

Commingled Bone Assemblages: Insights from Zooarchaeology and Taphonomy of a Bone Bed at Karain B Cave, SW Turkey

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Introduction

Paleontology, forensic anthropology, human osteology, and zooarchaeology may differ greatly in terms of their research questions, topical foci, and theoretical agendas, but their research interests may strongly intersect when it comes to their methodological engagement with the most fundamental question: “what are these bones doing here?” Modern taphonomic research aids all these researchers and sheds light on the processes that accumulate, modify, and destroy bones. Ubelaker (2002, p. 332) describes commingling as mixing together of remains of different origins and usually of more than one individual. Zooarchaeologists commonly deal with exhaustively fragmented animal bone assemblages that are scattered and commingled. The same can also be said of human osteologists when they encounter archaeological contexts that do not present primary and undisturbed contexts with complete human bodies neatly entombed. Commingled human remains from such contexts are usually interpreted in terms of a series of antemortem, perimortem, postmortem, and postrecovery events (Sorg & Haglund, 2002). The degree of fragmentation and commingling, thus complexity, varies from context to context, depending upon taphonomic histories of human bone assemblages. Catastrophic events leading to mass graves, funerary rites, defleshing, trophy collection, secondary burials through post-burial cultural intervention, or intervention of nonhuman biotic or abiotic agents generate disarticulated, scattered, and fragmented human skeletal remains

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(e.g., Buikstra & Ubelaker, 1994 and references therein; Haglund & Sorg, 2002 and references therein; Knüsel & Outram, 2004).

Along the same lines, the formation of faunal assemblages is usually the result of a combination of complex, interacting factors including human activities, nonhuman animal ravaging, and diagenetic processes. These taphonomic filters do not necessarily operate simultaneously and may affect an assemblage differentially, increasing the preservation potential of some bones while destroying others. Some bones may escape the destructive effects of one or more filtering agents but may succumb to others, thus coming to be deleted from the archaeological record. The impact of these destructive processes will also vary in accordance with the chemical, morphological, and mechanical attributes of different skeletal parts. Therefore, before making inferences about cultural or natural phenomena, paleontologists, forensic anthropologists, human osteologists, and zooarchaeologists face the same challenging task of developing appropriate analytical protocols to sort out and identify signatures left by various agents. Yet, the task may not be a simple one, as the signature(s) of one agent sometimes may mimic the signature(s) of another. Thus, a major challenge for all the analysts is to deal with issues of apparent equifinality and to conclude which taphonomic process or processes created the patterns seen in archaeological bone assemblages (e.g., Bar-Oz & Munro, 2004; Lyman, 2004; Marean, Dominguez-Rodrigo, & Pickering, 2005; Rogers, 2000).

I echo Lee Lyman's assertion that methods and techniques of all these disciplines can significantly overlap (Lyman, 2002). To affirm my commitment to the same agenda, I borrow conceptual and methodological frameworks developed and used by vertebrate paleontologists and embed them within a taphonomy- and zooarchaeology-oriented explanatory framework. I do so by presenting a multivariate taphonomic approach and a comprehensive quantitative matrix using an Epipaleolithic archaeological bone bed from Karain B Cave, Turkey, as a case study. This methodological framework can be applied to both animal and human bone assemblages, can reveal assemblage formation processes, and can identify natural and cultural agents of bone accumulation, modification, and destruction.

It is anticipated that the methodology presented here will also aid those who encounter commingled and fragmented human bone assemblages. This chapter, however, represents an individual approach rather than a blueprint universally used by all researchers. Zooarchaeologists may significantly differ in the complexity of their recording protocols and number of quantitative variables and amount of primary data they choose to record (*sensu* Atici, Kansa, Lev-Tov, & Kansa, 2012). Despite this, the ultimate goal of this chapter is to initiate a dialogue between paleontologists, forensic anthropologists, human osteologists, and zooarchaeologists and to explore a shared methodological framework.

The rest of this chapter is structured as follows: First, a conceptual framework reviewing paleontological approaches to the study of bone beds is presented. Then the necessary archaeological background is briefly provided for Karain B Cave and the Epipaleolithic bone bed used as a case study in the chapter. Last is an elaboration of the taphonomic and zooarchaeological methodology followed by analysis, results, and discussion.

Paleontological Approaches to Bone Beds

Behrensmeyer (2007, p. 66) defines bone bed as "...a single sedimentary stratum with a bone concentration that is unusually dense (often but not necessarily exceeding 5 % bone by volume), relative to adjacent lateral and vertical deposits." According to Eberth et al. (2007, p.106) a bone bed consists of the "...complete or partial remains of more than one vertebrate animal in notable concentration along a bedding plane or erosional surface, or throughout a single bed." Although there are nuances in the ways vertebrate paleontologists define the term "bone bed," the emphasis lies on rich, localized concentration of hard tissues representing multiple individuals of a single taxon or multiple taxa within a clearly defined and discrete depositional context.

In order to probe formation of bone beds and their taphonomic histories, vertebrate paleontologists often examine two lines of specific evidence. First, they classify bone beds according to element and animal size and taxonomic representation including relative abundance, diversity, richness, and evenness of taxa (Rogers, Eberth, & Fiorilla, 2007). Vertebrate paleontologists recognize two distinct categories of bone beds: *macrofossil* and *microfossil*. The former is thought to yield abundant skeletal elements that are greater than 5 cm in maximum dimension and that are from two or more animals, whereas the latter yields abundant hard tissues from animals with an average body mass of 5 kg or less (Behrensmeyer, 1991; Rogers & Kidwell, 2007). As far as taxonomic representation is concerned, *monospecific/monotaxic/monodominant* bone beds with low taxonomic diversity vs. *multispecific/multitaxic/multidominant* bone beds with high taxonomic diversity provide an explanatory framework. A low diversity, monospecific, or monotaxic bone bed consists of multiple skeletal elements originating from multiple individuals of a single, dominant taxon, whereas a high diversity, multispecific, or multitaxic bone bed mostly consists of remains of two or more dominant taxa (Behrensmeyer, 2007; Rogers & Kidwell, 2007; Weiss, 2012). It is essential, however, to also factor in the evenness (i.e., relative abundance) of each taxon in the event of multitaxic and high taxonomic diversity bone beds. The following hypothetical scenarios with two opposing taxonomic composition can best exemplify this point: the first assemblage comprises four taxa represented equally (25 % each) as opposed to an assemblage with three taxa represented by 65 %, 20 %, 10 %, and 5 %, respectively. The richness or the number of taxa represented for both assemblages is the same (4), while evenness or the relative abundance of each taxon is significantly different in the two assemblages. The first assemblage can be said to have a rich and even taxonomic representation, whereas the second assemblage can be said to have a rich but uneven taxonomic representation. Diversity statistics can be utilized to develop an absolute measure of dominance, richness, and evenness (Hammer, Harper, & Ryan, 2001). Eberth, Shannon, and Noland (2007) expand the discussion on taxonomic representation and propose causal relationships between temporal origins and diversity. According to these authors, monotaxic/monodominant bone beds can be associated with catastrophic, short-term, mass-death events and multiple death events resulting from a narrower set of agents and processes such as predation, trapping, and

disease, whereas multitaxic/multidominant bone beds can be linked to time-averaged, reworked assemblages resulting from a wide array of agents and processes (Eberth et al., 2007, pp. 120–121).

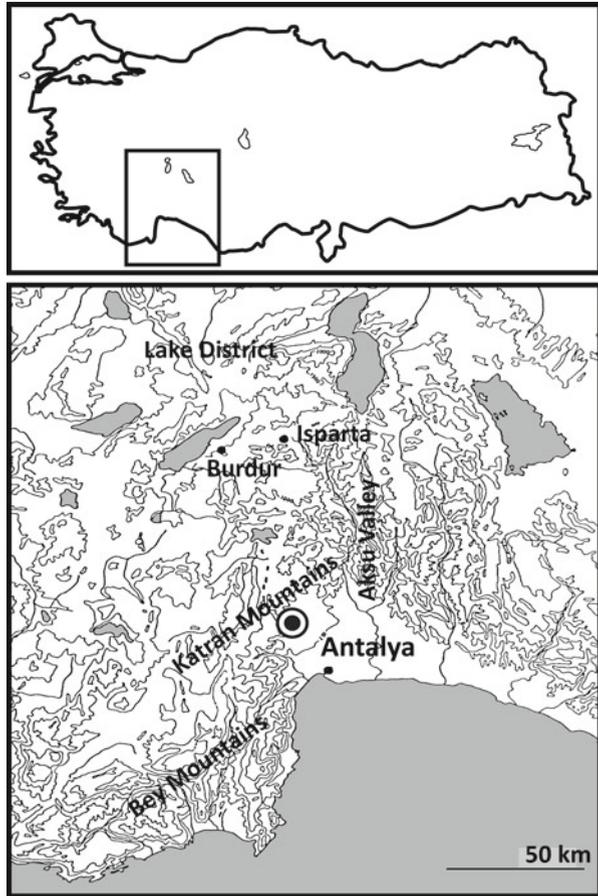
Second, vertebrate paleontologists seek to reveal taphonomic histories of bone beds through investigating and identifying the biological and physical taphonomic agents and processes responsible for accumulation, modification, and destruction of vertebrate hard parts. Bone assemblage formation is often associated with natural processes that include biological/biogenic/biotic and physical/geological/abiotic taphonomic agents. The biological category involves intrinsic biogenic accumulations that result from activities of accumulated animals themselves and extrinsic biogenic accumulations that result from activities of predatory and nonpredatory bone-collecting animals (e.g., Behrensmeyer, 2007; Lyman, 1994b; Rogers & Kidwell, 2007; Shipman, 1981). As far as the physical category is concerned, there are numerous factors including fluvial hydraulic activities; sedimentologic activities, such as erosion, sedimentary omission, pedogenesis, deposition, abrasion, attrition, and sediment compaction; and atmospheric activities such as wind and weathering (e.g., Behrensmeyer, 1991; Lyman, 1994b; Rogers et al., 2007; Shipman, 1981). By investigating bone beds and revealing their taphonomic histories, vertebrate paleontologists gain insights into paleontological, paleoecological, paleobiological, and geological phenomena.

Zooarchaeologists engage with a similar taphonomic agenda with the exception that they aim to identify the role played by cultural processes and human agency as primary taphonomic factors accumulating, modifying, and destroying bones. Humans, as a sort of extrinsic biogenic bone-accumulating agent or a predator, have interacted with animals throughout history in a myriad of ways from hunting to scavenging to taming to domesticating to large-scale industrial production. Humans have used animal hard parts not only for consumption but also for other postmortem utilizations such as toolmaking. Although animal hard tissues are found at almost every archaeological site in various quantities, archaeological bone beds are not that numerous (e.g., Dewar, Halkett, Hart, Orton, & Sealy, 2006; Frison, 1974, 1991; Frison & Todd, 1986; Gadbury, Todd, Jahren, & Amundson, 2000; Haynes, 1991; Hill, 2002; Hoffecker et al., 2010; Hofman & Todd, 1997; Meltzer, Todd, & Holliday, 2002; Todd, Hofman, & Schultz, 1990). Furthermore, the preponderance of archaeologically known bone beds comes from North American sites associated with Paleo-Indian large-game hunters, and bone beds from the Old World in general and from Southwest Asia in particular are scarce. As such, the taphonomic and zooarchaeological study of the Epipaleolithic bone bed at Karain B, Turkey, adds new data to research in bone beds.

Site Description and History of Research at the Site

Karain (“Black Cave”) is located in the foothills of the Taurus Mountains, some 30 km northwest of Antalya and of Mediterranean coast in southwest Turkey (Fig. 1). The site is a complex of several interconnected chambers (A–G currently known)

Fig. 1 Location of Karain B Cave



that are located 450 m above the sea level and 150 m above the travertine plain. The cave is situated in an ecotonal zone having access to a wide range of microenvironments including steep mountains cut by short valleys; broad, flat, travertine plain and open grassland with shrubs, marshes, and gallery forests; and pine forests limited to high altitudes.

Karain Cave was discovered in 1947 by Turkish prehistorian Kılıç Kökten who conducted excavations in B chamber between 1955 and 1973 (Yalçinkaya, 1995). After Kökten, excavations at Karain B intermittently continued by different teams. First, his successor Işın Yalçinkaya of Ankara University and a German team from Tübingen University excavated the cave between 1985 and 1988 (Albrecht, 1988b). Then, in 1996, a large interdisciplinary team restarted excavations that are still ongoing (Yalçinkaya & Otte, 1999, 2000).

Stratigraphy and Chronological Setting

The area excavated at Karain B covers 22 m² and includes both Holocene and Pleistocene strata. The Holocene component is divided into four geological horizons (GH): the Middle Ages, Roman Period, Iron and Bronze Ages, and Chalcolithic and Neolithic. Underlying deposits have yielded a Pleistocene component divided into three GHs: Epipaleolithic (PI.1 and PI.2), Upper Paleolithic (P.II), and Middle Paleolithic (P.III) (Yalçınkaya, Taşkiran, Kösem, Özçelik, & Atici, 2002) (Fig. 2).

A series of 29 radiocarbon dates form the basis for an absolute chronological framework at the site. Here, only the earlier phase of the Epipaleolithic strata, PI.2, the bone bed is detailed as the other strata are beyond the scope of this chapter. Radiometric range for PI.2 is ca. 19,950–19,250 calibrated years BP, and the bone bed appears to have accumulated rapidly during a short period from primarily of anthropogenic agents (Atici, 2011).

The Bone Bed at Karain B and Previous Zooarchaeological Work

The earlier phase of the Epipaleolithic at Karain B yielded faunal assemblages of extraordinary preservation and richness, warranting the label “bone bed.” The Turkish-German excavations at the site in 1985 unearthed approximately 70,000 bones from the Pleistocene strata, mostly from the Epipaleolithic layers (Albrecht, 1988a). These faunal assemblages were studied by Hubert Berke who expressed his fascination with the richness of the Epipaleolithic bone assemblages in the following words: “...it was possible in horizons 23 to 18 to identify 1000 to 1500 bones from only one square meter and 5 cm depth. In this part of the profile the sediment is almost totally built of bones!” (Berke, 1988, p. 38).

Subsequent excavations have also yielded extraordinarily rich and well-preserved faunal assemblages, verifying Berke’s preliminary diagnosis and increasing the sample size enormously. GH PI.2 at Karain B extends horizontally across the cave surface and forms a 30-cm-thick bone-rich layer that warrants the label bone bed. That a single layer in a square meter area, G12/18, yielded over 10,000 bone fragments weighing 25 kg in 2002 could best demonstrate the riches of the cave (Fig. 3). Epipaleolithic archaeofaunal assemblages from Karain B and nearby Öküzini caves have recently been analyzed with a special emphasis on Epipaleolithic forager economic adaptations by the present author (Atici, 2007, 2009a, 2009b, 2011).

Methodological Framework

As the success of zooarchaeological and taphonomic analyses will depend upon employing best practices in recovery, sampling, sorting, recording, identification, and quantification, I briefly describe the methodology before moving on to the taphonomic approach which is the major focus of this chapter.

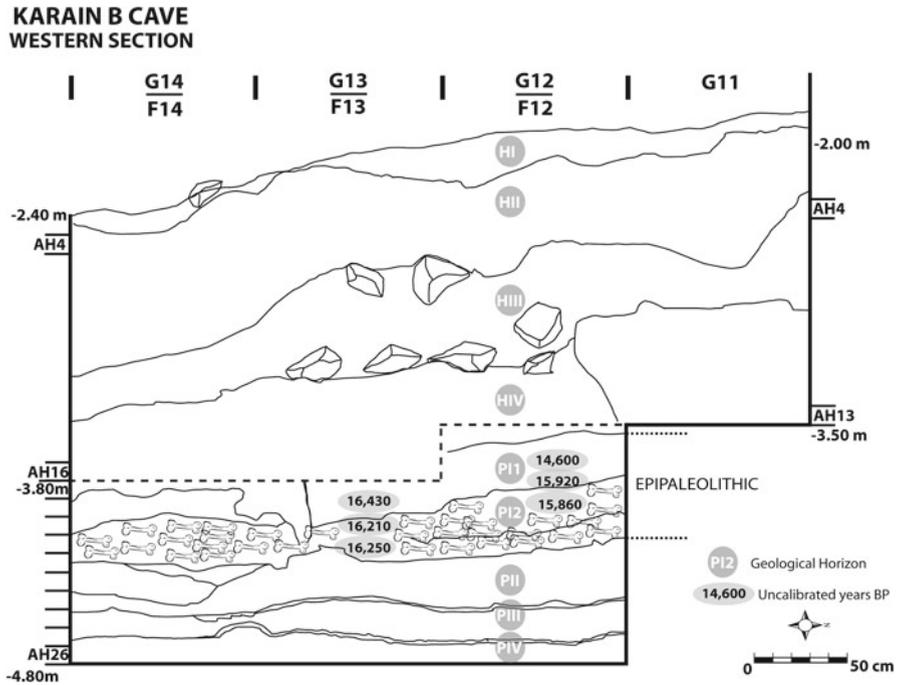


Fig. 2 The stratigraphy of Karain B Cave

Recovery

All deposits from the cave were systematically processed using bucket flotation during the excavation for full recovery of macro- and microfaunal remains. All the excavated sediments were wet screened using a set of nested sieves consisting of 4-, 2-, and 1-mm mesh size. Thus, there is no or minimal bias involved in the recovery of the assemblage. The author actively participated in every stage of the excavation and recovery of the faunal material from the site in an effort to minimize the effects of “controllable factors” (sensu Meadow, 1980).

Sampling

The basic excavation units—arbitrary archaeological horizons (AH)—formed the basis for sampling at Karain B (sensu Gamble, 1978). AHs were combined into GHs to generate larger and comparable analytical units. A total of 228 archaeological units were excavated in 22 m², equaling to a volume of 24.3 m³



Fig. 3 A close-up of the bone bed (upper) and animal bones sorted into skeletal element/portion (lower)

of sediment. From this overall assemblage, 60 archaeological units— 6.3 m^3 —are associated with the Epipaleolithic. From this Epipaleolithic assemblage, 17 AHs from 7 m^2 , making up 1.7 m^3 of sediment, were randomly sampled and analyzed for the bone bed. Thus, 31.8 % of the horizontal space and 28.3 % of the Epipaleolithic layers have been covered for this work. This sampling strategy is adequate to generate statistically viable samples and significant and robust results.

Recording

The recording protocol employed in this work entailed general documentation of the entire assemblage for the purpose of assemblage characterization and included every element, element portion, and nonidentified splinters recovered ($N=18,916$). A small subsample ($N=225$) of targeted, data-rich skeletal elements and portions were excluded to ensure consistency and to eliminate and/or minimize analyst-introduced biases. No presorting was practiced and all of the bones were packed and stored together in the storage area of the Karain dig house. Every fragment was scrutinized first by naked eye under strong light and then examined with a $\times 10$ – 15 hand lens again under strong light for bone surface modifications, while subsamples were randomly chosen for recording variables such as fracture platform angle and percussion and notches. All the fragments were identified to the maximum degree possible, refitted and mended when possible, weighed, counted, labeled, assigned unique individual specimen numbers, measured when appropriate, and entered into an automated FileMaker database (Atici, 2011). When individual recording of fragments was not necessary, grouped specimens were counted, weighed, and entered into the database as a single entry under the same specimen number (e.g., nonidentified long bone shaft fragments, nonidentified skull fragments, and splinters). Postcranial bones were entered into a postcranial layout, cranial bones were entered into a cranial layout, and taphonomic attributes were entered into a modification layout. Recording took place at the project's facilities near the site in Antalya, at the Prehistory Laboratory at Ankara University in Ankara, and at the Zooarchaeology Laboratory of Harvard's Peabody Museum in Cambridge, MA, between 2002 and 2007.

Identification

Taxonomic and skeletal element identifications were carried out partly using a modern comparative reference collection assembled by the author and partly using published manuals and articles describing identification criteria. When the degree of certainty of identification was high, specimens were identified to the highest taxonomic category, i.e., species, possible. When identification to a higher taxonomic category such as species, genus, or family was not possible, *methodological categories*, such as “medium artiodactyl” or “medium bovid,” commonly used by zooarchaeologists were employed. In other cases, for the purpose of statistical viability, the bones from wild sheep and goats were combined into an “O/C” (“caprine”) category and treated as a single analytical unit. According to Shipman (1981, p. 106), the microscopic bone structures and size of animals determine how their bones break. As such, combining the bones of medium-sized bovids such as sheep and goats for taphonomic purposes should not impact the validity of the taphonomic analysis and results presented here.

Quantification

Number of fragments (NF) (Lyman, 1994a, 2008), number of identified specimens (NISP) (Cannon, 2012; Dominguez-Rodrigo, 2011; Grayson, 1984; Lyman, 1994a, 2008), and minimum number of elements (MNE) (Bunn & Kroll, 1986; Dominguez-Rodrigo, 2011; Lyman, 1994a, 2008; Morlan, 1994) were quantitative measures employed in this chapter. NF was used to document entire assemblages including nonspecific skeletal part categories such as nonidentified bone splinters and long bone shaft fragments, and NISP was used when fragments could be identified to skeletal element and at least to a general taxonomic or size category. Comprehensive MNI (Chaplin, 1971; Dominguez-Rodrigo, 2011; Klein & Cruz-Uribe, 1984) estimations took into account several relevant biological variables such as individual animal body size, ontogeny, and biometry.

For the estimation of MNE—the minimum number of skeletal units required to account for all of the fragments in an assemblage that are identifiable as each skeletal category or skeletal portion—a combination of discrete features or landmarks and manual overlap approach were used. Besides eyeballing overlap, degree of completeness for all the specimens was recorded to achieve a certain degree of standardization and to avoid double counting and inflating the element numbers. Among other quantitative measures used were average bone weight for all fragments and average specimen size for long bone shaft fragments. A recent experimental study has confirmed that these measurements can shed light on the degree of fragmentation (Cannon, 2012).

Minimum animal unit (MAU) was calculated by simply dividing MNE of a skeletal element/portion by the number of times that skeletal element occurs in a complete skeleton (Binford, 1978, 1981). For example, if the MNE for distal humerus is 200, then the MAU value will be $200 \div 2 = 100$. %MAU is calculated by finding the element/portion with the highest MAU values, then setting %MAU value for it as 100 %, and ranking the remaining %MAU by dividing each MAU value by the highest MAU value (Binford, 1978; Lyman, 1994b).

In addition to MAU and %MAU, other derived measurements such as the ratio of MNI to NISP and MNE to NISP are presented to assess the degree and rate of fragmentation, specimen reduction, and deletion. Conventional zooarchaeological wisdom has held that NISP should increase with greater fragmentation, while MNI and MNE should not, and a negative relationship should be observed between MNI and NISP ratio and bone fragmentation. Cannon (2012), however, challenges this assumption and argues that MNI/NISP ratio does not vary with fragmentation.

I would like to refer more curious readers to Dominguez-Rodrigo's (2011) recent experimental work where he critically reviews these quantitative units and shows that NISP and MNI can actually produce independent errors of estimation, unlike previously thought. Similarly, Michael Cannon (2012) also sheds light on the relationships between NISP and bone fragmentation by providing new experimental data in a recent paper. Table 1 details some of the attributes of the quantitative measures adopted in this research.

Table 1 Potential limitations of the basic quantitative units used

Quantitative unit	Potential issues	References
NF: number of fragments	Differential fragmentation and identifiability	Lyman (1994a, 2008)
NISP: number of identified specimens	Differential fragmentation and identifiability; duplicate counts for same specimen, element, and individual	Cannon (2012), Dominguez-Rodrigo (2011), Grayson (1984), Lyman (1994a, 2008)
MNE: minimum number of elements	Duplicate counts for same individual; aggregation; dependency	Bunn and Kroll (1986), Dominguez-Rodrigo (2011), Lyman (1994a, 2008), Morlan (1994)
MNI: minimum number of individuals	Duplicate counts for same individual; aggregation; dependency	Chaplin (1971), Dominguez-Rodrigo (2011), Klein and Cruz-Urbe (1984)

Zooarchaeological and Taphonomic Concepts and Methodology

The multivariate taphonomic approach presented here is similar to the one pioneered by Shipman (1981) and Behrensmeier (1991) and to the more detailed, extended version of the one that has been extensively and particularly applied to Levantine faunal assemblages by Bar-Oz and colleagues (e.g., Bar-Oz, 2004; Bar-Oz & Dayan, 1999, 2003a, 2003b; Bar-Oz & Munro, 2004, 2007) and to Anatolian assemblages by the present author (Atici, 2009a, 2009b, 2011).

I formulate a quantitative matrix that includes 66 variables organized in two separate tables (Tables 2 and 3). Following the foregoing paleontological framework, I draw upon two lines of specific evidence and group variables into the following analytical categories to analyze the bone bed at Karain B:

1. *Taxonomic composition*, which entails relative abundance, diversity, richness, and evenness of taxa.
2. *Assemblage composition and formation*, which investigates taphonomic history of the bone bed. Specifically, assemblage composition and formation, fragmentation, differential preservation, skeletal completeness, and bone surface modifications were investigated. A stepwise analytical procedure determines the next set of questions and narrows the focus to isolate signatures left by primary bone collector(s), modifier(s), and destroyer(s).

Taxonomic Composition: Diversity, Richness, and Evenness

Trends in taxonomic diversity through time, and richness and evenness in animal species composition were examined based on NISP counts. All potentially intrusive taxa and species represented by individual specimens, however, were excluded.

Table 2 Variables used in the analysis of taxonomic representation

Variable	Analytical category	Specific observation	Values
1	Taxonomic representation	Number of taxa	13
2	Diversity, richness, evenness	%Number of fragments (NF) large game	98.7 %
3		%Minimum number of elements (MNE) large game	96.5 %
4		%Bone weight (BW) large game	98.2 %
5		%NF caprines of large game	99.9 %
6		%MNE caprines of large game	99.7 %
7		Minimum number of individuals (MNI) caprines	85
8		Small game/large game MNE	0.030
9		Dominance index	0.557
10		Simpson's diversity index	0.443
11		Evenness index	0.202
12		% Young (based on epiphyseal fusion stage >12 but <18 m)	12.8
13		% Young (based on the count of dP4 first 12 wear stages)	40.9

I computed several diversity indices to be able to detect a clear and consistent pattern of richness and evenness in the analyzed assemblage. Taxonomic richness refers to number of species present, whereas evenness examines relative abundance of species identified. The specific diversity statistics used include the following:

1. *Dominance index (D)*: ranges from 0 (all taxa are equally represented) to 1 (one taxon dominates the assemblage) (Hammer et al., 2001).
2. *Simpson's index of diversity (1 - D)*: ranges from 0 to 1; the greater the value, the greater the diversity (Hammer et al., 2001).
3. *Shannon diversity index (H)*: ranges from 0 for assemblages with only single taxon to higher values for assemblages with many taxa that are more evenly represented (Hammer et al., 2001).

Assemblage Composition and Formation

Carnivore Ravaging

Actualistic studies show that there can be considerable differences in pre-carnivore ravaged and post-carnivore ravaged assemblages. NISP counts for epiphyses in post-ravaged assemblages are dramatically lower than in pre-ravaged ones, and post-ravaged shaft NISP counts are significantly higher than pre-ravaged ones (Travis Rayne Pickering, Marean, & Dominguez-Rodrigo, 2003, p. 1473). This is

Table 3 Variables used in the analysis of assemblage composition and formation

Variable	Analytical category	Specific observation	Values	
1	Assemblage composition	NF	18,916	
2		Number of Identified Specimens (to skeletal element and taxon)	10,425	
3		MNE	4,298	
4		MNI	85	
5		BW	44,646	
6		NF per unit volume (m ³)	239.26	
7		Average fragment weight in grams (AFW)	2.46	
8		Average fragment length in centimeters (AFL)	3.6	
9		NISP/MNE	2.42	
10		NISP/MNI	122.6	
11		Nonidentified bone splinters	5,464	
12		Long bone shaft fragments	3,586	
13	Assemblage formation	%Identified	55.1 %	
14		Fragmentation	%Nonidentified fragments <1 cm	29 %
15		%Epiphyses	5 %	
16		%Long bone shaft fragments	19 %	
17		%Shaft fragments identified to element	16 %	
18		%Excavation breaks	21.3 %	
19		%Cylinders of long bones	2.09 %	
20		%Acute/obtuse fracture angles (<85 and >95 degrees) ^a	89.40 %	
21		%MAU-bone density significance (2-tailed) $p > 0.01$	Insignificant	
22		%MAU-economic utility significance (2-tailed) $p > 0.01$	Insignificant	
23		Cranial bone MNE:loose tooth MNE	0.063	
24		Differential preservation	Shaft:epiphysis	3.8
25	Upper vs. lower limb		Humerus:radius	0.9
26		Femur:tibia	0.5	
27	Proximal vs. distal limb bones	Proximal humerus:distal humerus	0.2	
28		Proximal radius:distal radius	1	
29		Proximal metacarpus:distal metacarpus	0.2	
30		Proximal metatarsus:distal metatarsus	0.5	
31		Proximal femur:distal femur	2	
32		Proximal tibia:distal tibia	0.2	

(continued)

Table 3 (continued)

Variable	Analytical category	Specific observation	Values
33	Articulating ends	Distal scapula:proximal humerus	7.4
34		Distal humerus:proximal radius	1.4
35		Distal femur:proximal tibia	1
36		Distal tibia:astragalus	1.1
37		Distal metapodia:proximal phalanx 1	0.7
38		Phalanx 1:phalanx 2	1.2
39		Skeletal evenness	Shannon's skeletal evenness
40	Skeletal completeness	% Axial completeness (all axial elements; large game)	23.50 %
41		% Carpal completeness (all carpals; large game)	100 %
42		% Tarsal completeness (all tarsals; large game)	85.10 %
43		% Phalanx completeness (all phalanges; large game)	37.30 %
44		Bone surface modification	%Weathering > stage 2
45	Erosion, abrasion and transport	%Trampling/sediment scratch marks	0.01 %
46		%Eroded edge/rounding	0.49 %
47		%Abraded/pitted/polished bone surfaces	0.00 %
48	Bioerosion	%Root etching/insect boring	0.01 %
49	Biotic modification	%Rodent gnawing	0.02 %
50		%Carnivore marks (gnaw, score, puncture)	0.08 %
51		Cultural modification	%Percussion marks/notches ^a
52		%Cut marks	1.08 %
53		%Burned bones	2.19 %

^aOnly applies to the randomly-selected shaft sub-samples

because carnivores attack first the more cancellous (spongy), less resistant, and greasier axial elements and long bone articular ends.

Tooth marks were recorded in order to determine the impact of nonhuman biotic agents on assemblage formation and modification. This is particularly important, as evaluation of the effects of potential taphonomic filters and identification of the major bone-modifying and bone-accumulating agent(s) are the major foci of taphonomic studies. Blumenshine (1995, p. 29) describes tooth marks as follows: "Carnivore tooth marks contain bowl-shaped interiors (pits) or U-shaped cross-sections that commonly show crushing that is conspicuous under the hand lens, and which, macroscopically, gives the mark a different patina than the adjacent bone surface." For this study, tooth marks were scrutinized first by the naked eye under strong light and then examined with a $\times 10$ hand lens again under strong light. Each located mark was examined and its features carefully considered in the light of experimentally derived tooth and percussion marks.

Table 4 Skeletal elements in anatomical order and their idealized %Survivorship values in “one” complete skeleton (MNI=1)

Skeletal element	MNE expected	MNE observed	MAU	%MAU	%Survival	Density ^a	MGUI ^b
Horncore	2	2	1	100.0	100.0	NA	1.03
Skull	2	2	1	100.0	100.0	NA	12.87
Mandible	2	2	1	100.0	100.0	0.55	43.6
Atlas	1	1	1	100.0	100.0	0.11	18.68
Axis	1	1	1	100.0	100.0	0.14	18.68
Cervical vertebra	5	5	1	100.0	100.0	0.13	55.33
Thoracic vertebra	13	13	1	100.0	100.0	0.24	46.49
Lumbar vertebra	6	6	1	100.0	100.0	0.22	38.9
Rib	26	26	1	100.0	100.0	0.25	100
Sternum	1	1	1	100.0	100.0	0.22	90.52
Scapula	2	2	1	100.0	100.0	0.33	45.06
Humerus proximal	2	2	1	100.0	100.0	0.13	37.28
Humerus distal	2	2	1	100.0	100.0	0.34	32.79
Radius proximal	2	2	1	100.0	100.0	0.36	24.3
Radius distal	2	2	1	100.0	100.0	0.21	20.06
Carpals	12	12	1	100.0	100.0	0.48	13.43
Metacarpus III+IV proximal	2	2	1	100.0	100.0	0.55	10.11
Metacarpus III+IV distal	2	2	1	100.0	100.0	0.44	8.45
Pelvis	2	2	1	100.0	100.0	0.26	81.5
Femur proximal	2	2	1	100.0	100.0	0.28	80.58
Femur distal	2	2	1	100.0	100.0	0.22	80.58
Tibia proximal	2	2	1	100.0	100.0	0.16	51.99
Tibia distal	2	2	1	100.0	100.0	0.36	37.7
Astragalus	2	2	1	100.0	100.0	0.63	23.08
Calcaneus	2	2	1	100.0	100.0	0.58	23.08
Metatarsus III+IV proximal	2	2	1	100.0	100.0	0.68	15.77
Metatarsus III+IV distal	2	2	1	100.0	100.0	0.39	12.11
Phalanx anterior/posterior 1	8	8	1	100.0	100.0	0.55	8.22
Phalanx anterior/posterior 2	8	8	1	100.0	100.0	0.4	8.22
Phalanx anterior/posterior 3	8	8	1	100.0	100.0	0.3	8.22

^aLyman (1994b)

^bBinford (1978)

Also presented are the MGUI of Binford (1978) and bone mineral density values of Lyman (1994b) for sheep, *Ovis aries*

Documenting the degree of carnivore ravaging on the assemblages and/or excluding them as potential bone collectors can enable the zooarchaeologist to focus on human behavior as a major bone-accumulating and bone-modifying agent. To this end, the present taphonomic analysis first examines and measures the impact of nonhuman biotic and abiotic agents.

Other Nonhuman Bone Accumulators and Modifiers

Predatory birds, small and large rodents, and artiodactyls have been reported as other major biotic bone-collecting and bone-modifying agents (Shipman, 1981). In particular, rodent gnawing of epiphyses and shafts of long bones may significantly alter bones. In so doing, rodents leave conspicuous traces easily identified with the naked eye.

Weathering

Weathering is the exposure of skeletal elements to the potentially destructive mechanical, physical, and chemical effects of weather, including fluctuating temperatures, humidity, and solar radiation. Behrensmeyer (1978) states that weathering is a continuous process taking place during both pre-burial and post-burial stages as well as in both aboveground and underground contexts. When bones are exposed to the physical and chemical effects of weathering, they can become mechanically and structurally altered to the point of disintegration (Lyman, 1994b). Investigation of weathering stages provides insight into duration of exposure and history of accumulation for bone assemblages and thus into the tempo and timing of depositional processes (Lyman, 1994b). If bones display traces of heavy weathering, this would indicate that they may have been remained on the surface for a long time before burial. If the weathering is minor or absent, we may assume rather rapid burial. Recording and analysis of weathering for the bone bed at Karain B used the six stages described by Behrensmeyer (1978).

Trampling and Abrasion

Surface scoring and scratch marks on bone surfaces may provide insights into depositional environments, sedimentary matrix (i.e., sediment grain size), size of bioturbators, the intensity of loading and mass of trampler, and the duration of trampling (Behrensmeyer, Gordon, & Yanagi, 1986; Eberth et al., 2007; Lyman, 1994b). Abrasion refers to mechanical removal of bone surfaces by sedimentary, hydraulic, chemical, and biological processes. Polish on bone surfaces, pitting of bones, and overall rounding of elements with broken crests and edges combine to aid the analyst distinguish mixed assemblages and identify the duration and velocity of bone transport (Eberth et al., 2007; Shipman, 1981). Following Shipman, trampling and

abrasion were recorded using broad categories and relative states such as slight, moderate, and heavy trampling and abrasion.

Root Etching

The wavy, “dendritic,” “sinuous,” and “spaghetti-like” patterns of plant roots etch into the bone surface as a result of dissolution by acids associated with growth or decay of roots or fungi before or after burial (Lyman, 1994b, pp. 375–376 and references therein). This process stains the bone surface and creates very conspicuous and easy-to-identify patterns. Traces of root etching have been recorded for the bone bed at Karain B when present.

Skeletal Part Abundance, Bone Survivorship, and Bone Density

The preservation potential of skeletal elements and their portions is primarily a function of the combined variables of age, size, morphology, composition, and other chemical and physical characteristics of the bones (Shipman, 1981). Documenting frequencies of skeletal parts in relation to bone mineral density has increasingly become more popular among zooarchaeologists as one of the most effective analytical techniques to examine completeness of faunal assemblages and to identify taphonomic agents responsible from their accumulation and modification. The relevance of bone density studies to zooarchaeology is in that many researchers have identified significant correlations between bone mineral density and abundance of skeletal elements. This association is typically referred to as “density-mediated attrition,” “postdepositional destruction,” or “in situ attrition” of bones (Binford, 1978; Brain, 1967, 1969; Klein, 1989; Lyman, 1982, 1984, 1985; Marean, 1991; Marean & Kim, 1998; Marean, Spencer, Blumenschine, & Capaldo, 1992; Stiner, 2002).

In examining skeletal part abundance, zooarchaeologists often focus either on the articular (epiphyseal) ends of long limb bones, with the assumption that these parts can be more reliable indicators of original skeletal part distributions, or put greater emphasis on the use of shaft fragments to obtain more reliable skeletal part profiles due to their mechanical resistance to cultural and natural taphonomic processes. The few archaeological assemblages to which both approaches have been applied show dramatic differences in the representation of the least dense elements and, consequently, in behavioral reconstructions with the “shaft approach” being particularly potent when carnivores are documented to have severely impacted the assemblages (Costamagno, 2002; Marean et al., 2005; Pickering, Dominguez-Rodrigo, Egeland, & Brain, 2005; Pickering & Egeland, 2006; Pickering et al., 2003; Yeshurun, Marom, & Bar-Oz, 2007). For the sites where carnivore ravaging can be ruled out, however, the time-consuming and labor-intensive analytical procedures that require the scrutiny of all shaft fragments can be deemed redundant to estimate MNE values and to construct skeletal part profiles. For such sites, a focus on the application of “epiphysis approach” or “rapid counting” (*sensu* Marom & Bar-Oz, 2008) would be

more viable and can easily be justified, as experimentally demonstrated by Capaldo (1998). For the Karain B bone bed, shafts were not ignored; they were routinely sampled and analyzed in order to document bone surface modifications and fragmentation patterns. Furthermore, long bone MNE values were calculated separately for shafts and epiphyses to independently test whether these two approaches agree or generate comparable values and to verify other researcher's observations.

Evaluating differential survivorship of skeletal parts for this chapter was approached by comparing expected and observed MNE values. Expected MNE values were estimated based on MNI values. Thus, for example, if the MNI for wild sheep has been calculated to be 100, then we expect to observe MNE for mandibles=200, for atlas=100, for other cervical vertebrae=500, for thoracic vertebrae=1,300, for ribs=2,600, and so forth. From these expected MNE values, the percentage survival for each skeletal part (e) is calculated as $(\text{MNE observed } e \div \text{MNE expected } e) \times 100$. Supposing that the expected MNE for distal humerus is 200 and only 79 distal humeri have been documented, the resulting %Survival value for the distal humerus is $(79 \div 200) \times 100 = 39.5$. Table 4 exemplifies skeletal elements and portions and their %Survival values in "one" hypothetical, complete sheep skeleton, with skeletal parts listed in anatomical order. The table includes expected and observed MNE values (observed=expected in this case) and %Survival values (=100 % in this case) along with their density values and economic utility indices. These data form the basis for calculations made for the Karain B bone bed. In contrast to the listing order in Tables 4, 5 and Fig. 4 show idealized bone mineral density values of skeletal portions in ascending order from the least dense to the densest using Lyman's (1994b) density values for sheep. Skeletal parts are divided into three categories with respect to their bone mineral density values: *low*, *medium*, and *high density* or "*high-survival elements*" (Faith & Gordon, 2007). Bone mineral density values and %MAU values were also used to test the correlation between density and bone survival. In addition, Spearman's rank correlation statistic (Spearman's rho) and the statistical significance of the correlation coefficient were provided. Ultimately, the assumption being tested here is that if bone destruction is density dependent, the skeletal part abundance pattern will be dominated by high- and medium-density bones, and a clear bias against low-density bones will be detected.

Skeletal Completeness and Differential Preservation

To assess degree of bone loss and differential bone preservation, the following variables were quantified: (1) percentage upper to lower limb, (2) percentage proximal to distal bones, (3) percentage articulating ends, (4) percentage cranial bones to loose teeth, (5) percentage complete to incomplete axial skeletal elements, (6) percentage complete to incomplete carpals and tarsals, and (7) percentage complete to incomplete phalanges (see Table 3). Completeness is defined as the ratio between broken/incomplete and unbroken/complete specimens. In so doing, one uses the binary opposition of "complete" to "incomplete." Degree of "brokenness" or "completeness" is not evaluated for these statistics. To deal with

Table 5 Skeletal parts and their density values in ascending order from least dense to densest

Skeletal element	Density	Category	
Atlas	0.11	Low density	
Humerus proximal	0.13		
Cervical vertebra	0.13		
Axis	0.14		
Tibia proximal	0.16		
Radius distal	0.21		
Lumbar vertebra	0.22		
Sternum	0.22		
Femur distal	0.22		
Thoracic vertebra	0.24		
Rib	0.25		
Pelvis	0.26		
Femur proximal	0.28		Medium density
Phalanx anterior/posterior 3	0.30		
Scapula	0.33		
Humerus distal	0.34		
Radius proximal	0.36		
Tibia distal	0.36		
Metatarsus III +IV distal	0.39	High density	
Phalanx anterior/posterior 2	0.40		
Metacarpus III +IV distal	0.44		
Carpals	0.48		
Mandible	0.55		
Metacarpus III +IV proximal	0.55		
Phalanx anterior/posterior 1	0.55		
Calcaneus	0.58		
Astragalus	0.63		
Metatarsus III +IV proximal	0.68		

this shortcoming, one or more of the several indices widely used by zooarchaeologists to assess completeness of skeletal elements can be employed (e.g., Marean, 1991). The carpal/tarsal completeness index of Marean measures completeness by using the following algorithm: average percentage completeness = $100 [(comp\ 1 + comp\ 2 + comp\ 3 + \dots + comp\ n)/n]$, where comp = proportion of the element present with a whole bone = 1. A hypothetical example might be average percentage completeness = $100 [(1 + 0.75 + 0.50 + 0.25)/4] = 62.5\ %$. In contrast, the binary method yields a result of 25.0 % (one out of four elements is complete). I prefer the latter approach because average percentage completeness (also used by Bar-Oz, 2004) inflates bone completeness in a situation where, particularly for compact bones and phalanges, what is taphonomically important is whether a bone is complete or not complete.

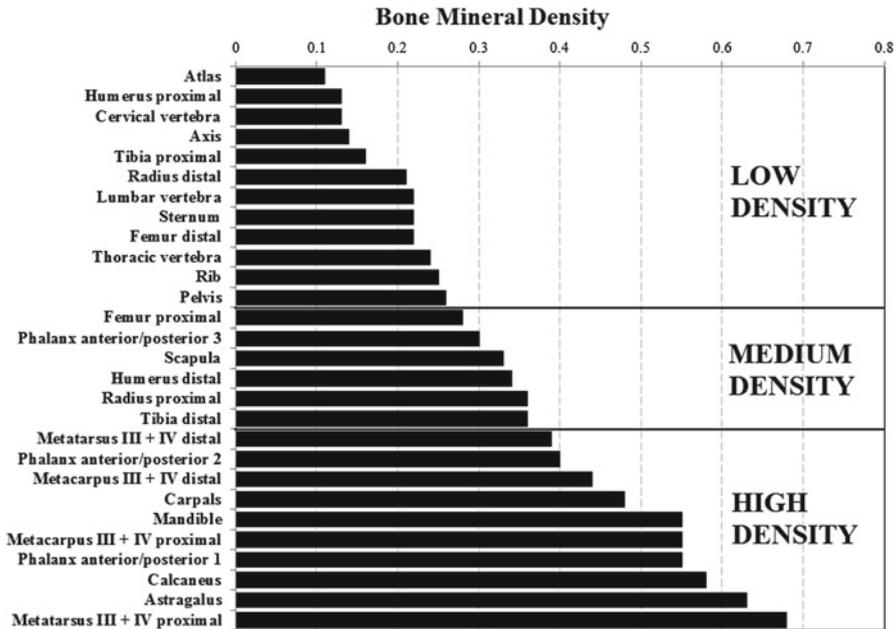


Fig. 4 Skeletal elements in ascending order according to their bone mineral density values

The frequency of body parts is often used by zooarchaeologists to assess bone loss and carcass processing (e.g., butchery) and transport patterns. This approach usually entails grouping skeletal elements into specific body parts or “anatomical regions” (e.g., Stiner, 2002). Decisions regarding grouping individual skeletal elements into anatomical regions or body parts vary from analyst to analyst. Here, frequency of body parts was analyzed by assigning skeletal elements into the following six body part categories:

1. *Head*: horn cores, cranial fragments, maxillar and mandibular teeth
2. *Axial*: all vertebrae, ribs, and sternum
3. *Forelimb*: scapula, humerus, radius, ulna, carpals
4. *Hind limb*: pelvis, femur, tibia, patella, fibula, tarsals
5. *Limb*: nonidentified long bone shafts and nonidentified carpals and tarsals
6. *Distal extremity*: metapodials, anterior and posterior phalanges, and proximal and distal sesamoids

The skull is not included in the axial skeleton because taphonomic processes affect the skull and axial skeleton differentially (Capaldo, 1998). The metapodials are included in the distal extremity group based on their low nutritional values and butchery practices. By lumping nutritionally disparate elements such as humerus, radius, and metacarpus or femur, tibia, and metatarsus together, meaningful variation in the dataset can be obscured (Pickering et al., 2003, p. 1472).

Carcass Processing, Economic Utility, and Skeletal Evenness

The presence of cut marks provides the most direct evidence for human modification of bones. Examination of cut marks and butchering practices reveals modes of prey procurement and of carcass processing and consumption. Zooarchaeologists record, count, and report cut marks and butchery practices in numerous ways, resulting in non-comparable data. Abe et al. (2002) provide a detailed discussion of the diversity of approaches for recording, counting, and presenting cut marks. Some analysts apply “fragment-count data” (counting the fragments with cut marks, not the cut marks), whereas others use “cut mark-count data” (frequency of individual cut marks on specimens within a skeletal element, e.g., proximal humerus or mid-shaft) (see Abe et al., 2002 and references therein). Blumenschine (1988) and Capaldo (1995, 1998) also produced NISP and MNE cut mark-count data and NISP and MNE fragment-count data. It is also known that cut mark counts can be affected by fragmentation.

For this chapter, I used the “fragment-count” approach and counted fragments with cut marks, not cut marks themselves. I also recorded depth and anatomical location and position of cut marks. Ultimately, I associated cut marks with three possible consumption patterns: skinning, disarticulation, and filleting or meat removal. As a function of the anatomy of butchering, cut marks that are on the mid-shaft and epiphyses of metapodials or on the skull and mandible are associated with skinning. Cut marks that are on or near epiphyses and vertebrae are interpreted as resulting from disarticulation, whereas multiple, parallel, and oblique cut marks that are not typically associated with other categories are interpreted as evidence for filleting. Filleting marks are usually found on ribs, on the medial side of scapulae, and on limb bone shafts.

One of the fundamental goals of skeletal element abundance and body part profile analyses in zooarchaeology is to investigate human decision-making processes regarding carcass process and transport. Experimentally generated data for some taxa commonly documented in archaeofaunal assemblages (e.g., gazelle, sheep, and deer) provide zooarchaeologists with a methodological and explanatory framework as to the quantity of food—meat, marrow, and bone grease—different parts of carcasses yield, and their zooarchaeological implications (Bar-Oz & Munro, 2007; Binford, 1978; Blumenschine & Madrigal, 1993; Lyman, 1994b; Madrigal & Holt, 2002; Marshall & Pilgram, 1991; Metcalfe & Barlow, 1992; Metcalfe & Jones, 1988; Morin, 2007; Outram, 2001). Toward this end, Binford’s (1978) modified general utility index (MGUI) values and %MAU values are often used to see the degree and significance of correlation between economic utility of portions (i.e., amount of attached meat) and their survival rates. In this chapter, correlation between %MAU was tested using Spearman’s rank correlation statistic (Spearman’s rho) and the statistical significance of the correlation coefficient was provided.

As an alternative to using MGUI, Faith and Gordon (2007) introduced a new analytical technique, *skeletal evenness index*, to probe carcass processing, transport, and consumption. This approach predicts that there is a direct and proportional relationship between skeletal element abundance and field processing. Thus, increase in abundance over time would indicate lower levels of field processing and increased

rate of nonselective carcass transport to include low-utility elements and parts, while decreased field processing would result in increased skeletal element evenness. An even distribution of skeletal elements results in an evenness of 1, with values approaching 0 as evenness declines. Following Faith and Gordon (2007), skeletal element evenness is measured in this research using the Shannon evenness index.

Bone Fragmentation Patterns

To analyze fragmentation patterns, shaft specimens were randomly sampled for the fragment size grouping, for the element identification, and for the analysis of percussion, notches, and the fracture platform angles. All sizes of long bone shaft fragments were represented, with the exception of those smaller than 3 cm and those with modern/excavation breaks. Specimens larger than 6 cm and smaller than 10 cm were sampled for analysis of platform angles and of percussion and notches since this size category best represents the breakage patterns affecting whole collections (Alcántara et al., 2005). MNE values based on shaft fragments were estimated by combining information from the following: (1) shaft section shape, (2) shaft thickness, (3) presence or absence of surface landmarks (i.e., muscle insertions or foramina), and (4) the texture of the surface of the medullary cavity.

The mode of bone fragmentation was assessed by the frequency of breakage planes and the angle range for longitudinal and especially oblique breakage planes. The way that a bone breaks follows basic physical principles (as also for notches). Dynamic loading (i.e., hammerstone percussion) creates more acute or obtuse angles than does static loading (i.e., carnivore gnawing), whereas the latter shows more right angles than the former (Alcántara et al., 2005; Pickering & Egeland, 2006; Pickering et al., 2005). Dynamic loading through hammerstone percussion creates an impact on the bone that expands according to the density of the bone and the force of the impact, detaching a fragment with an angle that tends to be either acute or obtuse. This is the same phenomenon as that occurring when a lithic flake is detached through percussion. In contrast, carnivore broken bones tend to have breakage planes more at right angles, just as do pressure-flaked lithics (Alcántara et al., 2005).

Burning

The presence of burned bones does not necessarily indicate cooking or food preparation activities. Bones may be burned as fuel, disposed into the fire for cleaning purposes, accidentally burnt near fireplaces, or indirectly affected by the heat when buried (e.g., Payne, 1983; Schiegl, Goldberg, Pfretzschner, & Conard, 2003; Shipman, Foster, & Schoeninger, 1984; Stiner & Kuhn, 1995; Thery-Parisot, 2002). As such, degree of burning should be evaluated, not simply the presence or absence of burned bones. Intensely burned bones that are grayish or white in color suggest deliberate or accidental burning, not cooking (Payne, 1983, p. 151). Having conducted experimental studies on burning, weathering, and trampling, Stiner

(2005, p. 48) has documented that burning causes a loss of organic matrix, increasing the fragility of bones and the degree of fragmentation, while reducing the size of fragments. Accordingly, Stiner (2005) also reports that the size of the carbonized bone fragments rarely exceeds 1 or 2 cm. The results of Stiner's experiments have interesting implications for interpreting archaeological burned bones. She shows that even buried bones can be altered when exposed to heat and that calcined bones are usually found in the form of powder due to crushing and sediment compaction (Stiner, 2005, pp. 48–50). Goat bones buried 5 cm below a firebed displayed conspicuous morphological and structural modifications, whereas bones 10 cm below the heated zone showed no change (Stiner, 2005, p. 50).

Along the same lines, burned bones from Karain B were counted, weighed, measured, and color coded following Nicholson's (1993) scheme for burned sheep bones. Fragment size categories for burned bones were tabulated to test whether Stiner's findings hold for the bone bed.

Results

Taxonomic Composition

The Epipaleolithic bone bed at Karain B is dominated by the remains of two principal taxa: wild sheep (*Ovis orientalis*) and wild goat (*Capra aegagrus*). Their bones combine to comprise 98.7 % of the entire assemblage, making caprines the exclusively targeted taxa of the Epipaleolithic inhabitants of Karain B. The contribution of the secondary taxa is marginal and insignificant (Tables 2 and 6). Thus, as a first step, it is a straightforward task to establish the stratum PI.2 at Karain B cave as a macrofossil bone bed in terms of element and animal size categorization.

Taxonomic Diversity, Richness, and Evenness

Table 6 lists taxonomic categories with 13 taxa listed at the genus level. The representation of large game (wild sheep and goat, fallow deer, wild boar, and aurochs) is 98.7 % in the bone bed. Of the bones identified to large game, caprines account for 99.9 %, while 11 other taxa collectively account for only the remaining 0.1 %. Thus, despite a rich and diverse taxonomic composition, the assemblage lacks evenness in proportions as only two taxa contribute over 99 % of the bones analyzed. The high dominance index (D) (0.5572) as opposed to low Simpson's index of diversity ($1 - D$) value (0.4428) as well as low evenness (H/S) value (0.2017) converge to indicate a diverse but uneven taxonomic composition for the bone bed at Karain B. As such, the Epipaleolithic bone bed at Karain B can be said to have a multispecific, multitaxic, or multidominant taxonomic representation since the

Table 6 Relative abundance of taxa

Taxonomic ID	NF	MNE	Weight (g)	%NF	%MNE	%Weight
Small bird	13	4	11	0.1 %	0.1 %	0.0 %
Medium bird	30	7	32	0.2 %	0.2 %	0.1 %
Large bird	41	24	121.6	0.2 %	0.6 %	0.3 %
<i>Columba sp.</i> (pigeon)	3	3	3	0.0 %	0.1 %	0.0 %
<i>Alectoris chukar</i> (partridge)	36	35	40	0.2 %	0.8 %	0.1 %
Accipitridae (eagle/ hawk)	20	19	62	0.1 %	0.4 %	0.1 %
<i>Otis tarda</i> (great bustard)	17	15	68	0.1 %	0.3 %	0.2 %
<i>Lepus europaeus</i> (hare)	71	30	116	0.4 %	0.7 %	0.3 %
<i>Lynx lynx</i> (lynx)	2	2	22	0.0 %	0.0 %	0.0 %
<i>Vulpes vulpes</i> (red fox)	6	5	15	0.0 %	0.1 %	0.0 %
<i>Canis lupus</i> (wolf)	8	4	16	0.0 %	0.1 %	0.0 %
<i>Sus scrofa</i> (wild boar)	7	7	52	0.0 %	0.2 %	0.1 %
<i>Dama dama</i> (fallow deer)	10	5	115	0.1 %	0.1 %	0.3 %
<i>Bos primigenius</i> (aurochs)	7	3	294	0.0 %	0.1 %	0.7 %
<i>Capra aegagrus</i> (wild goat)	280	251	2,449.51	1.5 %	5.8 %	5.5 %
<i>Ovis orientalis</i> (wild sheep)	621	600	4,758.3	3.3 %	14.0 %	10.7 %
Ovis/Capra	17,744	3,284	36,470.32	93.8 %	76.4 %	81.7 %
Grand total	18,916	4,298	44,645.73	100.0 %	100.0 %	100.0 %

remains of two dominant, medium-sized bovids, caprines to be more specific, exclusively dominate the assemblage.

Assemblage Composition and Formation

The analysis of 18,916 bone fragments weighing over 44 kg indicates that degree of fragmentation is high, and nonidentified bone splinters and long bone shaft fragments dominate the assemblage. Table 3 details the bone surface modification data and shows that traces of weathering, trampling, abrasion, erosion, root etching, and rodent gnawing are very sporadic and extremely rare in the bone bed. This indicates a lack of vegetation growing in the cave, and perhaps, could form an independent line of evidence for intensive occupation, site maintenance, sweeping, or cleaning floors and burning the vegetation inside the cave by the occupants. Alternatively, the

data may also suggest a stable depositional environment and rapid burial of bones, eliminating the chance for nonhuman biotic and abiotic agents to access the bones. Given that overall bone surface preservation is good and that traces of abrasion, rolling, edge erosion, hence bone transport, are also marginal, rapid burial scenario seems to be more plausible and congruent with the bone surface modification data. The proportion of carnivore ravaging is below 1 %, while the proportion of cylinders or long bone diaphyses, which are considered as the indicator of carnivore activity, is 2.09 %. Yet, when cylinders are associated with carnivore ravaging, they are most likely to be accompanied by heavy gnawing, biting, and tooth marks. At Karain B, however, no such traces were observed. The presence of cylinders cannot be attributed to carnivore ravaging either, ruling out a role for carnivores in assemblage accumulation, modification, and destruction. During this first stage of taphonomic analyses, thus, a role for carnivores and other biotic and abiotic taphonomic filters in the accumulation, modification, and destruction of bones from the bone bed at Karain B can be ruled out safely.

Figure 5 shows the presumed inverse relationship between NF, NISP, MNE, and MNI on a logarithmic scale given the large range of values. The figure also shows a high degree of fragmentation and the subsequent preponderance of nonidentified splinters and shaft fragments ($N=8,491$ or 45 % combined). Figure 6 visualizes various variables pertaining to fragmentation. Worthy of note are the relatively high degree of identifiability ratio with a proportion of 55.1 %, average fragment length (3.6 cm), and high number of bones with excavation breaks (21.3 %). The high ratio of modern breaks is related to the packed and dense nature of the bones in the bone bed.

Skeletal Part Abundance, Bone Survivorship, and Bone Density

A glance at the log-scale line graph in Fig. 7 reveals that all skeletal elements and portions are represented in varying proportions. When expected vs. observed MNE estimates (derived from MNI of 85 for caprines based on combined mandibular dP4 and M3) are compared, however, a rather clear pattern is detected: a conspicuous bias against some axial elements in general and long bone epiphyses in particular (see Table 7). There is a big plateau between the expected vs. observed rib, sternum, thoracic vertebra, lumbar vertebra, proximal humerus, proximal metacarpus, carpals, distal femur, proximal tibia, proximal metatarsus, and third phalanx MNEs. These element portions are severely underrepresented by the magnitude of many times as the plateau covers a full logarithmic interval. Figure 8 provides further insights into the above-mentioned mixed patterning and manifests that bone density is a significant factor as to whether a bone element or portion succumbed to or survived the effects of combined destructive forces. It is clear that skeletal parts were differentially destroyed by various forces. Thus, processes governing bone destruction should be further explored to examine how much bone loss could be linked to bone mineral density.

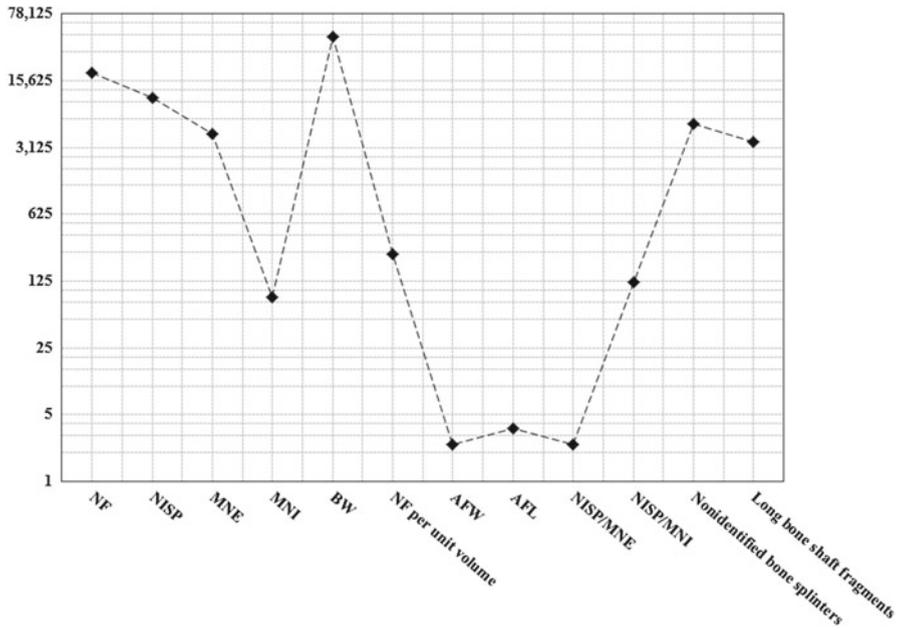


Fig. 5 The relationship between basic and derived quantitative units using log scale

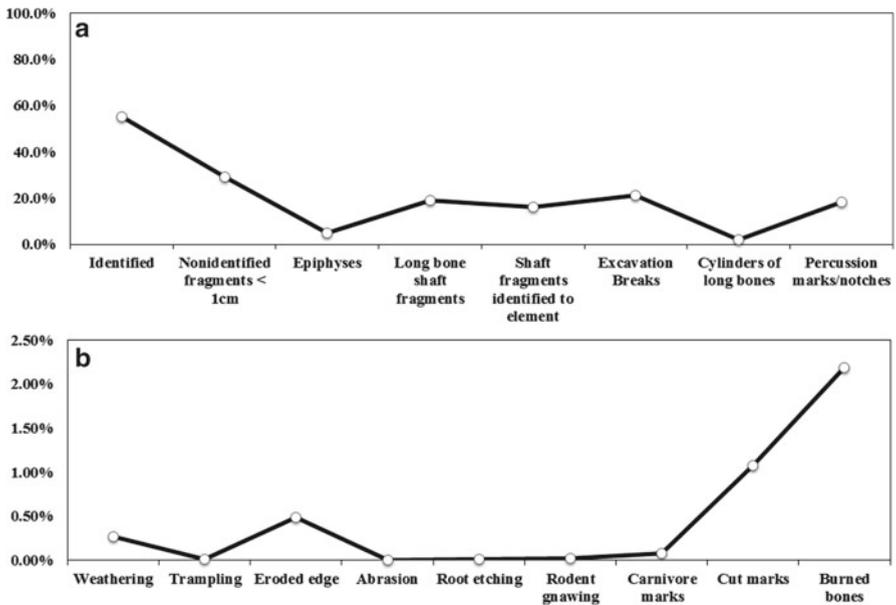


Fig. 6 Some of the basic taphonomic variables used to characterize the assemblage

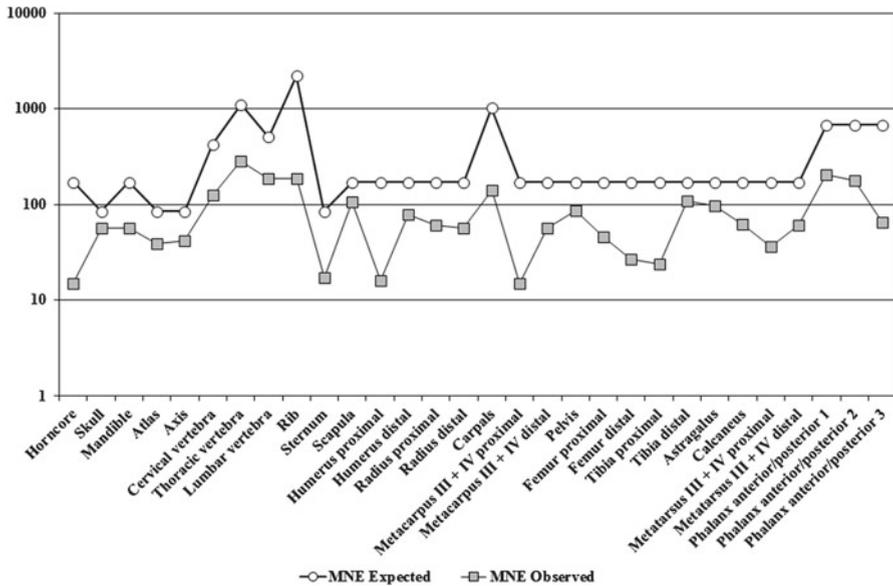


Fig. 7 Expected vs. observed MNE values to probe skeletal part abundance using log scale

In order to determine whether there is a real correlation between %MAU and density and to verify its statistical significance, Spearman’s rank order correlation (Spearman’s rho) was computed and significance test for the correlation coefficient was generated. The correlation is only slightly positive but statistically not significant ($r=0.080$; $p=0.711$).

Skeletal Completeness and Differential Preservation

In order to examine the degree of bone loss and differential bone preservation, I measure the preservation of upper vs. lower limb pairs, proximal vs. distal limb bone pairs, and skeletal completeness for body parts (Fig. 9). For the humerus-radius pair, the log-scale graph shows good and nearly equal representation, whereas there is a clear bias against femur in femur-tibia pair. Because the values for both pairs were generated by lumping proximal and distal portions together and taking the average, the biased patterns may be a result of differential preservation of proximal and distal portions due to their different density values or other reasons. This possibility is explored next through examination of ratios between proximal and distal portions of various bones.

Proximal humeri, proximal tibiae, distal femora, and distal radii are among the low-density skeletal parts in contrast to proximal and distal metapodia which are high-density parts, while distal humeri, proximal radii, proximal femora, and distal

Table 7 Expected vs. observed MNE, MAU, %MAU, and %Survivorship values

Skeletal element	MNE expected ^a	MNE observed	MAU	%MAU	%Survival
Horncore	170	15	7.5	13.2	8.8
Skull	85	57	57	100	67.1
Mandible	170	57	28.5	50	33.5
Atlas	85	39	39	68.4	45.9
Axis	85	42	42	73.7	49.4
Cervical vertebra	425	126	25.2	44.2	29.6
Thoracic vertebra	1,105	285	21.9	38.5	25.8
Lumbar vertebra	510	186	31	54.4	36.5
Rib	2,210	186	7.2	12.6	8.4
Sternum	85	17	17	29.8	20.0
Scapula	170	107	53.5	93.9	62.9
Humerus proximal	170	16	8	14	9.4
Humerus distal	170	79	39.5	69.3	46.5
Radius proximal	170	60	30	52.6	35.3
Radius distal	170	56	28	49.1	32.9
Carpals	1,020	140	11.7	20.5	13.7
Metacarpus III+IV proximal	170	15	7.5	13.2	8.8
Metacarpus III+IV distal	170	56	28	49.1	32.9
Pelvis	170	87	43.5	76.3	51.2
Femur proximal	170	46	23	40.4	27.1
Femur distal	170	27	13.5	23.7	15.9
Tibia proximal	170	24	12	21.1	14.1
Tibia distal	170	110	55	96.5	64.7
Astragalus	170	97	48.5	85.1	57.1
Calcaneus	170	62	31	54.4	36.5
Metatarsus III+IV proximal	170	36	18	31.6	21.2
Metatarsus III+IV distal	170	61	30.5	53.5	35.9
Phalanx anterior/posterior 1	680	205	25.6	45	30.1
Phalanx anterior/posterior 2	680	177	22.1	38.8	26.0
Phalanx anterior/posterior 3	680	65	8.1	14.3	9.6

^aBased on MNI = 85

tibiae are considered to be medium-density skeletal parts. This way of looking at the data provides us with a means to further evaluate the role of structural bone density on differential survivorship and destruction of bones. Figure 9 demonstrates the log-scale relationships between long limb bone parts. The lower panel of the graph (i.e., below 1) shows typical bias against low-density portions such as proximal humeri, proximal femora, proximal radii, and proximal tibiae. Exception to this pattern is radius for which proximal and distal ends are equally represented. Thus, for these elements, it appears that density-mediated attrition was important. This contrasts with the situation for metapodia. There is a conspicuous bias against proximal metacarpals, one of the densest elements with a density value of 0.55 g/cm³ (e.g., compared to the proximal humerus value of 0.13), and against proximal metatarsals, the densest bone portion of those considered, with a value of 0.68. This situation underlines the

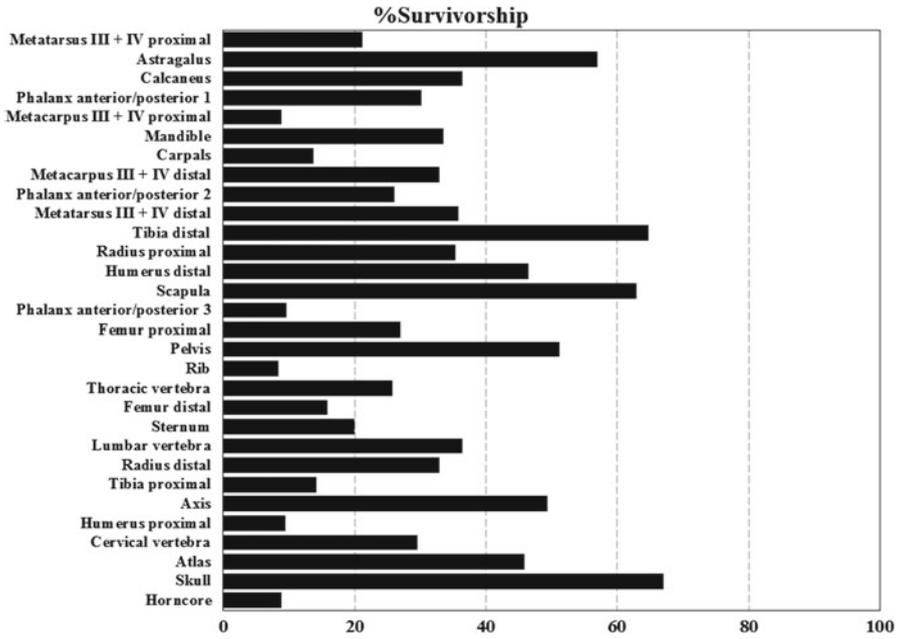


Fig. 8 %Survivorship of skeletal parts in the bone bed assemblage

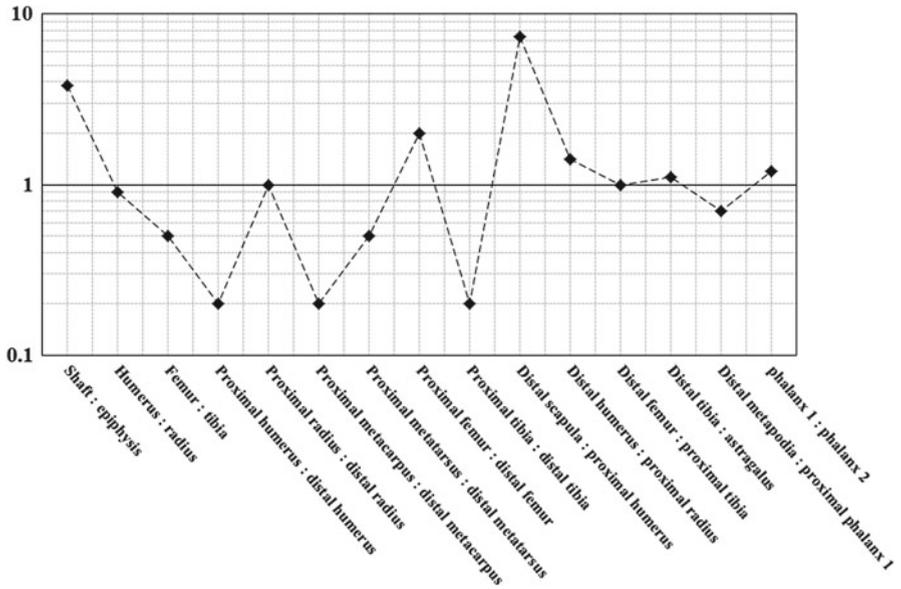


Fig. 9 Ratios of upper to lower and proximal to distal limb elements on a log scale

fact that bone loss was not exclusively density-mediated even though low-density parts overall were destroyed more frequently than high-density parts. Had bone destruction been only density dependent, these two high-density skeletal parts would have been among the best-represented portions of the skeleton. Underrepresentation of these two high-density parts attests to selective predepositional removal or destruction, for use as tools, not by in situ or density-mediated postdepositional attrition.

In addition to comparing proximal vs. distal portions of long bones, a ratio between shafts and epiphyseal fragments was also established. A shaft to epiphysis ratio of 3.8 is very similar to the ratio (5 to 1) obtained through actualistic and experimental research concerning the average number of fragments per limb bone (Capaldo, 1998). Along the same line, Table 8 offers an independent and verifying line of evidence as to how MNE estimates based on epiphyses and shafts yielded either similar results, or articular ends yielded greater MNE values, suggesting that this time-consuming and labor-intensive analytical procedure is not really necessary to estimate MNE values for the Karain B bone bed. This last affirmation also lends support to proponents of “rapid count” or “diagnostic zones” approach if and when carnivore ravaging can be securely ruled out as in the case presented here.

According to the body part profiles generated for the bone bed, forelimb, hind limb, and distal extremities are outnumbered by axial and cranial elements. This is an abnormal pattern particularly for the axial elements (21.7 %) which are more prone to destruction and underrepresentation in archaeofaunal assemblages because of their low-density values. Skull fragments (including teeth and mandibular fragments) comprise 28.6 % of the assemblage followed by the distal extremity, hind limb, and forelimb, respectively (Table 9). This trend does not change when NISP values are used, with the exception of decreased skull MNE values. This is an artifact of much higher skull fragmentation rates as attested by cranial bone MNE to loose tooth MNE ratio of 0.063 (Table 3). Among the axial elements, rib fragments comprise the largest group with a proportion of 20.7 %, whereas all other axial elements contribute 16 % of the total number of bones in the assemblage.

Given that very little impact from carnivore ravaging and other biotic factors has been demonstrated for the bone bed, the completeness of small, compact, and high-density bones such as carpals, tarsals, and phalanges should further illuminate the taphonomic processes that created observed patterns in the assemblages. Low degree of completeness for these bones would indicate intensive carcass processing or predepositional breakage. In contrast, axial skeletal elements with low density, inherent fragility, and high nutritional values are more susceptible to fragmentation. Thus, higher axial completeness values may indicate less intense processing and relatively low-level postdepositional bone loss. Figure 10 shows that axial elements are heavily fragmented, since their degree of completeness is low, with a proportion of 23.5. This pattern can be an artifact of bone density or more intensive processing and selective destruction of axial elements. Carpals have a completeness proportion of 100 %, whereas tarsals have a somewhat lower completeness degree in 85.1 %. The relatively lower completeness of tarsals may be due to the larger sizes of astragali and calcanei. In addition, their shape and anatomical position between marrow-rich tibiae and metatarsi make them susceptible to damage during butchery. The low

Table 8 MNE values for long bone shafts and epiphyses

Element	Portion	NF	MNE
Humerus	Proximal	37	16
	Distal	84	79
	Shaft	71	12
Radius	Proximal	80	60
	Distal	59	56
	Shaft	67	0
Ulna	Proximal	69	64
	Distal	15	15
	Shaft	41	0
Metacarpus III + IV	Proximal	30	15
	Distal	66	56
	Shaft	34	2
Femur	Proximal	55	46
	Distal	70	27
	Shaft	117	26
Tibia	Proximal	33	24
	Distal	118	110
	Shaft	162	18
Metatarsus III + IV	Proximal	89	36
	Distal	70	61
	Shaft	32	0
Grand total		1,399	723

Table 9 Body part frequencies

Body part	%MNE	KB1
Head		28.6
Axial		21.7
Forelimb		13.3
Hindlimb		15.6
Distal extremity		20.8
Total		100

completeness of phalanges, with a proportion of 37.3 %, indicates heavy fragmentation of these parts. These elements are relatively small and poor in nutrients. Only the first and second phalanges contain small amounts of marrow. Thus, their deliberate fragmentation would point to a level of prey procurement intensity compatible with predictions of optimal foraging models.

Carcass Processing, Economic Utility, and Skeletal Evenness

A detailed look into butchery and carcass processing might offer further insights into skeletal completeness. The bone bed has 201 specimens with cut marks with almost all skeletal elements bearing traces of butchery (Table 10). It is also worth

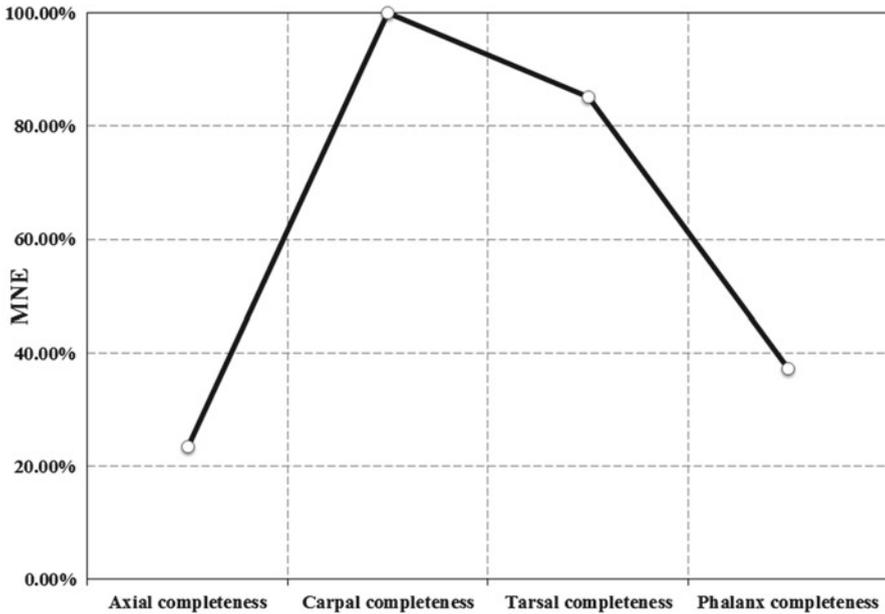


Fig. 10 Completeness of skeletal elements and body parts based on MNE

mentioning that majority of cut marks are on long bone shafts and ribs (45.8 %). This preponderance of cut marks on shafts and ribs may be symptomatic, an extremely important, and fundamental methodological issue in zooarchaeology. Many zooarchaeologists adopt a “diagnostic zones” approach; choose to record only more easily identifiable skeletal elements, such as teeth and articular ends; and exclude elements such as vertebrae, ribs, and long bone shaft fragments. Therefore, justification of ignoring long bone shaft fragments and other not so easily identifiable bones becomes even more problematic.

To further illuminate butchery, carcass processing, and bone transport, Spearman’s rank order correlation was performed for the %MAU and MGUI pair. A slightly positive but statistically insignificant correlation ($r=0.044$; $p=0.819$) determines that there does not seem to exist a statistically meaningful and significant relationship between skeletal part abundance and the nutrients element portions contain. Moreover, using the standardized MAUs ($N=292$) for only high-density and high-survival elements (i.e., skulls, mandibles, humeri, metapodia, radii, femora, and tibiae), a Shannon evenness index of 0.975 was generated. Since skeletal evenness values very close to 1 indicate extremely even distribution of skeletal elements, a nonselective carcass transport includes low-utility elements (i.e., bones with low meat, marrow, and grease content) and parts, and no field processing would be inferred. In other words, carcasses were brought to the cave without field processing and without selective transporting of the parts with higher nutritional content and value.

Table 10 Frequency of butchered specimens

Skeletal element	NISP	%NISP
Mandible	14	7.0
Atlas	2	1.0
Cervical vertebra	1	0.5
Rib	32	15.9
Scapula	9	4.5
Humerus proximal	1	0.5
Humerus shaft	7	3.5
Humerus distal	16	8.0
Radius proximal	3	1.5
Radius shaft	5	2.5
Radius distal	4	2.0
Ulna	2	1.0
Metacarpus proximal	0	0.0
Metacarpus shaft	4	2.0
Metacarpus distal	2	1.0
Pelvis	3	1.5
Femur proximal	1	0.5
Femur distal	1	0.5
Femur shaft	16	8.0
Tibia proximal	1	0.5
Tibia shaft	25	12.4
Tibia distal	4	2.0
Astragalus	6	3.0
Calcaneus	2	1.0
Metatarsus proximal	4	2.0
Metatarsus shaft	3	1.5
Phalanx 1	1	0.5
Phalanx 2	2	1.0
Nonidentified shaft	30	14.9
Grand total	201	100

Bone Fragmentation

The relative frequencies of long bone shaft fracture angles coupled with the presence or absence of notches and percussion marks permitted identification of deliberate breakage of bones for marrow extraction and bone grease rendering. The fracture angle data coupled with percussion marks and notches suggest that most bone breakage was the result of dynamic loading or hammerstone blows when the bones were in a fresh state. Such green breakage is likely to have been the result of human demarrowing. The fragment size distribution in this assemblage shows that 84.2 % of shaft fragments ($N=3,019$) fall in the size range of 1–5 cm (Fig. 11). Acute and obtuse angles were observed in the randomly sampled shaft assemblage with a

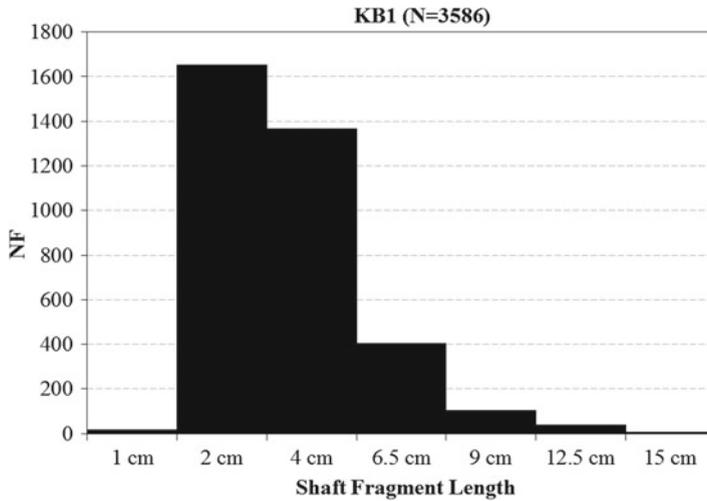


Fig. 11 Long bone shaft fragment size frequencies

proportion of 89.4 %. This interpretation is further supported by direct evidence for dynamic loading, i.e., by percussion marks and notches. In the absence of carnivore ravaging, the data clearly point to human modification and reduction of marrow bearing long bones.

Burning

Of the 419 burned bones from the bone bed, 45.6 % represent fragments smaller than 1 cm. Another 35.8 % make up the burned long bone shaft fragments within the 1–3 cm category. Burned long bone epiphyses or articular ends, which can be exposed directly to fire and heat when meat is cooked, account for only 12.4 % of the total number of burned bones. Thus, the high ratio of burned splinters and minute long bone shaft fragments suggest burning associated with either fuel management or site maintenance and not necessarily with cooking. A substantial portion of the burned bone sample, when it could be identified, consists of cancellous fragments. Use of cancellous bones as fuel may account for the large number of missing axial skeletal elements, whereas overrepresentation of other potentially combustible bone portions still begs for an explanation. Furthermore, the fact that other dense and less greasy bone portions (i.e., proximal metacarpals) are underrepresented exacerbates this issue. Given the size distribution among burned bones, burning may account for a part of the bone loss and might have facilitated, accelerated, or increased the number of nonidentified bones. It is also highly likely that burning may have deleted, altered, or masked some bone surface modifications (e.g., cut marks) that could have been conspicuous otherwise.

Discussion and Conclusions

Drawing upon two lines of specific evidence, taxonomic composition and assemblage formation, the present work shows that the Epipaleolithic stratum PI.2 at Karain B is a macrofossil bone bed with multispecific, multitaxic, or multidominant taxonomic representation, since the remains of two caprine species exclusively dominate the assemblage.

As far as the genesis and formation of the bone bed is concerned, the first stage of the taphonomic analyses revealed that the actions of nonhuman biotic or abiotic agents may not account for bone accumulation, modification, and destruction, leaving human behavior as the primary taphonomic filter. The archaeofaunal assemblage from the Epipaleolithic bone bed at Karain B provides a good example of human-accumulated and human-modified assemblage exhibiting differential bone preservation.

Despite the complete lack of carnivore ravaging and impact of other noncultural processes, a commonly observed trend toward underrepresentation of the most cancellous portions of limb bones (i.e., proximal humerus, proximal tibia, and distal femur) in archaeofaunal assemblages is also identified in this assemblage. This is a most striking aspect of the bone bed given that structurally weak and least dense axial elements, which are usually severely underrepresented in archaeofaunas, are relatively well represented in the bone bed. Because cancellous axial elements and articular ends contain tissues rich in fat and lipids and thus calories, they are the most likely targets for marrow and grease rendering processes that result in the smashing up of these elements (Speth, 1991). Defleshing meat from bones, cracking open long bones to extract marrow, and pounding and boiling axial bones and cancellous articular ends to render grease result in the loss of these skeletal elements and/or portions. Bar-Oz (2004) documented several Levantine Epipaleolithic assemblages with similar patterning and interpreted this as a product of intensified human exploitation of within-bone nutrients, in particular bone grease. At Karain B, there is no clear evidence for bone grease rendering nor is there much evidence for the practice of extensive butchery.

The taphonomic evidence indicates that meat and marrow extraction were the primary economic activities and thus primary cause of long bone fragmentation. Brain (1981) asserts that length of bone fragments tends to be remarkably consistent having a mean length of about 5 cm, probably as an artifact of efficient marrow extraction. A similar fragment size distribution in the bone bed reinforces the idea of an efficient marrow extraction. A secondary cause of bone fragmentation would be use of bones for combustion. A substantial portion of the burned bone sample, when it could be identified, consists of cancellous fragments. Use of cancellous bones as fuel may account for the large number of missing axial skeletal elements, whereas overrepresentation of other potentially combustible bone portions still begs for an explanation. Furthermore, the fact that other dense and less greasy bone portions (i.e., proximal metacarpals) are underrepresented exacerbates this issue. Still, the scarcity of cut marks may be a

product of the combined marrow extraction processes and accidental burning of bones or their use as combustibles. This means that most of the shaft fragments underwent a size reduction that could have led to a poor visibility for cut marks or even to their total deletion.

A second most striking aspect of the bone bed assemblage is the lack of correlation between bone density and skeletal part representation and between MGUI and skeletal part representation. The analysis that was carried out by Bar-Oz (2004) on the five Levantine Epipaleolithic assemblages shows that humans were the major bone-accumulating and bone-modifying agents with minimal or no carnivore impact. This is an aspect shared by both the Levantine and the Karain B assemblages. The Levantine assemblages, however, show a strong correlation between bone density and skeletal part representation, suggesting a pronounced density-mediated bias in gazelle skeletal part profiles (Munro & Bar-Oz, 2005). This is in sharp contrast to the Karain B Epipaleolithic assemblage in which density-mediated attrition is not so evident. Therefore, pre-burial bone destruction must have occurred in addition to, or instead of, postdepositional bone loss. The Levantine assemblages are similar to those from Karain B also in that there does not seem to be a significant relationship between bone preservation and food utility index. This is interpreted to represent an absence of the selective transport of high-utility body parts. This difference is of paramount significance and has broader theoretical implications. There may be significant differences in results even when using very similar or identical analytical approaches. These differences may be due to the variation in behavior of bone-accumulating and bone-modifying agents. Therefore, generalizations and universal laws concerning past human behavior should be reconsidered.

A third most striking aspect of the bone bed assemblage has broader theoretical and methodological implications concerning the hotly debated research paradigm that entails the “shaft only”/“epiphysis only” binary. The bone bed at Karain B provides a good example of the sort of site that is free of carnivore impact, increasing the preservation potential of cancellous epiphyseal fragments for equally accurate, consistent, and representative MNE estimates. This also justifies a scenario if and when a zooarchaeologist chooses to skip time-consuming and labor-intensive shaft approach in favor of rapid-counting or data-rich diagnostic zones.

To conclude, the multivariate taphonomic approach and comprehensive quantitative matrix used in this work can be applied to all types of bone assemblages, and will help develop high-resolution picture of taphonomic histories—cultural, natural, or a combination of both. This methodological framework enables both intrasite and intersite probing at a local scale or at a higher, regional scale.

Acknowledgement I would like to extend a special thank you to Anna Osterholtz, Kathryn Baustian, and Debra Martin for organizing a very stimulating symposium, where I presented an earlier version of this paper at the 77th Society for American Archaeology (SAA) annual meeting in Memphis, TN, on April 19, 2012, and for putting this exciting special volume together.

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