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“Fold but not sheepfold”: The Chalcolithic level (3000–2500 cal BCE) of the Abrigo de la Castañera (Obregón de Villaescusa, Spain)☆

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ABSTRACT

The functional interpretation of cave deposits known as *fumiers* (organic accumulations generated by livestock stabling) has traditionally been linked to the keeping of small ruminants, particularly sheep and goats. However, recent archaeozoological research suggests that such deposits may reflect a wider range of herding practices and species management strategies.

This study examines the Chalcolithic faunal assemblage (3000–2500 cal BCE) from the rock shelter of *El Abrigo de La Castañera* (Obregón de Villaescusa, Cantabria, northern Spain) to reassess the nature of these contexts. A total of 6,874 faunal remains were analyzed using taxonomic, taphonomic, and mortality-profile criteria. The results confirm the presence of a typical fumier deposit, characterized by the abundance of neonatal remains, burnt layers and a high bone fragmentation, but with an atypical taxonomic composition. Unlike Mediterranean sheepfold caves dominated by ovines and caprines, the assemblage from La Castañera is overwhelmingly composed of cattle (*Bos taurus*) and pigs (*Sus domesticus*), while sheep and goats (*Ovis/Capra*) play a secondary role.

Mortality profiles and butchery marks indicate species-specific management strategies: cattle were used for meat and milk; pigs were raised intensively for fast meat and fat production; and caprines played a minor economic role. These data reveal a diversified herding system adapted to the humid Cantabrian environmental conditions, challenging the taxonomic definition of fumiers and emphasizing their interpretation as multifunctional stabling and consumption deposits reflecting the economic and social complexity of Chalcolithic communities.

1. Introduction

Since the Paleolithic, caves and rock shelters have played a key role in the organization of human communities in the Cantabrian region which made intensive use of these shelters. In these contexts, cave spaces were used for a wide range of purposes: domestic, funerary and ceremonial, highlighting their versatility and significance within the social and symbolic dynamics of these groups.

At the onset of the Holocene, hunter-gatherer groups continued to use caves and shelters, which in some cases gave rise to shell middens, material evidence of the intensive exploitation of marine resources. From the Neolithic onwards, with the introduction of domestic animals, around the second half of the 6th millennium cal BCE in the Iberian Peninsula (Saña et al., 2020) and during the 5th millennium cal BCE in the Cantabrian region (Altuna and Mariezkurrena, 2012; Cubas et al., 2016; González-Rabanal et al., 2020; González-Rabanal, 2022), communities began to seek suitable spaces to control and protect their herds, including caves and rock shelters, thus significantly transforming their

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function (Angelucci et al., 2009; Martín et al., 2022; Martín and Tornero, 2024; Radović et al., 2008; Saña et al., 2020; Vergés et al., 2016).

As a result, cave occupations began to produce an entirely different stratigraphy. The stabling of animals in these shelters led to the formation of organic deposits characterized by the formation of successive layers of dung, ash and charcoal, commonly referred to by the French term *fumier* (Bergadà, 1997; Brochier et al., 1992; Vergés et al., 2016). These deposits, composed largely of accumulated and often partially burnt dung, possibly intentionally, as a means of hygienizing the space and reducing its volume, depended on both the duration of use and the size of the herds (Acovitsioti-Hameau et al., 1988; Brochier et al., 1992; Vergés et al., 2016). Regarding their function, such cavities have traditionally been interpreted as spaces used for the stabling of small ruminants, especially sheep and goats, due to their prevalence in the archaeological record. For this reason, they are commonly referred to as *sheepfold caves*. This likely represented their main function throughout much of the Mediterranean, both in prehistory and, in some cases, up to the present (Acovitsioti-Hameau et al., 1988; Aguilera Aragón, 1993; Brochier et al., 1992; Cano Montoro, 2006; Gárate, 2002; Martín and Tornero, 2024; Rubio Valverde, 2014; Jimeno Guerra, 2018; Radović et al., 2008).

However, the mere presence of faunal remains within a *fumier*-type context cannot, by itself, be taken as conclusive evidence of specific herding practices, since taxonomic analysis alone cannot determine whether a given space functioned as a stable. These stratigraphic deposits reflect complex taphonomic dynamics derived from the repeated burning of agricultural, pastoral, and domestic residues (Angelucci et al., 2009; Brochier et al., 1992; Martín and Tornero, 2024; Vergés et al., 2016). Their analysis requires a multidisciplinary approach, encompassing micromorphology, isotopic studies, sedaDNA, and archaeobotany, as well as detailed examination of variables such as age-at-death profiles, processing marks, and anatomical representation patterns (Lancelotti and Madella, 2012; Shahack-Gross, 2011). Indeed, the application of these bioarchaeological proxies is essential for reconstructing specific husbandry regimes, such as leaf foddering and forest grazing, which are often invisible to standard archaeozoological analysis (Balasse et al., 2012; Delhon et al., 2008).

Recent research, however, has revealed that this model does not always correspond to archaeological reality. Several sites across Europe show alternative stabling patterns, with a significant or even predominant presence of cattle or pigs (Alcalde et al., 2002; Arbogast, 1990; Bonsall et al., 2009; Martín and Tornero, 2024; Mata et al., 2025; Saña et al., 1997; Schibler, 2006; Vega-Maeso et al., 2016), representing a notable exception to the most commonly accepted functional interpretation of these spaces.

Previous archaeozoological studies at *El Abrigo de la Castañera*, identified a *fumier* dated to the Chalcolithic period (3000–2500 cal BCE), revealing an atypical faunal composition compared to other Iberian *fumiers*, where bovines and suids predominated (Vega-Maeso et al., 2016).

Due to the presence of material recovered during recent excavation campaigns, a comprehensive study of the entire faunal assemblage was carried out to ascertain economic behavior during the whole Chalcolithic sequence. The main objective of this work is to better understand livestock practices among Chalcolithic communities in the Cantabrian area through the analysis of the faunal assemblage recovered from *El Abrigo de la Castañera* (Cantabria). The study aims to confirm the use of the shelter as a stabling space, to examine the differential management of domestic species present, to assess livestock production, and to identify changes or continuities in productive strategies throughout the different occupational phases of the site. Furthermore, stratigraphic units interpreted as habitation areas are compared with *fumier* deposits in order to detect potential differences in taxonomic representation, carcass processing, and mortality profiles. The ultimate goal is to provide a more nuanced understanding of Late Prehistoric livestock economies in the Cantabrian region and to challenge the exclusive association of *fumier*-type deposits with the herding of sheep and goats.

2. El Abrigo de la Castañera

El Abrigo de la Castañera is a rock shelter of approximately 85 m^2, located at 53 m.a.s.l. and oriented to the northeast, forming part of a karstic complex composed of seven caves located south of the Bay of Santander, in the village of Obregón (Villaescusa, Cantabria), northern Iberian Peninsula (Fig. 1) (Vega-Maeso et al., 2016). The site was first recorded in the late 1960s (Guirado, 1972), and excavations began in the following decade under the direction of the *Seminario Arqueológico Sanz de Sautuola*. These early interventions revealed that the site had been subject to clandestine activities that partially altered the original stratigraphy. Since 2011, a multidisciplinary research team, funded by the Department of Culture, Tourism, and Sport of the Government of Cantabria, has resumed fieldwork under the direction of two of the authors of the present study, documenting a long and well-preserved stratigraphic sequence (Vega-Maeso et al., 2016).

Excavations within the shelter have revealed multiple stratigraphic units, grouped into phases and periods that reflect the sequence of occupation and use of space over time. The most recent phase corresponds to deposits disturbed by modern (20th-century) interventions, derived from earlier, in some cases illicit, excavations that affected part of the underlying layers. During the Bronze Age (2100–1500 cal BCE), two phases associated with the funerary use of the site have been documented (Vega-Maeso et al., 2016).

Regarding the stratigraphy attributed to the Chalcolithic (3000–2500 cal BCE), three main phases have been distinguished. The most recent phase is characterized by the partial removal of the preceding stratigraphy, manifested in the excavation of a large pit and the formation of a corresponding depositional unit (phase 3).

This is preceded by a stabling phase (phase 2), identified by the presence of organic accumulative deposits up to 50 cm thick, indicative of intensive herding activity. This phase consists of sediment with a plastic texture containing small, horizontal lenses of white, grey, and black ash rich in charcoal and organic matter, which alternate between unburnt, partially burnt, and fully calcined layers.

The earliest events were linked to a habitation phase (Phase 1). This phase is defined by an occupation surface cut by several postholes. In spatial association with these postholes, two hearths and a layer of burnt pebbles, likely derived from hearths, were documented, alongside fragments of tapial (daub). Collectively, these structural remains suggest the presence of a hut or domestic shelter at the site.

Occupation during the Neolithic is also represented by three phases: the most recent, corresponding to the Late Neolithic, dated to 3340–3030 cal BCE (95.4% probability), with clear evidence of human activity; an intermediate phase in which no apparent use of the shelter is detected; and an earlier phase marked by episodic occupations, the oldest dated to 4540–4360 cal BCE (95.4% probability). Finally, an even earlier occupation has been identified, corresponding to the Final Upper Paleolithic.

This sequence makes the site a key reference for the study of early herding practices in the Cantabrian area, a region where the adoption of agro-pastoral economies occurred later than in other parts of the Iberian Peninsula. Within this context, *El Abrigo de la Castañera* provides clear evidence of the use of the shelter as a livestock pen, with a Chalcolithic assemblage composed of rapidly accumulated strata and several fumier deposits formed over approximately five centuries (Vega-Maeso et al., 2016). The distinctive feature of this site lies in the predominance of cattle and pig remains, in contrast to the dominant pattern observed in most Iberian sheepfold caves, where caprines typically prevail.

The present study is based on the archaeozoological analysis of the complete faunal assemblage recovered from the recent excavations (2011–2016). While the materials were originally studied by UEs as individual stratigraphic units, they are here regrouped by phases in order to establish a clearer chronological framework and to enhance the

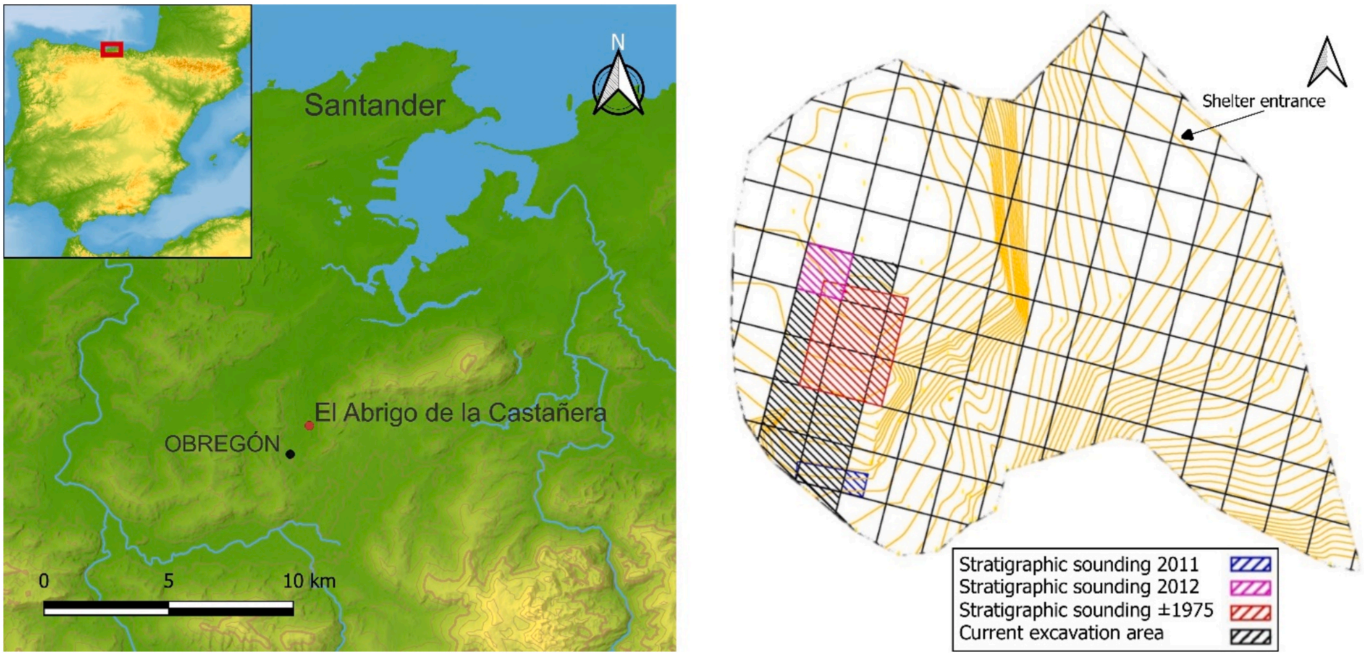

Fig. 1. Location of El Abrigo de la Castañera in the autonomous community of Cantabria, in the north of the Iberian Peninsula, along with the site plan of the archaeological area (Vega-Maeso et al. 2016).

statistical robustness of the sample. The study integrates both previously unpublished data and earlier published records.

3. Methods

The archaeozoological study was conducted through the anatomical and taxonomic identification of bone remains, using the reference collection of the *Archaeozoology Laboratory of the Autonomous University of Barcelona*, in conjunction with classical manuals of comparative anatomy (Schmid, 1972; Barone, 1976). For analytical purposes, domestic species were grouped into three main categories (*Ovis/Capra*, *Sus*, and *Bos*), along with broader size-based groups for mammal remains that could not be identified to taxon level. Specifically, these indeterminate fragments were classified into five categories: small ruminant, small carnivore, small mammal, medium-sized mammal, and large-sized mammal.

Metric analyses followed the standards proposed by Payne and Bull (1988) and von den Driesch (1976). The distinction between morphologically similar species, such as sheep, goat, and roe deer, was addressed using established criteria for dentition (Balasse and Ambrose, 2005; Gillis et al., 2011; Halstead et al., 2002; Helmer, 2000; Payne, 1985; Zeder and Pilaar, 2010) and for postcranial elements (Boessneck, 1970; Boessneck et al., 1964; Prummel and Frisch, 1986; Zeder and Lapham, 2010). Differentiation between wild and domestic forms, particularly for suids (*Sus scrofa* vs. *Sus domesticus*) and bovines (*Bos primigenius* vs. *Bos taurus*), relied on osteometric comparison against standard reference datasets (Albarella et al., 2006; Altuna, 1980; Davis, 2008), assessing size reduction as the primary indicator of domestic status.

Age-at-death estimation was conducted through both dental analysis and epiphyseal fusion. For caprines, tooth eruption and wear sequences followed Payne (1973, 1987), complemented by those of Helmer (1995), while epiphyseal fusion stages were assessed according to Zeder (2006), and age-class histograms followed the methodology of Gerbault et al. (2016). For bovines, dental analysis was based on Grant (1982) and age classes defined by Legge (1992), while epiphyseal data were evaluated following Silver (1969). In the case of suids, the studies of Lemoine et al. (2014) and Zeder et al. (2015) were used as references. Finally, the resulting mortality profiles were interpreted by comparing the results with the theoretical ethnographic models for milk, meat, and wool production proposed by Payne (1973), as well as the specialized husbandry strategies for Neolithic contexts described by Helmer (1992) and Vigne and Helmer (2007).

The taphonomic analysis aimed to characterize post-depositional alteration processes, distinguishing between those of anthropogenic and natural origin.

Cut marks were identified following the morphological classification proposed by Pérez-Ripoll (1992) and Potts and Shipman (1981). Carnivore alterations, including tooth pits, punctures, and scores, were analyzed based on the criteria defined by Blumenschine (1995) and Fernández-Jalvo and Andrews (2016). Regarding post-depositional modifications, weathering stages were evaluated according to Behrensmeyer (1978), while other alterations such as root etching, trampling marks, and biochemical staining were recorded following Lyman (1994). Fracture patterns were analyzed according to the model of Villa and Mahieu (1991), which considers parameters such as angle, profile, and fracture-edge morphology. Evidence of burning was assessed following the criteria of Shipman et al. (1984) and Stiner et al. (1995), focusing on color and texture modification, distinguishing between slightly burnt (brown/reddish), carbonized (black), and calcined (grey/white) elements. Finally, fragmentation patterns and breakage processes were interpreted according to Reynard and Henshilwood (2018), allowing for an integrated understanding of the formation and transformation processes affecting the faunal assemblage.

Regarding natural modifications, specific variables were recorded, including weathering, cortical staining, abrasion, postdepositional fractures, root etching, and concretions. The interpretive framework was based on the model proposed by Saña (1999), itself grounded in earlier works by Binford (1981) and Lyman (1994). Specific methodologies were applied to identify different alteration agents, including chemical processes (Asmussen, 2009; Jiménez-Manchón et al., 2020; Marín Arroyo et al., 2008), atmospheric weathering (Reynard and Henshilwood, 2019), and mechanical damage (Reynard and Henshilwood, 2018).

Quantification was performed using the Number of Identified Specimens (NISP), defined as the direct count of identified fragments per taxon. To account for fragmentation, the Minimum Number of Elements (MNE) was calculated based on the recurrence of non-overlapping diagnostic zones (Lyman, 2008). Finally, the Minimum Number of Individuals (MNI) was estimated from the most frequent MNE, taking into consideration laterality, age and stratigraphic provenance. Furthermore, age-at-death data, derived from dental wear patterns and epiphyseal fusion states, were integrated to distinguish discrete individuals and refine the final MNI count.

To assess the statistical significance of the differences observed between the assemblages, Pearson's Chi-square tests (χ^2) were performed on the raw data counts (NISP) to evaluate taxonomic representation. Additionally, Mann-Whitney U tests were employed to compare continuous variables, specifically for biometric dimensions. All analyses were conducted using PAST software (Hammer et al., 2001), with a significance threshold set at $p < 0.05$.

4. Results

The faunal assemblage comprises a total of 6874 remains, of which 10.28% (n = 707) were identified both anatomically and taxonomically (Table 1). The relatively low proportion of identifiable specimens is largely due to the high degree of fragmentation observed in the assemblage (97.39%, n = 6695), although overall preservation is notably good.

A high degree of thermal alteration was recorded across the entire assemblage (67.67%; n = 4652), indicating prolonged exposure to heat sources, most likely associated with recurrent combustion activities. These thermal modifications are accompanied by other alterations typically found in stabling contexts, such as cortical staining produced by organic matter (18.53%; n = 1274) and severe weathering (14.78%; n = 1016). Among chemical and pedogenic alterations, mineral concretions (6.41%; n = 441) and anomalous colorations resulting from the action of humic acids are noteworthy. Root etching (1.92%; n = 132) and surface abrasion (1.10%; n = 76) were also recorded, likely related to sedimentary dynamics within the depositional stratigraphic sequence (see Supplementary Material; Fig. S2).

Teeth marks suggest occasional activity by carnivores (3.52%; n = 242) and rodents (0.34%; n = 24), primarily affecting the long bones of large and medium-sized mammals.

The faunal spectrum of the site shows a clear predominance of domestic species, accounting for 92.22% of all identified specimens (NISP = 652; MNI = 49). Within this group, cattle (*Bos taurus*) constitute the most represented taxon, with 42.14% (n = 298; MNI = 16). Biometric dimensions fall within the typical range for domestic individuals documented at contemporaneous sites in the region, confirming their domestic status (see Supplementary Material; Table S2 & S3) (Altuna, 1980; Galindo-Pellicena et al., 2019, Galindo-Pellicena et al., 2020).

Pigs (*Sus domesticus*) represent the next most abundant species, comprising 35.21% of the NISP (n = 249; MNI = 19). Identification as domestic forms is based on biometric criteria consistent with values recorded for domestic pigs in the Iberian Peninsula (see Supplementary Material; Table S2 & S4). Specifically, statistical comparison of the lower third molar lengths reveal no significant differences with the domestic reference population (Mann-Whitney *U* = 52, *p* = 0.41).

Table 1

NISP and MNI data and percentage of the animal remains found in the different Chalcolithic phases in *El Abrigo de la Castañera*.

	Phase 1				Phase 2				Phase 3			
Domestic mammals	Total		Total		Total		Total		Total		Total	
	NISP	%	MNI	%	NISP	%	MNI	%	NISP	%	MNI	%
Equus sp.					7	1.25%	1	2.38%				
Bos taurus	48	46.60%	4	28.57%	226	40.43%	10	23.81%	24	53.33%	2	22.22%
Sus domesticus					25	4.47%						
Sus sp.	33	32.04%	3	21.43%	177	31.66%	12	28.57%	14	31.11%	4	44.44%
Ovis aries					1	0.18%			1	2.22%		
Capra hircus					3	0.54%						
Ovis/Capra	12	11.65%	4	28.57%	76	13.60%	6	14.29%	4	8.89%	2	22.22%
Canis familiaris					1	0.18%	1	2.38%				
Subtotal domestic	93	90.29%	11	78.57%	516	92.31%	30	71.43%	43	95.56%	8	88.89%
Wild mammals												
Sus scrofa					1	0.18%	1	2.38%				
Cervus elaphus					1	0.18%	1	2.38%				
Capreolus capreolus					1	0.18%	1	2.38%				
Oryctolagus cuniculus					6	1.07%	2	4.76%				
Meles meles					4	0.72%	1	2.38%				
Lutra lutra					1	0.18%	1	2.38%				
Subtotal wild					14	2.50%	7	16.67%				
Subtotal MAMMALS	617				4057				557			
Avifauna	3	2.91%	1	7.14%	6	1.07%	2	4.76%				
Malacofauna	5	4.85%	1	7.14%	11	1.97%	1	2.38%	2	4.44%	1	11.11%
Microfauna	2	1.94%	1	7.14%	12	2.15%	2	4.76%				
Subtotal OTHERS	10	9.71%	3	21.43%	29	5.19%	5	11.90%	2	4.44%	1	11.11%
Subtotal NISP	103	100%	14	100%	559	100%	42	100%	45	100%	9	100%
Size mammals categories												
Large-sized mammal	121	23.09%			943	26.74%			81	15.76%		
Medium-sized mammal	382	72.90%			2353	66.71%			385	74.90%		
Small mammal	20	3.82%			227	6.44%			48	9.34%		
Small ruminant					3	0.08%						
Small carnivore	1	0.19%			1	0.03%						
Subtotal General	524	100%			3527	100%			514	100%		
Subtotal determined	627	99.68%			4086	75.25%			559	68.59%		
Undetermined	2	0.32%			1344	24.75%			256	31.41%		
TOTAL	629	100%			5430	100%			815	100%		

However, the possible presence of wild individuals (*Sus scrofa*) cannot be completely ruled out.

Sheep and goats (*Ovis aries/Capra hircus*) are less represented, accounting for 13.71% of the assemblage (n = 97; MNI = 12). Due to the high fragmentation of remains, specific distinction between sheep and goat was often not possible, and these were therefore grouped under the general caprine category (OC).

Wild taxa are present only in residual proportions (1.9%; n = 14; MNI = 7), restricted to the second Chalcolithic phase. The absence of butchery marks on these remains precludes confirmation of hunting as their mode of acquisition, suggesting alternative pathways of incorporation into the archaeological record. The most represented wild species are the rabbit (*Oryctolagus cuniculus*), followed by wild boar (*Sus scrofa*), red deer (*Cervus elaphus*), roe deer (*Capreolus capreolus*), badger (*Meles meles*), and otter (*Lutra lutra*).

Additionally, small and highly fragmented fragments of bivalve shells and gastropod remains were recorded, representing 2.54% of the NISP (n = 18). Microfaunal remains account for 1.98% (n = 14), and undetermined avian remains make up 1.27% (n = 9).

The analysis of the three Chalcolithic events documented at the site reveals a generally homogeneous pattern in the representation of domestic species. Across all three phases, cattle and pigs remain the dominant taxa, while wild fauna appears exclusively in the second of the three identified phases.

4.1. A domestic use phase

Phase 1, interpreted as a human occupation episode with a residential function (Vega-Maeso et al., 2016), represents 9.15% of the faunal assemblage (n = 629; MNI = 14). The assemblage is highly fragmented (n = 590; 93.79%); fracture profiles are characterized by a prevalence of irregular outlines (n = 536; 85.21%), with longitudinal and oblique types occurring much less frequently. In addition, it shows significant thermal alteration (87.75%), which has hindered identification. Regarding the intensity of combustion, the assemblage is dominated by slightly burnt elements (n = 349; 55.48%), followed by carbonized (n = 124; 19.71%). Calcined remains (n = 75; 11.93%) are present to a much lesser extent (Table 2). A total of 3.97% of the remains show evidence of carnivore activity.

Cattle (*Bos taurus*) are the most represented taxon (46.6%, n = 48). Mortality profiles indicate a minimum of four individuals: one perinatal, one between 6 and 26 months, one between 3 and 6 years, and another between 6 and 10 years of age. The mortality distribution shows a similar pattern (Fig. 2), with individuals slaughtered between 6 months and several years old. Anatomical representation reveals a predominance of cranial elements (likely due to fragmentation bias), such as mandibles and skull fragments, as well as parts of the axial skeleton, including ribs, vertebrae, and pelvis fragments (Fig. 3). Limb bones are scarce, represented only by fragments of femora, tarsi, and phalanges. Butchery marks (n = 5; 10.41%), including cuts on mandibles, femora, tarsal bones, vertebrae, and phalanges, indicate systematic meat processing, accompanied by impact traces such as percussion fractures (n = 5; 10.41%) on long bones and vertebrae.

Pigs (*Sus domesticus*) account for 33.04% of the remains in this phase (n = 33). The minimum number of individuals (MNI) is three: one perinatal, one aged 3–8 months, and one between 52 and 72 months. A developing male canine was identified, likely belonging to the youngest individual (Jourdan, 1976). Anatomical representation (Fig. 3) is dominated by cranial and distal limb elements (phalanges, tarsi, and ulnae). Only one butchery mark was observed on the younger pig, consisting of a cut on a second phalanx.

Sheep and goats (*Ovis aries/Capra hircus*) represent 11.65% of the NISP for this phase (n = 12). Due to the high degree of fragmentation and the absence of clear diagnostic elements, species-level distinction was not possible. No dental material was preserved for mortality analysis; however, based on epiphyseal fusion, a minimum of four individuals was estimated: one fetal, one perinatal, one older than 3 months, and one adult over 48 months. Anatomical representation is limited to limb bones and a few vertebral elements. No cut marks were recorded, though evidence of burning and anthropogenic fracturing was observed.

4.2. A livestock stabling area

Phase 2 is interpreted as a livestock stabling episode, a conclusion supported not only by the stratigraphic sequence of organic, ash-rich deposits described above but also by the archaeological material. Specifically, the ceramic assemblage exhibits high fragmentation, attributed to animal trampling, as well as widespread thermal alterations, surface erosion, and calcareous concretions. The faunal assemblage remains dominated by domestic species, though a notable increase in pig remains is evident, along with the exclusive presence of wild fauna and other taxa such as canids and equids. This phase yielded a total of 5,430 faunal remains, of which 95.58% are fragmented (n = 5299) and 3.99% show evidence of gnawing (n = 217). Fracture patterns are characterized by a predominance of irregular contours (n = 2493; 45.91%), accompanied by a significant incidence of longitudinal fractures (n = 1192; 21.95%), while transverse and oblique shapes are much less common. Thermal alteration affects 67.66% of the assemblage; although slightly burnt specimens (n = 1683; 30.99%) are the most numerous, calcined (n = 1170; 21.54) and carbonized (n = 778; 14.32%) bones follow closely, appearing in similarly high proportions. Only 10.29% of the assemblage was anatomically and taxonomically identified (n = 559; MNI = 42).

Cattle (*Bos taurus*) represent 40.43% of the NISP (n = 226). A minimum of ten individuals was estimated: two perinatal, two aged 3–6 months, two aged 6–15 months, one aged 15–26 months, and three aged

Table 2
Number of remains with processing marks, fractures, thermal alterations, and post-depositional taphonomic marks from different phases.

	Phase 1	Phase 2	Phase 3		Phase 1	Phase 2	Phase 3
Irregular	536	3965	668	*Cut marks*	9	76	4
Longitudinal	31	1192	125	*Incision marks*	6	52	3
Long. oblique	15	93	3	*Scratch marks*	1	13	
Oblique	4	15		*Hack marks*	3	19	1
Transverse	4	34	2	*Sawing fracture*	1	1	
Fractured	590	5299	798	*Dry cutting*		1	
Unfractured	39	131	17	*Rounded*		1	
				Blow	4	53	1
	Phase 1	**Phase 2**	**Phase 3**				
Roast marks	3	40			**Phase 1**	**Phase 2**	**Phase 3**
Boiled	1	3		*Vermiculations*	25	102	5
Calcined	75	1170	119	*Weathering*	91	749	176
Carbonized	124	778	97	*Dyeing*	98	1072	104
Slightly Burnt	349	1683	210	*Concretions*	65	371	5
Unburnt	77	1756	389	*Abrasion*	15	60	1

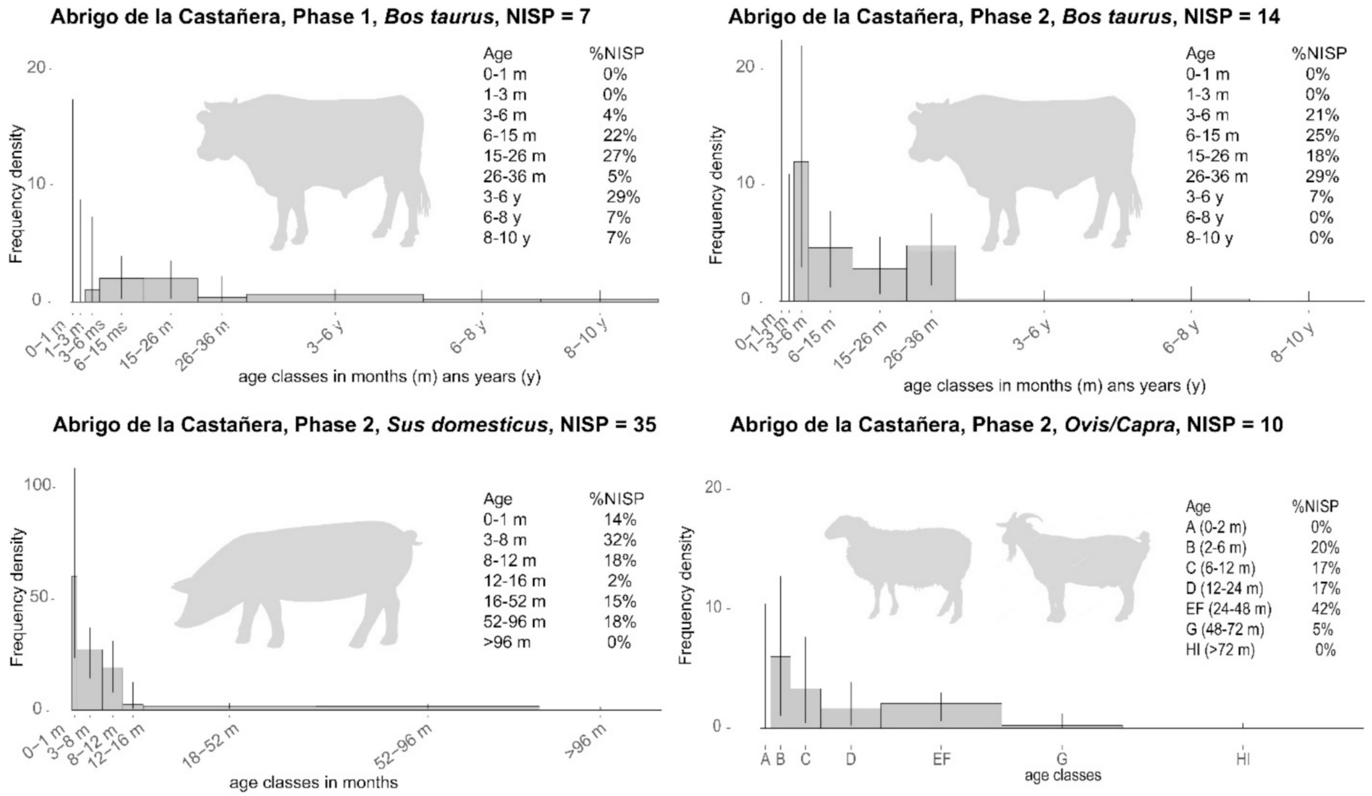

Fig. 2. Mortality profiles of different domestic taxa (Phases 1–2), displaying relative frequency (Y-axis) across dental age classes (X-axis; see Methods). Phase 3 is excluded due to insufficient sample size. Mortality profiles based on epiphyseal fusion are provided in the Supplementary Material Fig. S1.

26–36 months. The mortality profile is consistent with these values, with all individuals under 36 months and a concentration of animals slaughtered before 15 months of age (Fig. 2). Anatomical representation is broad, including cranial fragments, mandibles, limb bones, and, to a lesser extent, axial elements (Fig. 3). Butchery marks indicate skinning on skull and limb elements, together with clean incisions (n = 25; 11.06%) and anthropic fractures (n = 52; 23%), and clear evidence of thermal alteration (n = 121; 53.53%) (Table 2) (see Supplementary Material; Fig. S2).

Pigs (*Sus domesticus*) account for 36.1% of the NISP (n = 202). The mortality profile indicates a minimum of 12 individuals: two between 0 and 1 month, one between 3 and 5 months, one between 3 and 8 months, three between 6 and 12 months, four older than one year, and one over 52 months. Mortality data (Fig. 2) suggest that most individuals were slaughtered before one year of age, with a notable concentration of very young specimens. Analysis of canines allowed sex determination for six individuals: two males and four females. Anatomically, cranial and mandibular elements dominate, followed by ribs, vertebrae, and long bones (Fig. 3). Cut marks (n = 10; 4.42%), scraping traces (n = 11; 4.87%), percussion fractures (n = 29; 12.83%), and clear thermal alteration (n = 90; 39.8%) are common (Table 2).

Caprines (*Ovis/Capra*) account for 14.31% of the NISP (n = 80). High fragmentation prevented reliable differentiation between sheep and goats. Mortality analysis (Fig. 2) estimates a minimum of six individuals: one fetal and one aged 2–6 months (unidentified caprine), one aged 2–6 months and two between 2 and 4 years (*Capra hircus*), and one between 1 and 4 years (*Ovis aries*). The remains mainly include mandibles and limb bones (Fig. 3), with some cut marks (n = 4; 5%) and percussion fractures (n = 6; 7.5%) (Table 2).

A single young individual represents the equid, although the scarcity of diagnostic elements prevents taxonomic identification to species level, making it impossible to determine whether it was a donkey or a horse (n = 7; MNI = 1). Age estimation, based on moderate incisor wear and the state of zygomatic fusion, suggests a juvenile. Cut marks were recorded on the mandible, which also exhibits extensive black burning, indicating possible direct cooking, such as roasting (Table 2).

Regarding the canid, only a single fused first phalanx was recovered. Although scarce, its presence is significant, confirming the occurrence of this species within the assemblage. However, the absence of additional elements limits interpretations about its origin or role, whether as a domestic companion, participant in herding activities, or as a natural intruder into the deposit.

4.3. *The dismantling of the fumiers*

The final Chalcolithic occupation episode (Phase 3) displays overall continuity with the preceding phases, characterized by a clear predominance of domestic fauna, particularly *Bos taurus*. In total, 815 faunal remains were recovered, 97.91% (n = 798) of which are fragmented. Fracture profiles are primarily irregular (n = 668; 81.9%), with a secondary presence of longitudinal breaks (n = 125; 15.33%). Thermal alteration affects 52.27% (n = 426) of the assemblage; regarding intensity, slightly burnt elements (n = 210; 25.76%) are the most abundant, closely followed by calcined remains (n = 119; 14.6%), while carbonized specimens (n = 97; 11.9%) are less represented. Only 45 elements were anatomically and taxonomically identified, representing 5.52% of the total assemblage (MNI = 9).

Cattle account for 53.33% of the NISP (n = 24). A minimum of two individuals was estimated: one juvenile and one adult between three and six years of age. Due to the scarcity of diagnostic elements, detailed mortality reconstruction was not possible. Anatomical representation is limited to a few teeth, a frontal bone, and isolated postcranial fragments. The only evidence of anthropogenic activity is a cut mark on a lunate carpal bone (Table 2).

Pigs represent 31.11% of the NISP (n = 14). The mortality profile indicates a minimum of four individuals: one fetal, one perinatal, one

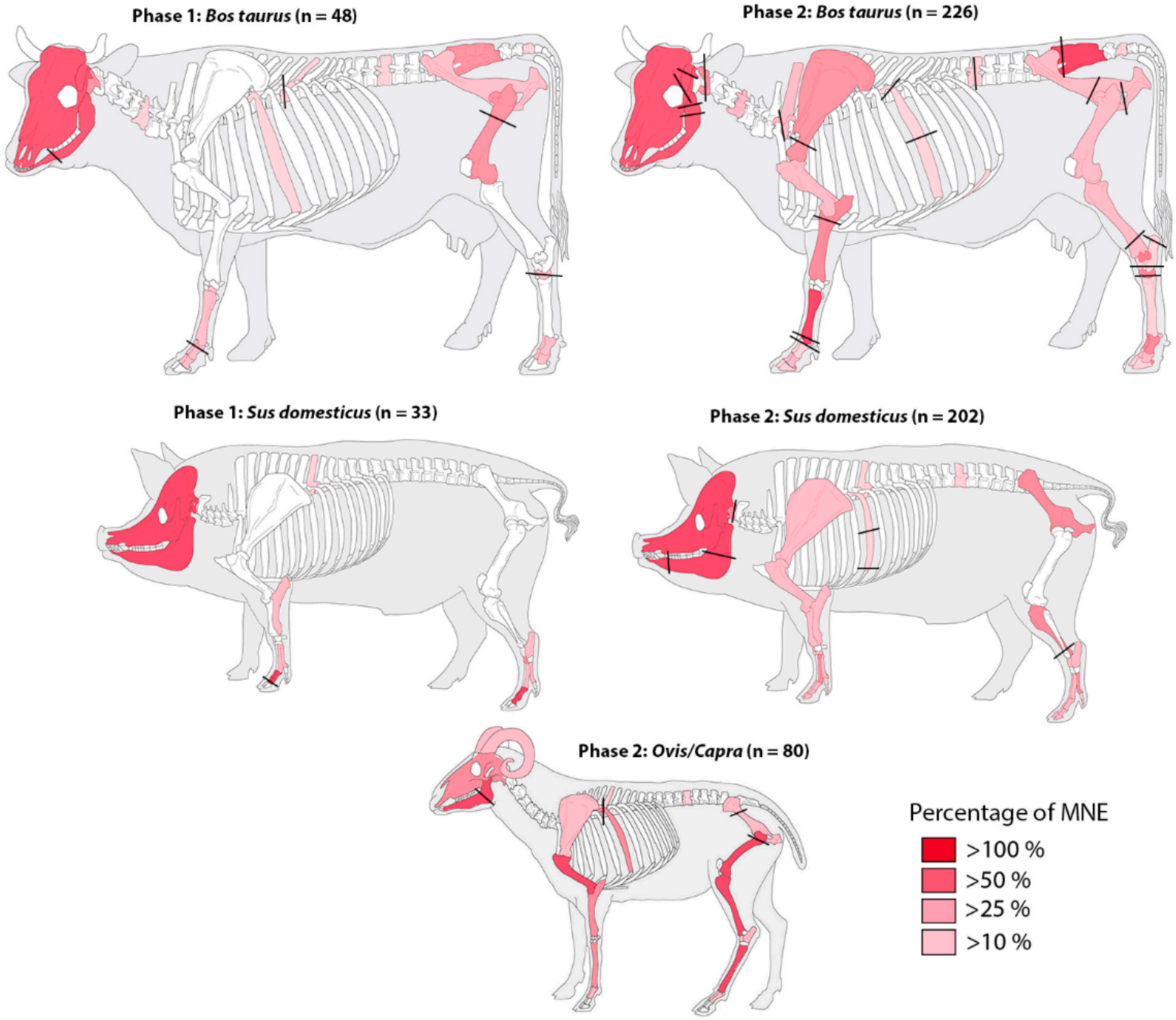

Fig. 3. Anatomical representation of the different domestic taxa found in the Chalcolithic phases. Black lines show the location of the cut marks. Due to the small sample size, phase 3 is not represented. All data are available in Supplementary Table S1.

between 6 and 12 months, and one between 18 and 72 months. Anatomical representation includes mainly teeth, mandibles, and forelimb elements, with no axial skeletal remains. No cut marks or other anthropogenic modifications were observed.

Caprines are very scarce, represented by only five remains (11.11% of the NISP, n = 5). The limited material prevents detailed analysis of herd management strategies. However, examination of dental remains and epiphyseal fusion suggests at least one individual of *Ovis aries*, aged between six and twelve months.

Statistical analysis of the main domestic taxa (*Bos taurus*, *Ovis/Capra*, and *Sus domesticus*) reveals no significant differences in herd composition across the sequence (see Supplementary Material; Table S6). Comparisons between Phase 1 and Phase 2 ($\chi^2 = 1.6$, $p = 0.4$, Cramer's $V = 0.05$), as well as between Phase 2 and Phase 3 ($\chi^2 = 2.7$, $p = 0.25$, Cramer's $V = 0.07$), indicate a remarkable stability in the livestock management strategy. Despite the stratigraphic evidence for varying intensities of stabling (particularly in Phase 2), the relative proportions of domestic species remained constant throughout the Chalcolithic.

5. Discussion

The archaeozoological analysis of the Chalcolithic faunal assemblage from *El Abrigo de la Castañera* provides new insights into livestock management strategies among Chalcolithic communities in the Cantabrian region. The results contribute novel data to the broader debate on the function of *fumier* deposits and the diversity of stabling practices during the Late Prehistory across the Iberian Peninsula. The taxonomic, taphonomic, and processing patterns identified here clearly diverge from those traditionally associated with so-called *sheepfold caves*, where caprines generally occupy a dominant role (Brochier et al., 1992; Martín and Tornero, 2024; Radović et al., 2008).

First, the taphonomic indicators recorded in Phase 2 –with very high fragmentation rates (95.58%), frequent evidence of burning (67.66%), mineral concretions, humic-acid staining, and the abundance of neonatal remains– confirm that the main deposit should be interpreted as a *fumier*. Although soil micromorphological analyses were not performed in this study, the macroscopic evidence of dung accumulation, its subsequent partial combustion, and the mechanical modification of bones, caused by continuous trampling and gnawing by livestock (Pérez Ripoll, 2016; Jiménez-Manchón et al., 2020), explain both the intense fragmentation and the preservation of bones from young animals, including fetal and perinatal elements (2 perinatal calves, 4.86% of the NISP in cattle; 2 perinatal piglets, 6.43% in pigs; and a perinatal lamb, 12.5% in caprines). These specimens likely entered the sediment following natural deaths during or shortly after birth. They are characterized by complete skeletal elements without evidence of butchery. However, they exhibit gnawing damage, a pattern consistent with opportunistic scavenging by omnivorous suids or commensal carnivores (e.g., dogs) cohabiting the stabling area (Greenfield, 1988; Martín and García-González, 2015).

Moreover, comparative analysis reveals distinct functional patterns. Phase 1 is characterized by a predominance of low-utility anatomical elements (such as lower limbs), suggesting that meat-bearing portions were consumed or discarded elsewhere. Conversely, Phase 2 exhibits a generalized representation of the entire skeleton, indicating that the stabling area also functioned as a primary refuse dump.

This anatomical distinction is reinforced by taphonomic data: the significant increase in calcined remains and the occurrence of irregular and longitudinal fractures in Phases 2 and 3 evidences high-temperature combustion and intense trampling. This specific signature, combined with the demographic data, coincides with classical descriptions of cave and rock-shelter stabling deposits (Bergadà, 1997; Brochier et al., 1992; Vergés et al., 2016), providing solid evidence that the shelter functioned as a livestock pen rather than a habitation area, where dung, refuse, and faunal remains accumulated.

What distinguishes *El Abrigo de la Castañera* from most Mediterranean contexts is its taxonomic composition. Unlike typical Mediterranean *fumier* assemblages dominated by sheep and goats (Angelucci et al., 2009), this deposit shows a clear predominance of cattle (42.14%) and pigs (35.21%), while caprines play a secondary role (13.71%), and wild taxa are virtually absent (1.9%). This significant divergence from the standard regional pattern has been extensively analyzed and graphically demonstrated in previous studies at the site (Vega-Maeso et al., 2016) and other western Mediterranean sites (Martín and Tornero, 2024). The data presented here confirm that this specialization is a consistent and recurrent feature of the site's husbandry strategy rather than a situational anomaly.

The strong representation of cattle and pigs can be interpreted in light of the environmental conditions of the Cantabrian region, where recent syntheses of the Iberian Holocene (Carrión et al., 2022) confirm a climatic optimum. Holocene environmental records indicate a humid climate characterized by the expansion of deciduous forests (Iriarte, 2009; Muñoz Sobrino et al., 2005), conditions that are particularly favorable to both cattle grazing, which have significantly higher water and fodder requirements than caprines, and pig husbandry. These herds were likely sustained through specific management practices, such as leaf foddering and forest grazing, strategies recently documented in comparable Iberian contexts through stable isotope analyses, which indicate a strong reliance on forest-based resources and grazing in wooded environments (Villalba-Mouco et al., 2018).

However, this predominance may also reflect cultural, social, and economic factors. In the case of cattle, their significance may have extended beyond meat production, including secondary products such as milk, rather than traction, which is rarely attested for this period (Carmona, 2013). Additionally, the possession and slaughter of large bovids could have held symbolic or social value, functioning as expressions of generosity, reciprocity, or social prestige within egalitarian communities (Russell, 1998). In the Iberian Peninsula, recent research highlights the central role of cattle in commensal practices and feasting events, where their consumption reinforced social cohesion (Pérez-Romero et al., 2017). Pigs, on the other hand, are notable for their rapid growth and high reproductive rate, providing abundant meat despite demanding maintenance (Dietze, 2012). Their adaptation to forested environments made them particularly suitable for Cantabrian landscapes. Moreover, the pig may have had a sociocultural dimension, as its meat could have been consumed in communal or ritual contexts, reinforcing social cohesion and status through sharing and reciprocity (Albarella and Serjeantson, 2002).

Thus, the livestock model documented at *El Abrigo de la Castañera* reflects a differentiated exploitation strategy from that observed in Mediterranean regions, as initially noted by Vega-Maeso et al (2016). Comparable patterns have been identified at other northern sites such as El Hornazo, Pozo Nuevo, La Renke, Los Husos, Arenaza and El Mirón (Altuna, 1980; Altuna and Mariezkurrena, 2001, 2012; Carmona, 2013), where cattle and pigs likewise predominate over caprines. This points to a distinct Cantabrian husbandry system shaped not only by environmental factors but also by social and productive organization.

Comparison of mortality profiles across species and phases reveals distinct management strategies reflecting the exploitation of meat, milk, and secondary products. These results provide a fine-grained spatial and temporal perspective on herd management during the Chalcolithic occupation of the shelter. Only in Phase 3 does the small sample size and lack of diagnostic elements preclude a robust interpretation of livestock strategies.

Cattle mortality profiles reveal distinct management strategies corresponding to the site's changing function. Phase 1, characterized by adult and perinatal specimens suggest a dual-purpose system oriented toward both milk and meat production, with females maintained until the end of their productive lives and occasional use for traction (Blaise, 2009; Vigne and Helmer, 2007). In contrast, Phase 2 evidences a specialized strategy: the assemblage is dominated by specimens slaughtered before three years of age, consistent with intensive meat production and secondary milk exploitation. Crucially, the presence of individuals under six months and perinatal deaths likely reflects natural mortality inherent to stabling conditions, although early weaning cannot be ruled out. This demographic structure supports a model of continuous herd renewal and intensive stall-feeding (Blaise, 2009; Gillis et al., 2024; Mellor and Stafford, 2004; Vigne and Helmer, 2007).

Suid management undergoes a similar intensification. In Phase 1, the presence of three individuals of different ages suggests sporadic domestic consumption. However, Phase 2 shows a clear demographic shift with at least twelve individuals, including perinatal and juvenile pigs (3–12 months), and adult sows. The coexistence of breeding females and piglets points to in situ breeding and fattening cycles (Jourdan, 1976; Price, 2016; Sierra, 2020). This pattern is consistent with an intensive management strategy in which pigs were fed with domestic refuse to reach optimal slaughter weight at a young age, geared specifically towards meat and fat production (Albarella et al., 2011; Blaise, 2009; Hadjikoumis, 2012; Halstead and Isaakidou, 2011; Sierra, 2020).

Finally, although less abundant, caprines display a parallel strategy. The mortality profile of Phase 2, encompassing individuals from fetal to four years of age, combines elements of natural mortality within the pen and early culling to enhance milk yield. Adult individuals were likely maintained for secondary products such as milk or fiber and to ensure flock reproduction (Blaise, 2006; Helmer et al., 2007; Vigne and Helmer, 2007).

The presence of wild fauna is marginal, consisting of very few remains restricted exclusively to Phase 2. Although cut marks are absent, the analysis of bone fractures allows us to discern the origin of these accumulations. Specifically, anthropogenic fresh fractures observed on red deer, wild boar, and rabbit bones indicate the opportunistic human processing of these species. Conversely, the completely unmodified remains of badger, otter, and roe deer likely reflect natural mortality or later intrusive events, confirming that hunting was merely a supplementary practice to the dominant livestock management.

Interpretation of butchery marks and combustion traces must consider their anatomical location, functional context, and variability of human behavior (Binford, 1981). Overall, the evidence indicates that the shelter served not only as a stabling area but also as a locus of slaughtering, butchering, and consumption. In Phase 1 intentional fractures and butchery marks suggest selective domestic consumption. In Phase 2, a more complex pattern emerges, with evidence of skinning, dismemberment, defleshing, impact fractures, and thermal exposure, reflecting intensive on-site carcass processing and repeated consumption events. The higher frequency of cut marks and burning may relate to the functional distinction between phases: while Phase 1 corresponds to a domestic occupation, Phase 2 represents a *fumier*, where refuse, including bones, may have been discarded, used as feed supplements, or intentionally burned for hygiene (Angelucci et al., 2009; Brochier et al., 1992; Martín and Tornero, 2024; Vergés et al., 2016). Fire thus appears to have played a dual role, both culinary and as a management strategy for organic waste. In Phase 3, although data are scarce, the continuity of butchery marks indicates that the shelter remained associated with herding and food-processing activities, albeit with reduced intensity.

Overall, the results from *El Abrigo de la Castañera* challenge the traditional concept of the *«sheepfold cave»*. The predominance of cattle and pigs demonstrates that *fumier* deposits should not be defined taxonomically by the prevalence of caprines but should be understood as complex accumulations generated by stabling and the processing of multiple domestic species. Their composition reflects environmental adaptation as well as economic and social decisions.

The significance of this case extends beyond the local scale. During the consolidation of agropastoral economies in northern Iberia, the livestock management system documented at *El Abrigo de la Castañera* reflects a planned diversified strategy that combines stabling, processing, and consumption within a single space. The results indicate that Cantabrian Chalcolithic communities selectively managed species better adapted to humid, temperate environments or better suited to their production and social organization models. Cattle and pigs offered clear advantages over small ruminants, suggesting an early regional adaptation following the late adoption of agropastoral economies in the area (Cubas et al., 2016). Unlike earlier Neolithic sites such as Los Gitanos (Altuna and Mariezkurrena, 2009) or El Mirón (Altuna and Mariezkurrena, 2012), where sheep dominated, the balanced presence of cattle and pigs here suggests a diversification-oriented strategy rather than specialization. Since both species exploit different ecological niches –cattle relying on pasture and fodder, and pigs, as omnivores, consuming agricultural by-products and marginal resources– their combination would have optimized resource use. This diversified herd composition may thus be understood as a risk-minimization and economic diversification strategy (Iyer, 2021; Díaz del Río, 1995), ensuring complementary resources and greater resilience through the maintenance of a living reserve of meat and energy for times of shortage or crisis (Flannery, 1969).

6. Conclusions

Together with the archaeological and sedimentological evidence, the faunal assemblage from *El Abrigo de la Castañera* (Cantabria) confirms that the main deposit corresponds to a fumier, the result of the accumulation and partial burning of dung and refuse associated with animal stabling activities. The anatomic and taphonomic evidence, including extensive fragmentation, burning, neonatal remains, and trampling or gnawing marks, demonstrates that the shelter functioned primarily as a livestock pen and refuse area rather than as a habitation space.

The most remarkable feature of the site is its unusual taxonomic composition: cattle and pigs predominate, while caprines play a secondary role. This pattern contrasts sharply with the Mediterranean sheepfold caves, typically dominated by sheep and goats, and reflects a herding strategy adapted to the humid environmental conditions of the Cantabrian region as well as to specific economic and social choices.

Mortality profiles indicate species-specific exploitation strategies that confirm a diversified management system. Cattle were likely maintained for a mixed output of milk, meat, and occasional labor, whereas pigs were intensively bred and slaughtered for the rapid production of meat and fat. In contrast, caprines fulfilled a more secondary role within this economic model.

Overall, the evidence shows that fumier deposits should not be defined solely by the predominance of caprines but should be understood as complex accumulations produced through the stabling, processing, and consumption of multiple domestic species. This model reveals a distinct livestock strategy in the Chalcolithic Cantabrian region, oriented toward complementarity, productive flexibility, and economic resilience. Ultimately, this study challenges traditional models of stabling and demonstrates that the archaeological identification of fumiers must be expanded to encompass mixed-herd strategies across diverse environments, thereby providing a broader framework for understanding the resilience of prehistoric livestock farming.

CRediT authorship contribution statement

Sergi Mata-Ferrer: Writing – review & editing, Writing – original draft, Methodology, Investigation, Formal analysis, Data curation. **Alejandro Sierra:** Writing – review & editing, Validation, Supervision, Investigation, Data curation. **Cristina Vega-Maeso:** Writing – review & editing, Validation, Resources, Project administration. **Eduardo Carmona-Ballestero:** Writing – review & editing, Validation, Resources, Project administration. **Ana B. Marín-Arroyo:** Writing – review & editing, Validation.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jasrep.2026.105695.

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