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Unravelling Hominin Activities in the Zooarchaeological Assemblage of Barranco León (Orce, Granada, Spain)

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Abstract

Little is known about the subsistence practices of the first European settlers, mainly due to the shortage of archaeological sites in Europe older than a million years. This article contributes to the knowledge of the subsistence of the first Europeans with new zooarchaeology and taphonomic data from the Palaeolithic site of Barranco León (Orce, Granada, Spain). We present the results of the analysis of the faunal assemblages retrieved in the context of new excavations undertaken between 2016 and 2020. We have followed a standard methodology for the identification and quantification of species, mortality profiles, skeletal representation and taphonomic analysis. With regard to the taphonomic evidence, we have documented the extent of rounding, abrasion and other alterations. Finally, we examined traces from the activities of carnivores and hominins that led to the accumulation and alteration of the bone assemblages. Results indicate that the archaeo-paleontological deposits from Barranco León present a dual-patterned mixed taphonomic origin. The first phase primarily involved waterborne processes (BL-D1), which led to the accumulation of lithic raw materials, a few archaeological stone tools, and some faunal remains with percussion and cutmarks. The second phase (BL-D2) contains several stone tools associated with faunal remains with more anthropogenic alterations, such as cutmarks and percussion marks. After analysing the Barranco León zooarchaeological assemblage, the present study concludes that hominins had access to the meat and within-bone nutrients of animals of diverse sizes. However, the specific carcass acquisition mechanisms that hominins followed are less certain because the presence of tooth marks suggests that carnivores also played a role in the accumulation and modification of the Barranco León faunal assemblage.

Keywords Early Pleistocene · Taphonomy · First settlement of Europe · Cutmarks · Hominin-carnivore interactions · Bone surface modifications

Introduction

Barranco León (Guadix-Baza, Spain) is one of the oldest Early Pleistocene open-air sites in Europe (1.4 Ma). This site, alongside the nearby locality of Fuente Nueva 3, presents evidence of hominin behaviour, including the earliest lithic assemblages documented in the Iberian Peninsula (Turq et al., 1996; Gibert et al., 1998; Barsky et al., 2010, 2015; Titton et al., 2019, 2020, 2021; Toro-Moyano et al., 2009, 2010a, b, 2011, 2013; Yravedra et al., 2021). Barranco León has also produced hominin remains, specifically a mandibular left dm1 (Toro Moyano et al., 2013, although see also Gibert et al., 1999; Ribot et al., 2015). Bone modifications by biotic agents, including hominins, have also been documented at the site (Espigares, 2010; Espigares et al., 2019). On the basis of these associated discoveries, Barranco León is one of the main localities for the study of hominin subsistence strategies at the onset of the first hominin settlement of Europe (Rodríguez-Gómez et al., 2016). Nevertheless publications dealing with archaeozoology and taphonomy of the fauna assemblages have been scarce (Espigares, 2010; Huguet et al., 2013, 2017; Cheheb et al., 2019; Espigares et al., 2019).

From a sedimentological point of view, Barranco León level D was described as a secondary deposit whose archaeo-paleontological remains have been reworked (Anadón et al., 2003, 2015; Anadón and Gabàs, 2009; Anadón and Julià, 2010; Oms et al. 2011) and interpretations described a secondary origin of the paleontological remains assemblages (e.g. Turq et al., 1996; Toro-Moyano et al., 2010a, 2010b, 2011, 2013). The presence of in situ knapping activities was pointed out by Toro et al. (2013) based on a lithic refitting in level D. Nevertheless a recent study (Titton et al., 2021) has proved that Barranco León D1 (BL-D1) was both a raw material source and a knapping site. BL-D1 is therefore a mix of primary and secondary archaeo-paleontological evidence sealed by another depositional event (BL-D2). Thus, the present study aims to expand the zooarchaeological and taphonomic interpretation of Barranco León. Specifically we focus on (1) unravelling the activities played by hominins in the bone accumulation (2) establishing the timing of hominin access to animal carcasses.

Prior taphonomic assessments of the site have integrated insights from Fuente Nueva 3 (Espigares et al., 2019). The interplay of taphonomic factors in the Barranco León sequence demand a more in-depth focus on the evidence from this locality. This new analysis will allow for a re-assessment of the interpretations provided by Espigares et al. (2019), who claim that hominins only played a secondary role in terms of access to carcasses. From this perspective, these early hominin groups have been interpreted as scavengers of mammalian carnivore prey. This interpretation is in stark contrast with the evidence documented at other Early Pleistocene sites in Europe pre-dating 1Ma, such as Sima del Elefante, where taphonomic research has shown evidence of early human access to the carcasses prior to secondary carnivore involvement (Huguet et al., 2013, 2017). The interpretation of hominins as scavengers offered by Espigares et al. (2019) are also at odds with taphonomic evidence, such as the identification of cutmarks attributed to defleshing and evisceration activities reported in Espigares

et al. (2019, SF table s11), because evisceration cutmarks (i.e. those found on the ventral side of ribs) are generally associated with primary hominin access to carcasses. This reasoning is based on the fact that, upon hunting their prey, carnivores consume the viscera first; as such, cutmarks associated with evisceration imply that hominin access to the carcass preceded carnivore feeding.

Establishing the timing of carcass access by the different agents involved in the formation of the Barranco León assemblage is paramount for understanding and reconstructing hominin behaviour across the Orce Basin palaeolandscapes. As shown by Titton et al. (2021), the lithic assemblage from Barranco León evidences the existence of localised knapping activities involving the exploitation of blanks through several differentiated knapping sequences, as well as the use of multi-purpose tools. Furthermore, the taphonomic analyses of the faunal remains retrieved during the excavations carried out at Barranco León between 2017–2020 provide additional insights into the subsistence strategies of the first European populations.

This research contributes to enhancing our knowledge of hominin behaviour in Europe before 1Ma.

The Site of Barranco León

The Early Pleistocene site of Barranco León (37°43'28.4"N 2°27'03.7"W) is located in the northeastern part of the Cenozoic Guadix-Baza Basin, in close proximity to the town of Orce (Granada, Spain) (Fig. 1), where the Plio-Pleistocene Baza Formation contains abundant archaeo-paleontological deposits. This open-air site has an excavated area extension of ca. 150 m². The site is in the Upper Member, a deposit of lacustrine and palustrine origin resulting from the accumulation of silty calcareous deposits as well as a coarser fraction (Oms et al., 2011). The BL section has a thickness of roughly 25 m, and consists of mudstones, grey to yellow sands, gravels and limestones. The stratigraphy bounding the site is divided into nine levels (Anadón et al., 2003; Anadón and Gabás, 2009; Oms et al., 2011). From oldest to youngest these are: level A, beige calcisiltite to calcarenites; level B, black and dark green feldspar quartz muddy sands; level C, beige calcisiltites to calcarenites; level D is divided in BL-D1, greyish gravels with a sandy matrix; BL-D2, greyish quartz-bioclastic sands, ending in whitish limestones; level E, fine-to-medium grained quartz and feldspar sands, with reddish, brown and greenish colorations; level F1, black sandy mudstones; level F2, bioclastic sands of greyish quartz with small chalk nodules in the upper part; and finally, level G corresponds to beige-colored sands.

The two most important archaeological and palaeontological levels and those analysed in this study are BL-D1 and BL-D2. The chronology of level D has been estimated at ca. 1.5 Ma using a combination of ESR and U/Th dating techniques (Toromoyano et al., 2013). BL-D1 is the main level with more fossil and lithic material. It has a thickness steadily increasing from 0 to 75 cm in a NW-SE direction. At its base, the gravels and cobbles have eroded a large part of the underlying level C and come into direct contact with the level B. This erosion is more evident in the SE, where the central axis of the palaeocurrent that gave origin to this level is located. The formation of BL-D1 is associated with a sudden event whereby high-energy

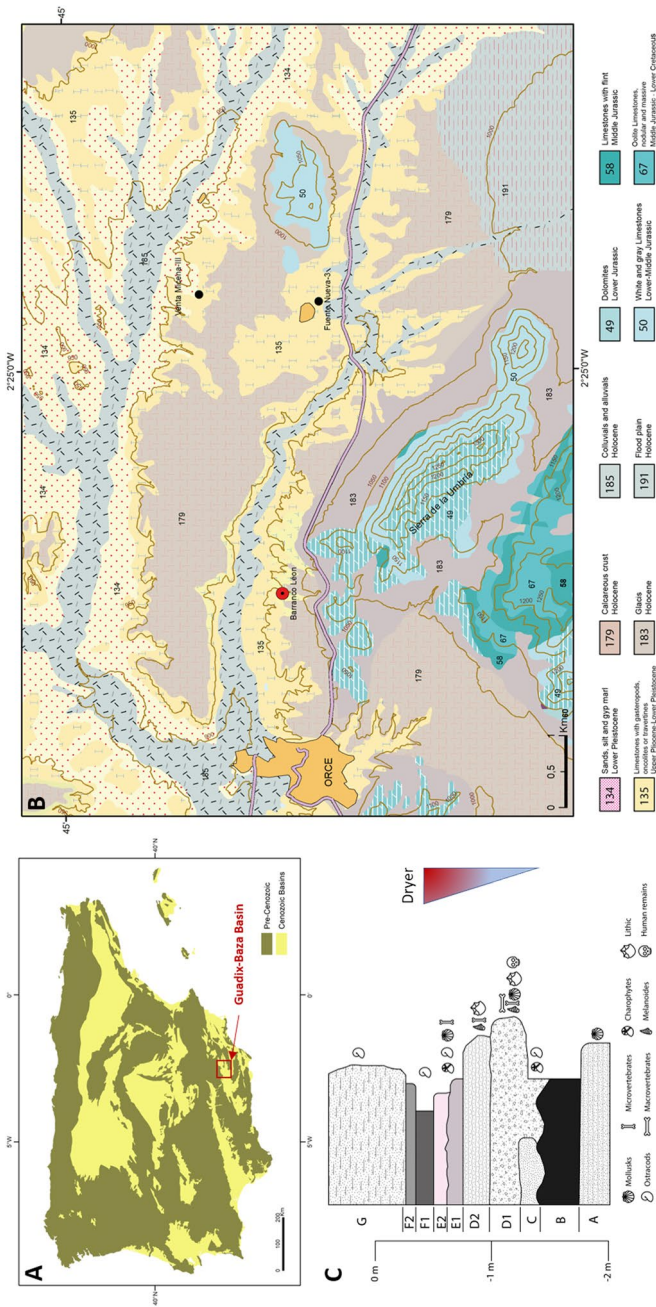


Fig. 1 Location of Barranco León (Guadix-Baza basin). A. General location of Guadix-Baza basin. B. Regional location of Barranco León. C. Stratigraphy for Barranco León (Guadix-Baza basin)

water flows brought gravels together with most of palaeontological and archaeological remains (Oms et al., 2011). The sedimentology and lateral variations of this level have been studied in detail by Anadón et al. (2003). The cobbles and the pebbles of the gravels were characterised by Anadón and Juliá (2010), who showed that they are dominated by palustrine intrabasinal siltstones with scarce Mesozoic siltstones from the adjacent External Zones. According to the stratigraphical sequence provided by Oms et al. (2011), we would therefore be dealing with a reworked level with a mixture of materials contributed from nearby distances and materials in primary position. BL-D2 has a regular thickness of between 15 and 20 cm of sands very similar to those found in BL-D1. Nevertheless, this level does not seem to be posteriorly modified. The density and dimensions of the archaeo-palaeontological assemblage are lower compared to D1. The upper part of BL-D2 is a level of whitish chalky limestone with abundant ostracods, mollusks and charophyte remains (Fig. 1c). Thus, it is important to point out that due to the stratigraphic complexity of Barranco León, well known since the work carried out by Oms et al. (2011), it is essential that all interpretations of this site refer to the levels defined there.

Sedimentological analyses indicate the existence of a marginal freshwater area in the periphery of the saline main lake (Anadón et al., 2015). The freshwater was sourced from the adjacent highlands and mixed with surface waters and hydrothermal ones. Palaeoecological analyses based on microfauna and tooth wear patterns indicate a predominance of Mediterranean woodland and open environments in the basin during much of the Early Pleistocene (e.g. Agustí et al., 2010; Blain et al., 2011; Sánchez-Bandera et al. 2020; Saarinen et al. 2021). Recent herpetofaunal studies (Sánchez-Bandera et al., 2020) show a tendency towards more arid conditions from BL-D1 to level E. The BL-D1 and BL-D2 depositional events took place in the context of a humid and wooded biotope.

Table 1 showing the faunal spectrum for large vertebrates has been updated after Martínez-Navarro et al. (2010) and includes *Ursus etruscus*, *Canis mosbachensis*, *Xenocyon* cf. *lycaonoides*, *Vulpes alopecoides* (Bartolini Lucenti and Madurell-Malapiera, 2020), *Meles* cf. *meles*, *Martellictis ardea* (Ros-Montoya et al., 2021), *Pachycrocuta brevirostris*, *Homotherium* sp., *Stephanorhinus etruscus*, *Equus altidens*, *E. sussenbornensis*, *Hippopotamus antiquus*, *Bison* sp., *Hemitragus* cf. *albus*, *Praemegaceros* cf. *verticornis* and *Metacervoceros rhenanus*. A rich micromammals set is also represented by *Mimomys savini* (showing a representativity of 80% in relation to the total rodents), *Allophaiomys* aff. *lavocati*, Erinaceinae indet., *Crocidura* sp., *Sorex minutus*, *Sorex* sp., *Galemys* sp., *Asoriculus gibberodon*, *Apodemus* aff. *flavicollis* and *Hystrix* sp. (e.g. Agustí et al., 2015). In addition, *Oryctolagus* cf. *lacosti* is recorded. In addition the herpetofauna list is composed by *Discoglossus* sp., *Pelobates cultripedes*, *Epidalea calamita*, *Bufo viridis* s.l., Bufonidae indet., *Hyla* sp., *Pelophylax* cf. *perezii*, Anura indet., Lacertidae indet. *Ophisaurus* sp., *Malpolon monspessulanus*, *Natrix maura*, *Natrix natrix* s.l., *Natrix* indet., cf. *Coronella* sp., *Zamenis scalaris*, Colubrinae indet. and Ophidia indet. (e.g. Blain et al., 2016; Sánchez-Bandera et al., 2020).

The lithic association from BL is composed of a considerable number of artefacts typical of the Oldowan (e.g. Turq et al., 1996; Gibert et al., 1998; Toro-Moyano et al., 2009, 2010a, b, 2011, 2013; Barsky et al., 2010, 2015; Titton et al., 2019,

Table 1 Taxonomic representation in the zooarchaeological assemblages of Barranco León D1 and D2, based on the faunal remains retrieved from the 2017–2020 field seasons, quantified in terms of NISP and MNI

NISP	NISP data						MNI data					
	D1	%	D2	%	Total	D1	%	S/A/J/I	D2	%	S/A/J/I	
<i>Stephanorhinus etruscus</i>	37	6.7	1	0.0	37	3	8.3	1/0/1/1	1	10.0	0/0/0/1	
<i>Equus sussenbornensis</i>	11	2.0	1	4.3	12	1	2.8	0/1/0/0	2	20.0	0/1/0/1	
<i>Equus altidens</i>	90	16.3	3	13.0	93	6	16.7	1/3/1/1	1	10.0	0/1/0/0	
<i>Equus</i> sp.	82	14.9	1	4.3	83	2	5.6	0/1/1/0	1	10.0	0/1/0/0	
<i>Hippopotamus antiquus</i>	93	16.9	4	17.4	97	4	11.1	0/2/1/1	1	10.0	0/1/0/0	
<i>Bison</i> sp.	11	2.0	0	0.0	11	2	5.6	0/1/1/0	1	10.0	0/1/0/0	
Bovidae	29	5.3	2	8.7	31	2	5.6	0/2/0/0	1	10.0	0/1/0/0	
<i>Capra alba</i>	36	6.6	0	0.0	36	2	5.6	0/2/0/0	1	10.0	0/1/0/0	
Cervidae	77	14.0	3	13.0	80	2	5.6	0/1/1/0	1	10.0	0/1/0/0	
<i>Metacervoceros rhenanus</i>	23	4.2	2	8.7	25	2	5.6	1/1/0/0	1	10.0	0/1/0/0	
<i>Praemegaceros</i> cf. <i>veriticornis</i>	9	1.6	2	8.7	11	1	2.8	0/1/0/0	1	10.0	0/1/0/0	
<i>Canis mosbachensis</i>	1	0.2	0	0.0	1	1	2.8	0/0/1/0	1	10.0	0/1/0/0	
<i>Xenocyon lycanoides</i>	1	0.2	0	0.0	1	1	2.8	0/1/0/0	1	10.0	0/1/0/0	
Canidae indet.	5	0.9	0	0.0	5	0	0.0		0	0.0		
<i>Pachycrocuta brevirostris</i>	3	0.5	0	0.0	3	1	2.8	0/1/0/0	1	10.0	0/1/0/0	
Felidae indet.	1	0.2	0	0.0	1	1	2.8	0/1/0/0	1	10.0	0/1/0/0	
Mustelidae indet.	1	0.2	0	0.0	1	1	2.8	0/1/0/0	1	10.0	0/1/0/0	
<i>Ursus etruscus</i>	2	0.4	0	0.0	2	1	2.8	0/1/0/0	1	10.0	0/1/0/0	
Carnivore indet.	10	1.8	0	0.0	10	0	0.0		0	0.0		
<i>Oryctolagus tiacosti</i>	30	5.4	5	21.7	35	3	8.3	0/2/1/0	1	10.0	0/1/0/0	
Total mammalia determ.	551	100.0	23	100.0	574	36	100.0	3/23/8/3	10	100.0	0/8/0/2	
Chelonia	896		33		929							

Table 1 (continued)

NISP	NISP data				MNI data					
	D1	%	D2	%	Total	D1	%	S/A/J/I	%	S/A/J/I
Mammalia indet size 0	44	3.0	5	5.0	49					
Mammalia indet size 1	45	3.0	1	1.0	46					
Mammalia indet size 2	314	21.1	19	18.8	333					
Mammalia indet size 3	376	25.2	29	28.7	405					
Mammalia indet size 3a	79	5.3	6	5.9	85					
Mammalia indet size 3b	391	26.2	18	17.8	409					
Mammalia indet size 4	195	13.1	21	20.8	216					
Mammalia indet size 5	53	3.6	2	2.0	55					
Indet	7,904		141		8,045					
Total	10,848		298		11,146					
Faunal remains determinable	1,447		56		1,503					
% Fauna determinable	13		19		13.48					
Mammalia indet	9,401		242		9,643					
% Fauna indeterminate	87		81		87					

Age classes: S, Seniles; A, Adults; J, Juveniles; I, Infants. Remains attributed to chelonians were excluded from overall MNI and NISP percentages; they are only represented by carapace fragments

2020, 2021). These include cores, flakes, flake fragments, debris, retouched pieces, angular fragments, hammers and unmodified cobbles. The raw materials used are predominantly flint and limestone from the nearby Jurassic formations, although there are several quartzite implements too (Toro-Moyano et al., 2011). Flint is mainly used for small and sharp tools while limestone is mostly used for the manufacture of percussion objects (Titton et al., 2019). The tool-kit is primarily focused on obtaining small, sharp-edged tools for immediate use on site. The in situ knapping processes at this site have been confirmed by several refitted lithic artefacts refittings (Toro-Moyano et al., 2013; Titton et al., 2021). Nevertheless, there is evidence for the use of heavy tools in the development of various active percussion activities other than knapping, such as bone fracturing, tendon processing, vegetal matter crushing or woodworking (Barsky et al., 2015; Titton et al., 2019). Among these tools, several spheroids and subspheroids may also have been used for these purposes (Titton et al., 2020; see also Assaf et al., 2020).

Materials and Methods

The materials analysed for this study came from BL-D1 and BL-D2, retrieved between 2016 and 2020. These levels account for 11,146 remains. The zooarchaeological and taphonomic analysis focused on the entirety of this assemblage.

Faunal remains were quantified by number of identifiable specimens (NISP), minimum number of elements (MNE) and minimum number of individuals (MNI). MNI estimates considered specimen side, ontogenetic age and all other relevant osteological data derived from morphological and taphonomic variables (Brain, 1969). Mortality profiles were generated by assigning elements to one of four categories described in Yravedra (2006): infantile, juvenile, prime adult-adult and senile, based on tooth eruption and crown wear and epiphyseal fusion.

Anatomical pattern were quantified in MNE, these are based on a division of the following anatomical regions: cranial (i.e. horn, cranium, mandible and teeth); axial (vertebrae, ribs, pelves and scapulae, according to Yravedra and Domínguez-Rodrigo (2009). Appendicular limbs are classified according to upper appendicular elements (humerii and femora); intermediate (radii, tibiae, patella and ulnae) and lower appendicular bones (metapodials, carpals, tarsals, phalanges and sesamoids). Long limb bones were further divided into anterior elements (scapulae, humerii, radii, ulnae, carpals and metacarpals), as well as posterior elements (pelves, femora, tibiae, patella, tarsals and metatarsals).

Indeterminate herbivore and carnivore specimens that could not be identified were assigned a weight/size class. The categories used for herbivores follow the taxonomic adaptation made by Espigares et al. (2019) of the classification system developed by Bunn (1982): (0), including species weighing less than 25 kg; very small size (1), including macro-vertebrates species weighing 25–50 kg; small size (2), including species weighing 50–125 kg; intermediate size (3), including species weighing 125–500 kg, with an additional division between 3a (125–250 kg) and 3b (250–500 kg); large size (4), including species weighing 500–1000 kg; and very large size (5) for species weighing >1000 kg. Carnivores were classified according to three size classes: small

carnivores (e.g. foxes), intermediate carnivores (e.g. wolves), and large carnivores (e.g. lions and hyenas), following Espigares et al. (2019).

Bone fragmentation was analysed according to three variables. Firstly, bones were divided into several categories according to their length: <3cm, 3.1–5.0cm, 5.1–10cm and >10 cm, in order to identify the intensity of bone fragmentation within the sample. Secondly, bones were classified according to the nature of their breakage planes (green or dry) following the criteria of Villa and Mahieu (1991). Criteria used to diagnose dry breaks included the existence of abundant breaks that are longitudinal and/or transverse to the axis of the bone as well as breakage planes that are uneven, rough and exhibiting micro-step fractures. Dry breaks are further characterised by cortical medullary surface angles that are close to 90°. In contrast, green breaks specimens have smoother surfaces and more abundant oblique breakage planes. Lastly, shaft preservation was recorded according to circumference types; where type 1 refers to specimens with <25% of the shaft circumference intact, type 2 refers to specimens with 25–50% of the shaft circumference intact, and type 3 refers to specimens with >50% shaft circumference and those with a complete circumference, following Bunn (1982).

The impact of water alterations was estimated with fragment size distributions, as well as the presence of abrasion, polishing and rounding on bone surfaces according to Cáceres (2002) and Yravedra (2006). Rounding and abrasion were additionally classified into different stages (light, intermediate, and intense) on the basis of their intensity on bone surfaces, following Yravedra (2006). According to Lyman (1994) and Fernández Jalvo and Andrews (2016), abrasion is a physical phenomenon that can be caused by a range of different processes. At Barranco León, bone abrasion has a mechanical origin, associated with friction with the sedimentary matrix. This fact has already noticed in lithic industries (Titton et al., 2021) and small vertebrates (Blain et al., 2011).

Weathering intensity was analysed following Behrensmeyer et al. (1978). Bone surface modification analyses were carried out using hand-held lenses at 10–40x magnification (Blumenschine, 1986). Tooth marks were classified as pits, scores or puncture, while furrowing was also analysed, following established criteria by multiple authors (Binford, 1981; Blumenschine, 1995; Blumenschine et al., 1996). Cut and percussion marks were classified according to Binford (1981), Blumenschine and Salvaggio (1988) and Blumenschine et al. (1996). Modifications were quantified for specimens with well-preserved bone surfaces, in terms of NISP values. Cut and trampling marks were analysed according to Olsen and Shipman (1988), Yravedra (2006) or Fernández Jalvo and Andrews (2016).

Other processes, such as manganese staining or biochemical alterations, were recorded using the criteria outlined by Fernández Jalvo and Andrews (2016).

Results

Zooarchaeological Analyses

The sample analysed comprises 11,146 remains, with most remains derived from BL-D1 (n=10,848), and 298 from BL-D2, of which 13% and 19% respectively

could be determined (Table 1). The herbivores are more heavily represented than carnivores, albeit both exhibit a considerable taxonomic diversity. The carnivore assemblage includes remains of canids, mustelids, small felids and ursids. Among the herbivores, several species of bovids, caprids, cervids and equids have been identified. From BL-D1 the most represented taxon in terms of MNI is *Equus altidens* (NISP=90, MNI=6), followed by *Hippopotamus antiquus* (NISP=93, MNI=4) and *Stephanorhinus etruscus* (NISP=37, MNI=3).

The remaining species for BL-D1 are less well abundant, with generally only one or two individuals (Table 1). On the basis of taxonomic groups, equids are the best represented, followed by cervids, bovids and caprids. Regarding indeterminate remains, the size 3 group (medium-sized animals) is the best represented group, in accordance with the predominance of equids and cervids at the site (Table 1).

From a palaeoecological perspective, a wide range of species from many different ecological settings are represented at BL-D1. While species associated with open environments, such as equids and rhinoceroses, predominate, cervids – generally linked to more wooded environments – are also well represented (Saarinen et al., 2021). Species that favour watercourses and wetland environments, such as hippopotami and turtles, are common, with taxa associated with upland areas or rocky settings such as *Capra alba* also being present.

The BL-D1 mortality profiles show a predominance of adult individuals across most taxa, with the exception of the largest species, such as rhinoceros and hippopotamus, for which infant and juvenile age classes are better represented.

Excavations of BL-D2 have returned a much smaller faunal assemblage (n=298), of which only 13.48% could be identified (Table 1). Among the specimens identified, species from various groups of herbivores have been found (Table 1), with remains from hippopotamus, bovids, several species of deer and equids identified at the species level. From a palaeoecological perspective, the species represented also imply a wide diversity of habitats, as there are animals well adapted to open spaces, such as equids, species associated with wooded environments, such as cervids, and animals dependent on watercourses, such as hippopotami and turtles. Mortality patterns show a predominance of adults in all taxa, although two infant individuals of horse were identified.

The skeletal part profiles observed for BL-L1 and BL-L2 show that only taxa of size 2 and 3 (50-500Kg) have a representative MNE (n > 100) (see Suppl. File 1). None of the remaining size classes exceed an MNE count of 100 elements, rendering them to be not very representative. Cranial elements, including teeth, are the most commonly represented remains identified at species level, with teeth comprising between 30-60% of the MNE for all size classes other than size 4. The remaining anatomical sections are also represented in the assemblage, although in comparatively lower quantities. Axial, carpals, tarsal and appendicular remains all reach over 10% for sizes 2-3 (Suppl. File 1), which imply that most anatomical elements were present at BL. The skeletal part biases identified, such as the mismatch between anterior and posterior appendicular elements, or the low MNE/MNI ratios for most size classes, could correspond to the impact of different taphonomic agencies in the assemblage, such as carnivore ravaging or waterborne processes, which could affect the loss of fossils.

Taphonomic Analyses

The fragmentation of the faunal assemblage is very high, with a predominance of bones smaller than 3 cm. This fact constrains taxonomic identification, and 87% of bones had to be categorised as indeterminate (Table 1).

Upon analysing each level, it can be seen that bone fragmentation is extensive across two levels. Among the long bones, the high level of fragmentation is reflected in both their circumference index as well as their relative length. More than 95% of long bones at both levels have either less than 25% of the circumference of the diaphysis or less than 25% of the total relative length of the bone (Table 2). This fragmentation likely reflects the impact of diverse biological and physical processes, given that >32.0% of bones from BL-D1 and >41.7% of bones from BL-D2 exhibit green fractures (Table 2). Nevertheless, a large number of long bone fragments present fracture planes that could not be ascribed to either category, and for which no cause of fragmentation could be established (Table 2).

In terms of preservation conditions, 61% of BL-D1 specimens and 57% of BL-D2 remains exhibit a poor cortical bone surface preservation (Table 3). Subaerial exposure is not the primary cause of these preservation conditions, since most bones show no weathering or only the early stages of this process (Table 3). In contrast, it is evident that hydraulic alterations are a more relevant factor for understanding assemblage composition and bone preservation, given the high incidence of rounding, abrasion and polishing alterations in the BL assemblages.

The main hydraulic alteration observed on bones from Barranco León is rounding; 53.9% of the BL-D1 bone sample and 49.3% of BL-D2 bones show rounding,

Table 2 Fragmentation patterns for the bones of BL-D1 and BL-D2 zooarchaeological assemblages

Taphonomic characteristics	D1	% D1	D2	% D2
Bones < 3 cm	9489	87.5	209	70.1
Bones 3.1–5 cm	1016	9.4	72	34.4
Bones 5.1–9.9 cm	303	2.8	14	19.4
Bones > 10 cm	40	0.4	3	21.4
Total NISP	10,848		298	
% Long Bone with fractures and their nature				
% Green fracture: oblique smooth	375	32.8	30	41.7
% Dry fracture: transverse jagged	217	19.0	7	9.7
% Indet. fracture	551	48.2	35	48.6
% Degree of circumference of shafts of long bones				
<25%	946	97.6	60	95.2
26–50%	18	1.9	1	1.6
>51%	5	0.5	2	3.2
% Length of shafts with respect to long bones				
<25%	967	99.7	60	95.2
26–50%	2	0.2	1	1.6
>51%	1	0.1	2	3.2
Total NISP	970		63	

with advanced stages of rounding in 33.6% and 26.5% of the assemblages, respectively (Table 3). The other two types of waterborne alterations (abrasion and polishing) feature less prominently at the site. Abrasion affects 3.3% of BL-D1 remains and 4.7% of BL-D2 remains, with polishing affecting 9.3% of the BL-D1 assemblage and 19.1% of the BL-D2 assemblage. Bones exhibit only a light stage of abrasion intensity, indicating a low incidence of abrasive sediment in the water flows. Moreover, the greater incidence of rounding in relation to abrasion suggests that

Table 3 Taphonomic alterations for Barranco León, levels D1 and D2 (see Methods section for details)

Taphonomic characteristics (NISP)	D1	D2	%D1	%D2
Samples with bone surfaces preservation excluding teeth				
Bad	5749	152	61.8	57.4
Good and moderate preservation	3559	143	38.2	54.0
Weathering stages (according Behrensmeier, 1978)				
Weathering stage 0	8368	203	89.9	76.6
Weathering stage 1–2	873	57	9.4	21.5
Weathering stage 3–4	68	5	0.7	1.9
Water alteration				
Light stage abrasion	266	9	75.1	64.3
Intermediate stage abrasion	66	3	18.6	21.4
Intense stage abrasion	30	2	8.5	14.3
Polishing	1012	57	9.3	19.1
Rounding	5842	147	53.9	49.3
Light stage rounding	1552	78	26.6	53.1
Intermediate stage rounding	2325	30	39.8	20.4
Intense stage rounding	1965	39	33.6	26.5
Calcitic concretions	176	11	1.6	3.7
Oxides (MN, FE)	6833	136	63.0	45.6
Trampling				
Trampling alterations	330	25	9.3	17.5
Biochemical alterations				
Biochemical and root-etching alterations	339	19	9.5	13.3
Rodent tooth marks				
Bones with rodent tooth marks	2	–	0.06	
Carnivore activity				
Bones with carnivore tooth marks	167	16	4.7	11.2
Digestive alterations	9	–	0.3	
Anthropogenic bone alterations				
Bones with cut marks	70	12	2.0	8.4
Bones with percussion marks	46	4	1.3	2.8
Total sample NISP				
Sample NISP	10848	298		
Sample NISP excluding teeth	9308	265		

bones were not exposed to repeated water flows damaging their cortical surface, and instead the waterborne alterations are more likely to have resulted from the high-energy fluvial processes, which transported and introduced these bones into the Barranco León sequence. Other waterborne alterations, such as oxide staining over the bone surfaces, have been frequently documented in the assemblages (63% of BL-D1 and 45.6% of BL-D2), but they do not seem to have masked other bone surface modifications.

With regard to biochemical alterations, root etching had no impact on bone surface preservation. Likewise, rodent activity was very limited, with only 0.06% of bones showing rodent tooth marks. The main biological alterations observed in the BL faunal assemblage were associated with carnivore activity; 4.7% of BL-D1 bones and 11.2% of BL-D2 remains exhibit carnivore tooth marks (Table 3). Nevertheless, carnivore activity was not particularly intense; only 0.3% of bones show digestive alterations, 3% of toothmarked bones have more than five tooth marks, and furrowing was detected in only 0.4% (BL-D1) and 1.4% (BL-D2) of the Barranco León faunal assemblage. The size of tooth mark pits exhibits some degree of variability (between 1 and 5 mm in diameter), with two pits reaching 5 mm. When we compare the toothmark frequencies with actualistic reference frameworks (see Supplementary File 1), the impact of carnivore activity in the assemblage appears low. Only cheetah carcass modification frequencies resemble those for animal size 1–2 from BL-D1 and BL-D2 (Fig. 2). The same patterns are observed with regard to toothmark distributions on bone shafts (Fig. 3) and on appendicular bones (Fig. 4), where only leopard and cheetah exploitation patterns show similar tooth mark frequencies to the upper limb bone patterns documented at BL-D1 (Fig. 4). The low toothmark frequencies documented at Barranco León therefore resemble more closely the patterns associated with secondary carnivore ravaging following human processing of the carcasses.

Evidence of human activity was also documented in the faunal assemblages from Barranco León. At BL-D1, 1.2% of the bones show cutmarks and 1.3% exhibit percussion marks, while at D2, 8.4% of the assemblage shows cutmarks and 2.8% of the bones exhibit percussion marks (Table 3).

Cutmarks have been observed on remains from animals of all sizes, including large specimens of sizes 4 and 5 (Table 4). The anatomical distribution of cutmarks offers insights into the type and degree of systematization of butchery behaviours represented in a faunal assemblage (López-Cisneros et al., 2019). In both levels, the presence of cutmarks on appendicular bone shafts is associated with filleting, and some cutmarks on bone joints are associated with disarticulation. We were not able to identify evidence for other butchery processes such as skinning or evisceration. The presence of percussion marks on long bones indicates that butchery processes included the intentional breakage of marrow cavities in order to gain access to their contents (Table 3).

However, the percussion mark frequencies documented in BL-D1 and BL-D2 are very low and do not directly correspond with either of the models generated through experimental and actualistic references (Fig. 5).

With regard to cutmark frequencies, the pattern is ambiguous. The frequencies of cutmarks for animal sizes 4–5 from BL-D1 fit with primary human access, and

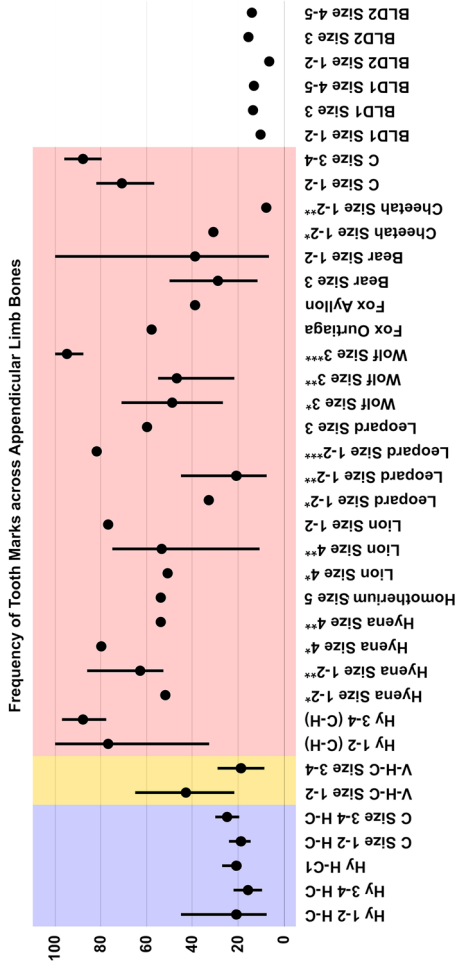


Fig. 2 Tooth mark frequencies on appendicular elements from Barranco León levels BL-D1 and BL-D2 by size classes in relation to the actualistic framework derived from carnivore feeding behaviours were documented in different contexts. The blue box highlights the range of toothmark frequencies that carnivores tend to leave on bones during secondary scavenging activities after human abandonment of the carcasses. The yellow box shows the toothmark frequencies resulting from a model in which vultures accessed first the carcasses, followed by humans and then carnivores, while the red box documents the main range of toothmark frequencies associated with primary carnivore accumulations. See Supplementary File 2 for the full bibliographic details of the relevant sources

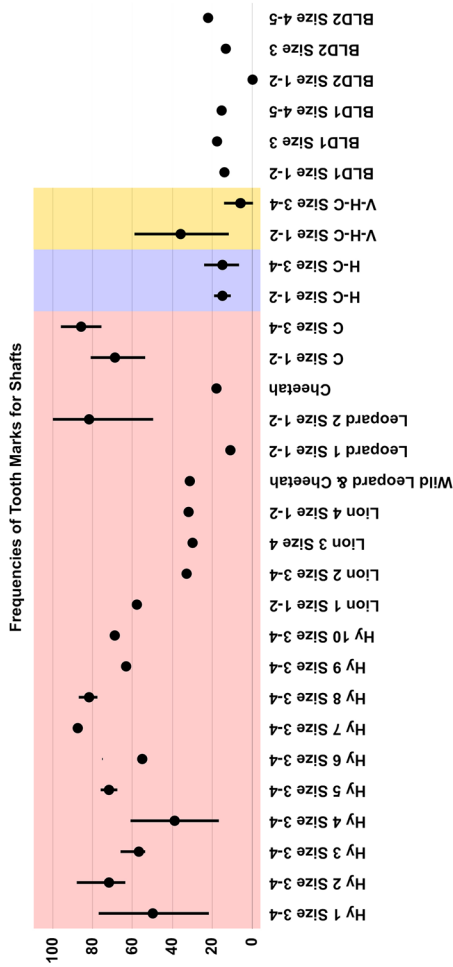


Fig. 3 Tooth mark frequencies on limb bone diaphyses from Barranco León levels BL-D1 and BL-D2 on animal size classes 1–2, 3, and 4–5, in relation to the actualistic framework derived from carnivore feeding behaviours documented in different contexts. The blue box highlights the range of toothmark frequencies that carnivores tend to leave on bones during secondary scavenging activities after human abandonment of the carcasses. The yellow box shows the toothmark frequencies resulting from a model in which vultures accessed first the carcasses, followed by humans and then carnivores – blue box, while the red box documents the main range of toothmark frequencies associated with primary carnivore accumulations. See Supplementary File 2 for the full bibliographic details of the sources

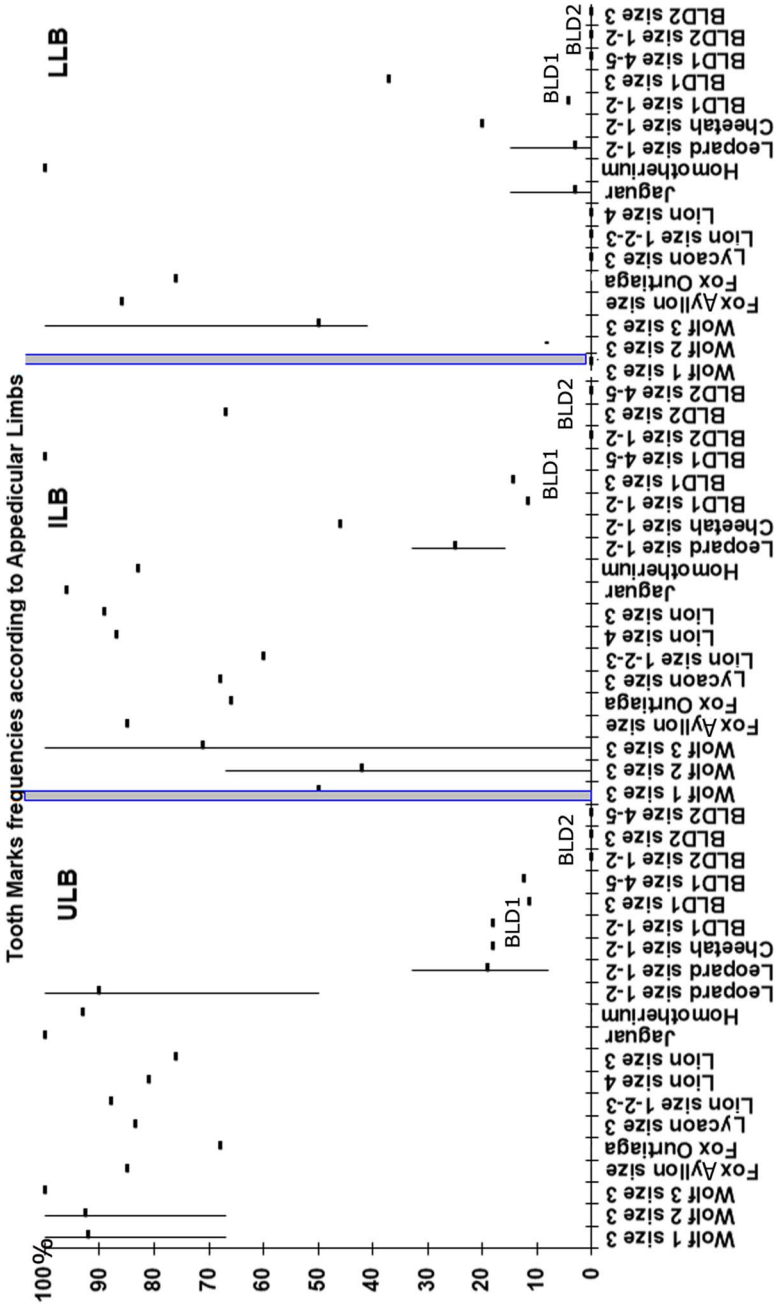


Fig. 4 Tooth mark frequencies on appendicular remains from Barranco León levels BL-D1 and BL-D2 on animal size classes 1–2, 3, and 4–5, in relation to the actualistic framework derived from carnivore feeding behaviours documented in different contexts. ULB refers to toothmarks on upper limb bones, such as humeri and femoral remains, ILB refers to intermediate limbs (tibiae, radii), while LLB stands for lower limb bones (i.e. metapodials). See Supplementary File 2 for more information on the comparative samples and their full bibliographic details

Table 4 Anatomical distribution of cut marks for Barranco León D1 and D2 by animal size class (see Methods section for details)

D1 (NISP)	1	2	3	3a	3b	4	5	Indet	Total
Vertebrae					1	1		2	4
Ribs		1	3					2	6
Scapula		1							1
Humerii					1	4			5
Femur			1		1		1		3
Estilopodials				1				1	2
Radii					1				1
Zeugopodials			1						1
Tibiae		1			1	1			3
Metacarpals					1				1
Metapodials		2	1		1				4
Carpals						1			1
Phalanges			1						1
Indeterminate fragment shafts	1	3	3	2	4	6	1	4	24
Plate of carapace								2	2
Indet			3		2	2		4	11
Total	1	8	13	3	13	15	2	15	70
D2	1	2	3	3a	3b	4	5	Indet	Total
Ribs	1				2				3
Indeterminate fragment shafts			2	1	1	1			5
Indet		1				1			2
Placa								2	2
Total	1	1	2	1	3	2		2	12

a similar behavioural interpretation can be deduced from the cut-mark data for size 3 animal remains from BL-D2. Nevertheless, the low frequencies documented for the remaining taxa resembles some scenarios with secondary hominin access (Fig. 6). Cut-mark frequencies on appendicular elements follow a similar pattern, as upper and intermediate limb bone data only indicate primary access for the larger size classes (4–5), whereas the low incidence of cutmarks on these elements may correspond to secondary access (Fig. 7). The data from lower limb bones are also ambiguous, since some frequencies are consistent with primary access while others may suggest secondary access. Lastly, the higher frequency of cutmarks on diaphyses is more indicative of primary anthropogenic access, particularly for BL-D2. In the case of BL-D1, the frequencies reported could fit carnivore-first or hominin-first actualistic scenarios (Fig. 7).

The different lines of evidence described in Figs. 2, 3, 4, 5, 6 and 7 show frequencies of tooth, cut and percussion marks that are somewhat ambiguous to interpret, preventing a clear assessment of temporality of access to animal carcasses accumulated at Barranco León. The presence of percussion marks indicates an exploitation

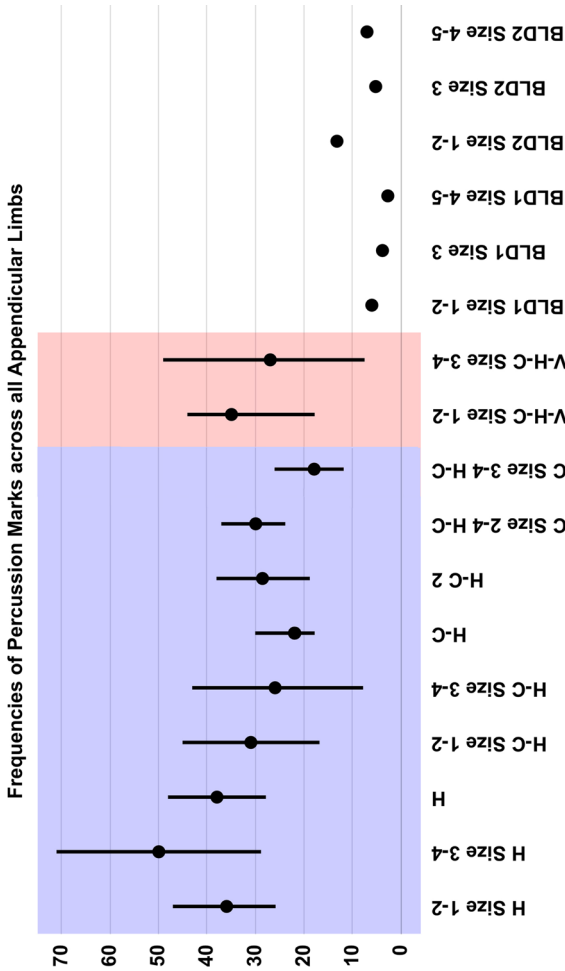


Fig. 5 Percussion mark frequencies on appendicular elements from Barranco León levels BL-D1 and BL-D2 on the basis of carcass size (1-2, 3, and 4-5) in relation to the comparative framework generated by several experimental and actualistic studies. The blue box represents the percussion mark frequencies generated by humans when they have early access to carcasses, and the red box encompasses the percussion mark frequencies in contexts of secondary access. See Suppl. File 2 for bibliographic details of the comparative samples employed

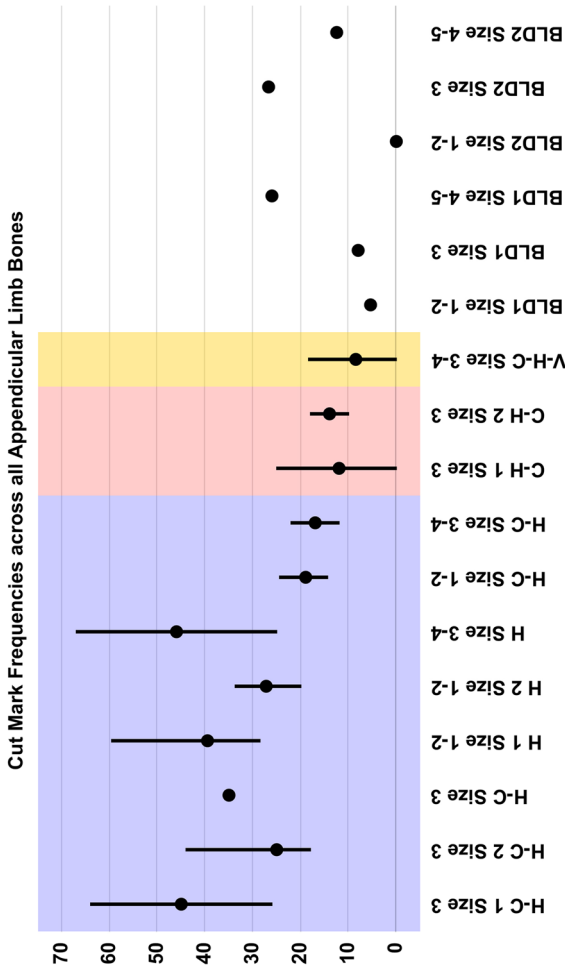


Fig. 6 Cut-mark mark frequencies on appendicular elements from Barranco León levels BL-D1 and BL-D2 on the basis of carcass size (1-2, 3, and 4-5) in relation to the comparative framework generated by several experimental and actualistic studies. The blue box represents the cut-mark frequencies generated by humans when they have early access to carcasses, the yellow box corresponds to cut-mark frequencies when human access followed the presence of vultures but preceded carnivore access, while the red box encompasses cut-mark frequencies from contexts of secondary access. See Suppl. File 2 for bibliographic details of the comparative samples employed

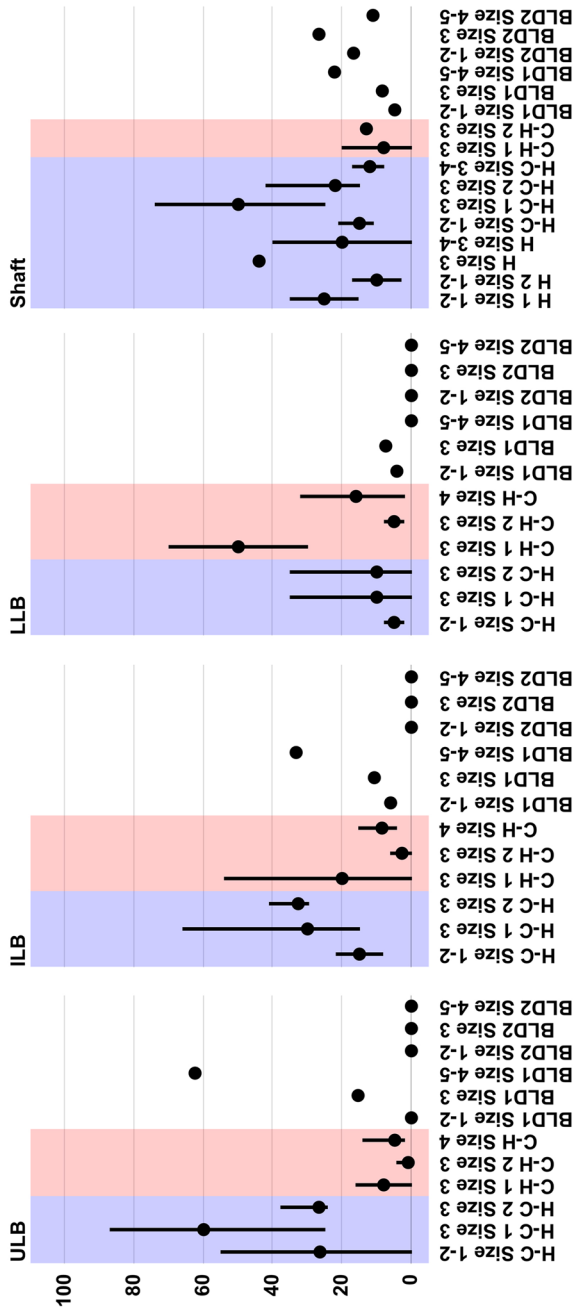


Fig. 7 Cut-mark frequencies on appendicular remains from Barranco León levels BL-D1 and BL-D2 on animal size classes 1–2, 3, and 4–5. ULB refers to toothmarks on upper limb bones, such as humeri and femoral remains, ILB refers to intermediate limbs (tibiae, radii), while LLB stands for lower limb bones (i.e. metapodials). The blue box represents cut-mark frequencies left by humans in early carcass access contexts, while the red box shows cut-mark frequencies in contexts of secondary access. Cut-mark frequencies on diaphyses are shown on the right hand side of the graph. See Suppl. File 2 for more information on the comparative samples and their full bibliographic details

of medullary contents of limb bones across all animal sizes, and the cut-mark data indicate patterns of defleshing and disarticulation across all animal sizes (Table 4). Although we do not have conclusive results regarding the precise timing of access to carcass, we can confidently say that hominids had access to high-quality animal resources, such as meat and within-bone nutrients resources from various species, including very large prey.

At this stage, however, it is important to bear in mind that over half of the faunal assemblage from BL-D1 show signs of waterborne rounding, of which 39% exhibit a stage of intense alteration and 36% correspond to an intermediate stage of alteration. The depositional origin of these bones with considerable hydraulic alterations may correspond to the high-intensity fluvial flash flood processes responsible for the incorporation of part of the mixed lithic and faunal assemblages (Titton et al., 2021); as such, they may contribute little to our assessments of the temporality of carcass access by hominin and carnivore agents. Under this premise, it is paramount to assess whether there are taphonomic differences between the subset of the assemblage that exhibits considerable waterborne alterations resulting from fluvial transport and those that are in primary position.

According to the data from Table 5, it appears that bone surface modification frequencies of bones with little to no rounding, attributed to a primary depositional context, do not show substantial differences from the calculations derived from the total sample. Both samples exhibit both anthropogenic and carnivore alterations, although frequency data suggest that carnivores played a more relevant role than humans in the modification of the faunal assemblage with greater waterborne rounding. This pattern also suggests that the bones with intense rounding were transported from an accumulation area (i.e. potentially a different site) where both humans and carnivores were also involved. Therefore, it is clear that BL-D1 is a very complex depositional and taphonomic sequence, encompassing a palimpsest of carnivore and hominin activities, with the added caveat of including exogenous elements with their own taphonomic biographies involving both carnivores and early humans, and originating from a different place in the landscape. In this context, it would be premature to establish a definitive temporality of carcass access by the different biological agents involved in the accumulation.

Discussion and Conclusions

Zooarchaeological and taphonomic analyses of fauna from Barranco León offer useful perspectives on site formation processes and hominin and carnivore behaviour. The considerable number of faunal remains with intense rounding (Table 1), alongside lithic implements featuring waterborne alterations (Titton et al., 2019, 2020, 2021), represent a first depositional input in secondary position, with materials transported into the site by high-intensity hydraulic processes. On the other hand, a large number of bones with good cortical preservation, with green fracture planes and without waterborne alterations (Tables 1, 3, and 5) most likely derive from a subsequent accumulation in primary position (Oms et al., 2011; Titton et al., 2021).

Table 5 Bones modified by humans and carnivores from BL-D1 and BL-D2. The faunal assemblage was subdivided into three categories: total sample, sample with clear evidence of rounding, sample with light to no rounding (see Methods section)

Taphonomy Barranco León - level D1		NISP	%	NISP with no rounding or light stage rounding	%	NISP with rounding alterations	%
Bone surfaces		NISP total	10848	6553	4295		
	Total (excl. teeth)	9308	85.8	5300	80.9	4008	93.3
	Specimens with poor preservation	5749	61.8	3051	57.6	2698	67.3
	Samples with good or regular preservation excluding teeth	3559	38.2	2249	42.4	1310	32.7
Rounding		Bones with rounding (incl. teeth)	5842	62.8	4290	23.7	99.9
	Light stage rounding	1552		1552		0	
	Intermediate stage rounding	2325		0	2325		
	Intense stage rounding	1965		0	1965		
Trampling		Trampling alterations	330	9.3	200	8.9	9.9
Carnivore activity		Bones with tooth marks	167	4.7	133	5.9	2.6
Human activity		Bones with cut marks	70	2.0	63	2.8	0.5
	Bones with percussion marks	46	1.3	41	1.8	5	0.4
More specific evidence of human and carnivore activity		NISP	%	NISP with light to no rounding	%	NISP with clear rounding alterations	%
Sample with good cortical surface and excluding teeth		Animal size 1–2	228	194	34		
	Animal size 3	543		398	145		
	Animal size 4–5	142		110	32		
Elements with cut marks		Animal size 1–2	9	8	1	2.9	
	Animal size 3	29	5.3	26	6.5	3	2.1
	Animal size 4–5	17	12.0	15	13.6	2	6.3

Table 5 (continued)

Taphonomy Barranco León - level D1		NISP	%	NISP with no rounding or light stage rounding	%	NISP with rounding alterations	%
Sample with percussion marks	Animal size 1–2	14	6.1	13	6.7	1	2.9
	Animal size 3	21	3.9	20	5.0	1	0.7
	Animal size 4–5	4	2.8	3	2.7	1	3.1
Sample with tooth marks	Animal size 1–2	24	10.5	21	10.8	3	8.8
	Animal size 3	75	13.8	61	15.3	14	9.7
	Animal size 4–5	19	13.4	13	11.8	6	18.8
Sample of appendicular limbs with good surfaces preservation	Animal size 1–2	92		81		11	
	Animal size 3	224		176		48	
	Animal size 4–5	50		35		15	
	Animal size 1–2	5	5.4	4	4.9	1	9.1
Appendicular limbs with cut marks	Animal size 3	18	8.0	15	8.5	3	6.3
	Animal size 4–5	13	26.0	12	34.3	1	6.7
	Animal size 1–2	12	13.0	9	11.1	3	27.3
Appendicular limbs with tooth marks	Animal size 3	37	16.5	27	15.3	10	20.8
	Animal size 4–5	10	20.0	5	14.3	5	33.3

These co-occurring assemblages are both characterised by a low incidence of weathering alterations, which implies two possible interpretations: (1) that only a short timespan had elapsed between the first natural accumulation and the traces of hominin behaviour at the site recorded in the primary-position deposit, suggesting rapid burial; (2) that bones were on a relatively humid substrate, with vegetation providing shelter from subaerial exposure, particularly sun radiation, and sudden changes in temperature and humidity, thus delaying bone weathering trends (Andrews and Whybrow, 2005; Fernández-Jalvo and Andrews, 2016). This second interpretation is not implausible, given how the BL palaeoenvironmental data suggests a humid and wooded biotope (Sánchez-Bandera et al., 2020; Saarinen et al., 2021). Moreover the presence among herpetofauna of a treefrog (*Hyla* sp.) suggest that the body of water would have been surrounded by abundant marshy vegetation (Blain et al., 2011; Sánchez-Bandera et al., 2020). Either way, the processes that contributed to the formation of both subsets of the BL D1 faunal assemblage palimpsest described in the present study led to low weathering patterns.

Barranco León therefore presents a complex taphonomic history that is difficult to interpret. Previous taphonomic research on the Barranco León assemblage that focused almost entirely on carnivore and hominin behaviour (e.g. Espigares et al. 2019) have not taken into sufficient consideration other crucial site formation processes. BL-D1 comprises two intertwined taphonomic histories, with bones exhibiting differences in the nature and intensity of waterborne alterations (rounding, polish, abrasion), weathering, and breakage types (dry vs green) that may indicate a sequence of different depositional events. At the same time, Fernández-Jalvo and Andrews (2003) showed that variability in the nature and intensity of waterborne alterations do not necessarily imply different stages or sub-assemblages; bones may all be simultaneously abraded to varying extents. These results imply that the different waterbone alterations may correspond to a single depositional event. While the assessment of these site formation processes is well discussed in the taphonomic literature, particularly regarding palimpsest formation due to waterborne inputs (Voorhies, 1969, 1970; Behrensmeyer, 1982; Fiorillo, 1988; Aslan and Behrensmeyer, 1996; Ziegler and van Huet 2021); discriminating between these two scenarios is still difficult, particularly since weathering patterns at Barranco León may offer little additional insights regarding the temporality of accumulation. This is because of the aforementioned pattern that favourable climatic conditions, such as those documented at the site (Sánchez-Bandera et al., 2020), may delay the weathering trends of exposed bones (Andrews and Whybrow, 2005; Fernández-Jalvo and Andrews, 2016).

Nonetheless, despite these caveats, other lines of evidence further reinforce the plausibility of the hypothesis that two depositional events took place at Barranco León. Titton et al. (2021) suggests that it is likely that different depositional events contributed to the formation of the lithic assemblage, with a first input of transported material, and a second phase representing more localised processes with a greater and clearer anthropogenic signature.

In terms of hominin–carnivore interactions, the dual-patterned taphonomic sequence recorded in BL-D1 led to the incorporation of bones with both carnivore and hominin alterations to the site. The fossil remains in secondary position are

therefore likely to derive from a different locality where both hominins and carnivores interacted with animal carcasses. The action of carnivores appears more substantial in this subset of the assemblage than in the remains associated with a primary deposition, although the unknown nature of the inferred locality from where the displaced elements would have derived from prevents the suggestion of further behavioural hypotheses.

With regard to the subset of the assemblage in primary position, both hominins and carnivores played a role in the modification, and likely accumulation, of the faunal assemblage. Nevertheless, the results in Table 5 are ambiguous, and it is not possible to determine if hominins had primary or secondary access to the carcasses.

With regard to early human behaviour and the role that hominins played in the accumulation of the fossil assemblage of BL-D1, the results obtained are not entirely conclusive. When analysing the frequency and distribution of tooth marks, the present data reports carnivores to have had a rather limited impact on the assemblage (Figs. 2, 3 and 4). The comparison of tooth mark data with actualistic frameworks suggests that carnivore access to carcasses was likely secondary to hominins. This assessment, and the data presented in Yravedra et al. (2021) for Fuente Nueva 3, are actually in agreement with the conclusions reached by Espigares et al. (2019:10) for these Orce localities: 'carnivore activity in these sites seems to have been residual compared to hominin activity'.

At the same time, primary access to animal carcasses by hominins at Barranco León cannot be conclusively determined on the basis of comparative assessments of cut and percussion mark frequencies with actualistic frameworks (Figs. 5, 6 and 7). The data from Fig. 6 suggests hominins to have had primary access to animal sizes 4–5 at BL-D1 and size 3 carcasses at BL-D2. Nevertheless, the small sample sizes included here hinder further conclusions, while the remaining size classes at BL-D1 had rather low cut-mark frequencies, inconsistent with the expectations of primary access by hominins. The ambiguity from cut-mark frequency data is also reflected in Fig. 7, since the counts per anatomical unit are generally very low, and only those on limb bone diaphyses would match actualistic expectations of primary access to carcasses by hominins. Nevertheless, overlap is still present between secondary hominin access models. Therefore, the detailed taphonomic and zooarchaeological data for BL-D1 presented here does not currently allow the establishment of a definitive order of whether hominins or carnivores had primary access to the carcasses.

The present study was able to identify cutmarks on a wide range of carcass sizes, such as hippopotamus (size 5, BL-D1), equids and chelonian remains in both BL-D1 and BL-D2. These results are consistent with the reported observations by Espigares et al. (2019). Nevertheless, in contrast to these previous efforts (Espigares et al., 2019, Table S11), the present study was unable to identify cutmarks that could be unambiguously attributed to evisceration. While the present study was able to identify cutmarks on several rib fragments (Table 4), future research with more detailed documentations of these types of trace could be useful to confirm an early access to the carcasses by hominins. Carnivores tend to consistently consume viscera first when processing a newly acquired prey, as documented for felines (Schaller, 1972; Blumenschine, 1986; Blumenschine and Cavallo, 1992; Rodríguez-Alba et al. 2019), canids (Mech, 1970; Stahler et al., 2006; Yravedra et al., 2011) or hyenas

(Kruuk, 1972; Blumenschine, 1995; Faith, 2007). As such, the evidence of evisceration reported by Espigares et al. (2019) would therefore be inconsistent with their proposed secondary scavenging scenario at BL and Fuente Nueva-3.

In addition to the intertwined depositional histories of the two sub-assemblages from BL-D1, the archaeological sequence of Barranco León also encompasses BL-D2, a finer coarse deposit with few small pebbles and some associated fauna accumulated in the context of low-energy fluvio-lacustrine sedimentation. The BL-D2 faunal sample is small and the inferred insights into hominin–carnivore interactions, as well as early human subsistence strategies, are similarly ambiguous and inconclusive (Figs. 2, 3, 4, 5, 6 and 7). Undertaking future analyses once the available samples for taphonomic examination are expanded through fieldwork or careful restoration of less well-preserved specimens may offer more conclusive results.

Furthermore, the incorporation of new technologies applied to the study of cut-marks, such as artificial intelligence, 3D microscopic images and confocal microscopy, may allow the identification of which raw materials and types of lithic implements were employed in the activities of defleshing and disarticulation documented at the site (e.g. Bello and Soligo, 2008; Courtenay et al., 2017; Linares-Matás et al., 2019; Maté-González et al., 2019; Yravedra et al., 2019). This approach would assist in relating the zooarchaeological and the lithic assemblages at BL. Similarly, a geometric morphometric assessment of the tooth marks would give us insights into the specific carnivore(s) that played a role in the accumulation and/or alteration of the bone assemblages at the site (cf. Aramendi et al., 2017; Arriaza et al., 2019; Courtenay et al., 2019, 2020). Additionally, future high-resolution spatial analyses may provide additional evidence for resolving the issue of the occupational sequence at BL, as well as potentially enable a better understanding of distribution patterns, which may provide evidence of site space management in the context of hominin–carnivore interactions in the Early Pleistocene (e.g. Giusti and Arzarello 2016; Luzón et al. 2021; Linares-Matás et al. 2021).

In summary, even though insights from the zooarchaeological and taphonomic study of Barranco León are constrained by the nature, size and resolution of the samples under analysis, there are some relevant conclusions that can be put forward in an attempt to enhance our understanding of early European subsistence strategies >1 Ma. These communities were able to exploit a considerable range of carcass sizes in a multi-stage butchery sequence, combining access to meat with the acquisition of within-bone nutrients, such as marrow, in line with behaviours documented in the African continent during the Early Pleistocene (e.g. Bunn and Ezzo, 1993; Ferraro et al., 2013; Linares-Matás and Clark 2021), including the exploitation of large and very large animal taxa (cf. Linares-Matás and Yravedra 2022). In the absence of clear evidence regarding the order of carcass access, and joint exploitation by hominins and carnivores, suggestions of secondary or confrontational scavenging at BL (e.g. Palmqvist et al., 2005, 2011; Rodríguez Gómez et al., 2016; Espigares et al., 2019) must be regarded with caution. At the same time, based on the present data, conclusions cannot be drawn to confirm whether or not hominins had primary access to the carcasses, a pattern documented, for example, at Sima del Elefante (Huguet et al., 2013). In this regard, the available evidence from Barranco León resembles the pattern observed at other Early Pleistocene localities in Europe

predating 1 Ma, such as Kozarnika (Sirakov et al, 2010), Trilika (Vislobokova et al., 2020) or Pirro Nord (Cheheb et al., 2019), where complex site formation processes, insufficient sample sizes and/or issues related to bone surface preservation are obscuring the inferences to be derived from faunal assemblages.

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