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Lower Paleolithic hominin ecology at the fringe of the desert: Faunal remains from Bizat Ruhama and Nahal Hesi, Northern Negev, Israel[☆]

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ABSTRACT

The Southern Levant is a pivotal area for the study of hominin paleoecology during the Lower Paleolithic, because of its location on the out-of-Africa dispersal route and its significant ecological diversity. Important information has been gained by archaeofaunal studies, which usually reveal that exploitation of diverse Mediterranean environments with woodlands, marshes and lake margins, represents a dominant subsistence strategy for Lower Paleolithic hominins. Here, we present new taxonomic and taphonomic data from two sites in the southern coastal plain of the Southern Levant, at the fringe of the Negev Desert: Bizat Ruhama (Early Pleistocene) and Nahal Hesi (Middle Pleistocene). The sites preserve anthropogenic faunas, with the former signaling a marrow-exploitation strategy, perhaps related to scavenging from carnivore kills, and the latter showing evidence for primary access to fleshed ungulate carcasses. The species composition of these Northern Negev sites is unique for the Levantine Lower Paleolithic in that these sites lack typical woodland and riparian species, probably indicating an open, relatively uniform environment with patchy water sources and trees, much like this semiarid region today. Bizat Ruhama and Nahal Hesi are among the only Levantine Lower Paleolithic faunas associated with such a setting, thereby widening the known spectrum of environments exploited by hominins in the region. It is suggested that the two sites, coupled with the nearby Late Pleistocene evidence, reflect a largely stable semiarid environment on the northwestern fringe of the Negev Desert throughout much of the Pleistocene.

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Introduction

Studies of hominin interactions with their environments in the Lower Paleolithic are essential for understanding the ways of life and adaptations of pre-modern humans. Sites in the Mediterranean southern Levant, on the main route of dispersals from Africa (e.g., Tchernov, 1988; Bar-Yosef, 1998; Klein, 1999; Goren-Inbar et al., 2000; Bar-Yosef and Belfer-Cohen, 2001; Dennell, 2003; Belmaker, 2009), have been studied through a variety of approaches, with archaeofaunal studies greatly contributing to the understanding of paleoenvironments, biochronology and hominin paleoecology and subsistence. Archaeofaunal studies often reconstruct a mosaic environment of open grasslands, woodlands, and freshwater lakes

or marshes. Many of the reconstructed site-settings contained rich and diverse faunal communities, including mammals from both African (Ethiopic) and Eurasian (Paleoartic and Indian) origins, with browsing, grazing and amphibious animals. Hominin activities during the Levantine Lower Paleolithic were therefore associated with diverse Mediterranean ecological zones and frequently linked to lake-margin habitations (e.g., Bate, 1937; Haas, 1966; Tchernov, 1986; Tchernov et al., 1994; Horowitz, 1996; Goren-Inbar et al., 2000; Feibel, 2004; Martínez-Navarro, 2004; Belmaker, 2006; Monchot and Horwitz, 2007a).

The place of Levantine hominins in the “food chain” of Lower Paleolithic fauna (cf., Blumenshine, 1986, 1995) has been studied at a few sites using taphonomic methods, and interpretations have ranged from weak or ambiguous evidence for hominin hunting (e.g., Tchernov et al., 1994; Belmaker, 2006; Monchot and Horwitz, 2007b) to systematic butchery of medium and large mammals, perhaps indicating modern hunting behavior or nearly so (e.g., Goren-Inbar et al., 1994; Gaudzinski, 2004a, b; Chazan and Horwitz, 2006; Rabinovich et al., 2008; Stiner et al., 2009). Some Lower Paleolithic faunas in the Levant do not show clear anthropogenic

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signals and many are badly preserved, stressing the need for more data from diverse ecological settings in order to obtain meaningful temporal and regional reconstructions of hominin paleoecology and subsistence.

Most evidence concerning hominin exploitation of the environment during the Lower Paleolithic of the Levant has been derived from sites in northern and central Israel. These localities reside in the present-day Mediterranean climatic zone, exhibiting diverse faunas (and in the case of Gesher Benot Ya'aqov – also flora) mostly indicative of a mosaic of Mediterranean environments. Here we present the first detailed faunal analyses of two nearby sites in the southern coastal plain of the Levant, on the northern fringe of the Negev desert, in the present semiarid zone of Israel: Bizat Ruhama (Early Pleistocene) and Nahal Hesi (Middle Pleistocene). We utilize zooarchaeological and taphonomic analyses to shed light on hominin subsistence and ecology and to portray the environment of the Northern Negev during the Lower Paleolithic, in which hominins and animals were interacting. Specifically we investigate the possibility that the bone assemblages are anthropogenic, i.e., represent hominin food debris, thus allowing inferences concerning hominin subsistence be drawn from them. In addition, the location of these sites on the present-day desert fringe suggests that Lower Paleolithic hominins regularly utilized the semi-arid zone. However, this transitional region may be prone to environmental changes and it may be possible that hominin occupation took place in a Mediterranean environmental setting, similar to the more northern sites. We explore this issue using archaeofaunal remains from the Northern Negev as a paleoenvironmental proxy for the ecology of early hominin foragers.

The sites and their settings

The Lower Paleolithic sites of Bizat Ruhama and Nahal Hesi are located on the Negev coastal plain, 25 km east of the present Mediterranean shoreline (Fig. 1). This region is a transitional zone between the Mediterranean and the semiarid climatic belts in the Irano-Turanian phytogeographical region, with an average yearly rainfall of 300–400 mm, and is located just 30 km north of the Saharo-Arabian phytogeographical region characterized by an average yearly rainfall of less than 200 mm. The geographic position of the area in the desert fringe supposedly makes the region highly sensitive to environmental changes deriving from fluctuations of climatic belts during the Quaternary (Horowitz, 1979; Magaritz, 1986; Magaritz and Goodfriend, 1987; Vaks et al., 2006, 2007). The part of the coastal plain where sites are located is built of low undulating Quaternary sand and loess hills (160–190 m above sea level) that descend gently to the east and the north toward Nahal Shiqma (Shiqma Stream), the largest stream in the region. The loess hills are occasionally eroded, thus creating typical badland landscape.

During the Quaternary, the environment of the Negev coastal plain was influenced by sea level fluctuations, the vicinity of the desert, and pedogenetic processes. The base of the Quaternary sequence in the area is the Pliocene/Early Pleistocene Pleshet and Ahuzam formations (Bar-Yosef, 1964; Gvirtzman and Buchbinder, 1969; Sneh and Buchbinder, 1984; Zilberman, 1984, 1986; Sneh et al., 1998). The major parent material of the rocks and soils that build the Quaternary sedimentological cover is quartzitic sand swept from the Nile Delta along the eastern Mediterranean shoreline during numerous sea transgressions. Sand-dunes were often transformed either into sandstone (*kurkar*), or red sandy loam (*hamra*). The sandstone outcrops only in few locations west of Bizat Ruhama (Issar, 1961; Bar-Yosef, 1964; Nir and Bar-Yosef, 1976; Horowitz, 1979; Nir, 1989). It seems that Quaternary sand invasion did not make its way into the Nahal Hesi area, where the Pleshet

Formation is directly overlain by loess that has been accumulating in the Negev from the Middle Pleistocene to recent times. The thickness of the loess deposits in the Negev reaches 12–15 m (Yaalon and Dan, 1974; Bruins and Yaalon, 1979), but it is lower in the vicinity of the sites, because the area is close to the northern boundary of loess deposition in Israel. The loess constitutes the upper stratigraphic unit in both sites, but in the vicinity of Bizat Ruhama it was largely removed by erosion that created the badlands and exposed the underlying *hamra*, thereby enabling the discovery of the site.

Some stratigraphic and paleoenvironmental data from the Negev coastal plain were obtained from the Bizat Ruhama section, the Ruhama section, located on the other side of the Bizat Ruhama badland, some 700 m from the site, and the Tel-Sheruhen section, located in the Nahal Besor region some 30 km south of the study area. Lengthy erosional phases are evidenced during the Early Pleistocene in the Tel Sheruhen section (Menashe, 2003) and during the Middle Pleistocene in the Ruhama section (Ron and Gvirtzman, 2001; Dassa, 2002). The erosional gaps were linked to humid environmental conditions (Menashe, 2003). More humid conditions relative to the present were also suggested by Dassa (2002) during the formation of the Early Pleistocene *hamra* in the Ruhama section and by Rosen (1986) during the formation of the Middle/early Upper Pleistocene terraces of Nahal Shiqma. However, the climatic fluctuations documented in the Middle Pleistocene of Tel Sheruhen section are all within the range of semiarid environment that characterize the region until present (Menashe, 2003).

Bizat Ruhama

Bizat Ruhama is a single-horizon open-air site located in a badland landscape. The archaeological layer (10–15 cm thick) was discovered at the bottom of two erosional channels on the edge of the badland field between Nahal Shiqma and Kibbutz Ruhama. Erosion exposed a ca. 20 m thick depositional sequence. The archaeological finds are embedded in a clayey sand layer 20–50 cm thick at the bottom of the sequence sandwiched between *hamra* and black clay of palustrine origin (Fig. 2). The archaeological finds occur in patches of different densities over an area of a few thousands square meters (Ronen et al., 1998; Zaidner, submitted, in preparation).

The site was excavated in 1996 by Ronen and Burdukiewicz (Ronen et al., 1998) and in 2004–2005 by Zaidner (submitted). Paleomagnetic studies showed reversed polarity for most of the sequence except for the upper 0.5 m, where inconclusive measurements were read. The dating results place the archaeological site of Bizat Ruhama in the Matuyama reverse polarity chron (1.96–0.78 Ma). Stratum 3, overlying the archaeological Stratum 4, and the lower part of the Stratum 2 were also accumulated during the Matuyama chron. No sediments corresponding to the Brunhes normal polarity chron were found in the studied section (Laukhin et al., 2001; Fig. 2).

The Bizat Ruhama industry is characterized by the use of simple knapping sequences with frequent use of bipolar or hard-hammer-on-anvil techniques (e.g., Barsky, 2009; Carbonell et al., 2009), production of thick flakes that were often further modified by breakage on an anvil, and Clactonian notching or simple rough retouch. The site shows no evidence for biface production and is one of the few core-and-flake (Mode 1) assemblages discovered beyond Africa (Zaidner, 2003a, b, submitted; Zaidner et al., 2003).

The first excavation produced several dozen animal bone and tooth fragments from an excavated area of 11 m² at the north of the site. Equid teeth and a possible bovid metapodial fragment were noted, as well as a “worn tooth fragment of a hippo(?)” (Dayan in Ronen et al., 1998: 169). This fragment was not marked by the analyst;

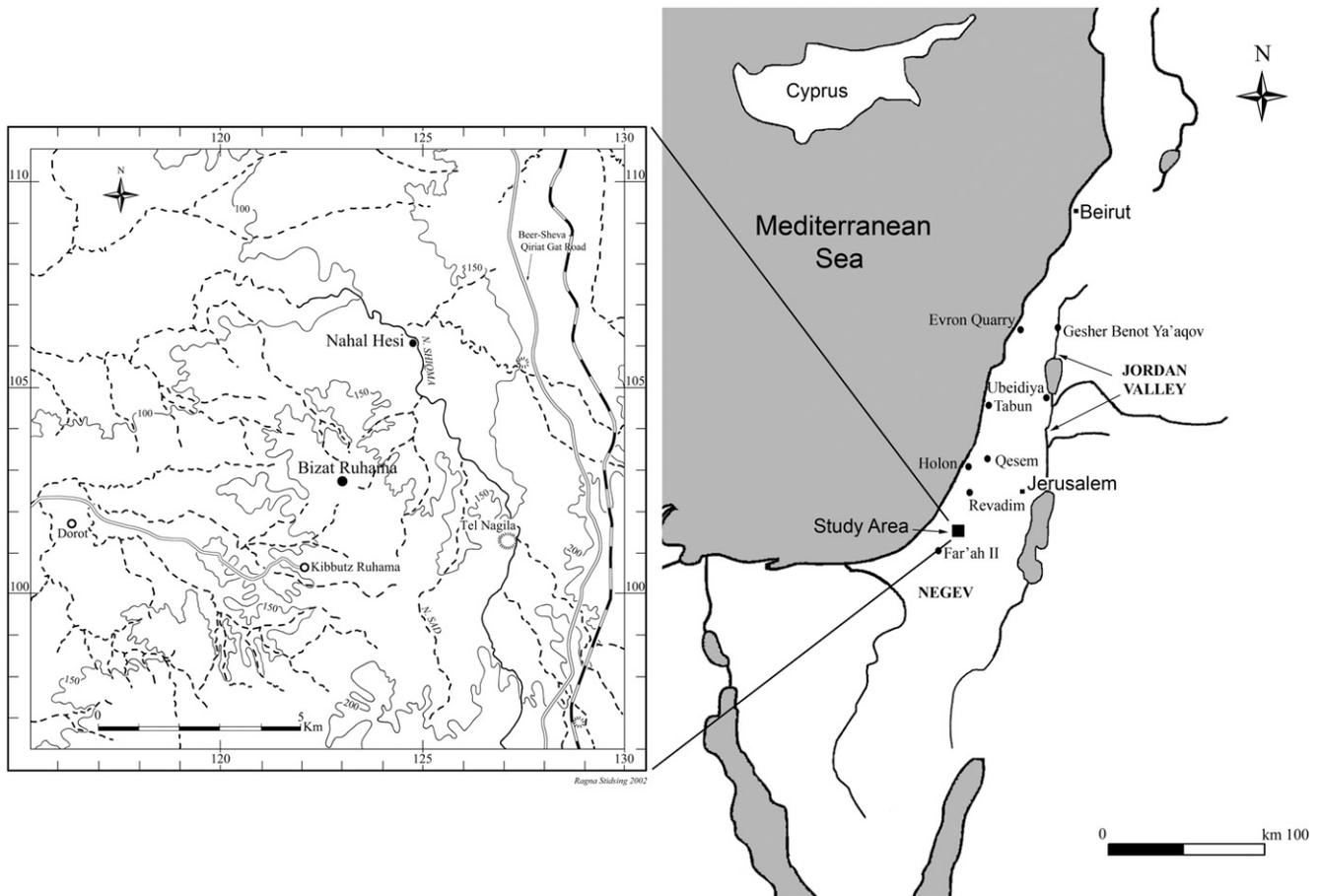


Fig. 1. Location map showing Bizat Ruhama, Nahal Hesi and other sites mentioned in the text. The enlarged study region is indicated.

in the course of the present research we examined the only specimen that matches this description (ca. 1 cm long) and found that at this stage it was impossible to tell if it belonged to a hippo canine, a boar tusk, or to another species. The faunal remains reported in the present study originate from BR AT5, an area excavated in 2004–2005 by Zaidner, located approximately 50 m south of the first excavation. A distinct horizon of flint artifacts and animal bones was discovered in this ca. 25 m² exposure (Zaidner, submitted). This locality yielded significantly more faunal remains than the old excavation area or other soundings throughout the site, and therefore the BR AT5 faunal assemblage was selected for this study.

During fieldwork at Bizat Ruhama excavators plotted every observed bone fragment using three-dimensional coordinates, and then bagging fragments separately onsite. All of the remaining excavated sediment was collected, and half of it was wet-sieved through 1 mm mesh. All faunal remains that were not plotted in the field were hand-picked from the 1 mm sieves. The procedures concerning both piece-plotted and sieve-recovered faunal remains are detailed below.

Nahal Hesi

Nahal Hesi is an open-air site located on the bank of Nahal Shiqma (Fig. 1). The site was excavated in 1971 and 1973 by the late David Gilead, but never published and the documentation of the excavation was lost. The stratigraphic section was briefly studied by one of us (YZ). The archaeological finds occur in a clayey and sandy deposit covered by loess (Fig. 2). The underlying unit includes sand, small flat pebbles and calcareous sandstone. According to the field observations this unit correlates with the Pleshet Formation. If this

is the case, a long period of erosion or non-sedimentation occurred between the deposition of the Pleshet Formation and accumulation of loess (Zaidner, in preparation).

Reports of fauna from Nahal Hesi have never been published except for several equid teeth described by Davis (1980). The faunal remains reported in this study originate from the 1971–1973 excavation and are associated with Lower Paleolithic industry, under study by Zaidner (in preparation). This industry is composed of handaxes, choppers, cores, flakes and retouched flake tools, showing well-defined Acheulian characteristics. Some of the handaxes, and especially the flake tools, demonstrate a high degree of refinement characteristic of the Late Acheulian, thereby assigning the site to the Middle Pleistocene.

The collection method of bones (and lithic artifacts) at Nahal Hesi, excavated in the early 1970's, is not known, as documentation was lost. It seems that bones were collected quite meticulously during excavation and were completely retained (see below). The faunal (and lithic) assemblage from the site was located by Y.Z. in the Zinman Institute of Archaeology, University of Haifa, and the equid teeth published by Davis, which were curated in the Department of Evolution, Systematics and Ecology in the Hebrew University, Jerusalem, were also incorporated in this study.

Methods

The research protocol applied here included the identification of all skeletal elements and systematic documentation of bone-surface modifications and mode of bone fragmentation. We used a multivariate taphonomic approach (Behrensmeier, 1991; Bar-Oz and Munro, 2004); multiple primary taphonomic data and

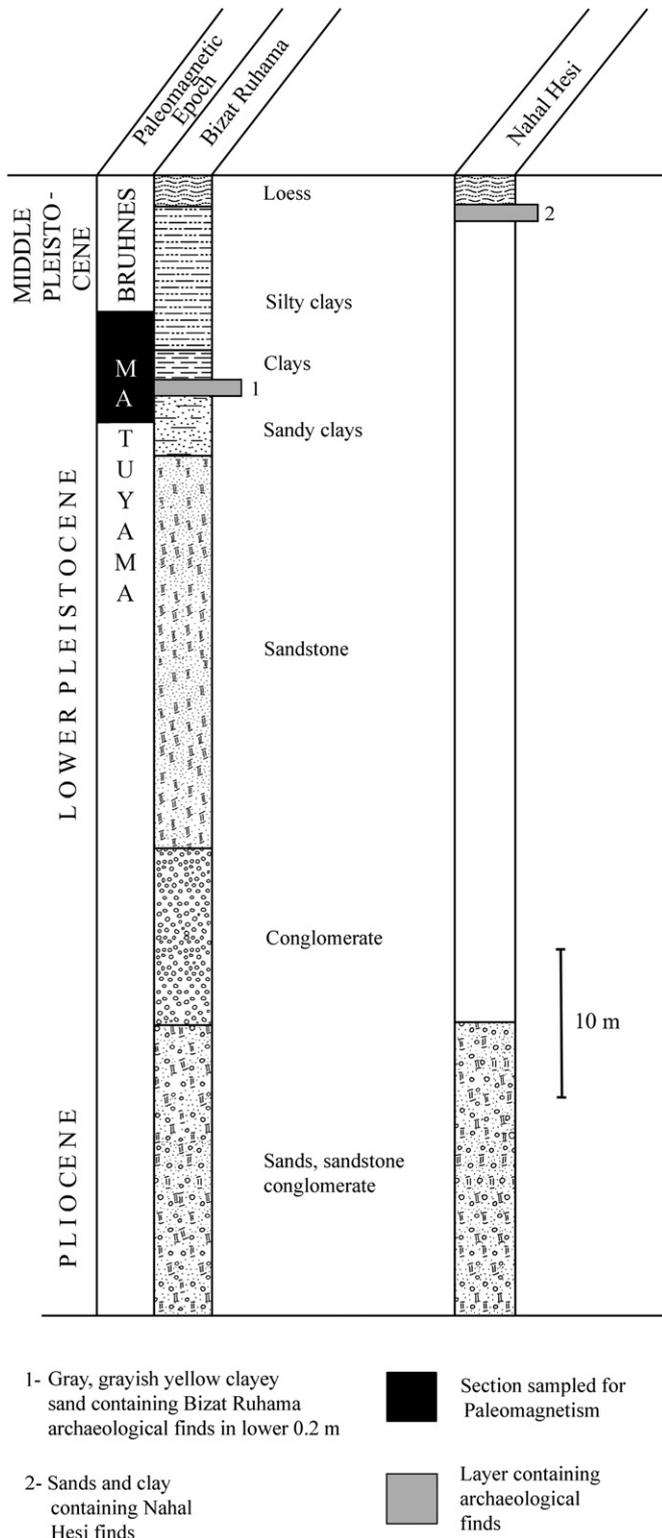


Fig. 2. Composite section showing the stratigraphic position of Bizat Ruhama and Nahal Hesi, based on Bar-Yosef (1964), Laukhin et al. (2001), Mallol (pers. comm., 2008) and Zaidner (in preparation).

taphonomic analyses are integrated to discern the taphonomic history of the assemblage, with special reference to human subsistence behavior.

In order to clean bone cortical surfaces, faunal remains were gently washed with fresh water and left to dry slowly. No further cleaning was needed for most specimens. All bones were saved and

the identifiable specimens were selected for analysis. Identifiable elements (henceforth NISP; Number of Identified Specimens) included long bone articular ends, long bone shaft fragments with diagnostic zones (Stiner, 2004) or indicative characteristics such as thickness and morphology of the cross section and medullary cavity (Barba and Dominguez-Rodrigo, 2005), teeth, cranial fragments, ribs, vertebrae, and all other recognizable bone fragments. We also recorded unidentifiable long-bone shaft fragments that could be assigned to size-class and measured ≥ 4 cm in length (henceforth NUSP; Number of Unidentified Specimens). Their approximate location within the limb (i.e., ‘upper limb’ for humeral/femoral fragments, ‘intermediate limb’ for radial/tibial fragments and ‘lower limb’ for metapodial fragments) was noted when possible. Both identified fragments (NISP) and unidentified but recorded limb shafts (NUSP) form the total assemblage used for the taphonomic analysis (NSP; Number of Specimens).

Taxonomic identifications of complete elements (almost all teeth) were undertaken by VE (equids of the two assemblages) and BM-N (Bizat Ruhama bovids). Other identifications were based on the comparative collection of the Laboratory of Archaeozoology, Zinman Institute of Archaeology, University of Haifa. Because of the high fragmentation, the majority of the identified specimens were assigned to one of three ungulate body-size classes: small, medium and large. These size-classes may be compared to bovid size 1, size 2–3 and size 4–5, respectively, in the terminology of Africanist zooarchaeology (Brain, 1981). At both sites the small-size ungulate class comprised gazelles, the medium-size ungulate class includes equids and medium-size bovids, and the large-size ungulate class comprised entirely of large bovine remains (Table 1).

All identified specimens (henceforth NISP; defined as fragments whose precise location in the skeletal element, or portion thereof, can be determined and quantified, and can be assigned to species or size class) were recorded according to skeletal element (e.g., proximal shaft of a humerus) and coded according to Lam et al. (1999, Fig. 1) scan site codes (e.g., a proximal shaft of a humerus was coded as HU2). In addition, the location of each element (e.g., dorsal-lateral) and its completeness (i.e., percentage of that portion of element represented) was documented (following Klein and Cruz-Urbe, 1984). In recording limb shaft fragments we used both “diagnostic zones” (following Stiner, 2004) and other morphological characteristics of the shaft fragments (e.g., Barba and Dominguez-Rodrigo, 2005). The former refer, for example, to nutrient foramina, tuberosities and grooves, and portions thereof, and the latter refer to indicative characteristics such as cortical thickness and morphology of the cross section and medullary cavity. The completeness of these morphological traits was quantified by assigning percentage of completeness. This enabled us to compute the Minimum Number of Elements (MNE; Lyman, 1994) and Minimum Animal Units (MAU; Binford, 1981) of every fraction of an element and each skeletal element. This procedure was designed to achieve a maximum accuracy of the MNE count, in light of recent critiques of identification procedures that are biased

Table 1

Ungulate body size classes in Bizat Ruhama (Early Pleistocene) and Nahal Hesi (Middle Pleistocene) assemblages

Ungulate body size class	Range of weight (kg)	Bizat Ruhama	Nahal Hesi
Small ungulate	15–25	<i>Gazella</i> sp.	<i>Gazella</i> sp.
Medium ungulate	60–300	<i>Equus</i> cf. <i>tabeti</i> , Antelopini gen. et sp. indet.	<i>Equus</i> cf. <i>melkiensis</i>
Large ungulate	800–1000	Bovini gen. et sp. indet.	<i>Bos primigenius</i>

Weight ranges for bovids are from Mendelsohn and Yom-Tov (1999) and from Nowak (1999). Weight ranges for equids were calculated by regression techniques on an M¹ tooth at Bizat Ruhama, and by comparison to contemporaneous faunas (see Eisenmann and Sondaar, 1998).

against shaft fragments (e.g., Marean and Kim, 1998; Pickering et al., 2003; Marean et al., 2004).

Fragments whose precise location in the skeletal element could not be determined and quantified were not included in the NISP. Thus, all identified specimens contributed to the Minimum Number of Elements (MNE) counts. The validity and necessity of using MNE-derived counts is currently under debate (e.g., Grayson and Frey, 2004; Lyman, 2008). However, we used MNE-derived measures such as Minimum Animal Unit (MAU; Binford, 1981) for most analyses of skeletal-element representation in this work, because it compensates better for differential fragmentation of elements and species (e.g., Yeshurun et al., 2007a) and because the characteristics of assemblages hint at the possibility that many bone fragments were, in fact, part of the same element or individual (see below, especially for the Bizat Ruhama assemblage). This makes the use of MNE-derived counts justified and even required.

All recorded specimens were systematically examined for bone surface modifications using a stereoscopic microscope with a high intensity oblique light source, at 8–56 magnification, following the procedure described in Blumenschine et al. (1996). We searched for cut-marks (Binford, 1981) and hammerstone percussion marks, including conchoidal notches (Bunn, 1981; White, 1992; Capaldo and Blumenschine, 1994; Pickering and Egeland, 2006) and percussion pits and striations (Blumenschine and Selvaggio, 1988; Blumenschine et al., 1996; Pickering and Egeland, 2006). We also looked for carnivore punctures, scoring and digestion marks (Binford, 1981; Stiner, 1994), as well as rodent gnaw marks (Brain 1981; Fisher, 1995), and biochemical (root) marks (Dominguez-Rodrigo and Barba, 2006, 2007). We sought evidence of trampling striations (Behrensmeyer et al., 1986; Fiorillo, 1989; Oliver 1989) and abrasion of bone edges (Shipman, 1981; Shipman and Rose, 1988), and we noted weathering (Behrensmeyer, 1978). As a result of manganese staining in the Bizat Ruhama assemblage and bleaching of bones at Nahal Hesi we could not reliably record burning using visual criteria.

We recorded the mode of bone fragmentation either for each shaft fragment that retained a portion of epiphysis or for the shaft near an epiphysis to determine the stage at which the bones were broken (i.e., fresh-green vs. old-dry). The morphology of the fracture angle and fracture outline was recorded following Villa and Mahieu (1991). We also recorded the percentage of shaft circumference (Bunn, 1983) to describe limb breakage and to demonstrate the quality of retrieval of the faunal remains (Marean et al., 2004).

Results

The faunal assemblage of Bizat Ruhama

Zooarchaeology and taphonomy The retrieved bone assemblage of the Early Pleistocene site of Bizat Ruhama (NSP = 141) is heavily

Table 2

Breakdown of the two faunal assemblages, detailing the number of specimens identified to species and the number of specimens identified to size class (NISP) as well as the number of unidentified but recorded specimens attributed to size-class (NUSP) and total number of specimens (NSP)

	Bizat Ruhama			Nahal Hesi		
	Small ungulate	Medium Ungulate	Large ungulate	Small ungulate	Medium Ungulate	Large ungulate
Total NISP	6	74	12	6	49	22
ID to species	3	38	6	1	19	11
ID to size-class	3	36	6	5	30	11
NUSP	2	22	25	3	36	44
Total NSP	8	96	37	9	85	66

fragmented. Complete bone elements are nearly absent and the assemblage is essentially composed of isolated teeth and some limb bone shaft fragments (SOM, Table 1). These were found in direct association with flint artifacts, incorporated within a 10–15 cm thick archaeological layer, sometimes totaling dozens of faunal specimens per square meter (Zaidner, submitted). No clear anatomical articulations were noted during fieldwork, but the distribution of several fragments hinted at the possibility of some articulated elements disintegrating *in situ* (i.e., teeth seemingly from the same jaw that were found isolated, but in the proximity of each other). Three conjoins, each consisting of two bone fragments with ancient fractures found within ca. one meter of each other, were found during analysis, indicating the value of a systematic refitting program in the future to determine the integrity of the site and its spatial patterns. The limited vertical distribution, the direct association with lithics, the conjoins, and the possibility of several articulations may signal that the faunal assemblage of Bizat Ruhama remained largely *in situ*. Naturally, more data on the geology of the site and the taphonomy of the finds are needed to support this conclusion.

Bones identified to size-class rather than species make up about half of the NISP count and include almost all of the postcranial elements owing to the high level of fragmentation (Table 2). Taxonomically, *Equus cf. tabeti* dominate the assemblage, followed by a medium-sized spiral-horned antelope (Antelopini gen. et sp. indet., probably *Pontoceros ambiguus* or *Spirocerus* sp.), some bovine materials (probably *Bison* sp.) and gazelle remains (*Gazella* sp.) (Table 3; see data on taxonomic identification below). No remains of small game were found, despite the careful recovery procedures employed at the site. These fragments identified to species were combined with identified fragments that were assigned to size-class only and, when possible, with unidentified but recorded shaft fragments to enable the taphonomic analysis (Tables 1 and 2).

Black manganese coats the vast majority of the bones and teeth, probably indicating postburial water activity in this location, but otherwise the bones display fair preservation. The incidence of bleaching, weathering, cortical exfoliation and abrasion of bone edges is low (Table 4), indicating relatively quick burial of faunal remains in a favorable sedimentological environment. In particular, the weathering is surprisingly low for an open-air site, albeit still high compared to Pleistocene cave-sites (e.g., Bar-Oz and Dayan, 2003). The scarcity of rounded edges, cracking and exfoliation provides additional evidence of the minor role of water or other geological agents in the deposition and destruction of the assemblage. Root (biochemical) marks and trampling striations appear on about one-third of the specimens (Table 4). The latter may be induced either by sediment compaction or by hominin and animal

Table 3

Species composition at Bizat Ruhama and Nahal Hesi

	NISP		NISP teeth		MNI
	n	%	n	%	n
Bizat Ruhama					
<i>Equus cf. tabeti</i>	27	57%	27	61%	3
<i>Gazella</i> sp.	3	6%	1	2%	1
Antelopini gen. et sp. indet. (cf. <i>Pontoceros antiquus</i> or <i>Spirocerus</i> sp.)	11	23%	10	23%	2
Bovini gen. et sp. indet. (cf. <i>Bison</i> sp.)	6	13%	6	14%	1
Total ID to species	47	100%	44	100%	7
Nahal Hesi					
<i>Equus cf. melkiensis</i>	30	71%	28	88%	3
<i>Bos primigenius</i>	11	26%	3	9%	2
<i>Gazella</i> sp.	1	2%	1	3%	1
Total ID to species	42	100%	32	100%	6

trampling. Both agents are expected as the faunal remains were deposited in the context of hominin and carnivore activities (see below), which could trample the bones, and within fine, abrasive sediment.

Bone surfaces bear some evidence for hominin modifications (Table 4, Fig. 3). One definite cutmark was found on a rib shaft of a medium-sized ungulate. Percussion marks, including pits, microstriations, and conchoidal notches, were found on five specimens, all from medium-sized ungulates (11% of relevant NSP). This figure rises to 25% if considered as a proportion of MNE, meaning that at least one-quarter of limb bones were cracked open for marrow. Almost half of limb bone shaft fragments from all size classes include 'green' (fresh) fractures, and nearly all shafts retain less than half of their original circumference, thereby strengthening the notion that hominins routinely exploited bone marrow at Bizat Ruhama.

A total of four bones with probable carnivore gnawing marks were recorded, including a tooth score and crenulated edges, all from middle-sized ungulates (Table 4; Fig. 3). One crenulation

occurred on the proximal shaft of a tibia (the anterior crest) and the others on unidentified portions of shaft fragments. Two of the gnawed bones also display 'green' fracture patterns lacking percussion marks, suggesting that some pre-burial limb-bone breakage was the result of carnivore ravaging rather than hominin fracturing for marrow. Unfortunately, the faunal sample of Bizat Ruhama is too small for a detailed quantitative study of the hominin and carnivore marks in order to evaluate the timing of access of each agent to the ungulate carcasses (e.g., Blumenschine, 1995; Dominguez-Rodrigo and Pickering, 2003).

The dominant skeletal parts within each size class at Bizat Ruhama are teeth (all isolated) followed by limb-bone shaft fragments. In the medium-sized ungulate group, which comprises the largest sample, heads are well-represented, limbs are less-represented and axial parts are almost absent (Fig. 4; Supplementary Content, Table 1). The survival of bone parts correlates significantly with their mineral density (Table 4; the low *r* value probably stems from the exclusion of teeth, which have no published BMD values). Overall, the densest elements in the body, which best resist

Table 4

Bone-surface modification data, bone fracture data and values of key taphonomic variables for the three size-classes at Bizat Ruhama and Nahal Hesi.

	Bizat Ruhama				Nahal Hesi			
	Small ungulate	Medium ungulate	Large ungulate	Total	Small ungulate	Medium ungulate	Large ungulate	Total
NSP	8	93	40	141	9	85	66	160
NSP excluding teeth (limb shaft NSP)	7(3)	59(45)	31(28)	97(76)	8(6)	57(50)	63(57)	128(113)
Manganese coating	<i>n</i> 7 % 88%	90 97%	37 93%	134 95%	0 0%	0 0%	0 0%	0 0%
Bleaching	<i>n</i> 1 % 13%	3 3%	1 3%	5 4%	3 38%	54 95%	51 81%	108 84%
Green fracture	<i>n</i> 2 of 2 %NSP 100% %MNE –	10 24 42% 50%	3 8 38% –	15 34 44% –	0 1 0% –	6 9 67% 33%	9 14 64% 44%	15 24 63% –
Shaft circumference	<50% 3 >50% 0 100% 0	42 1 1	28 0 0	73 1 1	6 0 0	50 0 0	57 0 0	113 0 0
Weathering (stage 3–5)	<i>n</i> 0 % 0%	7 12%	1 3%	8 8%	1 13%	23 40%	30 48%	54 42%
Cutmarks	<i>n</i> 0 %NSP 0% %MNE –	1 2% 6%	0 0% –	1 1% –	0 0% –	4 7% 27%	7 11% 15%	11 9% –
Percussion marks	<i>n</i> 0 %NSP 0% %MNE –	5 11% 25%	0 0% –	5 0% –	0 0% –	1 2% 14%	0 0% –	1 1% –
Carnivore gnawing	<i>n</i> 0 % 0%	4 7%	0 0%	4 4%	0 0%	0 0%	1 2%	1 1%
Rodent gnawing	<i>n</i> 0 % 0%	0 0%	0 0%	0 0%	0 0%	1 2%	1 2%	2 2%
Root-marks	<i>n</i> 1 % 14%	24 41%	8 26%	33 34%	2 25%	30 53%	36 57%	68 53%
Trampling striations	<i>n</i> 1 % 14%	20 34%	10 32%	31 32%	3 38%	15 26%	22 35%	40 31%
Exfoliation	<i>n</i> 2 % 29%	7 12%	1 3%	10 10%	0 0%	0 0%	0 0%	0 0%
Abrasion	<i>n</i> 2 % 29%	1 2%	1 3%	4 4%	0 0%	2 4%	0 0%	2 2%
Abundant skeletal elements		Teeth and limb shafts				Teeth and limb shafts		
Cranial bone to teeth MNE	0/1	0/5	1/1		0/0	1/2	0/1	
Isolated teeth/all teeth NISP	1(1)	37(37)	6(6)		1/1	28/28	3/3	
Correlation BMD*MAU		<i>r</i> = 0.26 <i>p</i> = 0.02				<i>r</i> = 0.40 <i>p</i> < 0.01		
Correlation GUI*MAU		<i>r</i> = 0.54 <i>p</i> = 0.17				<i>r</i> = 0.25 <i>p</i> = 0.95		
Correlation Marrow*MAU		<i>r</i> = 0.52 <i>p</i> = 0.23				<i>r</i> = –0.16 <i>p</i> = 0.74		

Note: %MNE of green fractures, cutmarks and percussion marks was computed as MNE of bones with these attributes/total MNE of relevant bones in the assemblage. NUSP were not included in the %MNE count.

All correlations are Spearman's *r*. Bone Mineral Density (BMD) values are from Lam et al. (1999). General Utility Index (GUI) and Marrow Weight were taken from Outram and Rowley-Conwy (1998) for horse, and porous elements were omitted. These analyses included only the NISP.

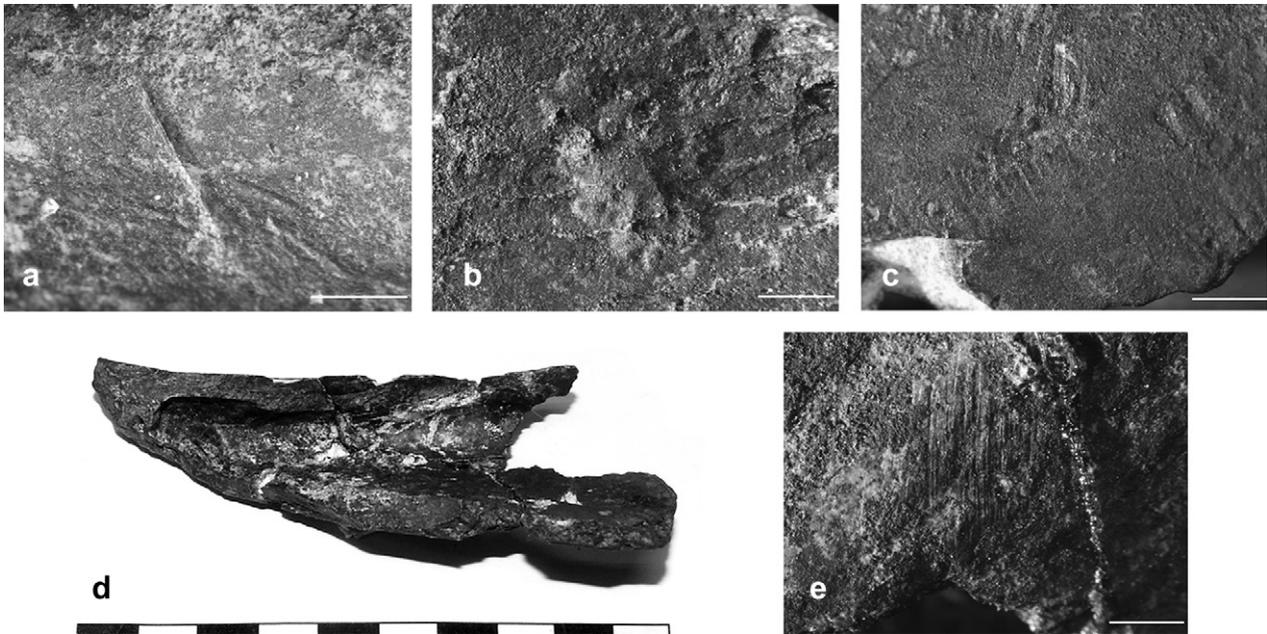


Fig. 3. Selected bone surface modifications and bone fracture patterns from Bizat Ruhama (all medium ungulate bones. Scales are 2 mm): (a) BR-37, a cutmark on a rib shaft; (b) BR-109, carnivore tooth pit on an unidentified long bone shaft fragment; (c) BR-139, percussion mark displaying a pit and microstriations on the caudal aspect of a humerus midshaft; (d) BR-139, humerus fragment showing its spiral fracture edge and conchoidal notch, probably induced by hammerstone percussion; (e) BR-127, microstriations on the anterior aspect of a metacarpus midshaft – probably a percussion mark.

a plethora of pre- and post-depositional destructive processes, are the best represented (teeth). The next densest parts, limb bone shafts, are the next best represented, and almost no elements with low density values have survived. While limb-bone ends and skull pieces are nearly absent, denser parts of these elements do exist in the assemblage (long bone shafts and the skull teeth and petrosium) indicating that more porous parts of the skeleton were indeed brought to the site but were differentially preserved and subsequently were lost as a result of destruction processes. For instance, dense limb-bone shafts outnumber porous limb-bone ends for all limb bones in the assemblage, sometimes in the proportion of 3:1, in spite of the fact that they were probably brought to the site as a complete bone before being fractured by hominins or carnivores.

In light of this pronounced density-mediated attrition, we examined the nutritional utility of skeletal elements in relation to their survival in the assemblage using only the high-density elements, which are expected to better represent hominin behavior (following Marean and Cleghorn, 2003; Cleghorn and Marean, 2004). Weak and nonsignificant positive correlations

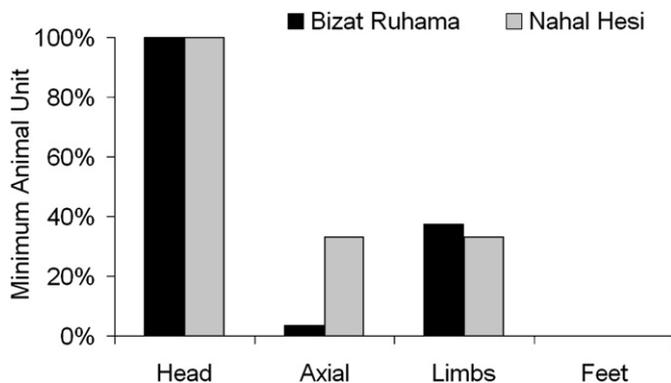


Fig. 4. Body part distribution at Bizat Ruhama and Nahal Hesi. Data are from Supplementary Online Material 1 and 3.

were found between the skeletal element survival (MAU) of the medium ungulate size class and either the General Utility Index (GUI), the mean meat weight or the mean marrow weight for horse (Table 4; data from Outram and Rowley-Conwy, 1998). However, these quantitative analyses have to be taken with caution because of the small sample of relevant skeletal elements in the assemblage. To conclude, it can be suggested that heads and (less frequently) limb units underwent some carnivore ravaging and marrow-oriented hominin butchery at Bizat Ruhama, and that carcass parts subsequently suffered from density-mediated post-depositional decay, which was largely taking place *in situ*.

Family Equidae The sample comprises only cheek teeth (eight upper and 12 lower) some of which are fragmentary (Supplementary Online Material, Table 2). On the upper teeth, protocones are rather small, *plis caballin* are present on the premolars and the enamel of the fossettes is moderately plicated. In this regard, the teeth of Bizat Ruhama resemble some specimens from 'Ubeidiya and Gesher Benot Ya'aqov (Eisenmann, 1986) (Fig. 5). Occlusal size and protocone length fall inside the scattergram of upper cheek teeth of *E. tabeti* from Ain Hanech, Algeria, as do the teeth from Gesher Benot Ya'aqov (Fig. 6a). Occlusal size and length of the protocone are slightly smaller than at 'Ubeidiya (Fig. 6b). The lower cheek teeth have rounded double knots, with deep lingual grooves. Unlike extant asses and hemiones, the vestibular grooves are deep on the molars. The pattern is 'stenonid' with rounded double knots (unlike horses), deep lingual grooves (unlike hemiones), deep vestibular grooves on molars (unlike hemiones and asses), and again resembles the pattern observed at 'Ubeidiya and Gesher Benot Ya'aqov (Fig. 5). Thus, it seems reasonable to refer the teeth from Bizat Ruhama to an equid close to *E. tabeti*. There are no complete equid bones from the site, but two first phalanges of the similar species from Gesher Benot Ya'aqov have the proportions of African asses (Eisenmann, unpublished data).

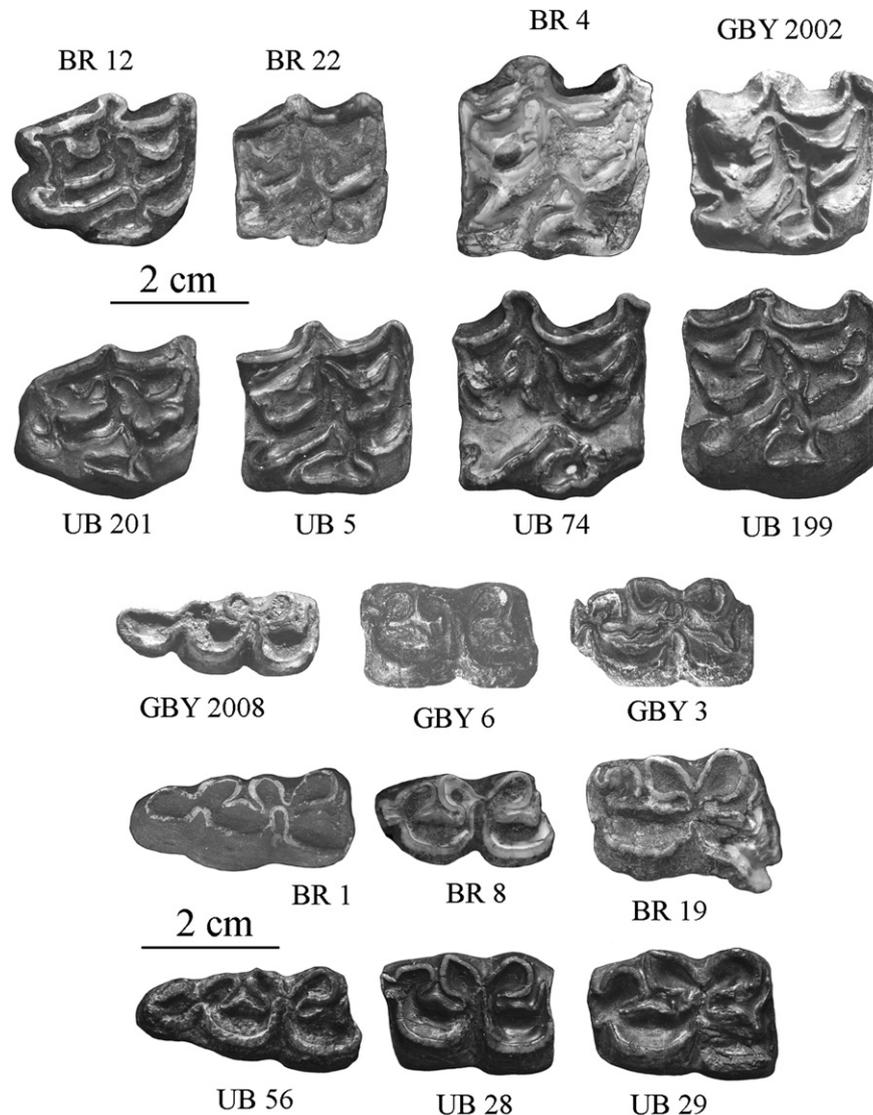


Fig. 5. Selected equid teeth from Bizat Ruhama (BR), 'Ubeidiya (UB) and Gesher Benot Ya'aqov (GBY).

In sum, teeth from Bizat Ruhama resemble the equid teeth from Gesher Benot Ya'aqov and the teeth of *E. tabeti* from Ain Hanech and (less so) *E. cf. tabeti* from 'Ubeidiya. They differ from extant wild asses by smaller protocones and deep vestibular grooves. Comparison with material from the similar species at Gesher Benot Ya'aqov shows the body proportions to resemble those of extant wild asses; therefore they suggest a dry environment as extant gracile equids typically inhabit such environments.

Family Bovidae The sample comprises fourteen cheek teeth and one nearly complete distal metacarpus. The systematic study of these fossils is hindered by the small collection with broken and not always well-preserved fossils and the lack of complete horn-cores. Within this sub-assemblage three species of the family Bovidae are present: Bovini gen. et sp. indet. (cf. *Bison* sp.), Antelopini gen. et sp. indet. (cf. *Pontoceros ambiguus* or *Spirocerus* sp.) and *Gazella* sp. (*Gazella* cf. *G. gazella*).

Bovines are represented by two molars (Table 5; Fig. 7). The size of these dental specimens and the general anatomy indicate that they probably correspond to the genus *Bison*, which is less hypsodont and smaller than *Pelorovis* (synonym of *Bos* after Martínez-Navarro et al.,

2007). *Bison* is present at 'Ubeidiya (Haas, 1966; Geraads, 1986; Martínez-Navarro et al., in preparation), and probably at Gesher Benot Ya'aqov (Martínez-Navarro and Rabinovich, 2011).

A total of nine fossil teeth and a distal end of a metacarpus correspond to Antelopini gen. et sp. indet. (cf. *Pontoceros ambiguus* or *Spirocerus* sp.) (Table 5; Fig. 7). This species is characterized by a brachydont and prismatic dentition with relatively thin enamel. Probably all the dental pieces ascribed to this species correspond to the same individual with the exception of BR 104, that has to be from another older individual. The distal left metacarpus BR 34 (Fig. 7) corresponds to an antelope of small middle size, in the variability of APL 99, APL 188 and APL 100, from Apollonia-1, all of them ascribed to *Pontoceros ambiguus* (Kostopoulos, 1997), and DM 2625 and DM 60 from Dmanisi (Buhksianidze, 2005) and smaller than APL 548, also corresponding to a middle size antelope from Apollonia-1. As in Dmanisi (Buhksianidze, 2005) in Apollonia there are probably two species of antelopes, *Pontoceros* and *Spirocerus*. The metacarpus from Bizat Ruhama likely corresponds to one of them. A similar Antelopini species, if not the same, is also present at the Early Pleistocene site of 'Ubeidiya (according to a revision by Martínez-Navarro et al., in preparation). It is not present in the later site of Gesher Benot Ya'aqov (Martínez-Navarro and Rabinovich,

Table 5
Description of selected Bovid specimens from Bizat Ruhama (see also Fig. 7)

Identification	Catalog number	Specimen	Description
Tribe Bovini (cf. <i>Bison</i> sp.)	BR-28	Lower molar	Well-developed parastylid and metastylid, mesostylid only present in the apical region of the crown, well developed exostylid covering 3/4 of the total height of the crown, absence of goat fold, simple pre and post-fossetas.
	BR-65	Probably lower M1 (anterior lobe and the mesial region of the second lobe)	
Tribe Antelopini (cf. <i>Pontoceros ambiguus</i> or <i>Spirocerus</i> sp.)	BR-31	Upper P2	Developed second mesial lobe in the lingual face, presenting two lobes. The buccal face is concave with a mesial fold related with the anterior lingual lobe. In the occlusal view it shows the fosseta displaced to the anterior region in between both lobes.
	BR-55	Upper P4, no lingual face, only one lobe	Buccal face is sub-plane with well developed para- and metastyle. The fosseta is simple and slightly displaced to the mesial region.
	BR-66	Upper M1	Three teeth that probably correspond to the same individual.
	BR-26	Upper M2	M1 is more worn than M2, and M3 is practically unused. All are semi-prismatic with the base larger than the apical region.
	BR-25	Upper M3	The anterior lobe is mesio-distally more compressed and bucco-lingually larger than the posterior one. The M1 and M2 have similar anatomy with plane buccal faces, and para- and metastyle less developed than the mesostyle. In the occlusal view, the pre- and post-fossetas are relatively simple. The M3 is similar to the other two but the second lobe is mesio-distally more compressed in the apical region and the distal metastyle is not prolonged.
	BR-110	Lower P4, no mesio-labial region	Displays paraconid-metaconid junction
	BR-27	Lower M2	All the lower molar specimens are prismatic and characterized by the presence of the Caprini fold in the mesial region. No exostylid. The M2 has two lobes and the M3's have a prolonged metastylid that seems the third distal lobe. The fossetas are simple.
	BR-104	Lower M3	
	BR-120	Lower M3	
	<i>Gazella</i> sp.	BR-34	Distal metacarpus
BR-24		Upper M3	Well-developed bucco-lingual diameter that is larger in the anterior lobe than in the posterior one. No entostyle. The buccal face is sub-plane, with the second lobe obliquely oriented from the first one, pronounced parastyle to the mesial region, marked mesostyle, and pronounced distal metastyle.

obscure some inconspicuous marks such as percussion pits and microstriations.

Cutmarks represent the most notable bone-surface modification at Nahal Hesi. Cutmarked specimens amount to 9% of NSP (11 specimens, four on medium-size class specimens and seven on large size-class specimens; Table 4, Fig. 8). All cutmarks were found on long bones, except for one ischial fragment. At least six of the cutmarked specimens represent filleting activities, as they are found on meat-bearing limb-bone shafts. Two specimens (fragments of limb joints) represent carcass dismemberment (following Binford, 1981). A detailed description of butchery at Nahal Hesi is beyond the scope of the present study; nevertheless it can be ascertained that the cutmarks attest to primary access of hominins to fleshed carcasses of medium and large ungulates, because they represent dismemberment and filleting activities. They also demonstrate that any carnivore involvement followed hominin butchery, not vice-versa.

As in the Bizat Ruhama assemblage, the Nahal Hesi collection is almost entirely composed of isolated teeth and long-bone shaft fragments. Some epiphyseal fragments are present, but ribs and vertebrae are entirely absent (Supplementary Online Material 3). Accordingly, the identified sample of the medium ungulate size class exhibits marked dominance of heads and an underrepresentation of limbs and axial elements (Fig. 4). The survival of skeletal elements correlates significantly with bone mineral density, even more so when considering the teeth are omitted from that analysis. No correlations between skeletal element survival (MAU) with either utility or marrow content were found (Table 4).

Family Equidae Our identification of the Nahal Hesi equids expands on the previous work by Davis (1980) using a larger sample and the body of data that accumulated since his study. The sample comprises five upper and 18 lower cheek teeth (Fig. 9;

Supplementary Online Material, Table 4). One upper tooth (NH 39V, probably a P3), seems caballine by its large stylids, a well developed *pli caballin*, and an elongated protocone; the wide and grooved mesostyle of an upper P2 (NH 64) is also a caballine character (Fig. 9). All of these characters, however, may occasionally occur in asses. Two lower cheek teeth have flat hypocones, a usual characteristic in caballines but the double knot of the premolar is not typically caballine (Fig. 9). Moreover, both teeth are much worn. All other cheek teeth could belong to an ass or a hemione. The pattern of the upper M3 may be found in both groups; on the lower cheek teeth, the vestibular groove is shallow even on the molars (Fig. 9). By its elongated metastylid, NH 109 closely resembles MOC 16 from the Aterian of Ain Tit Mellil, Morocco, referred to as *Equus melkiensis* (Eisenmann, 2006), a kind of ass, possibly present during the Middle Pleistocene at Tighenif (Geraads et al., 1986) and Tihodaïne (Algeria) (Thomas, 1977). Another specimen (NH 34V) resembles a specimen from Tabun C (British Museum, no number). In sum, the equid teeth from Nahal Hesi probably belong to a kind of primitive ass like *E. melkiensis*. The presence of a caballine is possible but far from certain. Given that recent asses inhabit dry environments, the asinine characteristics point to a dry environment at Nahal Hesi.

The Northern Negev sites presented here are dominated by Lower Pleistocene and Middle Pleistocene equids. The taxonomy and evolution of equids at the transition between the Lower and Middle Pleistocene are yet poorly understood. Schematically, there existed during the Lower Pleistocene slender middle-sized equids like *E. tabeti* of Aïn Hanech (Algeria), and the probably related equids of Ubeidiyeh (Eisenmann, 1986) and Latamné (Guérin et al., 1993). To this group we refer the equid from Bizat Ruhama. Lack of data, in particular of well preserved skulls, makes impossible to refer them to *Allohippus* or *Equus* (Eisenmann and Baylac, 2000). They are certainly not related to *E. mauritanicus*, a Middle Pleistocene North African plains zebra, and probably not to *E. hydruntinus*, which belongs to the group of Hemiones (Eisenmann, 1992;

Orlando et al., 2006). Most *Equus* species close to the extant seem to appear at the beginning of the Middle Pleistocene (Eisenmann, 2006). One of these is the North African *E. melkiensis*, probably related to extant Asses, to which we tentatively refer the equid of Nahal Hesi.

Discussion

Taphonomy and subsistence in the northern Negev during the Lower Paleolithic

Understanding the formation of the Bizat Ruhama bone assemblage is not straightforward. Some evidence exists for hominin modifications of the bones, in the form of fresh-fractured limb bones and percussion marks, indicating marrow extraction, and one cutmark indicating butchery. Some evidence also exists for carnivore involvement, in the form of several gnawed and tooth-scored bones. The clear association of the bones with lithic artifacts in what seems to be an *in situ* living surface (indicated by three bone conjoins [see also Zaidner, in preparation]), the absence of large carnivore remains and the evidence from bone-surface modifications and bone fracture patterns all suggest that the faunal remains of Bizat Ruhama represent anthropogenic food debris. Ungulate carcass parts underwent some butchery and consumption by hominins targeting bone marrow, which potentially provides important caloric intake (e.g., Speth, 1989; Bar-Oz and Munro, 2007). The ungulate remains may have been acquired by hunting, but presently we lack sufficient information (specifically cutmarks on meat-bearing skeletal parts) to support this. A likely alternative scenario is the acquisition of ungulate carcass parts by scavenging from carnivore kills, accounting for the gnaw marks (as a result of carnivore defleshing before hominin involvement), the rarity of cutmarks, and the evidence for extraction of marrow (possibly left available for hominins following carnivore consumption). The skeletal-element profile shows preference for heads, in accordance with the scavenging scenario (e.g., Stiner, 1994) but skeletal-element data may be problematic due to the small sample of identified elements and to the particularly strong density-mediated attrition.

At the later site of Nahal Hesi, the picture becomes clearer. The abundance of butchery marks on meat-bearing limb bones of large ungulates, the meager evidence for marrow extraction, and the rarity of signs for modification by carnivores demonstrate that this assemblage is the result of hominin acquisition of large ungulate prey as primary consumers, either by hunting or by aggressive scavenging (e.g., O'Connell et al., 2002; Dominguez-Rodrigo and Pickering, 2003). However, the skeletal-element profile at the site displays an abundance of heads over limbs, usually considered to represent marginal scavenging (e.g., Binford, 1981; Stiner, 1994). This seemingly contradicts the evidence for primary access of hominins to the carcasses, as indicated by butchery mark data. As in the earlier Bizat Ruhama site, it is possible that the strong fragmentation processes the assemblage had undergone broke many shafts to a point that they could not be identified anatomically and included in the skeletal-element analyses. This is in spite of the fact that the assemblage seems to be well-collected and curated, and despite our efforts to identify as many skeletal fragments as possible. The more durable teeth were less affected by attrition and subsequently were confidently included in the identified sample, thereby better-representing the number of animals brought to the site. In light of the preservation problems, we tend to prefer the evidence from bone-surface modification to discern the mode of carcass acquisition at Nahal Hesi.

The notion that the faunas of Bizat Ruhama and Nahal Hesi are anthropogenic is important in the context of the Lower Paleolithic.

At other sites in the Southern Levant and beyond archaeofaunal assemblages derive primarily from either carnivore kills or natural mortality, with restricted hominin input. Specifically, limited hominin involvement has been documented for Dmanisi and Akhalkalaki (Tappen et al., 2002a, b), Ambrona (Villa et al., 2005), Ubeidiya (Belmaker, 2006), most of the Olduvai Bed I sites (Dominguez-Rodrigo et al., 2007), and Elandsfontein (Klein et al., 2007; and see also Brain, 1981). Naturally, this limits the inferences that can be drawn from these assemblages with respect to hominin hunting and subsistence. Contrary to that, the assemblages presented here seem to have derived from anthropogenic activities representing butchery of large ungulate carcass parts, with at least the later case (Nahal Hesi) exhibiting plausible evidence for primary access to the carcass. This notion was recently echoed by studies of diverse Lower Paleolithic assemblages such as Early Pleistocene FLK *Zinjanthropus* and BK at Olduvai (Dominguez-Rodrigo et al., 2007, 2009), the Early-Middle Pleistocene transition at Gesher Benot Ya'aqov (Rabinovich et al., 2008), and the Middle Pleistocene sites of Schöningen (Voormolen, 2008), Xujiayao (Norton and Gao, 2008) and Qesem

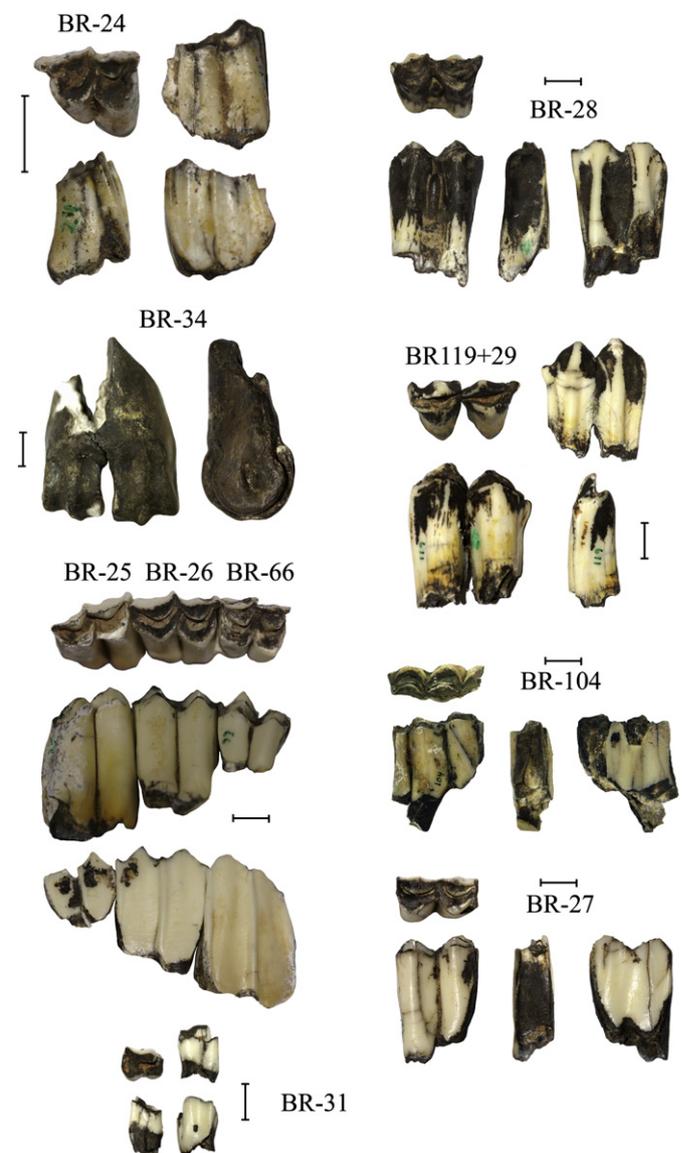


Fig. 7. Selected bovid specimens from Bizat Ruhama (see Table 5). Specimen BR119 + 29 represents a probable conjoin of two lower molar fragments of cf. *Bison* sp.