Archaeozoology

Taphonomic analysis of the bone remains from the Oldowan site of Garba IV

Ivana Fiore[1], Antonio Tagliacozzo[1]

Introduction

In the site of Garba IV, discovered in 1972 by J. Chavaillon, extensive excavations, that in the upper Levels C and D covered a surface of about 100 square metres, were carried out under the direction of M. Piperno (Piperno and Bulgarelli 1974-1975; Chavaillon *et al.* 1978, 1979; Berthelet *et al.* 2001). The site is composed by the superimposition of 5 archaeological Levels: C (the most recent one), D, E, F and G; these are covered by a tuff layer dated to 1.4 Ma. The base of the stratigraphic series can be instead correlated to the Oldowan site of Gombore I dated to 1.7 Ma. Levels C and D, the most extensively investigated, are represented by surfaces with pebbles included within a layer of fine sands. Camps had been established on these pebble banks as indicated by the presence of rich lithic industry and the abundance of faunal remains. The lithic industry, obtained mainly from volcanic rocks (basalt, obsidian, trachyte, etc.), is made for the most part of pebble tools (choppers and polyedrons) associated to frequent flakes and tools on flake (scrapers and denticulates) with rare handaxes and cleavers.

The highest concentration of artefacts and animal skeletal remains is on paleosurface D, where areas of obsidian knapping have been hypothesized, and there are also zones with large basalt blocks surrounded by numerous bones and horns as well as concentrations of bones and artefacts which may reflect, besides a long hominid frequentation of the site, also a possible spatial organization of the paleosurface (D'Andrea *et al.* 2002 a, b).

The faunal remains

There are 2945 faunal remains from the site of Garba IV; almost all of them (2580 equal to 87.6%) belong to Level D; 243 elements, equal to 8.2%, have been collected from Level C; the other Levels (E-F)

1. Soprintendenza Speciale al Museo Nazionale Preistorico Etnografico "L. Pigorini". Sezione di Paleontologia del Quaternario e Archeozoologia, P.le Marconi 14, 00144 Rome-Eur, Italy. Tel. 39 6 54952236; fax 39 6 54952310. pigorini@arti.beniculturali.it

and test trenches (A, B) yielded only few dozen of specimens (Tab. 1). Furthermore, there are 50 fragments whose exact stratigraphic position is not known.

The paleontological study (Geraads 1979; Geraads *et al.* in this volume), carried out on 2170 specimens (Tabs. 1, 2) allowed some kind of taxonomic attribution for 39.2% of the bone remains, but, because of the high fragmentation, only in few cases it was possible to identify the species; more often the attribution was done only at the genus or family level. The greatest difficulties were mainly for the Bovidae: in fact, the wide variety of genera and species included in this family allowed the identification only of a few species, mostly on the basis of tooth and horn morphometry (*Pelorovis turkanensis brachyceras* among the Bovini, *Connochaetes gentryi leptoceras*, *Damaliscus strepsiceras*, *Damaliscus* cf. *lunatus*, *Parmularius* cf. *angusticornis* among the Alcelaphini, *Gazzella* cf. *janeschi*, *Antidorcas* cf. *recki* among the Antilopini), while for the badly preserved post-cranial elements or cranial fragments, it has been almost impossible to identify the genus or the species. For these latter specimens sometimes the tribe was indicated (Bovini, Reduncini, Alcelaphini, Antilopini), but for the most problematic specimens it was not possible to go beyond a general indication of the family (Bovidae). For the taphonomic analysis, these specimens have been divided, on the basis of the dimensions and mainly on the thickness of the bones, into Large, Medium, and Small sized Bovids, indicating with Large remains referable to animals of the size of *Connochaetes* or *Pelorovis*, with Medium those of *Damaliscus* and *Parmularius*, and with Small those of *Gazzella* or *Antidorcas*.

The faunal assemblage from Garba IV is characterized, in the count of specimens, by the prevalence of hippopotamus (44.1%), followed by Bovids (41.6%) and, with much lower percentages, by Equids (10.9%) and Suids (1.5%), while Carnivores, Primates, elephants, giraffes, Birds and Reptiles are present only with rare remains, not reaching a total of 2%. The difficult estimate of the Minimum Number of Individuals, mainly for the above mentioned problems in the identification of Bovids, confirms only in part the proportions among species obtained from the number of identified specimens. The minimum number of hippopotamus individuals (MNI 16) is in fact lower than that of the Bovids (MNI 22), although it should be considered that the latter ones are surely underestimated. Equids and Suids are represented by five and four individuals respectively (Tabs. 1, 2 and Figs. 1-3).

Among the Bovids, mainly coming from Level D, Alcelaphini remains are prevalent (16.8% and 16 individuals), while Bovini and Antilopini, represented by a few dozen specimens, have values around 1-2% and belong to at least five individuals; Reduncini are represented only by a single specimen (Tabs. 1, 2).

The estimate of the age at death indicates that remains of adult individuals are prevalent. Few juvenile specimens can be referred to the Equids, the hippopotamus and the Alcelaphini.

Anatomical composition

The whole faunal sample is characterized by high fragmentation and the analysis of the skeletal portions in the different levels at Garba IV shows that most of the 2945 remains cannot be referred to a particular anatomical portion (32.4%) or belong to diaphyseal fragments of an indeterminate limb (22.8%) (Tab. 3A, B).

Among the specimens whose anatomical position could be identified, cranial elements are prevalent (27.4%). These are mainly isolated teeth and horn-core fragments (20.8% and 4.5% respectively) while fragments of maxilla are very rare (just five) in contrast to those of the mandible (30) and, together with few other cranial fragments, represent a total of just 2.1% of the skeletal portions (Tab. 3A, B). The scapular and pelvic girdles represent only 1.8% of the sample. Limb bones are indicated primarily by front limb elements (2.5%), mostly radius fragments (30 out of 35 specimens), and by some fragments of ulna and

Taxa	C	D	E	F	A	B	Indet.Lev.	Tot. remains	MNI
Enhydriodon aethiopicus			1					**1**	1
Small carnivore		1						**1**	
Theropithecus cf. *osvaldi*		1						**1**	1
Elephantidae		2						**2**	1
Hipparion sp.		3						**3**	1
Equus sp.	6	44					1	**51**	5
Equidae	1	33			2	1	2	**39**	
Hippopotamus cf. *amphibius*	3	19	1				1	**24**	4
Hippopotamus sp.	29	303	7	3			9	**351**	16
Kolpochoerus majus		2	1					**3**	1
Metridiochoerus cf. *compactus*		1						**1**	1
Suidae		8	1					**9**	1
Giraffa cf. *jumae*		1						**1**	1
Sivatherium maurusium		1						**1**	1
Pelorovis turkanensis brachyceras		11					2	**13**	2
Pelorovis sp.		5					1	**6**	
Reduncini		1						**1**	1
Connochaetes gentryi leptoceras		2						**2**	2
Connochaetes sp.	1	30					3	**34**	8
Damaliscus strepsiceras		1						**1**	1
Damaliscus cf. *lunatus*		1						**1**	1
Damaliscus sp.		27	1				2	**30**	7
Parmularius cf. *angusticornis*		2					2	**4**	1
Alcelaphini	3	64	1			1	2	**71**	10
Gazzella cf. *janeschi*		1						**1**	1
Antidorcas cf. *recki*		4						**4**	1
Antilopini		4					1	**5**	2
Bovidae	5	43				1	8	**57**	
Large Bovid		10						**10**	
Medium Bovid	5	49	2		1			**57**	
Small Bovid	1	56						**57**	
Crocodile	1	5						**6**	2
Testudinoidea		1						**1**	1
Aves			1					**1**	1
Indeterminate									
Hippopotamus size	4	51						**55**	
Large size	30	278	9	1				**318**	
Large-Medium size	3	69	5					**77**	
Medium size	36	211	6	1	1			**255**	
Medium-Small size	1	24	1					**26**	
Small size	8	61	2					**71**	
Completely Indeterminate	47	443	7	0	2	4	15	**518**	
Total remains analyzed	184	1873	46	5	6	7	49	**2170**	
Not analyzed	59	707	5		2	1	1	**775**	
Total remains	**243**	**2580**	**51**	**5**	**8**	**8**	**50**	**2945**	

Tab. 1. Total number of remains for the different *taxa* by level.

Taxa	C	D	E	F	A	B	Indet. Lev.	Total	%	MNI
Carnivora		1	1					**2**	0.2	1
Primates		1						**1**	0.1	1
Elephantidae		2						**2**	0.2	1
Equidae	7	80			2	1	3	**93**	10.9	5
Hippopotamus	32	322	8	3			10	**375**	44.1	16
Suidae		11	2					**13**	1.5	4
Giraffidae		2						**2**	0.2	2
Bovini		16					3	**19**	2.2	3
Reduncini		1						**1**	0.1	1
Alcelaphini	4	127	2			1	9	**143**	16.8	16
Antilopini		9					1	**10**	1.2	2
Bovidae indet.	11	158	2		1	1	8	**181**	21.3	
Aves			1					**1**	0.1	1
Reptilia	1	6						**7**	0.8	3
Total identified	**55**	**736**	**16**	**3**	**3**	**3**	**34**	**850**	**39.2**	**56**
Total indeterminate	**129**	**1137**	**30**	**2**	**3**	**4**	**15**	**1320**	60.8	
General Total	**184**	**1873**	**46**	**5**	**6**	**7**	**49**	**2170**		

Tab. 2. Frequency of the groups of the different *taxa*.

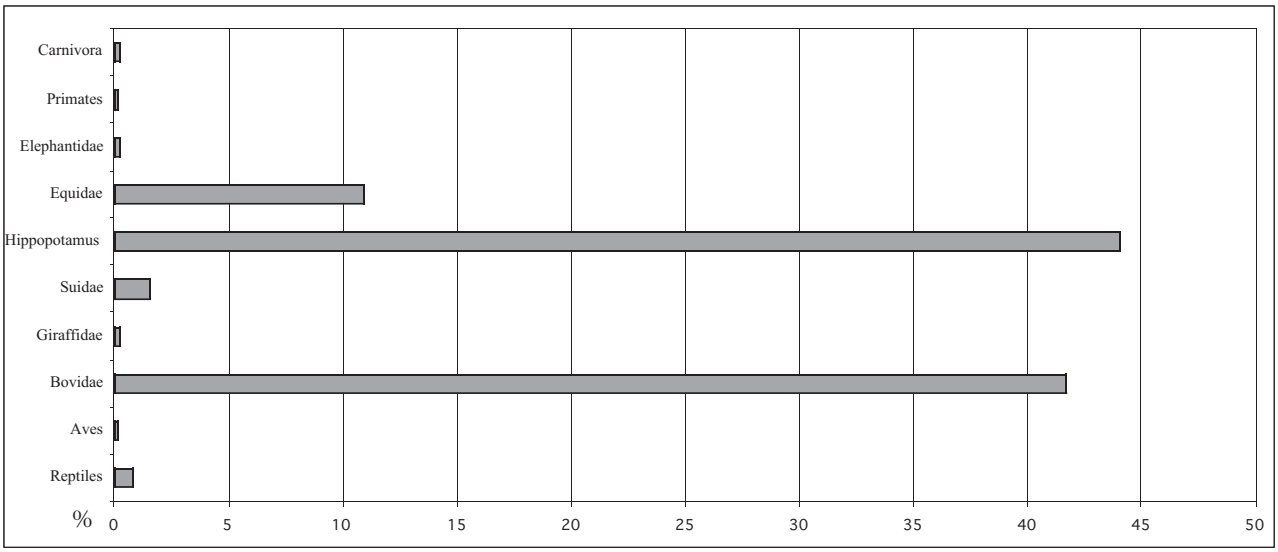

Fig. 1. Total number of remains: proportions among the different *taxa*.

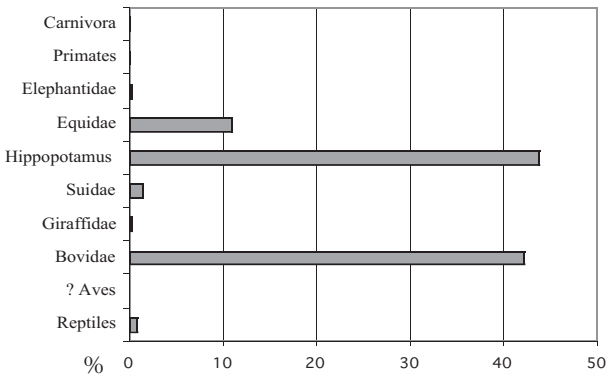

Fig. 2. Level D: proportions among the different *taxa*.

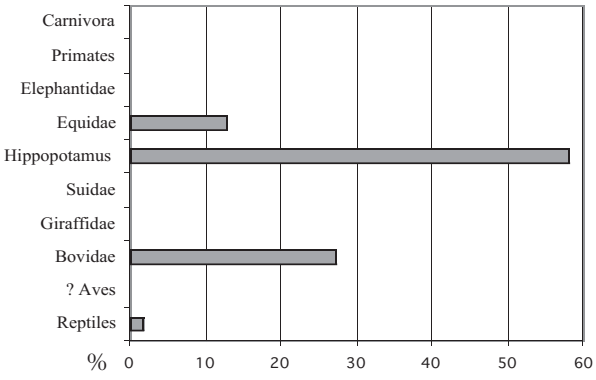

Fig. 3. Level C: proportions among the different *taxa*.

Skeletal portion	C	D	E	F	A	B	Indet. Lev.	Total N
Horn	2	86	1				8	**97**
Cranium	6	39					1	**46**
Tooth	33	390	8	3	3	3	12	**452**
Girdle	3	36	1					**40**
Axial	16	91	3	1		1	3	**115**
Front limb	4	47					3	**54**
Hind limb	1	32	2				1	**36**
Distal limb	7	110	6			1	9	**133**
Indet. long bone	66	418	6	1	1		2	**494**
Exoskeleton		1						**1**
Indeterminate	46	623	19		2	2	10	**702**
Total N	**184**	**1873**	**46**	**5**	**6**	**7**	**49**	**2170**

A

Skeletal portion	C	D	E	F	A	B	Indet. Lev.	%
Horn	1.1	4.6	2.2				16.3	4.5
Cranium	3.3	2.1					2.0	2.1
Tooth	17.9	20.8	17.4	60.0	50.0	42.9	24.5	20.8
Girdle	1.6	1.9	2.2					1.8
Axial	8.7	4.9	6.5	20.0		14.3	6.1	5.3
Front limb	2.2	2.5					6.1	2.5
Hind limb	0.5	1.7	4.3				2.0	1.7
Distal limb	3.8	5.9	13.0			14.3	18.4	6.1
Indet. long bone	35.9	22.3	13.0	20.0	16.7		4.1	22.8
Exoskeleton		0.1						0.1
Indeterminate	25.0	33.3	41.3		33.3	28.6	20.4	32.4

B

Tab. 3. Skeletal portions: A) number of remains; B) percentages.

humerus. The hind limb bones are much more rare (1.7%), represented mainly by tibia fragments (19 out of 21 specimens). Distal limb elements (metapodials, carpals, tarsals, and phalanges) are quite abundant (6.1%) and are represented mainly by metatarsal (32) and metacarpal (25) fragments and by numerous fragments of indeterminate metapodials (35); phalanges are rare (9), as are the calcanei (6), the astragali (4) and the other carpal and tarsal bones. Axial elements represent 5.3% of the remains and include mainly rib fragments (73) and more rare vertebral fragments (42).

The skeletal composition in the two levels with the highest number of remains is very similar in percentage, although Level D is characterized by a higher frequency of horn remains and a lower proportion of axial elements compared to the overlaying Level C (Fig. 4).

The analysis of the skeletal portions carried out for the different species, genera and/or families is, as expected, not very different from the general one (cranial elements are always prevalent), but evidenced some particularities.

Equids (*Equus* and *Hipparion*) are represented almost exclusively by isolated teeth (82.8%) and distal limb fragments (12.9%; Tab. 4). Among the latter ones five metacarpals, four indeterminate metapodials, a calcaneus, a magnum and a phalanx have been identified. Limb bones are represented only by two tibia and one radius fragments, while axial elements are completely absent.

The hippopotamus (*Hippopotamus* sp. and *Hippopotamus* cf. *amphibius*) is represented by tooth fragments, Number of Identified Specimens (NISP) 231 equal to 61.6%, most of which cannot be referred to a specific element. Among the identified ones canine fragments are prevalent (NISP 75); molars (25), incisors (20),

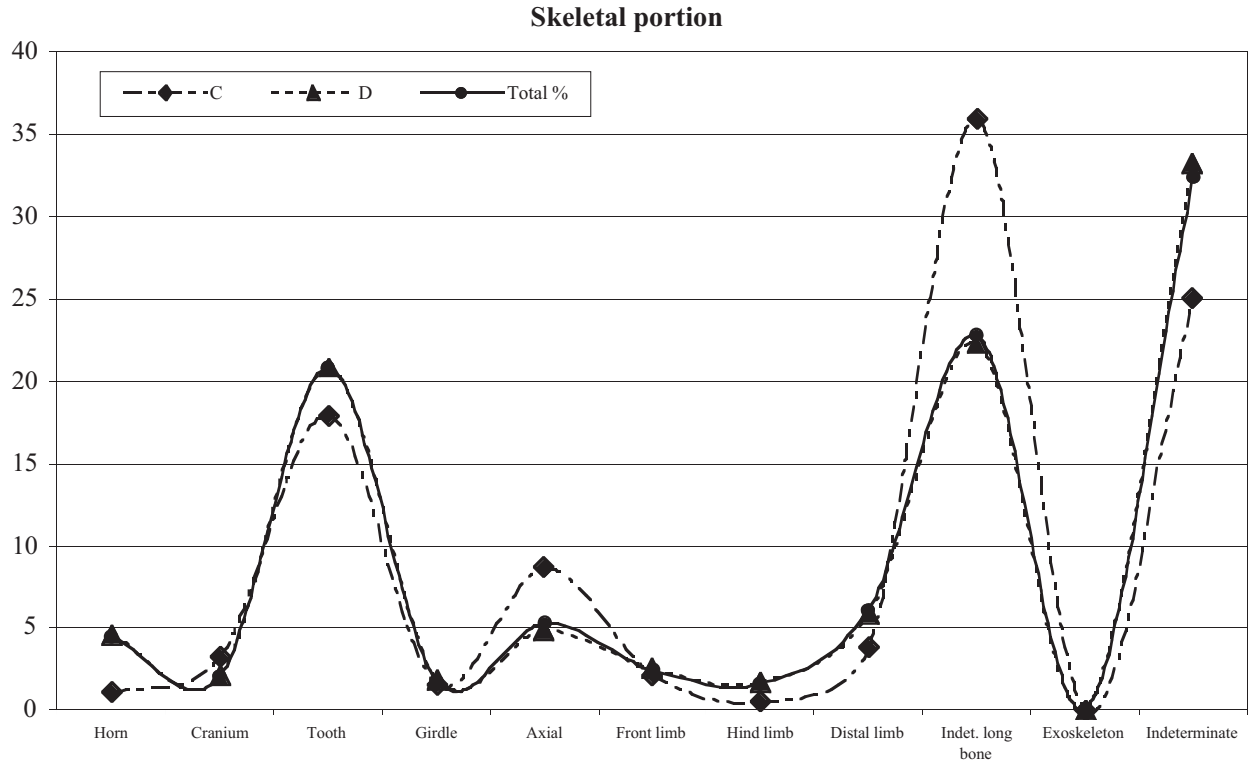

Fig. 4. Frequency of skeletal portions in Levels C and D.

Equidae							
Skeletal portions	**C**	**D**	**A**	**B**	**Indet. Lev.**	**Total**	**%**
Cranium		1				1	1.1
Tooth	7	64	2	1	3	77	82.8
Girdle							
Axial							
Front limb		1				1	1.1
Hind limb		2				2	2.2
Distal limb		12				12	12.9
Total NISP	**7**	**80**	**2**	**1**	**3**	**93**	

Tab. 4. Skeletal portions of the Equids.

and premolars (10) are more rare (Tab. 5A, B). Distal limb elements are the best represented post-cranial portion (NISP 25 equal to 6.7%), with 13 metapodials, three calcanei, one astragalus, and eight carpal and tarsal bones. Axial elements make up 6.1% of the hippopotamus remains, with one atlas and 16 vertebrae, while there are only six ribs. The girdles too are relatively well represented (4.5%), especially pelvis fragments (11) and more rare scapulae (6). The hind limb is better represented than the front one and both femurs and tibiae are present. However, limb elements are more abundant than indicated because there are also several indeterminate long bones shaft fragments referable to the hippopotamus (3.5%).

The identified remains of Alcelaphini are almost exclusively cranial elements (93.8%), with horn fragments (41.3%) prevailing over isolated teeth (38.5%; Tab. 6). The only other portions represented are the front limb (a humerus fragment and a radius fragment) and the distal limb bones, mainly metatarsal fragments (Tab. 6). The Antilopini are represented by ten specimens: five are referable to the cranium (one horn and four mandibles), four to the front limb (three humeri and one radius), and one to the distal limb (Tab. 7). Among the Bovini remains cranial elements are prevalent with few distal limb bones (two carpals,

***Hippopotamus* cf. *amphibius* and *Hippopotamus* sp.**

Skeletal portion	C	D	E	F	Indet. Lev.	Total
Cranium	1	5				6
Tooth	16	207	2	3	3	231
Girdle	1	15	1			17
Axial	5	16	1		1	23
Front limb	1	3				4
Hind limb	1	8	1		1	11
Distal limb	2	16	3		4	25
Indet. long bone	4	8			1	13
Indeterminate	1	44				45
Total NISP	**32**	**322**	**8**	**3**	**10**	**375**

A

***Hippopotamus* cf. *amphibius* and *Hippopotamus* sp.**

Skeletal portion	C	D	E	F	Indet. Lev.	%
Cranium	3.1	1.6				1.6
Tooth	50.0	64.3	25.0	100.0	30.0	61.6
Girdle	3.1	4.7	12.5			4.5
Axial	15.6	5.0	12.5		10.0	6.1
Front limb	3.1	0.9				1.1
Hind limb	3.1	2.5	12.5		10.0	2.9
Distal limb	6.3	5.0	37.5		40.0	6.7
Indet. long bone	12.5	2.5			10.0	3.5
Indeterminate	3.1	13.7				12.0

B

Tab. 5. Skeletal portions of the hippopotamus: A) number of remains; B) percentages.

Alcelaphini

Skeletal portion	C	D	E	B	Indet. Lev.	Total	%
Horn		52	1		6	59	41.3
Cranium		20				20	14.0
Tooth	3	47	1	1	3	55	38.5
Girdle							
Axial							
Front limb		1				1	0.7
Distal limb	1	6				7	4.9
Indet. long bone		1				1	0.7
Total NISP	**4**	**127**	**2**	**1**	**9**	**143**	

Tab. 6. Skeletal portions of the Alcelaphini.

one metacarpal, one naviculo-cuboid, and two metatarsals; Tab. 7). Among the undeterminable Bovid remains, divided on the basis of size, although cranial elements are still prevalent (38.4%), post-cranial bones are also well represented, in particular distal limb elements (33.5%), mainly metatarsals (25), while metacarpals and phalanges are more rare. The front limb includes manly radius fragments and is better represented that the hind limb (Tabs. 8, 9).

Suids are represented exclusively by teeth as is the Primate and the Reduncini, while the giraffe is documented by a tooth and a metatarsal (Tab. 7).

Comparing the data from the two main Levels (C and D), and considering the high number of remains characterizing Level D compared to C, for the hippopotamus remains it is possible to observe small differ-

	Antilopini		Bovini		Suidae	
Skeletal portion	**D**	**Indet. Lev.**	**D**	**Indet. Lev.**	**D**	**E**
Horn	1					
Cranium	4		5	2		
Tooth			4	1	11	2
Girdle						
Axial						
Front limb	3	1				
Hind limb			1			
Distal limb	1		6			
Indet. long bone						
Total NISP	**9**	**1**	**16**	**3**	**11**	**2**

Tab. 7. Skeletal portions of Antilopini, Bovini and Suids.

Skeletal portion	**Bovidae**	**Large Bovid**	**Medium Bovid**	**Small Bovid**	**Total NISP**	**%**
Horn	13	2	7		22	11.9
Cranium	2		1	2	5	2.7
Tooth	18	4	9	13	44	23.8
Girdle			4	5	9	4.9
Axial						
Front limb	6	1	9	11	27	14.6
Hind limb	1		5	6	12	6.5
Distal limb	17	3	22	20	62	33.5
Indet. long bone	4				4	2.2
Total NISP	**61**	**10**	**57**	**57**	**185**	

Tab. 8. Skeletal portions of the indeterminate Bovids recovered in the different levels at Garba IV.

Skeletal portion	**Bovidae**	**Large Bovid**	**Medium Bovid**	**Small Bovid**	**Total NISP**	**%**
Horn	12	2	6		20	12.7
Cranium	1		1	2	4	2.5
Tooth	15	4	7	13	39	24.7
Girdle			3	5	8	5.1
Axial					0	0.0
Front limb	4	1	7	11	23	14.6
Hind limb	1		5	6	12	7.6
Distal limb	10	3	20	19	52	32.9
Total NISP	**43**	**10**	**49**	**56**	**158**	

Tab. 9. Skeletal portions of the indeterminate Bovids recovered in Level D.

ences in skeletal composition between the two samples. These are evident above all in the prevalence of cranial remains (mainly teeth) in Level D compared to Level C, where post-cranial bones are more abundant (Tab. 5A, B). However, it is not possible to suggest hypotheses about the causes of such differences: if these are related to different butchering and carcass exploitation models or, more simply, have been produced by natural processes related to the formation of the deposit.

Spatial distribution of the bone remains from Level D

The analysis of the spatial distribution of the animal skeletal remains have been carried out only on the specimens from Level D (the graphic output with the spatial distribution were made employing the program ArcView® GIS). The archaeological remains are not uniformly distributed, but they have been found

in two Sectors (Western and Eastern) separated by a drain. In this study all the bones recorded during the excavation have been considered although not all of them have been analyzed under a paleontological or taphonomic point of view. The 2580 faunal remains are distributed over 92 squares, with an average of 28 specimens per square metre, varying from a maximum of 128 remains in square 9E-6N to a minimum of one in squares 1E-10N, 7E-4N, 10E-2N (Figs. 5, 6; see also Plate XXVI, Volume II). In the two sectors it has been possible to evidence the areas with the highest concentration of specimens considering the adjacent squares with a number of remains above 40. In the Western Sector (WS) such area has a NE-SW orientation and ideally connects square 3E-9N to square 1W-3N, involving the adjacent squares. It includes 19 squares with a total of 1050 remains and an average of 52 specimens per square metre. In the Eastern Sector (ES) the area with the highest number of remains is W-E oriented and is defined by the row of squares 7-12E/6N and 8-12E/5N. It includes 11 squares with a total of 639 bone remains and an average of 58.1 specimens per square metre. The remaining 62 squares have an average of 14 specimens per square metre although most of those located close to the area identified in the WS yielded over 30 bones.

The remains referred to the hippopotamus (*Hippopotamus* sp. and *Hippopotamus* cf. *amphibius*), mainly the smaller fragments (teeth and tooth fragments), are widely distributed over the excavation area, while the largest specimens are found mainly in the WS (Fig. 7). It has been estimated that in Level D there are teeth belonging to at least ten individuals. It was not possible to evidence and recognize any post-cranial skeletal element in sure anatomical connection and the post-cranial remains recovered are numerically much fewer than expected. In the WS the highest density of remains can be observed in the area of squares 1-2E/7-8N and in that of squares 1W-5N, 1W-2E/4N; a particular cluster was evidenced in squares 1E/1-2N where two cervical vertebrae in strict association have been recovered, maybe belonging to a single

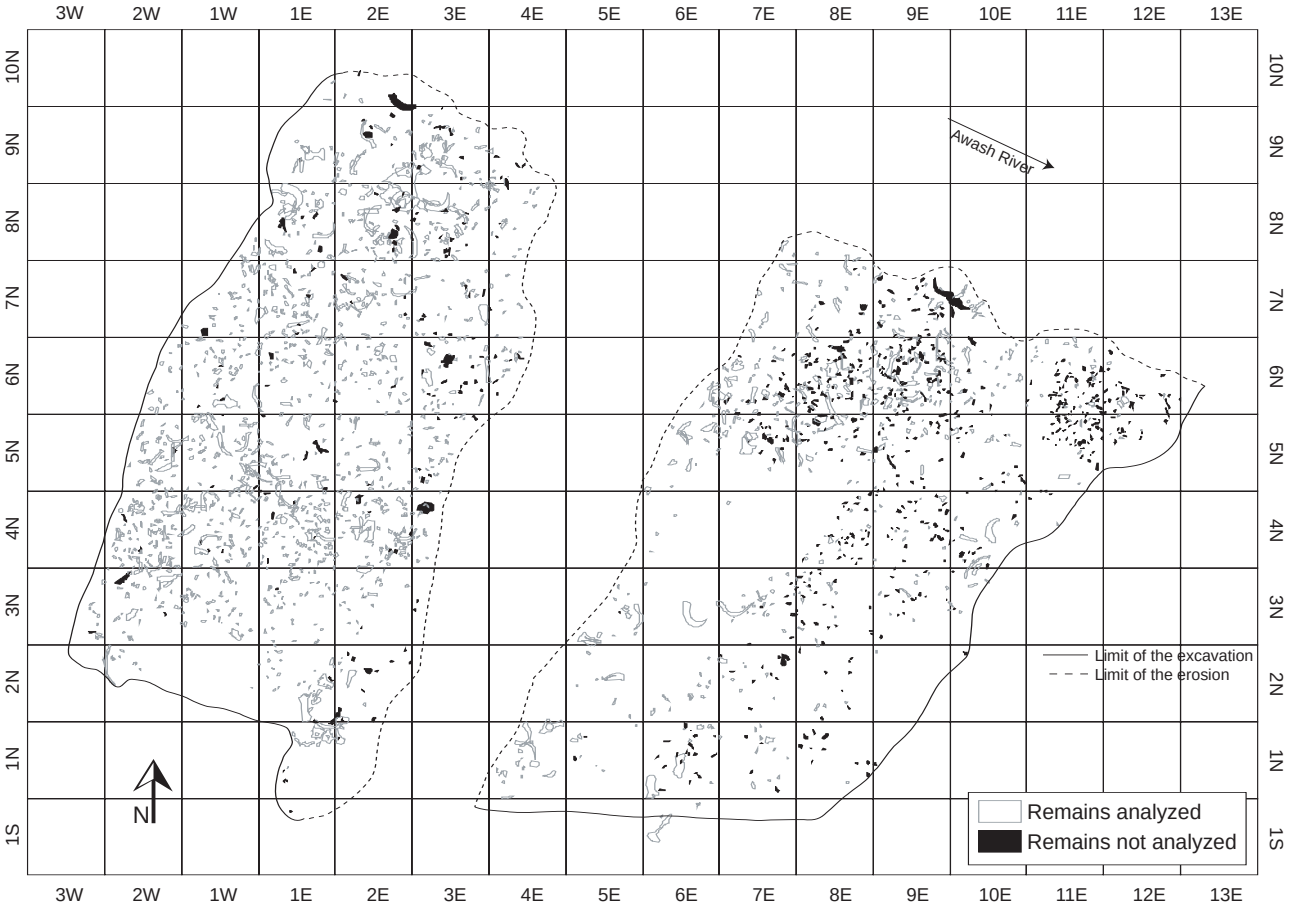

Fig. 5. Level D: spatial distribution of the whole assemblage.
(Original plan by G.M. Bulgarelli and M. Piperno, digital map by R. Gallotti)

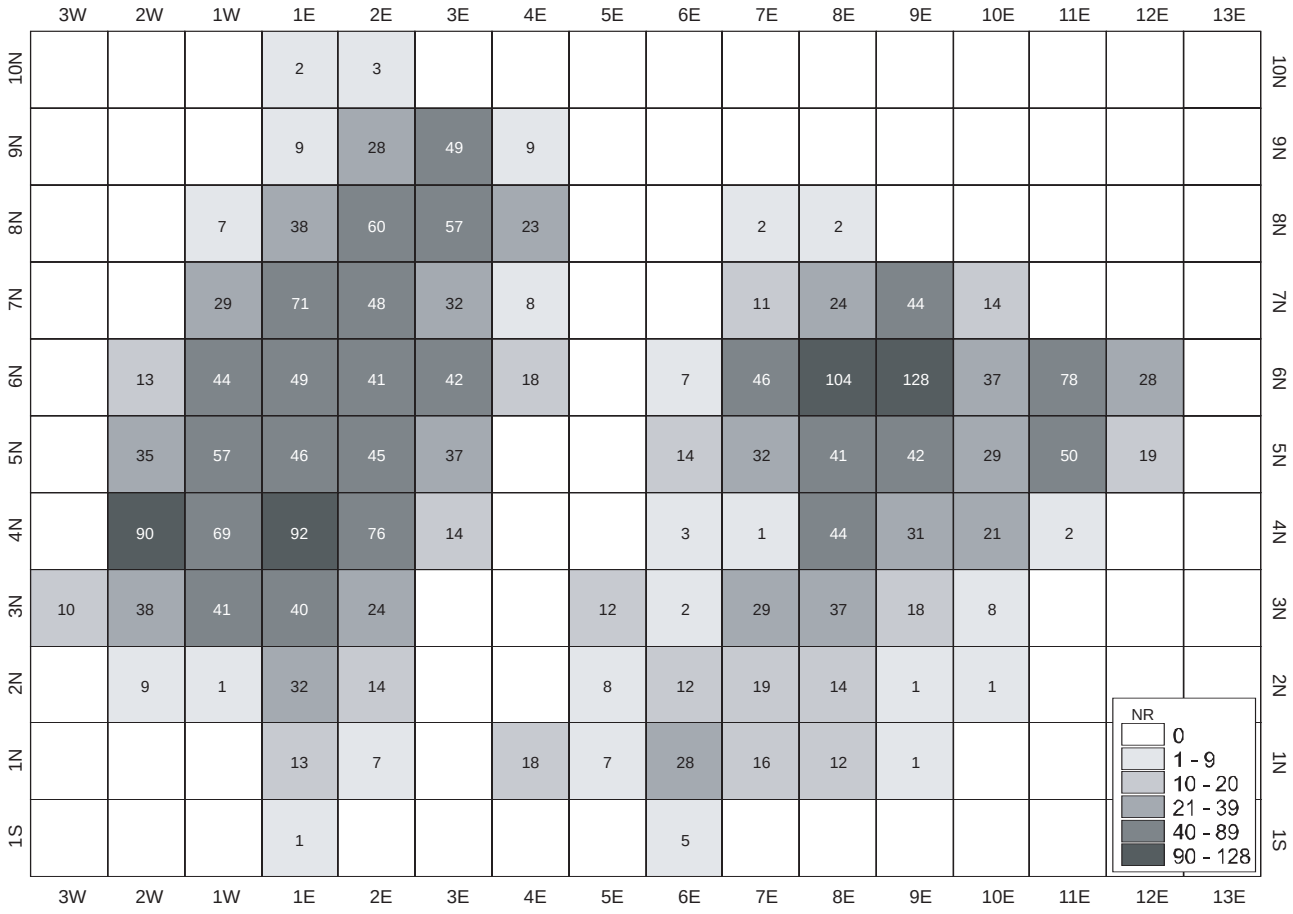

Fig. 6. Level D: frequency of the total number of remains.

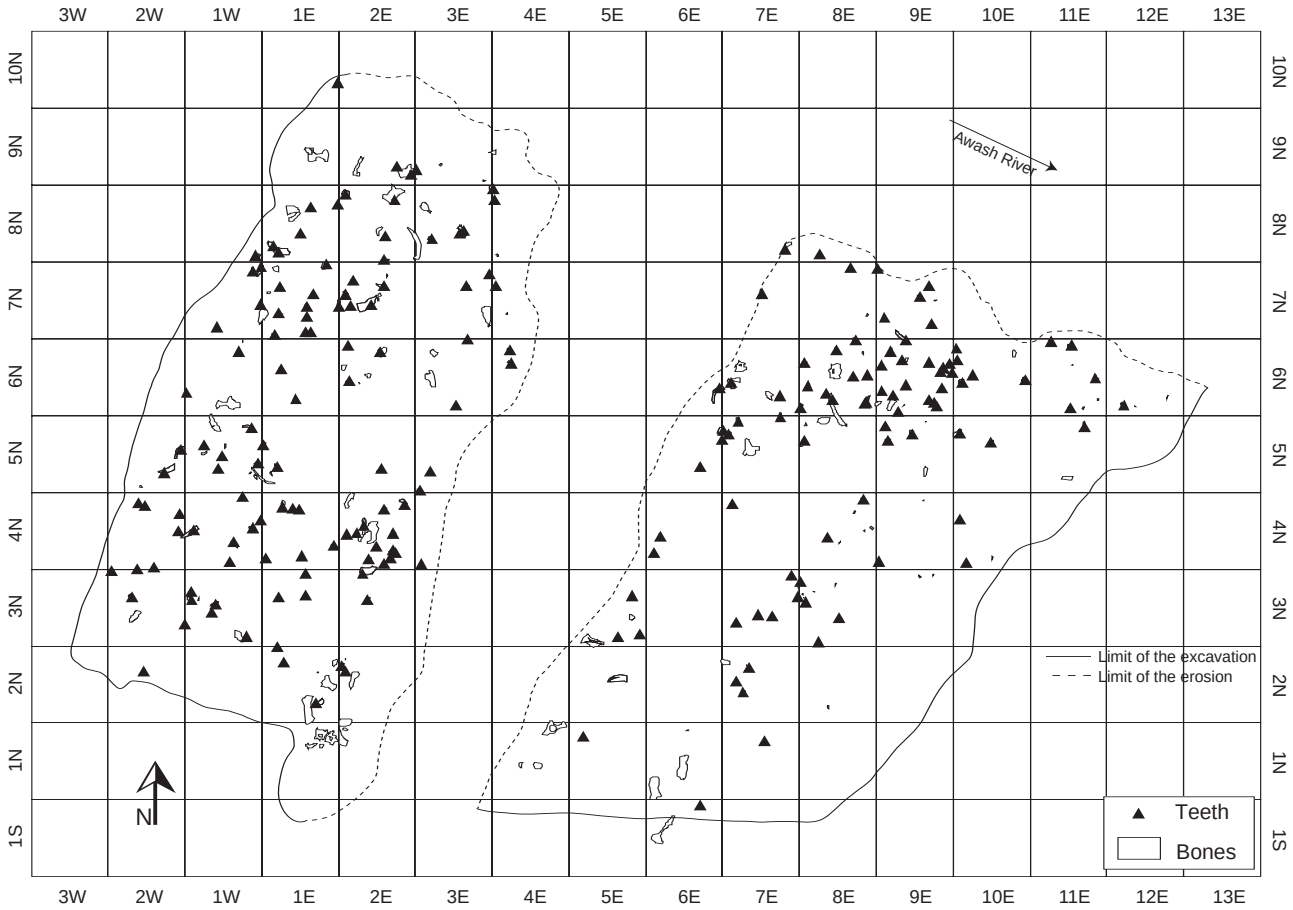

Fig. 7. Level D: distribution of the hippopotamus remains.

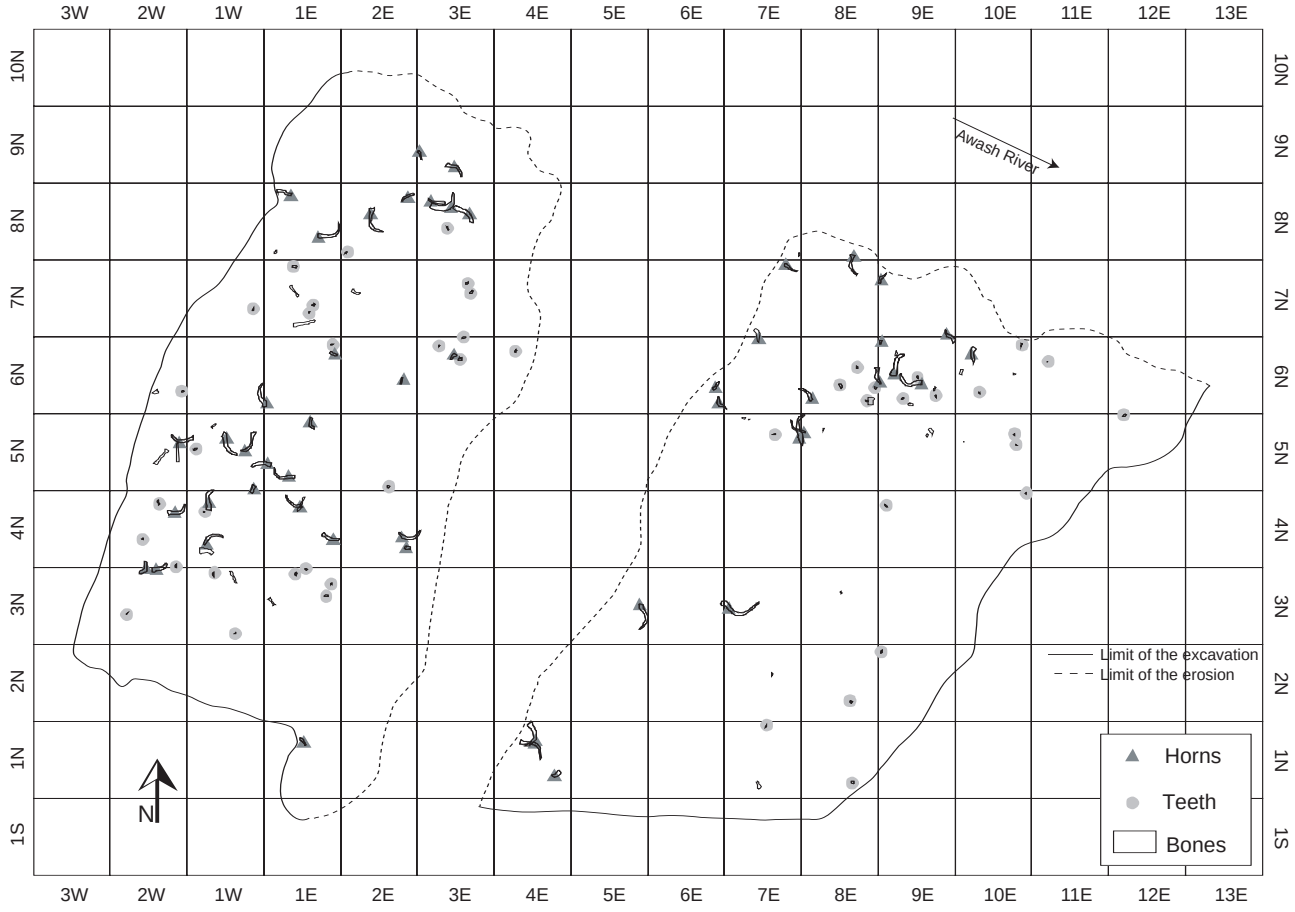

Fig. 8. Level D: distribution of the Alcelaphini remains.

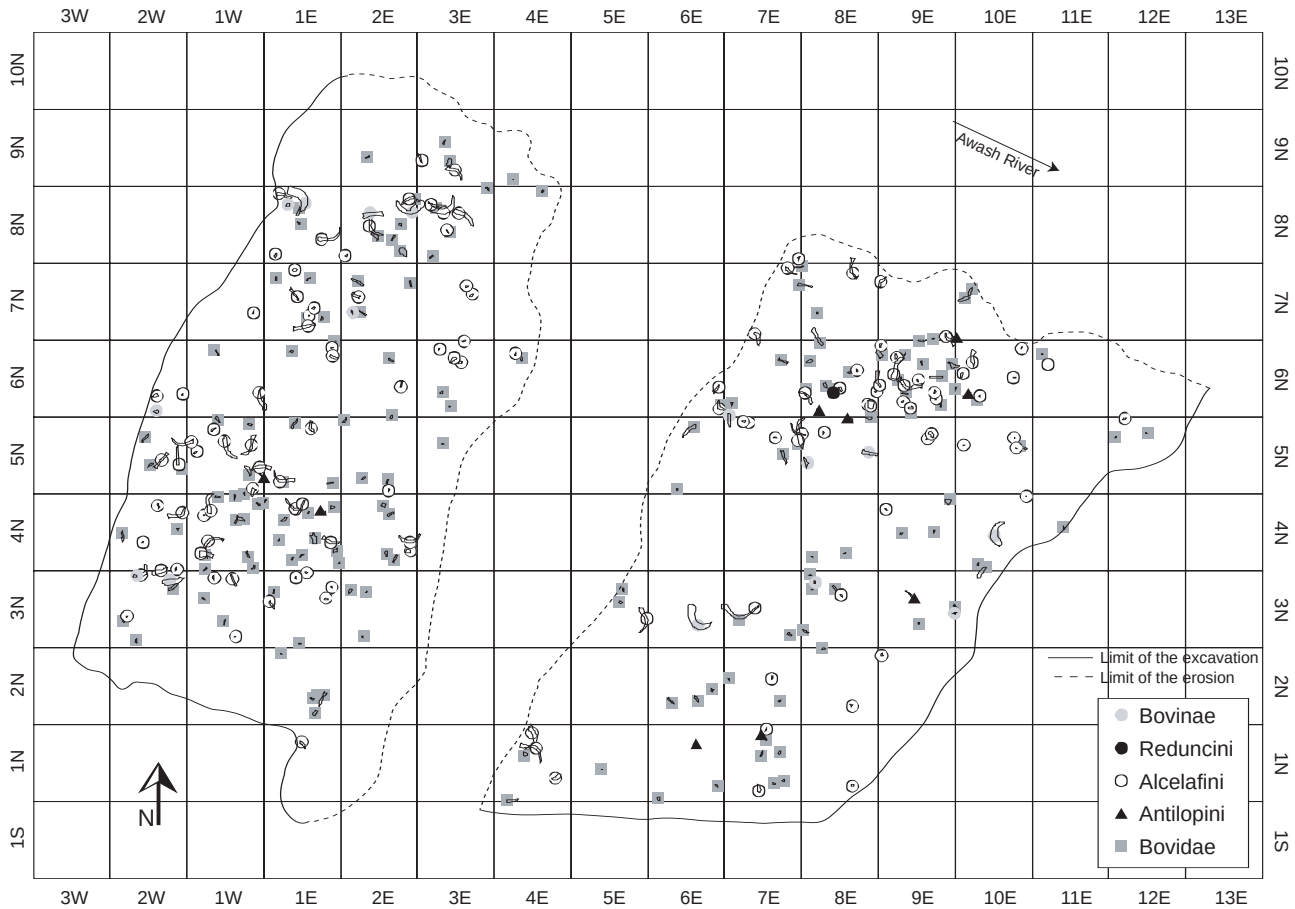

Fig. 9. Level D: distribution of the Bovid remains, on the basis of tribe and family.

individual. In the ES most of the remains are in area of squares 7-9E/6N and in the adjacent squares; it should be noted, among the numerous teeth, the presence of three vertebrae and some rib fragments, which could indicate the remains of the axial portion of a carcass.

The bone remains of the Alcelaphini, almost exclusively horn fragments an isolated teeth, are also widely distributed over the excavated area, although they are found mainly in the WS and are concentrated mostly in the area of squares 2W-1E/5-4N, the adjacent squares, and in some squares of the rows 7-8N (Fig. 8). In the ES the highest quantity of specimens is in the area of squares 8-10E/6N. The concentration of the Alcelaphini remains reflects in part the distribution of the hippopotamus elements (Figs. 7, 8).

Also the Bovids present the highest concentration of remains in squares 2W-1E/5-4N and 8-10E/6N. Equid specimens are widely distributed over the surface without evidencing particular concentrations with a prevalence of teeth in the southern squares of the WS (Fig. 9). The other identified remains (Carnivores, elephant, giraffes, Primates, and Reptiles) are too few to allow any consideration (Fig. 10).

The spatial distribution of the faunal remains, although with a wide dispersion, evidenced some concentration areas where the bones of hippopotamus and Alcelaphini as well as those of the other Bovids are resting. However, it is not possible to recognize segments of carcasses in anatomical connection or association; all this seems to reflect a strong dispersion and fragmentation due to post-depositional factors before the burial.

Dimensions of the specimens and their spatial distribution

The faunal sample from Garba IV is characterized by a high fragmentation: complete elements are rare, represented mainly by isolated teeth and distal limb elements (some metapodials as well as carpal and

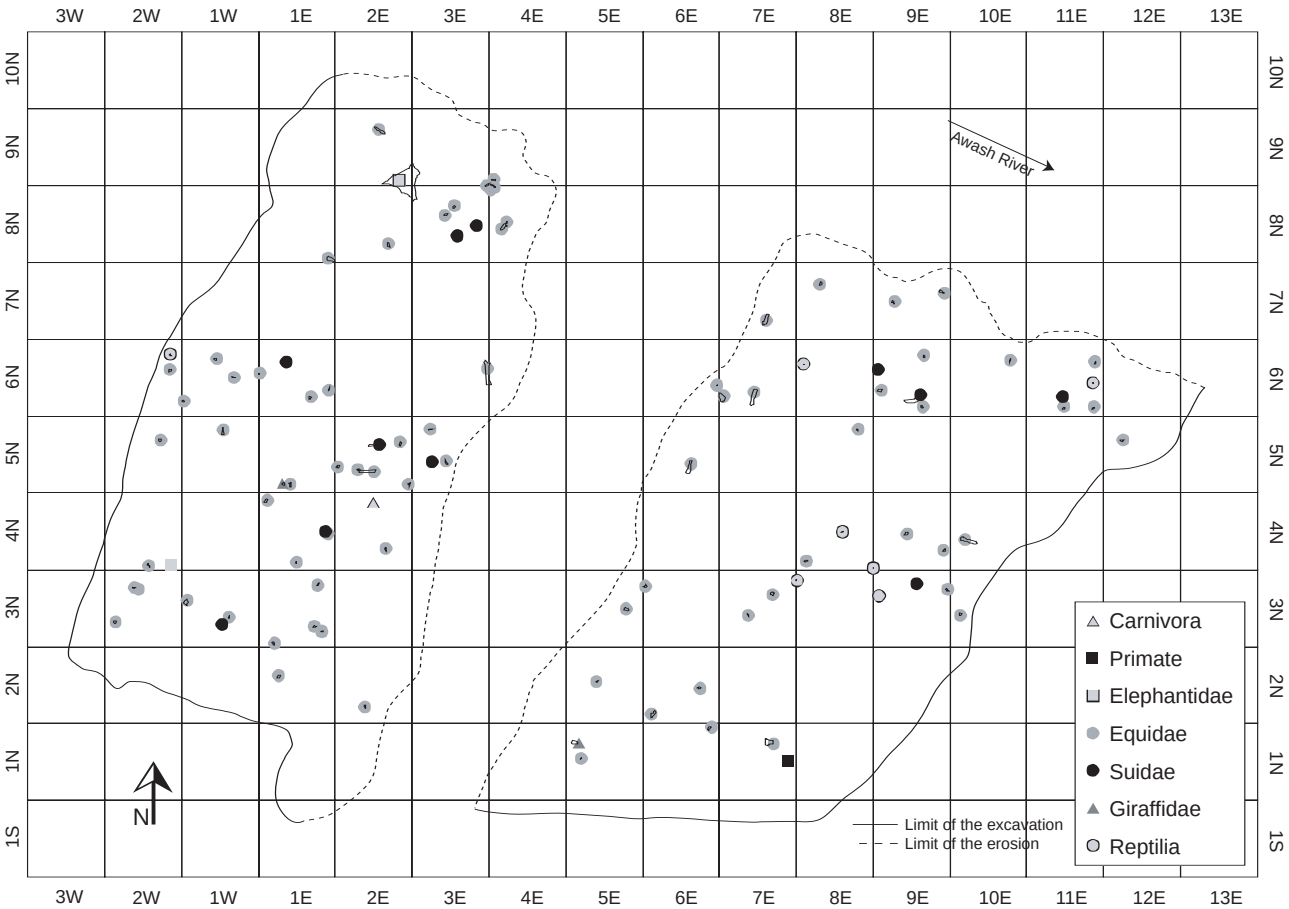

Fig. 10. Level D: distribution of the remains of the most rare *taxa*.

tarsal bones). Length and width are available for 2887 of the 2945 specimens recovered. Length varies from a minimum of 9.2 mm (length of a fragment of hippopotamus tooth) to a maximum of 550 mm (length of two ribs, one of a Bovid and one of a hippopotamus). The fragments have been divided into 21 dimensional classes by 25 mm increments in length (Tab. 10A, B). The class with the highest number of bones (1510 equal to 52.3%) is the one with length between 25 and 50 mm followed by the class between 51 and 75 mm with 614 remains (21.3%). Fragments with length between 1 and 25 mm and between 76 and 100 mm are also quite numerous representing about 6-7% of the sample. The other classes with the largest elements, include few specimens and those in the interval between 151 and 550 mm do not reach a value of 1%. The first class (1-25 mm) includes almost exclusively small undeterminable fragments, teeth and teeth fragments (38%). The class with the highest number of fragments (25-50 mm) comprises mainly undeterminable fragments (57.8%), followed by isolated teeth and tooth fragments (19.3%) and undeterminable long bone shaft fragments (16%). Also the class in the 50-75 mm length interval includes mainly undeterminable fragments and long bone shaft fragments, but also isolated teeth and tooth fragments are numerous, mainly belonging to the hippopotamus (8.8%); there is also a fair amount of mandible and horn fragments (4.7%) as well as of axial elements (4.3%). In the other classes over 75 mm, besides the always abundant undeterminable fragments, there is also the presence of better preserved specimens such as hippopotamus canines, fragments of ribs and vertebrae, large portions of horn and of proximal and distal ends of long bones, in rare cases even complete.

Considering Levels C and D separately, for the first one the length of 240 specimens is available and for the second one such information is known for 2571 fragments. Despite the great difference in the number of remains, the proportions among the dimensional classes are almost identical in the two levels, indicating a similar fragmentation (Tab. 10A, B and Figs. 11, 12).

The analysis of the spatial distribution by specimen dimension was carried out only for Level D (Tab. 10).

Classes	mm	Total	Level C	Level D
A	0.1-25	**201**	17	174
B	26-50	**1510**	128	1347
C	51-75	**614**	54	547
D	76-100	**216**	20	188
E	101-125	**112**	8	98
F	126-150	**65**	4	61
G	151-175	**21**	1	20
H	176-200	**41**	1	40
I	201-225	**19**	1	18
L	226-250	**22**		21
M	251-275	**5**		5
N	276-300	**15**	2	13
O	301-325	**11**		10
P	326-350	**12**	1	11
Q	351-375	**3**		3
R	376-400	**10**	2	7
S	401-425	**3**		3
T	426-450	**2**		2
U	451-475	**1**		1
V	476-500	**1**	1	
Z	> 500	**3**		2
	Total N	**2887**	**240**	**2571**

A

Classes	mm	Total	Level C	Level D
A	0.1-25	7.0	7.1	6.8
B	26-50	52.3	53.3	52.4
C	51-75	21.3	22.5	21.3
D	76-100	7.5	8.3	7.3
E	101-125	3.9	3.3	3.8
F	126-150	2.3	1.7	2.4
G	151-175	0.7	0.4	0.8
H	176-200	1.4	0.4	1.6
I	201-225	0.7	0.4	0.7
L	226-250	0.8		0.8
M	251-275	0.2		0.2
N	276-300	0.5	0.8	0.5
O	301-325	0.4		0.4
P	326-350	0.4	0.4	0.4
Q	351-375	0.1		0.1
R	376-400	0.3	0.8	0.3
S	401-425	0.1		0.1
T	426-450	0.1		0.1
U	451-475			
V	476-500		0.4	
Z	> 500	0.1		0.1

B

Tab. 10. Bone remains divided by dimensional classes: A) number of remains; B) percentages.

The 174 remains belonging to class A (1-25 mm), are uniformly distributed over the paleosurface and there are only some slight prevalence in the WS in squares 2W/4E and 1E/3N and in the ES in squares 9E-6N, 11E-6/5N (Fig. 13A).

Class B (26-50 mm), with the highest number of fragments (1347), is distributed more uniformly in the two sectors reflecting in general the distribution of all the remains. A high density of specimens was evidenced in squares 2W-2E/4N, 8-9E/6N, and 11E/6N with values between 41 and 67 items, representing over one half of the specimens collected from these squares (Fig. 13B).

The 547 specimens of class C (50-75 mm) are more abundant in the WS mainly in the rows of squares 2W-3E/4N and 2E/4-8N as well as in some adjacent squares with values between 11 and 19 fragments; in the ES the highest concentration was found in the two squares 8-9E/6N with over 20 specimens and only in other two squares (11E/6N and 6E/1N) the concentration was just above 10 items (Fig. 13C).

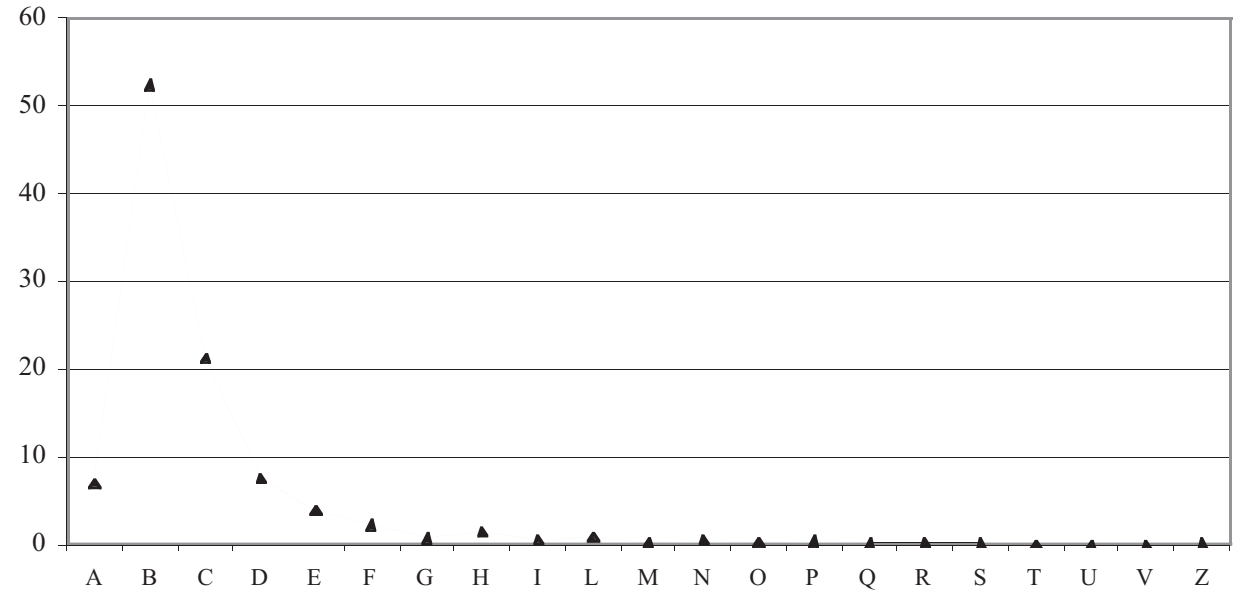

Fig. 11. Frequency of bone remains by dimensional classes.

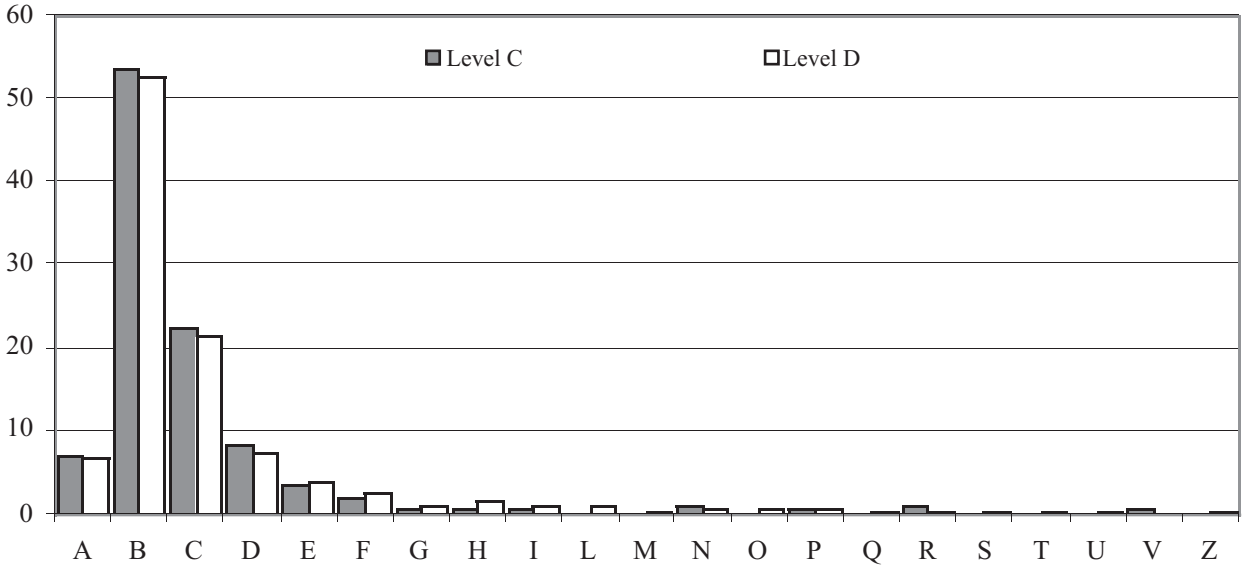

Fig. 12. Frequency of bone remains in Levels C and D by dimensional classes.

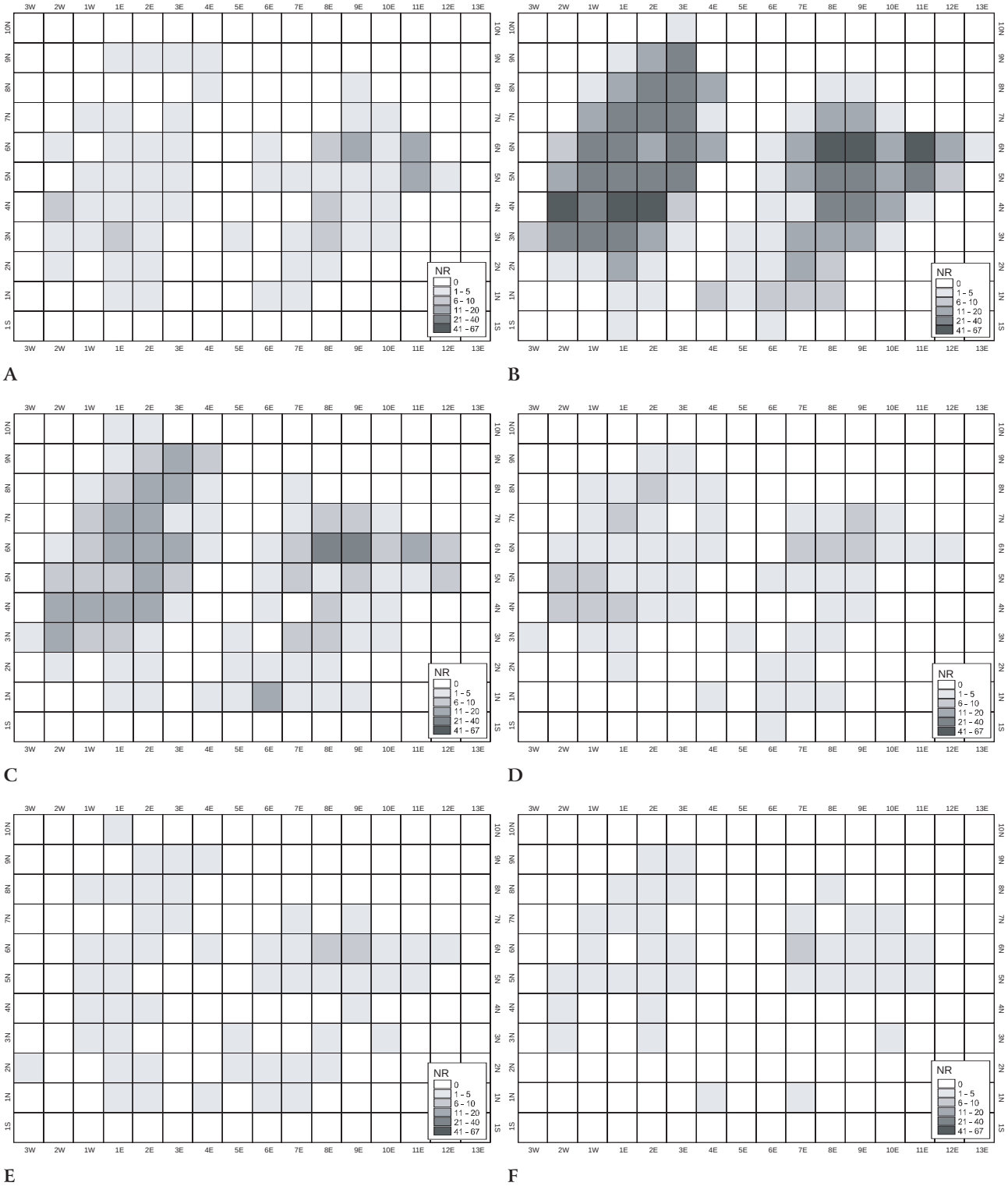

Fig. 13. Level D: distribution of the remains on the basis of dimensional classes. A) class A, from 1 to 25 mm; B) class B, from 26 to 50 mm; C) class C, from 51 to 75 mm; D) class D, from 76 to 100 mm; E) class E, from 101 to 125 mm; F) class F, from 126 to 150 mm.

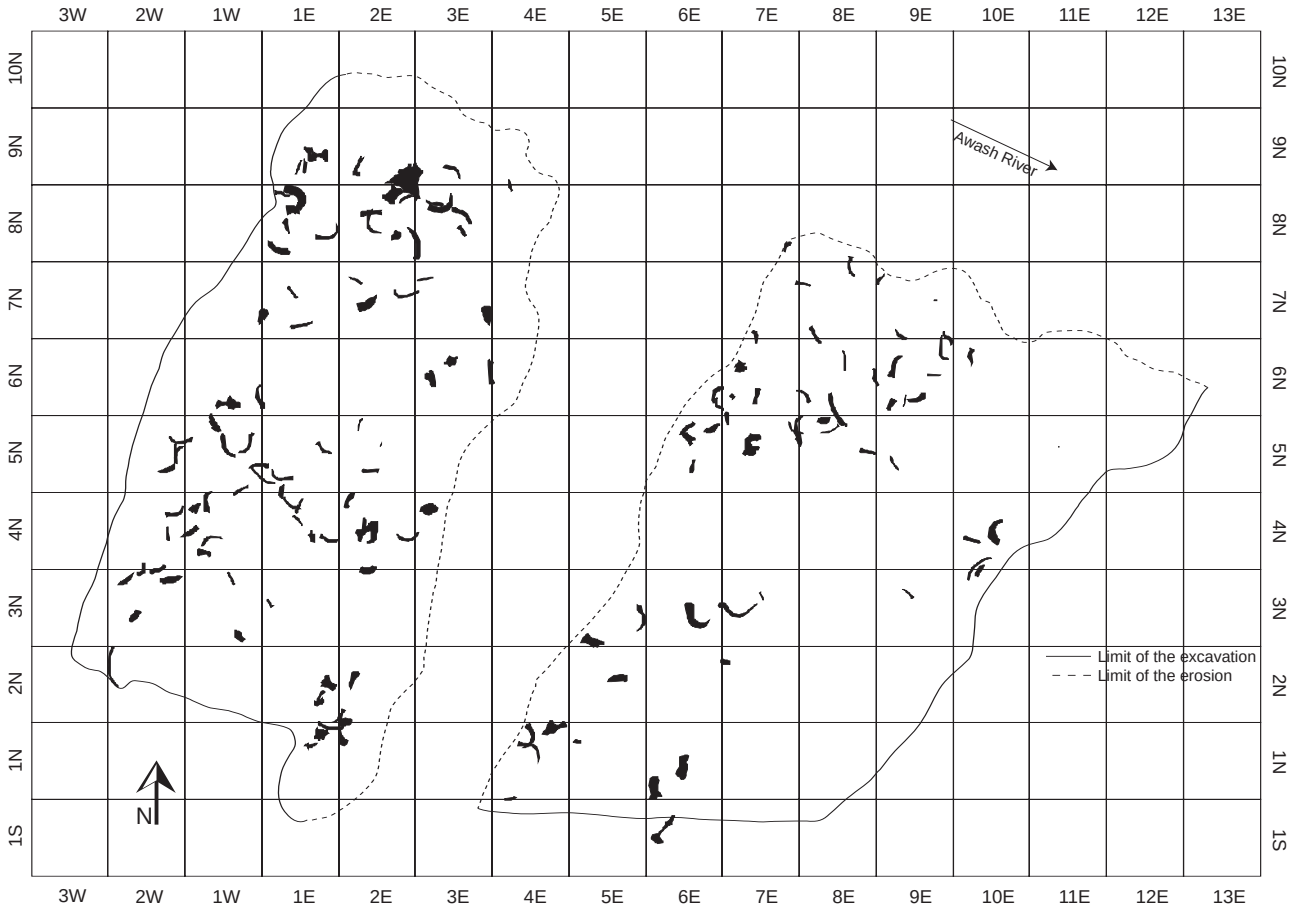

Fig. 14. Level D: distribution of the remains with length above 151 mm (Classes G-Z).

The 188 remains of class D (76-100 mm) are also more represented in the WS, where they have been found more frequently in the area defined by squares 2W-1W/5N and 2W-1E/4N, and in the adjacent squares 2E/8N and 1E/7N; in the eastern part they are found mainly in squares 7-9E/6N (Fig. 13D).

The 98 specimens of class E (101-125 mm) are more represented in the ES in squares 8-9E/6N with 9 and 7 items respectively, while in the WS they are more widely distributed (Fig. 13E).

The 61 fragments belonging to class F (126-150 mm) are not widely distributed in the two sectors and, although they are represented only by few specimens (Fig. 13F), there is a tendency to concentrate in the northern strip of the excavation and they are strangely absent in the squares where the remains of class B were numerous (see for example squares 3-4N/1W-1E).

The 168 elements referable to the other 15 classes with length over 151 mm have been considered as a whole; they are more numerous in the WS and are concentrated in two areas formed by squares 9-7N/1-3E and 2W-2E/5-4N. In the ES they are numerous in the area represented approximately by squares 6-9E/5-6N (Fig. 14).

Orientation and transport

The data on the orientation were not recorded during the excavation, but have been drawn from the maps. Specimens with a length at least twice the width and well characterized on the maps have been selected for this analysis: they all belong to classes above 100 mm. There are 338 remains whose orientation could be determined: most of them (212) are in the WS, the others (126) in the ES. The orientation

was measured in degrees and the specimens have been grouped in classes by increments of 10 degrees from 0 to 180 (Tab. 11).

The general diagram shows that numerous remains have a tendency to be WE oriented, but mainly along the NW/SE axis (Fig. 15A). Considering the two sectors separately it is possible to note that the western one behaves in a way completely similar to the total assemblage, with a NW/SE preferential orientation (Fig. 15B), while in the ES the orientation is less defined. In any case it is evident, also in this case, a slight prevalence of NW/SE orientation, but those oriented along the N/S and ENE/WSW axes are also numerous (Fig. 15C).

The data on the orientation of fragments alone do not allow to suggest hypotheses on the causes that produced the distribution of bones on the paleosurface of Garba IV.

A certain degree of preferential orientation of the remains and the location of the excavated area close to the banks of an ancient river bed require an analysis of the anatomical elements on the basis of their greater or lesser susceptibility to water transport. However, it should be considered that the substrate is made mainly of stones, some of which even of large dimensions, including the abundant lithic industry and this may have influenced the dispersal of the bones by water.

The anatomical elements at Garba IV have been divided in transport groups on the basis of the work by Badgley (1986), where the author correlates the different composition and quantity of skeletal elements recovered in some Miocene sites in Pakistan with the respective geological and paleontological characteristics; as a result she defines four taphonomic assemblages with different degrees of susceptibility to transport increasing from IV (light transport) to group I (heavy transport). Groups IV and III have been interpreted as biological concentrations accumulated over a relatively short time span with light hydraulic transport, groups I and II are instead accumulations produced by fluvial currents.

Considering the Level D of Garba IV specimens as a whole and using the thirteen groups of anatomical elements employed by Badgley, the resulting quantitative ranking shows in the first place limb bones (the undeterminable long bone diaphyses have also been added) followed by teeth, with percentages over 30%; by the cranium, the metapodials and the ribs with percentages between 6.7-5%; then the girdles

Degrees	Total N	%	WS	%	ES	%	Totale N oriented	Expected N
0-10	33	9.8	24	11.3	9	7.1	33	18.7
11-20	13	3.8	5	2.4	8	6.3	13	″
21-30	21	6.2	11	5.2	10	7.9	21	″
31-40	23	6.8	15	7.1	8	6.3	23	″
41-50	10	3.0	9	4.2	1	0.8	10	″
51-60	16	4.7	11	5.2	5	4.0	16	″
61-70	19	5.6	15	7.1	4	3.2	19	″
71-80	15	4.4	7	3.3	8	6.3	15	″
81-90	14	4.1	8	3.8	6	4.8	14	″
91-100	20	5.9	9	4.2	11	8.7	20	″
101-110	18	5.3	13	6.1	5	4.0	18	″
111-120	19	5.6	12	5.7	7	5.6	19	″
121-130	28	8.3	16	7.5	12	9.5	28	″
131-140	25	7.4	16	7.5	9	7.1	25	″
141-150	18	5.3	12	5.7	6	4.8	18	″
151-160	17	5.0	11	5.2	6	4.8	17	″
161-170	17	5.0	10	4.7	7	5.6	17	″
171-180	12	3.6	8	3.8	4	3.2	12	″
Total	**338**		**212**		**126**			

Tab. 11. Orientation in degrees of some remains from Level D.

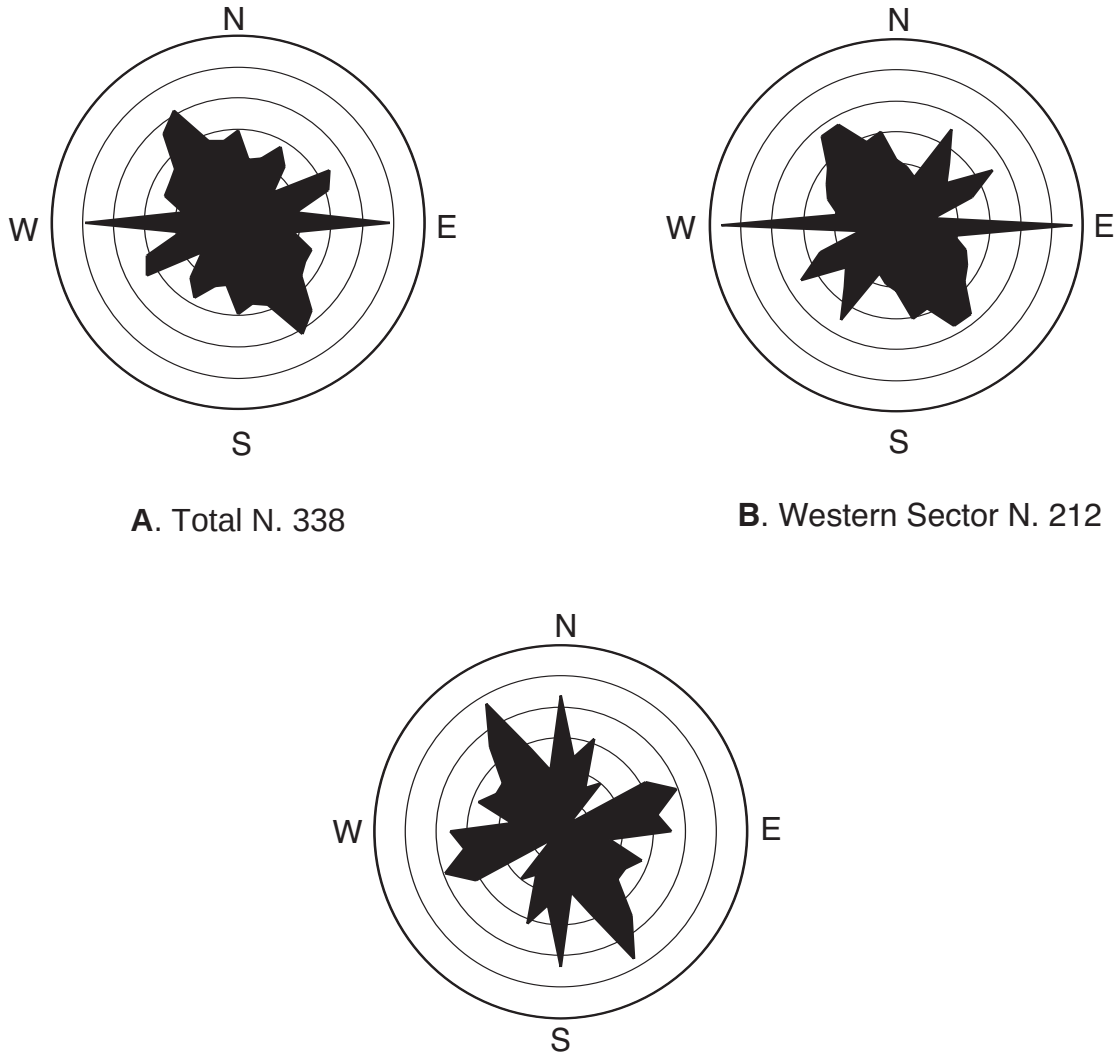

Fig. 15. Level D, orientation of the bone remains. A) total; B) Western Sector; C) Eastern Sector.

(scapula/pelvis), the vertebrae, the podials (carpals and tarsals) and the mandibles with percentage values of 2.8-2% (Tab. 12). The least represented elements are phalanges, maxillae, and ulna/fibula with values below 1%, while patellae are completely absent. Comparing the ranking of the anatomical elements at Garba IV with that of the taphonomic groups suggested by Badgley, there are strong analogies with groups I and II, which indicate a strong hydraulic transport and in particular with group I. In fact in such group teeth are prevalent followed by limbs. prevailing also at Garba IV, although in the opposite order. However, the high degree of fragmentation of limb long bones in the site analyzed should be taken into account. The metapodials in the fourth place, ribs in the fifth, vertebrae in the seventh and mandibles in the ninth position correspond exactly to the ranking in group I. Phalanges in the tenth place correspond to group II. In the data from Garba IV Level D the third place for the cranium in the list of abundance is anomalous; in fact, this anatomical portion in Badgley's taphonomic assemblages never go beyond the sixth place (group III) and in groups I and II is found in the eighth position. Also for the scapula/pelvis the sixth place is not common because they do not go beyond the eighth place (group III) in abundance ranking. As regards the cranium it must be stressed that the sample of Garba IV is mostly made of large portions and fragments of Bovid horns that surely have a degree of susceptibility to transport different from cranial portions without

% Level D		I	II	III	IV
38.9	Limb	Tooth	Tooth	Rib	Tooth
32.1	Tooth	Limb	Rib	Tooth	Vertebra
6.7	Cranium	Podial	Limb	Vertebra	Limb
6.2	Metapodial	Metapodial	Vertebra	Limb	Podial
5.0	Rib	Rib	Metapodial	Podial	Rib
2.8	Scapula/Pelvis	Phalanx	Podial	Cranium	Mandible
2.8	Vertebra	Vertebra	Mandible	Metapodial	Cranium
2.1	Podial	Cranium	Cranium	Scapula/Pelvis	Phalanx
2.0	Mandible	Mandible	Scapula/Pelvis	Phalanx	Scapula/Pelvis
0.6	Phalanx	Scapula/Pelvis	Phalanx	Mandible	Ulna/Fibula
0.3	Maxilla	Ulna/Fibula	Patella	Maxilla	Metapodial
0.3	Ulna/fibula	Patella	Maxilla	Ulna/Fibula	Maxilla
0	Patella	Maxilla	Ulna/Fibula	Patella	Patella

Tab. 12. Comparison between the abundance groups (I-IV) of Badgley (1986) and those of Garba IV Level D.

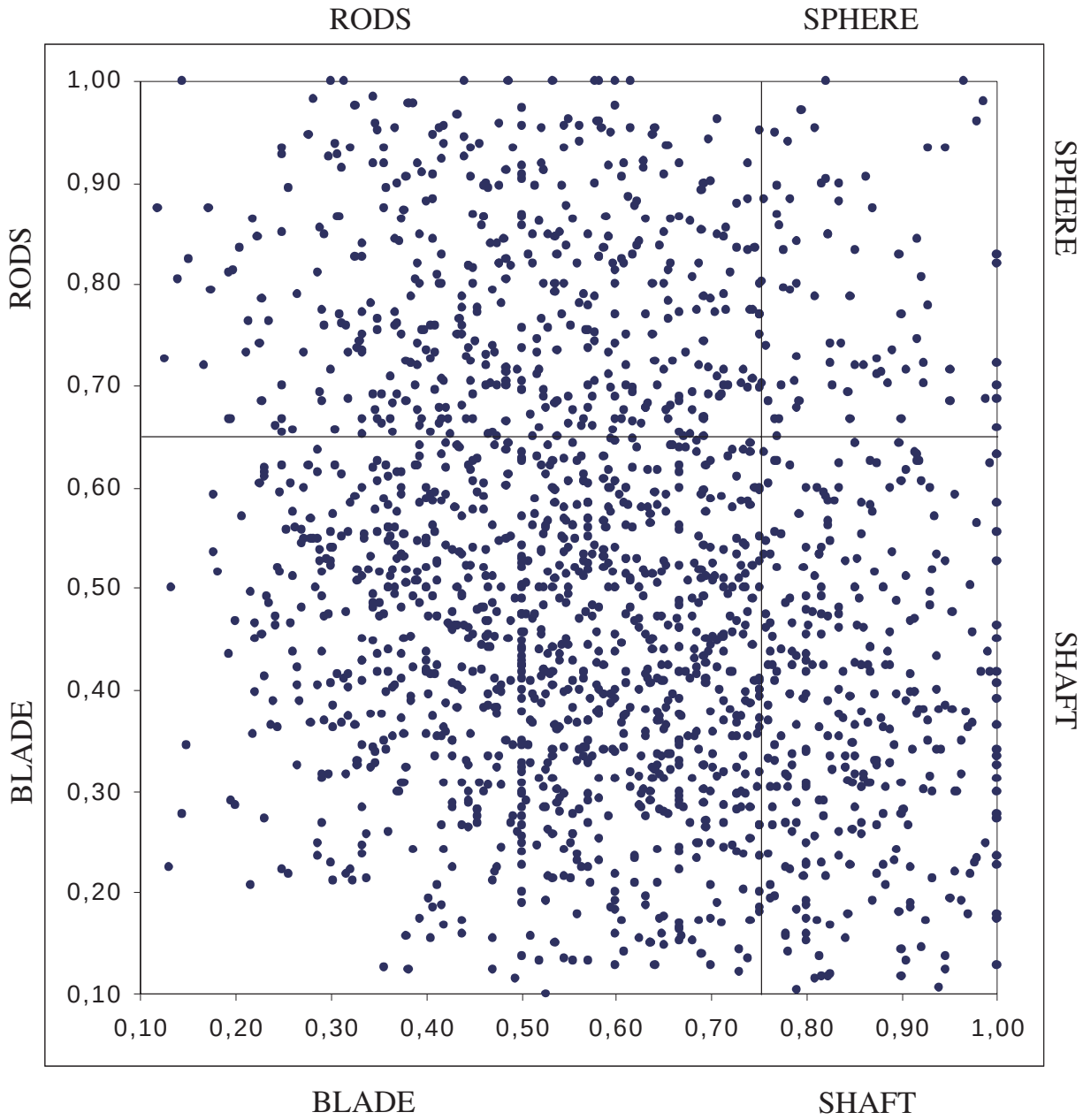

Fig. 16. Level D: distribution of bone remains on the basis of their shape.

horns. Also regarding the scapula/pelvis these belong mainly to the hippopotamus therefore they are large sized, heavy and difficult to transport.

In the evaluation of these data, it should be also considered that the lesser or greater transportability of the bone remains is mainly related to the specific weight, the shape and the dimensions of the specimens, these characteristics are in turn influenced by the fragmentation of the elements. The fragments can be divided on the basis of the three main axes (length, width and thickness) in four shapes: sphere, rod, disc, blade (Frostick and Reid 1983; Lyman 1994). The experimental observations showed that the bones with a rod and sphere shape are more easily transported than those with a disc and blade shape. Therefore in theory if in the faunal assemblage there are few rods and spheres these may have been dispersed by hydraulic transport. However in general, density is the most important factor in the dispersion, in fact light bones (some anatomical elements such as vertebrae or the remains of small sized animals such as small carnivores, rodents, birds, etc.) go farther than heavy elements, while shape and dimensions will influence the speed of the transport (flat and long fragments may be transported better than circular ones even if they have the same weight).

The measures of the three dimensions (length, width and thickness) are available for over 2000 specimens from Garba IV; these data have been elaborated following Frostick and Reid (1983), in order to obtain information on the shape and on the sphericity of the remains, indicating with: a (maximum dimension); b (mid dimension); c (minimum dimension), without taking into account the anatomical orientation of the bone. The graphic representation has been obtained plotting for each specimen the data c/b and b/a (Fig. 16). The results show how the shape prevailing in the site analyzed is the blade one, with more than 42.4%, followed by rods with 31.2% and by discs 19.3%; cuboid or spherical specimens are very rare with 8.1%. In general, since blade and disc shapes are prevalent (over 60%) over the rod and pseudospherical ones, it is possible to suggest that hydraulic action almost surely influenced the composition and the dispersion of our assemblage.

Certainly an accumulation of bone remains on a paleosurface, such as that of Garba IV, located close to the banks of a river, may have been affected by the dispersal of some remains, originally laying on the surface, which have been redeposited downstream, but may have received bones coming from upstream areas (Voorhies 1969; Dodson 1973; Hanson 1980; Behrensmeyer 1982, 1990; Shick *et al.* 1989). Very important is the nature of the bank: if it presents medium and large pebbles as well as big rocks, these may obstruct the transport both of the external bones coming in with the current and of those originally present on the surface. This will introduce other variables that will be difficult, if not impossible, to control.

All the data on the transportability of the Garba IV remains should be undoubtedly considered with caution, but considering the preferential orientation of the specimens, the correspondence between the proportion of the anatomical element and that of the transport groups related to a strong current, the shape of the remains, the low proportion of vertebrae and ribs as well as of remains of small animals, it is evident that among the different taphonomic agents influencing the Garba IV accumulation, hydraulic action surely played an important role.

Degree of preservation of the remains and analysis of the surfaces

The study has been carried out only on the bone remains now stored at the Center for Research and Conservation of Cultural Heritage in Addis Ababa (Tab. 13). 1664 bone elements have been analyzed representing 56.5% of the total assemblage from Garba IV; therefore they make up a statistically valid sample for the analyses of bone surfaces and of butchering marks.

In the two main levels 133 remains (equal to 54.7%) have been analyzed from Level C and 1476 specimens (equal to 64.5%) from Level D. 42 out of the 51 remains found in Level E have been observed, as well as all the bones from Level F, although these are just five, and only three bones without exact stratigraphic attribution (Tabs. 13, 14).

However, the fragments undergoing surface investigations represent accurately the faunal range of Garba IV, in fact between 70 and 80% of the remains of the most frequent animals, such as hippopotamus and Alcelaphini, have been analyzed (Tab. 14). The specimens studied also reflect the total composition of anatomical elements at Garba IV, in fact there are numerous cranial elements (25.4%), among which isolated teeth are prevalent (16.9%). Of course on teeth it is unlikely to find traces referable to the exploitation of the carcass, with the exception of some hippopotamus canines showing impact marks. There is a fair amount of post-cranial elements analyzed and long bone shaft fragments and unidentifiable remains are also numerous (Tab. 15).

All the bones from Garba IV show variable degrees of abrasion of the surfaces or cracking produced both before and after burial, indicating the important role played by post-depositional agents (Behrensmeyer 1975, 1976, 1978, 1982, 1990; Behrensmeyer and Hill 1980; Behrensmeyer and Kidwell 1985; Frison and Todd 1986; Agenbroad 1989; Dunbar *et al.* 1989; Marshall 1989; Lyman 1994; Miller 1994; Fisher 1995). Very often such abrasions do not allow the observation of possible traces on the fragments. In any case the analysis of the surfaces and of bone fracturing detected traces of different modifying agents on the specimens.

Evaluating the different degrees of abrasion, 9.1% of the remains resulted moderately abraded, 50.2% abraded, 35.9% strongly abraded, and 3.1% with surfaces and edges completely abraded by water action. Only 1.8% of the specimens displayed well preserved surfaces (Tab. 16).

An attempt has been made to verify the existence of relationships between the abrasion classes identified and particular anatomical elements or animals of different size (Tab. 17).

The rare specimens with well preserved surfaces (30) are mainly referred to Alcelaphini, indeterminate Bovid and hippopotamus teeth as well as to rare fragments of diaphysis and ribs not referable to species. Among the different parts of the skeleton teeth are the best preserved ones because they have a higher mineral component compared to the other elements and are therefore less prone to destruction.

Taxa	**C**	**D**	**E**	**F**	**A**	**Indet. Lev.**	**Total**	**%**
Carnivora		1					**1**	0.1
Primates		1					**1**	0.1
Elephantidae		1					**1**	0.1
Equidae		22			2		**24**	1.4
Hippopotamus	12	257	6	3		2	**280**	16.8
Suidae		8					**8**	0.5
Giraffidae		1					**1**	0.1
Bovini		8					**8**	0.5
Reduncini		1					**1**	0.1
Alcelaphini		96	2				**98**	5.9
Antilopini		8					**8**	0.5
Bovidae	8	143	2		1		**154**	9.3
Aves			1				**1**	0.1
Reptilia		1					**1**	0.1
Indeteterminate	113	928	31	2	2	1	**1077**	64.7
Total remains	**133**	**1476**	**42**	**5**	**5**	**3**	**1664**	
%	8.0	88.7	2.5	0.3	0.3	0.2		

Tab. 13. Bone remains analyzed from a taphonomic point of view.

The remains with moderately abraded surfaces (151), those with relatively preserved cortical face and recognizable articular surfaces, excluding the animals represented by one or few specimens, are mainly indeterminate fragments (57.6%), followed by hippopotamus (19.9%) and by indeterminate Bovids (13.9%; Tab. 17). Long bone fragments are prevalent and they are represented by both indeterminate shafts (31.1%) and determinable elements of the limb and of the extremities (19.5%); teeth are numerous also in this case (17.9%) especially those of hippopotamus; the presence of hippopotamus pelvis and rib fragments should also be mentioned.

The remains with abraded surfaces, those with original surface almost completely absent sometimes displaying exfoliation and cracking, are the most abundant ones (835). They are also represented mainly by indeterminate (59.8%) and hippopotamus (21.6%) specimens, followed by indeterminate Bovids and Alcelaphini with values between 6-8% (Tab. 17). Indeterminate long bone fragments are the prevalent elements (30.5%) followed by indeterminate specimens (24.2%) and teeth (23.2%), the latter one belonging mainly to the hippopotamus.

Taxa	Total	Taphonomic analysis	%
Carnivora	**2**	1	50.0
Primates	**1**	1	100.0
Elephantidae	**2**	1	50.0
Equidae	**93**	24	25.8
Hippopotamus	**375**	280	74.7
Suidae	**13**	8	61.5
Giraffidae	**2**	1	50.0
Bovini	**19**	8	42.1
Reduncini	**1**	1	100.0
Alcelaphini	**143**	98	68.5
Antilopini	**10**	8	80.0
Indet. Bovidae	**181**	154	85.1
Aves	**1**	1	100.0
Reptilia	**7**	1	14.3
Total identified	**850**	587	69.1
Total indeterminate	**1320**	1077	81.6
General Total	**2170**	**1664**	**76.7**

Tab. 14. Ratio between the total number of remains and those analyzed from a taphonomic point of view.

Skeletal portion	C	D	E	F	Indet. Lev.	A	Total	%
Horn		67	1				**68**	4.1
Cranium	5	33					**38**	2.3
Tooth	6	266	5	3		3	**283**	17.0
Girdle	3	31	1				**35**	2.1
Axial	13	84	3	1	1		**102**	6.1
Front limb	2	31					**33**	2.0
Hind limb	3	18	1		1		**23**	1.4
Distal limb	3	67	2			1	**73**	4.4
Short bone		18	4		1		**23**	1.4
Long bone	67	436	6	1		1	**511**	30.7
Indeterminate	34	425	19				**478**	28.7
Total	**133**	**1476**	**42**	**5**	**3**	**5**	**1664**	

Tab. 15. Skeletal portions of the remains analyzed from a taphonomic point of view.

Level	Preserved surfaces	Moderately abraded	Abraded	Strongly abraded	Rounded	Total
C	1	10	76	30	16	**133**
D	29	136	738	538	35	**1476**
E		1	18	23		**42**
F		1	1	3		**5**
A		1	2	2		**5**
B						
Indet.		2		1		**3**
Total	**30**	**151**	**835**	**597**	**51**	**1664**
%	1.8	9.1	50.2	35.9	3.1	

Tab. 16. Bone remains by abrasion classes.

The strongly abraded specimens (597), presenting invasive surface removals and cracking without any portion of the original surface, include mainly indeterminate fragments (74%), followed by few remains of indeterminate Bovids and of hippopotamus (both 9.4%) and by Alcelaphini (4.5%; Tab. 17). Indeterminate anatomical elements are also numerous (38.7%) as are the long bone shaft fragments (28.3%), followed by Bovid horn fragments (7.2%), that for their structure are the least preservable elements.

The rounded specimens (51) are the rolled fragments whose edges, medullar and cortical surfaces are indistinguishable. They are represented mainly by indeterminate fragments (51%) and by indeterminate long bone shaft fragments (31.4%).

Considering the time spent by the specimens within the sandy sediments we should not be surprised by the high number of remains with abraded or strongly abraded surfaces recovered in the sample. Excluding the strongly abraded and rounded elements, the remains belonging to the other abrasion classes allow a good understanding of some characteristics and modifications of their surfaces.

Considering the animals with the highest number of remains (Alcelaphini, indeterminate Bovids and hippopotamus), excluding small variations, it is not possible to evidence particular relationships between the degree of abrasion and the size of the animal. The Alcelaphini are those with the highest number of specimens with preserved surfaces (11.2%) while hippopotamus and Bovids present the highest number of moderately abraded remains (10.7 and 13.6 respectively). If we sum the values for these two classes, representing the best preserved specimens, values between the 13.6% for the hippopotamus, 17.3% for the Alcelaphini and 17.5 for the Bovids are reached; such values can be considered quite similar (Tab. 17). The hippopotamus is the animal with the highest number of abraded remains (64.3%), followed by the Alcelaphini (55.1%) and by the Bovids (44.8%).

The indeterminate Bovids are those presenting the highest number of strongly abraded specimens (36.4%), followed by the Alcelaphini (27.6%), while the hippopotamus is the one presenting the smaller number of badly preserved specimens (20%).

Differences in the degree of preservation have been detected mainly between the anatomical elements rather than between the different animals. Teeth of Alcelaphini and Bovids are always better preserved, while horns and horn fragments are those that have been more strongly affected by post-depositional phenomena. Hippopotamus teeth had different histories, in fact they are represented in all abrasion classes, from the one with well preserved surfaces to the strongly abraded one; this may have been due to the different dimensions and morphology especially of the canines whose outer enamel is often removed.

The degree of abrasion of 1664 remains has been also related to the dimensions of the specimens. The best preserved elements (30) and the rounded ones (51) belong mainly to the two first dimensional classes (less than 50 mm); however, all these specimens belong exclusively to the dimensional classes below 100 mm (Tab. 18).

As expected the moderately abraded (151), abraded (835), and strongly abraded (597) specimens are numerous in the two classes with length between 26 mm and 75 mm, representing the most common classes at Garba IV. However, the abraded and strongly abraded elements are prevalent mainly among the specimens between 26 and 50 mm, while the moderately abraded ones are more uniformly distributed (34.4 and 31.1%) in the two dimensional classes. The moderately abraded specimens are still quite numerous (but with percentages below 10%) in the three classes with length between 76 and 150 mm and are rare in the higher dimensional classes (Tab. 18). In the dimensional classes above 100 mm elements with abraded or strongly abraded surfaces are prevalent evidencing a tendency, although weak, towards a correlation between the large size of the specimen and a stronger effect of the post-depositional phenomena. The data of Level D reflect exactly the proportion among classes evidenced in the whole assemblage (Tab. 19).

	Taxa	Preserved surfaces	Moderately abraded	Abraded	Strongly abraded	Rounded	Total N
	Carnivora			1			**1**
	Primates		1				**1**
	Elephantidae		1				**1**
	Equidae		1	18	5		**24**
	Hippopotamus	8	30	180	56	6	**280**
	Suidae		1	4	3		**8**
	Giraffidae		1				**1**
	Bovini		1	3	4		**8**
	Reduncini			1			**1**
	Alcelaphini	11	6	54	27		**98**
	Antilopini		1	4	3		**8**
	Indet. Bovidae	6	21	69	56	2	**154**
	Aves				1		**1**
	Reptilia			1			**1**
	Indeteterminate	5	87	499	442	43	**1076**
A	**Total remains**	**30**	**151**	**835**	**597**	**51**	**1664**

	Taxa	Preserved surfaces	Moderately abraded	Abraded	Strongly abraded	Rounded	%
	Carnivora			0.1			0.1
	Primates		0.7				0.1
	Elephantidae		0.7				0.1
	Equidae		0.7	2.2	0.8		1.4
	Hippopotamus	26.7	19.9	21.6	9.4	11.8	16.8
	Suidae		0.7	0.5	0.5		0.5
	Giraffidae		0.7				0.1
	Bovini		0.7	0.4	0.7		0.5
	Reduncini			0.1			0.1
	Alcelaphini	36.7	4.0	6.5	4.5		5.9
	Antilopini		0.7	0.5	0.5		0.5
	Indet. Bovidae	20.0	13.9	8.3	9.4	3.9	9.3
	Aves				0.2		0.1
	Reptilia			0.1			0.1
B	Indeteterminate	16.7	57.6	59.8	74.0	84.3	64.7

	Taxa	Preserved surfaces	Moderately abraded	Abraded	Strongly abraded	Rounded
	Carnivora			100.0		
	Primates		100.0			
	Elephantidae		100.0			
	Equidae		4.2	75.0	20.8	
	Hippopotamus	2.9	10.7	64.3	20.0	2.1
	Suidae		12.5	50.0	37.5	
	Giraffidae		100.0			
	Bovini		12.5	37.5	50.0	
	Reduncini			100.0		
	Alcelaphini	11.2	6.1	55.1	27.6	
	Antilopini		12.5	50.0	37.5	
	Indet. Bovidae	3.9	13.6	44.8	36.4	1.3
	Aves				100.0	
	Reptilia			100.0		
	Indeteterminate	0.5	8.1	46.4	41.1	4.0
C	**Total remains**	**1.8**	**9.1**	**50.2**	**35.9**	**3.1**

Tab. 17. Abrasion classes on the basis of the different *taxa*: A) number of remains; B) proportions within the abrasion classes; C) proportions within *taxa.*

	Classes	Preserved surfaces	Moderately abraded	Abraded	Strongly abraded	Rounded	Total
	A	4	7	74	28	9	**122**
	B	24	52	451	276	32	**835**
	C	1	47	151	130	9	**338**
	D	1	15	66	44	1	**127**
	E		12	23	38		**73**
	F		7	15	27		**49**
	G			9	8		**17**
	H		5	15	13		**33**
	I			6	3		**9**
	L		1	4	13		**18**
	M			1	1		**2**
	N		1	3	5		**9**
	O			6	1		**7**
	P		2	3	3		**8**
	Q			1	1		**2**
	R			3	4		**7**
	S		2	1			**3**
	T			1			**1**
	U			1			**1**
	V						
	Z			1	1		**2**
A	**Total remains**	**30**	**151**	**835**	**596**	**51**	**1664**
	A	13.3	4.6	8.9	4.7	17.6	7.3
	B	80.0	34.4	54.0	46.3	62.7	50.2
	C	3.3	31.1	18.1	21.8	17.6	20.3
	D	3.3	9.9	7.9	7.4	2.0	7.6
	E		7.9	2.8	6.4		4.4
	F		4.6	1.8	4.5		2.9
	G			1.1	1.3		1.0
	H		3.3	1.8	2.2		2.0
	I			0.7	0.5		0.5
	L		0.7	0.5	2.2		1.1
	M			0.1	0.2		0.1
	N		0.7	0.4	0.8		0.5
	O			0.7	0.2		0.4
	P		1.3	0.4	0.5		0.5
	Q			0.1	0.2		0.1
	R			0.4	0.7		0.4
	S		1.3	0.1			0.2
	T			0.1			0.1
	U			0.1			0.1
	V						
	Z			0.1	0.2		0.1
B							
	A	3.3	5.7	60.7	23.0	7.4	
	B	2.9	6.2	54.0	33.1	3.8	
	C	0.3	13.9	44.7	38.5	2.7	
	D	0.8	11.8	52.0	34.6	0.8	
	E		16.4	31.5	52.1		
	F		14.3	30.6	55.1		
	G			52.9	47.1		
	H		15.2	45.5	39.4		
	I			66.7	33.3		
	L		5.6	22.2	72.2		
	M			50.0	50.0		
	N		11.1	33.3	55.6		
	O			85.7	14.3		
	P		25.0	37.5	37.5		
	Q			50.0	50.0		
	R			42.9	57.1		
	S		66.7	33.3			
	T			100.0			
	U			100.0			
	V						
	Z			50.0	50.0		
C	**Total remains**	**1.8**	**9.1**	**50.2**	**35.8**	**3.1**	

Tab. 18. Abrasion classes by dimensions: A) number of remains; B) proportions within the abrasion classes; C) proportions within the dimensional classes. *(see also Tab. 10)*

Classes	Preserved surfaces	Moderately abraded	Abraded	Strongly abraded	Rounded	Total
A	3	7	65	23	6	**104**
B	23	49	391	253	27	**743**
C	1	42	132	116	5	**296**
D	1	12	55	40	1	**109**
E		10	20	35		**65**
F		6	13	26		**45**
G			9	6		**15**
H		4	15	12		**31**
I			6	3		**9**
L		1	4	12		**17**
M			1	1		**2**
N		1	3	4		**8**
O			6	1		**7**
P		2	3	3		**8**
Q			2	1		**3**
R			5	1		**6**
S		2	1			**3**
T			1			**1**
U			1			**1**
Z			1	1		**1**
A Total remains	**28**	**136**	**734**	**538**	**39**	**1476**
A	2.9	6.7	62.5	22.1	5.8	
B	3.1	6.6	52.6	34.1	3.6	
C	0.3	14.2	44.6	39.2	1.7	
D	0.9	11.0	50.5	36.7	0.9	
E		15.4	30.8	53.8		
F		13.3	28.9	57.8		
G			60.0	40.0		
H		12.9	48.4	38.7		
I			66.7	33.3		
L		5.9	23.5	70.6		
M			50.0	50.0		
N		12.5	37.5	50.0		
O			85.7	14.3		
P		25.0	37.5	37.5		
Q			66.7	33.3		
R			83.3	16.7		
S		66.7	33.3			
T			100.0			
U			100.0			
Z			100.0	100.0		
B Total remains	**1.9**	**9.2**	**49.7**	**36.4**	**2.6**	
A	10.7	5.1	8.9	4.3	15.4	7.0
B	82.1	36.0	53.3	47.0	69.2	50.3
C	3.6	30.9	18.0	21.6	12.8	20.1
D	3.6	8.8	7.5	7.4	2.6	7.4
E		7.4	2.7	6.5		4.4
F		4.4	1.8	4.8		3.0
G			1.2	1.1		1.0
H		2.9	2.0	2.2		2.1
I			0.8	0.6		0.6
L		0.7	0.5	2.2		1.2
M			0.1	0.2		0.1
N		0.7	0.4	0.7		0.5
O			0.8	0.2		0.5
P		1.5	0.4	0.6		0.5
Q			0.3	0.2		0.2
R			0.7	0.2		0.4
S		1.5	0.1			0.2
T			0.1			0.1
U			0.1			0.1
Z			0.1	0.2		0.1
C						

Tab. 19. Abrasion classes by dimensions of the remains from Level D: A) number of remains; B) proportions within the abrasion classes; C) proportions within the dimensional classes. *(see also Tab. 10)*

The spatial distribution of the remains divided by abrasion classes has been analyzed only for Level D (1476 specimens). The abraded remains are more abundant in the WS and are concentrated in the area defined by squares 1W-2E/5-4N and in the two squares 1E/7N and 3E-8N; in several squares of the rows 3-5N of this sector they represent over 40% of the specimens recovered. In the ES they are widely distributed and are numerous in squares 8-11E/6N; most of the specimens collected from this sector belong to these same squares (Fig. 17A).

Numerous strongly abraded remains have been found in the nearby squares 1W-3E/4N, corresponding in part to the squares with the highest frequency of abraded remains, in some adjacent squares, in the row 3-2N and in the most external squares 3E/4-5N. In such squares they represent over 40% of the specimens recovered, reaching sometimes even values around 65%. In the ES they are widely distributed and a weak concentration can be found in squares 7E-9E/6N (Fig. 17B).

In the WS, the moderately abraded remains are concentrated in the most internal squares of the excavated area, mainly along the line conjoining square 3E/9N to 1W/4N, with a fairly good prevalence in the squares of the rows 4-5N (Fig. 17C). In the ES they are more rare and widely distributed. Most of the remains with well preserved surfaces were recovered in this latter sector, while they are almost completely absent in the WS, where also teeth fall within the abraded and moderately abraded classes. Rounded specimens are more numerous in the WS, but there are no significant clusters (Fig. 17D).

The spatial distribution of the remains divided by degree of surface preservation is not substantially different from the quantitative distribution, with the classes containing the highest number of specimens

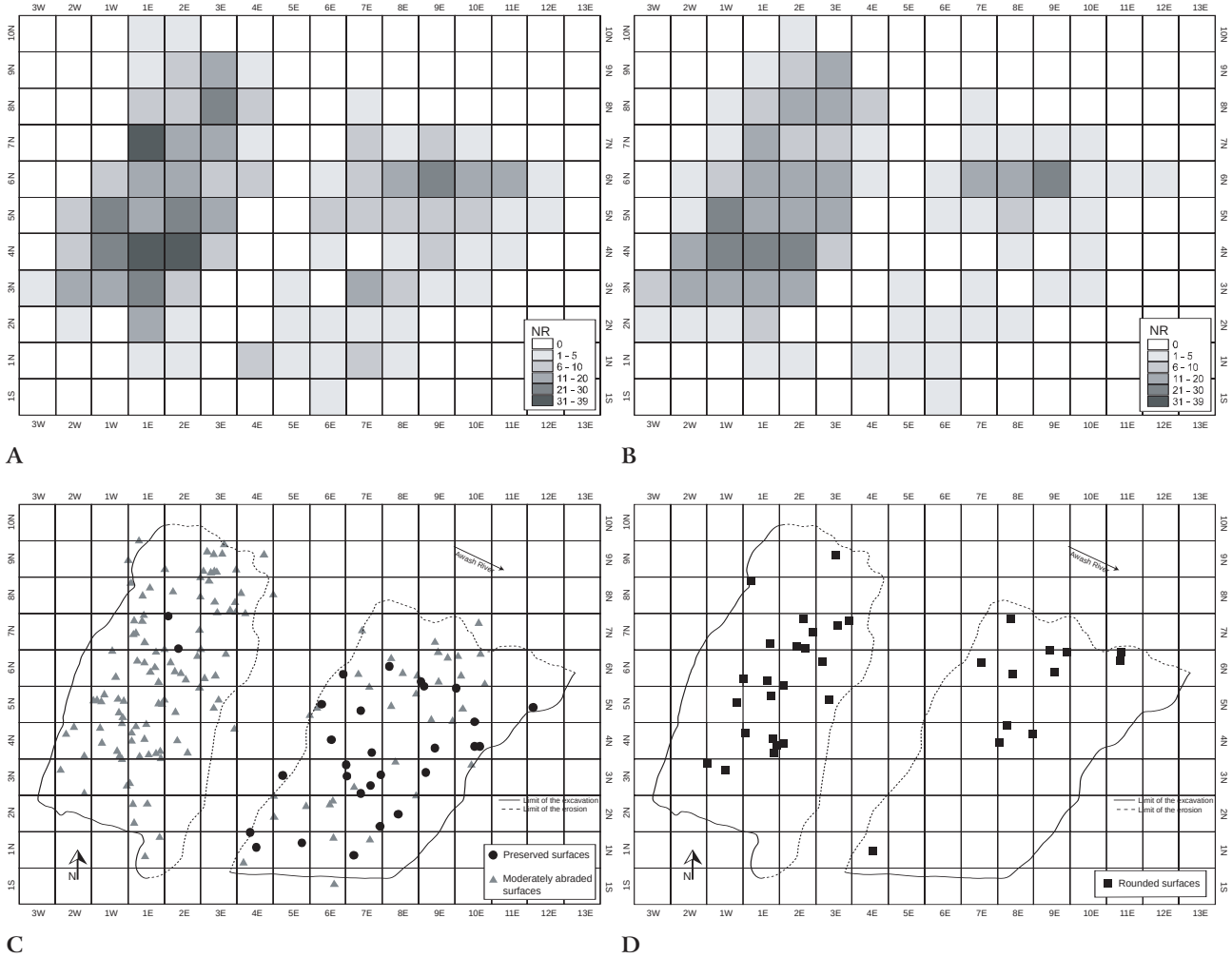

Fig. 17. Level D; distribution of the remains by abrasion classes. A) abraded; B) strongly abraded; C) preserved and moderately abraded; D) rounded.

(abraded and strongly abraded) located exactly in the areas with the highest frequency of remains, evidencing that all the specimens of the paleosurfaces were affected by the same erosive phenomena. A better preservation of the remains seems to involve the eastern area of the excavation that yielded almost all the specimens with well preserved surfaces.

Fracturing of the bone remains

Fragments with traces of intentional fracturing, such as impact points and percussion flakes (cones and primary flakes) represent the most evident traces of anthropic modifications at Garba IV (Bonnichsen 1973, 1979, 1989; Binford and Bertram 1977; Haynes 1980, 1983; Myers *et al.* 1980; Binford 1981; Johnson 1985; Bunn 1989; Lyman 1994; Blumenschine 1995; Fisher 1995; Madrigal and Blumenschine 2000). The fragments displaying these features are 66 (50 impact and 16 cones and primary flakes), representing 4% of the specimens analyzed from a taphonomic point of view (Tab. 20). Impact points have been identified also on 27 other fragments, but because of some of their characteristics and mainly for the bad preservation of the surfaces and fracture edges, human intentional fracturing is not sure. The 66 specimens, that on the basis of our analysis are intentionally fractured, come from Level D (56 specimens equal to 3.7% of the remains analyzed from this level), while from Level C there are 8 fragments (6.0% of the remains analyzed from this level) and only two remains from Level E (Tab. 20; Fig. 18; Plate 1).

All these 66 fragments and the 27 fragments with dubious impact points present also features of the fracture edge typical of a fresh bone break, such as a spiral or sinuous outline and grooves and lines on the fracture surfaces produced respectively by strain and compression phenomena.

These features have also been detected on many other fragments without impact marks, notches or medullar removals. Such specimens are 139 and also in this case they come mainly from Level D (121); Level C yielded 16 of such fragments, Level E three fragments and one is from test trench A (Tab. 20). These specimens cannot be surely attributed to intentional fracturing because in the absence other evidences (impact points), such fractures may have been also produced by other factors such as carnivores, trampling, and other natural phenomena affecting the bone when it was still fresh (Plate 2, *1-3*).

Intentional fracturing of the bones is represented mainly by impact points identified on 50 fragments and on 4 flakes, and by 4 impact cones. Most of the impact points have been recognized on elements from Level D (42), four from Level C and two from Level E. A percussion cone is the removal produced in the point where the force applied on the surface of the bone is stronger, the detached fragment is essentially conchoidal (convex) and on the specimens where it came from it is possible to recognize a negative scar

Taphonomy	**C**	**D**	**E**	**F**	**A**	**B**	**Indet. Lev.**	**Total**	**% out of the analyzed N**
Total number of remains	243	2580	51	5	8	8	50	**2945**	
Number of analyzed remains	133	1476	42	5	5		3	**1664**	
Impact	4	44	2					**50**	3.0
Impact?	2	25						**27**	1.6
Percussion cones and primary flakes	4	12						**16**	1.0
Fragments with fresh bone breaks	16	121	1		1			**139**	8.4
Total with fresh bone breaks	26	202	3		1			**232**	13.9
Stria ?		1						**1**	0.1
Carnivore	1	21						**22**	1.3

Tab. 20. Level D: modified bone remains.

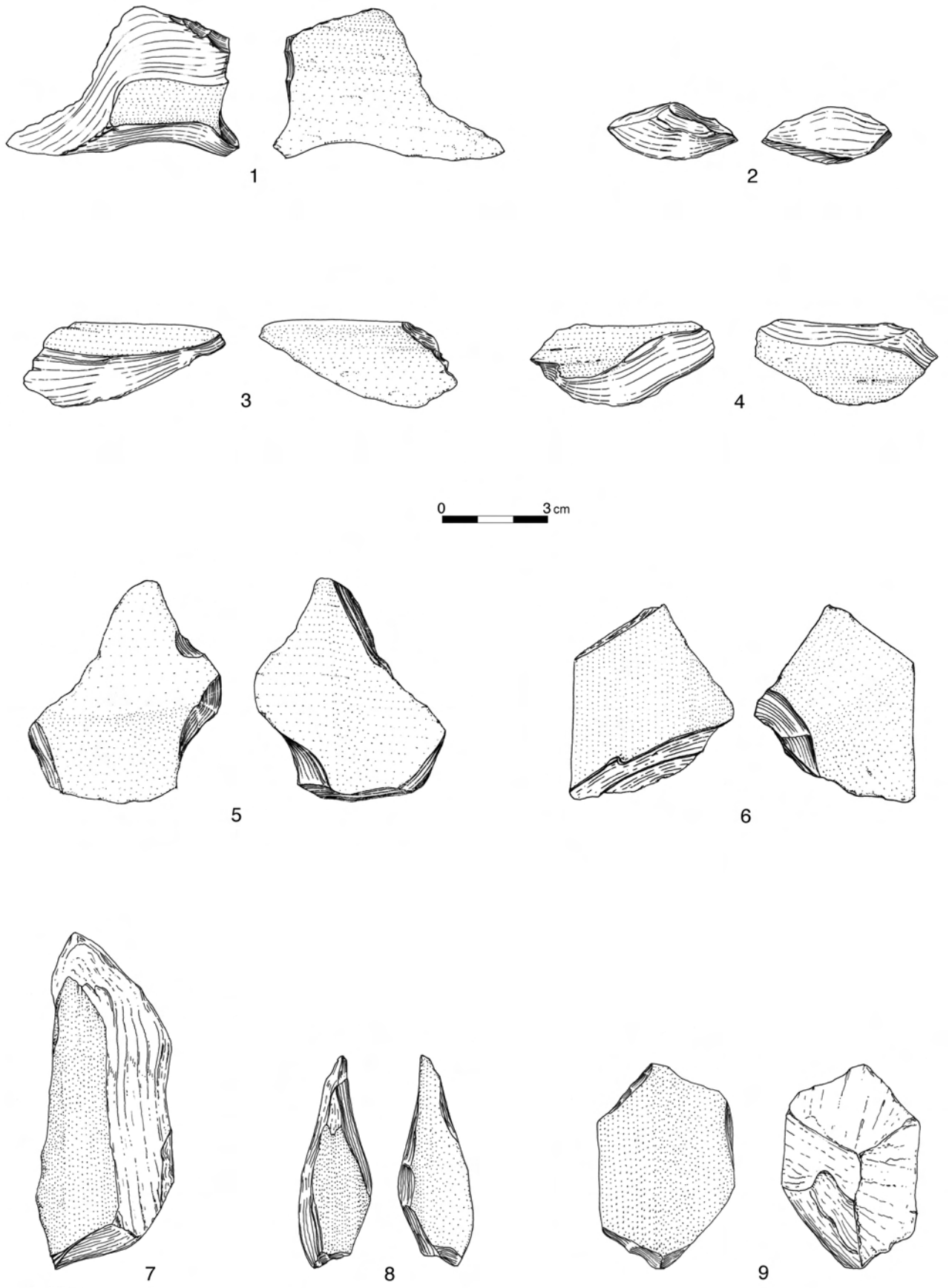

Fig. 18. Levels C and D: percussion cones and percussion flakes. 1: MK 2435; 2: MK 4381; 3: MK 4467; 4: MK 4966; 5: MK 56; 6: MK 2278; 7: MK 4169; 8: MK 6373; 9: MK 8678.

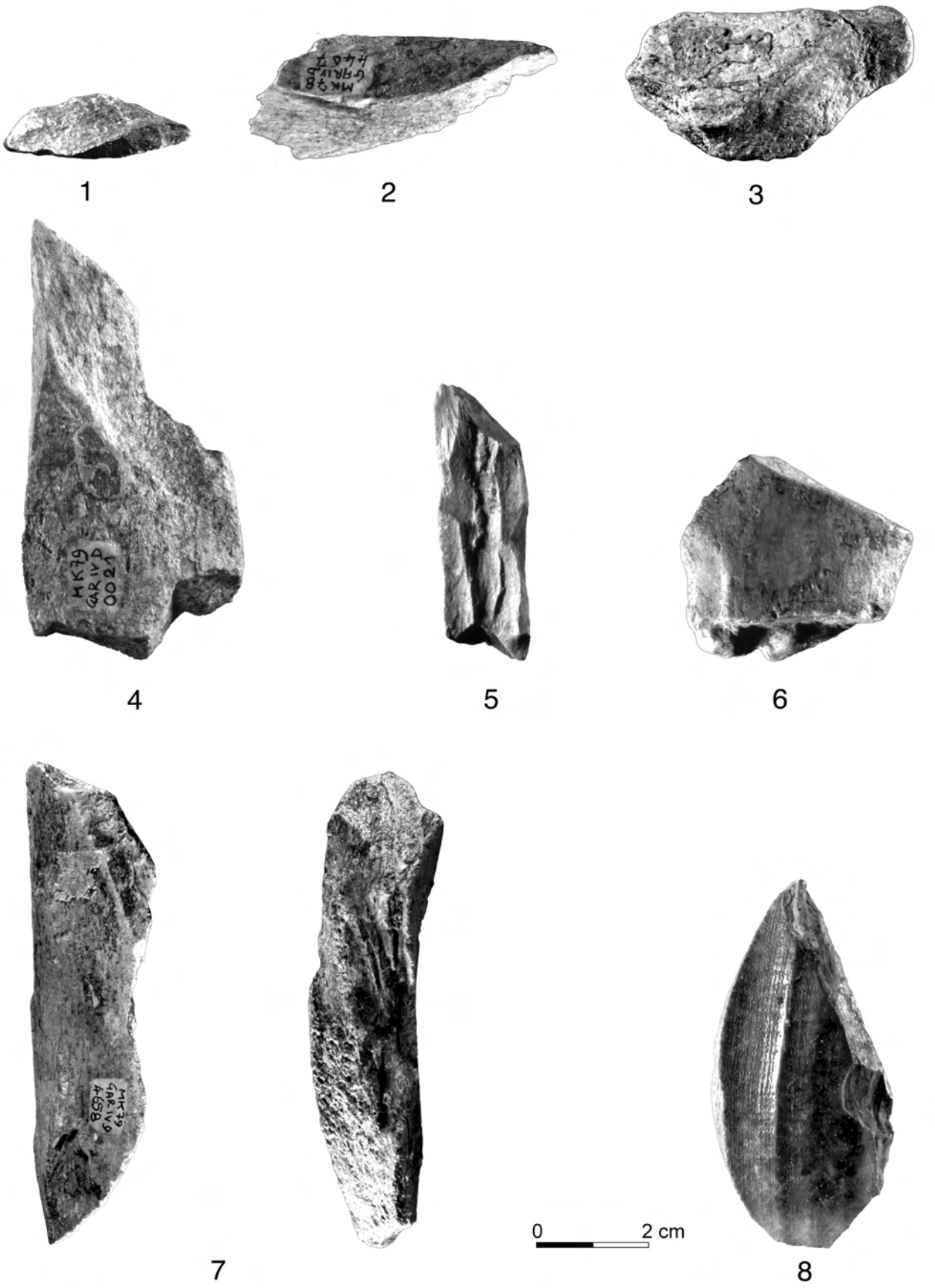

Plate 1. Level D: impacts and percussion cones.

(concave). The percussion cones are made mainly of medullar surface and their shape may vary on the basis of the anatomical element, the exact impact location on the bone and the number of blows. The primary flakes are those fragments detached from the impact area often presenting traces of the impact marks on the cortical surface and sometimes of the negative scar of the percussion cone on the medullar surface; they are usually made mainly of cortical surface and present thinning of the medullar portion.

There are four percussion cones, all from Level D (MK 2435, MK 4381, MK 4467, MK 4966). These flakes belong to long bone diaphyses of medium-large sized animals; on two of them (MK 4467, MK 4966) traces of the impact point have also been detected (Fig. 18, *1-4*; Plate 1, *1*, *2*).

There is a total of 12 primary flakes, eight from Level D and four from Level C. As expected none of these elements can be referred to a single animal or a precise skeletal element, but in general are on diaphyses of long bones belonging to large sized animals (Fig. 18, *5-9*).

The features of each single element will be described below in detail.

1972, MK 2435
Level D, square 6E/2N
Length 65; Width 40.2; Thickness 9.3 mm.
Percussion cone on an indeterminate bone fragment belonging to a medium sized animal. It presents well preserved surfaces with fresh bone longitudinal fractures on all edges. The cone is constituted by cortical surface with a very wide fracture edge and little medullar cavity. Both edges, the first rectilinear the other sinuous, are regular. The first fracture has a regular point, the second is convex regular. The blow seem to be located in the area of the first fracture (Fig. 18, *1*).

1978, MK 4381
Level D, square 1E/4N
Length 35; Width 16.5; Thickness 10.6 mm.
Percussion cone on a long bone shaft fragment belonging to a medium-large sized animal. It is a small flake, completely medullar without cortical surface and with abraded fracture edges (Fig. 18, *2;* Plate 1, *1*).

1978, MK 4467
Level D, square 1W/4-5N
Length 56; Width 23.5; Thickness 9.4 mm.
Percussion cone on a long bone shaft fragment of an animal of undeterminable size. It has well preserved surfaces with fresh bone longitudinal fractures on all edges. The cone preserves traces of the impact point on the medullar surface and a wide edge of medullar fracture. Both edges, the first rectilinear, the other concave, are regular. The first fracture is pointed, the second is denticulated oblique (Fig. 18, *3*; Plate 1, *2*).

1976, MK 4966
Level D, square 4E/7N
Length 52; Width 27; Thickness 17 mm.
Percussion cone on a long bone shaft fragment belonging to a large sized animal, preserving two small impact notches on the medullar surface. The edges and the surface are abraded. One edge is spiral and sinuous, the other has a concave outline, both are regular. All edges present fresh bone longitudinal fractures; one is rectilinear with two notches on the medullar face, the other is regular pointed (Fig. 18, *4*; Plate 1, *3*).

1975, MK 24
Level C, square 1E/6N
Length 62; Width 42.8; Thickness 15.9 mm.
Percussion flake on a long bone shaft fragment belonging to a large sized animal. The surface and the edges are strongly abraded. One edge is regular concave, while the other has a sinuous regular outline. There are longitudinal fresh bone fractures on all edges; one is regular pointed and the other oblique convex. On the sinuous edge, on the cortical face, a surface removal is present, referable to an impact, while on the corresponding medullar face there is the removal of a conchoidal flake.

1975, MK 56
Level C, square 1W/5N
Length 66; Width 56; Thickness 16.5 mm.
Percussion flake on a long bone shaft fragment belonging to a large sized animal. The surface and the edges are abraded. One edge is sinuous spiral while the other has a sinuous regular outline. There are longitudinal fresh bone fractures on all edges; one is regular pointed, the other is rectilinear transversal. On the sinuous spiral edge it is possible to observe both a notch produced by the impact and a thickening of the medullar tissue taking the aspect of a bulb (Fig. 18, *5*).

1973, MK 795
Level C, square 9E/3N
Length 44; Width 22.4; Thickness 12 mm.
Percussion flake on a long bone shaft fragment belonging to a large sized animal. The surface and the edges appear to be abraded. One edge is regular concave while the other has a rectilinear outline and presents a wide fracture edge. There are longitudinal fresh bone fractures on all edges; one is rectilinear oblique, the other is concave.

1973, MK 2553
Level C, square 12E/5N
Length 39; Width 27.2; Thickness 16.8 mm.
Percussion flake on a long bone shaft fragment belonging to a large sized animal preserving on the cortical face a semicircular surface removal. The surface and the edges are strongly abraded. One edge appear to be sinuous regular, while the other has a rectilinear regular outline. There are longitudinal fresh bone fractures on all edges; one is convex, the other is sinuous with impact marks on the cortical surface.

1972, MK 2278
Level D, square 4E/1N
Length 48; Width 44.8; Thickness 22 mm.
Percussion flake on a long bone shaft fragment belonging to an hippopotamus sized animal. The surface and the edges are abraded. Both edges are rectilinear regular. There are longitudinal fresh bone fractures on all edges; one is oblique rectilinear regular and the other irregular with a sinuous outline and a thickening of the medullar portion (Fig. 18, *6*).

1972, MK 4169
Level D, square 7E/7N
Length 96; Width 40; Thickness 30.8 mm.
Percussion flake on a long bone shaft fragment belonging to a large sized animal. The surface and the edges are abraded. One fracture edge is very wide, sinuous regular while the other has a rectilinear regular outline. There are longitudinal fresh bone fractures on all edges; one is regular convex and the other sharp rectilinear (Fig. 18, *7*).

1976, MK 4973
Level D, square 4E/8N
Length 47; Width 24; Thickness 8 mm.
Percussion flake on a long bone shaft fragment belonging to a medium-large sized animal, preserving on the surface a small punctiform notch produced by an impact. The surface and the edges are very abraded. One edge is sinuous with a wide fracture edge; while the other has a concave outline. There are longitudinal fresh bone fractures on all edges, one is regular convex, the other oblique rectilinear with a small punctiform notch.

1977, MK 5603
Level D, square 2E/4N
Length 34; Width 23.9; Thickness 121 mm.
Percussion flake on a long bone shaft fragment belonging to a medium sized animal with several fracture planes. The surface and the edges appear rounded. Both edges are sinuous while there are longitudinal fresh bone fractures on all edges, with a regular pointed shape.

1974, MK 6131
Level D, square 11E/6N
Length 73; Width 47.8; Thickness 11.9 mm.
Percussion flake on a long bone shaft fragment belonging to a large sized animal. The surface and the edges appear abraded. There are longitudinal fresh bone fractures on all edges; one is regular pointed and the other irregular rectilinear with a thickening of the medullar surface.

1974, MK 6373
Level D, square 10E/6N
Length 60; Width 34.3; Thickness 15 mm.
Percussion flake on an indeterminate bone fragment belonging to a large sized animal with an hexagonal shape and six fracture planes. The surface and the edges appear to be strongly abraded. All the edges are regular and rectilinear. There are longitudinal fresh bone fractures on all edges with a pointed shape (Fig. 18, *8*).

1978, MK 8678
Level D, square 2W/3N
Length 53.5; Width 18; Thickness 11.8 mm.
Percussion flake on a long bone shaft fragment belonging to a large sized animal preserving a scaled impact point on the medullar surface. The surface and the edges are very abraded. One edge is sinuous with a wide fracture edge and a notch on the medullar face, while the other has a sinuous regular outline. There are longitudinal fresh bone fractures on all edges; one is regular pointed, the other transversal rectilinear (Fig. 18, *9*).

1980, MK 10882
Level D, square 1E/7N
Length 82; Width 45; Thickness 18 mm.
Percussion flake on a long bone shaft fragment belonging to a large sized animal. The surface is preserved and the edges are abraded. One edge is regular rectilinear, while the other has a sinuous and spiral outline. There are longitudinal fresh bone fractures on all edges; one is irregular rectilinear and the other is pointed with clear impact marks on the cortical surface.

The four flakes from Level C can be all referred, on the basis of their thickness, to the diaphyses of large sized animals (Tab. 21). In three cases (MK 24, MK 56, MK 2553) the flake preserves impact traces on the cortical surface; on the medullar surface of fragment MK 24 a negative scar of a conchoidal removal is present.

The eight flakes from Level D, on the basis of thickness, can be referred in one case to the diaphysis of an animal of the hippopotamus size, the remaining ones to diaphyseal fragments referable to medium and large sized animals with a prevalence of the latter ones (Tab. 22). In three cases impact traces are preserved on the cortical surface (MK 4973, MK 8678, MK 10882). On the fracture edges of two other fragments (MK 2278, MK 6131) it is possible to observe a small area with a convex thickening of the medullar tissue similar to a "bulb", observed also on a flake from Level C (MK 56). These latter diaphyseal fragments can be referred in one case to an animal of hippopotamus size and in the other two instances to large sized animals. Therefore these are very thick bones which may have favored the formation of such "bulb". In two cases (MK 5603, MK 6373) the fragments have been considered primary flakes because, besides the recognition of fresh bone fracturing, it is possible to identify between 5 and 6 fracture edges.

Level C	**Anatomical element**	**Impact**	**Impact?**	**Percussion flake**	**Total**
Large size	Cranium	1			**1**
Large size	Long bone		1		**1**
Large size	Long bone	2		4	**6**
Medium size	Long bone	1	1		**2**
Total		**4**	**2**	**4**	**10**

Tab. 21. Modified bone remains from Level C.

Level D	Total N	N with traces	%	Anatomical element with traces	N	N with traces	N with traces/N	Impact	Impact?	Percussion cone	Percussion flake	Stria?
Small carnivore	**1**	1		Radius	1	1	100.0		1			
Hippopotamus	**257**	7	2.72	Canine frg.	46	5	10.9	3	2			
				Femur	3	1	33.3	1				
				Long bone shaft	7	1	14.3	1				
				Total				**5**	**2**			
Medium Bovid	**49**	6	12.24	Humerus	3	2	66.7	1	1			
				Tibia	4	1	25.0		1			
				Metatarsal	8	2	25.0	1				1
				Metapodial	8	1	12.5	1				
				Total				**3**	**2**			**1**
Small Bovid	**56**	8	14.29	Radius	9	1	11.1		1			
				Metatarsus	11	4	36.4	3	1			
				Femur?	1	1	100.0	1				
				Long bone (femur)	1	1	100.0		1			
				Tibia?	4	1	25.0		1			
				Total				**4**	**4**			
Hippopotamus size	**51**	9	17.65	Long bone	22	8	36.4	5	2		1	
				Indeterminate	21	1	4.8		1			
				Total				**5**	**3**		**1**	
Large size	**278**	25	8.99	Femur?	2	1	50.0	1				
				Tibia	1	1	100.0	1				
				Flat bone	1	1	100.0		1			
				Long bone shaft	159	21	13.2	13	3	1	4	
				Indeterminate	82	1	1.2				1	
				Total				**15**	**4**	**1**	**5**	
Large-Medium size	**69**	7	10.14	Long bone	20	6	30.0	2	2	1	1	
				Indeterminate (rib)	6	1	16.7		1			
				Total				**2**	**3**	**1**	**1**	
Medium size	**211**	13	6.16	Radius	4	1	25.0	1				
				Femur	2	1	50.0	1				
				Tibia?	1	1	100.0		1			
				Long bone	138	9	6.5	6	2		1	
				Indeterminate	21	1	4.8			1		
				Total				**8**	**3**	**1**	**1**	
Medium-Small size	**24**	2	8.33	Long bone	13	2	15.4	1	1			
Small size	**60**	2	3.33	Radius	2	1	50.0	1				
				Long bone	44	1	2.3		1			
				Total				**1**	**1**			
Indeterminate	**235**	2	0.85	Long bone	11	2	18.2		1	1		

Tab. 22. Modified bone remains from Level D.

In Level C the impact points are localized mainly on indeterminate long bone shaft fragments and on a skull fragment of large sized animals (animals in the large Bovid range, not reaching the size of the hippopotamus). In two cases the impact points are present on long bone shaft fragments of medium sized animals (Tab. 21).

In Level D impact traces have been detected on hippopotamus remains; besides post-cranial elements, notches and flaking, related to intentional fracturing, have been found also on teeth. There are canine fragments with dimensions between 60 and 70 mm presenting semicircular notches (MK 465, MK 7475, MK 10189); the fracture edges have a regular outline and features typical of fracturing in a fresh state (Tab. 22; Plate 1, *8*). However, most of the analyzed canines show cracking and irregular edges, with flaking mainly related to post-depositional factors.

A fragment of hippopotamus proximal femur (MK 1811) presents on the lateral surface a large concentric removal of cortical surface forming a notch and, corresponding to it on the medullar face, an almost conchoidal surface removal is recorded.

A long bone shaft fragment (MK 4686) presents on one fracture edge an impact mark on the cortical surface corresponding, on the opposite edge, to large removals of medullar surface which may have been produced by the counterblow.

Other eight diaphyseal fragments, that for their dimensions and thickness may belong to animals of the hippopotamus size, present clear notches on the cortical surface (MK 10840, MK 21) and surface removals that are often scaled and more rarely conchoidal; in two cases (MK 2221, MK 6615) the blows are repeated with more than one mark on the cortical surface.

On the remains referable to medium sized Bovids, impacts have been detected on two humerus diaphyseal fragments: in one case (MK 2436) there are three small, almost punctiform, notches visible on the fracture edge, in the other case (MK 4466) there is a single wider semicircular notch. The finding of multiple and punctiform notches raised the doubt that these could have been produced by carnivore action, but the identification of multiple punctiform notches on other shaft fragment belonging to medium and large sized animals (MK 12020, MK 11659, MK 3823, MK 8347) and in particular the analysis of the surfaces, carried out also by means of casts (obtained with silicon rubber from which positives have been made using araldite) observed with an optical microscope, did not evidence traces of tooth pressure or scoring. It is therefore possible that these fragments have been intentionally fractured not by direct percussion, but by a launched one (Anconetani 1996). On shaft fragments of a tibia and of an indeterminate metapodial (MK 408, MK 476) traces of an impact and of the corresponding counterblow have been observed, while on a metatarsal shaft fragment (MK 6233) only the impact notch has been detected. The impact marks on the metatarsal and on the metapodial were found on the anterior face.

On the fragments referable to small sized Bovids, notches due to impact points with the removal of medullar flakes, have been found mainly on shaft fragments of the hind limb (metatarsal and femur) and only in two cases probably on fragments of radius and tibia. Also in this case it has been possible to recognize in some fragments both the impact point and the counterblow (radius fragment MK 688; femur shaft MK 3178; metatarsal fragment MK 4412; Plate 1, *5*). On the metatarsals the impact point is not always located on the same face: fragment MK 1463 presents repeated impacts on the anterior face, MK 3078 one impact on the medial face, and MK 8757 on the posterior one.

Impact points identified on indeterminate shaft fragments referable to large sized animals (excluding the specimens with a thickness of the hippopotamus size) are frequent; such fragments are 15 and present clear notches and removals on the cortical surface (MK 16, MK 508, MK 2553; Plate 1, *6*). Particularly interesting is fragment MK 11171 presenting impact marks and a conchoidal percussion flake still *in situ*.

Impacts are less frequent on the bones of medium-large sized animals; these have been found mainly on diaphyseal fragments (MK 10038; Plate 2, *1*), but with some doubts, also on a rib fragment (MK 3823). This latter presents two small notches not associated to other kinds of modifications (for example carnivore scoring) and since small notches have been found also on other fragments (MK 12020, MK 11659, MK 8347) it is not possible to exclude that these also represent traces of intentional fracturing. In fact they are evident on some fragments attributed to medium sized animals and present the already described features: notches with medullar removals and in some cases traces of the counterblow; this is also valid for the few specimens with impacts referable to medium-small and small sized animals.

On a radius fragment referable to a carnivore a small notch with scaled removals has been identified; the fracture edges are wide and present the features of a fresh bone fracture, therefore it is not possible to exclude that also this element has been intentionally fractured.

Therefore, as a whole, sure traces of carcass exploitation have been detected on remains of hippopotamus, indeterminate Bovids, and probably on a carnivore bone, but mostly on long bone shaft fragments belonging to indeterminate species of large size. No traces have been identified on determined remains of

the different Bovid tribes/families (Bovini, Reduncini, Alcelaphini, Antilopini) and on those of Equids and Suids; this is due, besides the high fragmentation of the analyzed specimens, to the difficulty of identification based mainly on cranial remains, mostly isolated teeth and horns, and just on few long bones.

Considering only Level D (MK 1476), the highest percentage of modified remains has been found for the indeterminate bones referable to the hippopotamus size (9 out of 51 equal to 17.6% of the remains with traces of intentional fracturing); however, also the remains surely attributed to the hippopotamus should be added to these (Tab. 22). Traces of intentional fracturing on hippopotamus remains have been detected on long bone shaft fragments (very often it was not possible to determine the anatomical element) and on canine fragments. Of course the breakage of long bones may be related to marrow retrieval, while that of the canine fragments may be due to the extraction of the tooth from the mandible and/or its use as raw material for knapping.

Among the indeterminate Bovids, those referable to small sized animals present the highest number of intentionally fractured bones (14.3% of the remains attributed to them): these are long bones of the fore and hind limbs (radius, tibia, femur and metapodials). They are followed by medium sized Bovids (10.2%): also in this case the remains are referable to limb long bones (humerus, tibia and metapodials).

Among the indeterminate remains the highest number of traces was found on the specimens with thickness referable to large sized animals (25 elements out of 278 equal to 9%) although as a percentage the highest value is referred to remains of medium-large sized animals with 10.1% (7 remains out of 69); those of medium and small sized animals follow with 6.2% (13 remains out of 211) and 3.3% (2 remains out of 60) respectively. The traces have been detected mainly on long bone shaft fragments and in some cases it has been possible to recognize the anatomical element (femur, radius and tibia; Tab. 22).

Traces of intentional fracturing identified on 10 specimens from Level C are present exclusively on indeterminate long bone shaft fragments (Tab. 21); remains referable to large sized animals are prevalent (8) followed by medium sized ones (2).

Spatial distribution of the modified remains

The analysis of the spatial distribution of the intentionally fractured remains from Level D shows that they are mainly located in the WS (Fig. 19).

Of the four percussion cones, three are in the WS (squares 4E/7N, 1W/5N, 1E/4N) and one in the ES (square 6E-2N). Of the eight percussion flakes, four are in the WS and four in the eastern one; each one is located in a different square and are widely distributed over the paleosurface (Fig. 19). In the ES three of these are in the row of squares 6N and are relatively close.

The 73 specimens with impact traces are mainly in the WS (54) and are widely distributed over the surface, although some concentrations could be evidenced in square 9N/3E and in the adjacent squares, where 10 remains with impacts and one percussion cone were found, and in square 4N/1W and in the adjacent squares with 8-10 specimens plus two percussion flakes. In the ES there are 19 fragments with impact points and these are widely distributed over the surface, with the exception of a slight concentration in the squares of rows 6-7N where there are also three percussion cones.

There are 121 bones from Level D presenting fresh bone fracture patterns (Fig. 20); these are mostly referable to limb long bones of indeterminate large (45) and medium (26) sized animals; among the bones identified to species it is worth mentioning the metatarsal of *Giraffa* cf. *jumae* and a humerus, a radius and a femur of hippopotamus. Typical outlines referable to fresh bone fracture have been identified on two mandibles of an Alcelphine, on a hippopotamus canine and, probably, at the base of a horn

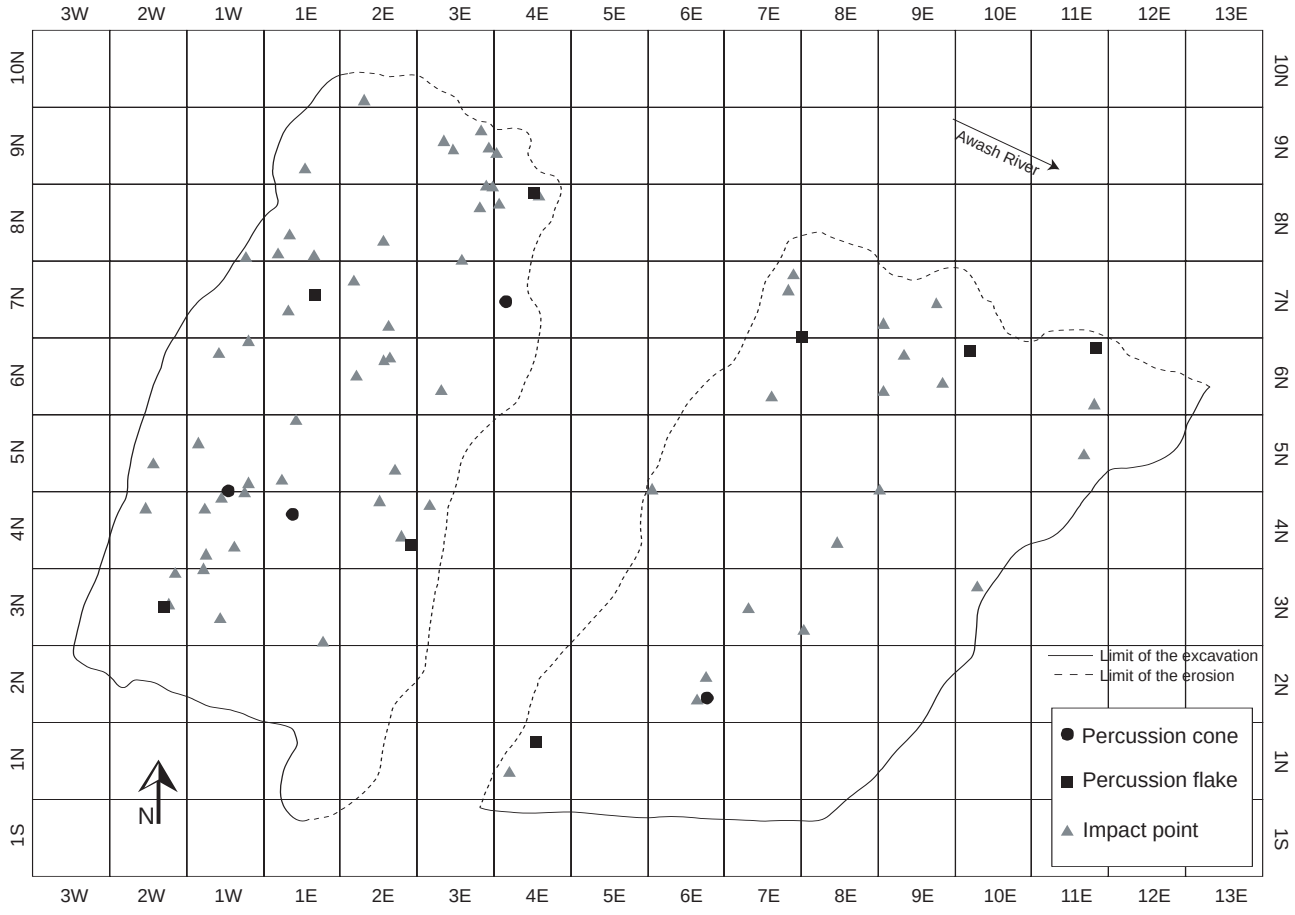

Fig. 19. Level D: distribution of the intentionally fractured remains.

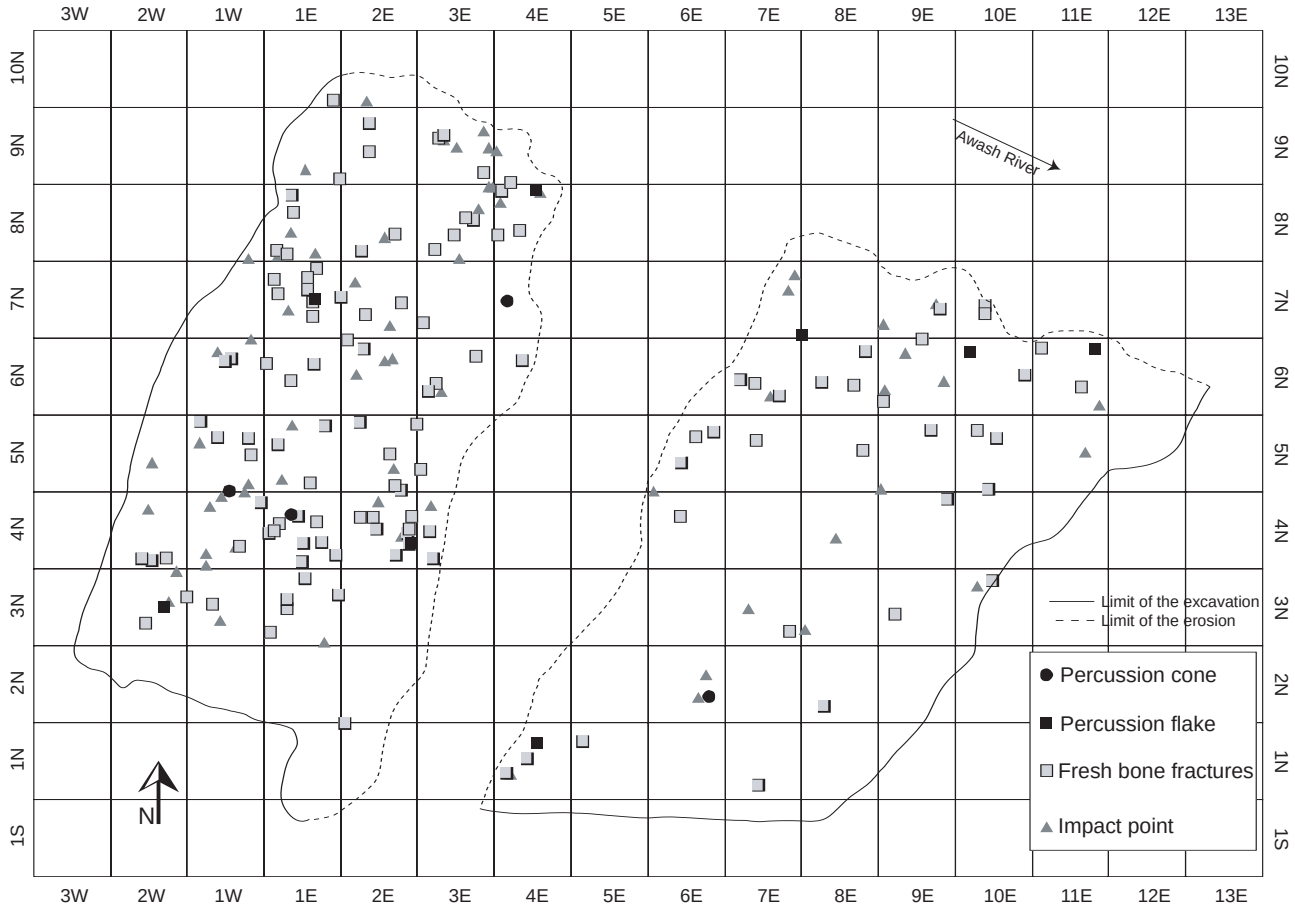

Fig. 20. Level D: distribution of the intentionally fractured remains and fresh bone fractures.

of *Damaliscus* sp. The remains result to be more present in the WS, uniformly distributed without any particular concentration.

The distribution of the intentionally fractured remains and of those presenting fresh bone fractures does not evidence particular concentrations, but simply reflects the quantification of the whole assemblage.

Striae

The analysis of the surfaces was carried out at the Center for Research and Conservation of Cultural Heritage in Addis Ababa with the simple aid of a magnifier. Casts have been made of the rare surfaces preserving striae; such casts have been then observed with a stereomicroscope. All the bone surfaces of Garba IV, as already mentioned, present different degrees of abrasion and no shaft fragment preserves perfectly the original surface. Erosion traces are evident on the surfaces that, on some fragments, form real pits; striae produced by sediment abrasion are relatively frequent. Well preserved abrasion striae have been identified on fragment MK 10038 close to an impact notch; the striae are well preserved, wide, short, and superficial (Plate 2).

Only on two specimens there were striae which could be related, with some doubts, to the action of a stone tool (Binford 1978a, b; Shipman and Rose 1983, 1984; Olsen and Shipman 1988; Behrensmeyer *et al.* 1989; Fiorillo *et al.* 1989; Gifford-Gonzalez 1989).

On a diaphyseal fragment of a Bovid metatarsal (MK 3451) there is a group of striae oriented obliquely to the bone axis. The striae have different lengths and the bottom and the walls are eroded and not well preserved. The longest stria (10 mm) has a different degree of preservation along its length (Plate 3, *1*, *2*). It presents a narrow and clear beginning with a V section and it is possible to recognize secondary striae within the groove; the continuation of the groove seems to be marked by erosion phenomena: the edges become less clear and the groove widens. Although in the best preserved portion of this stria it is possible to recognize some of the features of the cuts produced by stone tools, it is not possible to exclude completely abrasion phenomena due to the sediment. On fragment MK 4417 there is some kind of dent where, notwithstanding it is badly preserved and affected by abrasion phenomena, it is possible to recognize a clean edge and a V section. Such dent may represent the trace of a blow produced by a hammerstone with a sharp edge (Plate 3, *3*).

Gnawed remains

Carnivore gnaw marks (Binford *et al.* 1988; Bunn 1989; Irving *et al.* 1989; Oliver 1989, 1994; Lupo 1994, Blumenschine *et al.* 1994, Selvaggio 1998; Ruiter and Berger 2000; Lupo and O'Connell 2002) identified on the Garba IV fragments are pits and scores produced by the pressure and scoring of teeth on the surface (Plate 4, *1-2*). There are also fragments presenting wide portions of the fracture edges that are completely gnawed. (Tab. 20; Plate 4, *5*).

Gnaw marks are mainly found on Bovid as well as on medium and large sized animal long bones; only in one case they have been found on a pelvis (MK 2478).

In Level C carnivore activity is evidenced only by a humerus diaphysis referred to a medium sized Bovid (MK 3), presenting on the cortical surface pits and scores produced by teeth. On one of the edges it is possible to observe a wide scaled notch probably produced by the gnawing action.

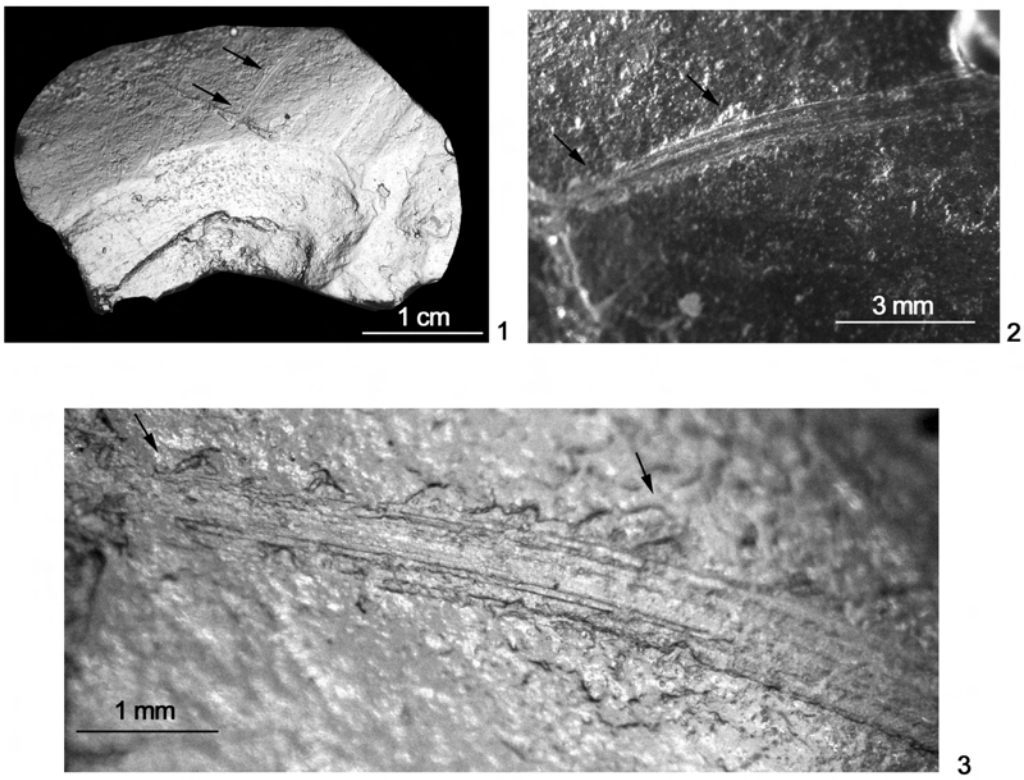

Plate 2. Level D: 1) abrasion stria produced by sediment and impact notch by hammerstone on specimen MK 10038; 2, 3) details of stria.

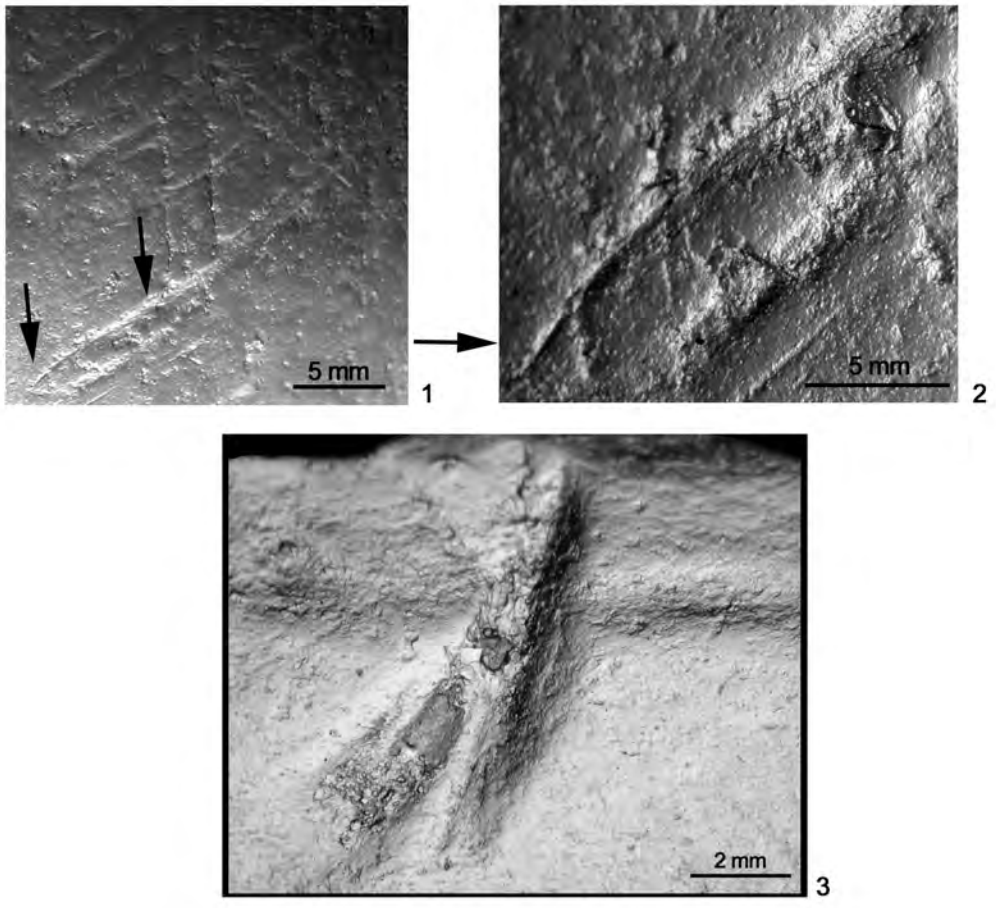

Plate 3. Level D: 1, 2) probable stone tool striae on specimen MK 3451; 3) probable blow of the hammerstone on specimen MK 4417.

In Level D the gnawed bone remains are more numerous: sure traces have been detected on 15 specimens while on 6 other fragments, for the bad preservation of the surfaces, they are of difficult interpretation and there are doubts if they should be attributed to carnivores or to the crocodile. Sure traces produced by a gnawing action of a medium-large sized carnivore are present on a medium sized Bovid metacarpal (MK 5464; Plate 4, *2*). On the distal portion of the anterior face there are evident marks of tooth scoring; at half diaphysis there are pits due to tooth pressure, with small adjacent scoring, while the posterior face of the shaft is broken and presents numerous circular tooth impressions. The same kind of traces has been recovered on a radius diaphysis referable to a small-medium sized Bovid (MK 10247). It shows a spiral outline of the fracture edges, on the anterior face it presents several punctures by tooth pressure and a portion of the fracture edge is sinuous and rounded by prolonged gnawing. Another example is

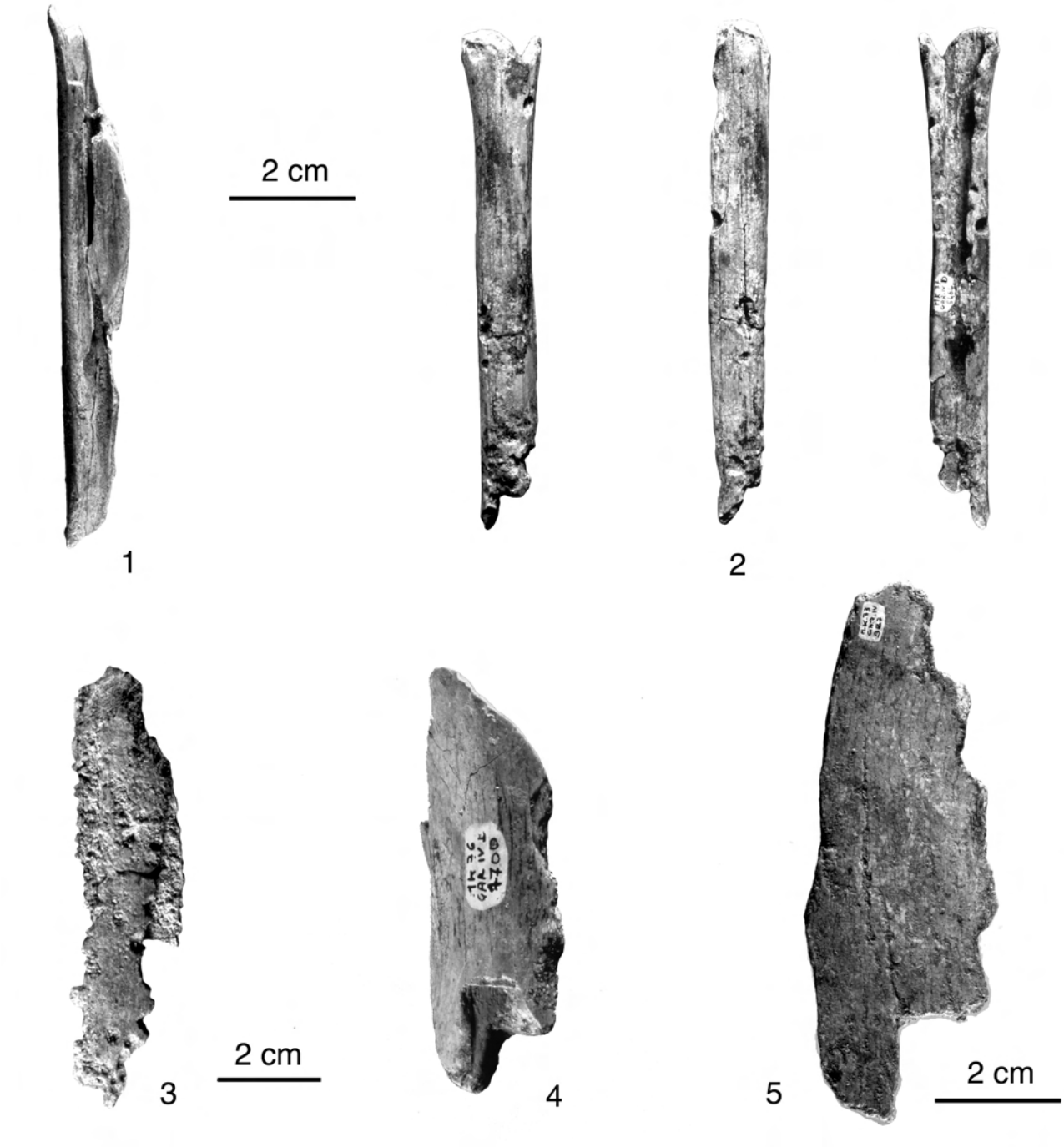

Plate 4. Level D: bone remains with traces of carnivore activity.

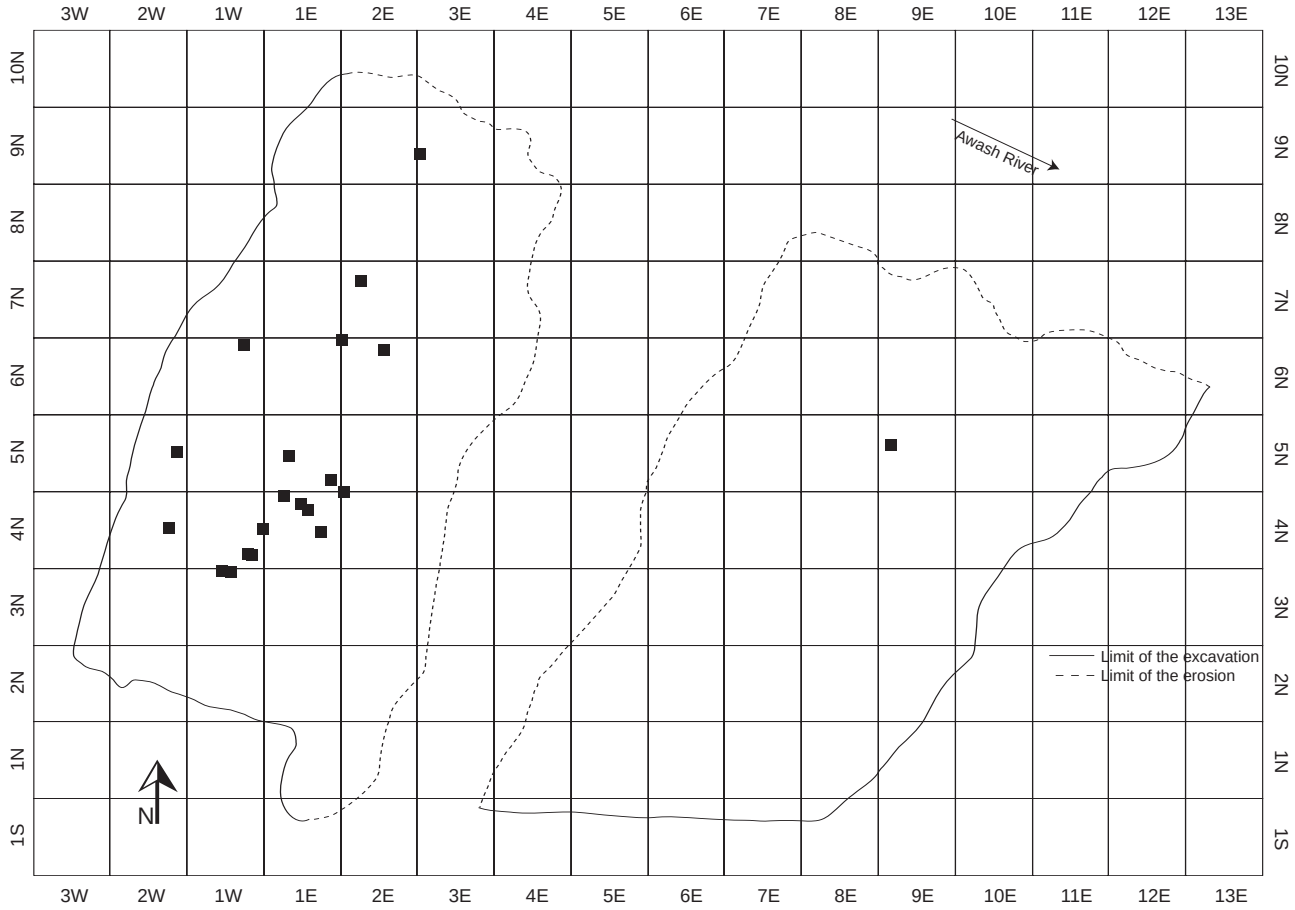

Fig. 21. Level D: distribution of the remains with gnaw marks.

represented by two holes identified on a pelvis fragment belonging to a medium sized animal (MK 2478). These two holes, with a conical shape, have a circular entrance, a maximum width of about 11 mm and a depth of about 9 mm; they present on the edges small circular removals produced by the pressure of a large carnivore tooth.

The analysis of the spatial distribution of the gnawed and probably gnawed elements evidences a particular concentration in squares 1W-1E/5-4N of the WS of Level D (Fig. 21).

Results

The taphonomic analysis of the faunal remains from Garba IV was affected by differences in the data available for each single specimen. Out of the 2945 remains collected during the excavations, the paleontological study was carried out on 2170 elements, while the analysis of the surfaces was done on 1664 specimens. Dimensional data were available for 2886 elements. The analysis of the spatial distribution was carried out only for Level D, and involved 2580 bones, 1873 of which had been studied from a paleontological perspective and 1476 also from a taphonomic point of view; most of these remains came from the WS.

The Garba IV faunal assemblage is characterized by a prevalence of hippopotamus remains, followed by Bovids, and, with much lower percentages, by Equids and Suids; Carnivores, Primates, elephants, giraffes, Birds, and Reptiles are present with rare remains. The difficult estimate of the Minimum Number of Individuals revealed instead the prevalence of Bovids over the hippopotamus.

The osteological sample is characterized by a high fragmentation and complete elements (mainly isolated teeth or distal limb bones) are very rare. The length of the specimens varies from a minimum of 9.2 mm to a maximum of 550 mm. The dimensional class with the highest number of specimens (52.3%) is the one in the 25-50 mm range, followed by the class with remains between 51 and 75 mm (21.3%). The other classes, comprising the largest elements, are composed only by few elements and those including specimens in the 151-550 mm size range do not reach 1%. The proportions among classes are practically identical in the two Levels, C and D, indicating a similar fragmentation.

The bone remains include mainly elements not referable to any skeletal portion (32.35%) and by indeterminable limb diaphysis fragments (22.6%). The skeletal composition in the two levels is very similar as percentage, although in Level D there is a higher proportion of horn remains and a lower percentage of axial elements compared to the overlying Level C. As expected, the analysis of the skeletal portions carried out on the different species, genus and/or family, is not different from the general one (cranial elements are always prevalent), but evidenced some peculiarities: while for the hippopotamus cranial elements, mainly teeth, are prevalent, for the Bovids there is a relevant presence of horn remains. Small variations in the skeletal composition of hippopotamus have been evidenced between the two levels, with the prevalence of cranial remains (mainly teeth) in Level D and more numerous post-cranial bones in Level C. However, it is not possible to suggest a single hypothesis on what or who produced such skeletal composition and on the causes of these slight variations. In fact, in theory these could be due to several factors: different butchering or carcass exploitation models, carnivore intervention (with removal and destruction of some elements) or, more simply, natural processes related to the deposit formation.

The spatial distribution of the bone remains, although widely dispersed, evidenced some areas of higher concentration with hippopotamus bones as well as horns of the Alcelaphini and the other Bovids. However, it was not possible to evidence skeletal portions in anatomical connection, and the post-cranial elements are numerically scarcer than expected from the Minimum Number of Individuals: all this seem to reflect a strong dispersion and fragmentation due to post-depositional phenomena before burial. Only in two cases it was possible, from the spatial analysis, to hypothesize cases of anatomical connection for small axial portions of the hippopotamus: two cervical vertebrae in strict association in the WS and three vertebrae with some rib fragments in the ES.

The disposition of the remains shows that they are mainly oriented in a N-W/S-E direction and numerous are also in E-W direction. The analysis of the shape of the specimens evidenced the prevalence of blades and discs (over 60%), that are those more easily subject to hydraulic action, compared to rods and pseudo-spheres. The analysis of transport groups, proposed by Badgley (1986), evidenced that the abundance ranking of the skeletal elements is very similar to that of groups I and II, that reflect a strong hydraulic action. Certainly an accumulation of bone remains on a paleosurface located close to a river, such as that of Garba IV, may have been affected by the removal of some remains originally resting on the surface, and then redeposited downstream, but it may have been also influenced by the redeposition of remains transported by water from upstream. The nature of the bank affected the transportability of the bones and the presence of large pebbles as well as big rocks obstructed the arrival of bones coming from outside as well as the removal of those originally present on the bank, introducing other variables that will be difficult, if not impossible, to control.

Taking into account the preferential orientation of the remains, the correspondence of the anatomical elements with that of the transport groups with fast current, the shapes of the specimens, the low frequency of vertebrae and ribs as well as of small sized remains, it is evident that among the different taphonomic agents influencing the accumulation of Garba IV, hydraulic action surely played an important role.

The analysis of the bone surfaces revealed that the remains, with few exceptions, do not preserve the original surface, but have been affected by abrasion phenomena. Considering the span of time the specimens spent within sandy sediments, it is not surprising that the number of bones with abraded or strongly abraded surfaces is very high. Such modification does not seem to be related only to the size of the animal, but also to the dimensions of the specimens and to their structure. Alcelaphini and Bovid teeth are better preserved than horns that are the elements that were more strongly affected by post depositional phenomena.

However, the analysis of the surfaces revealed the presence of butchering marks that are in most cases represented by impact points and small percussion flakes, while striae produced by lithic tools are almost completely absent. The absence of striae is not due to the modes of access and exploitation of the carcasses, that would document the interest of hominids only in marrow extraction (marginal scavengers for marrow in large carnivore kill sites; Binford 1981, 1983, 1984), but may be instead related to the effects of hydraulic action and/or to the permanence of the bone remains in the sandy deposits of Garba IV. In fact, experimental studies carried out on bones with cut marks demonstrated that microscopic features of the cuts are erased after a little bit more than 5 hours of abrasion (Shipman 1989). On the other hand, cut marks have been identified, even numerous, on the bone remains recovered in several Plio-Pleistocene sites in Africa, even older than Garba IV, such as Koobi Fora and FLK "Zinjanthropus" at Olduvai (Isaac 1967; Binford 1981, 1983, 1984; Bunn 1981, 1983, 1994; Potts and Shipman 1981; Bunn and Kroll 1986; Stern 1993; Kroll 1994; Oliver 1994; Selvaggio 1994; Domìnguez-Rodrigo 1997, 2002). Besides cut marks, the retrieval of meat at Koobi Fora has been also documented by use wear analysis directly on the stone tools (Keeley and Toth, 1981; Shipman 1983; Vrba 1989).

Traces of intentional fracturing detected on some hippopotamus canine fragments from Garba IV may document the utilization of the carcass as source of raw material. Hippopotamus and Suid canines with characteristics similar to those identified on the fragments from Garba IV have been recovered in several sites at Olduvai (BK II, SHK II, MNK II) and were interpreted by M.D. Leakey (1971) as tools. The reanalysis of the Leakey's materials was carried out by Shipman (1989): the study was done only on the bone remains because teeth did not present enough diagnostic features of their utilization as tools and therefore they were excluded from further studies (Shipman 1989, p. 322). However, the analysis of the other remains ascertained the use of the bones as implements and anvils.

The activity of large carnivores at Garba IV, although not directly documented by the finding of their skeletal remains, is evidenced by the presence of gnawed, fractured and probably digested bones as well as by a coprolite. It was not possible to establish, mainly for the state of the surfaces, if there is overlap on the same fragment of traces of human and carnivore activity. On the basis of the data from the analysis of the surfaces and the fractures at Garba IV, carnivore activity is less important than that of humans, in fact specimens with sure carnivore traces are 1.3% while those with evidence of intentional fracturing are 4%.

Conclusions

Considering the important incidence of hydraulic action and the impossibility to establish which and how many bones have been accumulated and/or removed, it is difficult if not impossible to suggest valid hypotheses on the typology of the site, on hominid access to the carcasses, on meat consumption, on the transport of carcass portions, and on the interactions between humans and carnivores.

What is the place of an assemblage such as that of Garba IV formed by thousands of bones associated to as much numerous lithic industry, within the typology of sites developed for the Plio-Pleistocene in

Africa (Isaac 1967, 1977, 1978)? Level D of Garba IV is very different from the type A sites, considered as workshops because they are characterized by a higher concentration of lithic industry compared to animal bones. Certainly it has no relation to the type B sites also called butchering or kill sites (FxJj 3, FLKN6, FLKN *Deinotherium*, Barogali), because these are referred to a short event and are mainly formed by remains of the carcass (complete or partial) of a large animal associated usually with a few lithic tools (Leakey 1971; Isaac 1977; Bunn 1981; Potts 1983; Berthelet and Chavaillon 1996). Considering always the incidence of hydraulic action, some analogies may be found with the site classified as type C, characterized by a high concentration of lithic artefacts and animal bones belonging to different species, called camps or living floor with occupations repeated over time.

Another question that is difficult to answer is: which human behaviors contributed to the formation of the association between the lithic industry and the animal remains? Several models have been developed: Isaac (1983, 1984) suggests the model of the "central place", replacing the "home base" one that he previously suggested (1978), and applies to the hominid the behavior of some animals (carnivores, leporids, etc.). In fact, in zoology, the "central place", may be represented by a nest or a den and it is a precise and well-defined place to which the animal systematically returns after searching for food (Potts 1994). This model implies a strong sociality and cohesion leading humans to select a place to which individuals converged to share the resources collected in the territory (plants and animals); the activities related to this sharing, repeated over time, would produce the formation of large accumulations with the association of bones and lithic remains.

Potts (1983, 1994) in the "cache model", argued that humans kept the raw materials in precise spots scattered over the territory where later they processed the carcasses of the animals. Binford (1984) suggests the "routed foraging model" in which the choice of the places to occupy is based on the characteristics of the territory and the localization of the resources (raw material outcrops, water, shelter, shade) in well defined areas that are repeatedly occupied forming accumulations of bones and lithic industry. Blumenschine (1986, 1987) proposes a model alternative to that by Binford: the "riparian woodland model" in which the traces of human activity occur in particular vegetational zones where resources may be easily found, such as for example in woodland areas close to water sources where it is easy to find carcasses to be exploited, as observed in the Serengeti during the dry season.

There are many critiques to these models, but as Potts (1994) argues, rather than adopting one or the other, these are useful because they allow to hypothesize from each one of them different variables (resource transport, tethering, different habitat, potential predation, strong social aggregation) that in different moments and/or simultaneously influenced human behavior.

The environment surrounding the site of Garba IV, being close to a water course, was certainly humid (presence of hippopotamus and crocodile) with bushes, and/or woods, as evidenced by the presence of the genera *Alcelaphus*, *Damaliscus* and *Connachaetes* that a revision by Plummer and Bishop (1994) indicates as living in an "Intermediate" environment (bushland, woodland, swamp) rather than an open habitat, as previously suggested by Scott (1985) and Gentry (1992).

This kind of environment (presence of water, food and shade) surely represented an attraction for the ungulates that in turn attracted carnivores and humans. The hominids may have considered this place favorable for its characteristics (shade and water), for the access to carcasses left by carnivores or naturally dead, and as an ambush place.