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Systematic Butchery by Plio/Pleistocene Hominids at Olduvai Gorge, Tanzania[1]

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HUMAN ORIGINS RESEARCH by archaeologists and other paleoanthropologists during the last 25 years has expanded the evidence of many aspects of ancient hominid behavior in its formative stages. The influx of data has stimulated new interpretations and posed new challenges as increasingly complex, interdisciplinary questions have been addressed. Archaeological research, for example, has revealed concentrations of stone artifacts and bones of Plio/Pleistocene age at sites along the East African Rift Valley (e.g., Leakey 1971, Isaac and Harris 1978, Isaac and Crader 1981, Harris 1983, Isaac 1984). Interpretations of the composition and spatial arrangement of the assemblages of stone artifacts and bones have ranged from direct technological and dietary inferences to indirect interpretations of subsistence activities, social organization, and land use patterns. It is worthwhile to consider whether or not all this has increased our understanding of particular aspects of ancient hominid behavior, for example, their diet and subsistence activities.

The fossil animal bone assemblages from archaeological sites at the two main East African localities of Plio/Pleistocene age, Olduvai Gorge, Tanzania, and Koobi Fora, Kenya, constitute one of the most important and controversial classes of data for the evaluation of early hominid diet and subsistence activities. A decade or so ago, it was assumed that hominids transported animal bones as parts of meaty carcasses to their living floors or home bases, where they abandoned the bones as food refuse in association with stone tools (Isaac 1971, Leakey 1971). In more recent years, however, it has been recognized that many taphonomic agencies can create or drastically modify bone accumulations and that early hominid involvement with animal carcasses and bones at Olduvai and Koobi Fora must be demonstrated rather than assumed. To that end, there has been a return to the basic archaeological bone data, including detailed analyses of the Plio/Pleistocene bone assemblages (Bunn et al. 1980; Bunn 1981, 1982*a*, 1983*a*, n.d.*a;* Potts and Shipman 1981; Potts 1982, 1983, 1984; Shipman and Rose 1983; Shipman 1983) and manipulations (Binford 1981) of the preliminary bone data available in Leakey (1971). These efforts have resulted in further examination and development of interpreta-

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Both authors contributed to "FxJj 50: An Early Pleistocene Site in Northern Kenya" (*World Archaeology* 12:109–36) and to Glynn Isaac's posthumous volume on the Plio-Pleistocene archaeological sites at Koobi Fora (Oxford: Clarendon Press, in preparation). They have ongoing research interests in the Plio/Pleistocene archaeological sites at Koobi Fora and are currently engaged in ethnoarchaeological research in Botswana and East Africa. Both were graduate students of the late Glynn Isaacs, and this paper (submitted in final form 24 II 86) is dedicated to him.

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tions. The outcome has been at least three different appraisals of the dietary and related subsistence activities of ancient hominids, as follows:

1. Using a sample of several hundred bones with cut marks at numerous skeletal locations from a variety of taxa represented in the bone assemblages from Olduvai Gorge and Koobi Fora, Bunn (1981, 1983*a*) has argued in favor of an efficient hominid strategy of carcass skinning, joint dismemberment, and meat removal and for a significant amount of meat-eating by hominids nearly two million years ago.

2. From a sample of 18 or 19 bones with cut marks from six different bone assemblages from Olduvai Gorge, Potts and Shipman (1981) conclude that early hominids were not principally interested in obtaining meat from carcasses but instead were principally trying to obtain usable material such as tendons and skin. Shipman (1983:40) has further concluded "that the Olduvai hominids are rarely if ever disarticulating carcasses."

3. Binford (1981, 1983*a*, 1984), largely ignoring the recently published cut mark evidence from the Olduvai Gorge and Koobi Fora archaeological bone assemblages, has alleged that Plio/Pleistocene hominids had little access to meat as a food item and were, instead, the most marginal of scavengers of bone marrow at large-carnivore kill sites. Turning for corroborating evidence to the Oldowan stone tool assemblages, Binford (1983*a*:57) states that "despite much discussion, the fact remains that the earliest Oldowan tools are simply smashed rocks which could probably have served only as hammerstones, clubs or choppers. The flakes struck off them were not in general utilized, for in the lowest deposits cutting tools are rare, while morphologically sophisticated tools (such as scrapers) are entirely absent."

These three interpretations cannot all be correct, and it is possible that none is correct. It is instructive to examine some of the points of contention.

We believe that Potts and Shipman's exceedingly small sample has affected their assessment of the location of cut marks in favor of a relative abundance on nonmeaty bones. In addition, Shipman's (1983, 1984) reliance on Holocene archaeological bone data as a basis for rejecting meat-eating and carcass disarticulation by Plio/Pleistocene hominids is very likely to require reassessment after further consideration is given to the appropriateness of those data as a controlled measure of human butchery practices.

Binford's assertions seem to us questionable in light of the available evidence. Sharp-edged stone flakes and flake fragments are among the best-known cutting tools and numerically constitute the bulk of the Oldowan assemblages from Olduvai Gorge and Koobi Fora. Simple, unmodified stone flakes were used to produce cut marks on bones from Olduvai Gorge and Koobi Fora (Bunn et al. 1980 and other references cited above). Microwear analysis (Keeley and Toth 1981) further indicates that unmodified stone flakes from Koobi Fora were used to cut meat. Far from being rare, unretouched cutting "tools" seem to have been the most abundant type of Oldowan stone artifact. In addition, Binford's numbers for the Olduvai bone assemblages, extrapolated from the preliminary bone data presented in Leakey (1971), can be usefully supplanted by recently collected bone data (see below).

Potts, Shipman, and Binford have all been critical of Bunn's set of bones with cut marks. The methodology Bunn has used to identify cut marks combines macroscopic and microscopic examination of linear grooves in relation to controlled modern grooves of known origin (including gnawing damage by carnivores and rodents, abrasive scratching by sediments, and humanly induced cut marks) with consideration of the anatomical location and orientation of presumed cut marks, as has long been advocated by some of the archaeological pioneers in the study of cut marks (e.g., Guilday, Parmalee, and Tanner 1962) and by subsequent researchers (e.g., Binford 1981). The cut mark sample we are using in this paper includes only those specimens that meet the criteria (macroscopic, microscopic, *and* locational) agreed upon by our colleagues.

Criticisms of methodology and careful scrutiny of the cut mark data are a healthy aspect of ongoing research. The brief critique just offered points to the need for further study of the basic sets of archaeological bone data. In this paper, we return to those data to examine the nature of ancient hominid involvement with animal carcasses. Our purpose is to consider why and how ancient hominids were processing carcasses. That is, were hominids transporting and accumulating carcass parts and bones, or were they operating at the kill sites of large carnivores? And what were they after—meat, tendons, marrow? We will also briefly consider the alternative ways in which they might have obtained the carcasses in the first place—(1) hominid scavenging from carcasses of animals that had died of natural causes other than predation, (2) hominid scavenging from carcasses that had been abandoned by large carnivores at their kill sites, (3) confrontational scavenging by hominids from fresh, largely uneaten carcasses at carnivore kill sites while carnivores were still present, and (4) hunting by hominids of small and large animals.

The archaeological bone data used by the various researchers have included skeletal part frequencies, bone fracture patterns, and surface modifications on bones from Olduvai Gorge (Binford 1981, 1983*a*, 1984; Bunn 1981, 1983*a;* Potts and Shipman 1981; Potts 1983, 1984) and from Koobi Fora (Bunn et al. 1980; Bunn 1981, 1982*a*, n.d.*a*). In this paper, we will emphasize skeletal part frequency data and cut mark data from Bunn's analysis of archaeological bones from Olduvai, especially from the FLK *Zinjanthropus* site, in relation to modern taphonomic and ethnoarchaeological information on bones and site formation.

Recent laboratory analyses of the Olduvai and Koobi Fora bone assemblages have revealed that the animal bones cannot be attributed exclusively to the activities of early hominids; rather, the assemblages have complex taphonomic histories involving the interaction of many biological and physical processes that may have added, modified, and subtracted parts of the evidence. In an East African savanna environment, the agencies that are capable of creating or significantly modifying bone accumulations are large carnivores (e.g., hyenas), large rodents (e.g., porcupines), and flowing water (e.g., river channels, sheetwash, wave action at lake margins). These agencies have been studied in modern contexts for the diagnostic patterning that each produces in the composition and character of bone accumulations. The diagnostic patterning is in effect a signature of great interpretive value, because it is possible to identify the same patterning in ancient bone assemblages and to infer equivalent causative agencies. This makes it possible to identify and factor out nonhominid contributions to a fossil bone assemblage, thereby isolating any residual patterning that may be attributable to hominid behavior.

Of course, diagnosing hominid involvement in an ancient bone assemblage is not simply a process of elimination. Butchery and bone fracture experiments and ethnoarchaeological studies of the subsistence practices of modern humans also help by documenting the kinds of patterns that characterize bone accumulations formed from human transport and human processing of animal carcasses for meat and marrow. Differential transport of carcass parts of different nutritional value is reflected in skeletal part frequencies, and the locations and frequencies of cut marks on different skeletal parts can be directly linked to the skinning, disarticulation, and defleshing of carcasses. Fracture patterns of marrow-yielding limb bones can also serve to identify humanly induced bone breakage with hammerstones, but because some aspects of bone breakage seem to be related more to the structure of the bone than to the agency applying force, the use of bone fracture data is a more complex, though not insurmountable, problem (Johnson 1985; Bunn 1983*b,* n.d.*b*).

THE FLK *ZINJANTHROPUS* SITE AND BONE ASSEMBLAGE

The archaeological evidence from the FLK *Zinjanthropus* site was recovered several decades ago through the pioneering work of Louis and Mary Leakey (L. S. B. Leakey 1965, M. D. Leakey 1971, Cole 1975). Following the discovery of the *Zinjanthropus* skull in 1959 by Mary Leakey, an excavation was conducted preliminarily by Louis Leakey and then over several field seasons by Mary Leakey. The excavation exposed a 300-square-meter area on an ancient, lake-margin land surface that was overlain by a volcanic tuff dated to approximately 1.75 million years before the present. An Oldowan stone artifact assemblage of approximately 2,500 pieces and many thousands of beautifully preserved, though fragmented, fossilized bones were recovered from the excavation and have been described by Leakey (1971). The bones of the various animal taxa have been studied by paleontologists; most notably, Gentry and Gentry (1978) have examined the abundant remains of bovids, or antelopes, focusing for their primarily taxonomic purposes on the most complete and the most diagnostic specimens. In the late 1970s, Bunn (1982*a*) and Potts (1982), from a taphonomic perspective, conducted archaeological studies of the entire bone assemblage, including the fragmented and taxonomically less diagnostic bone specimens. The mammalian bone assemblage from the FLK *Zinjanthropus* site comprises approximately 60,000 bone specimens from a range of taxa and is clearly in a class by itself in terms of its value for paleoanthropological study.

Table 1 shows the general composition of the FLK *Zinjanthropus* bone assemblage as analyzed by Bunn. Of the total number of mammalian specimens, approximately 16,000 pieces are derived from microfauna, and over 40,000 pieces are too fragmentary to be assigned to a taxonomic or skeletal part category. More than 3,500 bone specimens are identifiable at least to a general skeletal part category of the various larger mammalian taxa, and these specimens provide the primary data for this paper. Additional nonmammalian bones not considered here include those of a range of lower vertebrates and an appreciable quantity of bird bones (D. Matthieson, personal communication, 1982).

Figure 1 provides information on the taxonomic diversity of larger mammals, the minimum number of individuals (MNI), and the number of specimens by which the different taxa are represented. Bovids are predominant in the assemblage, with at least 29 individuals represented, ranging from the small springbok, *Antidorcas recki,* through the very large buffalo, *Syncerus acoelotus*. Large bovids ranging in estimated live weight from 250 to 750 pounds are most abundant, and both grazing and browsing forms are present. Suids and equids are represented by at least 5 individuals in each family, while other mammalian taxa are less common. On the basis of tooth eruption and wear, approximately 50% of the bovids, suids, and equids are prime adults.

TABLE 1

GENERAL COMPOSITION OF THE FLK *ZINJANTHROPUS* BONE ASSEMBLAGE

CATEGORY	TOTAL NUMBER OF BONE SPECIMENS
Identifiable as larger mammal	~3,500
Identifiable as mammalian microfauna	16,000
Unidentifiable	
<10 mm maximum length	2,575[a]
10–20 mm maximum length	35,033[a]
>20 mm maximum length	2,800
Total	±60,000

[a] An estimated 20% of these specimens are recently broken fragments probably derived from larger specimens already counted into the total.

Because the bone surfaces are so well preserved, it has been possible to identify several types of surface modifications, including artifact-induced cut marks, carnivore- and small-rodent-induced gnaw marks, and cracking and flaking of bone surfaces from subaerial weathering. Bones representing all of the bovid genera retain cut marks, and cut marks also occur on suid, equid, and giraffid bones. Gnaw marks made by carnivores, especially by large carnivores such as hyenas, and by very small rodents are numerous. Approximately 400 bones exhibit gnaw marks made by carnivores, and over 100 bones exhibit gnaw marks made by very small rodents.

The numbers of bones gnawed by carnivores and rodents, when expressed as percentages of the total number of identifiable bones, are several orders of magnitude lower than the percentages of gnawed bones that characterize bone accumulations made by modern carnivores and rodents (Brain 1981, Bunn 1983*b*). It is thus unlikely that carnivores or rodents were principally responsible for accumulating the FLK *Zinjanthropus* bone assemblage (see also the discussion on skeletal part frequencies). In view of the cut mark evidence to be discussed below, scavenging carnivores, possibly including hyenas, and small rodents were probably attracted to the FLK *Zinjanthropus* bone and artifact concentration after its formation.

It is also unlikely that the action of moving water was important in the formation of the FLK *Zinjanthropus* site. Analysis of the spatial configuration of the stone artifacts and bones

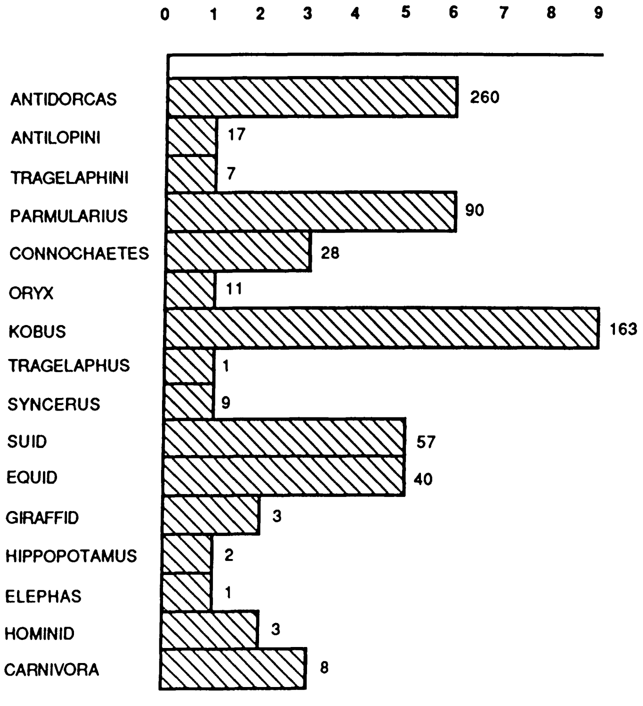

FIG. 1. Minimum number of individuals estimates for larger mammals in the FLK *Zinjanthropus* assemblage. Numbers adjacent to bars indicate the number of identifiable specimens for each taxon; number of equid specimens is from Leakey (1971).

(Kroll and Isaac 1984, Kroll 1986) has shown that the geometry of the overall stone artifact and bone distributions does not reflect arrangement by water currents and that the spatial concentration of many pieces of stone and bone of differing size, shape, and density (hence of differential hydraulic transport potential) is inconsistent with a hydraulic mode of accumulation. Moreover, as Hay (1976) has reported, the stone and bone accumulation at the site was buried by an ash fall.

The duration of subaerial exposure of the bone concentration is another aspect of site formation requiring evaluation because of its relation to the duration and intensity of hominid activities at the site. Behrensmeyer (1978) has demonstrated that descriptive criteria on cracking, flaking, and disintegration of modern bones, expressed as a series of weathering stages, can be predictably linked to subaerial exposure time, expressed in years. Bones in the FLK *Zinjanthropus* assemblage are lightly weathered, predominantly exhibiting either Stage 1 (cracking) or early Stage 2 (flaking). Despite Potts's (1984) claims to the contrary, the bone weathering data do not effectively measure accumulation time at the site. What is really being measured is burial time. Because Behrensmeyer (1978) found that bones of the same carcass can exhibit weathering characteristics as much as two stages apart, the FLK *Zinjanthropus* bone weathering data are not incompatible with a short accumulation period, although final burial of all bones might have required several years.

Although multiple biological and physical agencies affected the final character of the site, we conclude that neither carnivores, rodents, nor flowing water created the observed bone and artifact concentration. In view of the bone evidence discussed below, it is probable that the FLK *Zinjanthropus* site was formed principally by hominid subsistence activities.

SKELETAL PART FREQUENCY DATA

Skeletal part frequency data can provide key evidence on the taphonomic history of an archaeological bone assemblage. Generally, the heavier and less nutritious portions of a carcass (the axial skeleton) tend to remain at animal death sites, while the lighter and more nutritious portions of a carcass (the appendicular skeleton or limbs, and even whole carcasses of smaller animals) tend to be transported more extensively away from animal death sites. This pattern, recognized by archaeologists in the 19th century (Lartet and Christy 1865–75) and popularized by Perkins and Daly (1968) as the "schlepp effect," is often used to distinguish camp sites, where carcasses were processed and consumed, from kill or butchery sites, where animals died. Ethnoarchaeological and taphonomic studies indicate that the variables which control the movement and preservation of skeletal parts of differential transportability and durability are actually more complex, but the underlying principle remains useful.

In examining the skeletal part frequency data for the FLK *Zinjanthropus* assemblage for patterning related to the schlepp principle and for patterning indicative of potential hominid access to carcass portions of differing nutritional value, we shall compare the results of Bunn's laboratory analysis of the FLK *Zinjanthropus* bone assemblage with Binford's FLK *Zinjanthropus* numbers in an effort to identify more accurately the nature of hominid involvement with animal carcasses. Binford extrapolated his data set from Leakey's preliminary faunal report, in which she cautioned readers about the in-progress nature of the faunal data and their analysis (Leakey 1971:248). Because Binford's Olduvai numbers and interpretations based directly on his numbers have now appeared in three books (Binford 1981, 1983*a*, 1984) and have repeatedly been cited in his critiques of alternative analyses and interpretations of the Plio/Pleistocene East African sites, we must conclude that Binford places confidence in his numbers and analysis and that he intends them to be taken seriously.

Table 2 presents skeletal part information for the FLK *Zinjanthropus* assemblage, by expressing proportional skeletal representation as the Minimum Number of Elements (MNE), the Minimum Animal Units (MAU), and the percentage MAU (for discussions of this terminology and the related, more traditional Minimum Number of Individuals [MNI] method, see Chaplin 1971 or Binford 1978, 1984). The MNE is the minimum number of skeletal units required to account for all of the often fragmentary specimens in an assemblage that are identifiable as each skeletal category. The skeletal category may be distal humerus, whole humerus, or any other element or part thereof. Regardless of age, sex, or side of animal, what is sought in MNE values is the highest justifiable estimate of

TABLE 2

FLK *ZINJANTHROPUS* SKELETAL PROPORTIONS AFTER BUNN AND BINFORD

						EXCLUDING HEADS	
	BUNN			BINFORD		Bunn	Binford
SKELETAL PART[a]	MNE	MAU	% MAU	MAU	% MAU	% MAU	% MAU
CRA/TTH	38	38	100	13.07	100	...	...
PEL 1/2	18	9	24	11.26	86	94.7	100.0
SCAP	14	7	18	10.74	82	73.7	95.4
RIB	31	1.19	3	8.97	69	12.5	79.7
VERT	35	1.30	3	3.42	26	13.7	30.4
HUM PSH	5	2.5	7	3.58	27	26.3	31.8
HUM DSH	19	9.5	25	9.21	70	100.0	81.8
RUL PSH	14	7	18	9.21	70	73.7	81.8
RUL DSH	5	2.5	7	3.07	23	26.3	27.3
MCM PSH	15	7.5	20	5.63	43	78.9	50.0
MCM DSH	8	4	11	3.58	27	42.1	31.8
FEM PSH	6	3	8	3.07	23	31.6	27.3
FEM DSH	6	3	8	4.09	31	31.6	36.3
TIB PSH	10	5	13	3.07	23	52.6	27.3
TIB DSH	11	5.5	14	8.19	63	57.9	72.7
MTM PSH	15	7.5	20	8.19	63	78.9	72.7
MTM DSH	10	5	13	7.68	59	52.6	68.2

NOTE: MNE, minimum number of elements; MAU, minimum animal units; % MAU, each MAU divided by highest MAU × 100.

[a] CRA/TTH, skull fragments and teeth; PEL 1/2, right and left halves of pelvis; SCAP, scapula; RIB, rib; VERT, vertebra; HUM, humerus; RUL, radio-ulna; MCM, main metacarpal; FEM, femur; TIB, tibia; MTM, main metatarsal; PSH, proximal end plus shaft; DSH, distal end plus shaft (see Gifford and Crader 1977).

the original number of skeletal units in the chosen skeletal category that contributed to the assemblage. The MAU is a new term (Binford 1984) for the same value that Binford previously termed MNI (Binford 1978, 1981). The MAU is determined by taking into account the number of representatives of a chosen skeletal category present in a complete skeleton and dividing the MNE by that number. An MNE of two humeri, for example, yields an MAU of one. The procedure is then repeated for other skeletal categories chosen for analysis. The percentage MAU is calculated for all skeletal categories by assigning a value of 100% to the highest MAU and scaling the MAUs for the other skeletal categories to that highest value; each MAU is divided by the highest MAU and then expressed as a percentage.

Table 2 lists the skeletal categories employed by Binford (1981:264) in his Olduvai study and presents his mammalian (excluding microfauna and several nonungulate specimens) skeletal part data from the FLK *Zinjanthropus* site. Data from Bunn's analysis of the bone assemblage may be compared with Binford's numbers.

Metacarpals and metatarsals (Binford's lower limb bones) are overrepresented in Binford's percentage MAU values by several orders of magnitude, and his high rib and vertebrae patterns are strikingly reversed by the facts of the FLK *Zinjanthropus* bone assemblage. Binford's handling of Leakey's (1971) preliminary faunal data also leads to a spuriously low maximum MAU value of 13.07 based on teeth. Some parts of animals' heads are well represented in the assemblage, and, in fact, the data on teeth yield the highest MAU value of any skeletal part in the assemblage. This does not mean, however, that cranial parts are abundant, because Bunn's MNE and MAU values are based predominantly on the abundant lower jaws and lower teeth. Cranial parts of various animals, including small, platey fragments bordering the brain cavity, horn cores, fragments of the facial region, and others, are uncommon. Moreover, this pattern is not simply due to the greater fragility of the cranium relative to the more durable lower jaw. It is true that there are only 7 maxillary specimens with teeth, compared with 53 mandibular specimens with teeth, but of the total number of 689 isolated teeth and tooth fragments (excluding microfauna), only 28 are upper, maxillary teeth.

Excluding the heads and teeth and recalculating percentage MAU on the basis of postcranial skeletal part representation brings Binford's numbers more in line with the facts of the bone assemblage, but the proportions of ribs and vertebrae (portions which tend to remain at animal death sites) are still grossly overrepresented in Binford's numbers.

The proportions of limb epiphyses in Binford's numbers, while in error by as much as 25%, nevertheless exhibit many of the trends actually present in the bone assemblage. Interestingly, metapodial (metacarpal and metatarsal) epiphyses are relatively more abundant than Binford's numbers indicate. Metapodials are the pivotal skeletal element in Binford's arguments that hominids had access mainly to nonmeaty, low-utility bones, and the seemingly high overall representation of metapodial epiphyses could be taken as corroboration of his original interpretations.

The data from table 2 are, however, insufficient for answering questions about potential hominid access to or transport of meaty, high-utility bones compared to nonmeaty, lower-utility bones. First, the data for all sizes of animals are grouped together, so that the consequences of any schlepp effect are obscured. Smaller, gazelle-sized animals such as the extinct springbok *Antidorcas recki,* which could be readily transported as whole carcasses or as quartered carcasses with complete leg units, are included in the limb epiphysis totals in table 2. Any decisions regarding the handling of lower-utility bones of larger animals, which would have involved significant energy costs, will therefore be poorly reflected in the table 2 epiphysis values, inflated as they are by the inclusion of a high proportion of low-utility bones (metapodials) of smaller animals.

A second reason the table 2 data are insufficient for present analytical purposes is that the skeletal portions listed by Binford are the only ones being considered. Only specimens from the proximal or distal epiphyses of the limb bones are included; shaft specimens are left out entirely. This may seem inconsequential, but at modern open-air sites where fresh, still greasy bones are subjected to scavenging carnivores, such as hyenas, the selective removal of the nutritionally more attractive pieces, including limb epiphyses, is very likely (Bunn et al. 1980). The selective removal and consequent underrepresentation of limb epiphyses at the Plio/Pleistocene sites at Olduvai and Koobi Fora and elsewhere are demonstrable features of the bone assemblages. For that reason, MNE values for limbs based solely on limb epiphyses will differentially underestimate actual MNE values and distort patterning in MNE representation among the different limbs. To avoid that serious pitfall, limb shaft specimens, which are less nutritious and less likely to be removed by scavengers, must be included in the determination of comprehensive MNE values for limbs.

Table 3 provides a better, more comprehensive measure of limb representation in the FLK *Zinjanthropus* assemblage by sorting the data into meaningful animal size-groups and by incorporating limb shaft specimens into the analysis. MNE estimates for the six different limb bones were determined by detailed specimen-by-specimen comparisons among all specimens in each limb and animal size category. Within each animal size-group, every specimen identifiable as representing a particular limb was examined individually and then in relation to every other specimen. Careful attention was paid to areas of overlap of homologous parts, to conjoining, to differences in size and morphology, and to other attributes that could categorically and unambiguously rule out the possibility that two different specimens originally formed parts of the same complete bone. With femur specimens, for example, a total of 20 specimens from small to medium-sized (Size-Groups 1 and 2) femora and 52 specimens from large to very large (Size-Groups 3 and 4) femora were present. On the basis of comparisons of the 20 small to medium-sized specimens with each other and equivalent comparisons among the 52 larger specimens, a minimum number of femora necessary to account for the specimens was established. In other words, one or more femur specimens stands behind each increment in the MNE total and cannot be derived from any other femur counted into the total MNE. For femora of small to medium-sized animals, the MNE estimate is at least 8, while for femora of larger animals, the MNE estimate is at least 14. While all such estimates probably underestimate the total number of bones once

TABLE 3

FLK *ZINJANTHROPUS* MNE ESTIMATES FOR LIMBS

	SIZE-GROUP		
SKELETAL PART[a]	1,2	3	TOTAL
HUM	6	14	20
RUL	6	16	22
MCM	6	10	16
FEM	8	14	22
TIB	12	19	31
MTM	10	6	16

NOTE: Mammal size-groups are modified from Brain (1981) and refer to approximate live animal weight ranges as follows: Size 1, 50 pounds or less; Size 2, 50–250 pounds; Size 3, 250–750 pounds.

[a] HUM, humerus; RUL, radio-ulna; MCM, main metacarpal; FEM, femur; TIB, tibia; MTM, main metatarsal (see Gifford and Crader 1977).

present at the site for the taphonomic reasons discussed above, the table 3 data provide the most accurate MNE estimates that it is possible to achieve through careful analysis of the FLK *Zinjanthropus* bone assemblage.

Several informative patterns of limb representation are evident in table 3. First, the overall pattern of differential limb representation in table 2 changes dramatically when all limb specimens are considered. Using the higher of Bunn's table 2 limb epiphysis MNE values as a basis for comparison, we see that the total MNE for the radio-ulna (22) is actually more than 50% higher than the partial MNE based on proximal epiphyses (14); similarly, the total MNE for the femur is actually 22, a 367% increase, and the total MNE for the tibia is actually 31, a 282% increase. In contrast, the total MNE values for the humerus, metacarpal, and metatarsal are almost identical in tables 2 and 3, because those MNE values are based on epiphyses of relatively low nutritional value that would not have been particularly susceptible to selective removal by scavenging carnivores. Far from dominating the limb component of the FLK *Zinjanthropus* assemblage, metapodials are, in fact, significantly underrepresented relative to the meatier limb bones. In addition to being poorly represented, the metapodials that are present were occasionally not even being broken for marrow, because more than 20% of the 32 total MNE for ungulate metapodials are complete bones that cannot have been utilized for marrow.

Another significant pattern of differential limb representation becomes apparent with the separation of limb MNE values into smaller and larger animal size-groups. The smaller group (Sizes 1 and 2) includes *Antidorcas recki* and a larger, unnamed species of Antilopini, with approximate live weights of 50 pounds and 120 pounds, respectively; carcasses or at least complete limb units of those animals would not be very susceptible to the schlepp effect. In contrast, the larger group (Size 3), which includes a wide variety of bovid, suid, and equid taxa ranging between approximately 250 pounds and 750 pounds live weight, would be susceptible to the schlepp effect as revealed in differential skeletal representation of carcass parts of varying nutritional value and transportability.

For the smaller animals, there is a marked consistency in the representation of the three forelimb elements and the slightly more numerous three hindlimb elements. That consistency probably reflects the transport of complete leg units of smaller animals away from the animal death sites. It is noteworthy that fully half of the total MNE for metapodials at the FLK *Zinjanthropus* site are smaller-animal metapodials that simply came along for the ride while still attached to the other, meatier limb elements.

For the larger animals, there is a consistent but different pattern of limb representation. There is marked consistency in the representation of the meatier limb elements, including the humerus, radio-ulna, femur, and tibia. Those are the meatiest parts of the animal carcass and for large animals of Size-Group 3 would constitute a hefty load to transport. Metapodials are significantly underrepresented relative to meatier limb elements for both the forelimb and the hindlimb. The paucity of nonmeaty metapodials probably results from the schlepp effect.

Contrary to Binford's claims, skeletal part proportions, especially high limb representation and very low axial (cranium, rib, and vertebra) representation, indicate that the Olduvai site represents a place on the ancient landscape to which selected, highly nutritious carcass portions were transported.

CUT MARKS AND BUTCHERY PATTERNS

The location and frequency of cut marks on different skeletal parts can be used in conjunction with a knowledge of animal anatomy to identify patterning in the butchering techniques of present and past humans. Cut marks as artifact-induced grooves resulting from butchery by humans were recognized by 19th-century researchers in Europe (e.g., Lartet and Christy 1865–75), but systematic study of cut marks with the aim of reconstructing butchery patterns has been largely confined to the last several decades (e.g., Guilday, Parmalee, and Tanner 1962, Wheat 1972, Frison 1978). Recent ethnoarchaeological and experimental research (e.g., Binford 1978, 1981) has provided informative details on the links between some carcass-processing operations and the form and placement of cut marks on some skeletal parts. Cut marks on nonmeaty skin-covered bone surfaces, on or near epiphyses where connective tissues bind articulating joints, and on meaty bones at points of muscle attachment can provide unambiguous documentation of carcass skinning, joint disarticulation, and defleshing, respectively.

Since cut marks on bones of Plio/Pleistocene age were first reported (Bunn et al. 1980, Bunn 1981, Potts and Shipman 1981), there has been considerable debate and perhaps more discussion on the appropriate methodology for identifying cut marks than on the behavioral implications of the early Pleistocene cut mark evidence (e.g., Bunn 1982*a*, 1983*a;* Shipman 1981, 1983; Shipman and Rose 1983, 1984). There is even disagreement on the proper spelling of the term "cut mark." In examining the behavioral meaning of the cut mark evidence from the FLK *Zinjanthropus* assemblage, we will present data on both macroscopically identified cut marks and macroscopically-plus-microscopically identified cut marks but confine our analysis to the set of FLK *Zinjanthropus* bones with cut marks that have been studied and identified microscopically (i.e., to the cut marks that have been identified using methods and criteria advocated by all of the researchers studying Plio/Pleistocene cut marks). This reduces the sample size by one-third, but it also minimizes any ambiguity about the data set. The microscopically studied cut mark sample comprises an adequate data set of at least 172 bone specimens with cut marks, or about 5% of the approximately 3,500 bone specimens of larger mammals in the FLK *Zinjanthropus* assemblage that are at least minimally identifiable to a general skeletal part and taxonomic level (e.g., large-mammal limb shaft). The cut marks are not the randomly oriented, multidirectional, relatively shallow scratches that seem to typify abrasive trampling of bones by large animals (e.g., Behrensmeyer 1984, Fiorillo 1984). The cut marks are located in places that make anatomical sense relative to butchery requirements (Binford 1981, Bunn 1985), and many of the cut marks occur on bone surfaces that would not have been prominently exposed to any alternative processes of abrasion.

Table 4 presents the FLK *Zinjanthropus* cut mark and skeletal part frequency data for smaller (Size-Groups 1 and 2) and larger (Size-Groups 3 and 4) animals, along with cut mark percentages by skeletal portion and size-group. Although the size of the cut mark sample is reduced by restricting analysis to the microscopically studied sample and by further subdividing the sample into size-groups and skeletal portions, several noteworthy patterns are evident.

On a general level, there are several significant overall trends in the frequency and location of cut marks. Overall cut mark frequencies are slightly higher than 5% in table 4, because 689 isolated teeth and tooth fragments are omitted. By omitting the isolated teeth and tooth fragments, which are not prone to exhibit cut marks, the cut mark frequencies increase to 6.0% for smaller animals and to 6.3% for larger animals. Cut marks are concentrated on the meaty limbs of both smaller and larger animal carcasses. Sixty-two percent of all cut-marked bone specimens from smaller animals and 39.2% of all cut-marked specimens from larger animals are from the meaty limb bones.

A large majority of the cut marks on meaty limb bones occur on mid-shaft specimens rather than on or immediately adja-

TABLE 4

FLK *ZINJANTHROPUS* CUT-MARK FREQUENCIES AND PERCENTAGES FOR SMALLER (SIZE-GROUPS 1,2) and LARGER (SIZE-GROUPS 3,4) MAMMALS

	SMALLER MAMMALS[b]					LARGER MAMMALS[b]				
SKELETAL PART[a]	Macro-Sample	Micro-Sample	Total No. of Pieces	% of Pieces This Part	% of All Cut-Marked Pieces	Macro-Sample	Micro-Sample	Total No. of Pieces	% of Pieces This Part	% of All Cut-Marked Pieces
MANT, MAN	6	2	20	10.0	4	14	11	160	6.9	9.0
MAXT	0	0	2	0	0	0	0	4	0	0
CRA	0	0	47	0	0	3	2	42	4.8	1.6
VRTC	2	1	29	3.4	2	2	1	57	1.8	0.8
VRTP	0	0	28	0	0	5	3	59	5.1	2.5
STE	0	0	1	0	0	0	0	1	0	0
PEL	2	2	14	14.3	4	8	7	26	26.9	5.7
RIB PSH	0	0	25	0	0	8	7	51	13.7	5.7
RIB DSH	0	0	5	0	0	0	0	6	0	0
RIB SH	1	1	187	0.5	2	23	14	366	3.8	11.5
SCAP	1	0	7	0	0	3	2	22	9.1	1.6
HUM PSH	2	1	3	33.3	2	0	0	4	0	0
HUM DSH	5	4	6	66.7	8	7	6	17	35.3	4.9
HUM SH	4	3	13	23.1	6	14	8	45	17.8	6.6
RAD PSH	3	2	4	50.0	4	6	3	15	20.0	2.5
RAD DSH	0	0	3	0	0	1	1	6	16.7	0.8
RAD SH	3	3	12	25.0	6	11	10	45	22.2	8.2
ULN PSH	3	0	6	0	0	4	2	10	20.0	1.6
ULN DSH	0	0	0	0	0	0	0	4	0	0
ULN SH	1	0	4	0	0	1	1	11	9.1	0.8
CARP	0	0	13	0	0	0	0	17	0	0
MCM CO, PSH ..	2	2	6	33.3	4	1	2	10	20.0	1.6
MCM DSH	0	0	3	0	0	0	0	2	0	0
MCM SH	1	1	12	8.3	2	1	1	20	5.0	0.8
FEM CO, PSH ...	0	0	1	0	0	1	1	6	16.7	0.8
FEM DSH	1	1	2	50.0	2	0	0	5	0	0
FEM SH	5	2	17	11.8	4	10	7	41	17.1	5.7
TIB CO, PSH	3	2	9	22.2	4	0	0	1	0	0
TIB DSH	2	2	3	66.7	4	2	2	7	28.6	1.6
TIB SH	16	11	36	30.6	22	13	7	92	7.6	5.7
FIB	0	0	3	0	0	0	0	3	0	0
TARS	2	2	21	9.5	4	2	1	25	4.0	0.8
MTM CO, PSH ..	2	2	12	16.7	4	1	0	6	0	0
MTM DSH	0	0	2	0	0	2	1	4	25.0	0.8
MTM SH	2	1	15	6.7	2	3	2	13	15.4	1.6
MET	1	0	17	0	0	4	3	42	7.1	2.5
PHA	0	0	27	0	0	0	0	13	0	0
SES	0	0	16	0	0	0	0	21	0	0
PAT	0	0	1	0	0	0	0	1	0	0
LBN SH	4	5	208	2.4	10	28	17	667	2.5	13.9
Total	74	50	840		100	178	122	1,947		99.6

NOTE: Macro-sample, number of pieces with macroscopically identified cut marks; micro-sample, number of pieces also showing cut marks identified by microscopic criteria (the remainder of the macro-sample specimens have not been studied microscopically). Percentages are for the micro-sample in relation to all pieces of the given skeletal part and to all cut-marked pieces for the size-group. Isolated teeth and tooth fragments (37 from smaller mammals, 328 from larger mammals, 3 from mammals larger than 2,000 pounds, and 321 from mammals of indeterminate size, total 689) are omitted.

[a] MAN, mandible without teeth; MANT, mandible with teeth; MAX, maxilla without teeth; MAXT, maxilla with teeth; CRA, cranial element; VRTC, vertebra centrum; VRTP, vertebra process; STE, sternum; PEL, pelvis; RIB, rib; SCAP, scapula; HUM, humerus; RAD, radius; ULN, ulna; CARP, carpal; MCM, main metacarpal; FEM, femur; TIB, tibia; FIB, fibula; TARS, tarsal; MTM, main metatarsal; MET, miscellaneous metapodial; PHA, phalanx; SES, sesamoid; PAT, patella; LBN, miscellaneous limb; SH, shaft; PSH, proximal end plus shaft; DSH, distal end plus shaft; CO, complete.

[b] For Sizes 1–3, see table 3 n; Size 4, 750–2,000 pounds.

cent to epiphyses. At least 61.3% of the cut marks on meaty limbs of smaller animals and at least 68.9% of the cut marks on meaty limbs of larger animals occur on shaft specimens, and these values are generous underestimates. The overall cut mark percentages for meaty limbs increase by an additional 10% for smaller animals and 13.9% for larger animals if miscellaneous limb shafts, few if any of which are from nonmeaty metapodials, are included.

The cut marks on limb shaft specimens include both isolated single marks and multiple sets of often parallel marks, and they result from a slicing type of motion with a simple, sharp stone tool edge. The cut marks are predominantly oriented obliquely relative to the long axis of the limb bone (e.g., Binford's [1981:133] cut marks labeled Hd-6 or RCp-6). None of the cut-marked specimens even remotely resembles the heavily striated, cut and scratched surfaces that have been linked by Binford (1981:135) to periosteum removal during marrow processing. The removal of periosteum is not even a necessary step in the efficient fracturing of limb bones for marrow; as Bunn (1982*a*, n.d. *b*) has shown, qualitative and quantitative fracture patterns of limb specimens from the FLK *Zinjanthropus* site indicate that hominids were processing the limb bones for marrow, but probably without bothering to remove the periosteum first. From the abundant cut marks on meaty limbs, all indications are that hominids at the FLK *Zinjanthropus* site had access to carcass portions with substantial quantities of meat attached and were cutting large quantities of meat from the bones.

The somewhat lower percentage of cut marks on meaty limbs of larger animals (51.3% of all larger-animal cut-marked specimens, counting miscellaneous limb shafts) relative to smaller animals (72%) does not indicate different access to or handling of the meat from the limbs of large animals. Because more usable meat occurs on the nonlimb portions of large animals than on those of smaller animals, a higher percentage of cut marks on nonlimb portions and a correspondingly lower percentage of cut marks on limb portions of large animals may be expected. This relationship is shown quite clearly by the higher cut mark percentages for ribs, vertebrae, and pelves in larger than in smaller animals.

On a more detailed level, the distribution of cut marks on different skeletal parts provides evidence of specific butchery operations and overall butchery practices. Using Binford's (1981:97) criterion of 20% for the cut mark frequency within a skeletal portion that is necessary to identify a butchery pattern, we see that table 4 contains numerous cut mark percentage values in excess of that cut-off point. If we used table 2 MNE values instead of table 4 number-of-specimen values as a basis for calculating cut mark percentage values, this would decrease the skeletal part sample size and increase the cut mark percentages pretty much across the board, without affecting the overall butchery patterns. Figure 2 illustrates the general distribution of cut marks on smaller and larger animals and provides a visual impression of where cut marks are clustered on the full range of carcass portions. Figures 3–8 document several cut marks that can be directly linked to specific butchering activities using criteria and illustrations in Binford (1981).

Cut marks on smaller animal bones are clustered on the humerus shaft, distal humerus shaft, proximal radius shaft, metacarpal shaft, distal femur shaft, and tibia. Most of these cut marks document meat removal rather than dismemberment; for example, figure 3 shows a proximal radius of *Antidorcas recki* with defleshing cut marks that duplicate Binford's (1981:133) cut marks labeled RCp-6. A different *Antidorcas recki* elbow joint was excavated with the proximal radio-ulna still articulated to the distal humerus; defleshing cut marks are present on both the proximal radio-ulna and the humerus, and the complete humerus, reconstructed from several pieces found far apart in the excavation, also exhibits hammerstone-related fracture patterns (Bunn n.d.*b,* Kroll 1986, Kroll and Isaac 1984). Metacarpal cut marks relate to skinning operations.

Cut marks on the bones of larger animals are clustered at similar and additional skeletal locations. Cut marks are clustered at a 20% or greater frequency on the distal humerus shaft, proximal radio-ulna shaft, radius shaft, metacarpal shaft, pelvis, distal tibia shaft, and distal metatarsal shaft. Slightly lower cut mark frequencies of 17.8% and 17.1% characterize the humerus shaft and femur shaft, respectively. Repeated dismemberment of the elbow joint is documented by cut marks on the distal humerus and the proximal radio-ulna. Figure 4 shows a waterbuck (*Kobus sigmoidalis*) distal humerus with multiple cut marks that are equivalent to Binford's (1981:123) cut marks labeled Hd-2. None of the FLK *Zinjanthropus* cut marks occurs on the distal postero-lateral areas of the humerus shaft where Shipman and Rose (1984) have noted vascular grooves on modern humeri that they claim can be confused with cut marks. None of the FLK *Zinjanthropus* cut marks occurs transversely across the distal posterior shaft of humeri in the area where Binford (1981:124) states that marks produced by cutting through stiff joints would be located; cutting through stiff joints could have indicated hominid involvement with long-dead, scavenged carcasses. Other rarer but unequivocal examples of carcass dismemberment are shown in figures 5–7, involving dismemberment of the scapula (Binford 1981:122, cut mark labeled S-1), the femur (Binford 1981:117, cut mark labeled Fp-5), and the base of the neck, respectively. Repeated defleshing of meaty limbs is well documented by abundant, obliquely oriented mid-shaft cut marks; figure 8 shows a representative example. Metatarsal cut marks relate to skinning operations.

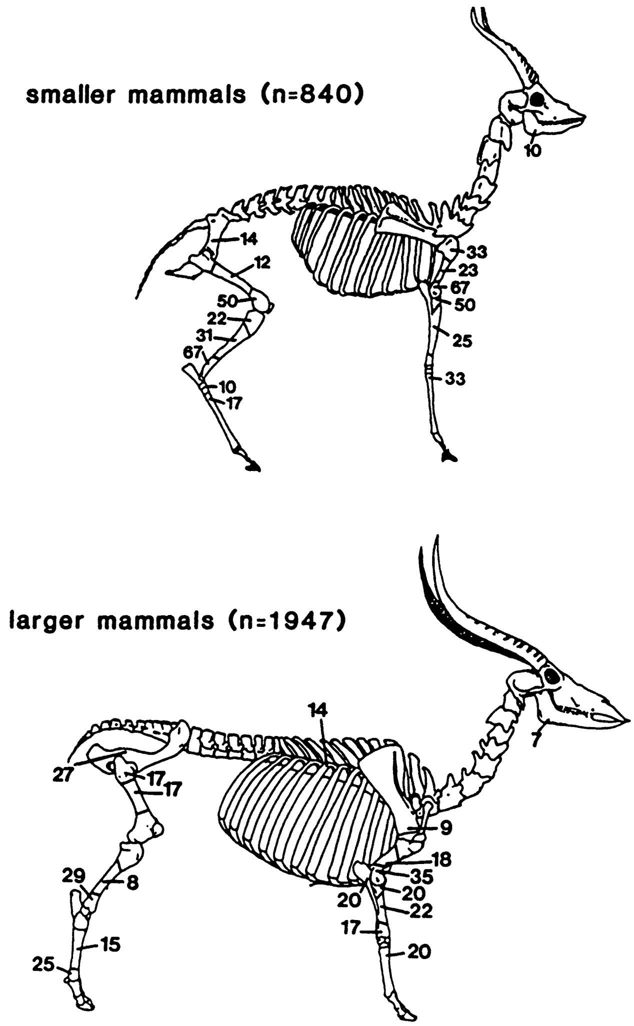

FIG. 2. Distribution of cut marks on bones of smaller and larger mammals in the FLK *Zinjanthropus* assemblage. Numbers indicate percentage of bone specimens with cut marks relative to total number of bone specimens of the given skeletal part in the size category (see table 4).

Specific butchering operations involving systematic processing of the major carcass portions can be listed as follows:

Head. As we have said, crania are poorly represented at the FLK *Zinjanthropus* site. The cranial specimens listed in table 4 are small fragments, and maxillae and isolated upper teeth are rare. One of the cranial cut marks is on a large bovid premaxilla and may represent the detachment of the nose. Lower jaws, on the other hand, are quite abundant, and cut marks on them occur mainly on the inferior borders and postero-medial surfaces. This placement of cut marks documents removal of the tongue. Interestingly, the second of the cranial cut marks listed in table 4 occurs on the only very large (Size 4) bovid hyoid bone present in the assemblage. Probably from the extinct buffalo *Syncerus acoelotus,* this hyoid has transverse multiple cut marks across the middle of the bone that unequivocally document hominid utilization of the buffalo's tongue.

Vertebrae and ribs. For the vertebrae and ribs, sample sizes are small and specimens, especially rib shafts, are highly fragmented. Cut marks are rare on the relatively unmeaty verte-

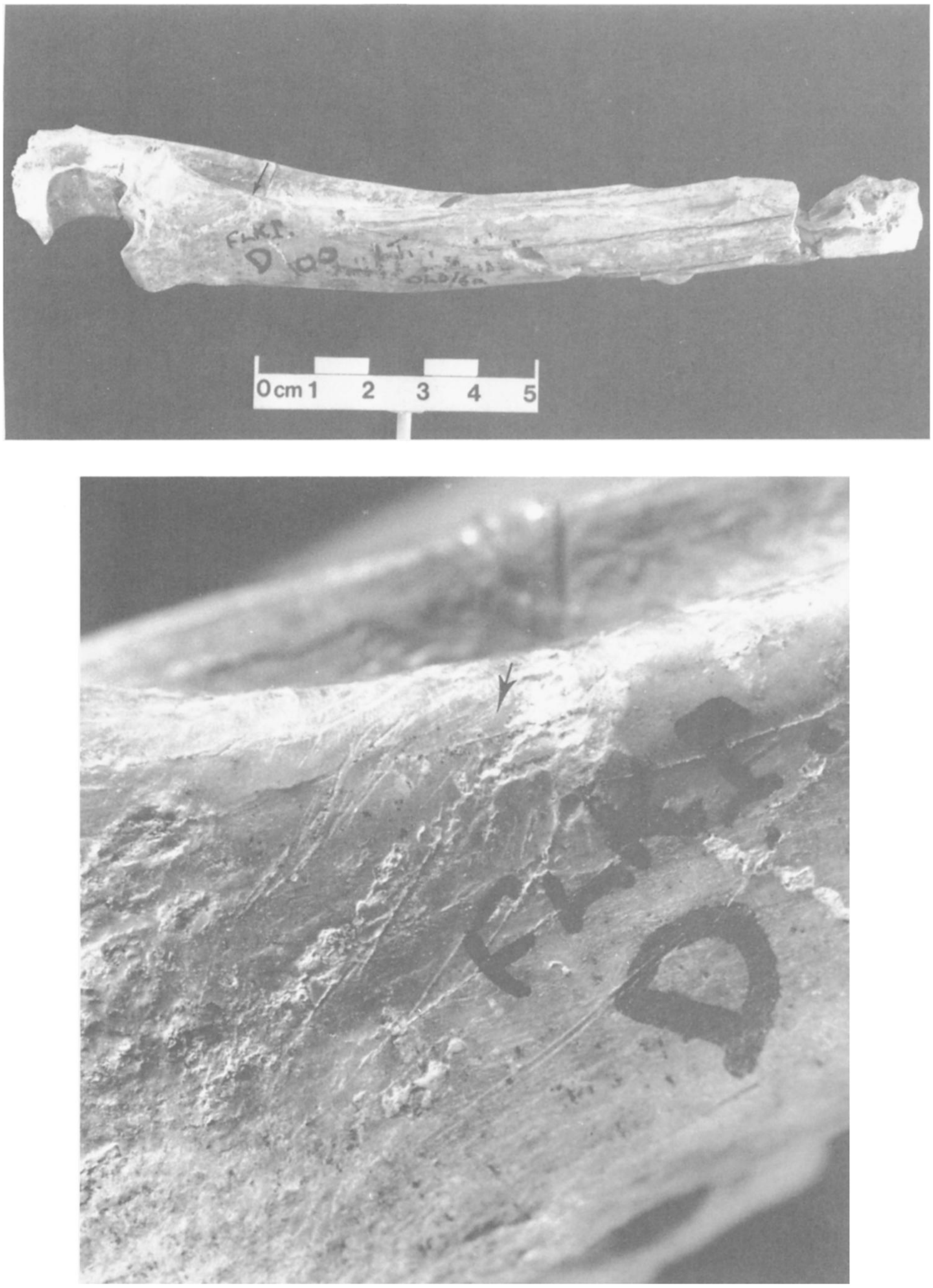

FIG. 3. *Antidorcas recki* radio-ulna with defleshing cut marks (*arrow*).

brae and ribs of small animals that are present in small numbers. Cut marks are somewhat more abundant on the vertebrae and ribs of larger animals, in some cases (fig. 7) providing unequivocal evidence of the separation of the neck from the rest of the vertebral column.

Scapula and pelvis. For the scapula and pelvis, sample sizes are small, and cut mark frequencies, at least for the scapula, are low. Both disarticulation of the scapula-humerus joint (fig. 5) and disarticulation (fig. 6) and defleshing of the pelvis are documented.

Forelimb and hindlimb. Evidence that both forelimbs and hindlimbs of smaller and larger animal carcasses were skinned, disarticulated, and defleshed is present in slicing marks on metapodials, a strong clustering of cut marks on the distal humerus/proximal radio-ulna joint and at least some unequivocal cut marks on the proximal femur-pelvis joint, and numerous, oblique slicing marks on muscle attachment areas of the meaty limb bones.

DISCUSSION

It is clear that Plio/Pleistocene hominids at Olduvai were not the most marginal of scavengers of bone marrow at predator kill sites as Binford has alleged. Our analysis reveals that ancient hominids had full access to meaty carcasses of many small and large animals prior to any substantial loss of meat or marrow bones through predator or scavenger feeding. Any claim that the FLK *Zinjanthropus* assemblage is dominated by heads and by lower limb bones (i.e., metapodials) should be regarded as a myth that is flatly contradicted by the archaeological facts. Contrary to Binford's claims, skeletal part

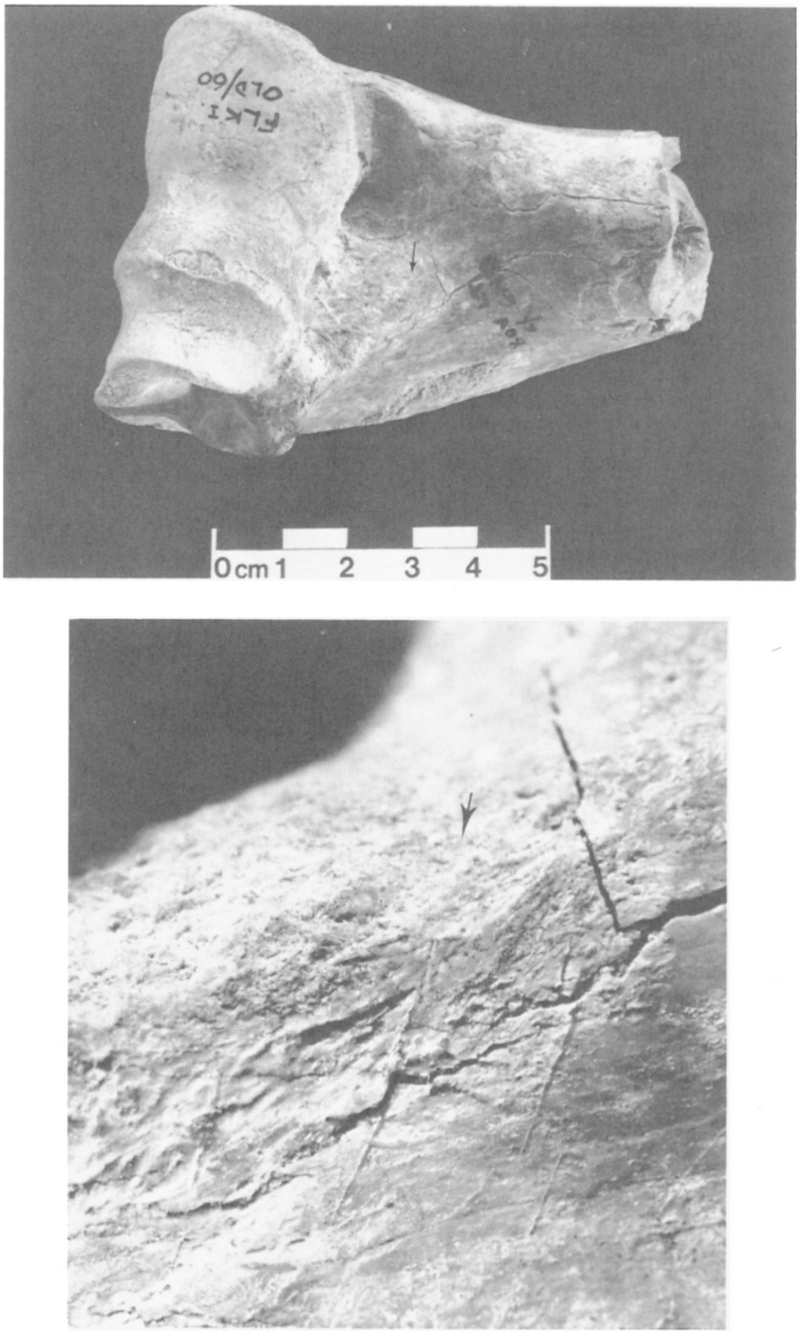

FIG. 4. *Kobus sigmoidalis* distal humerus with dismembering cut marks (*arrow*).

proportions, especially the high limb and very low axial (especially ribs and vertebrae) representation, indicate that the FLK *Zinjanthropus* site represents a place on the ancient landscape to which selected, highly nutritious carcass portions were transported.

In addition to revealing that ancient hominids had access to the meaty parts of carcasses of animals of all sizes, the cut mark data also provide evidence of the techniques of carcass processing by ancient hominids. Given a knowledge of animal anatomy and ethnoarchaeological data on the locations of butchery marks, the clustering of cut marks at particular locations on a whole range of skeletal parts of animals of different sizes defines a pattern of carcass processing by hominids which can be described as thorough butchery. What emerges is that early hominids at Olduvai were butchering carcasses by an efficient and systematic technique that involved skinning, dismemberment, and defleshing operations. Selective transport of the meatier carcass portions and marrow fracturing of limb bones by hominids are also documented. The FLK *Zinjanthropus* site probably represents a place where the secondary butchering of selected carcass portions and the consumption of substantial quantities of meat and marrow occurred.

In addressing the question of how the hominids at the FLK *Zinjanthropus* site obtained meaty portions of the carcasses of small and large animals, we face a difficult challenge for several reasons. Because the FLK *Zinjanthropus* site represents a place to which carcass parts were transported, contextual evidence from animal death sites is lacking. The complex taphonomic history of the bone assemblage and the statistically small samples by which many animals are represented make the task no easier. We approach the hunting-versus-scavenging question with the assumption that hominids inter-

FIG. 5. *Parmularius altidens* scapula with dismembering cut marks.

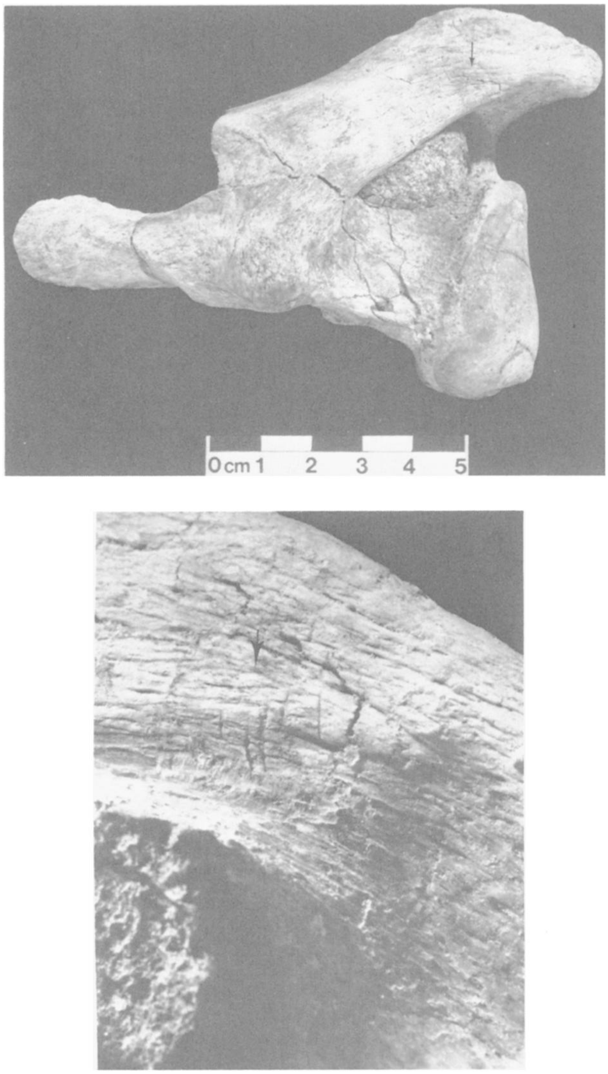

FIG. 6. *Parmularius altidens* proximal femur with dismembering cut marks (*arrow*).

ested in obtaining and eating meat, as some demonstrably were, would not have turned down good opportunities to do so. Thus, the question is not necessarily an either-or proposition, and it is quite possible that ancient hominids followed a subsistence strategy involving opportunistic hunting *and* scavenging to obtain the marrow and meat component of their diet. From the data presented in this paper, some tentative conclusions can be drawn.

Scavenging from carcasses of animals that died of natural causes (including starvation, disease, or accident but excluding predation) is one alternative method of obtaining meat. Provided that hominids were quick enough to beat other scavengers to the carcasses, the hominids would have been able to select meaty carcass portions and leave defleshing cut marks on the bones. The high proportion of prime adult animals in the FLK *Zinjanthropus* assemblage is, however, inconsistent with death from natural causes, which more often affect the more vulnerable, very young and very old members of a population. For that reason, it seems unlikely that scavenging from natural deaths was a principal method of meat and marrow acquisition.

Scavenging from abandoned predator kills is an alternative method that has recently received some support (*Science News,* March 9, 1985). In his study of the opportunities for scavenging carcasses in the Serengeti, Blumenschine (1985) has identified the parameters involved as including the predator and prey species and the timing, habitat, and season in relation to the affected skeletal parts and to the yield. The abundance of highly nutritious, once meaty limb bones in the FLK *Zinjanthropus* assemblage and the prevalence of defleshing cut marks on these same bones contradict the suggestion that meat and/or marrow acquisition by ancient hominids resulted primarily from scavenging from abandoned predator (and particularly lion) kills. The limb portions and tissues of larger animals that were most frequently processed by hominids for meat and marrow would not have survived initial large-predator feeding activity. The parts of carcasses of smaller animals that were also processed for meat and marrow by hominids simply would not have been available to hominid scavengers at abandoned large-predator kills. Observations of carnivore kills (e.g., Kruuk 1972, Schaller 1972) have shown that whole carcasses can disappear entirely within several minutes. Of course, the seasonal changes in the extent of modern predator feeding on carcasses that are documented by Blumenschine (1985) could come into play here. We do not know the frequency of activities at the FLK *Zinjanthropus* site, beyond the indication from the bone weathering data of a relatively short period of accumulation. It is certainly possible that many of the hominid feeding events at FLK *Zinjanthropus* could have occurred during a seasonally restricted period of less predator damage to carcasses.

A third method for obtaining meat and marrow, involving a more active, confrontational form of scavenging, remains a viable alternative, as does a fourth suggested method, active hunting by hominids. In attempting to evaluate these two remaining methods, we reach an impasse. There is no direct evidence that ancient hominids actively hunted animals, nor is there evidence of possible hunting methods (which might have included, for example, the snaring or persistent chasing of animals, methods which are used effectively by modern hunters

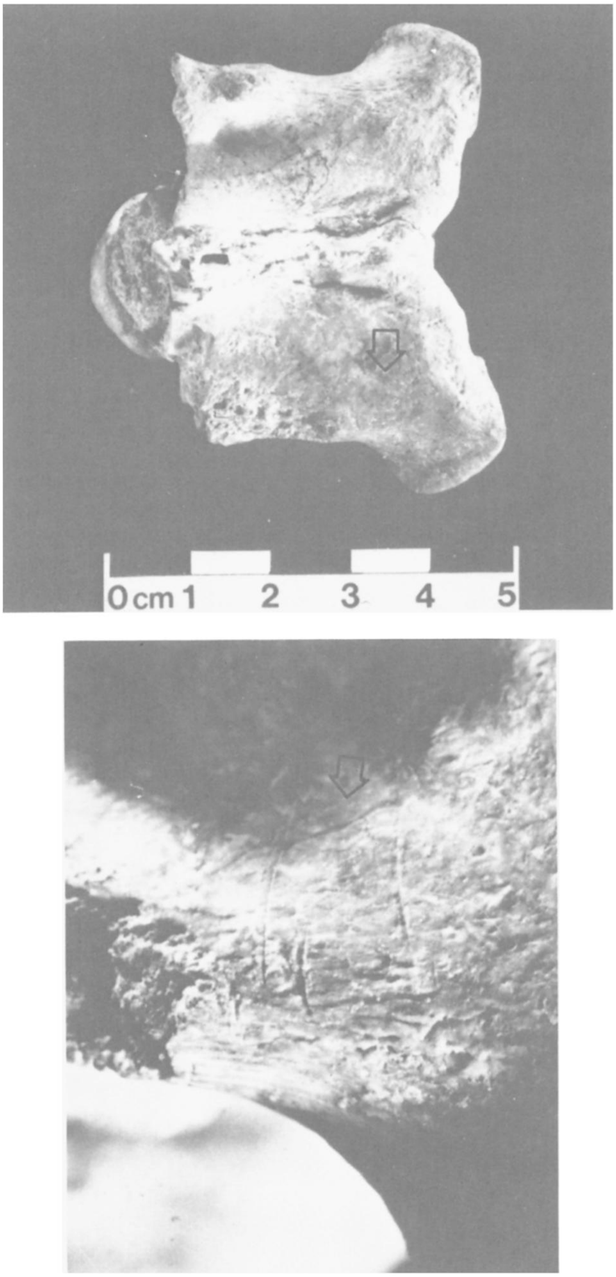

FIG. 7. Large bovid (possibly *Parmularius altidens*) sixth cervical vertebra with dismembering cut marks (*arrow*).

FIG. 8. Large bovid femur shaft with defleshing cut marks.

and require only minimal technology [Lee 1979, Silberbauer 1981, Bunn and Bartram n.d.]). Yet hominid hunting of the smaller, gazelle-sized animals represented at the FLK *Zinjanthropus* site appears likely simply because such smaller carcasses are eaten so rapidly by large predators. It is possible that hominids could have quickly taken control of smaller carcasses once large predators had made the kill, but the fact that a large predator can walk or run away with a whole gazelle carcass in its mouth reduces the likelihood that hominids would have been successful in the endeavor.

The acquisition by hominids of meaty portions of carcasses of larger animals posed a different challenge. As we have said, hunting cannot be categorically ruled out, but there is no solid evidence that the ancient hominids who formed the FLK *Zinjanthropus* site hunted larger animals. Yet, as we have shown, some ancient hominids were obtaining still-meaty portions of carcasses of larger animals and transporting them to the FLK *Zinthanthropus* site. An active, confrontational form of scavenging at large-predator kill sites might have enabled ancient hominids to achieve at least temporary control of carcasses during the hours-long period when high-yield, meaty limb portions of larger-animal carcasses would still have been available. Indeed, Shipman (1983, 1984), among others, has recently suggested this as a possible method of access to carcasses, though in relation not to meat acquisition but to the use of carcasses as a source of skin and tendons. The abundance of prime adults in the FLK *Zinjanthropus* assemblage is in part consistent with the idea of scavenging from lion kills, because data on modern lion kills of bovid species that are closely related to those at the FLK *Zinjanthropus* site, such as the waterbuck, also show a predominance of adult animals (Kingdon 1982). The abundance of prime adults is equally consistent with the idea of selective hunting by hominids to satisfy nutritional requirements during seasons of stress, when prime adult animals would provide the best source of fat (Speth and Spielmann 1983, Speth n.d.). Thus, the data on age structure do not, by themselves, provide a definitive answer to the hunting-versus-scavenging question.

Hominids probably obtained some smaller animals through hunting, but it is not certain whether they were successfully hunting larger animals or, perhaps more likely, taking control of still-meaty carcasses from large predators. Either way, coordinated group activity, repeated participation in dangerous subsistence pursuits, and a significant amount of meat and marrow eating were probably habitual components of the lives of some ancient hominids by 1.75 million years ago.

CONCLUSIONS

Analysis of freshly gathered data on skeletal part frequencies, cut marks, and other aspects of the Plio/Pleistocene archaeological bone assemblage from the FLK *Zinjanthropus* site at Olduvai Gorge has shown that some ancient hominids were using stone tools to systematically butcher the meaty carcasses of a range of smaller and larger animals and that substantial quantities of meat and marrow were probably being consumed by hominids. We believe that the data are consistent with a subsistence strategy combining hunting of at least small animals, hunting or aggressive scavenging of large animals, and transporting of portions of carcasses to favored localities in the Plio/Pleistocene landscape. Given the large quantities of meat and marrow available during hominid feeding events, it is likely that cooperative food sharing on a scale unknown among modern nonhuman primates occurred nearly two million years ago. It remains to be determined whether or not FLK *Zinjanthropus* and other Plio/Pleistocene archaeological sites represent highly transitory feeding locales or more intensively occupied places where diverse hominid activities occurred.

Comments

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Since 1980 paleoanthropologists have become increasingly willing to reevaluate simplistic interpretations of the meaning of Plio/Pleistocene archaeological sites. Leakey's (1971) interpretation of localized accumulations of stones and bones in fine-grained sediments on the East African savanna grasslands as home bases where hominids ate, slept, and shared food is no longer accepted without qualification. These accumulations are demonstrably the result of a variety of agents (Isaac 1983). Debate now focuses on whether the primary agent was a hominid or a carnivore (Binford 1981), whether the bones accumulated as the result of hunting or of scavenging (Shipman 1986), and whether these were localities where hominids slept or where stones were cached and carcasses brought for butchery (Potts 1984) over prolonged periods of time (Potts 1986).

Bunn and Kroll's lucid summary of the current diversity of interpretations of the archaeological evidence from FLK *Zinjanthropus* at Olduvai Gorge brings to my mind the image of the blind men and the elephant. Each investigator interprets the site formation processes and hominid behaviors they reflect on the basis of a narrow range of the potentially available lines of evidence, including cut-mark positioning, both anatomically and relative to carnivore tooth marks (Shipman 1986), body-part distributions (Binford 1981), and bone-weathering stages (Potts 1986). Bunn and Kroll, after several years of detailed examination of the faunal material from FLK *Zinjanthropus* and other sites, have assessed numerous lines of evidence and can *see* the beast for what it really might be. They arrive at conclusions about Plio/Pleistocene archaeological faunal assemblages and hominid behavior that bring us nearly full circle to the maligned, outdated notion of man the mighty hunter, and they do it convincingly.

Their most important contribution to this ongoing debate stems from the reconstruction of upper limb elements and identifications of long-bone shaft fragments to body part. While reading Binford's (1981, 1984) books on faunal assemblages from Olduvai Gorge Beds I and II and Klasies River Mouth Caves, I had a nagging feeling that his documented pattern of overrepresentation of lower limb elements was due to the fact that these elements have the lowest nutritional value and are thus among those least likely to have been smashed for marrow and most likely to be recovered. Conversely, the meat- and marrow-bearing bones, such as the humerus and femur, should be underrepresented because they are likely to be smashed for marrow, as is the case for recent African archaeological faunal assemblages from Masai Gorge Rockshelter (Gifford-Gonzalez 1985) and undoubtedly other sites as well. Following painstaking reconstruction of long-bone shaft fragments, an exercise too rarely conducted by zooarchaeologists, Bunn and Kroll show that the anatomical parts brought to the FLK *Zinjanthropus* site included numerous prime meat-bearing bones of very large, mature bovids and whole haunches of smaller bovids. The cut-mark and hammer-fracture-mark data they collected further show that these prime cuts were then butchered with stone tools and broken up for marrow.

These data are then interpreted, with appropriate caution, as evidence for early access to large carcasses of freshly killed, prime-condition bovids. Whether hominids hunted and killed the animals or drove large carnivores off of freshly killed ones remains an open question, and erecting testable hypotheses remains a challenging objective of future research. Regardless of which of these modes of access to animal carcasses characterized early hominid foraging strategies, the implications are clearly significant for our understanding of the evolution of the human brain and man's capacity for communication and cooperative social organization. Both modes of foraging require complex communication and large cooperative foraging group formations for hunting and killing animals (if this was actually done), for defense of carcasses, and for displacement of other carnivores from carcasses. The social-carnivore model of socio-territorial organization, as proposed by Schaller and Lowther (1969), thus seems appropriate for early hominids.

This behavioral reconstruction is consistent with the evidence for brain enlargement and reorganization, especially with cranial endocast evidence for the appearance of Broca's area on the left hemisphere of the brain of *Homo habilis* (Falk 1983). In modern humans this region of the brain is devoted to speech and language. If a social-carnivore mode of socio-territorial organization characterized early man, there would have been strong natural-selection pressures for increased intelligence and communication. The language-related features of the early hominid brain preserved on cranial endocasts are thus to be expected. Brains are metabolically expensive because they require five times more energy per gram than most other body tissues. Hence brain enlargement has definite costs in terms of increased nutrient requirements and increased nutrient quality. Such nutrient demands can be fulfilled by the consumption of high-quality resources. In the open savanna grasslands where early hominids apparently foraged, the most readily available resource would have been meat rather than ripe fruit or tubers.

Thus, no matter what caused the initial brain expansion of early *Homo,* it undoubtedly required a high-quality diet such as that provided by meat. Bunn and Kroll are to be congratulated for presenting such a clear and convincing case for regular meat eating among Plio/Pleistocene hominids.

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The authors have met their own challenge to "demonstrate rather than assume human-carcass involvement" in this report based on careful study of the original bone and artifact assemblages of the FLK *Zinjanthropus* site. The combination of species, body-size, and skeletal-part data and the cut-mark distributions make a strong case for significant carnivorous activity among the hominids that inhabited the Olduvai Basin 1.7–1.8 million years B.P.

It is clear that "meat-bearing" limb parts were brought at different times to the site. The bone modification patterns and conjoining limb pieces show that at least some meat-bone processing was carried out in the site area. There is little doubt that a number of different bone-modifying agents were involved, and cut marks remain the strongest line of evidence for the extent of this activity that was purely human. The percentages on figure 2 and the photographs are impressive testimony to the diagnostic patterning of stone-tool use. While I have seen only a small sample of replicas of the cut marks from the site, the photographs and corroborating evidence from studies by Potts (1982) lead me to believe that most of the deep isolated grooves and clusters of marks positioned near limb ends are not due to trampling. Trampling may well account for many of the marks on shafts, however, particularly if there was a period of surface exposure after sharp-edged artifacts had accumulated at the site.

The question of hunting versus scavenging is difficult to resolve using taphonomic evidence, since patterns indicating early access to meat-bearing parts do not show who actually killed an animal. Bunn and Kroll leave this issue open, although they favor at least some hunting because of the evidence for early access to carcasses. Early access does not necessarily mean hunting. The total of 43 ungulates (MNI) at this site, if accumulated over five to ten years (Potts 1986), would amount to only a maximum of 4–8 or so per year, and this could easily represent relatively short-term (perhaps seasonal?) activities of the hominids plus additional carcass collecting and processing by other animals. The observed taphonomic features could be accounted for if hominids used active confrontational scavenging from smaller or more timid predators and scavenging of carcasses abandoned after minimal to extensive utilization by large carnivores. The degree of initial carcass consumption by primary predators is highly variable, and scavenging opportunities can be especially attractive during stress periods for prey animals.

This study demonstrates how essential it is to know the taphonomic and recording biases in original data before proposing hypotheses based on these data. Bunn and Kroll's hypothesis of significant utilization of meat as well as marrow at the FLK *Zinjanthropus* site should take the place of Binford's hypothesis of minimal scavenging, at least until better evidence in support of the latter is provided from studies of the actual bones and artifacts.

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This paper is a welcome reporting of important observations on the fauna from the *Zinjanthropus* (FLK 22) location. I cannot sufficiently stress how important it is that at last, after so much argument, we have some facts about this fauna. This is, however, a report by advocates of a particular point of view, and as is frequently the case with such reports, a number of distortions and shifts in emphasis favor the writers' interpretations.

Bunn and Kroll begin by introducing current alternative points of view on the behavior of early hominids, and very early they expose their bias. For instance, in discussing my recent analyses of the faunas from Olduvai, they state that I am "largely ignoring the recently published cut mark evidence." This is simply incorrect; I have consistently cited the cut-mark data in support of my arguments from the time of their first appearance. They then quote my observations on the character of artifact assemblages as summarized from three sites in Olduvai (FLK NN3, FLK 15, and FLK 13 [Binford 1981:281]) as if I were unaware of the variation in Oldowan assemblages. Next they point out that flakes are common in *some* Oldowan assemblages. I knew this. Everyone studying this material knew this. To whom is this comment directed?

This attitude carries over into their discussion of the fauna from the *Zinjanthropus* floor as transformed by me from table 8 of Leakey's (1971:276) summary of the Olduvai material. They repeatedly refer to "Binford's" estimates of MAU values, "Binford's" data, "Binford's" percentages, etc. I have never produced any data on the Olduvai faunas. I have never seen the fauna, and I have never generated any observational data. I simply attempted to transform Leakey's table into a form that could be compared with control data on anatomical-part frequencies under known conditions. I discussed my procedures (Binford 1981:253, 262–63) and presented the results as only an approximation. I explicitly noted the problems with estimating mandibular and skull parts from teeth, which had been recorded without differentiation as to maxillary or mandibular origin. I am not at all surprised that my approximations are in error, but at the time the tabulations in the Leakey volume were all that was available (see Binford 1981:253 n. 2, 3). In fact, it is reassuring that Bunn and Kroll's counts of parts of the appendicular skeleton exhibit the same pattern as the one my conversions indicated. What their data show is that my conversions overestimated parts of the axial skeleton (something of which I was aware), particularly skulls, vertebrae, ribs, and pelves. This recognition brings the *Zinjanthropus*-floor data back in line with patterns observed elsewhere; mandibles and limb bones dominate the assemblage (something I have repeatedly asserted and, in fact, expected [Binford 1985]).

The cut-mark frequencies and the assignment of diaphysis fragments to bone elements are very useful new data sets. I have grave doubts, however, about Bunn and Kroll's interpretations of these data. For instance, they report that animal gnawing is also present on the bones studied (400 of the 3,500 "identifiable" bone fragments, or 11%, exhibit gnaw marks), yet in their tabulations of studied bones they report a total of only 2,787 identifiable bones (table 4), of which only 6% exhibit cut marks. If the reported 400 gnawed bones refer to this studied collection, then gnawing is represented on 15% of the bones—hardly insignificant. Why do the authors not report the gnawing frequencies in the same way they report the cut marks (particularly since I have argued that gnawing frequencies at animal kills contrast with those in dens [see Binford 1984:165–75])? Bones transported by hominids from scavenged animal kills can be expected to exhibit patterns similar to those known from animal kills and different from those produced by animals with access only to previously disarticulated bones (the situation that would be expected if Bunn and Kroll's interpretation of the animal-gnawed bones present on the *Zinjanthropus* floor were correct). In an attempt to salvage their belief that early hominids were hunters, they repeat what by now is certainly the standard argument (see Binford 1985:308) that after the hominids had accumulated food debris from their "substantial" consumption of meat, carnivores scavenged the abandoned hominid food debris. I find this very difficult to accept, particularly given the spatial distribution of animal-gnawed bone as reported by Kroll for the site (see Kroll and Isaac 1984:26, fig. 14), where conjoining animal-gnawed bones are clearly clustered in the same place as cut-marked pieces and generally coincide with the cluster of stone artifacts (see Kroll and Isaac 1984:fig. 2). In my experience with carnivores, they rarely gnaw bones encountered in their environment in the places where they are found; they almost always move them to more "protected" spots for gnawing. This is in fact what occurred in Isaac's (1983:11) experiments, yet we find no evidence for such dispersion in the data on gnawing thus far reported from the *Zinjanthropus* location. (See Binford 1983*b*:373 for further comments on the argument of postabandonment carnivore gnawing.)

Bunn and Kroll's failure to treat the gnawing data casts considerable doubt on the cut-mark evidence that is the centerpiece of their argument. Shipman (1986), in an expanded sampling of modified bones from Olduvai sites, notes that many of the bones she examined had previously been identified by Bunn as cut-marked. Her finding that the tool-inflicted cut marks are clustered in the same general areas as the animal-inflicted tooth marks is hard to reconcile with Bunn and Kroll's view that carnivores were scavenging the abandoned bones of hominid meals, since the hominids had demonstrably broken up most of the bones. It seems inconceivable to me that the alleged postoccupational behavior of carnivores would include the gnawing of broken and already processed bones in the same manner that hominids had earlier processed meat from more complete and probably partially articulated skeletons (see Shipman 1986:table 1). Again, Shipman's report that most of the cut marks are on the non-meat-bearing bones while animal gnawing occurs more on meat-bearing bones (1986:table 2) is essentially impossible to square with Bunn and Kroll's claim that carnivores visited the site after the bones had been processed by the hominids; we would have to imagine the hominids ignoring available meat in favor of non-meat-bearing bones and then leaving the meat for the carnivores.

The willingness of Bunn and Kroll to introduce unjustified propositions to support their beliefs about early hominids is probably nowhere better illustrated than when they note a discrepancy between the MAU estimates for femurs and tibias made on diaphysis counts and those made on articular ends. They suggest that the latter pieces were carried off by carnivores after the hominids had abandoned the site. I can only wonder where all the bone fragments (more than 40,000 unidentified pieces) came from. It is more likely that the high degree of fragmentation demonstrable at the site is in fact referable to rather haphazard bone processing by hominids and destruction of articular surfaces by carnivores before the bones were introduced to the site by the hominids.

Arguments about hominid behavior based on the analysis of fauna must take into account the role and context of nonhominid involvement. Thus far this issue has not been addressed by the most vocal interpreters of the *Zinjanthropus* site data. As long as the matter of carnivore involvement remains unresolved, interpretations such as those of Bunn and Kroll are unjustified. Bunn and Kroll claim that "repeated defleshing of meaty limbs is well documented by abundant, obliquely oriented mid-shaft cut marks." They go on to comment, "It is clear that Plio/Pleistocene hominids at Olduvai were not the most marginal of scavengers of bone marrow at predator kill sites as Binford has alleged. Our analysis reveals that ancient hominids had full access to meaty carcasses of many small and large animals prior to any substantial loss of meat or marrow bones through predator or scavenger feeding." This is nonsense without some discussion of the source of the bones accumulated on the *Zinjanthropus* floor. I have already suggested that this problem can be cleared up by studying the anatomical placement and anatomical-part frequency of the bones with animal gnawing present on the *Zinjanthropus* floor. Bunn and Kroll have avoided these data, which seemingly have been available to them.

At present the only way of addressing the question of where the bones came from rests with comparative anatomical-part frequencies, which Bunn and Kroll have now provided. In a recent study (Binford and Stone 1986), just this type of comparative data has been accumulated (much of it having been in the literature for some time) and used to identify the agents responsible for the bulk of the bones found at Zhoukoudian. Table 1 presents some of the case summaries in terms of MNE values for the bone classes reported for all the sites. These data were normalized by calculating chi-square values for all cells in the matrix of cases and variables, and the chi-square values were then used in calculating distance measures (squared Euclidean distances) among the subjects corresponding to rows of the data (cases). These values were subjected to a cluster analysis (maximum-linkage cluster analysis of a vector of *n[n – 1]/2* distances or dissimilarities among the *n* subjects). Figure 1 summarizes the relationships among the cases compared.

FIG. 1. Similarities among samples of bovid MNE values.

The two cases of bovids from Combe Grenal, a European Mousterian site, are grouped together. The clear bias in these data in favor of meat-yielding upper limb bones demonstrates a meat-seeking bias on the part of the hominids (see Binford 1985). A separate cluster comprises the *Bubalus* bones from Zhoukoudian, the bovids from Antu, a Chinese hyena den that did not yield any evidence of hominid activity, and the bovid bones reported from the striped-hyena den of Arad. Clearly, hyena den assemblages have some distinctive properties, and, as we have argued (Binford and Stone 1986), the *Bubalus* bones from Zhoukoudian seem to have been accumulated

TABLE 1

MNE BY SITE FOR SELECTED ANATOMICAL PARTS

ANATOMICAL PART	ZHOUKOUDIAN	ARAD	ANTU	COMBE GRENAL WÜRM II	KLASIES	COMBE GRENAL WÜRM I	FLK-22	RICHARDSON'S DATA	SMALL-KILL MODEL
Maxilla	2	3	0	0	37	1	2	0	37
Mandible	5	17	1	2	82	0	37	35	85
Innominate	1	8	0	2	17	0	18	30	97
Rib	0	0	0	3	0	0	31	71	156
Scapula	0	8	0	1	35	0	14	25	54
Proximal humerus	1	3	0	3	7	1	5	22	31
Distal humerus	7	8	2	7	27	3	19	23	47
Proximal radiocarpal	4	8	3	6	24	2	14	19	36
Distal radiocarpal	0	5	1	1	20	0	5	21	24
Proximal metacarpal	5	9	7	0	51	0	15	16	18
Distal metacarpal	4	6	6	0	50	0	8	15	23
Proximal femur	0	1	0	3	25	0	6	18	33
Distal femur	1	5	0	4	14	0	6	19	22
Proximal tibia	0	2	0	2	7	0	10	22	36
Distal tibia	0	7	1	5	41	1	11	22	44
Proximal metatarsal	5	25	7	1	39	1	15	21	42
Distal metatarsal	4	14	6	0	26	0	10	22	37

SOURCES: Binford (1981:230, table 5.08, column 5; 1984:168–69), Binford and Stone (1986), Bunn and Kroll table 2.

primarily by hyenas. The hyena dens and the hominid-accumulated bones of Combe Grenal are then grouped together, both of course being transported bone assemblages and therefore having some properties in common. The Bovid Size-Class IV bones from Klasies River Mouth Cave 1 are then linked to the hyena dens and the hominid-transported bones as still another transport-biased assemblage (although with different biases [see Binford 1984]).

Contrasting with and independent of these clusters are the MNE data summarized by Bunn and Kroll for the *Zinjanthropus* floor (their table 2) and two other very instructive assemblages. The bones that share the most characteristics with the *Zinjanthropus*-floor data are the anatomical-part frequencies observed by Richardson (1980; see Binford 1984:168–69, table 4.31, column 1) in carcasses left behind after they had been ravaged by predator-scavenger animals. Merging with the *Zinjanthropus*-floor data and the ravaged-carcass case are the pooled or "smoothed" data on ravaged kill sites previously presented (Binford 1981:230, table 5.08, column 5) for small prey animals. (Bunn and Kroll suggest that these small animals would not have been available to hominids, but nevertheless they are found in nature.) This suite of cases is only minimally related to the clusters described above. I think it is clear that the best estimate for the source of the bones on the *Zinjanthropus* floor is already-ravaged ungulate carcasses from which the hominids simply took the available and usable parts.

Bunn and Kroll might object by pointing to their inflated limb bone counts as estimated from long bone splinters. They will find, however, that the increased estimates for femur and tibia are significant. If such values are used for the *Zinjanthropus*-floor data, the relationships change; the assemblage will now be grouped between the Combe Grenal bovids and the ravaged-kill data. That is perhaps where they belong, since the Combe Grenal bovids are also scavenged from ravaged animal carcasses but biased in favor of meat.

Alternatively, Bunn and Kroll might object by citing their cut-mark data, but in my opinion the cut-mark frequencies they provide seem inflated, and the frequency of marks on long bone shafts is certainly inflated by any comparative standards for hunted foods with which I am familiar. It is perhaps germane that Shipman's (1986:29) recent restudy of bones considered to bear cut marks by Bunn and others found around 40% to be misidentifications. Nevertheless, all researchers seem to agree that there are many cut marks on bone shafts. This reflects, I think, not great amounts of usable meat, as suggested by Bunn and Kroll, but extreme difficulty in processing already partially desiccated limb parts that had been previously ravaged by carnivores, leaving little usable meat available to the hominids. Shipman's (1986) study certainly supports this interpretation. Rather than backing up their own arguments, Bunn and Kroll's data strongly support mine. The *Zinjanthropus* site is a place where marginal foods were extracted from parts scavenged from previously ravaged animal carcasses. There is no convincing support for the view that early man was a hunter, that he cooperated with others in dangerous activities, or that he shared food obtained in these imagined activities. This study has no intellectual anchor beyond an imagined picture of early hominid life.

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Bunn and Kroll provide the first detailed and systematic description of the important archaeological faunal assemblage from the FLK *Zinjanthropus* site. What makes this paper particularly important is the major revision of MNE and MAU tallies for skeletal parts from those calculated by Binford (1981). Specifically, the lower number of postcranial axial and cranial parts relative to appendicular parts and the higher representation of upper limb bones relative to foot bones obtained from the exhaustive, archaeologically oriented analysis of Bunn (1982) calls into serious question Binford's (1981) interpretations for the mode and agent of bone accumulation for not only FLK *Zinjanthropus* but also all the other Olduvai sites he has analyzed.

The new interpretations of the data offered here are, however, not without their difficulties. Bunn and Kroll invoke the schlepp effect along with access by hominids to meaty carcasses to account for the limb-bone-dominant body-part representation and cut-mark distribution seen. Hunting is suggested to have been a primary mode of acquisition for at least the smaller and possibly also the larger animals represented. What remains to be explained satisfactorily is the paucity or absence of defleshing cut marks on the relatively few postcranial axial parts present, many of which bear, on complete carcasses, at least as much flesh as upper limb bones (Blumenschine and Caro n.d.)

I have argued (Blumenschine 1986) that the limb and head (now mandible) dominance at FLK *Zinjanthropus* is consistent with accumulation by scavenging. Scavengers typically have access to largely defleshed carcasses from abandoned predator (especially lion) kills which still provide limb bone marrow and head contents (brain and pulps). Although the high frequency of mid-shaft cut marks on meaty upper limb bones seems to disqualify scavenging of largely defleshed carcasses, it is not known from the evidenced butchery how much meat was actually removed. Mammalian carnivores typically abandon substantial scraps of flesh on limb and other bones, and therefore the mid-shaft cuts might simply reflect removal of these scraps by scavenging hominids before the primary nutritional goal (marrow) was realized. This would explain the relative rarity of postcranial axial parts and the few cut marks they bear, for once defleshed by initial consumers (as they are typically before forelimbs) these parts do not provide a further feeding opportunity for a scavenger with early-hominid characteristics. Clearly, experiments are needed to determine if differences exist in the quantity and location of cut marks inflicted while defleshing whole muscle masses or small scraps of flesh. Until these experiments are conducted, the cut-mark data from FLK *Zinjanthropus* can be interpreted unequivocally to mean only that processing by hominids was concentrated on limb parts, the goal(s) of this processing beyond marrow extraction being uncertain. It may be premature to conclude, as Bunn and Kroll do, that hominids had access to large quantities of meat and hunted at least the small animals present. Of course, the opportunity to assess accurately the merits of these alternatives is provided in the first place by the important new data Bunn and Kroll present.

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Bunn and Kroll's informative article raised several questions in my mind that I hope they will address in their reply.

1. What accounts for the superabundance of microfauna at the FLK *Zinjanthropus* site? Could it mean that raptors roosted in trees overhead or that small carnivores often defecated at the locality? If so, could it not imply further that the site was originally a cluster of shade trees or bushes near water that might have attracted a variety of creatures, some of which brought bones or found the presence of bones an additional attraction? Clusters of bones near shade trees or bushes may of course be observed in Africa today. Hominids need not have been the major bone accumulators in such a system, though they would obviously be responsible for the artifacts and the cut marks on bones.

2. How were tooth eruption and wear used to distinguish prime adults from ones past prime (past 40–50% of potential

life-span) at the site? Among the 50% of bovids, suids, and equids that are not prime adults, how many are past prime? This is the crucial question for determining the meaning of mortality profiles at the site. In any case, is the sample large enough to talk meaningfully about mortality profiles?

3. What accounts for the abundance at the site of isolated teeth and tooth fragments versus partial jaws with teeth? Is it possible that the abundance of isolated teeth reflects postdepositional profile compaction and leaching? Could these factors also be partly or mainly responsible for the very large number of bones that were too fragmented to assign to skeletal part and taxon? Are there known modern agencies that create bone assemblages in which highly comminuted pieces and isolated teeth dominate so heavily? (There are many fossil assemblages like this.) If not, and if postdepositional destructive factors did play an important role at the site, how much of the patterning in skeletal-part representation and mortality profiles might they explain? More generally, don't postdepositional factors have to be taken into account before comparing the FLK *Zinjanthropus* assemblage directly to recent bone assemblages (from carnivore kills or dens, from human sites, etc.) which lack a comparable postdepositional history?

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Until very recently, we knew that hominids lived and ate meat on the silty clay of the *Zinjanthropus* floor nearly two million years ago (Leakey 1971); perhaps this was their home base and they shared their food (Isaac 1978). Then the wind shifted, and we learned that the Lower Pleistocene sites contained little evidence of hominid meat eating (Binford 1981). But how then were we to account for the cut marks on the bones (Bunn 1981)? Perhaps scavenging for tendons and skin was the explanation (Shipman 1983). Now Bunn and Kroll bring us full circle to what appears to us to be convincing evidence at FLK of substantial meat procurement.

A major dietary change probably did occur at about two million years ago. It is at this time that the genus *Homo* first appears. One of the major differences between early *Homo* and all preceding hominids is the reduction in the chewing apparatus. Cheek-tooth size increases relative to body size from the earliest species of *Australopithecus* to the latest (McHenry 1984). With the appearance of *Homo* at two million years ago the trend is reversed, and there is a rapid decrease in relative cheek-tooth size. The hypertrophied masticatory apparatus of *Australopithecus* might imply a diet of small objects such as seeds (Jolly 1970) or of small hard-shelled fruits (Walker 1981), herbivory (Pilbeam and Gould 1974), omnivory (Peters 1981), or a diet of grains, roots, and some meat (Wolpoff 1973). The reduced cheek teeth of *H. habilis* might be explained in terms of a shift to greater reliance on meat and the use of tools in the preparation of food.

If meat was an important part of the diet, then it is interesting to examine the role of seasonality in this activity. There is a substantial literature on methods for identifying the seasonal use of sites, the most applicable of which may be the analysis of dental cementum annuli (Kay 1974, Spiess 1976, Bourque, Morris, and Spiess 1978, Koike and Ohtaishi 1985). While the majority of these studies have been done in temperate zones, application of the method to equatorial species is feasible (Spinage 1976). As Bunn and Kroll note, seasonality may have a direct bearing on the "affected skeletal parts and . . . yield." It will be interesting to see the results of an in-depth study of seasonal factors affecting hominid access to carcasses.

A point of contention in this debate appears to be the availability of carnivore kills for use (meat, tendons, or otherwise) by early hominids. While Bunn and Kroll cite a single study (Blumenschine 1985), it is apparent that additional empirical and modeling studies need to be conducted in this area. One important question is what skeletal *elements* remained when hominids happened upon a kill. Is it possible that the frequency and location of cut marks are the result of differential access to skeletal elements at a kill site? If so, then the distribution of elements that Shipman (1983) noted might not preclude meat eating.

Bunn and Kroll note that the relationship between animal carcasses and hominid activity must "be demonstrated rather than assumed." Similarly, as Binford (1985:311–12) notes, "We need solid descriptive studies of the important Olduvai sites in terms consistent with current methods of analysis. The faunas need to be described in detail: the frequencies of cut marks, animal gnawing, and breakage patterns must be reported in such a way that the patterning regarding the interaction among agents, which most certainly stands behind the archaeological record, can be recognized." It appears clear that Bunn and Kroll are doing just such a study. Much remains to be investigated in this area, and, given the quantity of debate generated thus far, further studies will no doubt prove stimulating and enlightening.

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Binford has recently been postulating that *Homo* was not an efficient hunter until the latter part of the Late Pleistocene. Until then, he has argued, meat was obtained by scavenging, and at Olduvai and Koobi Fora meat constituted only a small part of the food supply. The Early Pleistocene hominids are, as Bunn and Kroll remind us, considered by him the most marginal of scavengers of bone marrow at large-carnivore kill sites. Such an assessment of their subsistence pattern is, of course, totally at variance with previous assumptions that they were efficient scavengers and probably hunters and that meat constituted a fair proportion of their diet. For the most part, however, these were assumptions, and this new study by Bunn and Kroll is a very welcome critical evaluation of some faunal assemblages at Olduvai specifically to determine whether meat was being butchered on a large scale or not and what might be implied. Their methods involve a highly critical standard for accepting cut marks and a series of convincing arguments to support their main conclusion, contrary to Binford, that these early hominids were consuming substantial quantities of meat and marrow.

I wish to confine my comments to the stone tools found in Bed I and the lower part of Bed II at Olduvai, described as the Oldowan industry. Bunn and Kroll have cited Binford's surprising statement that the Oldowan industry was just smashed rock, flakes were not used, and scrapers were entirely absent. This is, of course, as they state, simply not true. Certainly, some of the technology is so crude that the term "smashed rock" is not inappropriate, but some of the knapping is surprisingly controlled. In the absence of microwear studies on suitable rock types, it is impossible to state whether the flakes were used or not, but retouched flakes which could be described as scrapers are plainly present. No discussion of this seems necessary unless one is doubting the stratigraphical position of the artifacts or their associations with the bones. Of more importance to the subject of butchery is the presence of thousands of flakes, for many of these would have been quite suitable as primitive knives, considerably more efficient for taking meat off bones than human teeth or nails. It is reasonable to conclude that "smashed rocks" (cores) were mainly the residual pieces from the production of flakes. Furthermore, if these early hominids were not butchering meat with these flakes, what were they making them for? The simplest answer is that they were making them to butcher meat with. The simplest answer is, of course, not necessarily the correct one, but taken with the other evidence put forward by Bunn and Kroll I suspect it is.

Reply

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We thank the distinguished colleagues who have commented on our paper. Although most of them are supportive of our principal conclusion that some Plio/Pleistocene hominids included significant quantities of meat and marrow in their diet, there is also a consistent message that the bone assemblages from FLK *Zinjanthropus* and other sites have complex formational histories and are thus subject to alternative interpretations. We fully agree and repeat that there is much more to be learned about the Plio/Pleistocene bone assemblages and associated behavior patterns of ancient hominids. If our more tentative conclusions about hunting and scavenging prompt further research and lead to increased understanding about the procurement and utilization of carcasses by ancient hominids, then we will feel amply rewarded.

The comments by Ambrose, by McHenry and O'Brien, and by Wymer show a fundamental agreement with our findings. Their most important contribution to our understanding of ancient hominid behavior is insight into lines of evidence that we did not discuss or referred to only briefly. Ambrose and McHenry and O'Brien discuss aspects of hominid skeletal morphology of direct relevance to diet and behavior. Ambrose argues convincingly that the expanded brain of *Homo habilis* would have necessitated a higher-quality diet than the smaller brains of earlier hominids and that aspects of brain reorganization in *H. habilis* are linked to selection pressures for the enhanced communication abilities in obtaining meat and marrow. McHenry and O'Brien point out that changes in relative cheek-tooth size are best understood in relation to a probable shift about 2 million years ago to greater reliance on meat and on tools for food preparation. In his discussion of Oldowan tools, Wymer emphasizes that although retouched scrapers are present, the principal goal of the earliest stone tool makers seems to have been the production of sharp-edged flakes that would have been suitable as knives. We and others have argued that the need for sharp-edged cutting tools, particularly for use in butchering carcasses, provided a major incentive for the development of a flaked stone technology in the first place. It is reasonable to ask how and why the changes noted in hominid morphology and stone tool technology occurred if there was not a significant shift about 2 million years B.P. to higher-quality food resources, particularly meat and marrow. The converging evidence and viewpoints of Ambrose, McHenry and O'Brien, and Wymer provide the basis for a strong argument that a dietary shift to greater reliance on meat and marrow did occur in hominid evolution by about 2 million years ago, along with an increasing utilization of sharp-edged cutting tools for processing such food items.

The comments by Klein, by Behrensmeyer, and by Blumenschine provide a constructive and thought-provoking basis for further discussion of the FLK *Zinjanthropus* evidence and its implications. Klein poses questions about (1) the scale of hominid bone-accumulating activity at a demonstrably complex site involving the dynamic interaction of several agents capable of accumulating and modifying bones, (2) the abundance of isolated teeth and tooth fragments and the possible effects of postdepositional fragmentation of bones, and (3) the analytical methods used to determine mortality patterns from tooth eruption and wear and the meaning of the resulting patterns. His first question reemphasizes the point that the magnitude of hominid involvement with the accumulation of bones at ancient open-air sites must be demonstrated from the bones themselves and not simply assumed from associations with stone artifacts. The available data suggest that most such assemblages were influenced to some degree by more than one agent of accumulation or modification. A sensible research goal is identification of the dominant, rather than the exclusive, agent of bone accumulation or modification in an assemblage and, where possible, factoring out of other agents. For example, the presence of at least one cut-marked bone at the Olduvai site of FLK NN Level 2, a low-density scatter of bones not associated with stone artifacts, does not overrule the strong indications from the high proportion of carnivore gnawing and low degree of fragmentation of limb bones that the dominant agent of bone accumulation there was the activity of large carnivores such as hyenas (Bunn 1982*a*, Potts 1982). On the other hand, for assemblages lacking strong evidence of accumulation by nonhominid agents, the presence of even a small proportion of bones with cut marks has probable significance beyond those specimens. In modern butchery using metal knives (which typically produce more cut marks than stone knives) and without other taphonomic biasing of the bones, only moderate proportions (<30%) of identifiable bones retain cut marks (Bunn 1983), and in recent archaeological assemblages, for which the exclusive role of stone-tool-using humans as bone accumulators is not in doubt, the proportions are low (<10%) (e.g., Gifford, Isaac, and Nelson 1980, Crader 1984, Marshall 1986).

Is the documentation of a relatively large sample of cut-marked bones in the FLK *Zinjanthropus* assemblage sufficient to link the *entire* bone accumulation to hominid feeding activity? In itself, we think not; however, when it is combined with indications of extensive hammerstone breakage of marrow bones, the case for hominid activity as the dominant accumulating agent of the larger mammal bones is strong. Bones of microfauna are abundant at FLK *Zinjanthropus* and at other so-called living floors at Olduvai, including FLK N Levels 1 and 2, and it is our understanding that concentrations of microfauna are also present at other Bed I localities lacking artifacts. Andrews (1983) studied a sample of microfauna from FLK N Levels 1 and 2 and attributed it to the activity of small mammalian carnivores (such as genets). A convincing case for attributing the microfauna at FLK *Zinjanthropus* to hominid feeding activity has not been made, although the utilization of small animals by hominids at Olduvai has recently been discussed (Jones 1984).

Klein raises another important point in noting the possibility that the abundance of isolated teeth, tooth fragments, and unidentifiable bone fragments in the FLK *Zinjanthropus* assemblage may result from postdepositional profile compaction. Some fragmentation of buried bones during fossilization undoubtedly occurred and is reflected in the presence of a few partially crushed and distorted bones. Such crushing and the separation of small fragments from crushed specimens has probably inflated the percentage of unidentifiable bones, particularly in the smallest size fraction. We have tried to measure and factor out the fragmentation from recent breakage, as shown in table 1, although some fragmentation of buried bones is probably still represented in the numbers. Regarding the larger bone specimens with well-preserved fractured edges, fragmentation patterns strongly resemble those produced by breakage of fresh bones rather than breakage of dried or fossilized bones. Patterns of limb fragmentation strongly resemble those produced by experimental hammerstone breakage, as discussed by Bunn (n.d.*b*). The presence in the same bed at Olduvai of other bone assemblages, such as FLK NN Level 2, that lack the high degree of fragmentation present in the FLK *Zinjanthropus* assemblage argues against postdepositional profile compaction as the dominant agent of the observed fragmentation pattern. Studies of modern bones on East African land surfaces have shown that the fragmentation of teeth and the loss of teeth from jaws can result from subaerial exposure, with repeated wetting and drying of teeth and shrinkage and disintegration of connective tissues, of even moderate duration (Hill 1975, 1980; Behrensmeyer 1978; Behrensmeyer and Dechant Boaz 1980).

To determine mortality patterns from tooth eruption and wear, Bunn used a crude descriptive system of four age-classes: neonate, subadult, prime adult, and aged adult (Bunn et al. 1980, Bunn 1982*a*) instead of measuring tooth-crown heights as advocated by Klein (Klein et al. 1981). The first two crude age-classes correspond roughly to the first 20% of an animal's life-span and the last age-class to the last 20–30% (see Klein et al. 1981). On qualitative grounds, more than half of the bovids from FLK *Zinjanthropus* that fall into the crude prime-adult age-class are probably past prime (i.e., between 50 and 70–80% of the life-span). The overall mortality profile for bovids at FLK *Zinjanthropus,* with the small samples for different taxa lumped together, is an attritional rather than a catastrophic one.

Although Behrensmeyer's comments are supportive of our principal conclusion that hominids were transporting meaty limbs to the FLK *Zinjanthropus* site and processing them there for meat and marrow, she raises several issues for further consideration. Her suggestion that trampling of the bones and artifacts by large animals may well account for many of the cut marks on limb shafts is a useful extension of previous scrutiny of the cut-mark evidence, and we have several observations to make. A recent experimental study by Behrensmeyer, Gordon, and Yanagi (1986) demonstrated that trampling of bones resting on very coarse, sandy sediments can produce linear trample marks on the bones that show the microscopic features that Potts and Shipman (1981) consider diagnostic of cut marks. The sedimentary matrix at FLK *Zinjanthropus* is, however, a very fine clay, and this limits the applicability of the experimental findings.

Behrensmeyer suggests that the purported trample marks on the limb shafts at FLK *Zinjanthropus* resulted from trampling in which the feet of large animals brought the bones and stone artifacts into physical contact. This could have occurred, presumably, if the animals got sharp-edged artifacts wedged into their hooves and then shuffled across the bones, or if the animals kicked or stepped on bones or artifacts that were already near each other. If trampling occurred at FLK *Zinjanthropus* on the scale suggested by Behrensmeyer, then predictable patterning in the skeletal locations of the trample marks and in bone breakage should be present: (1) Assuming a random trample at FLK *Zinjanthropus,* the percentages of cut marks on the shaft fragments of different limb elements and on other fragments of similar shape, such as broken rib shafts, should be equal. (2) At least some trample marks should occur on the exposed internal surfaces of broken bones or on the exposed inner cortical bone of fractured edges of limb shafts. (3) Lightly weathered metapodials should exhibit the characteristic fragmentation into elongate rectangular slivers with right-angled fractures that is known to result from trampling (Gifford 1977, Bunn 1982*a*). None of these predictions is fulfilled by the FLK *Zinjanthropus* bones (see, e.g., table 4). The observed patterns in these characteristics in the FLK *Zinjanthropus* bone assemblage thus reduce the likelihood that trampling produced the cut marks on limb shafts. We await additional experimental work by Behrensmeyer and others for much-needed documentation of the effects of trampling by large animals.

Citing a recent study of bone weathering by Potts (1986), Behrensmeyer suggests that hominids accumulated carcasses at FLK *Zinjanthropus* at a low rate of only four to eight carcasses per year, perhaps as a short-term, seasonal activity, over a five- to ten-year period. (Potts identified differential weathering patterns on a small sample of limb shafts from FLK *Zinjanthropus* from which he concluded that hominids had accumulated the bones over a period of this length.) Behrensmeyer's (1978) documentation of at least three weathering stages on bones from the same carcass at Amboseli in Kenya shows, however, that a range of weathering stages can readily reflect a moment of accumulation time rather than five to ten years. Variable exposure to weathering prior to final burial, resulting from factors such as different orientation on the ground, partial burial, and position relative to patches of vegetation or shade trees, leads to differential weathering in a bone assemblage without requiring a lengthy period of accumulation. Moreover, data on the limb shaft specimens from FLK *Zinjanthropus* show a predominance of specimens in stages 0–2 and relatively few that can be unambiguously attributed to more advanced ones. Thus, the burial of most bones at the site probably required no more than two to three years or so, and the accumulation of parts of carcasses by hominids probably occurred at a faster rate than envisioned by Behrensmeyer.

Although Behrensmeyer correctly points out that the degree of carcass consumption by large carnivores is highly variable (see also Blumenschine 1985), it does not necessarily follow that hominids regularly scavenged from abandoned carcasses during seasonal stress periods for prey animals. As Speth (n.d.) points out, prey animals use up their fat reserves (including marrow fat) during seasonal stress periods, such as the late dry season. Scavenging from fat-depleted carcasses would have yielded too much protein and too little fat to satisfy basic nutritional requirements.

Behrensmeyer raises yet another intriguing possible mode of acquisition of the meaty carcasses of small animals at FLK *Zinjanthropus,* arguing that early access to still-meaty carcasses of small animals could result from scavenging from small or timid predators. We agree that this is possible. Small or timid predators such as jackals or cheetahs do kill many Thomson's gazelles, small bovids of the same size as *Antidorcas recki* at FLK *Zinjanthropus,* and they also frequently lose the carcasses to scavenging by large carnivores such as lions and hyenas. For reasons discussed in our paper, hominids scavenging from small or timid predators would probably have had to beat large carnivores to the small-animal carcasses. This is plausible; however, given the limited yield available from small carcasses, we believe that hominids faced with the choice between outdistancing large carnivores as scavengers and outdistancing small prey animals as hunters would most likely have chosen the latter option.

While Behrensmeyer accepts our interpretation that hominids processed meat-bearing limbs but questions the derivation of cut marks on limb shafts, Blumenschine accepts the identification of cut marks on limbs but questions our interpretation of them. He argues that the cut marks on the mid-shaft portions of limbs may reflect the removal of scraps of flesh abandoned by predators rather than of substantial quantities of meat. He is also interested in the paucity or absence of defleshing cut marks on the once-meaty axial parts, such as vertebrae, that are present. Additional experimental work will certainly provide definitive answers to these questions. Perhaps zookeepers will help us to obtain partially defleshed limbs from carnivore feeding that can be used in the much-needed butchery experiments. Meanwhile, we have the following observations:

First, inflicting deep slicing cuts into the surfaces of limb shafts does not further the efficient removal of meat from the bones, and it dulls the cutting edge of the knife. The slight miscalculations regarding the relative positions of meat and bone that produce such cuts are most likely to occur when it is difficult or impossible to see where the bone is, as when a complete, meaty limb bone is being defleshed. For these reasons, we have argued that the presence of many obliquely oriented slicing cut marks on once-meaty limb bones indicates that hominids removed substantial quantities of meat from the bones. Blumenschine's alternative viewpoint is that the observed cut marks on limb shafts from FLK *Zinjanthropus* result from the removal only of adhering scraps of meat. In our view, the partial defleshing of meaty limbs prior to hominid access to the carcasses would have rendered the surface of the limb bones more readily visible and thus reduced the number of cut marks. Bite sized scraps of meat could simply have been bitten directly from the bones by hominids. If larger muscle masses had been partially torn away by carnivore feeding, hominids might well have had the option of grasping the torn, exposed portions of the muscle masses and stripping the meat back toward one or both joints with little or no cutting of the bone. We suggest that this would have left fewer cut marks than defleshing of complete, meaty limbs and perhaps distinct patterns of orientation of those cut marks.

The paucity or absence of defleshing cuts on the small sample of postcranial axial fragments is not unexpected. Cut mark frequencies on meaty axial elements, such as vertebrae, of domesticated and wild fauna at Holocene archaeological sites in Africa are typically quite low, even though access to the complete carcasses is not in doubt (Gifford et al. 1980, Crader 1984, Marshall 1986).

Finally, we address the comments by Binford. We will try to be brief, because many of his questions have already been answered in our paper or in his own previous publications.

We stand behind our statement that Binford has been largely ignoring the published cut mark evidence. His 1981 citation misquotes and distorts the information then available. Since our submission of this paper, he has again referred to the cut mark data (1985:323):

> I am very skeptical of Shipman's claims for lack of ambiguity in identifications when her methods are used. I have seen many bones from geologic contexts in North America where human presence is unequivocally *absent* yet marks having all the characteristics she describes are nonetheless present! Similarly, many marks reported by Bunn as cut marks are in my opinion matched in control collections where young carnivores gnawed bones. At present, I trust my experience in cut-mark recognition, which is based on a great deal of experience and employs a configurational approach (see Binford 1984) and recognizes ambiguous cases.

Binford attempts to qualify the statement (1983*a*:57) on Oldowan stone artifacts that we quoted. It was a generalization about the earliest Oldowan tools and their function, and it cleared the way for his calling the early hominids "the most marginal of scavengers" of bone marrow (p. 59). Now he tells us that his discussion was restricted to three of the smallest Oldowan assemblages yet reported from Bed I by Leakey (1971). Two of the assemblages, FLK Level 15 and FLK Level 13, consist of 9 and 11 artifacts, respectively, and probably represent low-density, background scatters rather than so-called living floors. Judging the composition of Oldowan artifact assemblages from these two small samples would be like judging the United States from a visit to Disneyland. In any case, these levels are higher in the sequence at Olduvai than the earliest tool-bearing levels. The third assemblage, FLK NN Level 3, consists of 48 artifacts, and more than 70% of it is debitage, predominantly sharp-edged flakes and flake fragments (i.e., potential cutting tools). Thus, Binford's (1983*a*:57) statement is incorrect even when applied only to the small assemblages that he has now identified as the basis of his generalization. A more representative view of Oldowan artifacts comes from the much larger assemblages reported by Leakey (1971), including FLK *Zinjanthropus* (2,470 artifacts, 92% debitage), DK (1,198 artifacts, 72% debitage), and FLK N Levels 1 and 2 (1,205 artifacts, 70% debitage). We are as surprised by Binford's current reliance on artifact data from FLK NN 3, FLK 15, and FLK 13 as the basis for an understanding of Oldowan assemblages as we were by the generalization about Oldowan tools that we quoted.

Rather than confront our data directly, Binford discusses gnawing data at length, even though we chose not to present those data in our paper on butchery patterns. The reported total of approximately 400 bones gnawed by carnivores is a generously high estimate that includes a significant number of ambiguously fractured bones along with the specimens that show undoubted surficial gnawing by carnivores. Even at 14.4% of the total of 2,787 identifiable bones (this is our table 4 total that excludes 689 isolated teeth and tooth fragments, identifiable mammalian bones of indeterminate size-group, and the few identifiable mammalian bones of Size-Groups 5 and 6), the proportion of gnawed bones is several orders of magnitude lower than the proportion in spotted hyena dens with which we are familiar.

Binford reverses the sequence of site-forming events as reported by Kroll and Isaac (1984) in their discussion of spatial patterns at the FLK *Zinjanthropus* site. His sequence is rendered doubtful by the skeletal part evidence for transport and the cut mark evidence for skinning, disarticulation, and defleshing, all of which indicates that hominids transported bones to the site and discarded them in the observed pattern that generally coincides with the distribution patterns of artifacts. Binford does not seem to realize that even after processing by hominids for meat and marrow, bones (especially joints) still retain grease and are attractive to scavenging carnivores.

In a surprising about-face (see Binford 1985), Binford finds merit in a recent article by Shipman (1986). Shipman studied a sample of bovid bones from an unspecified number of Olduvai sites, and by restricting analysis to diagnostic bovid bones she must have missed many of the less diagnostic mammalian bone fragments, such as limb shafts. She also conducted a supposed accuracy test of cut mark identifications by Bunn. Because no sample size or composition is reported and no listing of Bunn's specimens with cut marks has been published or distributed, we place little value on her test (see also Bunn and Blumenschine n.d.).

Binford is skeptical about the high frequencies of cut marks on limb shafts at FLK *Zinjanthropus*, yet a recent analysis of a Holocene archaeological assemblage from Kenya by Marshall (1986) shows comparably high frequencies of defleshing cut marks on limb shafts in a context in which complete utilization of carcasses by stone-tool-using modern humans is not in doubt.

Abandoning his earlier argument that the FLK *Zinjanthropus* site is a location where carnivores repeatedly killed animals, Binford now alleges that hominids transported bones to the site. It is difficult to understand why hominids would have transported bones that already had had their flesh and joints removed by carnivores, as Binford claims, and why they would have left disarticulation and defleshing cut marks on those bones.

Having issued a call for skeletal part frequency data from the Olduvai sites (1985:311), stating that "the only evidence currently independently justifiable for demonstrating a bias toward the use of meat is from anatomical part frequencies, a data domain they [Isaac and Bunn] both seem to judiciously avoid," Binford now seems reluctant to deal directly with the data we have provided. Although we showed that the skeletal part data in our table 2 are incomplete because of the skeletal categories used, Binford uses them anyway for a multivariate analysis. After some uncertainty, he finds a branch on his diagram for the FLK *Zinjanthropus* assemblage, which for him seems to fall "between the Combe Grenal bovids and the ravaged-kill data. That is perhaps where they belong, since the Combe Grenal bovids are also scavenged from ravaged animal carcasses but biased in favor of meat." We find this statement hard to reconcile with Binford's (1985:319) recent assertion that there is "good evidence that the majority of the moderate-body-sized animals at Combe Grenal were hunted for meat. This pattern is particularly striking for the faunas of Würm II levels at the site." We are left with a feeling of uncertainty about Binford's analysis, given the small sample sizes he used and the inherent sample bias of some of the data sets (see, e.g., Binford and Stone 1986). Moreover, it is certainly possible that the statistical groupings interpreted by Binford are products of the analytical techniques themselves rather than the taphonomic histories of the bone assemblages. Binford may feel reassured by our skeletal part data, but tables 2 and 3 expose Binford's conversions of the FLK *Zinjanthropus* bone data and his resulting patterns and interpretations as seriously in error. His argument by assertion that "rather than backing up their own arguments, Bunn and Kroll's data strongly support mine" is unconvincing in the presence of contradicting facts.

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Free Materials

■ *Nuclear Winter: The Anthropology of Human Survival (Proceedings of a Session at the 84th Annual Meeting of the American Anthropological Association, December 6, 1985, Washington, D.C.)* is available as Los Alamos National Laboratory Document LA-UR-86-370. The document records the only scientific exposition of nuclear winter that focuses explicitly on humans, and contributors to it consider it a first step toward an anthropological assessment of the long-term consequences of nuclear winter for human existence. It takes the form of a written transcript and a limited number of audio cassette tapes. Panelists included George J. Armelagos, M. Catherine Bateson, Robert Dirks, Eric M. Jones, and Laura Nader. Requests for the entire proceedings or the transcript alone should be directed to the session organizer, M. Pamela Bumsted, at Los Alamos National Laboratory, Mail Stop G740, CHM-1/INC-DO, Los Alamos, N.M. 87545, U.S.A.