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Economic and symbolic role of animals during the Late Chalcolithic period of Areni-1 Cave, Armenia☆

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ABSTRACT

Areni-1 Cave in Armenia is a special-purpose site that provides a unique window into human-animal interactions in the Chalcolithic period (ca. 5200–3400 BCE) of the southern Caucasus. Areni-1 is known for its extensive funerary and votive practices characterised by exceptional preservation. But the people who used the cave also engaged in animal exploitation for subsistence-related purposes. We use contextual taphonomy to explore differences in the depositional history of bones in areas of the cave where symbolic ritual activities and domestic activities were most concentrated. Our contextual taphonomic analyses as well relative abundance measures confirm field observations about the ritual nature of activities deep inside the cave. We show that wild animals, such as canids and possibly wild cattle, were more common in these ritual contexts, and that bones from these contexts were buried relatively faster than in the areas of mixed domestic-ritual activities at the mouth of the cave. We also demonstrate that people who used the cave herded a mix of sheep, goat, and cattle for a range of their primary and secondary products. Finally, craft production activities inside the cave included manufacturing leather shoes from the hide of pigs and/or boars; but caprines, cattle, and possibly foxes were also skinned and processed for their hide and hair.

1. Introduction

This paper uses faunal remains to explore symbolic ritual and subsistence-related animal exploitation practices during the Late Chalcolithic occupation of Areni-1 Cave in the Republic of Armenia. The Chalcolithic period in the southern Caucasus (ca. 5300–3400 BCE) is bracketed by the Late Neolithic farming villages of the sixth millennium BCE, and the Early Bronze Age Kura-Araxes cultural tradition of the mid-fourth millennium BCE (Gasparyan and Arimura, 2014; Palumbi and Chataigner, 2014; Rothman, 2017; Sagona, 2017). Until recently, the Chalcolithic period of the region remained an archaeological enigma because of a lack of consensus on the chronological and cultural scope of its ceramic horizons (Sagona, 2014: 24). Excavations of numerous newly-discovered sites during the last decade, as well as a growing series of reliable radiocarbon dates, have refined our definitions of the period and its chronological boundaries (Gasparyan and Arimura, 2014). Meanwhile, the zooarchaeological studies for the period are still rare, and so interpretations of its animal economies have traditionally been based on other archaeological indicators. Chalcolithic settlement patterns are generally characterised by an increase in the number of sites and the habitation of the hills and highlands surrounding the region's extensive riparian network (Fig. 1) (Chataigner, 1995; Connor and Sagona, 2007; Sagona, 2014, 2017; Sagona, 2011). This pattern is foundational to the established canon that some Chalcolithic animal economies were organised into itinerant pastoral lifeways, as people adapted to this mountainous region's seasonal Mediterranean climate (Chataigner, 1995; Kushnaerva, 1997: 49; Kiguradze and Sagona, 2003; Marro et al., 2011; Palumbi, 2011). To examine the impact of climate and environment on subsistence practices, however, interpretations of animal exploitation strategies must be verified using the study of faunal remains.

Areni-1 Cave in southern Armenia is particularly significant in this regard, because of its outstanding preservation of faunal remains. Areni-1 is a unique special-purpose site known for its votive and funerary practices (Areshian et al., 2012; Wilkinson et al., 2012). But people using the cave also engaged in food preparation and craft

☆ We dedicate this paper to the memory of Gregory Areshian, one of the principal investigators at Areni-1, who passed away before the publication of this paper. His untimely passing is a great loss to the archaeological community of Armenia and to all who are interested in the archaeology of ancient Caucasus.

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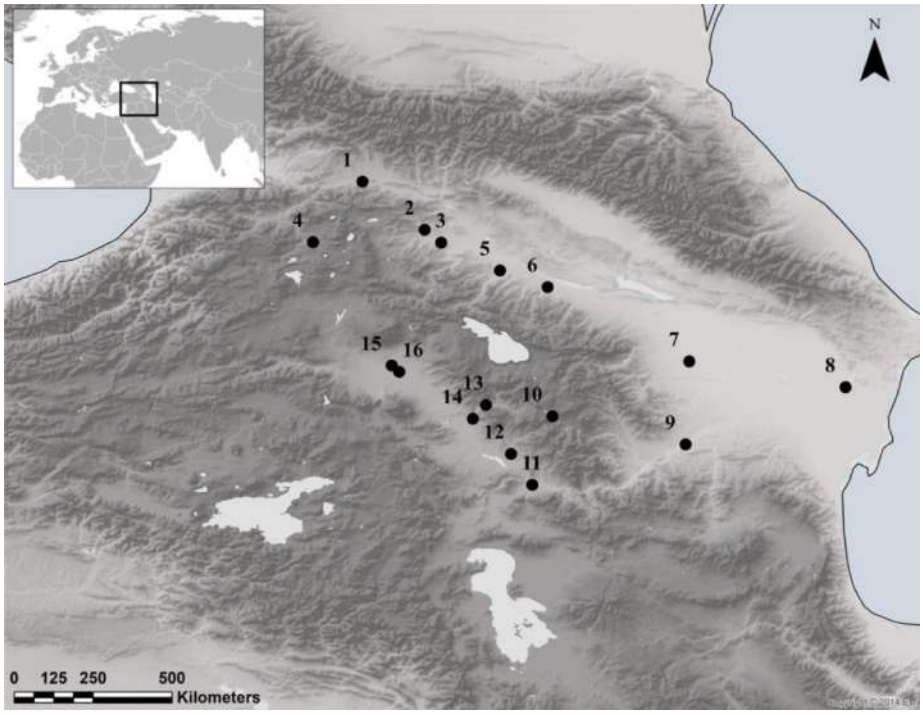

Fig. 1. Location of major Chalcolithic sites in the southern Caucasus: 1. Berikldeebi, 2. Sioni, 3. Tsopi, 4. Bavra-Ablari, 5. Baba Dervish, 6. Mentesh Tepe, 7. Leilatepe, 8. Alikemek Tepesi, 9. Köhne Pasgah Tepesi, 10. Nerkin Godedzor, 11. Kül Tepe-Jolfa, 12. Kültepe 1, 13. Areni-1, 14. Ovçular Tepesi, 15. Aratashen, 16. Aknashen-Khaturnakh.

production (Smith et al., 2014). Bone recovery from areas associated with domestic activities and elaborate symbolic ritual practices allows us to investigate the diverse role of animals in human activities at the site. Ritual practices in particular can result in the differential treatment and deposition of animal remains. We can therefore use a contextual taphonomic approach (Yeshurun et al., 2014; Meier et al., 2017a) to examine and control for potential differences in the depositional and taphonomic history of bones between contexts where symbolic ritual and mundane subsistence practices were most concentrated.

In this paper we ask several specific questions: what types of domestic and wild animals and animal products were exploited for economic purposes, including both subsistence and craft production? What were the pastoral strategies of those who visited and used the cave? How were animals incorporated into symbolic ritual practices? How is the taphonomic history of ritual practices different from areas of the site with evidence of more profane, subsistence-related activities? And how do our observations at Areni-1 fit within the broader picture of Chalcolithic animal economies in the region?

2. Background

2.1. Cultural and chronological setting

Using a small number of available radiocarbon dates and data from more recent excavations, Sagona (2014) broadly divided the Chalcolithic of the southern Caucasus (present-day Armenia, Azerbaijan, and Georgia), as well as northwestern Iran and eastern Turkey into an Early Chalcolithic (EC, ca. 5000–4000 BCE) and a Late Chalcolithic phase (LC, ca. 4000–3500 BCE). In Armenia, recent excavations and new radiocarbon dates allow for a more precise three-partite periodization of the entire period: Early (ca. 53/5200–50/4900 cal. BCE), Middle (c a. 49/4800–44/4300 cal. BCE) and Late (ca. 44/4300–35/3400 cal BC) phases (Bobokhyan et al., 2014; Gasparyan and Arimura, 2014). The middle and late phases are more securely dated, because they are based on data from a large number of sites, while the earliest phase is defined primarily on evidence from a smaller number of sites in Armenia—Areni-1, Barepat-1, and Getahovit-2 Caves; Sotk-2, Karmir-Sar and Armash-1 settlements (Smith et al., 2014; Gasparyan and Arimura, 2014; Kalantaryan and Ghanem, 2019); and in Azerbaijan—including Leilatepe, Nakhchivan Tepe, and Ovçular Tepesi (Marro et al., 2011; Kulieva and Bahşeliyev, 2019).

Until recently, it was also thought that the Chalcolithic period included two important ceramic horizons: Chaff-Faced Ware (CFW) and Sioni Ware. Sagona stressed that Sioni Ware was locally produced primarily in Western Georgia, while CFW was a more extensive horizon that originated in Northern Mesopotamia (2014). The geographic distribution of CFW is interpreted as evidence of cultural interaction along a north–south axis from Northern Mesopotamia, through the southern Caucasus, and into the southern edges of the Eurasian Steppe (Akhundov, 2007; Lyonnet, 2007; Marro, 2010; 2012). While some scholars relate these horizons to chronological periods (e.g. Late Sioni), Sagona contends that evidence for regionalism in CFW ceramic forms, hybridity between the two ceramic types, and the occasional co-occurrence of the horizons in the same strata, reflect a mosaic of cultural groups in the southern Caucasus, each with their own cultural identity. Data from more recent excavations show that the Chalcolithic ceramic repertoire is not limited to CFW and Sioni Ware, and that other ceramic types such as Painted Ware (PW) and Grit Tempered Ware (GTW) were also made and used by local Chalcolithic populations (Zardaryan, 2014a).

In general, the techno-morphological characteristics of ceramic production cannot be the sole criterion for building accurate chronological frameworks and for reliably conceptualizing ancient human interactions. They must be accompanied with other lines of evidence (i.e. architecture and construction techniques, lithics, bone industry, etc.) and, what is most important, with reliable radiocarbon dates for a specific site or group of sites. All of these, particularly ceramic studies, must be supplemented with zooarchaeological studies and taphonomic analyses of animal bones to explore site formation processes and the environmental and economic nature of human-animal interactions (Lyman, 1994; Stiner, 1994; Munro and Stiner, 2015; Samei et al,., 2016; Meier et al., 2017a).

In the southern Caucasus, the Chalcolithic period is most easily defined chronologically in relation to the preceding Late Neolithic and subsequent Early Bronze Age Kura-Araxes traditions. Most of the Late Neolithic farming villages of the Aratashen-Shulaveri-Shomu tradition

are densely clustered in the valleys of the Kura and Araxes Rivers and their tributaries. The climate during this period and much of the early half of the Chalcolithic was generally warm and wet and associated with the expansion of mixed oak forests (Roberts et al., 2001; Arikan, 2015; Chataigner, 2016). The end of the Late Neolithic period in the third quarter of the sixth millennium BCE coincides with changes in the hydrological regime of rivers that pushed Chalcolithic people into higher elevations above 400–500 m above sea level (asl), and across a wider range of ecosystems (Connor and Sagona, 2007; Sagona, 2014; Ollivier et al., 2016); a possible marker of increased human mobility. The increased mobility would have been an apt adaption to the drier and more seasonal precipitation regime of the Mediterranean climate that was established in the region in the early fourth millennium BCE. The transition to the Kura-Araxes tradition in the mid-fourth millennium BCE is also characterised by a sudden shift in settlement patterns and the appearance of a new ceramic repertoire. Kura-Araxes sites and material culture are found either in new sites that lack Chalcolithic occupations, or are superimposed on Chalcolithic occupations of multi-component sites following a clear stratigraphic break (Kiguradze and Sagona, 2003). Areni-1 is one of a handful of sites in the southern Caucasus were Kura-Araxes ceramics were recovered from Chalcolithic deposits (Zardaryan, 2014b; Wilkinson et al., 2012). These rare finds are at the heart of heated discussions about the origins of the Kura-Araxes tradition (Sagona, 2014).

2.2. Areni-1 cave

Areni-1 is a large karstic cave located at about 1100 m asl in the Vayots Dzor Region of Armenia (Fig. 2). Its entrance is situated in a rocky cliff on the left-hand bank of the Arpa River, a tributary of the Araxes River. Areni-1 is known for its exceptionally well-preserved Chalcolithic and Medieval occupations (Areshian et al., 2012; Wilkinson et al., 2012). In the Chalcolithic period, this is attested by large quantities of seeds, fruit pits, desiccated fruits, textiles, basketry, metal objects, and multiple leather shoes (Pinhasi et al., 2010; Areshian et al., 2012; Bobokhyan et al., 2014; Smith et al., 2014; Stapleton et al., 2014). This exceptional state of preservation is enabled by the cave's stable microclimate and layers of thick, hardened dung that sealed the Chalcolithic deposits. Excavations at Areni-1 were conducted between 2007 and 2014 under the direction of several Armenian and International teams headed by Boris Gasparyan (Institute of Archaeology and Ethnography of the

National Academy of Sciences of the Republic of Armenia), Keith Wilkinson (University of Winchester, United Kingdom), Ron Pinhasi (University College Dublin, Ireland), and Gregory Areshian (Cotsen Institute of Archaeology, University of California-Los Angeles). The faunal remains analysed in this study originate from excavations inside the cave (Trenches 1–3) (Fig. 3).

Cultural deposits inside the cave primarily come from three Medieval, one Middle Chalcolithic, and three Late Chalcolithic horizons. The Late Chalcolithic horizons (LC) (*sensu* Gasparyan and Arimura, 2014) are LC III: 4300–4000 cal. BCE; LC II: 4000–3800 cal. BCE; and LC I: 3700–3400 cal. BCE (Areshian et al,., 2012; Smith et al., 2014). Trenches 1 and 2 are located in the main or first gallery inside the cave. In Trench 1, 40 m^3 were excavated, yielding 4.5 m of LC II and III deposits divided into four excavation layers (Unit 1002–1005). These layers overlay a limited Neolithic occupation in the lowermost stratum (Unit 1006) dating to 6390–6240 cal. BCE (Wilkinson et al., 2012). Together, these prehistoric deposits rest on a Late Pleistocene–Early Holocene bed of sand and gravel (Unit 1007) and are capped by a 15–20 cm-layer of desiccated dung (Unit 1001) that was formed after the Chalcolithic period (Areshian et al., 2012; Wilkinson et al., 2012). The areas exposed in Trench 1 (Fig. 4) were primarily used for food storage and funerary activities. Major finds include rounded clay structures and three sealed funerary jars dating to LC II. Three of these jars in Units 1003 and 1004 contained single plastered human crania belonging to individuals approximately 6–21 years in age (Khudaverdyan et al., 2017). A cranium and long bone shaft fragments of a subadult male were found in the third jar (Wilkinson et al., 2012; Khudaverdyan et al., 2017). The LC II occupation in Trench 1 also included several large storage vessels filled with a rich assortment of plant remains, basketry, obsidian and metal artifacts, and parts of sacrificed human bodies. These jars and various clay structures were associated with a grape pressing installation used for wine production (Barnard et al., 2011; Smith et al., 2014). The finds in Trench 1, along with large amounts of reed stems recovered from other trenches,

Fig. 2. View of the Areni-1 Cave and its entrance from the north. Photo Credit: Diana Zardaryan.

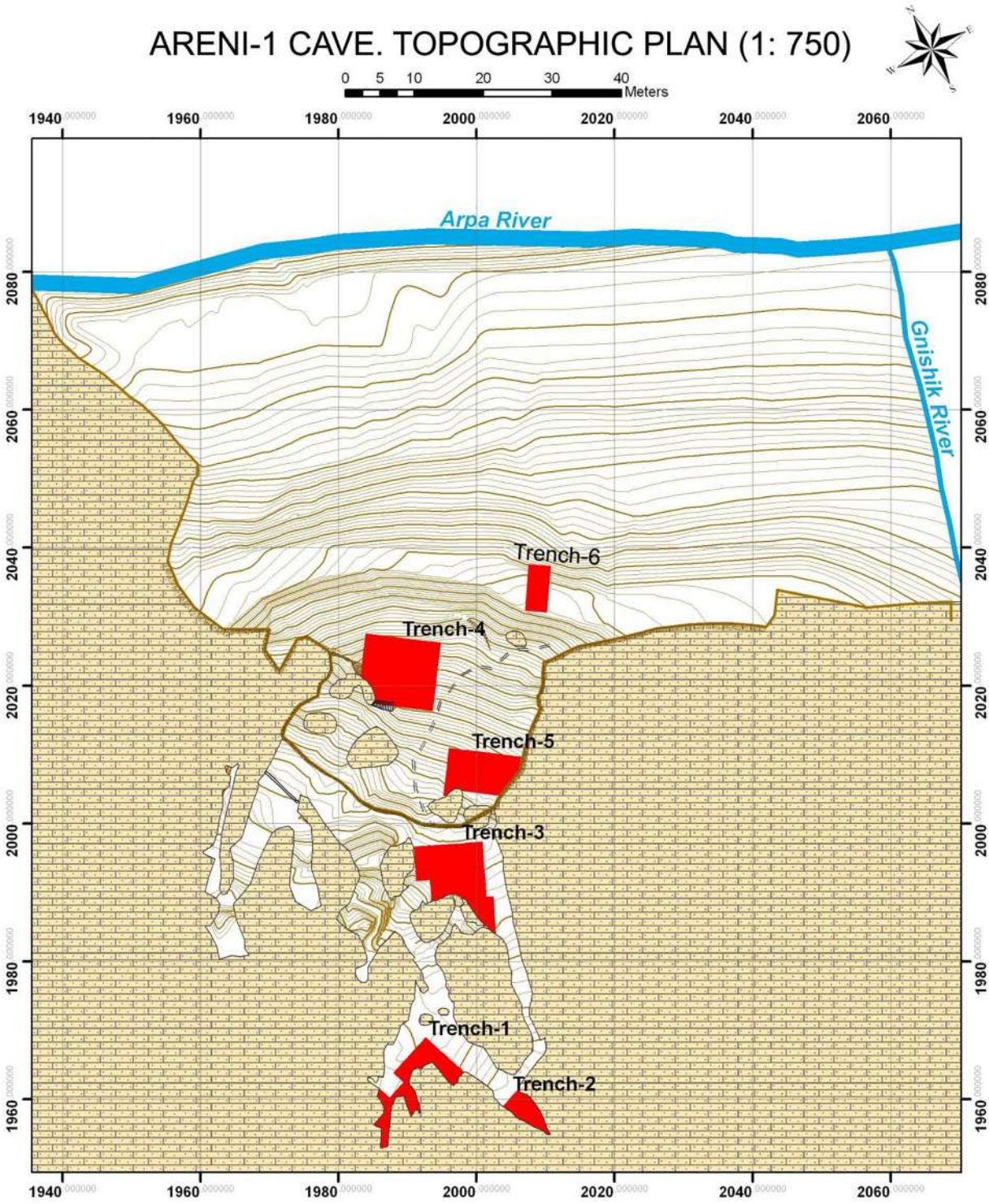

Fig. 3. General plan of Areni-1 and the excavations; Trenches 1–3 are located inside the cave. Detailed trench plans are provided in Appendix A.

indicate that extensive fiber processing took place inside the cave (Wilkinson et al., 2012; Smith et al., 2014).

Excavations by Gregory Areshian and his team in Trench 2 yielded 2.5 m of Chalcolithic deposits in 55 m^3 of excavations. The Chalcolithic deposits were overlain by several meters of dung and a disturbed Medieval matrix (Fig. 5). The uppermost Chalcolithic layer in Trench 2 corresponds with the LC II horizon in Trench 1; it includes clay structures and pots with cremations, as well as isolated human bones from the interspersed sediments (Smith et al., 2014).

Trench 3 located under the overhang at the entrance of the cave yielded the largest amount of archaeological material (135 m^3) (Fig. 6), but it also has the most complex stratigraphy. This trench was first excavated by Keith Wilkinson, who initially reported it as Trench 2. Following an expansion of Wilkinson's trench by Diana Zardaryan, it was relabeled as Trench 3. Whereas Wilkinson excavated a deep sounding, Zardaryan excavated a large horizontal exposure.

Wilkinson's excavations revealed 1.6 m of cultural deposits (Units 2001–2008) overlaying a Late Pleistocene–Early Holocene silt and sand matrix (Unit 2009) (Wilkinson et al., 2012). These cultural deposits consist of a complex web of floors, hearths, middens, and ceramic

Fig. 4. View of the uppermost Chalcolithic horizon in Trench 1 (LC II); the wine-making complex is in the upper left-hand corner. Photo taken by Dmitri Arakelyan.

vessels used for both storage and funerary purposes. Unlike Trenches 1 and 2, The LC I horizon (3700–3400 cal. BCE)

is also present in Trench 3. Each horizon is truncated by the subsequent Chalcolithic occupation, and all three horizons are further truncated by a Medieval dwelling (7th–9th centuries CE) and storage pits and ovens (11th–14th centuries CE). LC II, which is separated from LC I by a layer of dung, is the most extensive occupation in all three trenches. LC III is much less extensive, and it was separated from LC II by another layer of dung.

Despite inter-horizon mixing within and Medieval intrusions into the Chalcolithic deposits, the site has preserved areas with exclusive Late Chalcolithic contexts and sequences. The inner part of the first gallery (Trenches 1 and 2) primarily served as a ritual space during LC III and LC II, while the front of the cave (Trench 3) was dedicated to more subsistence-related domestic and production activities in LC III–II, including metallurgy, basketry, textile and leather processing, and knapping, and bone tool manufacturing. The slope in front of the cave (Trenches 4–6) was also used by the same people as a garbage and waste accumulation area. In contrast to LC III–II, the mouth of the cave (Trench 3) and the slope in front of the cave served as both ritual and profane spaces during LC I when people operated in considerably more limited areas. The aforementioned Medieval intrusions have also created a large number of potentially mixed Chalcolithic areas. We therefore used data from the existing secure Chalcolithic and Medieval contexts to design a sampling strategy to identify additional secure Chalcolithic areas from this larger pool of potentially mixed contexts. Only the fauna from these secure contexts were used to study the economic and symbolic role of animals at Areni-1. The sampling strategy is detailed in Appendix A.

Fig. 5. View of the LC II horizon in Trench 2. Photo taken by Dmitri Arakelyan.

Fig. 6. View of Trench 3 near the mouth of the cave. Photo taken by Diana Zardaryan.

3. Economic and symbolic value of animals

Human exploitation of animals for subsistence needs and symbolic ritual practices are recorded in the zooarchaeological record (Zeder, 1991; Atici et al., 2014; Hill et al,., 2016; Meier et al., 2017b). In Chalcolithic societies animal products were derived from domestic herds and wild game. Small agropastoral communities with largely self-sufficient households often keep a variety of animals with wide ranging behavioral and physiological traits to satisfy their daily needs. This mixed strategy provides herd security in the face of seasonal changes in temperature and rainfall, as well as unpredictable water and feed supplies (Redding, 1981; Halstead, 1992; Kuznar, 2001). In addition to primary products such as meat, bone, and leather, herd animals also provide secondary products such as milk, fleece, labour, dung, and social capital, and thus may serve as "walking larders" or wealth on the hoof (Redding, 1984; Clutton-Brock, 2014). Hunting can provide an alternative source of animal products that does not deplete the capital of herd animals. Wild animals also provide a range of unique products such as antler for tool making, as well as hide and fur.

Symbolic rituals pertain to elaborate practices such as mortuary activities and feasting practices, among others (Russell, 2012). The intentional burial of animals and their inclusion in human graves signal the presence of a strong emotional bond between humans and animals (De france, 2009), while feasts serve to reinforce a sense of group identity. Feasts may also be associated with burial practices, where they highlight the social status of the deceased or their living kin (Grosman et al., 2008; Hayden, 2009). Evidence of symbolic ritual practices are manifested in the zooarchaeological record in several ways. They may include rare, exotic, or dangerous wild animals that have specific symbolic meanings. Wasteful behavior is also a common feature of feasts and may include slaughtering a large number of very young or immature animals (Crabtree, 1990). High-value herd animals such as prime-aged females may also be sacrificed to signal social status. Finally, rituals may include the interment of whole animals, such as pets; the deposition of specific body parts or meatiest body parts of an animal following a feast (Hill et al., 2016); or the ceremonial inclusion and display of symbolically meaningful body parts, like the skull and horn of animals (Hodder and Meskell, 2010).

Contextual taphonomic analyses can expose differences in the depositional and taphonomic history of bones from ritual and subsistence-related activities. Bones deposited during feasting or funerary activities may be purposely cached or buried faster than the trash from food processing and consumption (Meier et al., 2017a). Consequently, they may also be exposed to less fragmentation, weathering, or burning, and may undergo little to no processing for bone marrow extraction (Yeshurun et al., 2013). A rapid burial process may also reduce bone access to carnivores, such as dogs. We therefore explore the differences between postulated ritual and domestic faunal deposits at Areni-1 using a contextual taphonomic approach (Yeshurun et al., 2014; Meier et al., 2017a), in which Trenches 1–3 are compared using taphonomic properties and depositional histories.

4. Methods

Data collection took place at the Center of Excellence in Applied Biosciences at Yerevan State University. For each specimen in the identifiable fraction of the assemblage, various taxonomic, anatomical, demographic, and taphonomic variables were recorded using Stiner's (2004) coding system. Taphonomic variables included location, intensity, and type of animal gnawing; location, intensity, and type of cutmarks (Lemke, 2013); location and extent of fragmentation (Villa and Mahieu, 1991); and intensity of burning (Stiner et al., 1995). Maximum effort was made to assign specimens to the most specific taxonomic classification or body size categories using comparative collections and published identification keys (Olsen, 1960; Boessneck, 1969; Brown and Gustafson, 1979; Lister, 1996; Zeder and Lapham, 2010; Zeder and Pilaar, 2010) (Appendix B, Table B1.). Caprids—which consist of bones identified to sheep (*Ovis* sp.), goat (*Capra* sp.), and the broader sheep-goat category (Caprinae)—make up 90% of the small and medium ungulates that have been assigned to species. Therefore, caprids are combined with bones identified to small and medium ungulates in all analyses. The same was not possible for the large ungulate category, since they could belong to any of four large ungulate species—cattle (*Bos taurus*), red deer (*Cervus elaphus*), fallow deer (*Dama* sp.), and onager (*Equus hemionus*) — all of which are well represented at Areni-1. What follows in this section and is listed in Table 1 is a summary of the methods used in this paper. Further methodical details are provided in Appendix C.

4.1. Taphonomic analyses

We monitor differences in bone depositional history across the three

Table 1
List of analyses and their corresponding indices used in this study; NISP = number of identified specimens, LSI = log size index, MNE = minimum number of elements.

Analyses	Indices	Units of Measurement
1. Taphonomy	a) Mean and median cattle and caprid bone fragment sizes	NISP
	b) Percentage of complete ungulate bones of all ungulate bones	NISP
	c) Percentage of ungulate bones with carnivore gnawing of all ungulate bones	NISP
	d) Percentage of burned ungulate bones of all ungulate bones	NISP
	e) Percentage of ungulate bones with fresh/spiral fractures of all ungulate bones	NISP
	f) Percentage of ungulate bones with hammerstone impact notches of all ungulate bones	NISP
2. Herding and hunting	a) Percentage of cattle, caprids, and suids	NISP
	b) Sheep to goat ratio	NISP
	c) Presence of wild sheep and goat	LSI
	d) Percentage of wild game of total finds	NISP
	e) Percentage of wild ungulate, carnivore, and bird categories	NISP
	f) Percentage of taxa within wild ungulate, carnivore, and bird categories	NISP
3. Herd management	a) Sheep, goat, caprid, and cattle survivorship curves based on long bone fusion	MNE
	b) Sheep and goat mortality profiles based on tooth wear and eruption	MNE
4. Food provisioning	a) Caprid and cattle body part profiles	MNE and NISP
	b) Percentage of specimens with cutmarks of all specimens	NISP
	c) Percentage of cutmark types of all specimens with cutmarks	NISP

trenches by exploring patterning in several taphonomic variables. Differences in fragmentation are explored by comparing mean and median fragment lengths (Meier et al., 2017a) for cattle and caprids to account for possible bone processing for fat rendering and the role of other natural agents such as trampling (Yeshurun et al., 2007). Cattle and caprids also represent animals of different sizes, and so we can account for the role of bone density in fragmentation (Lyman, 1994).

Because of the small number of bones identified to cattle and caprids in Trenches 1 and 2, the remaining taphonomic indices will measure patterning among all ungulate bones. These include a second fragmentation index that measures the percentage of complete and near-complete bones (Bar-Oz and Munro, 2004). Similarly, animal access to discarded bones is assessed by calculating the percentage of specimens that sustained any degree of carnivore gnawing. Finally, we explore differential treatment of bones by calculating the percentage of burned bones, bones with fresh fractures, and bones with percussion notches and pits (Munro and Bar-Oz, 2005). The fresh fracture and percussion indices are essential in determining the extent of bone processing for access to bone marrow. All indices are measured using the number of identified specimens (NISP).

4.2. Demographic and economic analyses

We evaluate the significance of various domestic species by examining the relative abundance of cattle, caprids, and suids. The suid category may include both wild boar and domestic pig, because with the exception of two specimens, the wild or domestic status of the bones could not be determined. We then measure the ratio of sheep to goats (Redding 1984) using only caprid specimens identified to genus (sheep and goat). The Log Size Index (LSI) is used to identify large, potentially wild sheep and goats in the assemblage. The LSI combines measurements from multiple bone elements and compares each of them using measurements from a standard animal (Uerpmann and Uerpmann, 1994; Meadow: 289, 1999). Details about the standard animals are provided in Appendix B.

The contribution of wild game is further examined using a series of taxonomic abundance measures. We first determine what proportion of the assemblage in each trench belongs to wild animals by calculating the percentage of wild game NISP out of the total NISP for each trench. Then, we divide the wild game fraction of the assemblage into three broad categories—wild ungulates, birds, and carnivores—and calculate the percentage of each. Finally, we compare the percentage of major taxa represented within each of the broad categories. For example, for the wild ungulate category, we compare the abundance of aurochs, boar, wild caprids, cervids, and equids.

Sheep, goat, and cattle management goals are explored using survivorship curves based on long bone fusion data, and mortality profiles based on mandibular tooth eruption and wear data (Appendix B, Tables B2–B4.) (Payne, 1973; Grigson, 1982; Zeder, 2006). Survivorship and mortality are calculated using the minimum number of elements (MNE) (Lyman, 1994). These data are interpreted based on published theoretical models for meat, milk, and wool production, and animal use for labour (Payne, 1973; Greenfield, 2010). Milk is differentiated from meat exploitation by high male mortality in the first year of life. In contrast, male caprids are culled primarily in their second and third years in a meat strategy, while cattle are culled in their third and fourth years. Wool and labour exploitation require that some male animals be kept alive well into adulthood. Use of cattle for labour can also be assessed using specific pathologies on weight-bearing bones, such as phalanges (De Cupere et al., 2000).

Cattle and caprid body-part profiles are constructed to investigate the percentage of high- and low-utility anatomical regions and their constituent body parts. Utility is determined by the meat yield of body parts (Table 2) (Binford, 1978: 72; Metcalfe and Jones, 1988: Table 1). Body-part profiles are constructed using the minimum number of animal units (MAU) and they are presented as anatomical regions using Zeder's (1991: Table 4) groupings (Table 2). Pooling skeletal elements into these regions evens out inter-element variation in structural density that mediate bone survivorship in the archaeological record (Lyman, 1994). Caprid profiles include small and medium ungulates, but large ungulates are not included in the cattle profile for reasons explained above.

The frequencies of cutmarked bones and cutmark types are examined to investigate butchering patterns. The frequency of cutmarked bones is calculated as the percentage of specimens with at least one cutmark out of all identified specimens. Cutmark types include meat

Table 2
Body parts and their anatomical regions and utilities. Anatomical regions based on Zeder (1991: table 4); body part utilities follow Metcalfe and Jones (1988: Table 1).

Body parts	Regions	Utility
Mandibles, crania	Head	Low
Atlases, axes, cervical vertebrae	Neck	Low
Thoracic vertebrae, lumbar vertebrae, ribs, sacra	Axial	High
Scapulae, humeri	Shoulder	High
Radii, ulneae	Lower Front	Low
Pelves, femora	Haunch	High
Patellas, tibiae, astragali, calcanei	Lower Hind	High
Metatarsals, metacarpals, phalanges	Feet	Low

Table 3
Major taphonomic measures used in this study.

Cutmarks	Trench 1	Trench 2	Trench 3
Total NISP	232	230	1722
% Cattle of total NISP	9.1	7.4	3.7
% Caprine of total NISP	57.8	68.3	70.5
% Ungulate of total NISP	78.4	91.3	89.1
Cattle fragment size in mm (mean/median)	80.9/73.5	58.6/56	66.2/60
Caprine fragment size in mm (mean/median)	61.8/55	47.9/39	46.1/40
% Ungulate completeness	14.5	9.5	10.9
% Ungulate carnivore gnawed	1.6	0.5	3.7
% Ungulate burned	18.3	55.9	53.9
% Ungulate fresh fractures	11.1	11.8	12.3
% Ungulate bones with hammerstone impact notches	3.2	2.4	2.5

Table 4
The number of identified specimens (NISP) and ratios of major taxa. Caprid NISP includes all sheep and goat specimens, bones identified to subfamily (Caprinae), as well as small and medium ungulates. The small and medium ungulate NISPs included in the calculation of caprid NISPs are also provided in parentheses.

Taxa	Trench 1	Trench 2	Trench 3
Cattle	21	17	63
Caprids (small/medium ungulates)	133 (46)	157 (47)	1214 (304)
Suids	4	10	53
All sheep	15	12	91
All goats	12	12	189
Sheep: goats	1.3:1	1:1	0.5:1

removal, disarticulation, skinning, tongue removal, and head removal (Binford, 1981). Cutmarks produced during head removal are located at the base of the skull, and the articulations of the atlas and axis vertebrae, while tongue removal marks appear on the mandible. Skinning cutmarks are most common on the crania, phalanges, and distal metapodials. Disarticulation marks are found on carpals, tarsals, and bone articular ends. Finally, meat removal cuts include slices on the midshaft of limb bones and nicks around ligament attachment scars (Binford, 1981; Lemke, 2013).

In general, we had better success in identifying wild cattle (*Bos primegenius*) and wild caprines in the assemblage than wild boar. The aforementioned abundance measures of domestic ungulates, sheep-to-goat ratios, survivorship and mortality profiles, and body part profiles do not include these specimens. The protocols used in identifying wild cattle and wild caprines are provided in Appendix C, Section 1.3.

4.3. Statistical analyses

Because of differences in excavation volume across trenches (see Section 2.2 above), statistical testing is deployed to determine the extent to which bone recovery and spatial patterning of various taphonomic and demographic variables are associated with excavated volumes. Sample sizes in the study are too small for Spearman's test of rank correlation, and so Chi-Square testing is used instead. In reporting our test results, we also include an effect size coefficient (Cramer's V) as a measure of the strength of the associations (e.g. Wolverton et al., 2016; Marom et al., 2020). The coefficient ranges from 0 to 1, with 1 indicating a perfect association.

5. Results

In total, 5264 specimens were identified from discrete contexts inside the cave, 2184 of which were assigned to secure Chalcolithic contexts following our sampling strategy (see Appendix A). Nearly 80% of the identified fraction of the assemblage (NISP = 1722) was recovered from Trench 3, and 11% was recovered from each of Trenches 1 and 2 (Fig. 7a). The distribution of identifiable finds across trenches, and hence bone recovery, is driven in part by the volume of excavations (X^2 [2, N = 2414] = 51.01, p < .05, Cramer's V = 0.14). Therefore, in subsequent statistical tests, we shall use the total number of identified bones from each trench as a proxy for excavation volume. It should however also be noted that these excavation volumes include all periods of habitation, including Neolithic, Chalcolithic, Medieval, and mixed contexts.

Only 44% of the Chalcolithic bones were securely attributed to a specific horizon. Since there are no major differences in the relative abundance of ungulate taxa and sheep and goat between these horizons (Appendix A), and in the interest of incorporating the largest possible number of bones into this study, faunal remains from all horizons in each trench are analysed together, with meaningful patterns across the different horizons presented when possible.

5.1. Taphonomic analyses

Mean and median fragment sizes for cattle and caprids are 16–22 mm larger in Trench 1 than in the other two trenches (Table 3). While these inter-contextual differences in fragment size are not considerable, lower bone fragmentation in Trench 1 is confirmed by a higher ungulate bone completeness index (15%) compared to Trench 2 (10%) and Trench 3 (11%). Ungulate bones in Trench 1 also have a significantly lower degree of burning (18%) than in Trenches 2 and 3, where over half of all ungulate bones were burned (X^2 [2,

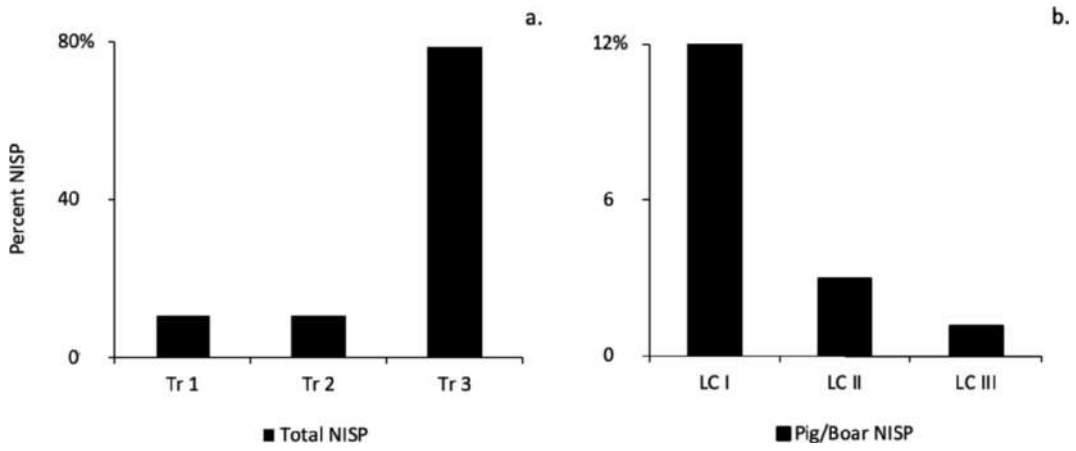

Fig. 7. Percentage of all identified bones across Trenches 1–3 (a); percentage of pig/boar specimens out of all major ungulate bones identified in secure Chalcolithic horizons in Trench 3 (b).

$N = 3160] = 47.75, p < .05$, Cramer's V = 0.13). The low effect size coefficient, however, suggests that other factors such as differences in bone recovery across the trenches played a role in the distribution of burned bones. Carnivore gnawing is low across the excavated areas (1–4%), but it is significantly higher in Trench 3 (X^2 [2, $N = 3015] = 196.91, p < .05$, Cramer's V = 0.26), a pattern which, as is suggested by the higher effect size coefficient, is much strongly—though not entirely—driven by the higher bone

recovery in Trench 3 than ungulate burning. Finally, there are very few differences across the three trenches in the low percentage of ungulates bones with spiral fractures (12–16%) and hammerstone impact notches (2–3%) (Table 3).

5.2. Demographic and economic analyses

Caprids, cattle, and suids (pig/boar) are present in all three trenches. In each case, caprids are the dominant ungulates (85–91%), followed by cattle (Table 4). The only notable variation in relative abundance occurs in Trench 3, where secure samples from all three Chalcolithic horizons are present. Although the suid sample in Trench 3 is small (NISP = 53) and an even smaller fraction of them were identifiable to individual horizons (NISP = 17), they are more abundant in LC I (12%) than in LC II (3%) or LC III (1%). This abundance in LC I is somewhat significant (X^2 [2, $N = 776] = 9.99, p < .05$, Cramer's V = 0.11) (Fig. 7b). Suid NISP in Trench 3 is not significantly higher than in the other two trenches (X^2 [2, $N = 2114] = 2.07, p > .05$, Cramer's V = 0.03), which suggests that suid abundance is not driven by the substantially greater bone recovery in Trench 3.

Sheep are found in equal or nearly equal proportions as goats in Trenches 1 and 2, but are under-represented in Trench 3 where the sheep-to-goat ratio is 0.5:1. The LSI distribution of sheep specimens is slightly negatively skewed, but for the most part symmetrical, while the distribution of goat specimens is positively skewed (Fig. 8). In both instances, the largest LSI values may hint at the presence of very large, possibly wild individuals.

Wild animals make up nearly 20% of the faunal assemblage in Trench 1, compared to 9% and 11% in Trenches 2 and 3 respectively (Fig. 9a), though the data from Trench 1 (NISP = 44) and Trench 2 (NISP = 20) are based on very small samples. Ungulates account for the majority of wild taxa in all three trenches (40–65%), but carnivores (40–42%) and birds (11–20%) are far more abundant in Trenches 1 and 2 than in Trench 3 (27 and 8%) (Fig. 9b). These patterns in wild animal and bird abundances are particularly noteworthy given substantially lower volume of excavations and bone recovery in Trench 1 than in Trench 3. In all three trenches, wild ungulates are dominated by cervids (59–88%), namely red deer and fallow deer (Fig. 9c). Trench 1 is unique, because specimens that were tentatively identified as aurochs (wild cattle), which are rare or absent in the other trenches, make up 30% of wild ungulates. Similarly, dog or wolf (*Canis* sp.) also account for 50% of carnivores in Trench 1 compared to only 14–17% in the other trenches (Fig. 9d). In contrast, fox (*Vulpes vulpes*) is relatively more abundant in Trench 2 (43%) and Trench 3 (63%). This pattern could not be tested using Chi-Square, because fox NISPs in Trenches 1 and 2 are lower than five. However, the fox NISP of 22 in Trench 3 suggests that fox bone distribution across trenches was affected by overall bone recovery and excavation volume. Finally, the bird assemblage is rich, but most species are represented by only one or two specimens. They include golden eagle (*Aquila chrysaetos*), common wood pigeon (*Columba palumbus*), chukar partridge (*Alectoris chukar*), common teal (*Anas crecca*) and mallard duck (*Anas platyrhynchas*).

To increase sample size, survivorship and mortality profiles are constructed using combined samples from all trenches. Nearly all cattle survived the first two years of life (Fig. 10a), but survivorship declined to 67% in Stage C (24–30 months), and 40% in Stage D (42–48 months). Virtually all caprids also survived beyond the first year of life (Fig. 10b). Caprid survivorship remains high at around 70–80% through the second year of life (Stages A–D), but drops suddenly to 37% in the third and fourth years (Stage E). Only 25% of caprids survived beyond the fourth year (Stage F). Specific sheep and goat profiles demonstrate only slight differences in survivorship (Fig. 10c–d). In both instances, nearly all individuals survived the first two years. The largest decline in survivorship took place during the third and fourth years, between stages D and E. A slightly steeper decline in sheep survivorship between the third and fourth years is mirrored in a higher sheep mortality (56%) in Stage EF (2–4 years) (Fig. 11a). Similarly, a steeper decline in goat survivorship between the second and third years is reflected in higher goat mortality (72%) in Stage D (12–24 months) (Fig. 11b).

Despite some variation in relative representation of some elements, neck and axial bones of both cattle and caprids are significantly underrepresented in all trenches, while head and limb parts are consistently over-represented (Fig. 12). The more even body-part profile of caprids is due to the larger sample size and the inclusion of small and medium-sized ungulates in the analysis. Within each trench, the proportion of cutmarked cattle and caprid bones are similar (Table 5). In all trenches, meat removal and dismemberment produced the most cutmarks (Table 5). Head removal and tongue removal are also present in smaller

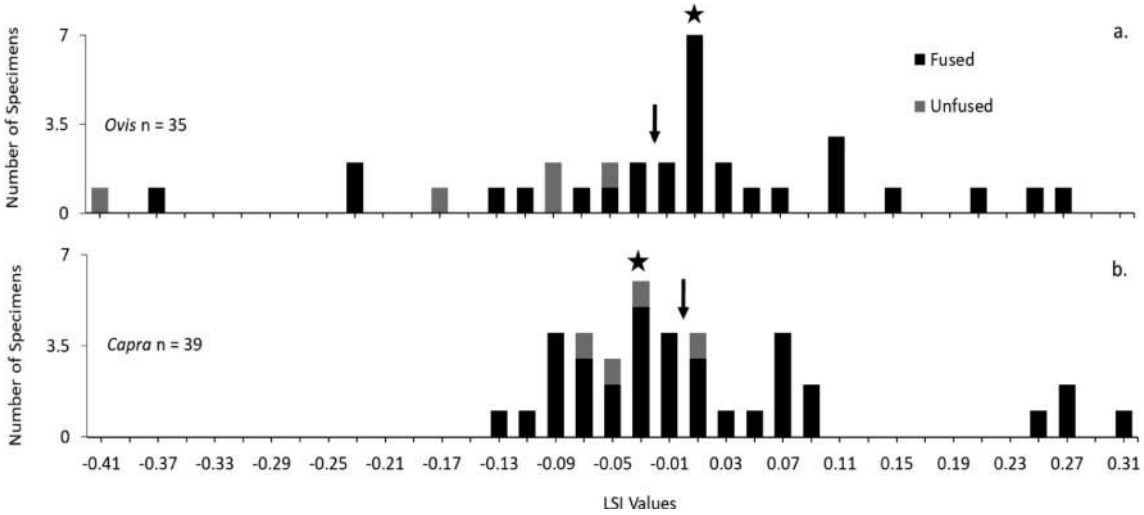

Fig. 8. Sheep and goat LSI values for each horizon calculated following Meadow (1999: 289) and based on standards provided by Uerpmann and Uerpmann (1994). Stars mark mean values and arrows mark median values. Further information about the construction of the LSI graphs, including details about the standard animals, are provided in Appendix C.

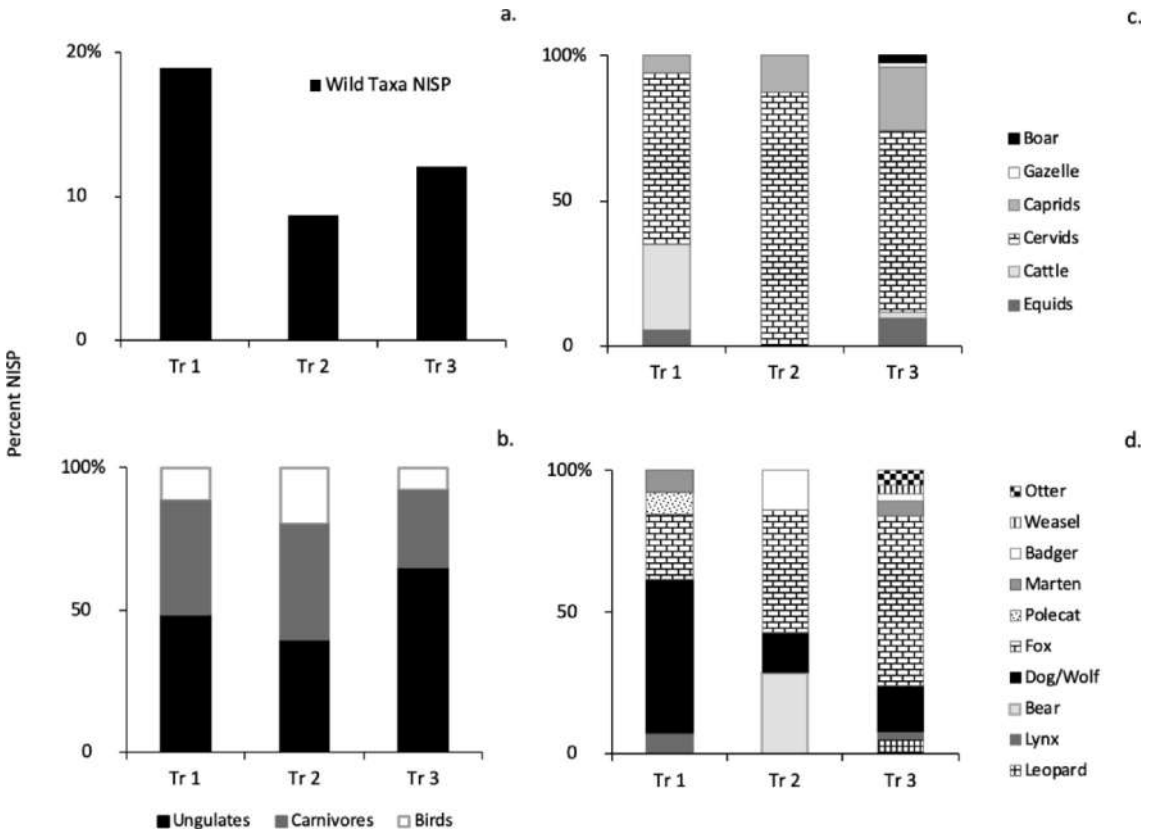

Fig. 9. Relative abundance of wild taxa plotted by trenched based on NISP: a) percentage of all wild animals out of the total finds in each trench; b) percentage of major classes of wild taxa; c) percentage of wild ungulates; d) percentage of carnivores.

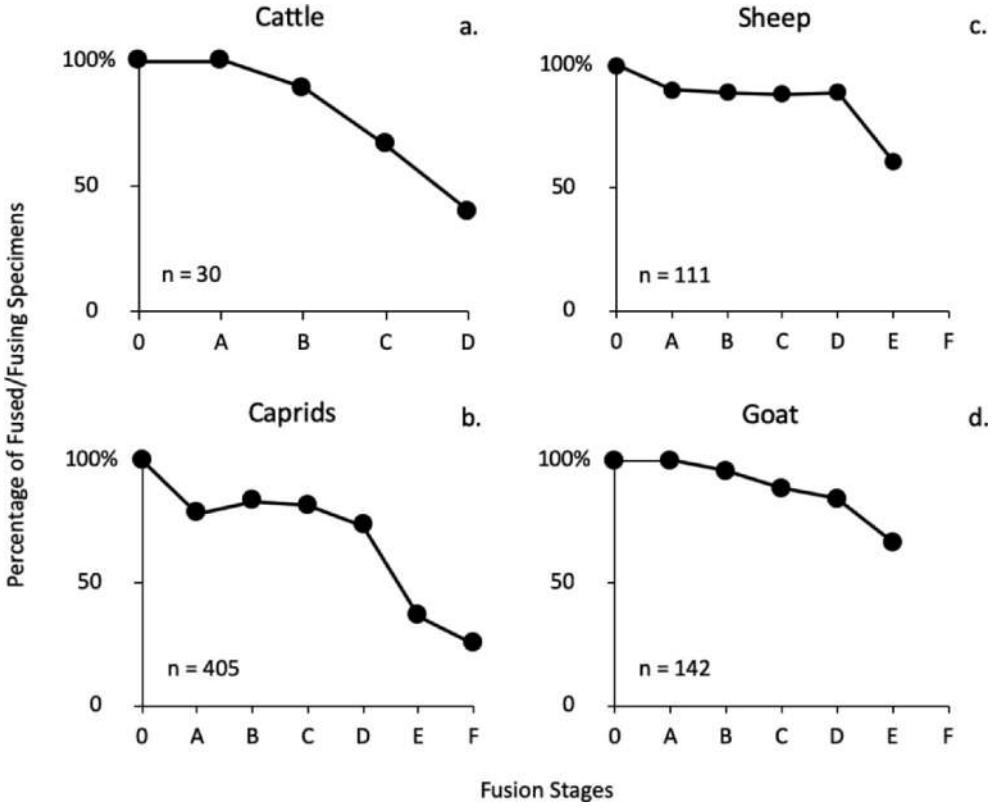

Fig. 10. Caprid, sheep, goat, and cattle survivorship; caprids include specimens identified to sheep, goat, and caprinae, and small and medium ungulates. Caprid, sheep, and goat fusion stages are based on Zeder (2006): A (0–6 months), B (6–12 mos), C (12–18 mos), D (18–30 mos), E (30–48 mos); because of small sample size, age class F (48 + mo) is not included here. Cattle fusion stages are based on Grigson (1982): A (7–10 mo), B (12–20 mos), C (24–30 mos), D (42–48 mos). Methodological aspects of survivorship curves are explained in Appendix C.

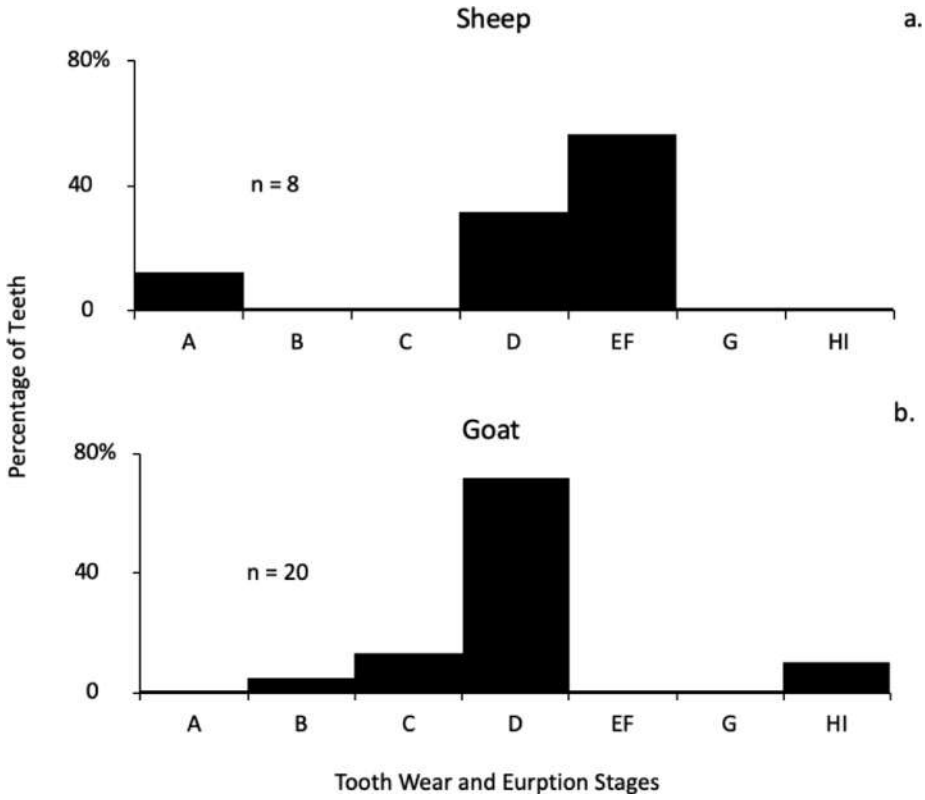

Fig. 11. Sheep and goat tooth wear and eruption stages based on Payne (1973): A (0–2 months), B (2–6 mos), C (6–12 mos), D (1–2 years), EF (2–4 ys), G (4–6 years), HI (6–10 + yrs). Methodological aspects of mortality profiles are explained in Appendix C.

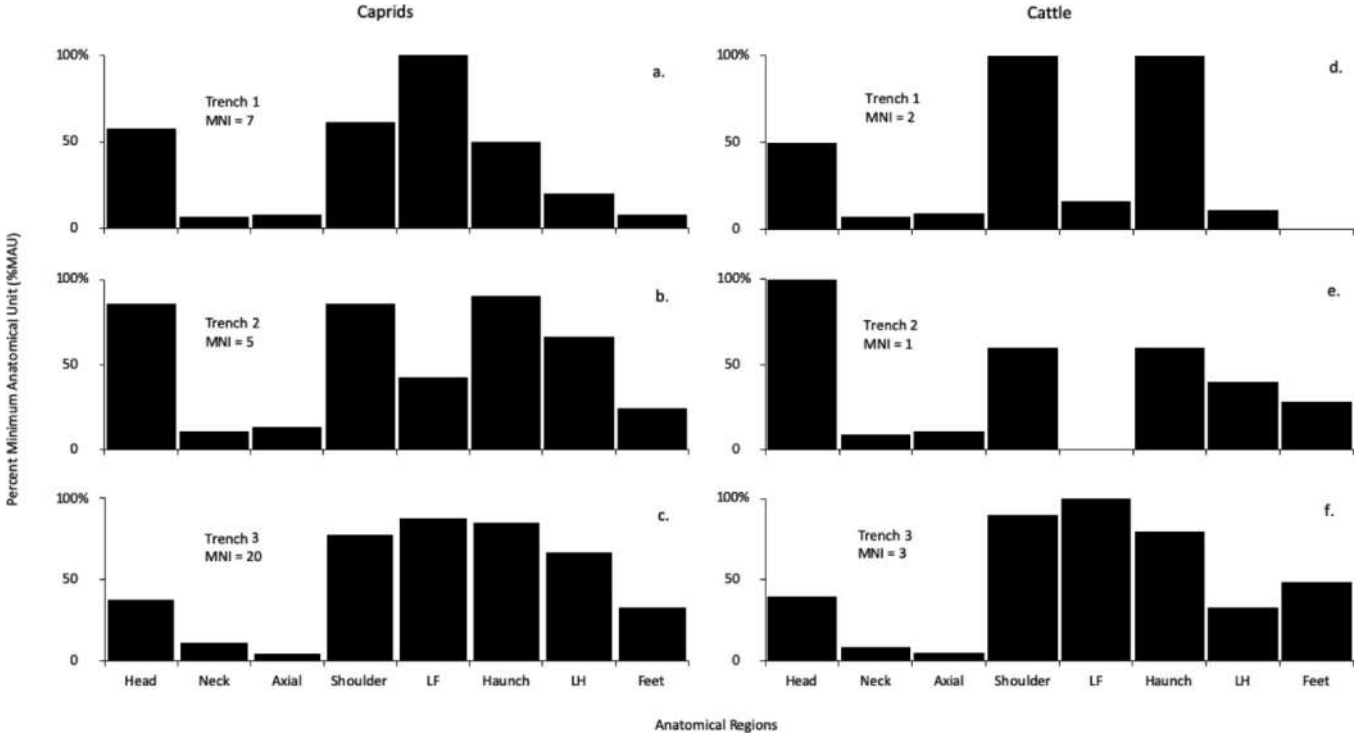

Fig. 12. Cattle and caprid body part profiles from each trench based on the minimum number of animal units (MAU), standardized against the frequency of each anatomical region in the body. Caprid profiles include small and medium ungulates; large ungulates are not included with the cattle. The body parts are based on Zeder's anatomical regions (1991: Table 4). LF = lower front; LH = lower hind. Methodological aspects of body part profiles are explained in Appendix C.

Table 5
Percentage of cattle and caprid bones with cutmarks and percentages of cutmark types for each trench. Caprids include sheep, goat, caprinae, and small and medium ungulate bones.

Cutmarks	Trench 1	Trench 2	Trench 3
Caprids			
NISP of bones with cutmarks	31	17	230
Percentage of bones with cutmarks	23.1	10.8	18.9
Head removal	1.5	5.8	1.4
Tongue removal	2.8	5.8	4.1
Skinning	1.5	1.5	12.4
Dismemberment	51.8	69.6	41.2
Meat removal	43.4	17.6	40.9
Cattle			
NISP of bones with cutmarks	6	2	17
Percentage of bones with cutmarks	37.5	11.8	28.3
Head removal	0	0	3.2
Tongue removal	11.1	0	1.7
Skinning	0	0	20.9
Dismemberment	33.3	50.0	24.2
Meat removal	55.6	50.0	50.0

proportions. Finally, skinning cuts account for 12–21% of caprid and cattle cutmarks in Trench 3, but only 0–2% of cuts in Trenches 1 and 2.

6. Discussion

6.1. Intra-site variation in taphonomic indicators and species abundance

Trenches 1 and 2 are primarily associated with human burials and ritual offerings. While the secure samples for these trenches are significantly smaller than in Trench 3, our contextual taphonomic analyses shed light on differences in animal bone treatment and deposition across these contexts, particularly between Trenches 1 and 3. These taphonomic patterns, which with the exception of carnivore gnawing, were not driven by differences in excavation volume between the trenches, confirm our expectations of lower post-depositional attrition in the ritual contexts of Trench 1, and thereby confirm previous field observations about the symbolic ritual focus of this area of the cave.

Similarities in cattle and caprine bone fragmentation and body part profiles across the excavated areas demonstrate that ungulate body size was a minor factor in dictating patterns of fragmentation. The patterns suggest that relatively lower fragmentation and greater bone completeness in Trench 1 are due to differential treatment of bones and their faster burial (Meier et al., 2017a). As we show below, Trench 3 represents a more domestic space at the mouth of the cave where food processing and preparation as well as craft production took place. More intensive use of this space is evidenced by the substantially higher degree of bone burning in Trench 3. The low percentages of bones with spiral fractures and hammerstone impact notches across all three trenches suggests that processing bones for access to marrow was not a high priority at this special-purpose cave site. This observation, and the overall low percentages of carnivore gnawing across the site beg the question as to what agent was most responsible for bone destruction, given overall high rates of fragmentation? The definitive answer to this question requires more controlled excavations, but a clue lies in the high percentages of bones with dry fractures across all three trenches. We hypothesize that Medieval intrusion into and turnover of Chalcolithic deposits exposed bones to extensive trampling by people and animals, resulting in extensive post-depositional fragmentation (Yeshurun et al., 2007).

The special function of Trench 1 is also evidenced by its taxonomic composition. Trench 1 differs from the other two trenches in its concentration of wild game. These include canids and possibly aurochs, animals that are rare or absent in the other trenches. Aurochs are represented by only five specimens, and canids by seven, five of which are head fragments. Our interpretations are therefore tentative and best serve as testable hypotheses. Wild animals are often incorporated into ritual rites and ceremonial practices in a variety of ways, and carnivores in particular are believed to have played an important symbolic role among pastoral communities across West Asia (Maher et al., 2011; Anthony and Brown, 2017; Losey et al., 2018). While carnivore bones are scattered across different contexts, aurochs bones were derived exclusively from Units 1003 and 1004, each of which contained a secondary burial of a single plastered human cranium in a clay jar (Wilkinson et al., 2012). Unfortunately, stratigraphic mixing at Areni-1 does not allow us to specify the exact relationship between these bones and the human crania. But data from other sites suggest two possibilities.

Dog and wolf bones, particularly their skull bones and teeth, as well as the sporadic bones of other animals have been found in some Chalcolithic and Early Bronze Age human burials in the southern Caucasus (Kushnaerva, 1997; Muradyan, 2014; Poulmarc'h et al., 2016). These cases may be exceptions, however, because a recent comprehensive synthesis of Chalcolithic burial practices in the region makes no mention of animal inclusions in human burials (Poulmarc'h and Le Mort, 2016). In another case, burning prevented the identification of small bone fragments to either humans or animals (Lyonnet et al., 2008). Bones of wild game have also been recovered from animal burials. Berthon (2018) reports a case of intentional secondary placement of two foxes in the Chalcolithic occupation of the nearby site of Ovçular Tepesi in the Nakhchivan Republic of Azerbaijan. The deposits from which these jars were recovered are contemporaneous with LC III–II at Areni-1. Based on the stratigraphic context of the jars, Berthon argues that this deposition was related to rites associated with cycles of temporary abandonment and habitation of the site by pastoralists. Additional controlled excavations are needed to elucidate the role of carnivores in the funerary rites of Areni-1, and the role of carnivores in the ontology of pastoralist groups in the southern Caucasus.

6.2. Areni-1 animal economy

Our study shows that all four domestic animals—sheep, goat, cattle, and probably pig—were exploited by those who visited and used the cave. Mixed herds are a key feature of an animal economy focused on maintaining herd security. Keeping a variety of different animals provides a wider range of behavioral and physiological characteristics to better buffer against subsistence and production failure (Redding, 1981; Halstead, 1992; Kuznar, 2001). Greater taxonomic diversity also reduces the susceptibility of herds to the impact of environmental stressors, such as pronounced fluctuations in water availability or temperature. Maintaining herd security would have been paramount at this time, because the majority of the Chalcolithic period at Areni-1 coincided with the onset of a more unpredictable and seasonal Mediterranean climate (Connor and Sagona, 2007; Sagona, 2014; Ollivier et al., 2016).

Caprids make up the overwhelming majority of domestic animals at Areni-1. Cattle yield much more meat and milk per animal, but the costs associated with their management outweigh their benefits when herd security is paramount. Caprids have higher reproductive capacities and lower overall management costs than cattle, and have also far lower water and feed requirements and are better adapted to the rugged highland zones where access to pastures may require mobility ((Dahl and Hjort, 1976; Franklin: 141, 1980; Zeder, 2003).

Based on body part profiles and butchery data, we argue that sheep, goat, and cattle were transported as whole animals to the cave, where they were slaughtered, skinned, butchered, and prepared for consumption. Most sheep and goats were culled between the first and fourth years of life to optimize meat exploitation (Payne, 1973), while providing access to milk, wool, and hair from the herd's female reproductive core (Redding, 1981). Goats display a slightly steeper decline in survivorship and a younger mortality profile than sheep.

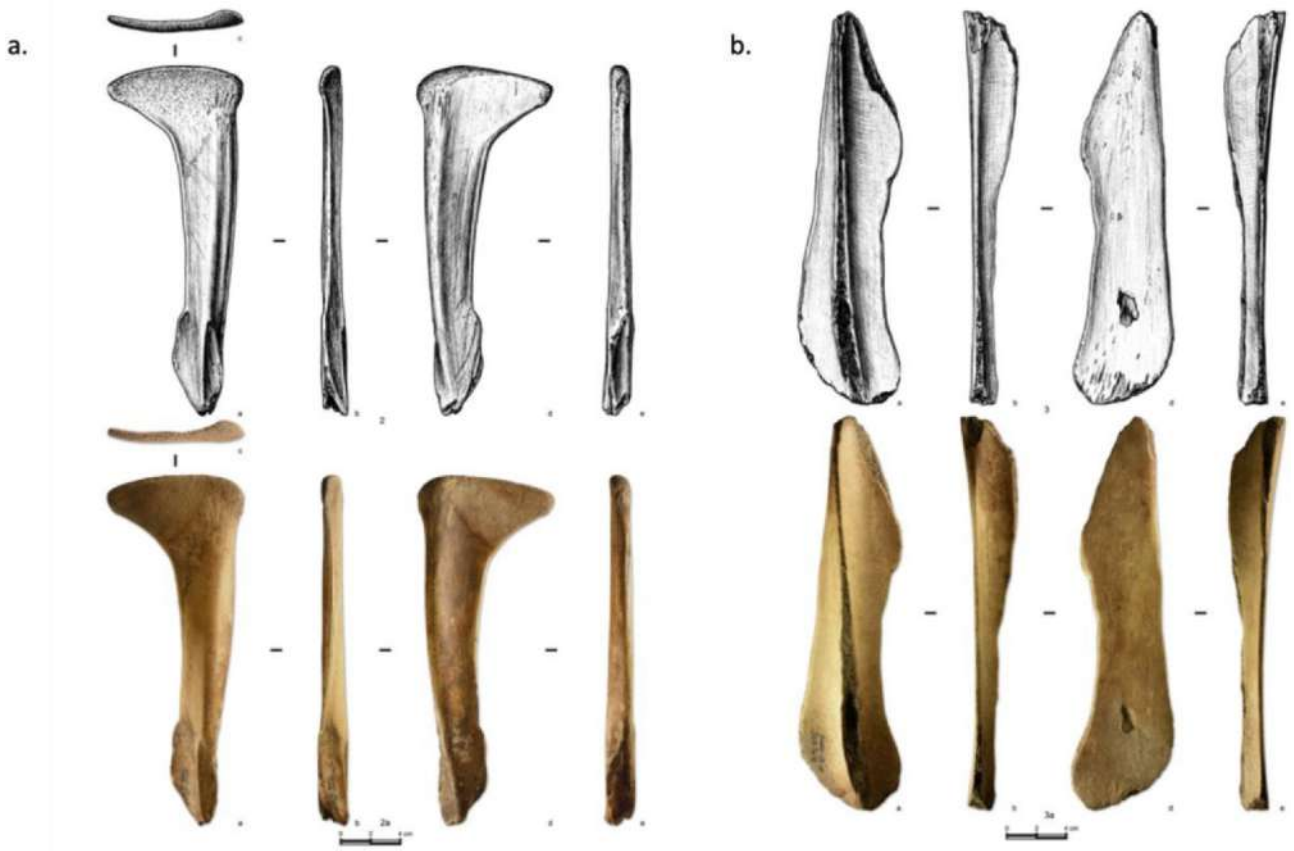

Fig. 13. Polishing implements recovered from Trench 3, made of the mandible (a) and scapula (b) of large ungulates. Photos taken by Dmitri Arakelyan; illustrations by Ani Sahakyan.

Similar patterns have been noted for other prehistoric sites and time periods in the highlands of Southwest Asia (Samei, 2019; Samei et al., 2019). Goats have a higher reproductive rate and are not as well adapted to cold winters, and so kids are often slaughtered in late fall to provide meat and doe's milk during the cold season (Halstead, 1998; Arbuckle et al., 2009), and to reduce competition for feed with lambs, and breeding and lactating females. Cattle also provide a variety of products, including meat, milk, and labour. Most cattle were however slaughtered before adulthood to reduce management costs, while providing access to large quantities of meat. This strategy also ensures access to cow's milk, because successful lactation requires calves' suckling stimulus in unimproved breeds (Greenfield, 1988).

Domestic pigs played a minor role at Areni-1. This is expected for economies that focus on herd security, because pigs do not yield any secondary products. Suids, however, make a relatively substantial contribution to the faunal assemblage in Trench 3. Preliminary DNA analysis, as well as scanning electron microscopy of the hair preserved on several Chalcolithic leather artefacts from Trench 3 suggest that some of the shoes were made of pig or boar hide. The recovery of several bone needles, perforators, and polishers made of mandibles and scapulae of large ungulates (Fig. 13), as well as anomalously high percentages of skinning cutmarks on caprid and cattle bones, all point to intensive skinning and hide processing in Trench 3. Fox bones from all parts of the body are also most concentrated in Trench 3. This anomalous concentration was in part associated with greater bone recovery and excavation volume in Trench 3, but it nevertheless still suggests that foxes were actively hunted and either incorporated into as-yet unknown ritual practices, and/or possibly processed for their fur.

Although Areni-1 is a special-function site, our observations of its animal economy are largely consistent with data from other Chalcolithic sites in the region. Published data and analyses are primarily limited to taxonomic abundance data from a small but growing number of zooarchaeological studies (Narimanov, 1977; Nebieridze, 1978; Marro et al., 2009; Badalyan et al., 2010; Lyonnet et al., 2012; Kovacs et al., 2013; Berthon, 2014; Varoutsikos et al., 2017; Samei, 2019). According to the available data, all four domestic species were herded at most other Chalcolithic sites in similar proportions to Areni-1. With the exception of one site in Azerbaijan (Narimanov, 1977; Lyonnet et al., 2012) and the site of Darkveti in Georgia (Nebieridze, 1978) caprids are more common than cattle across the board, with suids coming a distant third (Berthon, 2014). Greater reliance on caprids in Chalcolithic animal economies may be a sign of increased mobility relative to the earlier Late Neolithic period. But more fundamentally, it is becoming clearer that Chalcolithic communities in the southern Caucasus practiced a conservative, low-risk animal economy that responded to the immediate subsistence needs of households in an increasingly unpredictable and dry environment (Samei, 2019). Further taphonomic, zooarchaeological, and isotopic analyses will empower us to present a more nuanced and detailed reconstruction of Chalcolithic human-animal interactions in the southern Caucasus in both subsistence-related and ritual settings.

CRediT authorship contribution statement

Siavash Samei: Conceptualization, Methodology, Formal analysis, Investigation, Resources, Writing - original draft, Visualization, Funding acquisition. **Nelli Hovhannisyan:** Resources, Data curation, Writing - review & editing. **Boris Gasparyan:** Resources, Data curation, Writing - original draft, Writing - review & editing, Visualization, Project administration.

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Appendix A

Sampling strategy

The complex stratigraphy of Areni-1 poses two challenges for the study of the Chalcolithic occupation of the site. The first and most problematic challenge is intermixing between Chalcolithic and Medieval contexts. Mixing is caused by the turnover of Chalcolithic deposits by Medieval intrusions, as well as rodent burrowing, and illegal use of the cave as a shelter in recent years. Mixing has been particularly intrusive in Trench 3 at the mouth of the cave. Our first task was to distinguish secure, unmixed contexts from potentially mixed contexts so that only the most secure bones would be included in this study. The second task was to address intermixing between Chalcolithic horizons. For example, in all three trenches, particularly in Trenches 1 and 3, the ephemeral LC III is truncated by intrusive bins, pits, and burials dating to LCII (Wilkinson et al., 2012; Smith et al., 2014).

Contexts inside the cave consist of individual pits, ceramic vessels, and clay bins, and the sediments between them. Pits, vessels, and bins were assigned unique Locus numbers (Fig. A.1–3); whereas inter-loci sediments were identified with square and spit, with distinct cultural and sedimentological deposits assigned unit numbers. Given the stratigraphic complexities of the site, field notes, trench plans, and photos, as well as a large radiocarbon database provided by Smith et al. (2014) were used to identify secure Chalcolithic and Medieval contexts.

Secure Medieval contexts include ovens, circular dwellings, and pits that contain manuscript fragments, Medieval pottery, and glass, while being devoid of any Chalcolithic material or signs of intrusion from underlying Chalcolithic deposits. On the other hand, secure Chalcolithic contexts primarily consist of sealed jars, bins, and pits that are not compromised by intrusion or mixing with obvious Medieval contexts. Many of the secure Chalcolithic contexts have been directly radiocarbon dated; such as Pit 3 in Trench 3, which is famous for a leather shoe that was directly dated to LCI (Pinhasi et al., 2010). The shoe was accompanied by a fallow deer scapula, and the complete horns of two female wild goats (Fig. A.4). Contexts that could not be identified as secure Chalcolithic or

Medieval contexts were marked as “potentially mixed.” The bones from secure contexts were studied during two pilot study seasons in 2014 and 2015. Comparisons of these contexts revealed three key features that were typical of Medieval contexts and could be used to distinguish additional secure Chalcolithic contexts from the large pool of potentially mixed contexts mentioned above.

Secure Medieval contexts contained: 1) historical or recently introduced taxa, particularly chicken (*Gallus domesticus*); 2) significantly higher proportion of “fresh” bones with ligaments and bone surface grease (Behrensmeyer, 1978) (Fig. A.5a), and 3) instances of anatomical articulation. If any of these three features were observed in a bag of bones, the context from which those bones were collected were deemed unreliable and excluded from this study. If any context was represented by multiple bags of bones, all bags were excluded from this study even if they themselves did not contain evidence of mixing.

In total, 5264 specimens were identified from discrete contexts inside the cave. A small fraction of these contexts (n = 133) belonged to secure chronological periods, including 45 Chalcolithic and 87 Medieval contexts. The remaining contexts were identified as potentially mixed contexts. Following the implementation of the protocol described in the supplementary material, more than one hundred additional secure Chalcolithic contexts were identified from among the larger pool of potentially mixed contexts. Forty-two percent of the faunal assemblage (NISP = 2184) were assigned to this larger group of secure Chalcolithic contexts. Together bones from mixed Chalcolithic-Medieval contexts (NISP = 2331) and secure Medieval contexts (NISP = 285) account for 49% of the assemblage. The remaining 9% of the faunal assemblage (NISP = 473) was recovered from the small Neolithic area in Trench 1.

Deep intrusions have also resulted in intermixing between these Chalcolithic horizons. As a result, only 44% of the fauna from secure Chalcolithic contexts could be directly and reliable attributed to a specific horizon. There are no major differences in the relative abundance of ungulate taxa and sheep and goat between the secure samples from these horizons (Fig. A.5b–c). Therefore, in the interest of incorporating the largest possible number of bones into this study, faunal remains from all Chalcolithic horizons in each trench were combined and analysed together. Meaningful patterns and differences between different horizons are presented, when possible.

Appendix B

Data Used in the Zooarchaeological Analyses

Appendix C

Further Notes on the Methodological Approach

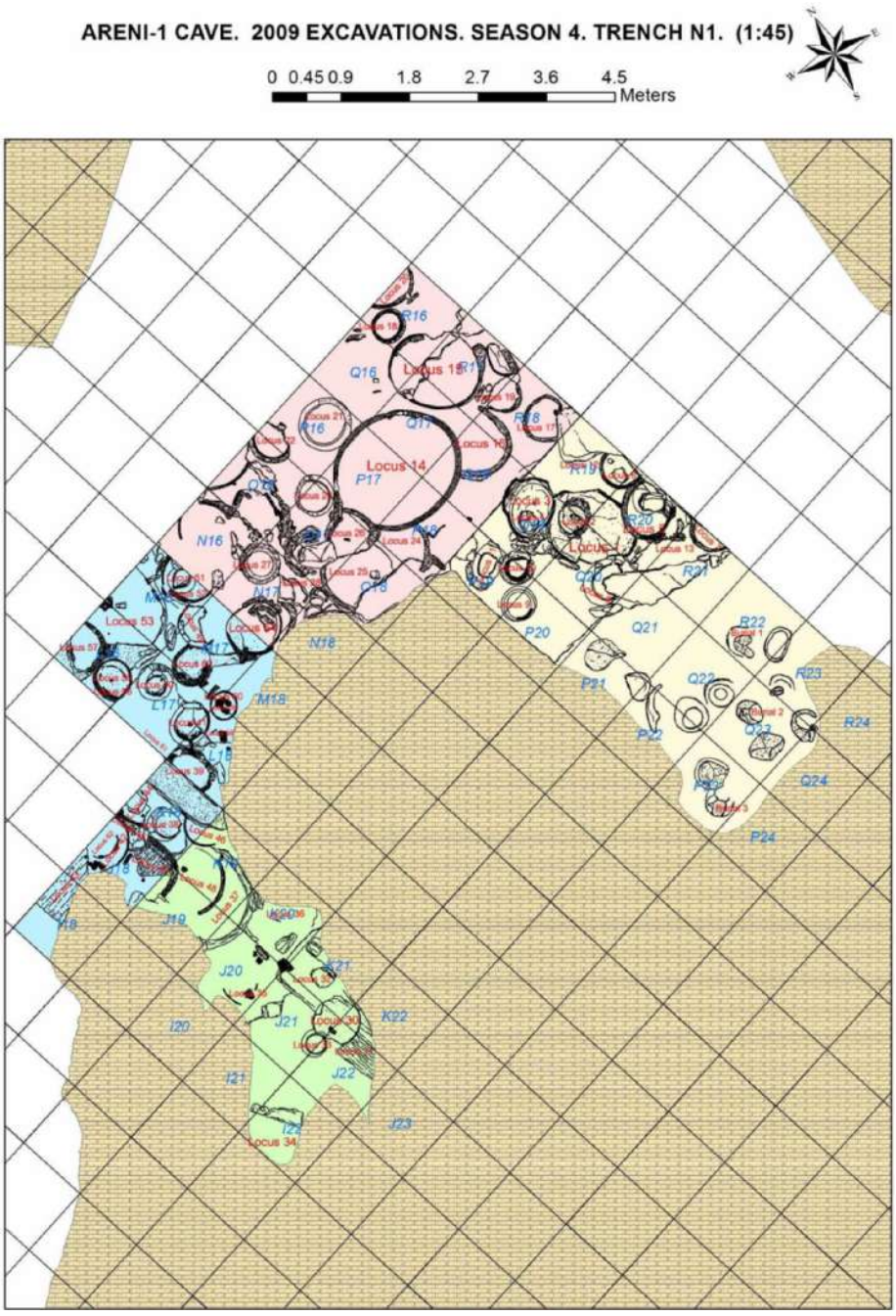

Fig. A1. The general excavation plan of the LC II horizon in Trench 1. The different colors broadly represent different excavation seasons. From right to left: yellow = 2007 first season; red = 2007 season; blue = 2008 season; green = 2009 season.

1. Methods

1.1. Identification

Maximum effort was made to assign specimens to the most specific taxonomic classification possible. Whenever this was not possible, specimens were assigned to a body size category. Body-size categories include small ungulates (goat/gazelle sized), medium ungulates (goat/boar-sized), large ungulates, (red deer/cattle-sized), and huge ungulates (auroch-sized).

1.2. Taphonomic analysis

Both fragmentation analyses—average size and percent-completeness—exclude teeth, as well as specimens that sustained new fractures during excavation and post-excavation handling.

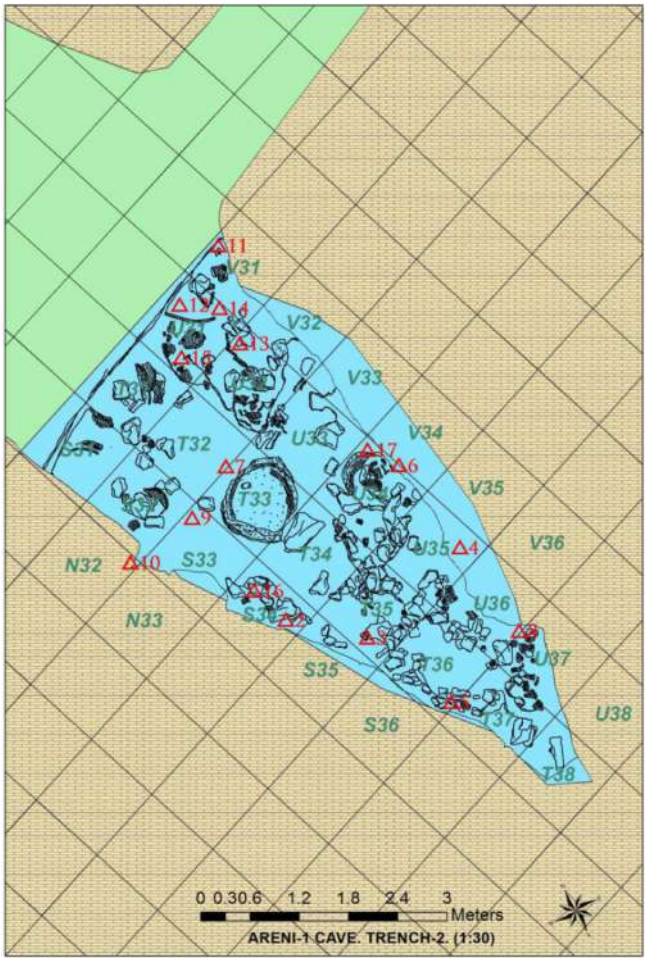

Fig. A2. The general excavation plan of the LC II horizon in Trench 2. The blue color denotes the boundaries of the excavated area red triangles and their numbers represent individual loci.

1.3. Demographic and economic analyses

In all demographic and subsistence-related analyses, the caprid category combines bones identified specifically to sheep (*Ovis* sp.) and goat (*Capra* sp.) with a much larger sample of bones identified to subfamily (Caprinae), as well as bones assigned to the small and medium ungulates. Sheep and goat bones used in calculating sheep-to-goat ratios, as well as bones identified to Caprinae include both wild and domestic forms, because the domestic status of sheep and goat can only be reliably assessed using a small number of diagnostic body parts. Boessneck (1969) and Hole et al. (1969: 270–81) were referenced to securely identify some of these parts, namely phalanges and horncores, as wild (see Table B.1). Cattle (*Bos taurus*) and pig (*Sus scrofa*) also have their wild counterparts. Following Olsen (1960), and Brown and Gustafson (1979), as well as the comparative collection at the Institute of Zoology, Scientific Center of Zoology and Hydroecology in Yerevan, several *Bos* specimens which included four long bones and one mandible fragment, were tentatively identified as wild cattle or aurochs (*B. primegenius*), based on their anomalous sizes and the rugosity of the attachment scars. These identifications, however, do not preclude the presence of other, as yet unidentified wild specimens in the assemblage. These identifications are also tentative given evidence of size overlap between taurine cattle and aurochs. By the same token, the suids may also include both domestic pig and wild boar. With the exception of two specimens, we were unable to ascertain the wild or domestic status of any of the suid specimens, because they were too fragmented to allow for size, shape, and geometric morphometric analyses (Evin et al. 2013; Owen et al., 2014).

1.4. Log size index

Log Size Index (LSI) can assist in examining the potential role of wild sheep and goat in the assemblage. LSI is calculated using measurements provided for two different sets of standard animals (Uerpmann and Uerpmann 1994). Standard measurements for goat are based on an average of measurements taken a modern wild male and wild female goat (*C. aegagrus*) from Turkey, while the standard animal for sheep is a modern wild adult female (*O. orientalis*) from western Iran. The LSI graph was constructed using only one depth or breadth measurement from each measurable long bone epiphysis, astragalus, calcaneum, and first phalanx. Bones were measured with a digital caliper following guidelines established by von den Driesch (1976). The LSI value for each individual bone measurement is calculated following Meadow (1999):

$$LSI = log(x/m) \quad \text{(Eq. C1)}$$

Where x is the dimension of the archaeological specimen and m is the corresponding measure from a standard animal. Specimens with similar LSI values are binned together and presented in a bar chart, where 0 represents the standard animals. Values higher than 0 represent specimens that are

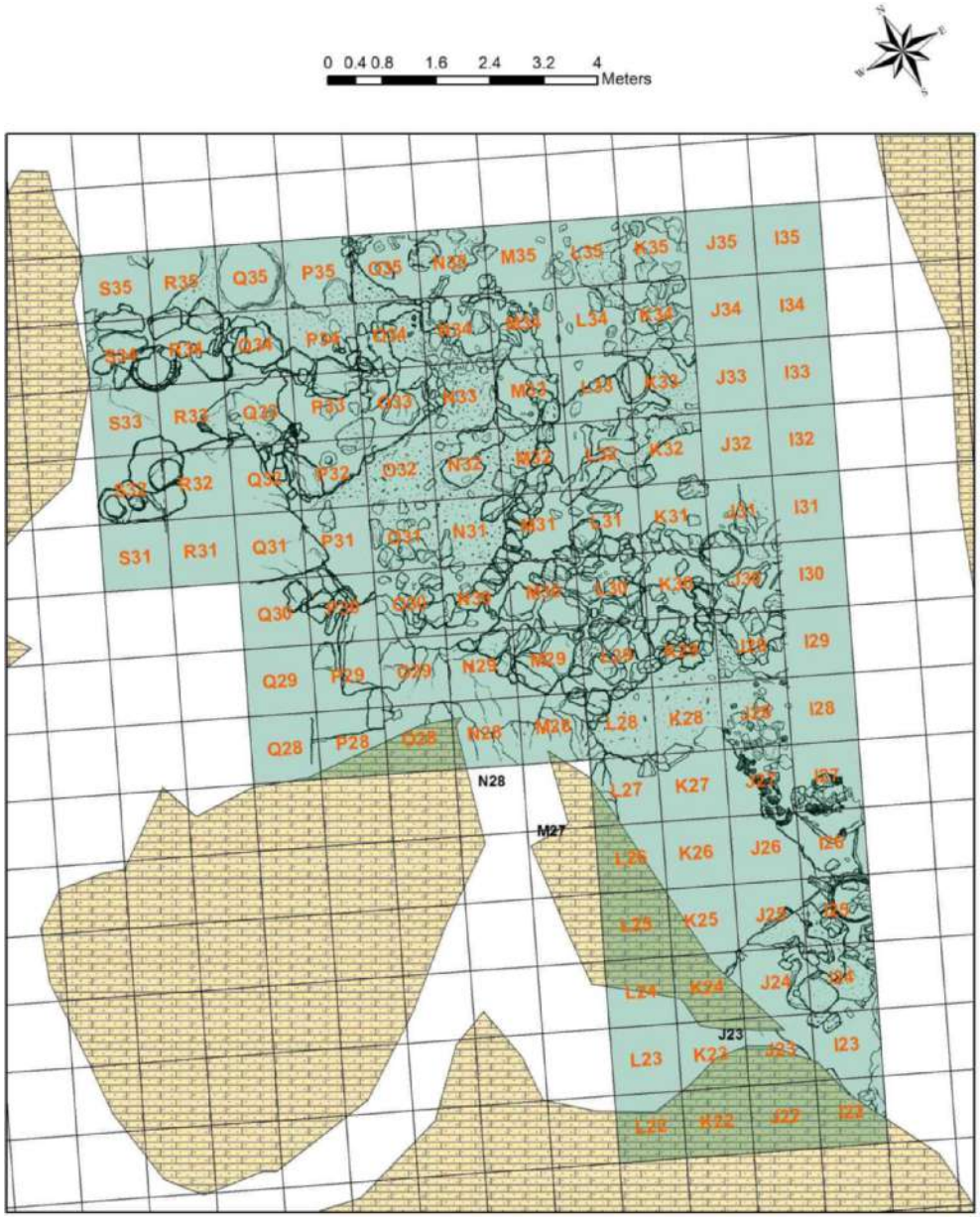

Fig. A3. The general plan of the horizontal excavations in Trench 3. The green color denotes the boundaries of the excavated area; Wilkinson's deep sounding is represented by the blank space in the lower right-hand corner, with square K26 in its center.

larger than the standard, while negative values represent specimens that were smaller than the standard.

1.5. Survivorship curves and mortality profiles

Sheep, goat, and cattle management goals are explored using survivorship curves based on long bone fusion data, and mortality profiles based on mandibular tooth eruption and wear data. The proximal and distal epiphyses of limb bones fuse to the bone shaft (or diaphysis) in a predictable sequence until around the end of the fourth year of life, when sheep, goat, and cattle reach full body size. Following published protocols epiphyses that fuse at similar age intervals are combined into four stages for cattle labeled A through D (Grigson 1982) and six stages for sheep, goat, and caprids labeled A through F (Zeder 2006). Survivorship in each stage is calculated by dividing the number of fused/fusing specimens by the total number of specimens from elements assigned to that stage, multiplied by 100. The percentage of fused bones in each stage represents the proportion of animals that survived until that age group.

Unlike bone fusion, tooth eruption and wear occur throughout an animal's life and thus provide higher resolution mortality data, especially after an animal reaches adulthood. The cattle tooth sample from Areni-1 is too small to render a reliable mortality profile. Following Payne's (1973) protocol, sheep and goat teeth that are in similar stages of eruption and wear are combined into nine discrete dental stages labeled A through I. Mortality for each stage is calculated by dividing the number of specimens in each stage by the total number of teeth assigned to all stages multiplied by 100. Our analysis includes complete mandibles, mandible fragments, and loose teeth. Isolated teeth whose wear and eruption fall into multiple stages are assigned to a specific stage following Payne's (1973) system of proportional allocation.

Both bone fusion and dental stages are displayed at equidistant intervals, but these stages do not represent equal periods of ontogenesis. For

Table B1
The number of identified specimens (NISP) at Areni-1.

Latin Names /Body Size Categories	Common Name	Trench 1	Trench 2	Trench 3	Total
Bos sp.	Cattle	16	17	60	93
Capra sp.	Goat	12	12	169	193
Ovis sp.	Sheep	14	12	86	112
Caprinae	Sheep/Goat	61	85	626	772
Sus sp.	Pig/Boar	4	10	51	67
Bos cf. *primigenius*	Aurochs	5		3	8
Equus cf. *hemionus*	Onager	1		13	14
Cervus elaphus	Red deer	5	1	33	39
Dama sp.	Fallow deer	1		4	5
Capreolus capreolus	Roe deer			7	7
Cervidae	Red/Fallow deer	4	6	38	48
Capra aegragrus	Bezoar goat			20	20
Capra orientalis	Mouflon	1		5	6
Caprinae	Bezoar/ Mouflon		1	4	5
Sus sp.	Boar			2	2
Gazella sp.	Gazelle			2	2
Lepus capensis	Cape hare	1		13	14
Ursus arctos	Brown bear		2		2
Canis sp.	Wolf/Dog	7	1	6	14
Vulpes vulpes	Red fox	3	3	22	28
Canidae				5	5
Panthera pardus	Leopard			2	2
Lynx lynx	Eurasian lynx	1		1	2
Lutra lutra	Eurasian otter			2	2
Martes foina	Stone marten	1		2	3
Meles meles	European badger		1	1	2
Mustela sp.	Weasel			3	3
Mustelidea		1		6	7
Carnivora		3	1	6	10
Aquila chrysaetos	Golden eagle	1		1	2
Alectoris chukar	Chukar partidge	2		2	4
Phasianidae			1	3	4
Anas crecca	Eurasian teal		1		1
Anas platyrhynchos	Mallard duck			2	2
Suliformes				1	1
Charadiformes				2	2
Strigidae		1			1
Anser sp.	Goose	1			1
Columba palumbus	Wood pigeon		1		1
Small ungulate	Goat/ Gazelle-sized	2	4	20	26
Medium ungulate	Goat/Boar-sized	44	43	284	371
Large ungulate	Red deer-sized	12	19	78	109
Huge ungulate	Aurochs-sized	1		28	29
Tiny bird	Sparrow-sized	1		2	3
Small bird			1		1
Medium bird	Partridge-sized			3	3
Large bird	Buzzard-sized			1	1
Huge bird	Vulture-sized				
Total		206	222	1619	2047

example, caprid bone fusion Stage A represents 6 months of growth (0–6 months), while stage E covers 18 months of growth (18–30 months).

1.6. Body part profiles

The profiles are constructed using %survivorship of each anatomical region. To determine %survivorship, the minimum number of elements (MNE) for each element is calculated based on the most commonly represented element portion (Lyman, 1994). Element portions are recorded based on their distinct morphological features (Stiner, 2004). The MNEs for all elements in an anatomical region are combined, and the total is standardised by dividing by the combined number of elements from that region represented in an animal's body, to produce the minimum animal units

Table B2
Cattle survivorship data based on bone fusion. Survivorship (%Fused) is calculated using the minimum number of elements (MNE) and following Grigson's age stages (1982); px = proximal epiphysis, ds = distal epiphysis, F = fused/fusing, U = unfused.

Fusion Stages	Corresponding Ages and (Stages)	F	U	*% Fused*
Pelvis	(A) 7–10 months	3	0	
Scapula		4	0	
Subtotal		7	0	*100.0*
Radius, px	(B) 12–20 months	3	1	
Phalanx 1		13	1	
Phalanx 2		8	0	
Humerus, ds		2	0	
Subtotal		26	2	*92.9*
Tibia, ds	(C) 24–30 months	3	1	
Metapodials, ds		3	2	
Subtotal		6	3	*66.7*
Humerus, px	(D) 42–48 months	0	0	
Ulna, px		0	2	
Femur, px		1	3	
Tibia, px		0	1	
Radius, ds		1	1	
Femur, ds		0	1	
Subtotal		2	8	*20.0*
Total		41	13	

Table B3
Caprid survivorship based on epiphyseal fusion. Survivorship is calculated using the minimum number of elements (MNE) and following Zeder's age stages (2006); px = proximal epiphysis, ds = distal epiphysis, F = fused/fusing, U = unfused. *Ovis* (sheep) and *Capra* (goat) categories include only specimens identified to genus. Caprinae includes specimens that could not be identified to genus. Total Caprids (plotted in Fig. 8a and b) is the total of the *Ovis*, *Capra*, and caprinae categories.

Fusion Stages	Corresponding Ages and (Stages)	*Ovis*		*% Fused*	*Capra*		*% Fused*	Caprinae		Caprids		*% Fused*
		F	U		F	U		F	U	F	U	
Radius, px	(A) 0–6 months	9	1		12	0		8	7	29	8	
Subtotal		9	1	*90.0*	12	0	*100.0*	8	7	29	8	*78.4*
Humerus, ds	(B) 6–12 months	8	1		16	0		6	6	30	7	
Pelvis		0	0		0	1		13	4	13	5	
Scapula		8	1		6	0		8	0	22	1	
Subtotal		16	2	*88.9*	22	1	*95.6*	27	10	65	13	*83.3*
Phalanx 1	(C) 12–18 months	13	2		26	3		2	6	41	11	
Phalanx 2		10	1		21	3		12	4	43	8	
Subtotal		23	3	*88.5*	47	6	*88.7*	14	10	84	19	*81.6*
Tibia, ds	(D) 18–30 months	8	1		14	2		6	9	28	12	
Metapodial, ds		16	2		13	3		4	5	33	10	
Subtotal		24	3	*88.9*	27	5	*84.4*	10	14	61	22	*73.5*
Calcaneus	(E) 30–48 months	4	1		5	4		0	7	9	12	
Femur, px		4	2		2	0		0	11	6	13	
Femur, ds		4	5		0	0		0	4	4	9	
Ulna, px		1	1		2	0		0	6	3	7	
Radius, ds		4	2		5	1		0	6	9	9	
Tibia, px		0	0		0	2		4	9	4	11	
Subtotal		17	11	*60.7*	14	7	*66.7*	4	43	35	61	*36.5*
Humerus, px	(F) 48 + months	0	0		0	1		2	5	2	6	
Subtotal		0	0	–	0	1	*0*	2	5	2	6	*25.0*
Total		89	20		122	20		65	89	276	129	

Table B4
Ovis (sheep) and *Capra* (goat) mortality data based on tooth wear and eruption, following Payne's (1973) age stages. Counts include isolated teeth that were proportionally allocated between stages.

Payne Stages	Age Group	*Ovis*	*Capra*
A	0–2 months	1	0
B	2–6 months	0	1
C	6–12 months	0	2.6
D	1–2 years	2.5	14.4
E	2–3 years	0	0
F	3–4 years	4.5	0
G	4–6 years	0	0
H	6–8 years	0	2
I	8–10 + years	0	0
Total		8	20

Fig. A4. Horns of a female wild goat (*Capra aegragrus*) recovered from Pit 3 in Trench 3. Photo taken by Siavash Samei.

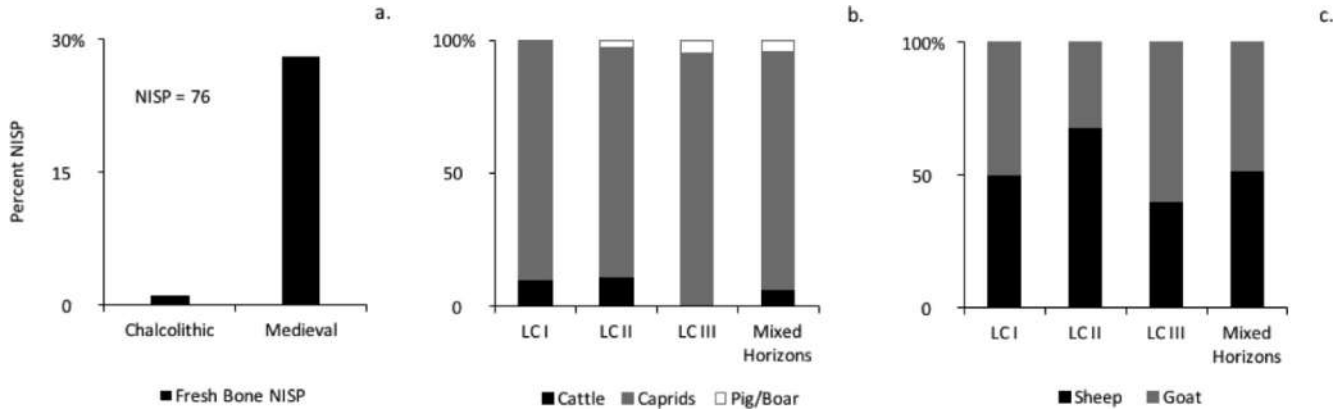

Fig. A5. Taphonomic and taxonomic differences between Chalcolithic, Medieval, and mixed contexts based on the number of identified specimens (NISP): a) percentage of fresh bones out of the total number of identified bones in secure Chalcolithic and Medieval contexts, freshness is defined as bones with ligaments or bone surface grease (Behrensmeyer, 1978); b) percentage of the three major classes of domestic ungulates out of all ungulates within discrete Chalcolithic horizons and secure but mixed Chalcolithic contexts; c) percentage of sheep and goat out of all caprids within discrete Chalcolithic horizons and secure but mixed Chalcolithic contexts.

(MAU). The MAU for each region is then divided by the minimum number of individuals (MNI, which is also the largest MAU from all regions) and multiplied by 100% to calculate %survivorship for each region (Lyman, 1994). Body-part profiles are examined separately for each trench. In Trenches 1 and 2 where sample sizes are small, NISP was used instead of MNE, since NISP has also been shown to correlate with MNE in zooarchaeological assemblages (Grayson and Frey, 2004).

Cattle and caprid body-part profiles are constructed to investigate the percentage of high- and low-utility anatomical regions and their constituent body parts. Utility is determined by the meat yield of body parts (Binford, 1978: 72; Metcalfe and Jones, 1988: Table 1). Low-utility joint bones such as the astragalus, calcaneus, and patella are included in high-utility lower-limb categories because they are often transported and discarded along with the meat-bearing femur and tibia bones (Zeder, 1991: Table 4; Stiner, 2004: Fig. 9).

Certain body parts, particularly vertebrae and ribs were identified to less diagnostic body-size categories and not to genus and species. These regions are broadly under-represented because of their low bone density and lower chances of preservation. But they are particularly under-represented for cattle, because cattle bones were not combined with bones assigned to the large ungulate category. By the same token, teeth are not included in the head category, because they have higher mineral density than bone and are thus more likely to preserve in archaeological sediments (Stiner, 1994).

1.7. Cutmarks

Specimens exhibiting more than one type of cutmark were counted once for each type. For example, a bone fragment containing a disarticulation cut and a meat removal cut, is counted twice when calculating the percentages of various cutmark types.

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