

# Chapter 8

## Taphonomy of the Pilauco Site, Northwestern Chilean Patagonia



Rafael Labarca

**Abstract** Pilauco shows two distinct layers containing remains of Pleistocene mammals (PB-7 and PB-8). The site is spatially divided into two sectors, East (45 m<sup>2</sup>) and West (27 m<sup>2</sup>). The current study is centered in the Western sector, where the majority of the materials come from layer PB-7 (%NISP = 92.5). Overall, this layer does not show signs of weathering, exhibiting instead trampling marks, and in a lesser quantity, large carnivore tooth marks. The fragmentation level is low, particularly for the fossils of Gomphotheriidae, for which most of the fractures occurred when the fossils were not fresh. No human marks of any kind were identified. The impact of these distinct factors in the formation of the record of PB-7 was evaluated using the available data and concluded in an in situ death of a gomphothere, to which would have been added anatomical elements of other taxa, redeposited coluvially and/or through vertical migration as a result of trampling. Carnivores would have been primarily responsible for the alteration and possibly subtraction of skeletal remains; as of now there is no evidence of human impact in this process. The materials recovered in PB-8 layer could also have been deposited by colluvial processes, although the sample is very small to discuss the taphonomic processes that have occurred in this layer.

**Keywords** Taphonomy · Carnivore · Trampling · Tooth · Marks · Colluvial

### 8.1 Background

Taphonomy is the study of all of the processes through which living organisms pass during their transition from death to their incorporation into the fossil record (Lyman 1994). Particularly in late Pleistocene archeological sites, where the cultural imprint is sometimes weak and/or debatable, and where distinct formational agents

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M. Pino and G. A. Astorga (eds.), *Pilauco: A Late Pleistocene Archaeo-paleontological Site*, The Latin American Studies Book Series,  
[https://doi.org/10.1007/978-3-030-23918-3\\_8](https://doi.org/10.1007/978-3-030-23918-3_8)

123

are stratigraphically combined, taphonomical interpretations play a fundamental role (Borrero 2015; Martin 2013; López et al. 2016; Suárez et al. 2014, when referring to South American cases). Following the work of Gifford-González (1991), one of the objectives of this discipline is to precisely determine the post-depositional influences on a certain bone assemblage in order to ponder the agents that affect it and thus describe its depositional history.

The Pilauco site is not an exception to this. Since scientific work began at the site, it has been suggested that it has a complicated formational history, not only from a stratigraphic point of view, but also paleontological and archeological, due to the spatial association between fossil remains and human artifacts (Navarro-Harris et al. 2019). Additionally, the absolute dates obtained for the layer containing these associations, which although are more or less contemporary with the occupation of Monte Verde II (Dillehay 1997), are located in a chronological range that exceeds the Pleistocene-Holocene boundary by several millennia (Pino et al. 2013; see Chap. 3, this volume).

Despite the fact that a taphonomic study would allow for the identification of all the processes involved in the formation of a fossil association, the paleontological studies developed in Pilauco centered almost exclusively in taxonomically identification of the bone fossil assemblage (Recabarren et al. 2011; González et al. 2010, 2014; Labarca et al. 2013, 2014). The limited work that addressed taphonomic issues (e.g., Labarca et al. 2013, 2014) was carried out from the perspective of a single taxon, that is, only the description of marks on certain bones were considered. The relationship between the described assemblage and the remaining taxon, and how these are associated and spatially arranged in the sedimentary matrix, were not considered. However, these studies allowed the generation of a primary characterization of the taphonomic processes occurring on the site, where processes such as trampling, abrasion, and large carnivores would have apparently had an important role in the preservation of the site's fossil record.

## 8.2 Materials and Methods

The fossil materials comes from layers PB-7 and PB-8 in the western sector of the site ( $N = 81$ ), recovered during the campaigns of 2010 through 2017. The fossil assemblage from the Eastern sector of the site (excavated during 2007 and 2008) were not considered in the present research due to differences in registry methodologies. Nevertheless, some taphonomic characteristics observed in those assemblages will be used as comparisons. The fossil materials of rodents, camelids, equids, deers, and gomphotheres have already been taxonomically studied elsewhere (e.g., Labarca et al. 2013, 2014; Recabarren et al. 2014; see Chaps. 4, 5, and 7, this volume), so the assignments made previously were respected (Table 8.1). As such, only one coracoid of a bird from layer PB-7 and two specimens of artiodactyl from PB-8 were determined in this work, for which reference skeletons in the author's possession and general manuals of osteology were consulted (e.g., Baumel and Witmer 1993;

**Table 8.1** Taxonomic richness of the Pleistocene layers of the Pilauco site (sectors E and W). In accordance with the taxonomic assignments of González et al. (2010, 2014), Pino et al. (2013), Labarca et al. (2013), and Recabarren et al. (2014), see also Chaps. 5 and 7, this volume

Taxa	PB-7	PB-8
<i>Conepatus</i> sp.	–	X
<i>Pilosa</i> indet.	X	X
<i>Notiomastodon</i> aff. <i>N. platensis</i>	X	–
<i>Equus</i> ( <i>A.</i> ) <i>andium</i> / <i>Equus</i> sp.	X	X
cf. <i>Hemiauchenia paradoxa</i>	X	X
cf. <i>Pudu</i> sp.	–	X
Artiodactyla indet. <sup>a</sup>	–	X
<i>Myocastor</i> cf. <i>M. coypus</i>	–	X
<i>Loxodontomys micropus</i>	–	X
Anatidae indet. <sup>a</sup>	X	–
Birds indet.	–	X
N TAXA	5	8

<sup>a</sup>Assigned in this work

Smuts and Bezuidenhout 1987). Age of death of the specimens, was estimated considering epiphyseal fusion, eruption, and dental wear, according to Silver (1963), Kaufmann (2009), and Mothé et al. (2010). Sex estimation of gomphotheres remains was estimated considering a metric approximation. This assumes the existence of sexual dimorphism between males and females in the Gomphotheriidae family, similar to the dimorphism documented for living members of the order Proboscidea (Haynes 1991). In this regard, several authors (e.g., Haynes 1991; Mothé et al. 2010; Ferretti 2010; Tassy 1996) have made ethological, ecological, and biological connections between extinct and living proboscideans, including members of the family Gomphotheriidae (e.g., Mothé et al. 2010). Measurements of long bones of gomphotheres were taken following Ferretti (2010).

The quantification of the remains was expressed in terms of NISP (Number of Identified Specimens), MNE (Minimum Number of Elements), MNI (Minimum number of Individuals), and MAU (Minimum standardized Anatomical units) (Binford 1978; Grayson 1984; Lyman 2008, among others). The fragmentation of the assemblage was estimated according to the quotient between the NISP and the MNE (Lyman 1994).

Several taphonomic modifications were considered, observed using a stereoscopic magnifying glass with magnification up to 40x. These included (1) marks generated due to consumption by carnivores, following the nomenclature of Binford (1981) and Muñoz et al. (2008); (2) rodent teeth marks; (3) trampling marks, for which the characteristics proposed by Domínguez-Rodrigo et al. (2009, 2012) were followed; (4) marks left by imprints of roots (Lyman 1994); signs of weathering (Bherensmeyer 1978) and (5) anthropic modifications (basically cut marks, scraping marks and percussion marks, see Mengoni-Goñalons (1999) for general definitions).

The fractures were classified as fresh or not fresh based on the morphology of their edge and surface (Outram 2001), independent of their causal agent. With regard to fragmentation, a specimen was considered complete if at least 90% of the original specimen was represented. Modern marks and fractures, which have resulted from the reexposure of the materials and their subsequent handling, were not considered in the present study.

With respect to trampling, five specimens of *Notiomastodon* aff. *N. platensis* (MHMOP/PI/611/614/615/629y/630) were selected. A quantification of the total number of marks was carried out in an area of 20 × 10 cm, recording the section, depth, shape of the groove's sides, and presence/absence of certain morphological characteristics such as striation and micro-abrasion of each mark, in accordance with the proposal of Domínguez-Rodrigo et al. (2009, 2012).

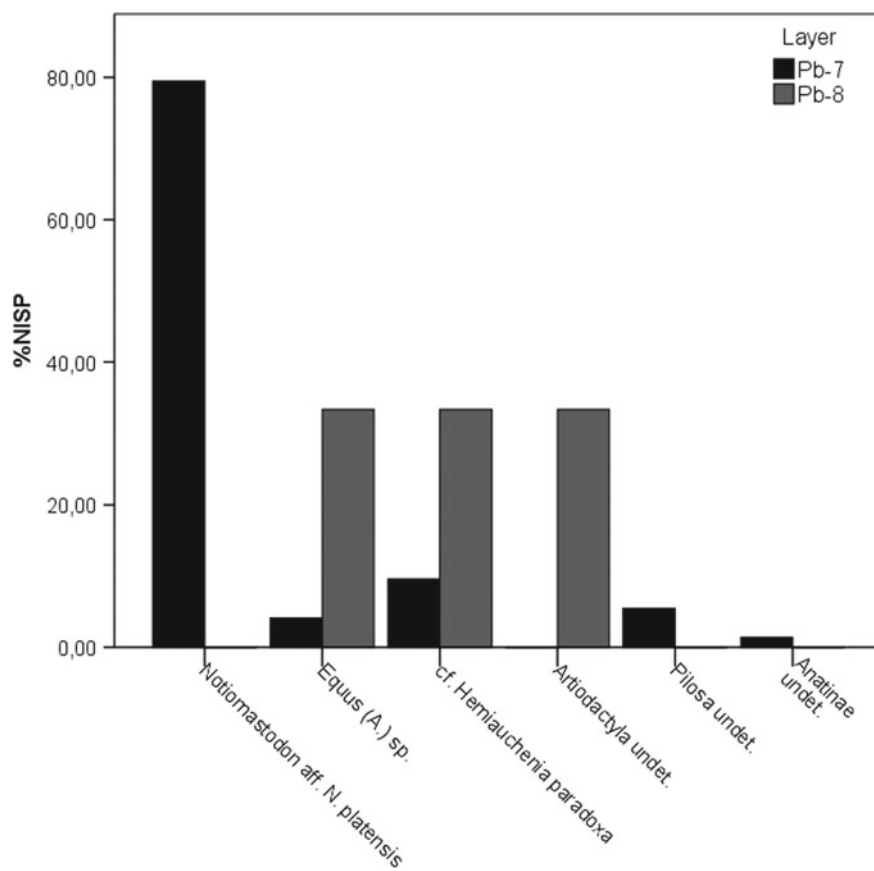
### 8.3 Taxonomic Richness and Abundance

Table 8.2 summarizes the absolute frequencies of the fossil remains per taxa in layers PB-7 and PB-8, sector W. The entire sample was taxonomically assigned at least at the order level (Labarca et al. 2013; Recabarren et al. 2014; see Chap. 5, this volume). As will be seen later, this is due to a practically complete absence of fragmentation. The vast majority of the remains identified were found in PB-7. Additionally, this layer showed the greatest taxonomic richness in this sector with a total of five taxa as compared to the three identified in layer PB-8 (Table 8.2). On this subject, Artiodactyla undet. was considered a different taxon other than cf. *H. paradoxa*, because the anatomical elements identified (portion of cervical vertebra and rib fragment) were smaller than the camelid bones recognized in the site. This assures the presence of a different taxon, not ruling out cf. *Pudu* sp., identified in the eastern sector, layer PB-8 (González et al. 2014). The values of the taxonomic richness of sector W contrast those reported for sector E, in which layer PB-8 shows the greatest number of identified taxa (PB-7 taxa number = 4; PB-8 taxa number = 8; Pino et al. 2013). Noteworthy here is the presence of four extant taxa (*Conepatus* sp., cf. *Pudu* sp., *Loxodontomys micropus* y *Myocastor* cf. *M. coypus*, Table 8.1). Evidently, despite being contiguous and belonging in the same layer, different depositional processes would have affected sectors E and W. Some differences in taphonomic alterations between the two sectors seem to confirm this impression (see below). In contrast, layer PB-7 does not vary greatly in terms of its taxonomic richness between the two sectors, only highlighting the presence of Anatinae undet. (portion of coracoid) in Sector W.

In PB-8, the few remains identified are distributed equally between equids, camelids, and indetermined artiodactyls, but the remains of gomphotheres are absent. In PB-7 however, the findings seem largely dominated by remains of proboscideans (%NISP = 79.5%), with many fewer representatives of specimens assigned to equids, camelids, and indetermined pilosans (Table 8.2; Fig. 8.1).

**Table 8.2** Absolute frequencies (NISP) of taxa identified in sector W of the Pilauco site

Taxa	PB-7 (lower)	PB-7 (upper)	PB-7 (total)	PB-8
<i>Notiomastodon</i> aff. <i>N. platensis</i>	60	0	60	0
<i>Equus</i> sp.	1	2	3	2
<i>Pilosa</i> undet.	2	2	4	0
cf. <i>Hemiauchenia paradoxa</i>	3	4	7	2
Artiodactyla undet.	0	0	0	2
Anatinae undet.	1	0	1	0
Total	67	8	75	6

**Fig. 8.1** Relative frequency (%NISP) of identified taxa per layer in Pilauco's sector W

Through the study of the vertical deposition of the fossil remains within layer PB-7, two depositional events were identified. They were designated as upper and lower PB-7, each separated by a few centimeters. The ages calibrated to the  $2\sigma$  range indicate that both events are statistically indistinguishable, although the lower event is stratigraphically older (see Chaps. 3 and 16, this volume). Based on the NISP, it is evident that the main depositional event corresponds to lower PB-7, which is dominated largely by remains of gomphotheres. In contrast, in upper PB-7 the register of gomphotheres is nonexistent, containing only scarcely represented remains of equids, camelids, and osteoderms of undetermined pilosans (Table 8.2). The upper segment of PB-7 corresponds taxonomically to PB-8, indicating a transition to this last layer. Considering the scarce sample of upper PB-7 and its apparent concurrence with lower PB-7, both assemblages were treated as a single unit.

## 8.4 Frequency of Skeletal Parts

In layer PB-8, the equid remains correspond to a proximal portion of fused first phalanx and a pm 3–4. These give an account of a single adult of more than two and a half years of age, judging by the presence of a permanent third or fourth premolar (Silver 1963). The identified remains of camelids correspond to a diaphyseal portion of a tibia and a practically complete radio-ulna. It is not possible to infer an age of death when the epiphysis is not preserved. However, the tibia segment could belong to a young individual, judging by a porous area toward the proximal section (Table 8.3).

In PB-7, three horse bone remains (fragment of mandibular ramus, portion of a pelvis, and astragalus) were recovered. These give an account of a single individual of older than 1.5–2 years, considering the presence of a pelvis with its bones completely fused (Silver 1963). On the other hand, the remains of camelids are more abundant (NISP = 7, MNE = 7). Elements of the axial skeleton and appendicular were registered (Table 8.3), and the presence of a single individual was estimated. Among the materials, a practically complete mandible with a very worn dental series stands out. Judging by the proposal of Kaufmann (2009), this individual would have been between 7 and 9 years at its time of death.

With regard to the fossils of Gomphotheriidae, in the PB-7 layers exposed until the year 2017 in sector W were recovered 60 specimens, which give an account of 49 bone elements, corresponding to 24% of a complete proboscidean skeleton. The rib cage is undoubtedly the most represented anatomical segment on the site. It constitutes more than half of the identified elements of gomphotheres (% MNE = 54.3). The %MAU indicates that more than 73% of total ribs found are registered (Table 8.4). Based on the morphology and curvature of the ribs, they were categorized into anterior, intermediate, and posterior (Ferretti 2010). From this categorization it was clear that there were a similar number of anterior (MNE = 9) and intermediate ribs (MNE = 9), while the posterior ribs appear less represented (MNE = 6). Six of the ribs could not be determined. Thoracic and lumbar vertebrae appeared to have values close to or equal to 40% of the MAU, while cervical and caudal vertebrae are poorly

**Table 8.3** Absolute frequencies (NISP) of anatomic units of artiodactyls, equids, and pilosans from sector W of the Pilauco site

	<i>Equus</i> sp.		<i>cf. H. paradoxa</i>		Artiodactyla undet.		Pilosa undet.	
	PB-7	PB-8	PB-7	PB-8	PB-7	PB-8	PB-7	PB-8
Mandible	1	–	1	–	–	–	–	–
Cervical V.	–	–	–	–	–	1	–	–
Lumbar V.	–	–	1	–	–	–	–	–
Rib	–	–	–	–	–	1	–	–
Scapula	–	–	1	–	–	–	–	–
Humerus	–	–	1	–	–	–	–	–
Radius-ulna	–	–	–	1	–	–	–	–
Pelvis	1	–	1	–	–	–	–	–
Tibia	–	–	–	1	–	–	–	–
Astragalus	1	–	1	–	–	–	–	–
Phalanx 1	–	1	–	–	–	–	–	–
Dermal ossicles	–	–	–	–	–	–	4	–
Premolar 3–4	–	1	–	–	–	–	–	–
Incisor	–	–	1	–	–	–	–	–
Total	3	2	7	2		2	4	

represented. The sacral vertebrae are not recorded in the sample studied. The front legs are entirely absent, even though a virtually complete left scapula was identified. Its right pair is located in the North profile of the excavation and has not yet been removed. The pelvis is absent, as are the femurs and patella. In contrast, the distal segment of the hind leg is represented through several right-side anatomical units, some of which articulate with each other: tibia, fibula, astragalus, calcaneus, and cuboid (Fig. 8.2). A fragment of left calcaneus is added to this record. All anatomical units are fused, including the skull sutures, which are completely closed. The only exception is a thoracic vertebral disk segment. As such, the anatomical elements identified give an account of a single adult individual. The calibrated radiocarbon dates made on remains of gomphotheres in PB-7 (UCIAMS101670, UCIAMS101830, PSUAMS2416, PSUAMS2421, PSUAMS2418, UCIAMS101831, PSUAMS2420, and PSUAMS2419) varies between 15,110 and 15,890 yr BP (Chap. 3, this volume). Thus, the dates are not consistent with this impression. These differences could be due to the variability in the processing techniques used by the two laboratories responsible for dating.

It is possible to estimate the age of death of the Pilauco gomphothere by comparing it with the epiphyseal fusion tables available for modern elephants (*Loxodonta africana* Linnaeus, Haynes 1991). Within these taxa, females reach sexual maturity before males. This signifies, among other things, that males continue to grow for a longer period of time (Krumrey and Buss 1968; Haynes 1991). The above implies

**Table 8.4** Frequency of skeletal parts of *Notiomastodon* aff. *N. platensis* in layer PB-7 of Pilauco

Anatomical unit	Number of elements	NISP	MNE	MNI	MAU	%MAU
Skull	1	4	1	1	1	100
Mandible	2	0	0	0	0	0
Atlas	1	1	1	1	1	100
Axis	1	0	0	0	0	0
Cervical V.	5	1	1	1	0.2	20
Toracic V.	17	8	7	1	0.411	41
Lumbar V.	5	2	2	1	0.4	40
Sacral V.	5	0	0	0	0	0
Caudal V.	22	1	1	1	0.042	5
Rib	34	30	25	1	0.735	74
Scapula	2	3	1	1	0.5	50
Humerus	2	0	0	0	0	0
Radius-ulna	2	0	0	0	0	0
Carpals	8	0	0	0	0	0
Metacarpals	10	0	0	0	0	0
Pelvis	2	0	0	0	0	0
Femur	2	0	0	0	0	0
Patella	2	0	0	0	0	0
Tibia	2	1	1	1	0.5	50
Fibula	2	1	1	1	0.5	50
Astragalus	2	1	1	1	0.5	50
Calcaneus	2	2	2	1	1	100
Tarsals	16	1	1	1	0.25	25
Metatarsals	10	0	0	0	0	0
Phalanx 1	20	1	1	1	0.05	5
Phalanx 2	12	0	0	0	0	0
Phalanx 3	20	0	0	0	0	0
Epiphysis undet.		1	1	1		
M2/m2		2	2	1		
Total	204	60	49	1		



that the epiphyses of the long bones are fused earlier in females than males (Haynes 1991). Thus, the sex of the gomphotheres must first be determined in order to more accurately apply the epiphyseal fusion tables of modern elephants.

Assuming that within the Gomphotheriidae family there would have been sexual dimorphism between males and females (Ferretti 2010; Mothé et al. 2010), the measurements of the tibiae MHMOP/PI/614 was compared with four specimens combined from three fossiliferous locations in Central Chile: Taguatagua (SGO.PV.687, 242), Tierras Blancas (SGO.PV.7) and Quereo, Los Vilos (SGO.PV.267) (Table 8.5).

As shown in Fig. 8.3, the measurements are clearly divided into two size groups. This division is interpreted as a product of sexual dimorphism. Thus, the specimen MHMO/PI/614, and therefore the individual deposited in layer PB-7, would correspond to a male. Haynes (1991) suggests that the tibia of male *Loxodonta africana* is completely fused around 32 years for the proximal epiphysis and between 28 and 32 years for the distal epiphysis. Thus, an age greater than 32 years is estimated for the time of death of the gomphothere in Pilauco sector W.

The presence of an unfused vertebral plate does not contradict this result. According to Haynes (1991), the vertebral plates are one of the last skeletal segments to fuse. A second way to estimate the age of death is from dental wear. Mothé et al. (2010) combined the stages of dental wear of Simpson and Paula-Couto (1957) with current data of elephants (Moss 1996), in order to calculate the age of death of a bone assemblage of gomphotheres from Brazil. Among the remains of Pilauco were identified two M2/m2 (MHMOP/PI/627 and/628) with similar states of wear (Category 3, Simpson and Paula-Couto 1957). Using this data could be proposed an age of death between 30 and 35 years, which corresponds to an individual adult, according to the categories proposed by Haynes (1991). Both estimates are therefore coherent with each other.

## 8.5 Horizontal and Vertical Distribution

The spatial distribution of the remains found in the PB-7 layer indicates a main sector of at least 16 m<sup>2</sup>, composed by gomphotheres bones (Fig. 8.4). However, the entire deposition area has not been completely excavated, as evidenced by the presence of fossils in the North profile of excavation (a scapula in the 14AD unit and a gomphothere anterior rib in the 14AB unit).

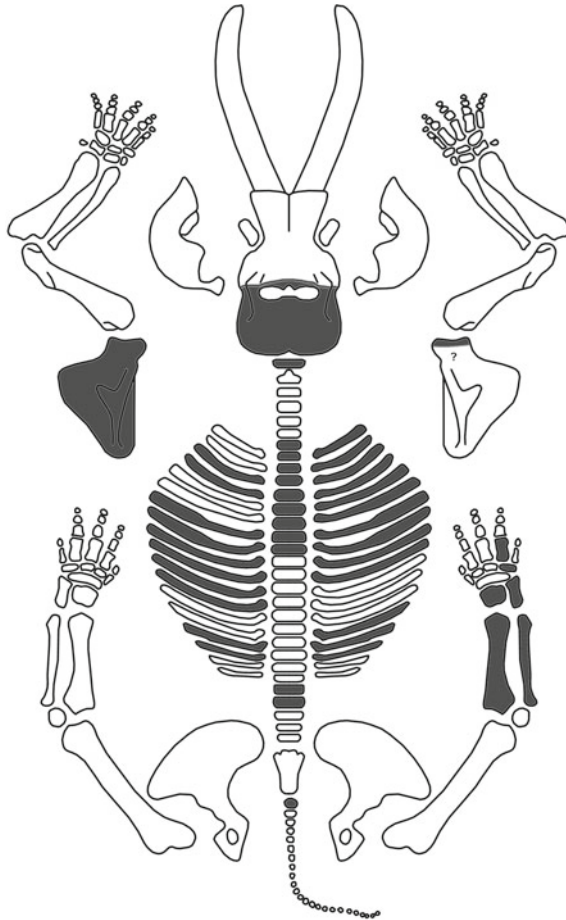
It may be assumed that the skull is relatively in situ (15AD unit), because its size and weight make its displacement unlikely (ca. 120 kg for a male African elephant, Haynes and Klimowicz 2015). Therefore, it is possible to suggest that an important part of the ensemble, composed primarily of ribs and thoracic vertebrae, would show relative anatomical coherence in a general SW-NE orientation (Fig. 8.4). However, the arrangement of the ribs according to their location on the rib cage is not in line with this impression, since ribs of the three segments of the thorax are spatially associated. On the other hand, in a scenario of high anatomical coherence, it is expected to find

**Table 8.5** Measurements (mm) of tibiae from gomphotheres of central Chile and Pilauco

	MHMOP/PI/614	SGO.PV.687 (TT2-C4H69)-Left	SGO.PV.687 (TT2-C2H19)-Right	SGO.PV. 7-Left	SGO.PV. 267-Left	SGO.PV. 242-Left
Maximum length	567	470	475	590	590	ND
Lateral length	490	375	380	480	483	ND
Medial length	550	457	450 <sup>a</sup>	573	570	ND
Breadth at mid diaphysis	115	73	78	115	105	83
Depth at mid diaphysis	123	88	95	126	115	92
Breadth of proximal articular surface	225	180	185 <sup>a</sup>	283	225	ND
Depth of proximal articular surface	ND	135	125	197	155	ND
Breadth of distal articular surface	179	143	142	203	180	175
Depth of distal articular surface	129	108	115	148	133	115

<sup>a</sup>approximated

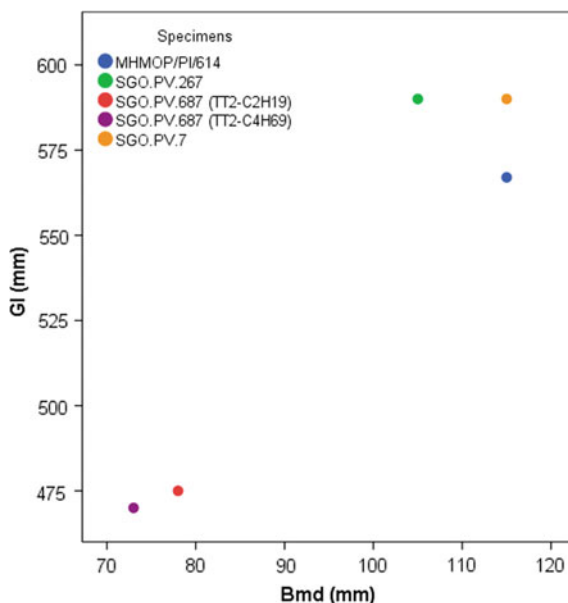
ND: No Data



**Fig. 8.2** Schematic sketch of a proboscidean skeleton showing the anatomical units (MNE) of the gomphotheres of Pilauco. The locations of vertebrae, ribs and phalanges are approximate. Modified from Santucci et al. (2016)

bones of the front limb and the scapular girdle close to the head. However, these are absent, except for the right scapula found in the profile of the 14AD unit. Conversely, the left scapula is located almost four meters from its right pair (15A unit), while less than a meter away from the skull is located five bones of the hind limb that articulate with each other (tibia, fibula, astragalus, calcaneus, and cuboid, mainly located in 14AC unit). The bones of the hind limbs and pelvis should hypothetically be found at the opposite end from the skull area, at the eastern boundary of the excavation. However, pelvis, femurs, or patellas have not been recovered. Moreover, beneath the skull, one of the two lumbar vertebrae were identified (Fig. 8.4). It is important to clarify that the posterior appendicular segment is not found in the east excavation of

**Fig. 8.3** Diagram of the dispersion of measurements of gomphothere tibia. GI: Maximum length; Bmd: Breadth at mid diaphysis



the site (campaigns 2007–2008), as bones of a second gomphothere were exhumed from there, located more than six meters from the Western concentration (Pino 2008). Thus, it may be postulated that the bones would have undergone different degrees of displacement from their original location, assuming an in situ death of the animal, although in a relatively limited area of dispersion. The bones of the front limbs may be located in the unexcavated areas north, perhaps in conjunction with the remaining cervical and thoracic vertebrae. However, the posterior appendicular bones, pelvis, and perhaps part of the lumbar vertebrae have apparently been removed from the site.

In contrast, artiodactyls and perissodactyls are scattered throughout the excavated area of PB-7, without forming defined concentrations. Some are even located outside the main concentration area, as is the case of the camelid diaphysis recovered in the grid 18A (Fig. 8.4). As noted above, some of the remains of both orders are located above the bones of gomphotheres. That could indicate at least a second depositional event (for example, in the 15AD and 14AC units, Fig. 8.4).

Based on the orientation of the fossils registered in layer PB-7, a rose diagram was plotted to examine the orientation of the materials (Fig. 8.5). The diagram did not show a clear trend. The fossils have a general NE-SW orientation, and to a lesser extent SE-NW. Those with an E-W orientation were less represented.

It is possible that the vertical arrangement of the parts indicates that not all parts are placed horizontally in the sedimentary matrix. In PB-7, 31 anatomical units (43% of the total NISP) present some degree of verticality, with elevation variations that range between 2 and 25 cm between opposite sides. This variation is more evident in the ribs due to their marked length. Part of the layout of the fossils may be

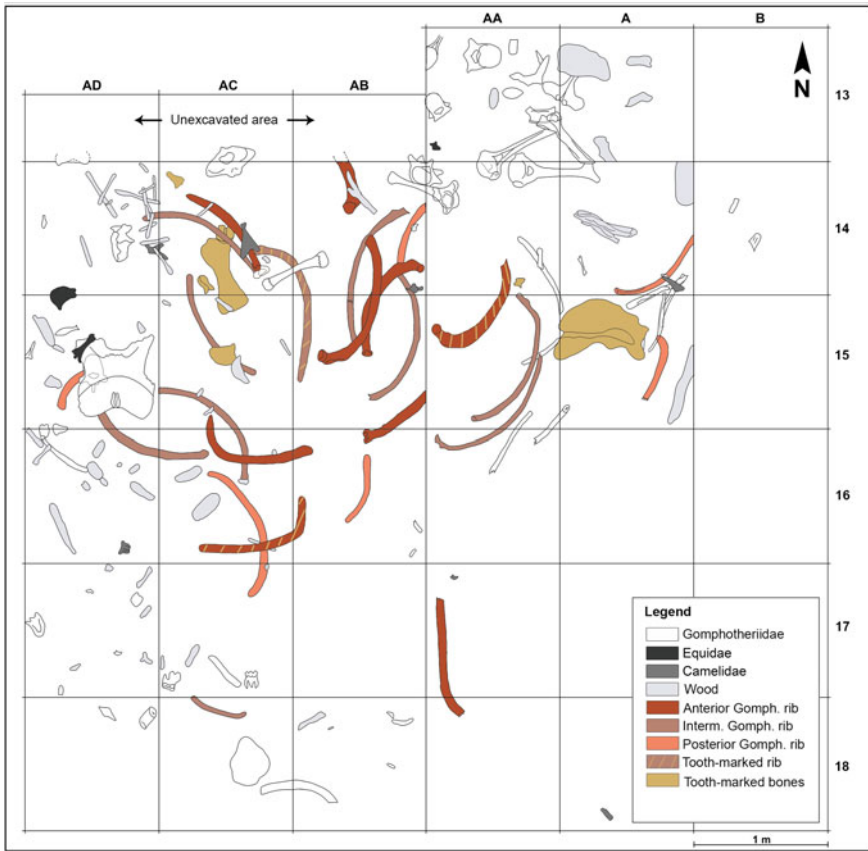


Fig. 8.4 Excavation layout for layer PB-7, sector W of Pilauco

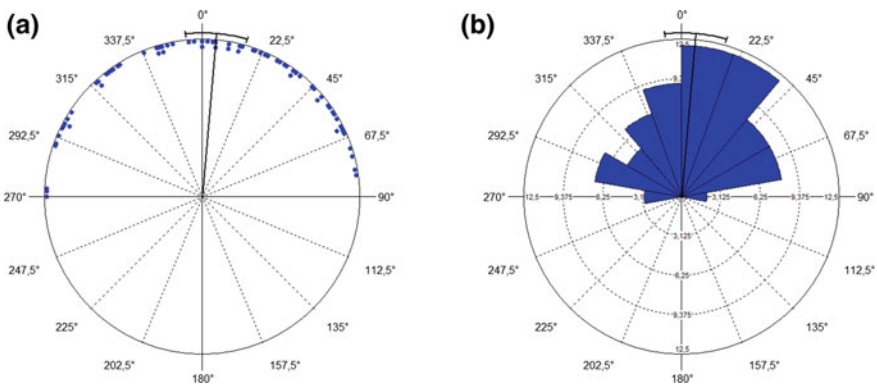
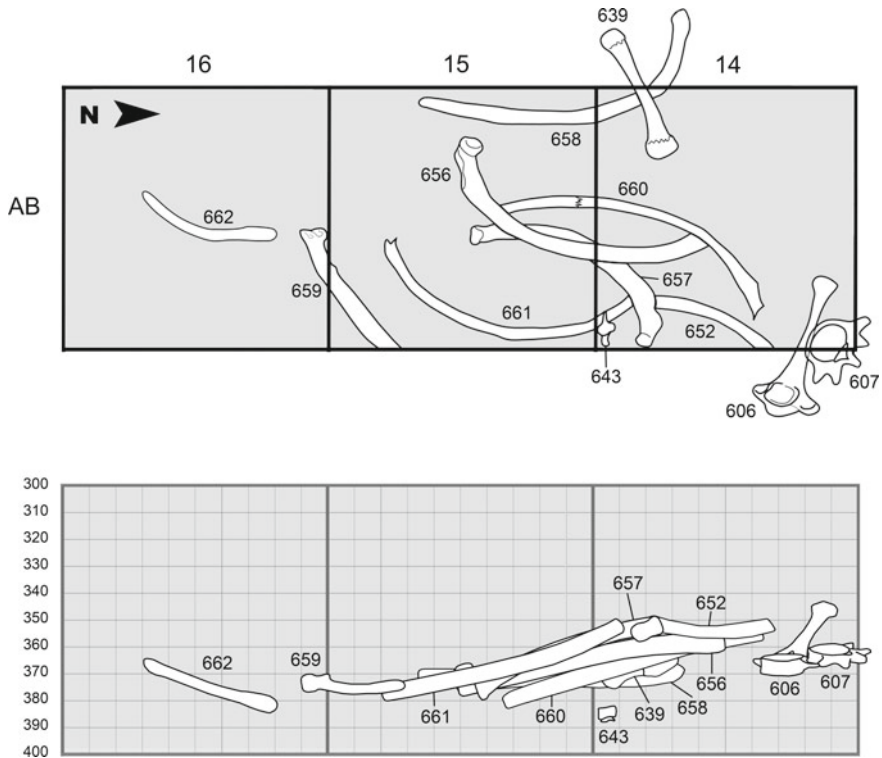


Fig. 8.5 Rose diagram (intervals of 22.5°) with the orientation of skeletal remains of layer PB-7, sector W of Pilauco



**Fig. 8.6** Horizontal (up) and vertical (down) layout of some of the bones from layer PB-7, according to the depth defined locally for the site. The numbers correspond to the last three numbers of the Museum codes assigned to each piece

seen in Fig. 8.6. In PB-8 a relatively similar situation is observed, where two pieces (a rib of indeterminate Artiodactyl and a radio-ulna of cf. *Hemiauchenia paradoxa*) were recovered in a practically vertical arrangement.

## 8.6 Fragmentation

The bone fragmentation is minimal, since the ratio MNE/NISP delivered a value of 0.81 for the remains of gomphotheres in layer PB-7. This is largely due to the considerable quantity of complete elements (%NISP = 49.3; NISP = 37, Table 8.4), but also due to each fragmented specimen is itself an element. Within this subsample are 14 ribs of *Notiomastodon* aff. *N. platensis*, which are extremely fragile largely due to their notable length and low thickness. As shown in Table 8.4, in general the MNE is constructed from a very low NISP, which is in part due to the aforementioned complete pieces, because the incomplete bones represent a significant proportion of this (over 70% approximately).

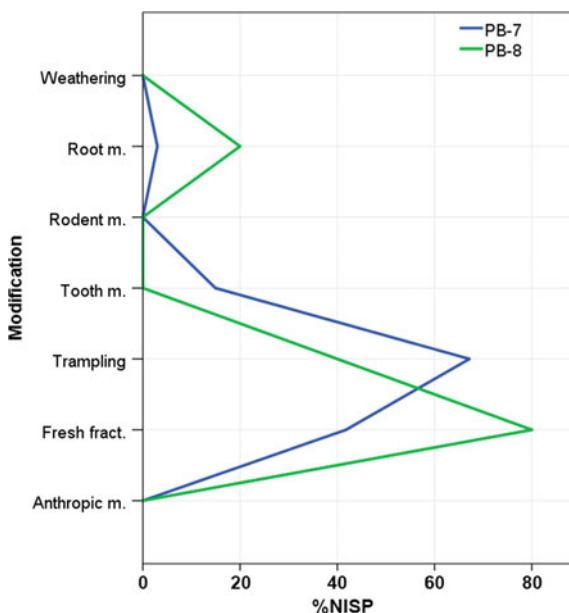
In Equidae and Artiodactyla a similar phenomenon occurs, although only one piece is complete (Equid tooth). In all other cases the NISP is equal to the MNE (Table 8.3). Later in this article, this point will be addressed when the causes of deposition of bone remains are discussed. However, neither splinters, fragments of diaphysis, portions of spongy tissue nor flat bones were recorded within the sample, except for a portion of gomphothere epiphysis. Therefore, strictly speaking there is no “fragmentary” bone. This resulted in 100% of the sample being identified, to at least the order level.

## 8.7 Surface Modifications

The inspection of the surface of the bones could be performed on a total of 68 remains (%NISP = 89.3) registered in layer PB-7. The remaining pieces showed adhered sediments or were dental pieces, which due to their structure generally are not affected by certain taphonomic processes (e.g., root action, tooth marks). In PB-8, the study was carried out on five specimens (%NISP = 83.3). The taphonomic modifications are not the same for all the sample (Fig. 8.7). Surface, shape, and angle of the fractures were considered (Outram 1994). It was determined that in PB-7 40% showed a fresh fracture (NISP = 35), while 54% showed non-fresh fractures and 6% showed both attributes (Table 8.6). Although the number of Equidae and Camelidae bones are low compared to Gomphotheriidae, it may be noted that in this last taxonomic group the non-fresh fractures predominate. However, in camelids, the situation is reversed.

The non-fresh fractures were located mainly in the dorsal and ventral areas of gomphothere ribs (NISP = 15). This was to be expected because they are the anatomical unit most represented in the sample. The fresh fractures do not present a clear trend, registering in gomphotheres on relatively small bones (vertebral disc, indeterminate epiphysis, cuboid, and astragalus) and fragments of skull (NISP = 3). From this last sample, a diaphysis of cf. *H. paradoxa* humerus stands out. It presents a sinuous profile fracture, smooth edges, and sharp angles (Fig. 8.8). However, it does not have evidence of fracture by direct percussion (negative impact, flakes, etc.) (Fig. 8.8). This piece is located at about 2.5 m from the main concentration area in the 18A unit (Fig. 8.4). The agents producing the fractures will be discussed later.

There are no bones in Pilauco with signs of weathering (Fig. 8.7), which implies that the fossils were at the surface for a short time, insufficient to allow the production of macroscopic modifications. Local conditions significantly affect the speed with which the bones are weathered (Behrensmeyer 1978). In the case of Pilauco, a humid and anoxic deposit environment undoubtedly led to a very good preservation of bone remains. It has been suggested that in temperate latitudes proboscideans bones need about 20 years or more to exhibit cracks and splinters. (Haynes 1991). The low rate of weathering is probably due to the anatomical peculiarities of the proboscideans. The thickness of the skin functions like a barrier, avoiding the disassembling and the weathering of the bones (Haynes and Klimowitz 2015).



**Fig. 8.7** Relative frequency of surface modifications in the sample studied. m: Marks

**Table 8.6** Absolute and relative frequency (in parentheses) of fracture types per taxa in layer PB-7

Taxa	Fresh	Not fresh	Combination	Total
<i>Notiomastodon</i> aff. <i>N. platensis</i>	9 (32)	18 (64)	1 (4)	28
cf. <i>H. paradoxa</i>	3 (75)	1 (25)	0	4
<i>Equus</i> sp.	1 (50)	0	1 (50)	2
Anatinae undet.	1 (100)	0	0	1
Total	14 (40)	19 (54)	2 (6)	35

Due to most of the gomphotheres bones in layer PB-7 showed non-fresh fractures, the absence of weathering could indicate that the fractures would have occurred once the bones were already in the sedimentary matrix, or the weathering was insignificant in this time.

Roots marks are scarce in the PB-7 sample. They are proportionately more abundant in PB-8, although here it is a very small sample (Fig. 8.7). In general, the marks did not affect the units completely. In two cases (*Notiomastodon* aff. *N. platensis* ribs), they were seen on only one side, suggesting some kind of post-depositional stability.

There was a significant proportion of evidence of trampling in the bone assemblage of PB-7 (%NISP = 67.1%). This modification is also recorded in the PB-8 layer, although it appears to be less significant (Fig. 8.7). The details of these modifications will be described below.



**Fig. 8.8** MHMOP/PI/642.  
Diaphysis of the humerus of  
*cf. Hemiauchenia paradoxa*  
showing fresh fracture, from  
layer PB-7 (for an  
archaeological interpretation  
see Chap. 16, this volume)



Finally, it is noted that no human marks of any kind (combustion marks, cut marks, scraping marks, percussion marks, etc.) were recorded in the sample analyzed, despite the study of the surface of the bones with magnification up to 40x. Special emphasis was placed on this topic due to the archeological character of the site. However, the marks that could be mistaken for cut marks correspond in fact to marks of trampling, according to the characteristics described in the literature (Olsen and Shipman 1988; Domínguez-Rodrigo 2009, 2012, among others).

## 8.8 Teeth Marks

The bones have no evidence of rodent marks, but there are traces of carnivore teeth exclusively in bones recovered from layer PB-7. The latter were observed in about 14% of the sample studied, affecting only remains of *Notiomastodon* aff. *N. platensis* (Fig. 8.7). Labarca et al. (2014) described four gomphothere anatomical units with teeth marks in layer PB-7, produced during consumption of the bones by a large carnivore, possibly an extinct felid. These pieces corresponded to a tibia, astragalus, calcaneus, and an indeterminate epiphysis. After that, in the detailed study of the whole sample, six more bones were identified with tooth marks, increasing the number of pieces with this component to ten.

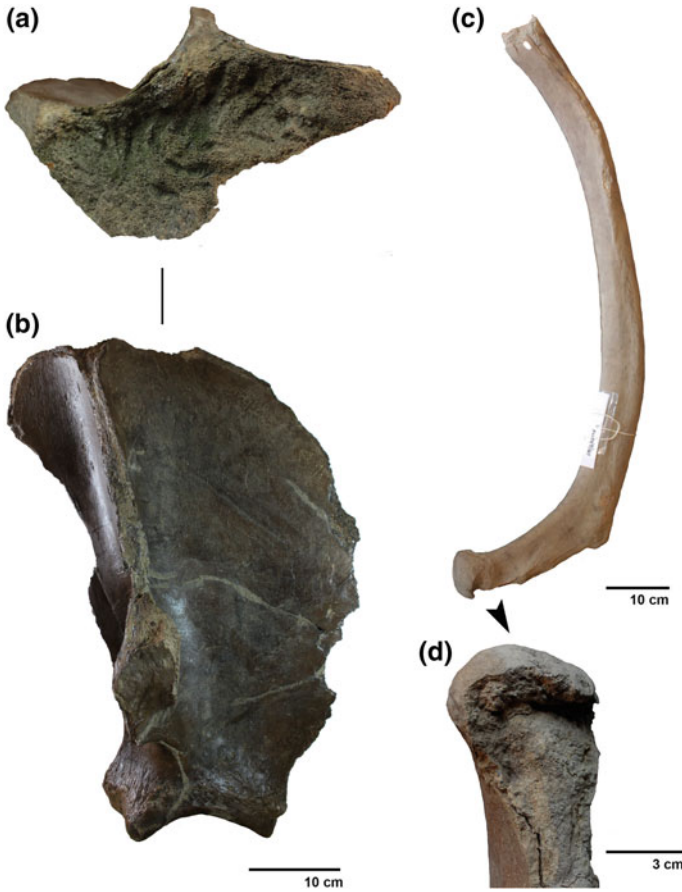
The scapula MHMOP/PI/640 has clear, very intensive, evidence of consumption by carnivores in its proximal segment, mainly in its lateral border. Consumption of scapular cartilage and of part of the proximal edge is observed, especially near to

the spine. Large amounts of scoring are recorded on the spongy tissue in different directions. The edges of the blade toward its medial border are irregular and serrated. The bone was consumed from lateral border to medial border, because the medial border has less evidence of consumption than the lateral (Fig. 8.9). The specimen MHMOP/PI/664 (anterior rib) exhibits an evident furrowing in the neck area, with removal of bone tissue concentrated toward the caudal edge. Scoring and irregular edges are observed at the dorsal part of the head, toward the caudal segment (Fig. 8.9). Also, the specimen MHMOP/PI/611 (anterior rib) shows an irregular border fracture at the dorsal part of the head (currently detached), with clear furrowing in a “U” shape. This sector, however, was modified in an undetermined time after the feline consumption, so it is possible that there were more marks that could not be registered. In the body of the specimen, three short, shallow, and relatively flat scorings are observed by the caudal edge. A longer scoring completely and diagonally traverses the piece. It has a U-shaped section and irregular edges, with a maximum length of ca. 38 mm by a maximum width of 6 mm.

The intermediate rib MHMOP/PI/658 presents a possible furrowing in the articulation of the head with the neck. This piece, however, has recently lost bone tissue, so its modifications are uncertain. The lateral and posterior portions of the right cuboid MHMOP/PI/679 are significantly altered by carnivores. Portion of the articular surface for the calcaneus and for the fourth metatarsal are missing. There is a deep lateral groove (13.6 mm of maximum length) that crosses the piece in its middle section, reaching to its posterior face. It is associated with other minor furrows. The fifth metatarsal articular surface and the remnant of the fourth metatarsal articular surface present on their posterior and lateral edges, respectively, at least three scorings, and some furrowing, which gives the edges a sinuous appearance (Fig. 8.10). The first has a maximum width of 10.1 mm, the second, 11.7 mm. They are parallel and separated from each other by about 14.3 mm.

Finally, the specimen MHMOP/PI/650, a first phalanx, shows abundant tissue removal by carnivores in its distal right lateral side. There is clear evidence of furrowing, which produced a deep U-shaped cavity of ca. 7 mm. In addition, in the distal side toward the left there is a very shallow scoring, arranged dorso-plantar/palmar, of 18.7 mm in length and 6.5 mm in width.

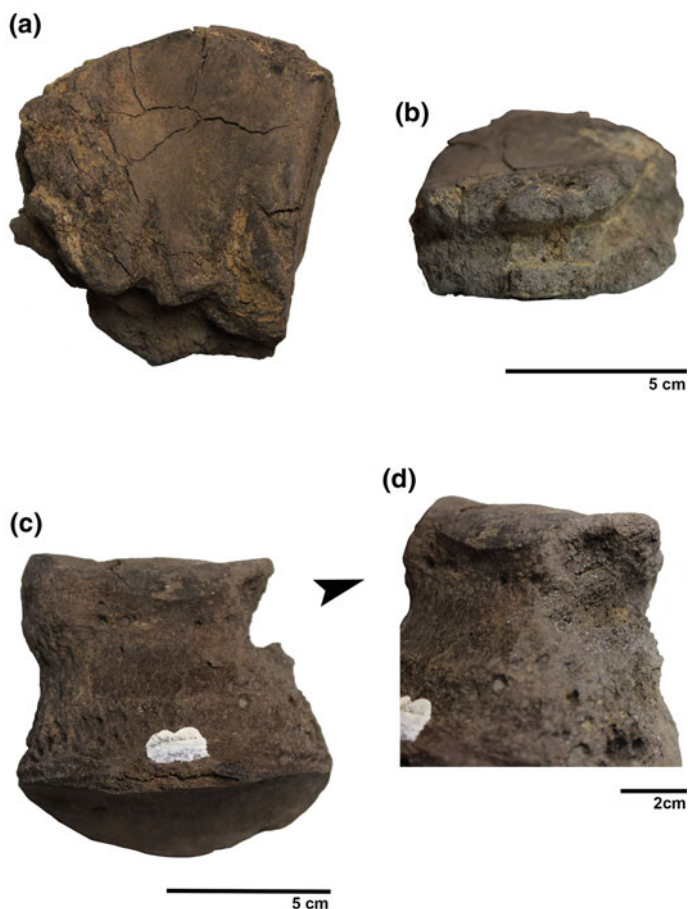
Labarca et al. (2014) noted that although the intensive consumption of bone remains is not characteristic of current felids, the dimensions of the pits and scorings observed in the Pilauco sample are not compatible with any reference canid. Rather they approximate the measurements of modern lions, according to the actualistic data of Domínguez-Rodrigo and Piqueras (2003) and Delaney-Rivera et al. (2009). Additionally, based on the morphology of the marks, they could not have been generated by bears (Haynes 1983; Saladié et al. 2011). Borrero et al. (1997) and Martin (2008, 2013) described that at least the Pleistocene jaguar of southern Patagonia (*Panthera onca mesembrina*) regularly consumed bone fragments of camelids, equids, and mylodontids. Marean and Ehrhardt (1995) documented teeth marks on unfused proboscidean bones that were produced by a species of felid in the family Machairodontinae family (*Homotherium* sp.) in a North American Pleistocene context. In agreement with these findings, Van Valkenburgh and Hertel (1993)



**Fig. 8.9** Teeth marks of carnivores in bones of *Notiomastodon* aff. *N. platensis*. **a** and **b** Scapula MHMOP/PI/640 in proximal and lateral view, respectively; **b** and **c** Rib MHMOP/PI/640 in caudal and dorsal view, respectively

found a high rate of fractures in teeth of large carnivores at the Rancho La Brea site (USA). This was interpreted as an indication of greater consumption of bones than the current species. Considering all of the above, Labarca et al. (2014) suggest that a similar situation may have occurred in the Pleistocene of northern Patagonia. A big felid, then most likely extinct, may have regularly incorporated bones into its diet, and could have been responsible for the teeth marks observed in Pilauco.

The new pieces found with tooth marks keep anatomical and/or spatial coherence with previously documented specimens (see below). In addition, they show similar metric attributes with the already documented marks, such as length of the scoring in the epiphysis. The newly observed marks were recorded primarily in the epiphyses or anatomical segments with spongy tissue (e.g., neck of the ribs), a situation similar



**Fig. 8.10** Carnivore teeth marks in bones of *Notiomastodon* aff. *N. platensis*. **a** and **b** Cuboids MHMOP/PI/679 in plantar and posterior view respectively; **c** and **d** Phalange 1 MHMOP/PI/650 in dorsal and latero-dorsal view, respectively

to the one already described. Thus, it is possible to point out that the producer of the new marks would have been the same that consumed the bones described by Labarca et al. (2014).

The horizontal distribution of bones with carnivorous tooth marks clearly show two spatially segregated loci where the carnivore would have consumed the skeletal remains. The first is located near the skull, around the grids 14AC and 15AC. Located here are a tibia, astragalus, calcaneus, cuboid, phalanx, and an intermediate rib (Fig. 8.4). The first four pieces have the same laterality (left), while the tibia articulates with the fibula and astragalus. Therefore, it is possible to suggest that this segment would have been displaced by the carnivore(s) from its original position, to be later consumed. Additionally, in this first locus, the individual(s) would have partially consumed the dorsal portion of a rib. The second locus is situated on the

15A and 15AA grids. It is associated with a left scapula, a left astragalus, and an anterior rib (Fig. 8.4). Assuming that the right scapula is relatively in situ (13AD grid), it is feasible to assume that the left scapula would also have been displaced from its original location to be consumed. The same can be postulated for the anterior rib, if it is assumed that the skull has not undergone major resettlement from its original location. The right calcaneus with teeth marks is noteworthy, as it corresponds to the only piece of the right posterior limbs recovered in the site, possibly suggesting that both hind legs are distal. They were consumed and displaced, but only one of them remained in the original bone concentration area.

## 8.9 Trampling Marks

Trampling marks considerably affected ~67% the bone ensemble excavated from layer PB-7. They were also detected in the PB-8 layer, affecting ~40% of the sample (Table 8.7). In the PB-7 layer, marks affect all taxa, even though they are proportionately more common in bones of gomphotheres (Table 8.8). With regard to the position over the bone, the majority were observed covering the complete specimen (%NISP = 75.5). This situation is expressed more clearly in the remains of proboscideans, where 82% of the sample shows traces of trampling on their entire surface. In camelids and equids, although the sample is small, the situation is inverted (Table 8.7). Various studies have pointed out the possibility that trampling marks could be confused with cut marks (Olsen and Shipman 1988; Behrensmeyer et al. 1986; Domínguez-Rodrigo 2009, 2012), as they may share some morphological attributes.

Considering the antiquity of the PB-7 layer and the presence of lithic artifacts spatially associated with the remains of extinct mammals, attempting to discern the cause of the striations was necessary. This was done in accordance with the protocol proposed by Domínguez-Rodrigo et al. (2009, 2012), who defined a series of visible morphological attributes with low magnification (40x). These could be analyzed together in order to reliably differentiate between types of marks.

Table 8.8 shows the quantification result of a five-bone sample from the PB-7 layer (Fig. 8.11) in accordance with the protocol proposed by Domínguez-Rodrigo et al.

**Table 8.7** Absolute frequency and relative frequency (in parentheses) of trampling marks per taxa, with consideration of their position, for the specimens of layer PB-7

	NISP/%NISP	Location	
		Complete	Partial
<i>Notiomastodon</i> aff. <i>N. platensis</i>	38 (71.7)	31 (81.5)	7 (18.4)
cf. <i>H. paradoxa</i>	4 (66.7)	1 (25)	3 (75)
<i>Equus</i> sp.	1 (33.3)	0	1 (100)
<i>Pilosa</i> undet.	2 (50)	2 (100)	0
Total	45	34 (75.5)	11 (24.5)

**Table 8.8** Summary of the absolute and relative quantification (in parentheses) of the strations attributes in bones of *Notiomastodon* aff. *N. platensis* (layer PB-7)

	MHMOP/PI/611	MHMOP/PI/614	MHMOP/PI/615	MHMOP/PI/630	MHMOP/PI/629
	Rib	Tibia	Rib	Skull	Atlas
Analyzed marks	116	21	64	81	12
Micro-abrasion	p	p	p	p	p
Overlapping estriae	p	p	p	p	a
Groove trajectory straight	12 (10)	4 (19)	2 (3)	11 (14)	1 (8)
Groove trajectory sinuous	104 (90)	17 (81)	62 (97)	70 (86)	11 (92)
Barb	0	0	0	0	0
Sides of the groove symmetrical	6 (6)	1 (5)	0	12 (15)	0
Sides of the groove asymmetrical	110 (95)	20 (95)	64 (100)	69 (85)	12 (100)
\_shape Groove	116 (100)	21 (100)	64 (100)	81 (100)	12 (100)
V shape Groove	0	0	0	0	0
Shallow Groove	106 (91)	18 (86)	64 (100)	81 (100)	12 (100)
Deep Groove	10 (86)	3 (14)	0	0	0
Internal microestriation	8 (7)	1 (5)	0	1 (1)	0
Microestriation on bottom	8 (7)	1 (5)	0	1 (1)	0
Microestriation on walls	0	1 (5)	0	0	0
Microestriation straight	0	1 (5)	0	1 (1)	0
Microestriation irregular	8 (7)	0	0	0	0
Microestriation continuous	1 (1)	0	0	0	0
Microestriation discontinuous	7 (6)	1 (5)	0	1 (1)	0

(continued)

Table 8.8 (continued)

	MHMOP/PI/611	MHMOP/PI/614	MHMOP/PI/615	MHMOP/PI/630	MHMOP/PI/629
	Rib	Tibia	Rib	Skull	Atlas
Shoulder effect	0	1 (5)	0	0	0
Flaking on shoulder	0	0	0	0	0
Max length (mm)	22.7	14.7	28.2	33.8	20.9
Max width (mm)	0.9	0.3	1.1	0.8	0.4

(2009, 2012). First, it highlights the importance of the number of marks presented by each sample, considering that only a surface of  $20 \times 10$  cm was studied in each bone. Olsen and Shipman (1988) have pointed out that the cut marks are comparatively less numerous than those generated by trampling, because they are produced by specific butchery actions. For this reason, they have also suggested that cut marks are located in specific parts of the bones, usually associated with muscle and/or ligament insertions, which contrasts with the Pilauco samples. In Table 8.8 and Fig. 8.12, a great homogeneity is observed in the proportions of the various attributes shown for each bone, independent of the number of striations. The marks have mainly a sinuous orientation, do not present barbs, exhibit asymmetrical sides, have sections in a “\\_/” shape, are mostly superficial, have very low internal micro-striation and they are irregular and discontinuous. To these characteristics should be added the presence of micro-abrasion, overlap of striations inside the incision, and the recurrent presence of marks that overlap each other. The proportions of the attributes recorded in the bones were compared with the experimental results obtained by Domínguez-Rodrigo et al. (2009) (Fig. 8.12). Through this comparison it was possible to establish similarities between the fossil bones and the trampling marks, dispelling the indicated proportions for the cut marks generated by unifacial stone flakes. Considering these results, we propose that the marks present on the surface of the bones studied correspond to trampling marks. Thus, the presence of cut marks in the sample analyzed should be discarded. The remaining bone units with incisions were studied in a less intensive manner, but generally present the same pattern (Fig. 8.13).

## 8.10 Discussion and Conclusions

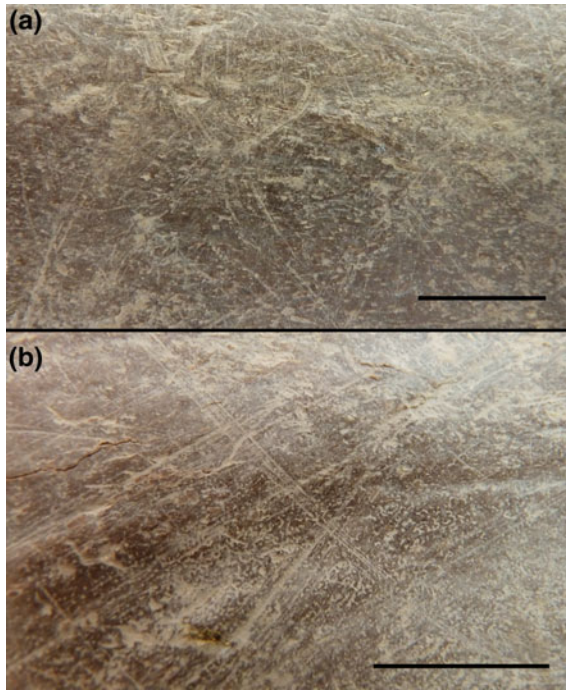
Borrero (2015) noted that all archeological evidence of the initial settlement of the continent should be studied as diligently as possible, without discarding unusual a priori evidence, and avoiding blind acceptance without discussion of information. The taphonomic study presented here is oriented precisely in that direction.

The results attained in this work confirm the general impressions indicated in previous publications. The Pilauco site presents an intricate formational history, where diverse taphonomic agents have aided in the configuration of the fossil record.

The spatial distribution in sector W of layer PB-7 showed a locus mainly consisting of a single gomphothere, associated with some isolated remains of equids, camelids, and dermal ossicles of an undetermined pilosa. The relative anatomical coherence presented by the remains of proboscideans indicated a relatively in situ death of the animal, even though some elements of the skeleton have not been recovered. Although the absence of a part of the gomphothere assemblage may be due to excavation decisions, it is possible that a portion of it may have been removed from its original place of deposit to other areas outside the site.

The PB-7 and PB-8 layers interfinger to the south with fluvial deposits of the ancient Damas. River. Therefore, could be possible that after the postmortem process of natural disarticulation (Hill 1979), the bones could have been perturbed by

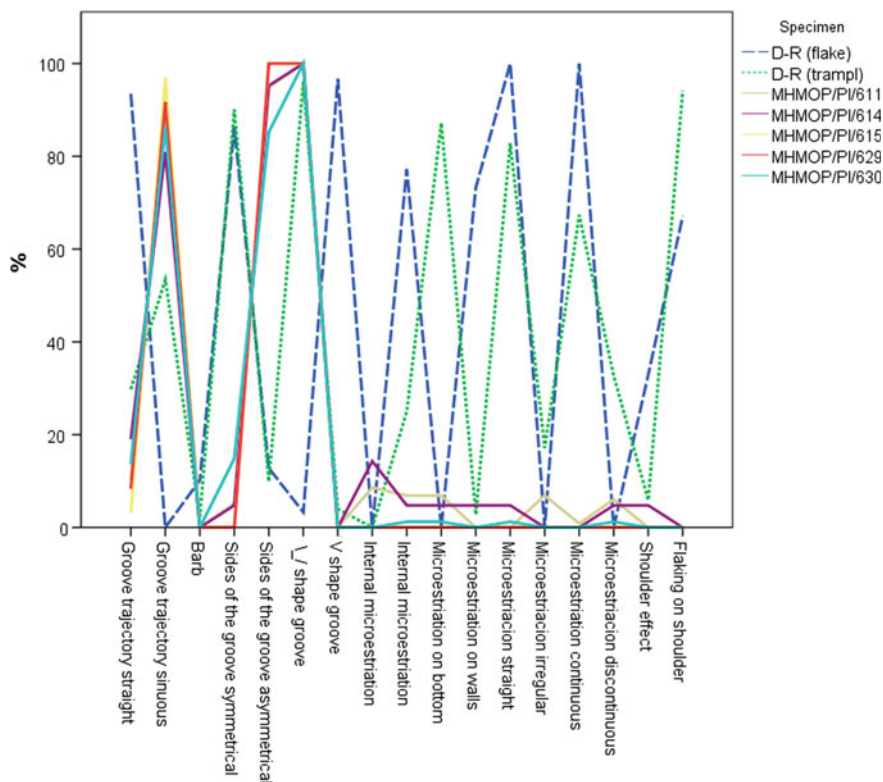




**Fig. 8.11** Marks of trampling on bones of gomphotheres from layer PB-7. **a** Rib MHMOP/PI/611; **b** Skull MHMOP/PI/630. The bar measures 1 cm

some type of rearrangement/displacement by hydric causes. However, there are no stratigraphic or sedimentological evidence of fluvial deposits in PB-7 and PB-8 layers (see Chap. 3, this volume).

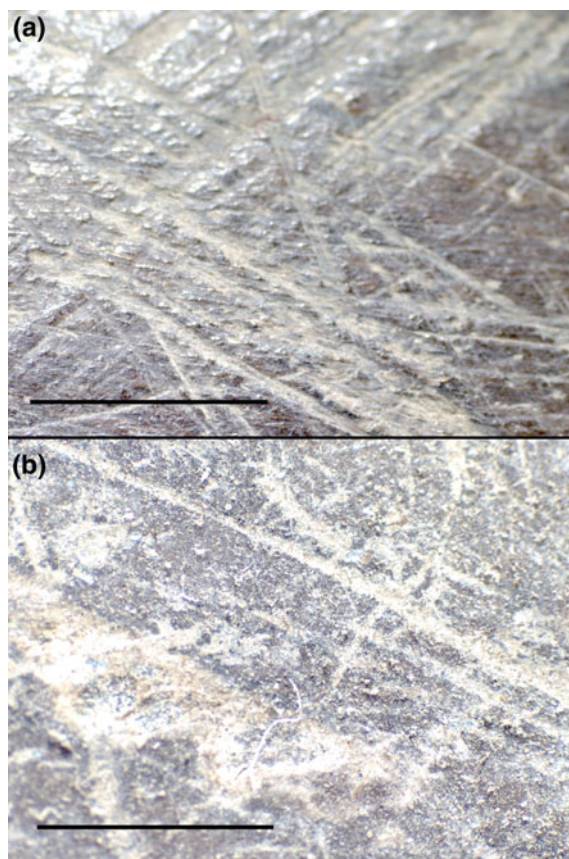
Since the initial works of Voorhies (1969), several experimental approaches have been developed to define which pieces are most susceptible to fluvial displacement (i.e., Boaz and Behrensmeyer 1976; Kaufmann 2009; Evans 2015; Domínguez-Rodrigo et al. 2017; Frison and Todd 1986). The results of these works have been somewhat dissonant due to the different variables incorporated in the studies (type of taxa, state and articulation of the bone remains, velocity of flow, etc.). According to the main taxa recovered at Pilauco and considering the low fragmentation of the sample, indices that were created from remains of African elephants (*Loxodonta africana*) were used (fluvial transport, FTI and saturated weight, SWI). The correlation between the % MAU of *Notiomastodon* aff. *N. platensis* and the FTI yielded positive but no statistically significant results ( $\rho = 0.376$ ;  $p = 0.151$ ;  $n = 16$ ). However, the correlation between the same % MAU and the SWI delivered slightly negative but statistical no significant results ( $\rho = -0.069$ ,  $p = 0.779$ ,  $n = 19$ ). These values suggest that the fluvial agents no modeled the Pilauco gomphotheres bone assemblage.



**Fig. 8.12** Relative frequency of distinct morphological attributes of the marks registered in the selected sample from Pilauco, and the comparative data of Domínguez-Rodrigo et al. (2009)

Within the sample are bones representing high (e.g., calcaneus and astragalus), medium (e.g., ribs), and low (e.g., skull) displacement chances. The absence of a predominant direction in the orientation of the bone remains (Fig. 8.5), would indicate the same. This also takes into consideration that the current channel of the river has a general NW-SE orientation. Moreover, the bone remains of gomphotheres of layer PB-7 sector W do not exhibit abrasion or polish marks associated with the action of water (Fernández-Jalvo and Andrews 2003). The latter also applies to the remains of artiodactyls and perissodactyls, so the deposition causes for these bones should be related to other agents. All of the above is concordant with the sedimentological analyses, which indicate a primarily colluvial origin for the sediments of layers PB-7 and PB-8 (see Chap. 3, this volume).

It is important to note that some skeletal remains assigned to cf. *Hemiauchenia paradoxa* registered in the East site sector show abrasion marks that were interpreted as generated by fluvial transport (Labarca et al. 2013). Some of these pieces correspond to anatomical elements regularly associated with a high probability of transport (e.g., astragalus, Voorhies 1969; Kaufmann et al. 2011). These differences



**Fig. 8.13** Trampling marks on bones of gomphotheres from layer PB-7 of the Pilauco site. **a** Rib MHMOP/PI/611; **b** Rib MHMOP/PI/620. The bar measures 5 mm

between sectors could be related to different taphonomic histories within the site. Another possibility is that other non-hydric processes, such as wind action, could generate similar abrasion marks. This issue cannot yet be resolved with the information available for sector E.

Another agent that could have contributed to the relocation and displacement of anatomical elements in the PB-7 layer are the humans. This includes the presence of a lithic industry consisting of small unifacial stone tools and their waste. They are manufactured mainly in dacitic volcanic glass and basalt, which are spatially associated with the remains of Pleistocene fauna (Navarro-Harris et al. 2019; Chap. 16, this volume). Moreover, Navarro-Harris et al. (2019) suggested that Pilauco was a working place to handle meat, at least during two intervals, since part of the lithic ensemble shows characteristics consistent with cutting and scraping activities. As noted previously, the detailed surface analysis of the skeletal remains in Pilauco

ruled out the presence of cultural cut marks. However, these could also be absent within a scenario of low-intensive butchering, which for now cannot be confirmed. Indeed, the actualistic studies developed by Haynes in Africa suggest that the possibility of leaving cut marks in bones of proboscideans is generally low. This is due to the large amount of muscle, fat, and thick periosteum that surround the skeletal remains (Haynes 1987, 1991; Haynes and Klimowicz 2015). This same author has suggested that skilled butchers can process an elephant without leaving any mark, although this depends on the intensity of the processing of the carcasses. If the animal is not intensively processed, it is unlikely for the tools to be able to reach the surface of the bones (Haynes and Klimowicz 2015). Thus, Haynes expects that archeological sites with remains of proboscideans should generally present a low frequency of cut marks on bones, with values around 1% of the total sample (Crader 1983; Haynes and Klimowicz 2015). Taphonomic studies of fossil materials in different parts of the world and with different chronologies seem to confirm this impression. In general, there is a limited presence of cut marks on bones of proboscideans in archeological sites (e.g., Saunders and Daeschler 1994; Yravedra et al. 2010; Saccà 2012).

Crader (1983) and Haynes and Krasinski (2010) recorded some anatomical units with percussion/chop marks in modern sites of elephant processing. In consideration of their experimental studies, De Juana et al. (2010) suggested that this is an effective technique to disarticulate anatomical units of large animals. This type of modifications leaves marks clearly visible, since it necessarily implies a contact between the bone and the butchering instrument. Despite the degree of anatomical disorder observed in the studied sample of layer PB-7 (Fig. 8.4), no marks of disarticulation by percussion have been observed in any bone in the collection. Therefore, the loss of the anatomical connection between the bones of the gomphotheres of Pilauco seems to be better explained by another process.

On the other hand, evidence of fracture by percussion (negative flakes, pits) in the diaphysis of long bones have been recorded in bone assemblages of archeological sites with remains of proboscideans (Santucci et al. 2016; Saccà 2012; Villa et al. 2005; Gaudzinski et al. 2005). These have been associated with obtaining raw materials rather than for bone marrow extraction (Saccà 2012). In Pilauco, no fractures or percussion marks that could be related to this type of activity have been identified in long bones of gomphotheres, as most of the fractures were made in a non-fresh state and on ribs. Therefore, the absence of cut and percussion marks (on diaphysis and epiphysis) in gomphothere bones enabled the ruling out of an intensive human processing of the carcass deposited in layer PB-7. It also led to the assumption that the anatomical disorder and rearrangement of the bone units would not have been due to human causes.

The study showed an absence of certain anatomical units, those that could have been moved to the residential camps for their high economic yield, such as femurs, coxal bones, and vertebrae (Binford 1978). However, the excessive weight of these bone units in the proboscideans makes this possibility unfeasible, except that the settlements are located near primary butchering area, as suggested by the ethnoarcheological evidence assessed with the Hadza people (e.g., Lupo 2006; Monahan 1998). Just the femur of an African elephant (without flesh) weighs between 14 and 23 kg, while the hip can weigh between 21 and 91 kg without flesh (Haynes and Klimowicz 2015). Fisher (1992) has documented ethnographically that the hip, along with the skull, jaw, and scapula, are bones that remain in the sites of elephant slaughter of the Ituri Forest People, while long bones were moved for the extraction of bone marrow. In these cases, temporary camps were set up 10 m from the processing site. With regard to Pilauco, it is not logical that high yield units such as ribs had been quickly butchered, while units of a similar yield, but heavier, such as femurs and coxal bones were moved toward the camps. In this way, the absence of anthropic marks (cut and percussion), the inconsistency in the eventual transport strategies and a lithic instrument not very suitable for intensive processing of large prey, makes it necessary to think of other alternatives that better explain the absence of the anatomical units of the pelvic girdle and rear extremity.

A third alternative is that the dispersal and selective extraction of the skeletal units have been carried out mainly by carnivores during their feeding process. This scenario has stronger empirical evidence, as teeth marks of large carnivores in the bones of proboscideans have been consistently documented in PB-7. In this regard, Labarca et al. (2014) were inclined to an extinct felid as the responsible agent, which until now is not represented in the fossil record of northern Patagonia. The consumption of bones by extinct Pleistocene felids has been well documented in southern Patagonia. Here the extinct jaguar (*Panthera onca mesembrina*) regularly incorporated bones of different species into their diet (Martin 2008, 2013). For the machairodonts (also identified in southern Patagonia through the genus *Smilodon populator* Lund, Prieto et al. 2010), the information available is comparatively limited. However, the paleontological research developed in North America suggests a certain tendency to avoid bone consumption due to the dental structure of Machairodontinae (Marean and Ehrhardt 1995). Labarca et al. (2014) suggest that the gomphothere carcass could have been scavenged by the carnivores, judging by the marks on the distal tibia and the fact that a felid could have hardly hunted an adult proboscidean with an estimated mass of around three tons (Ferretti 2010). This impression is maintained here, postulating a scavenging scenario of the units that could have been found partially articulated, such as the distal part of the right hind leg. The anatomical disarray observed in the ribs could also be due to the action of carnivores, which is confirmed by the presence of teeth marks in two of these anatomical units. It is not possible to support the idea that the scavenging events had necessarily happened immediately after the death of the animal. Haynes (1991) suggests that the skeletal remains of proboscideans can be maintained for several months with some degree of articulation. This is due to their ligaments and the thickness of their skin, which helps to delay the natural processes of disarticulation. It is interesting to



note that this same author suggests that from actualistic observation, the scavengers can accelerate the processes of disarticulation, especially in those cases that have been intensely scavenged. Indeed, Haynes (Haynes and Klimowicz 2015) suggests that the animals “begin to feed (...), by working their way through the thinnest skin of the abdomen, moving upwards on rear limb elements to the innomates, toothmarking and breaking back the edges of the ilium, then continuing to feed forward to the ribs, which are broken either in midshaft or near the vertebral articulation, and eventually forward to clean tissue from scapulae where vertebral borders are toothmarked and broken”. The disarticulation of the appendicular elements would occur in a later stage of scavenging, ending with the separation of the skull and the jaw from the spine, and the segmentation of the latter in several parts. The presence of ribs, scapula, and distal leg segment marked with teeth is consistent with that described by Haynes and seems to account for a carcass that was intensely scavenged before its final burial. It is possible that this process occurred with limited temporal intervals. Within this scenario, it may be suggested that part of the bone units could have been moved outside the central deposition area by the carnivores themselves. Haynes and Klimowicz (2015) mention scavenged bones separated up to 30 m from their original place of deposit. We know that at least the Patagonian jaguar moved bones for later consumption (Borrero et al. 1997; Martin 2008, 2013), who analyzed several rock-shelters with faunal assemblages which were interpreted as dens of the Pleistocene jaguar. Among the transported bones have been identified fragments of skull of mylodon (*Mylodon darwini* Owen), so it is possible that the hemipelvis or femurs of the gomphotheres of Pilauco could have been transported by carnivores.

Another group of marks very conspicuous in the sample studied are those generated by trampling. These would have been caused by the contact of the bones with abrasive particles of the sedimentary matrix containing the bones (Domínguez-Rodrigo et al. 2009). Therefore, this process necessarily occurred once the bones were already completely skeletonized. Several fossils are completely covered by marks of this type, suggesting that it was a systematic and continuous process, even after the burial of the bones. The presence of bones in oblique and subvertical positions suggests that trampling may have also contributed to the displacement of some parts, both horizontally and vertically. It is possible that some of the taxonomic similarity between PB-8 and upper PB-7 is due to this process, as materials could have migrated from PB-8 to PB-7. Similarly, trampling may have contributed to the fragmentation of some ribs. This assumes that the fractures would have occurred in situ, perhaps once the materials were already buried, judging by the considerable presence of non-fresh fractures. Limited experimental studies of trampling developed with humans on bone remains of cattle (*Bos taurus* Linnaeus) and sediments extracted from the Pilauco site have generated marks similar to those observed in the fossilized bones. However, these were recorded in lower intensity and appear to be more superficial (Guajardo 2013).

Finally, it is important to briefly discuss the depositional origin of the remains that do not correspond to proboscideans in the PB-7 layer. It was noted previously that the bones are scattered without defined concentrations, and some were even located around the remains of gomphotheres. In terms of modifications, they do

not show teeth marks nor cultural marks, but rather marks of trampling. Ruling out fluvial transport as a potential factor, it is possible to suggest a gravity-driven colluvial transfer of the elements from the high sectors located north of the site (see Chap. 3, this volume). Once inserted in the sedimentary matrix, the pieces would be subjected to trampling. Considering that pieces from both PB-7 and PB-8 show this type of modification, it is possible to assume that some bone elements of PB-8 could have vertically migrated to PB-7 due to trampling. This scenario could explain the presence of similar taxa between upper PB-7 and PB-8. The pieces in PB-7 don't show particularly significant variations that would denote a different taphonomic history than the bones of gomphotheres (e.g., higher level of weathering, significant root marks). Despite this, it is notable that the bone assemblages of camelids and equids present a greater proportion of fresh fractures, including a diaphysis of a humerus with a very clear, fresh fracture.

Finally, the origin of the few materials recovered in PB-8 could be related to a colluvial redeposition, even if the sample is too small to develop an extensive discussion. It is interesting to note that in east sector the fauna ensemble is more diverse and apparently more abundant (Recabarren et al. 2011; Pino et al. 2013; González et al. 2014). Again, this may suggest differences in the depositional processes between the two sectors, which for the moment cannot be evaluated comparatively.

Through the analysis of the surface modifications of the skeletal remains and their horizontal and vertical distribution, this research was able to define a series of taphonomic processes occurring within the Pilauco site, particularly in sector W of layer PB-7. All of the skeletal evidence recovered so far suggests that the Pilauco site corresponded mainly to a place of feeding for large extinct felids. These animals intensely modified a gomphothere carcass, probably dead in situ, accelerating a process of natural disarticulation that had apparently already begun. The carnivores that fed on the carcass (perhaps on more than one occasion) would have been principally responsible for the relative anatomical disorder of the units recovered on the site, and perhaps the absence of some anatomical elements. The evidence rules out human incidence in the formation of the fossil assemblage. In addition, the fossil set was enriched by the contribution of bones of equids, camelids, and pilosas transferred colluvially to the site, from high sectors. The trampling would have contributed to the horizontal and vertical displacement of anatomical units, while significantly marking the surface of the bones. Some of the fractures recorded in the sample could be explained by this process, which seems to have continued even once the remains were completely inserted into the sedimentary matrix.

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