

Terrestrial and maritime taphonomy: differential effects on spatial distribution of a Late Pleistocene continental drowned faunal bone assemblage from the Pacific coast of Chile

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Abstract Site GNL Quintero 1 (GNLQ1), located on the central coast of Chile, is the only documented Late Pleistocene drowned terrestrial site along the Pacific Coast of South America. Faunal evidence at the site is varied, and so far, remains of the following taxa have been found: extinct Camelidae, Cervidae, Equidae, Mylodontidae, Xenarthra, but also Myocastoridae, Canidae and Octodontidae. Both geological and paleoenvironmental data indicate that GNLQ1 developed in a floodplain or low-energy environment during the Last Glacial Maximum (LGM). Prior to the post-glacial rising of the sea level, the site would have been located several kilometres inland as the paleoshoreline was farther out on the continental shelf. In accordance with this background, the present study addresses the analysis of the spatial distribution of the bone deposits of GNLQ1 by considering both scenarios, the terrestrial phase related to the formation and modification of the fossil assemblage prior to the transgression, and the marine phase, subsequent to inundation. Results indicate modifications related to low-energy flow environment and carnivore activity dominated during the terrestrial phase

and the action of marine organisms during the marine phase. Other taphonomic modifications are not easily attributable to either one or the other environmental context.

Keywords Late Pleistocene · Extinct fauna · Taphonomy · Underwater archaeology · Central Chile · South America

Introduction

Site GNL Quintero 1, located on the Pacific coast of central Chile (32° S), provides the first conclusive evidence for the existence and preservation of a drowned landscape viable for both extinct megafauna and early human occupation and movement along the Pacific coast of South America during the Late Pleistocene (Carabias et al. 2014:145). Largely undisturbed deposits on the seabed containing a stratigraphic context of continental faunal remains have been systematically studied by research methods and strategies common to sub-

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merged prehistoric archaeology (Carabias et al. 2014; Cartajena et al. 2011, 2013; López et al. 2012).

The extended depositional history of this remarkable and unique site provides unexplored data for a better understanding of the complex and diverse site formation processes affecting late Quaternary paleontological/archaeological terrestrial deposits located on the continental shelf of the Andean Pacific coast. On the basis of a preliminary paleolandscape model for Quintero, GNL Quintero 1 (GNLQ1) was affected by only one singular marine transgression post-glacial event, with the site last being subaerially exposed by 11,000 BP (Carabias et al. 2014). Accordingly, the site's record includes the following data on:

- *Continental phase*: terrestrial-based processes developed in a probable floodplain environment during the Last Glacial Maximum (LGM).
- *Marine phase*: maritime-based processes developed in a shallow water environment subsequent to sea-level transgression during early post-glacial times.

Both phases involve poorly understood taphonomic processes, particularly those affecting bone remains located in freshwater and marine environments (Dunbar et al. 1989; Stright 1995; Stewart 1999; Hoyle et al. 2004; Boessnecker 2013; González et al. 2013).

Over the last decade, specific-site studies conducted at GNL Quintero 1 have enabled the acquisition of an important corpus of data regarding taphonomic agents and the refinement of methodologies for the controlled recovery and conservation of animal bone evidence. The analyses conducted during this early stage relied on a limited sample recovered during the subsurface test excavation of the site and the discussion focused primarily on the taphonomic agents operating during the continental phase (Cartajena et al. 2011, 2013; López et al. 2012). However, during the recent years, the adoption of a paleolandscape research strategy, which encompasses the comprehensive application of remote sensing technologies, geological interpretation of industrial land and offshore coring, paleoenvironmental reconstruction and extensive underwater archaeological excavations, has contributed to the formulation of new research-driven questions (Carabias et al. 2014). In this wider context, gaining a better understanding of the taphonomic agents that might have operated during the marine phase, particularly a shallow water environment exposed to the action of waves, currents and tides, represents a prime objective.

Research questions regarding the accumulation and dispersal of vertebrate remains, their distribution in space and time, and their potential connection with other evidence before, during and after inundation, all constitute key questions in this stage of research. The spatial disposition at the intra-site level is fundamentally determined by preservation conditions (especially of organic evidence), horizontal spatial relations between artefact and ecofact evidence, vertical and

stratigraphic distribution of the archaeological evidence and the area and location of the site itself (cf. Henry 2012). In this context, different cumulative ecological, geological, anthropic, chemical and physical factors are conducive to either the destruction or preservation of fossil bones (Lyman 2010). These analyses are particularly relevant for Late Pleistocene scenarios in the Americas, where detailed spatial studies are critical for carefully assessing potential evidence of human agency, especially when these cultural traces are either practically absent or of very low visibility (such characteristics having been identified in certain sites near Quintero Bay) (e.g. Núñez et al. 1994; López 2007). This is the case of GNLQ1, where at least two potential cut marks have been identified so far in the recovered assemblage. With such low frequencies the conclusive evidence to support human activities at GNLQ1 is still scarce and being highly scrutinized.

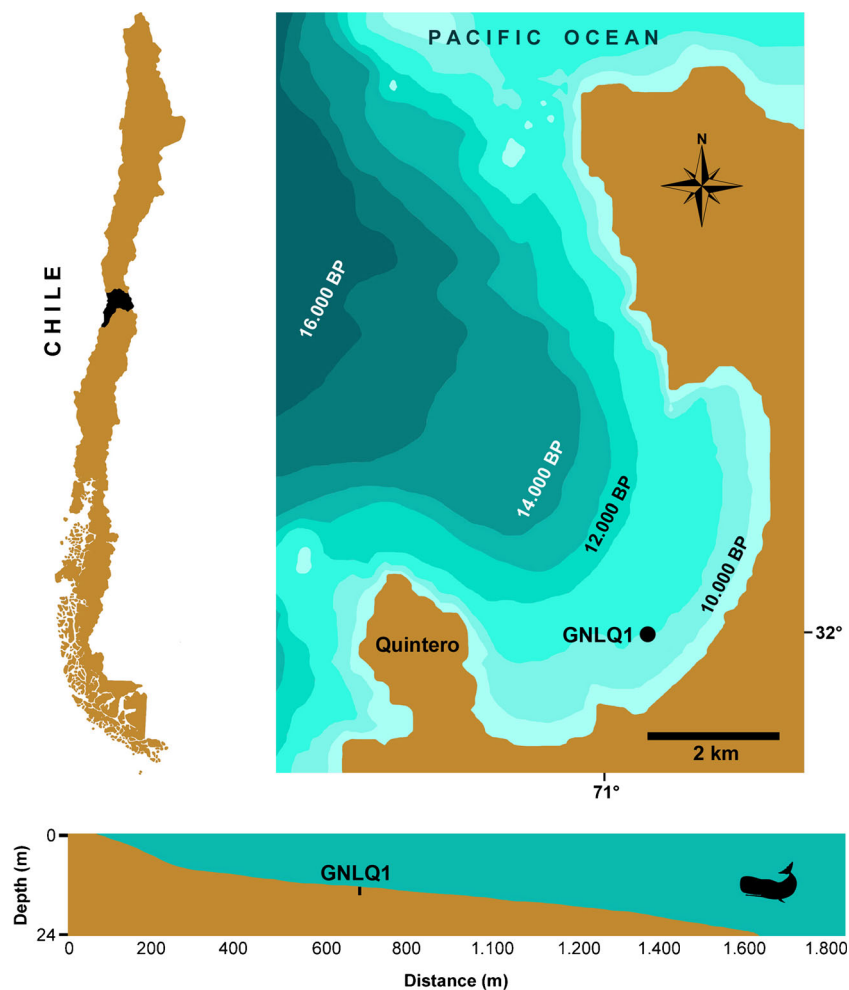
Within this research framework, this study aims to address the spatial distribution of animal bone fragments at GNL Quintero 1 by considering and integrating the transformation forces acting during both the continental phase and the marine phase of the site as cumulative long-term phenomena.

GNL Quintero 1

GNL Quintero 1 site (GNLQ1) is located on Quintero Bay (32° S), 50 km north of Valparaíso, on the coast of Central Chile. This is a shallow embayment no more than 55- to 60-m deep, 3-mi long and 1.5-mi wide, with a northwesterly orientation. The bay is protected from the dominant south westerly winds by Los Molles peninsula. The Campiche River—located northeast of Herradura beach—and other smaller streams drain into the bay, with permanent to perennial flow. The presence of coastal lagoons and wetlands trapped by mounds dunes—frequent along coastal area of Central Chile—can be found at both the northeast and southwest ends of the bay (Villa-Martínez and Villagrán 1997).

GNLQ1 is located 650 m from the present-day coastline, at a depth of 13 m (Fig. 1). The site was discovered in 2005 as the result of systematic archaeological survey of the seabed conducted as part of a Cultural Resource Management (CRM) project for a planned gas marine terminal. This exploration, as well as a preliminary survey, resulted in the identification of a dense concentration of animal bone remains deposited in a consolidated and partially buried stratum under 5 to 10 cm of modern sands. A series of subsurface test excavations were conducted and mechanical coring samples obtained at several targeted locations at the site in 2007. These locations were distributed across transects within an area of 40 × 25 m. One locus with well-delimited bone concentrations barely visible on the seabed was selected and sampled through a test excavation 1 × 1 m unit, producing 224 specimens. Taxonomic analysis identified a high diversity terrestrial extinct

Fig. 1 Location of GNLQ1 and general contour map showing early postglacial sea-level change of Quintero Bay



megafauna assemblage, including Camelidae, Cervidae, Equidae, Mylodontidae, Xenarthra, among other taxa (Cartajena et al. 2011).

Geomorphological context

The study area of Quintero is located on the Coastal Plain of Central Chile in a zone of exposed and eroded emergent terraces or beach ridges that comprise a sloping, softly undulating landscape. Both this area and the northern semiarid Chile feature marine terraces of varying sizes and heights that characterize coastal areas (Paskoff 1970). In particular, satellite images in Quintero reveal a marine terrace bordering the north and south of the bay, with an approximate height of 60 m above sea level at its western edge. Considering there are no available data for Quintero, in altimetrical terms this terrace might be tentatively correlated with Terrace III in the Talinay Heights (30–31° S), identified by Saillard et al. (2009, 2012) and which, according to dating based on U-Th and ^{10}Be , corresponds to a marine isotope substage (MISS7e) of 225 ± 17 ka (Saillard 2008, 2009, 2012).

The organic fraction of the sedimentary matrix containing the faunal assemblage has been ^{14}C dated and reported as 13.640 ± 40 BP. The lack of collagen, including in dentine, precluded direct age estimation. Therefore, skeletal elements and molars of various taxa were directly dated by the AMS-radiocarbon method using the bioapatite fraction and reported ages between 21.580 ± 60 and 24.890 ± 70 years not cal. BP (Table 1). Although this technique has been successfully used for dating bone and tooth enamel samples (Cherkinsky 2009; Cherkinsky et al. 2013), bioapatite diagenesis could affect radiocarbon ages (Zazzo and Saliège 2011). The observed chronological gap between the sedimentary matrix and bone radiocarbon dates needs to be clarified in order to understand possible carbonate exchanges between bioapatites and the burial environment and/or disturbances of the sedimentary matrix. A preliminary attempt at calculating the relative sea level (RSL) for Quintero Bay based on Spada and Stocchi (2007) SELEN 3.2 program combined with a mean estimated uplift rate of 0.5 m/ka was developed and provided a reasonably accurate paleolandscape model (Carabias et al. 2014). The simulation proved consistent with eustatic sea-level curves (Lambeck et al. 2002).

Table 1 ^{14}C dates of organic sediment and taxa on bioapatite fraction of bones and molars

Material	Lab number	^{14}C age years, BP	^{14}C age years cal, BP ^a
Juvenile molar (bioapatite) of <i>Equus (Amerhippus)</i> sp.	UGAMS#15535	24,890 ± 70	27,159–26,679
Molar (bioapatite) of Cervidae	UGAMS#15536	23,720 ± 70	25,974–25,659
Juvenile molar (bioapatite) of Camelidae	UGAMS#15537	21,580 ± 60	24,037–23,735
Ungueal phalanx (bioapatite) of <i>Xenarthra</i>	UGAMS#15538	23,060 ± 60	25,574–25,202
Radius-ulna (bioapatite) of cf. <i>Palaeolama</i> sp.	UGAMS#15539	21,690 ± 50	24,103–23,834
Organic sediments	UGAMS#9194	13,640 ± 40	14,656–14,247

^a Calibrated ages with OxCal 4.2, SH Cal 13 (Bronk Ramsey and Lee 2013; Hogg et al. 2013)

At present, the ledge bordering the Puchuncaví ravine has an extensive floodplain located northeast of GNLQ1, which may be spatially related to the site. In this floodplain, both lowlands and wetlands were formed as a result of the lowering of the water level of the river, which in turn was primarily determined by the amount of regional precipitation. As is the case along the entire coast of Central Chile, these rains now mainly occur during winter, with an average annual precipitation of 300 mm/year. The river drains into the northern end of Quintero Bay, where it forms a channel that creates what is now known as the Campiche lagoon and which is separated from the ocean by a sandy beach. When very heavy rains occur, the waters of the lagoon connect with the Pacific Ocean. Considering the structural context of Quintero as a shallow bay with gently sloping nearshore bathymetry and little sediment yield from rivers, it is very probable that site GNLQ1 developed in a continental fluvial low-energy environment, probably a floodplain with shallow marshes similar to the ones that characterize the contemporary coastal landscape.

Sedimentology sampling and depositional environment

Morphological and sedimentological analysis performed on a core sample (T1), provides a complete stratigraphic sequence for the site, with three stratigraphic units exhibiting clearly different sedimentological features (Fig. 2). Due to its relatively shallow depth, GNLQ1 is located on an upper shoreface environment, under the continuous influence of wave activity dominated by southwesterly winds, thus limiting the sediment deposition rate. Accordingly, unit 1 contains surficial, well-sorted fine sand, brown in colour and 5-cm thick.

Sediments belonging to the stratum designated as unit 2 were classified as clay gravel, supported by a matrix clast characterized by gravel-sized fragments in a matrix of fine clay sand. The clasts comprise agglomerations of highly resistant fine sand and clay, with evidence of oxidation and carbon residue. The size of the very fine grains (e.g. fine sand, silt and clay) observed in both the matrix as well as in the agglomerated fragments suggests that sedimentation occurred within a very low-energy environment. The presence of carbon lenses

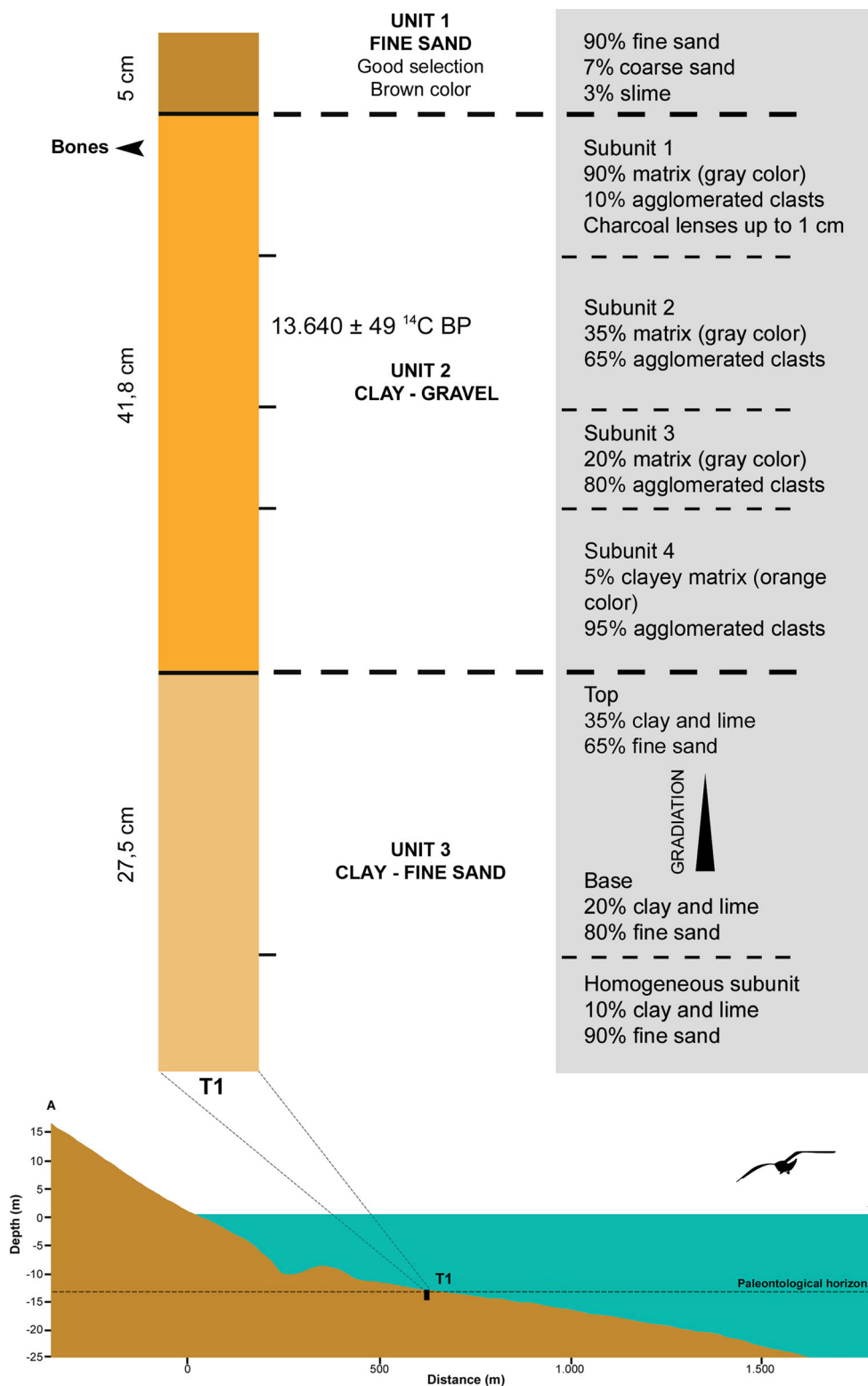
and carbon patinas, as well as the dark hue of the sediments, suggests a continental environment with a moderate contribution of organic material, a conclusion further supported by the impressions of small roots on the surface of the bones. The faunal remains were recorded in the upper portions of unit 2. On the other hand, the orange hues observed at unit 3 and at the base of unit 2 indicate that the sediments experienced a transition from a subaerial deposition environment to an underwater environment. The stratigraphic sequence of core T1, along with the interpretation of the geomorphological setting, indicates that the depositional environment probably reflects a fluvial setting arising within a semi-arid climate that was more humid than today. These specific conditions of sedimentation contributed to the reduced weight of this unit and also likely contributed to its scope being limited.

Material and methods

New extensive excavations covering a total surface of 8 m² were conducted at the site during 2012 and 2013. Despite the fact that bones were distributed in a continuum along the entire excavated area, 19 discrete bone concentrations were identified (Fig. 3). These concentrations were exhaustively recorded in situ through scale drawing and high-definition underwater photography.

In addition, a pre-disturbance 3D model of a section of the site covering approximately 12 m² (3.5 × 3.5 m) was generated through diver multi-image underwater high-resolution photogrammetry. Photogrammetry provided an accurate and rapid mapping method for recording in situ the faunal assemblage distribution and its depositional context. Photographic coverage was completed using a Canon 5D Mark II, Canon 20-mm lens and flash INON Z240 type 4 strobes. Trilateration of a network of control points was achieved using Site Recorder 4 (SR4). Image processing was achieved using Agisoft Photoscan. Excavations were carried out using 3" induction water dredges, and the material excavated was deposited first in a 6.5-mm holding basket underwater and then transferred to the surface for further examination. Skeletal remains were exposed via careful excavation using in situ decapage

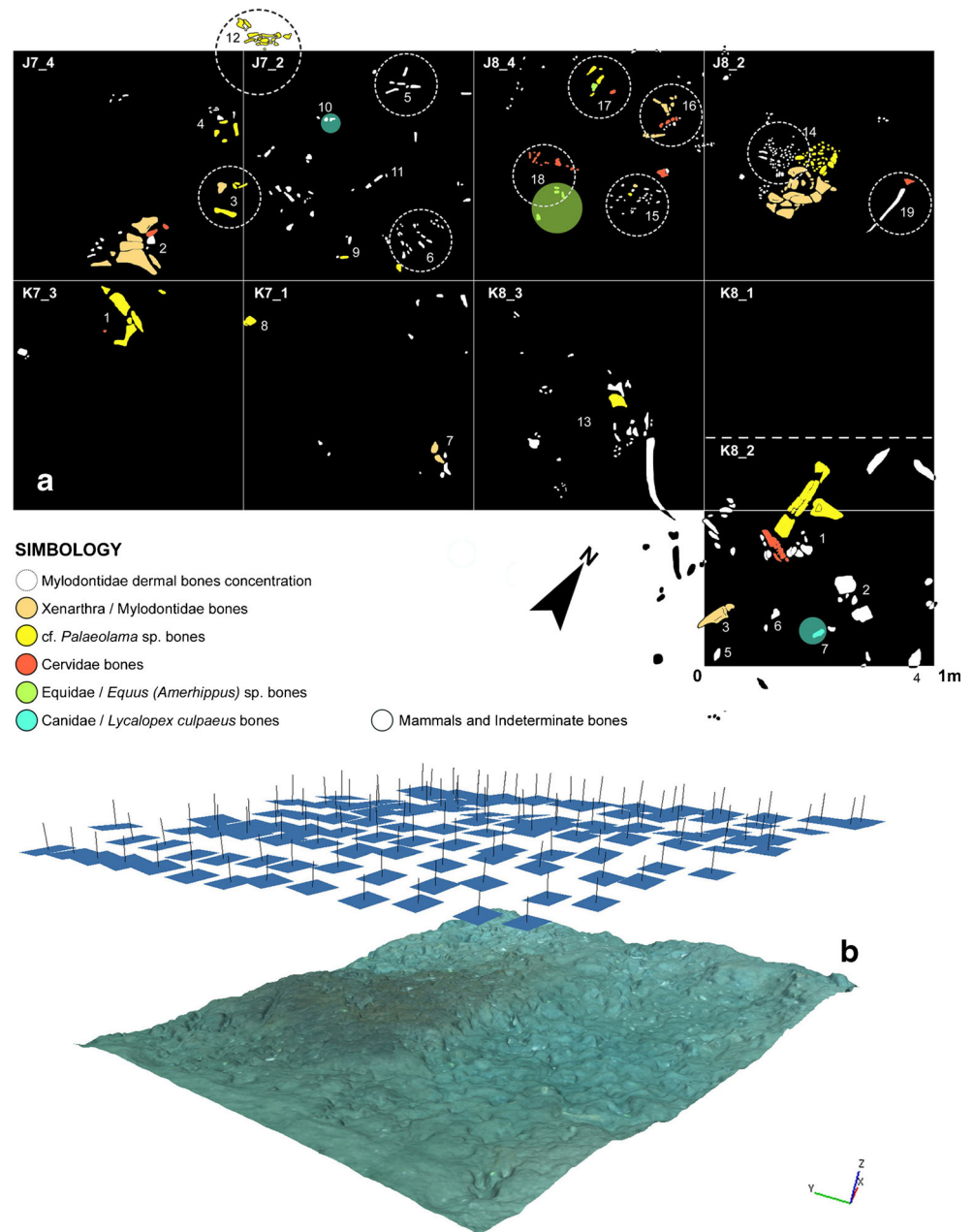
Fig. 2 Stratigraphic sequence and location of core T1 at the GNLQ1 site



techniques. The remains were recovered in blocks with their sedimentary matrix so that they could be micro-excavated in the laboratory, thereby minimizing any loss of contextual information and physical deterioration that may have occurred during underwater extraction (Carabias et al. 2014).

A total of 2935 bone specimens were recovered and analysed from the 2007, 2012 and 2013 fieldwork seasons (see Table 2 and Fig. 4). Despite the fact that specimens could be identified at different taxonomic levels (24 %), the majority were splinters, long and flat bone small fragments. Because of

Fig. 3 **a** Site plan with concentrations of fauna differentiated by colour. **b** 3D mesh model of a section of the site generated through photogrammetry and photo coverage



their characteristics, and despite the reconstruction attempts conducted, they were assigned to Mammalia. The faunal assemblage reflects a wide variety of extinct terrestrial megafauna, including two forms of Camelidae (cf. *Palaeolama* sp. and cf. *Lama gracilis*), Cervidae, *Equus (Amerhippus)* sp., Mylodontidae and Xenarthra. Also, a red fox-size carnivore (*Lycalopex culpaeus*), beaver (*Myocastor coypus*), rodents (Octodontidae, *Abrocoma* sp.), birds and fish were identified. The taxa with highest NISP representation is Mylodontidae, due to the high frequency of osteoderms, dermal ossifications that in the case of sloths are imbedded in their skin (cf. Hill 2006). Large camelids (cf. *Palaeolama* sp.) are also represented in great numbers, followed by

Cervidae, Xenarthra, Octodontidae, *Equus (Amerhippus)* sp. and *Myocastor coypus* (Table 2 and Fig. 4). Other taxa are represented in lower numbers. Overall, the recovered bone remains reflect not only a high taxonomic diversity but also demonstrate the effectiveness of the underwater archaeology excavation and recovery techniques applied (see Fig. 5).

In terms of MNI values, 26 individuals were recorded. According to body size (cf. Hoffman et al. 2010), 10 individuals belong to megafauna (e.g. large land mammals), 2 to medium-sized mammals and, finally, 13 to small fauna. The recovered faunal assemblage suggests paleoenvironmental conditions during the Late Pleistocene that favoured the congregation of

Table 2 Faunal assemblage recovered from GNLQ1 site (NISP values)

Taxa	NISP	%NISP
Mammalia	2238	76.25
Artiodactyla	14	0.48
Cervidae	68	2.32
cf. <i>Lama gracilis</i>	1	0.03
cf. <i>Palaeolama</i> sp.	129	4.40
Carnivora	2	0.07
Canidae	2	0.07
<i>Lycalopex culpaeus</i>	1	0.03
Rodentia	28	0.95
Octodontidae	22	0.75
<i>Myocastor coypus</i>	8	0.27
<i>Abrocoma</i> sp.	3	0.10
Equidae	2	0.07
<i>Equus (Amerhippus)</i> sp.	14	0.48
Xenarthra	53	1.81
Mylodontidae	341	11.62
Osteichthyes	4	0.14
Aves	5	0.17
Total	2935	100

diverse mammals in pastures and wooded areas and near lagoons (Carabias et al. 2014; Cartajena et al. 2013).

Today, site GNLQ1 is located in the upper shoreface under the influence of tidal and wave activity dominated by south-westerly winds. However, stratigraphic and sedimentary evidence suggests a low-energy fluvial continental floodplain environment during the LGM. Due to the nature of the continental deposition and the submerged post-depositional context of the site, one of the central aims of the research has been

the identification of the role that water might have had in the intra-site spatial distribution of the bone assemblage.

Water transport is a well-studied taphonomic agent in the formation of bone assemblages, based on hydrodynamic sorting of the anatomical elements in accordance with their intrinsic properties, water stream energy, distance between initial and final location, among other variables (Voorhies 1969; Hanson 1980, Beherensmeyer 1982; Fernández-Jalvo and Andrews 2003; Kaufmann and Gutiérrez 2004; Gutiérrez and Kaufmann 2007).

In order to determine the occurrence of any hydraulic displacement, the frequencies of the elements with different dispersion probabilities (e.g. resulting from differential degrees of flotation or suspension) were grouped according to Voorhies (1969) by using cf. *Palaeolama* sp. and Cervidae %MAU for skeletal part representation (Gutiérrez and Kaufmann 2007). In addition, *Palaeolama* sp. bone element frequencies were grouped, taking into account the fluvial transport potential groups defined by Kaufmann and Gutiérrez (2004) for adult guanacos (*Lama guanicoe*). These authors explored the role of water in the formation of guanaco bone assemblages in very low-energy lacustrine and fluvial environments by considering the weight, volume and density of the different guanaco elements. The three resulting groups are classified along a continuum, with floating bones with high dispersion probability on one end and those that do not float, and thus have a low dispersion probability, on the other end. We are aware of the different structural properties (e.g. size and density) of extinct and modern camelids and the fact that most long bones found at the GNLQ1 site are fractured, thus restricting the application of the model (Gutiérrez and Kaufmann 2007).

Bone abrasion can also be considered as an indicator of water transport, though abrasion can be caused by other

Fig. 4 Graphic representation of frequency (expressed in %NISP) of taxa identified at the GNLQ1 site (not including unclassifiable and Mammalia remains)

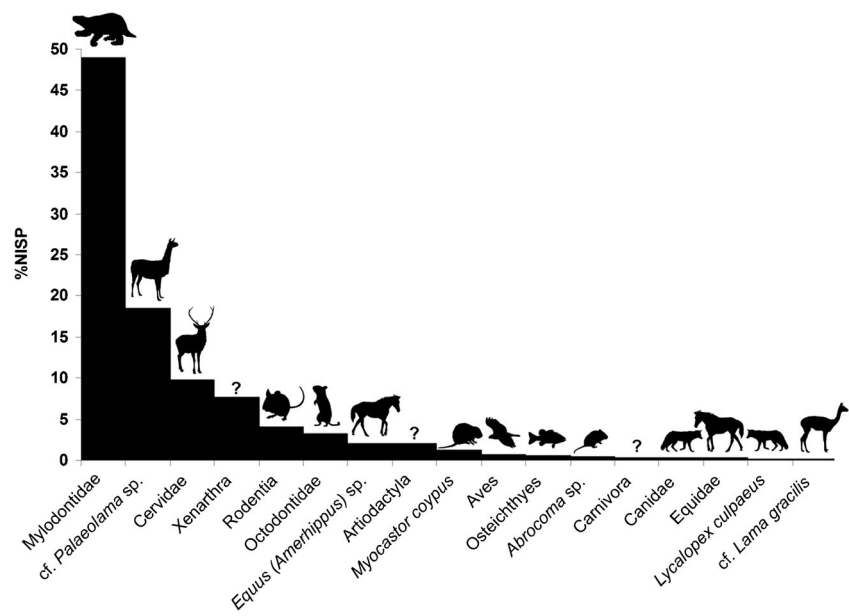
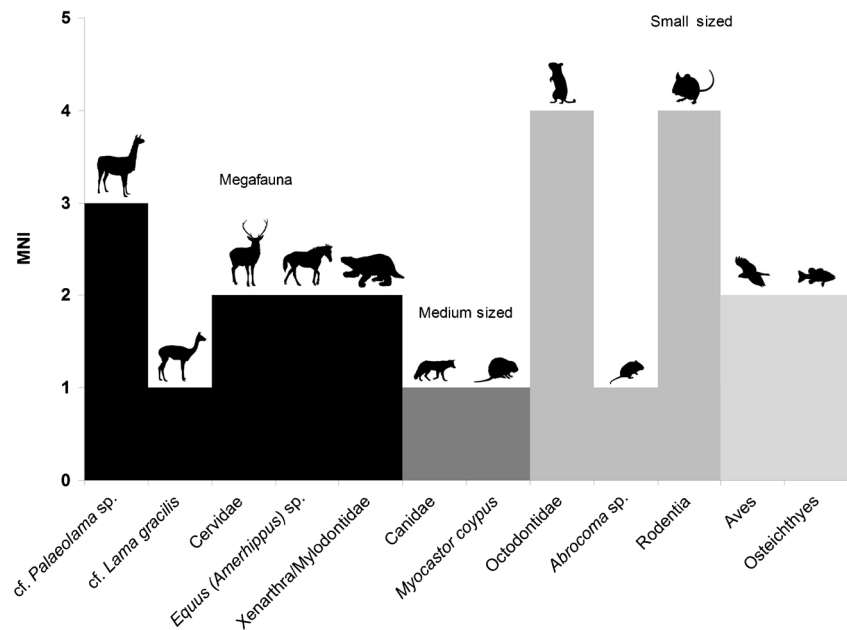


Fig. 5 Identified taxa in the GNLQ1 bone assemblage (MNI values)



processes such as trampling (Bromage 1984; Madgwick 2014). Fluvial activity may cause abrasion in bones during transport or in situ via contact with the sedimentary particles suspended in the water (Andrews 1995; Fernández-Jalvo and Andrews 2003). Abrasion was measured according to the stages proposed by Cook and Trueman (2009), taking into account the extension (e.g. one or both bone surfaces). Despite considerable abrasion, signs of weathering could still be observed. The effects of weathering on the bone assemblage were measured by using the six weathering stages proposed by Behrensmeyer (1978). Stage 0 corresponds to greasy bones, without cracking or flaking. In stage 1, bones exhibit cracking parallel to fibre structure and articular surfaces with mosaic cracking of covering tissue and bone. In stage 2, flaking of the outer surface (exfoliation) occurs and cracks are present. On the other hand, in stage 3, rough and homogeneously altered compact bone

resulting in fibrous texture is observed. In stage 4, splinters of bone loose on surface, with weathering penetrating inner cavities are present. Finally, stage 5 is characterized by bone falling apart in situ, with very fragile bone material (Lyman 1994:255). Other natural taphonomic agents were considered in order to address burial modifications or subsurface weathering (Andrews 1995), including the presence of root marks and staining. In addition, modifications due to rodent gnawing and carnivore activity (Binford 1981), and marine organisms, bioerosion and encrustation (Leonard-Pingel 2005) were recorded. Mechanical refitting of fragmentary bones and anatomical refitting of skeletal segments (bilateral and intermembral) were conducted in order to address spatial configurations and horizontal distribution of the fitted bones (Waguespack 2002).

Data regarding orientation were collected based on pre-disturbance site-plans derived from in situ drawing and

Fig. 6 Anatomical units grouped according to the scheme of Voorhies (1969) (%MAU)

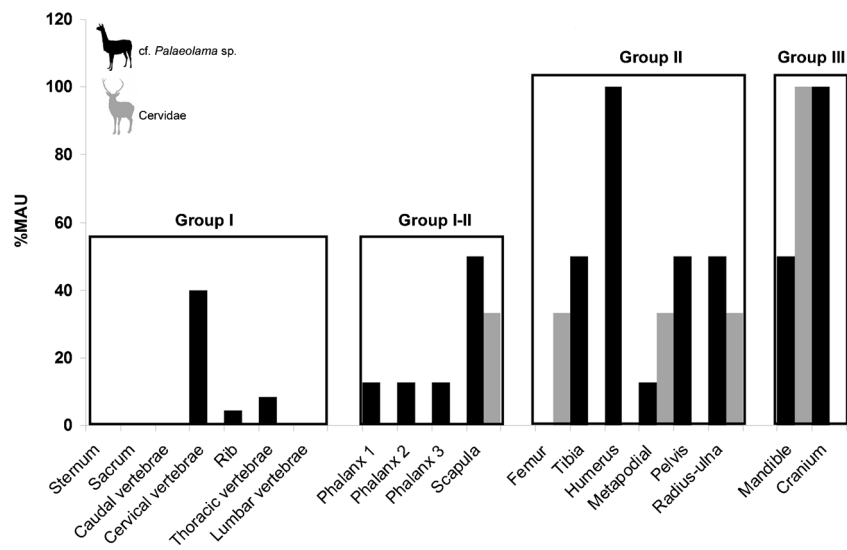
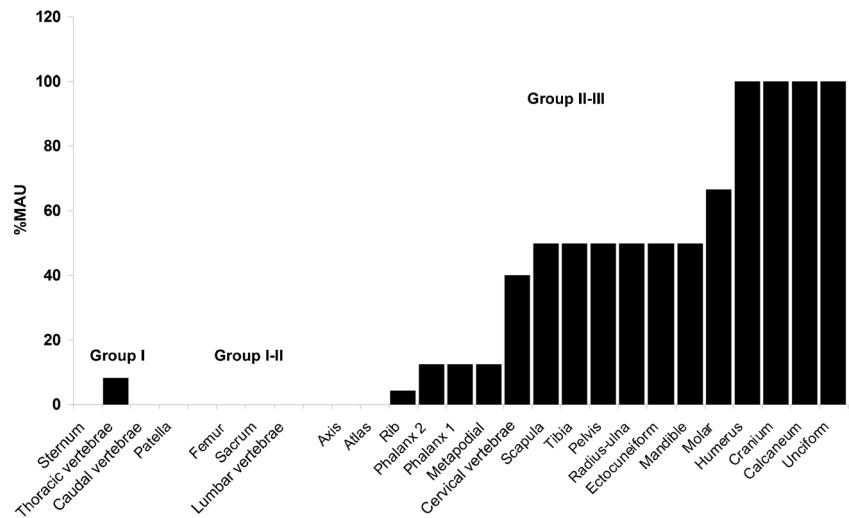


Fig. 7 Anatomical units (%MAU) grouped according to the scheme of Kaufmann and Gutiérrez (2004)



photogrammetry recording techniques. The orientation of each bone was subjected to rose diagrams, with the degree of isotropy (or randomness of orientation) or anisotropy of the orientations assessed via Kuiper’s (*V*), Rayleigh’s (*R*) and Watson’s (*U*²) tests. The Kuiper’s test (*V*) reveals that the sample of values has been obtained on the basis of a concrete distribution (whether uniform or von Mises distribution). The Rayleigh’s (*R*) test was used in order to detect a single modal direction within the set of vectors (i.e. in comparison to the alternative of randomness). The uniformity hypothesis is rejected if the mean length of the vector resulting from the sample produces a value higher than 4.33 (see Meintanis and Iliopoulos 2003, Table 1). Finally, the Watson’s test (*U*²) determines goodness of fit of the data set to a concrete distribution (e.g. such as the von Mises uniform distribution). The Watson’s test calculates the deviations between the data and the chosen distribution. If these deviations prove to be excessive (larger than 0.186, see Zar 1984, Table B35), the statistic used for calculation will also be, by definition, excessive and the null hypothesis will be rejected (Polo García and Felicísimo 2008; Domínguez-Rodrigo et al. 2012). In recent studies, both Domínguez-Rodrigo et al. (2012) and Domínguez-Rodrigo and García-Pérez (2013) have discussed the different protocols utilized in order to define the orientation angle of samples. In this case, due to the fact that some of the bones were removed in blocks as a result of the consolidation of the sediment in which they were borne,

angle direction was determined via the symmetrical longitudinal axis (SLA), which involves a line symmetrically dividing the bone fragment (Domínguez-Rodrigo and García-Pérez 2013). Use of the SLA was also adopted due to the sedimentary conditions of the assemblage and the excavation and recovery techniques applied which prevented in situ access to the surfaces of all of the bones (Domínguez-Rodrigo and García-Pérez 2013).

Results

The results depicted in Fig. 6 show that anatomical units of the three Voorhies (1969) groups are represented in the GNLQ1 fossil record, but that they show a significant variation in their representation (%MAU). For cf. *Palaeolama* sp., the group with the higher values is the lag deposit, composed of hydraulic transport-resistant bones (group III), followed up by group II. The least represented group (group I) comprises easily transported specimens. The results obtained suggest an assemblage affected by hydraulic sorting. The same tendency can be observed for Cervidae bones, despite their lower representation. When considering the hydraulic displacement potential groups established by Kaufmann and Gutiérrez (2004) for adult *L. guanicoe*, a similar pattern is observed for cf. *Paleolama* sp., where the most represented group (groups II–III) is again the lag assemblage (Fig. 7).

Table 3 Taphonomic alteration registered in the GNLQ1 bone assemblage (NISP and %NISP)

Bone weathering		Rodents gnawing		Carnivores marks		Root etching marks	
NISP	%NISP	NISP	%NISP	NISP	%NISP	NISP	%NISP
30	1.02	2	0.07	19	0.65	2524	86.09
Abrasion		Iron oxide		Marine bioerosion		Marine biofouling	
NISP	%NISP	NISP	%NISP	NISP	%NISP	NISP	%NISP
2929	99.86	2880	98.19	149	5.08	67	2.28

Table 4 Carnivore modifications registered in the GNLQ1 bone assemblage (NISP and %NISP)

Perforations		Pittings		Scoring		Furrowing		Crenulated edges	
NISP	%NISP	NISP	%NISP	NISP	%NISP	NISP	%NISP	NISP	%NISP
9	0.31	6	0.20	1	0.03	5	0.17	2	0.07

Some of the missing bones pertaining to groups I and I–II might belong to the Mammalia assemblage, where important percentages of flat bones (37 %), ribs (15 %) and vertebrae (1.8 %) are represented, thus reducing the apparent sorting effect by water transport. On the other hand, the total absence of bones belonging to these groups could not be attributed to mineral bone density ($r = 0.027$, $p = 0.917$).¹

The total assemblage is slightly to moderately abraded and can be classified into stages 1 and 2 of Cook and Trueman (2009) (Table 3). Although the bones are not heavily abraded, abrasion covers both surfaces (86 %), suggesting long-term in situ abrasion, which probably resulted from low-energy water flowing through the sediments. However, abrasion can be also attributable to the action of abrasive marine sediments.

Weathering was observed in only a few of the bones of the assemblage (Table 3) and concentrated on stages 1 and 2 of the Behrensmeyer (1978) scale. Despite abrasion, advanced stage-weathered bones were not observed (Fernández-Jalvo and Andrews 2003), thus supporting the conclusion that remains were not extensively exposed to subaerial conditions before they became buried. Although, weathering stages may suggest multiple depositional events, evidence indicates that the bones became rapidly buried. In contrast, subsurface alterations (cf. Andrews 1995) are highly represented in the fossil record, mainly by root marks (86 %) and iron oxide staining (98 %) (Table 3). Root marks indicate the growth of vegetation over the bone assemblage (López et al. 2012; Cartajena et al. 2013). The high percentage of oxidation staining can be explained by the interaction of bones with the sedimentary matrix, composed of ferrous elements that might have arisen as a result of the meteorization of the lateral boundaries of fluvial sediment (cf. Achyuthan 2004). Previous energy dispersive spectroscopy (EDS) analysis identified spheroidal bodies of pyrite in the osseous matrix of fragments of humerus from cf. *Palaeolama* sp. (López et al. 2012; Cartajena et al. 2013), which have been related to anoxic environments and to the action of sulphur-reducing bacteria (Borrego et al. 2003; Brown et al. 2010).

A low incidence of other natural agents such as rodents and carnivores can be observed at the record (Table 3). The most represented alterations in the GNLQ1 assemblage are related to perforations and pitting, attributed to both large and small carnivores (López et al. 2012; Cartajena et al. 2013) (Table 4). Big-size perforations suggest the role of large carnivores as a

taphonomic agent in the formation and modification of the faunal assemblage, which might be responsible for the accumulation and loss of bones and/or carcasses at the site due to selective scavenging. Overall, taphonomic studies suggest a low degree of preservation of vertebrae and ribs, in contrast to crania, mandibles and limb bones due to carnivore activity (cf. Marean and Spencer 1991; Faith and Behrensmeyer 2006). Although several taphonomic studies suggest a low degree of preservation of vertebrae and ribs, in contrast to crania, mandibles and limb bones due to carnivore activity (cf. Marean and Spencer 1991; Faith and Behrensmeyer 2006), the recovered anatomical units representation and the carnivore modifications observed at GNLQ1 needs to be contrasted with more accurate studies related to South American Cone preys and predators in order to understand the carnivore activity intensity (Borrero and Martin 1996; Borrero et al. 2005; Martin 2013).

Finally, around 7 % of the assemblage exhibits bone-surface alterations by marine organisms. These biogenic modifications have been divided into two categories according to the causal agent and the resulting alteration (Leonard-Pingel 2005) (Table 3). On the one hand, bioerosion grouped bones with striations, small furrows and orifices due to the action of marine borers such as Teredinidae, commonly found along the Pacific coast of Chile (Osorio 2002). On the other hand, biofouling encrustations, produced by cirripedes (barnacles) which embed and attach themselves to the bone, producing small cavities or holes, were detected. The lack of extended colonies and the presence of encrustations exclusively on one of the surfaces suggest a limited exposure of the bones on the seafloor to the water column, preventing a prolific colonization of cirripedes. Minor presence of benthic foliose red alga *Cryptopleura imbricata* (Dawson 1962), which attaches itself to the partially exposed clay-gravel-consolidated stratum of the seabed, was also observed on some bones.

Table 5 Concentration of values, means, variance and intervals of the sample angles of animal bone samples from the GNLQ1 site

Variable	Angles
Mean vector (μ)	354.954°
Length of mean vector (r)	0.612
Median	360°
Concentration	1.558
Circular variance	0.388
95 % confidence interval (\pm) for μ	334.287°/15.621°
99 % confidence interval (\pm) for μ	327.795°/22.113°

¹ Correlation (r) between bone mineral density values (Elkin 1995) and cf. *Palaeolama* sp. %MAU.

Table 6 Statistical tests of isotropy applied to GNLQ1 and their significance (*p*)

Watson's test		Kuiper's test		Rayleigh's test	
U^2	<i>P</i>	<i>V</i>	<i>P</i>	<i>R</i>	<i>P</i>
0.647	<0005	3.187	<0.01	11.6	2.988E-6

Bilateral, intermembral and mechanical refitting was achieved by using non-metric attributes for the most common taxa. Although a variety of taxa are distributed across the excavated area, refits were only accomplished within and not between delimited bone concentrations. In the case of *Palaeolama* sp., for example, the joint articulation between distal humerus and proximal radius-ulna was successfully refitted. A large portion of the diaphysis of the same radius-ulna could be assembled too. Despite other elements of the front limb (the carpals and first anterior phalanx) having been recorded, it was not possible to determine if they belonged to the same individual. A distal humerus from a second individual and a hemipelvis were mechanically refitted as well. Both hemimandibles of a cervid specimen could be bilaterally refitted. The molar series of a hemimaxilla and a metapodial diaphysis were both assembled through mechanical refitting. Mylodontidae osteoderms exhibit a continuous spatial distribution across several excavation units (J7_2, J7_4, J8_2 and J8_4), although they show high-density *loci* characterized by particular features, suggesting in situ decaying of Mylodontidae skin. This distribution coincides with the dispersion of most of the Mylodontidae/Xenarthra bones. Among them, a femur diaphysis could be mechanically refitted (Fig. 3a).

Determining the spatial distribution of archaeological and paleontological remains has been frequently addressed through the analysis of artefact and ecofact evidence orientation and the influence of agents such as water currents (Voorhies 1969; Petraglia and Potts 1994; Gutiérrez and Kaufmann 2007; Benito-Calvo and de la Torre 2011; Domínguez-Rodrigo et al. 2012; Domínguez-Rodrigo and

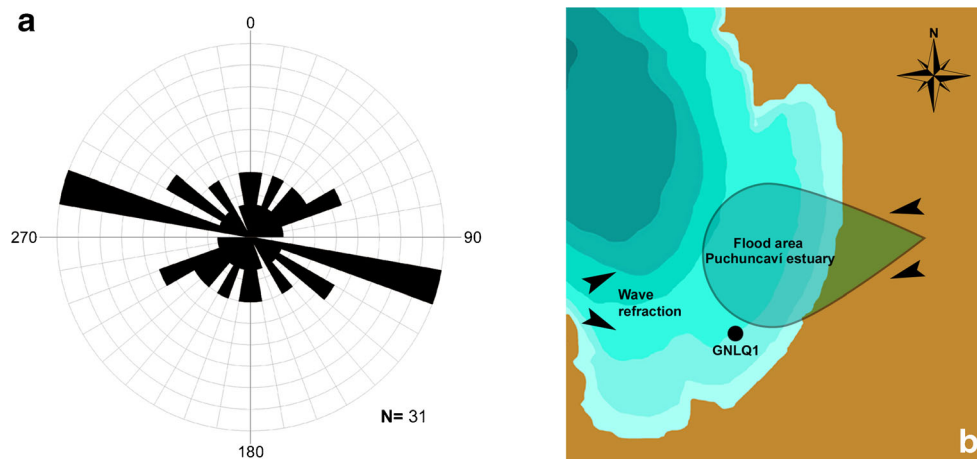
García-Pérez 2013). During both the continental phase and the marine phase of the GNLQ1 site, the influence of rivers and waves, tides and currents, respectively, might represent disruptive factors to the original dispersion of the bone assemblage. Various lines of evidence (e.g. abrasion, anatomical representation, among others) have been discussed earlier in this paper. However, the bone orientation is also relevant for identifying possible accumulations or dispersal of skeletal elements. As outlined above, in order to address these issues, a rose diagram was created, considering the orientation of long bones (e.g. humerus, radius-ulna, femur, tibia), long flat bones (ribs) and irregularly shaped bones (e.g. pelvis, vertebrae, scapula and mandible) of the units subjected to analysis. Regarding orientation, there were a number of tendencies displayed as regards the location of the axes, most of which were determined by the shape of the bones.

The results obtained indicate a slight tendency of accumulation between 280°–290°/100°–110°. Although the size of the sample is small ($n = 31$), statistical results partially support the presence of isotropy, thus resulting in a rejection of the null hypothesis for the site, while at the same time indicating a slight degree of anisotropy based on different kinds and shapes of bones (Tables 5 and 6 and Fig. 8a). These processes might have occurred during the continental phase of the site as the result of the effect of the ancient low-energy fluvial floodplain of Puchuncaví River located to the northeast of GNLQ1 (Fig. 8b). By contrast, the orientation of the bones does not seem attributable to the influence of wave action determined by the combined effect of the dominant southwesterly winds and the diffraction caused by Los Molles peninsula during the marine phase.

Discussion and conclusions

The high taxonomic diversity at the site, reflected in the varied body size groups recorded, along with the taphonomic agents

Fig. 8 **a** Rose diagram with dispersion of angles of animal bone remains at the GNLQ1 site. **b** Schematic representation of direction of water flow from the flood area of Puchuncaví estuary and as a result of wave refraction at Quintero Bay



identified, suggests an attritional or ‘normal’ mortality deposition in which the animals accumulated there gradually over the course of time (cf. Voorhies 1969). The representation of anatomical units supports the hypothesis that the assemblage of mammals was not accumulated by hydraulic transport, but rather that the animals died at or near the site. The action of carnivores may have also had an impact on the accumulation of carcasses during a relatively short period of time (cf. Tappen 1995; Tappen et al. 2002). However, during the continental phase of the GNLQ1 site, alterations resulting from exposure to subaerial conditions were minimal, indicating that the samples were rapidly buried, resulting in a well-preserved bone assemblage.

Despite carnivore activity, the absence of certain anatomical units may also be a result of hydraulic action of low-energy water flow during the continental phase. However, it is also possible that the loss of bones was in part the result of the wave erosion and dispersal action throughout periods of temporal exposure of the deposits in a shallow water environment, during the marine phase. Overall, it is possible to distinguish more clearly agents characteristic of the continental phase than the marine phase. The presence of radicles, as well as carnivore and rodent modifications are to be expected from a fossil assemblage like that of GNLQ1. In the case of the marine phase, the embedding of sea organisms and bioerosion resulting from such organisms are the most predictable changes. The action of waves in the upper shore-face requires short-term experimental and actualistic studies in order to understand the incidence of the exposed faunal assemblage as performed for other taxa (Kidwell 1985, 1998; Meldahl and Flessa 1990). However, not all taphonomic modifications can be assigned conclusively to one phase or the other. Abrasion may be the result of either the continual action of sedimentary particles in a low-energy flow environment during the continental phase or during the marine phase.

Unfortunately, during the last decade, both instability of the consolidated sediments of the deposit and deterioration of the bones have been confirmed during excavation, conservation and analysis stages of the GNLQ1 material. Once uncovered, the bones now become easily dislodged from the clay-gravel stratum and exposed to physical, chemical and biogenic alterations. In terms of conservation, highly fragmented, eroded and fragile material of the 2012–2013 fieldwork seasons contrasts significantly with the structurally sound bones recovered during the 2007 test-excavations stage. These accelerated deterioration processes caused by natural agents are indirectly attributable to human activity, particularly the modification of the depositional environment due to industrial activities taking place nearby in the harbour.

Finally, in a proximal *Xenarthra* order femur, two marks were found whose macroscopic and microscopic morphology (SEM) bear a close resemblance to those left as a result of the use of stone cutting instruments (Fernández-Jalvo and Cáceres

2010). This evidence is still being highly scrutinized; however, the possible incidence of human activity in the selection and accumulation of bone remains found at the GNLQ1 site should be therefore considered. Scarce human modifications might indicate low-intensity processing events, even scavenging activity (López 2007). In recent years, the discovery of several Final Pleistocene–Early Holocene (ca. 25,800–10,300 BP) sites containing extinct fauna further north have generated an interesting, although complex scenario due to weak or absent association between faunal and cultural remains and ambiguous cultural modifications in bones (López 2007; Méndez 2011). In summary, the potential anthropic evidence at GNLQ1, which requires significant further corroboration and new radiocarbon dates, opens up a discussion that exceeds the scope of the present study.

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