but it can also browse according to the available food and the time of the year. It lives mostly in open places, occupying areas of steppe or prairie, even though it can make use of the forest habitat (Cajal and Ojeda, 1994; Montes et al., 2000; Borrero, 2001). Its behavior may be described as seasonally territorial, though with exceptions related mainly to zones with water availability (Casamiquela, 1983; Oporto, 1983).

In wild populations of guanacos, three basic structures may be noticed: family groups, male groups and solitary individuals. The first are composed of an old male with females and young. These young are closely associated to their mothers and stay in the group until they reach the age of 10–15 months (Franklin, 1983). These family groups have a clear hierarchical order in which the male (the so-called "relincho") shows attitudes of dominance over females and young. These groups, in general, are made of a varied number of animals (5–13 members), with an average of 8.2 individuals (Puig and Videla, 1995). In male groups, the age range is wider, there is not a clear leadership behavior, and relationships of dependence between old and juvenile animals have not been observed. The size of male groups is slightly larger than the one studied for the family groups (7–20 individuals), with an average of 10 animals (Puig and Videla, 1995). Finally, the solitary individuals have been described as physically mature animals that show the impulse to join others (Oporto, 1983).

There are other structures described in some populations: family groups without males and mixed groups. In the case of family groups without males, they might be juvenile or old females with or without young that leave their territory probably due to the expulsion of the juveniles by the leader (''relincho''). All the authors that have identified this kind of groups (Franklin, 1982; Merino, 1988; Merino and Cajal, 1993) point out that they are not permanent, because they end up joining an existing family group or making a new one when joining a solitary male; they would be transitional social structures from their territory to the mixed groups and vice versa. The average of these groups is 2.6 animals (Puig and Videla, 1995). The mixed groups consist of additions of several kinds of social groups that are formed towards the end of autumn and migrate towards the winter areas, separating again when reproduction time approaches. The available estimates for mixed groups vary between 38.7 and 25.3 individuals (Puig and Videla, 1995). Table 1 summarizes the information available about the age structure of different guanaco populations and compares it with the age groups represented in the sites analyzed in this research work.

4. Faunal assemblages: methodology and description

Five faunal assemblages were surveyed: three formed under rockshelters and two in the open air. All were found on the west bank of Cardiel Lake, in the area called ''Cañadones'' (Goñi et al., 2004). This setting is distinguished by wide sandstone canyons that belong to the Cardiel Lake Formation (Ramos, 1982) that have allowed the formation of several rockshelters in a restricted area (Fig. 1). The earliest radiocarbon dating of the basin comes

Table 1
Age structure of guanaco populations studied (percentages considering young + juvenile and adult) (modified from Saba et al., 1995)

Locality/site	Young (%)	Juvenile + adult (%)	Author
La Payunia (Mendoza, Argentina)	21.4	78.6	Puig (1986)
Collón Curá (Neuquén, Argentina)	29.7	70.3	Gader and Del Valle (1982)
Ea. Don Carlos (Chubut, Argentina)	7.8	92.2	de Lamo et al. (1982)
Ea. Don Carlos (Chubut, Argentina)	6.8	93.2	Saba (1987)
Península Mitre (Tierra del Fuego, Argentina)	10	90	Merino and Cajal (1993)
Zona Central (Tierra del Fuego, Argentina)	16.7	83.3	Bonino (1988)
Los Guanacos 1 site (Santa Cruz, Argentina)	19.44	80.54	Rindel and Belardi (2006)
La Encajada site (Santa Cruz, Argentina)	9.09	90.9	In this paper
Olivero site (Santa Cruz, Argentina)	12.12	87.87	In this paper
Los Guanacos 3 site (Santa Cruz, Argentina)	27.58	72.41	In this paper
Los Guanacos 4 site (Santa Cruz, Argentina)	35.71	64.28	In this paper

Ea.: estancia (farm).

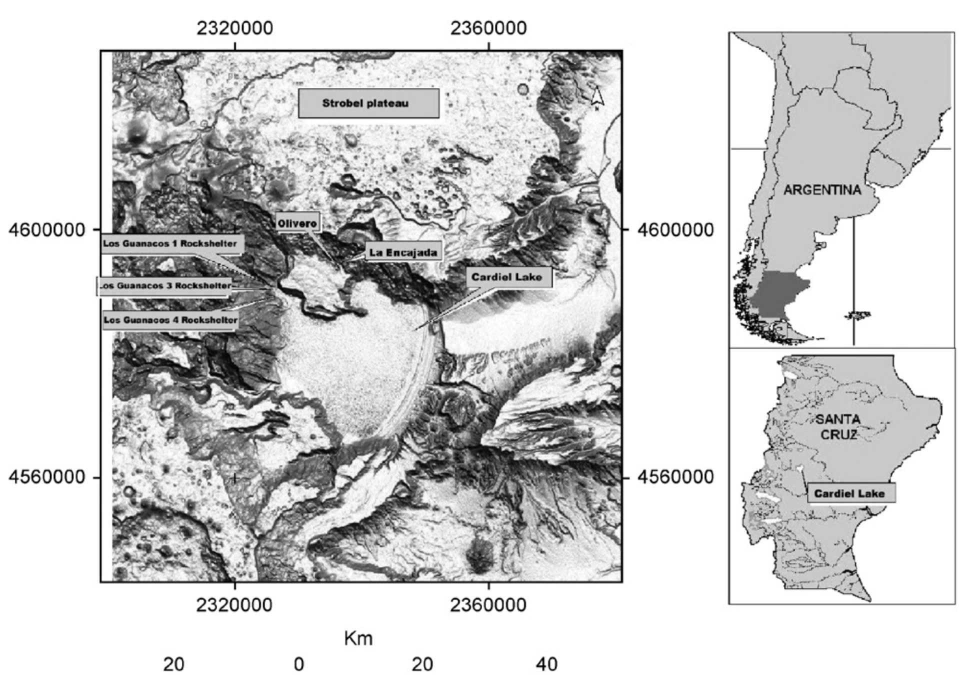

Fig. 1. Location of the sites referred in the text.

from Manuk 1 rockshelter (6790 ± 40 years BP) and El León rockshelter (6550 ± 40 years BP) (Goñi et al., 2004).

Arturo Olivero, an employee at "La Carlina" farm, knew those guanaco assemblages and pointed out that they were formed during the intense snowfalls of 2000. The "Alero Los Guanacos 1" has already been studied in detail (Rindel and Belardi, 2006), so the information provided by the other assemblages completes and enlarges the previous research. All the taphonomic assemblages overlie archeological material, being directly relevant to evaluate the degree of contamination of the archeological record by a natural bone deposition.

The surfaces were measured in the survey of the assemblages and sketches were made on millimetric paper. Photographs of the different individuals were also taken. The following variables were taken into account: state of preservation, age category, position at death, burying degree, articulation degree, carnivore activity, trampling, and the association between individuals and lithic artifacts. When it was possible to recognize different groups of carcasses within one assemblage, were noted down. Additional notes were taken about the general orientation of the assemblage, characteristics of the rockshelter sediments, and the presence of bones previously deposited in the site (on the basis of differential weathering stages comparative to the concentration considered). The state of preservation was estimated on the basis of the presence of fur, tissues, stomach contents and weathering stage in articulated carcasses. If there were not any modifications observed, the category "Excellent" was assigned, if element exposure was not over 25%, "Very Good"; between 26% and 50%: "Good"; between 51% and 75%: "Regular" and if the exposure was over 75% "Bad". Bone exposure degree was selected as a proxy to the preservation state of the carcasses as it is expected that the better visibility of the elements corresponds to a lower percentage of fur and, therefore, more possibilities of soft tissue decay.

Age and sex data of the individuals were estimated taking into account the criteria formulated by Raedeke (1976): the age of the animals was defined on the basis of the general size of the carcasses, the stage of fusion of long bones, the scapula, pelvis and the skull, and the dental eruption pattern. On the basis of these criteria, three age groups were defined: young, juvenile and adult. In the case of the young, the size of the carcasses, the presence of coracoids of the scapula and isquium–ilium–pubis of the pelvis not fused (Kaufmann, 2004) and the absence of the second and third molars (Raedeke, 1976), inferred that they were younger than 1-year-old. Those animals that showed non-fused long bones were considered juveniles. This process is complete in guanacos between 30 and 45 months of age (Kaufmann, 2004). Similarly, these animals showed no eruption of the third molar or an incomplete one (Raedeke, 1976). Finally, the adult category includes animals with complete fusion and in which the process of teeth eruption was complete. Sex was estimated according to the canine index (always measuring the mouth size) and the presence of suspensories tuberosities in the case of males.

It was possible to observe the position at death of most individuals in all the assemblages of the shelters. At the open-air sites, this characterization was not possible because of the great disarticulation of the skeletal remains. Lastly the assemblages are compared on the basis of the different variable values, aiming to evaluate the existence of patterns that allow characterization of the guanaco assemblages caused by winter stress. Table 2 describes the location, area and frequency of individuals in each assemblage.

4.1. Rockshelter locations (Fig. 1)

4.1.1. Alero Los Guanacos 1

The wall that forms the rockshelter faces northwest, and in some areas it has an overhang that provides some protection against rain and snow. The animals were found gathered against the wall of the rockshelter, distributed along a strip approximately 50 m long by 6 m wide. In February 2005, 36 guanaco carcasses were found. The remains of at least 16 more animals were also found in the contiguous wall. The assemblage faces northwest. The distribution of the carcasses is uneven, generally separated by vegetation and topographic characteristics of the rockshelter, like boulders and "steps" in the ground, generating contiguous groups of deaths. On the talus of the site, a large amount of archeological material was found on the surface: flakes, side scrapers, grinding stones and stone bolas preforms.

Lastly, a sample of bones that showed a particular fracture pattern indicating trampling was taken to be analyzed in the laboratory. As the presence of disarticulated bones was observed against the rockshelter wall, these

Table 2
Site, area and frequency of individuals in each assemblage

Assemblages	Location	Area (m^2)	Frequency of individuals
Los Guanacos 1: 48°48′42.4″S, 71°23′39.1″W	Rockshelter	300	36
Los Guanacos 3: 48°49′06″S, 71°24′25″W	Rockshelter	360	29
Los Guanacos 4: 48°49.359′S, 71°23.495′W	Rockshelter	56	15
Olivero: 48°47′24″S, 71°14′53″W	Open air	3514.5	33
La Encajada: 18°47′12″S, 71°14′39″W	Open air	994.5	11

Table 3
Los Guanacos 1 rockshelter: characteristics of the faunal assemblage

Individual	Age	Preservation	Burying	Death position	Articulated	Carnivore traces	Association among individuals	Artifact association
1	Juvenile	Very good	No	Lying	Yes	No	No	No
2	Juvenile	Very good	No	Sitting	Yes	No	No	Yes
3	Adult	Very good	No	Lying	Yes	No	No	Yes
4	Adult	Regular	No	Lying	No	Yes	No	No
5	Adult	Very good	No	Sitting	Yes	No	No	Yes
6	Juvenile	Good	No	Sitting	No	No	Yes	No
7	Adult	Very good	No	Sitting	Yes	No	Yes	No
8	Adult	Very good	No	Sitting	Yes	No	Yes	No
9	Juvenile	Very good	No	Lying	Yes	No	Yes	No
10	Young	Very good	No	Sitting	Yes	No	No	No
11	Juvenile	Very good	No	Sitting	Yes	No	No	No
12	Adult	Bad	No	–	No	Yes	No	No
13	Juvenile	Excellent	Yes	Lying	Yes	No	No	No
14	Adult	Good	No	–	No	Yes	No	No
15	Juvenile	Very good	Yes	Lying	Yes	No	No	Yes
16	Juvenile	Very good	No	Sitting	Yes	No	Yes	No
17	Adult	Very good	No	Sitting	Yes	No	Yes	No
18	Juvenile	Very good	No	Lying	Yes	No	Yes	No
19	Adult	Very good	Yes	Sitting	Yes	No	Yes	No
20	Young	Very good	No	Lying	Yes	No	Yes	No
21	Juvenile	Very good	No	Sitting	Yes	No	Yes	No
22	Young	Good	No	Lying	Yes	No	No	No
23	Juvenile	Good	No	Lying	Yes	No	No	No
24	Adult	Good	No	Sitting	Yes	No	No	Yes
25	Juvenile	Very good	No	Lying	Yes	No	Yes	No
26	Adult	Excellent	No	Sitting	Yes	No	Yes	No
27	Young	Excellent	No	Sitting	Yes	No	No	No
28	Juvenile	Very good	No	Lying	Yes	No	Yes	No
29	Adult	Excellent	No	Sitting	Yes	No	Yes	No
30	Adult	Excellent	No	Sitting	Yes	No	No	No
31	Juvenile	Good	No	Lying	Yes	No	No	No
32	Juvenile	Very good	No	Lying	Yes	No	Yes	No
33	Young	Good	No	Lying	No	No	Yes	No
34	Young	Very good	No	Lying	Yes	No	Yes	No
35	Adult	Very good	No	Sitting	Yes	No	Yes	No
36	Adult	Very good	No	Lying	Yes	No	No	No

Taken from Rindel and Belardi (2006, Table 2).

were surveyed along an 8 m length. Table 3 summarizes the registered information.

4.1.2. *Alero Los Guanacos 3*

This rockshelter is formed by a wall with a northeast–southwest orientation (parallel to Los Guanacos 1 site) and it has extensive vegetation coverage, mainly "molle" (*Schinus polygamus*) in the front area. The site is between 500 and 700 m south of Los Guanacos 1. The height is 510 masl. A large concentration of dead guanacos was observed (Table 4 and Fig. 2, upper left). They showed a better preservation and a higher concentration than at Los Guanacos 1. This rockshelter offers a better protection in certain areas due to the presence of a wider roof, and it is in those sheltered areas where the guanacos showed a better preservation. The guanaco concentration is 36 m long by 10 m wide. Transects show a high artefactual density ($0.7\,m^2$) with a regular distribution, so over time mixing with taphonomic bones could result.

4.1.3. *Alero Los Guanacos 4*

The site is located at the beginning of the canyon that is parallel to Los Guanacos 1, behind Ea. Cerro Bayo, at 385 masl. This canyon is approximately 400 m long, and the carcasses of 31 animals were observed along it. However, only the concentration found in a rockshelter at the beginning was analyzed in detail, because it shows the largest density of individuals (Table 5).

The extension of this rockshelter is approximately 19 m long by 3 m wide. Towards the bottom of the canyon there is an extensive slope in which bones of former dead animals (there are remains of guanaco and sheep with different weathering stages from those of the assemblages), and a few lithic artifacts were found. This rockshelter faces west, as do Alero Los Guanacos 1 and 3. Lithic artifacts in a very low density were observed in the animal's concentration zone (the flat surface close to the wall of the rockshelter) and mainly on the talus. A large amount of boulders fallen from the roof of the rockshelter was considered as a limit of

Table 4
Los Guanacos 3 rockshelter: characteristics of the faunal assemblage

Individual	Age	Preservation	Burying	Death position	Articulated	Carnivore traces	Association among individuals	Artifact association
1	Juvenile	Regular	Yes	Lying	Yes	No	Yes	Yes
2	Juvenile	Regular	Yes	Sitting	Yes	No	Yes	Yes
3	Young	Good	No	Lying	Yes	No	Yes	Yes
4	Young	Very good	No	Lying	Yes	No	Yes	Yes
5	Adult	Very good	No	Lying	Yes	No	Yes	Yes
6	Adult	Excellent	No	Lying	Yes	No	Yes	Yes
7	Adult	Excellent	No	Sitting	Yes	No	Yes	Yes
8	Juvenile	Excellent	Yes	Sitting	Yes	No	Yes	Yes
9	Adult	Excellent	No	Sitting	Yes	No	No	Yes
10	Adult	Good	No	Lying	Yes	No	Yes	Yes
11	Young	Excellent	No	Sitting	Yes	No	Yes	Yes
12	Adult	Very good	No	Lying	Yes	No	Yes	Yes
13	Adult	Very good	No	Sitting	Yes	No	Yes	Yes
14	Adult	Very good	No	Lying	Yes	No	No	Yes
15	Juvenile	Good	No	Lying	Yes (no hind limbs)	No	No	Yes
16	Adult	Very good	Yes	Lying	Yes	No	No	Yes
17	Young	Very good	No	Lying	Yes (no skull)	No	Yes	Yes
18	Young	Good	Yes	Lying	Yes (no skull)	No	Yes	Yes
19	Adult	Excellent	No	Lying	Yes	No	Yes	Yes
20	Adult	Excellent	No	Lying	Yes	No	Yes	Yes
21	Adult	Excellent	No	Sitting	Yes (no skull)	No	Yes	Yes
22	Young	Excellent	Yes	Lying	Yes	No	No	Yes
23	Adult	Excellent	No	Sitting	Yes	No	Yes	Yes
24	Adult	Excellent	No	Sitting	Yes	No	Yes	Yes
25	Adult	Excellent	No	Lying	Yes	No	Yes	Yes
26	Adult	Excellent	Yes	Lying	Yes	No	Yes	Yes
27	Young	Very good	No	Lying	Yes	No	Yes	Yes
28	Young	Regular	Yes	Lying	Yes	Yes	No	Yes
29	Adult	Bad	No	Lying	No	Yes	No	Yes

the assemblage. The rockshelter provides protection from rain and snow, and therefore the highest animal concentrations were there.

4.2. *Open air locations (Fig. 1)*

4.2.1. *Olivero*

A large amount of guanacos was found in this site, generally associated with "molles", which offer a certain degree of shelter. It is 54 m long by 66 m wide. This site is the highest point of the area (460 masl). It is evident that during the winter, the guanacos avoid the lower zones that accumulate snow and try to go to high places, where they finally die. This is similar to the case of the rockshelters. The site has a steep slope, approximately 45° in a south–north direction.

The preservation of animals in this site, comparing to the rockshelters, is poor. Most of the animals have not retained fur. The rate of disarticulation was faster than in the rockshelters, making it very difficult or impossible to survey and analyzed individual carcasses. The steep slope also contributes to make the process faster, favoring the migration of bones to lower parts of the site. The exceptions to this fur destruction process followed by a fast disarticulation of the skeletal elements are related to carcasses associated to vegetation ("molles" seems to act as an efficient barrier against carcass dispersion). Only seven carcasses had fur and were articulated. The number of individuals was estimated from the skulls. The information about the analyzed variables is shown in a qualitative way, due to the difficulties to survey individual carcasses.

Weathering and action of carnivores: Weathering profiles for most of the exposed elements are not over stage 1. Carnivore damage is low. As in the rockshelters, damages are found in the spine (transverse process), ribs, pelvis and front limbs, especially in the humerus. Scavenging evidence was also found in canid remains. This might suggest that in open air sites, the degree of competition between carnivores was higher than that of the rockshelters.

Disarticulation and burying: The pattern of disarticulation is similar to the one found for other ungulates (Hill 1980; Binford 1981; Borrero 1988; Nasti 1994–1995) and to the one found in the rockshelters. The skull appears loose or with the cervical vertebrae associated, especially if there

Fig. 2. Upper left: preservation and association degree between individuals (Los Guanacos 3 rockshelter). Upper right: Disarticulation degree and weathering stages in open air sites (La Encajada site). Bottom left: Association among individuals and carcasses preservation in open-air sites (Olivero site). Bottom right: Burying degree (Los Guanacos 4 rockshelter).

is fur associated, that keeps the different bones together. The fore limbs appear disarticulated more often than the hind limbs, showing the difference in the resistance to dislodgment of the scapula–humeral joint as compared with the pelvic–femur one. The last elements that stay together are the thoracic–lumbar–sacrum–pelvis vertebrae. Conditions for the internment of bones are not good. There is not a mechanism that is capable of producing the burying of materials. Trampling could be a favorable factor, but it would help bury only the smaller bones, being improbable that it contributes to the burying of big portions of a carcass.

Association with artifacts and association between individuals: Abundant archeological material (0.20 m^2) on surface was observed associated to guanaco bones. The process of crawling affects both of them. Another interesting aspect is that there are burnt bones. It was not possible to determine if this was due to a natural process of vegetation fire or if it was due to anthropogenic factors. The general distribution of the bones and animals appears as dispersed over the space. When it was possible to identify association between individuals, they were groups of no more than three carcasses. Big ‘‘molle’’ bushes are the places that seem to have been ‘‘animal concentrators’’. Table 6 summarizes the information of the site.

4.2.2. La Encajada

The site is found on a small hill (460 masl), 400 m north of Olivero site approximately and has an orientation northwest–southeast. The dispersion surface of this site is 39 m wide by 25.5 m long.

The process of fur loss and disarticulation of the individuals at La Encajada is even more extreme than in Olivero. The main bone remains concentration area is again a big size ‘‘molle’’ (4 m^2), which also concentrates

Table 5
Los Guanacos 4 rockshelter: characteristics of the faunal assemblage

Individual	Age	Preservation	Burying	Death position	Articulated	Carnivore traces	Association among individuals	Artifact association
1	Young	Good	No	Lying	Yes (no skull)	No	Yes	No
2	Juvenile	Very good	No	Lying	Yes (no skull)	No	Yes	No
3	Juvenile	Very good	No	Lying	Yes	No	Yes	No
4	Adult	Very good	No	Lying	Yes	No	Yes	No
5	Juvenile	Good	Yes	Lying	Yes	No	Yes	No
6	Adult	Very good	No	Lying	Yes	Yes	Yes	No
7	Young	Regular	Yes	Lying	Yes	Yes	Yes	No
8	Adult	Very good	No	Sitting	Yes	Yes	Yes	No
9	–	Very good	Yes	Sitting	Yes	No	Yes	No
10	Young	Very good	Yes	Lying	Yes (no skull)	No	Yes	No
11	Young	Excellent	No	Lying	Yes	No	Yes	No
12	Adult	Good	No	Lying	Yes	No	Yes	No
13	Juvenile	Excellent	No	Lying	Yes	No	Yes	No
14	Young	Regular	No	Lying	No	Yes	No	No
15	Adult	Very good	No	Lying	Yes	No	No	No

Table 6
Olivero and La Encajada sites: characteristics of the faunal assemblages

Site	Individuals frequency	Age	Preservation	Burying	Death position	Articulated	Carnivore traces	Association among individuals	Artifact association
Olivero	33	Young juvenile adult	Bad	No	71.42% of the articulated guanacos were sitting	No	Yes	Two groups of two guanacos + one group of three	Yes
La Encajada	15	Young juvenile adult	Bad. No furs	Yes	–	No. Just vertebrates	No	–	Yes

lithic material and burnt bones. From the "molle", the bones are more dispersed and disarticulated throughout the talus and the lagoon behind it. The MNI (11) was estimated from the number of skulls found. The age and sex of the individuals was determined, within the possibilities, according to the criteria explained for Olivero site. The analysis variables are shown in a qualitative way.

Weathering and action of carnivores: Most of the bones are scarcely weathered; not over stage 2. Damage caused by this agent was not observed.

Disarticulation and burying: The carcasses were almost completely disarticulated. The only exceptions were pieces of the spine, which agreed with other observations (Hill, 1980; Binford, 1981; Borrero, 1988; Nasti, 1994–1995) that say that this portion of the skeleton is the last to separate. Bones found furthest away from the main concentration are skulls, cervical vertebrae, scapulas, humeruses and radius–ulnas (those elements that separate sooner from the skeleton). As at Olivero, conditions for bone burial in La Encajada are not good. However, the main concentration area is an exception: bones are trapped by the vegetation and covered with sediments and dry leaves.

Association with artifacts and association between individuals: The highest densities of lithic material are found in front and behind a "molle" (0.7 m^2 compared with 0.46 for the whole area). Burnt bones were also found there. The observation that the area around the "molle" is the highest bone concentration seems to indicate that several animals died in close association. Table 6 summarizes the information.

5. Discussion

In Table 7, the comparison between the different surveyed variables in the assemblages is shown. The data are presented in a quantitative way for most variables, but this was not possible for some due to the characteristics of the assemblages, especially open air sites.

Animals belonging to all age categories were surveyed in all sites. The structure of the groups is very similar to that of living wild guanaco populations analyzed by other authors (Table 1). Remarkably, a wide predominance of the age category juvenile + adult is observed in all the sites. Considering sex, males and females were found. This allows rejection of the possibility that the animals surveyed

Table 7
Comparison of assemblages

	Assemblages				
	Rockshelters			Open air	
	Alero Los Guanacos 1	Alero Los Guanacos 3	Alero Los Guanacos 4	Olivero	La Encajada
Age					
Young (%)	19.44	27.58	35.71	12.12	9.09
Juvenile + adults (%)	80.54	72.41	64.28	87.87	90.9
Preservation					
Excellent (%)	13.88	44.82	13.33	0	0
Very good (%)	61.11	27.58	53.33	0	0
Good (%)	19.44	13.79	20	0	0
Regular (%)	2.77	10.34	13.33	24.24	0
Bad (%)	2.77	3.44	–	75.76	100
Burying (%)	8.33	27.58	26.66	0	0
Death position					
Lying (%)	50	72.41	86.66	28.58	Isolated bones
Sitting (%)	50	27.58	13.33	71.42	Isolated bones
Action of carnivores (%)	8.33	6.89	26.66	Yes	No
Association among individuals (%)	50	75.86	86.66	Low	Isolated bones
Artifact / individuals association (%)	13.88	100	Low	High	High

belong to male groups, and suggests that the analyzed assemblages belong to family groups or mixed groups that were gathered during the aggregative phase of the guanacos at the end of fall and beginning of the winter. Also, the age of the young, around 7 or 8 months, indicates that the probable death date of these animals was in June/July, at the beginning of the winter.

There are several factors that could help preservation: (a) environmental conditions of the study area, including low humidity average and high sun radiation, added to wind activity, that would speed up the evapotranspiration helping to mummify the tissues (Nasti, 1994–1995); (b) freezing and later thawing conditions of the tissues that would inhibit or slow down the rotting process to a great extent (Micozzi, 1986); (c) the environment in which they have been deposited itself. It is remarkable to notice that the differences in preservation between the rockshelters and the open-air sites (Table 7) seem to indicate that the protection that sheltered places provide, like rockshelters and caves, favors carcasses integrity. Here most of the animals have fur, hair, soft tissues and ligaments (Fig. 2, upper left and bottom right). It is also remarkable that there is variability among rockshelters themselves in relation to preservation: the sites where carcasses show a better preservation (for example Los Guanacos 3 rockshelter) are those that offer better protection. It is also important that the best-preserved carcasses within each shelter are those placed near the walls and/or under the roofs of the rockshelters; (d) a combination of the above-mentioned factors. No matter which of these or other factors has had more weight in explaining the high preservation degree of the animals in the sites, the final result is the same, as in all the cases it led to tissue mummification.

In some carcasses the only portions in which the bone is shown are: the facial area, the distal portions of the limbs (metapodials) and the pelvis area and the abdomen. The exposed bones appeared whitened and very slightly weathered (stage 1 *sensu* Behrensmeyer, 1978). This matches observations carried on in other environments, like the Puna (Nasti, 1994–1995) that indicate that fur protects bones from decay caused by weathering.

It is evident that the conditions of exposure to elements in open-air sites generate dramatic differences in the preservation state of the analyzed assemblages. One characteristic element is the scarce or non-existent fur preservation in the open-air sites. The process of disarticulation of the carcasses takes place at a much faster rate in the open-air sites (Fig. 2, upper right) and is also speeded up by the gradient of the slope where these sites are located. The exceptions to the fur destruction process followed by a fast disarticulation of skeletal elements are related to carcasses associated to vegetation (Fig. 2, bottom left). In this way, the presence of "molles" seems to act as an adequate barrier against carcasses dispersion. This is evident at Olivero site, where several animals were identified with fur, though in average more disarticulated than the guanacos observed in the rockshelters. Lastly, the weathering stages appeared very homogeneous in the bones that are found on surface and in very low stages in both cases.

Possibilities of burial in rockshelters are also different from those in open-air sites. In the first case, the carcasses lie on a ground made of fragments of the wall that forms the rockshelter and of a layer of sheep and guanaco dung. Isolated bones are also found, with advanced weathering stages that belong mainly to sheep and guanaco. Observations made in nearby regions such as Argentino Lake (Borrero, 2001) and the upper course of Chalía River indicate that dung layers accumulation inhibit the possibilities of bone interment to a great extent, as it seems to occur in the rockshelters. This is important, because before the introduction of sheep burial could have been faster. Apart from this factor, between 8% and 27.5% of the animals are in the process of burial (Table 7). Two important variables related to this process are the presence of vegetation and the existence of topographic features of the site including boulders and "steps" that facilitate the burial process (Fig. 2, bottom right). The process of fur loss and the disarticulation take place at a faster rate under open air. For this reason the possibilities of the carcasses to keep their integrity during burial are also low. The exceptions are situations in which vegetation acts as a trap for the carcasses, allowing preservation and burial of at least some of the articulated skeleton elements, particularly those segments which dispersion occurs later in the disarticulation sequence: spine, pelvis and sacrum. The conditions may be different in cases of mortality at open-air settings near water bodies where consecutive rises and drops of the water level may probably favor the burial and preservation of articulated bone remains. The guanaco assemblage at layer 2b of Ponsonby site, Magallanes, Chile (Lepetz et al., 2003) would be a case of these characteristics.

It is interesting to notice the continuous presence of isolated bones with different degrees of burial along the wall of the rockshelters. Rindel and Belardi (2006) pointed out that most of the bones found near the wall of the rockshelter belong to those parts of the body in which the fur is destroyed faster or in which the joint is weaker: skull and neck, front limbs and distal portions of the limbs.

The position at death was possible to be observed in most of the individuals of the assemblages deposited in rockshelters (Table 7). The animals were found mainly in two positions: reclined on their sides with their limbs stretched at the sides of their thoraxes ("lying" or in lateral reclining position, *sensu* Haynes, 1995) or resting on the abdominal area with their limbs bent under their bodies ("sitting" or in sternal reclining position *sensu* Clubb and Macdonald, 2004). Between 50% and 87% of the animals found in rockshelters were in lateral reclining position. The opposite tendency is observed at the Olivero site, where most of the animals that were articulated were in sternal reclining position. Probably these differences are related to the higher degree of protection from weather that the shelters provide. De Lamo (1995) has observed that heat loss due to strong wind exposure is reduced by 60% for the guanacos that adopt sitting positions, and also points out that the basal metabolic rate is 66% higher for a standing or slowly walking individual than for a lying one. This means that this position is normally adopted by animals to reduce energy demands associated with moving and heat loss by a forced convection of strong winds, as well as in strong stress moments. If this is the case, it would be expected, in less protected from wind and cold environments, the animals would more frequently adopt the sitting position rather than the lying one. Besides, 30% of the animals surveyed in the rockshelters approximately showed post-mortem contraction of the neck ligaments. This position has also been observed in wild camels (Haynes, 1995).

Traces of carnivores on guanaco carcasses were observed in four of the sites (Table 7). Damage was not severe, matching that caused by medium-size canids such as foxes or dogs and it affected adult, juvenile and young. The damage is usually found in ribs, pelvis and transverse and spinous processes of thoracic and lumbar vertebrae. It is also found in the upper parts of the limbs, such as scapula, proximal humerus and proximal femur. In some cases damages in the skull, especially the nasal area, were noted. The affected bones suggest an initial processing of the carcasses in which the carnivores are interested in the soft and easy access parts, such as the stomach and next, the front limbs (scapula–humerus joint) and back limbs (femur). In general, the carcasses in which this activity has been observed are those that showed a larger dispersion in space. This matches the observation that carnivore activity, even by small ones, when they take out pieces during feeding and/or when they expose individual bones and joints favors disarticulation and is an important variable that speeds up the separation process of a skeleton (Borrero, 1988; Mondini, 1995). Nevertheless, large modification of guanaco bones is not expected due to the small size of Patagonian carnivore scavengers (Borrero, 1988).

In the analyzed assemblages, several individuals appeared in close spatial association (Fig. 2, upper left). Most of these animals have their necks crossed and less commonly one individual's neck lies upon the body of another. Cases have also been observed in which one animal's body lies exactly on top of another one. In rockshelter Los Guanacos 3 for example, a high density of animals is observed, especially in the areas that offer better protection, near the wall and covered by the roof of the shelter. The animal density in this site is so high that it was not possible to count all the carcasses. Only minimal portions of certain bodies were able to be seen, because they were almost completely covered by other individuals. Of all the subassemblages surveyed, most have two or three individuals. However, there are groups of up to five individuals close together. This association takes place between individuals of all age groups, though the young are part of the groups more often than the juveniles and adults. Furthermore, in rockshelters, the young are closer to the wall of the shelter than the adults, being generally the males those that are alone in the less sheltered places. Concerning the open-air sites, there is only data from Olivero site where two groups made of couples, and one group of three individuals was found (Fig. 2, bottom left). Apart from the smaller amount of individuals in each group, they are not so close together as in the rockshelters. A first element that should be taken into account in this aspect is the great dispersion in space of the open-air sites (see Table 1). Several authors have pointed out that in the case of humans the open air sites do not cover a reduced area like rockshelters and caves (Barton and Clark, 1993). This seems to be also the case of the open-air guanaco sites as compared with those of the rockshelters, given that the general distribution of bones and animals appears more dispersed. It is possible that the fact that the space is not constricted as in the rockshelters makes the animals spread more evenly.

Finally, as it was noticed all the surveyed sites show association with lithic artifacts in a lower or higher degree. In the case of the rockshelters, the big amount of archeological material is related to the degree of protection offered and the percentage of horizontal and stable surfaces that allows the development of human activities. The rockshelters Los Guanacos 1 and 3 for example, show extensive stable surfaces in which hunter-gatherer populations were able to carry out a wide range of activities. In the case of Los Guanacos 4, the flat surface from the wall of the rockshelter to the talus is very narrow, only 3 m, which would be related to the low frequency of archeological material found. The open-air sites are also associated with large amounts of archeological material. In both cases, the presence of archeological material shows the redundancy in the use of spaces by human and guanaco populations. On one side protected shelters and on the other high areas associated with water courses and that at least at present, are associated with the presence of ‘‘molles’’.

6. Conclusions

Taphonomic information was introduced derived from observations carried out in several rockshelters and open-air sites. These observations concern the guanaco mass mortality event caused by winter stress in the year 2000. The evidence indicating an event of synchronic death is: the relationship of spatial proximity between individuals, the presence of fur and stomach contents in all the carcasses surveyed, as well as similar weathering stages in the exposed areas of the bones. These last two characteristics show the high integrity of the assemblage even when the activity of carnivores and traces of trampling have been surveyed. Also, the age structure, the amount of animals and the spatial association between individuals suggest that several mixed groups or family groups died together.

The assemblages surveyed have some common characteristics with guanaco mortality processes caused by factors not related to catastrophic situations. Thus, many of the criteria defined by Borrero (1989) and L'Heureux and Borrero (2002) for the recognition of assemblages made by humans compared with those caused by other agents are pertinent in this case. The observations carried out here allow postulation of the following additional criteria for massive assemblages caused by winter stress, and even though none of these criteria is enough in itself to define that we are facing a mass mortality event, the presence of several of them in an assemblage should indicate this kind of situation:

(a) The presence of a great amount of animals of the same species in a site. This might indicate the existence of communal hunting. However, the bone assemblages made by human beings in Patagonia do not show evidence of this. On the contrary, the MNI surveyed in each case are low and show changing fragmentation indexes (Borrero, 1990; Mengoni Goñalons, 1995).
(b) A high degree of overlying of animals related to positions at death and the gathering of individuals due to the search for protection against cold.
(c) Presence of whole carcasses and/or a large amount of segments (limbs and axial skeleton) with a high degree of articulation.
(d) In the case of open-air sites a high frequency of bones of the axial skeleton (especially vertebrae) in anatomic position might indicate an event of these characteristics, as it has been observed that the last bones to come apart are those of the spine.
(e) Axial/appendicular proportion similar to the one observed in complete individuals or predominance of axial skeleton segments over the appendicular.
(f) High proportion of complete elements.
(g) A sex and age structure matching that of certain segments of a guanaco population such as mixed groups or family groups.

The high proportion of carcasses or elements with homogeneous weathering stages might constitute an additional criterion. However, a longer time of observation is required.

Which are the implications of the mortality event caused by winter stress as related to the archeology of reduced spaces like caves and rockshelters? It is evident that under certain stress conditions (harsh weather conditions, illness, old age, etc) the rockshelters are proper places for animals to die because they offer shelter. This process is even more remarkable in the study area, where there is a high number of rockshelters in a space of less than 50 km^2 (Fig. 1). Dead animals have been found in other sites of northwest Santa Cruz province, such as Alero Destacamento Guadaparque and Alero Dirección Obligatoria, in Perito Moreno National Park (Goñi, 1988). Furthermore, animal mortality is not limited to guanacos, as remains of sheep have been observed in several sites. On the other hand, as is evident in the case of the analyzed sites, animal mortality in this kind of sites offers a potential mixture with residues left by groups of humans that used the same sites before: this is remains of feeding as well as of artifacts (see Savanti et al., 2005 for rockshelters). The result of this catastrophic mortality is a true ‘‘bone rain’’ overlaying lithic artifacts and bones of different taxa previously deposited in a restricted space. The enumerated criteria indicates the taphonomic characteristic of the bone assemblage. This kind of situation has also been observed in other environments in Tierra del Fuego and continental Patagonia, indicating that they may be the norm more than the exception in the regional archeological record (Borrero, 1988, 2001; L'Heureux and Borrero, 2002).

Caves and rockshelters have complex and idiosyncratic depositional histories (Barton and Clark, 1993), implying that there is variability in the burial potential of the remains. In the case of the rockshelters, the presence of a thick layer of sheep dung inhibits burial to a great extent. This situation has implications only since the moment of introduction of the sheep. However, certain conditions including the presence of vegetation and topographic features of the rockshelters favor this process in localized places within the sites and their implications may be considered with a greater time depth. On the other hand, the disarticulated bones that are placed close to the wall of the shelter also have a high burial probability, because the presence of the wall makes them stay stable and because it is a space that acts like a sedimentary trap. This has also implications related to the *drop* and *toss* zones model (Binford, 1989), as in restricted spaces like the ones mentioned accumulations analogous to a ''*toss*'' zone may be formed without human intervention.

The possibilities of potential mixture and confusion between archeological remains and natural guanaco bones accumulation are not restricted to caves and rockshelters, as the data shown in this work demonstrate. In open-air sites, animal accumulations caused by mortality processes due to winter stress do not take place by chance: it is evident that the guanacos look for high areas free of snow and with vegetation to feed on and that provide some protection. In this case, the overlaying with archeological remains takes place because humans use these same spaces from which there is an easy access to water bodies that are natural means of circulation and/or may be used as look out points.

The importance of this massive mortality as related to the subsistence of the populations that had the guanaco as their main prey is evident and different in the short and the long term. In this way, severe winters generate available food without the need of hunting. In spite of what might be thought, in certain cases (late autumn/beginning of winter) most of the individuals that die of winter stress are in good physical condition. Cajal and Ojeda (1994) point out that 40% of the carcasses surveyed by them showed a normal degree of nutrition, 27% showed an intermediate degree and only 33% were badly nourished. Furthermore, animal mortality does not take place by chance in the space but in a few limited areas. Therefore, winter stress mortality is a seasonal repetitive phenomenon with a predictable spatial location, which turns it very interesting as a source of food through scavenging strategies. At the same time it is a low cost and low risk strategy (Borrero et al., 2005) that uses an immediate offer that appears at a regional scale. Besides, it must be taken into account that Neotropical areas are characterized by the presence of a reduced carnivore community, composed mostly of small species unable to remove great amounts of flesh and marrow from carcasses. So the competition for the resources is greatly reduced in this setting, making probable the appearing and maintenance of scavenging strategies. For these reasons, scavenging by hunter-gatherer populations would not only be expected at initial moments of peopling (Borrero et al., 2005) but could be systematically used through time, or at least until horses were introduced. This last point is suggested because, knowing the existence of winter stress and its magnitude (see Meltzer, 2003; Rockman and Steele, 2003), the possibility of leaving spaces as a response to risk would have been favored by speed, distance of displacement and the possibility of loading that the horse provides.

It has also been observed that the fluctuations caused by this climatic variability in the density and structure of the ungulates populations are deep in the long term. An event of this kind may affect the dynamics of a population for years (Martinka, 1967; Reimers, 1982; Berger, 1983; Schaller and Junrang, 1988; Dumbar et al., 1999, among others). This does not imply that guanaco populations do not recover or that human groups do not have strategies to face this kind of risk. Human populations use different mechanisms to cope with this kind of shortage of resources (see Halstead and O'Shea, 1989 and references therein). One classic strategy used is moving. In low areas like Cardiel Lake, a decrease in the animal biomass might reduce regional productivity to a great extent. This could be a determinant factor in the discontinuous use of the region by the hunter-gathered populations. At the same time any kind of increased climatic harshness, like the ''Little Ice Age'' (1340–1660 A.D.) (Villalba, 1994), would favor the occurrence of the stated conditions. This has implications that reach further than the study of a particular case, considering that the guanaco was the base of subsistence for hunter-gatherer groups in southern Patagonia.

It is evident that animal mortality due to winter stress must have shaped in the past, as it does today, the taphonomic landscape of environments characterized by a high seasonality and unpredictable climatic variations, as it is the case of southern Patagonia, the Andean area and semidesertic highlands in general (Cuyo and the Puna). This environmental risk would have brought with it a possible mitigation strategy for the hunter gatherer populations: the use of a wide offer of resources in the shape of scavenging.

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