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Taphonomy, paleoecology, and hominids of Lainyamok, Kenya

Lainyamok is a hominid fossil and artifact locality west of Lake Magadi in the southern Kenya rift. It is assigned a Middle Pleistocene age, provisionally 0.70–0.56 Ma, based on K-Ar dates, regional association with the Oloronga Beds, and deposition prior to grid faulting in southern Kenya at the end of the Middle Pleistocene. Its fauna is modern compared with that of Olorgesailie Members 1–7 (*ca.* 0.9–0.7 Ma). From preliminary survey and mapping of surface finds, Lainyamok was initially interpreted as a possible location of hominid butchery activity. Associated clusters of bones of single animals and stone artifacts were found eroding out from a lake margin silt. Stringent criteria are proposed for identifying single animal butchery sites in the prehistoric record. Extensive excavation and geologic fieldwork at Lainyamok now show that none of the criteria for butchery sites is met. Instead, the primary fossiliferous layer (Khaki 2) represents a debris flow which introduced artifacts and possibly some bones into a lake margin setting. Evidence for carnivore damage and accumulation of the majority of excavated bones suggests that hyenas accumulated most of these bones in burrows after deposition of Khaki 2 and prior to deposition of higher strata. In addition to artifacts, a new femur and a previously described set of maxillary teeth indicate the presence of hominids in the area. However, Lainyamok is best considered a locality where evidence of hominid activities is negligible but which enables valuable ecological comparisons to be made to areas where hominids were considerably more active (e.g., Olorgesailie).

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Introduction

Lainyamok is a fossil and stone artifact locality found within Middle Pleistocene sediments in the rift valley of southern Kenya. This locality is situated approximately 8 km west of Lake Magadi and 40 km southwest of Olorgesailie, a well-known Middle Pleistocene locality (Isaac, 1977; see Figure 1). Following a survey of Lainyamok led by W. W. Bishop in 1976, extensive excavations and geologic fieldwork were carried out for the first time in this area in 1984. Preliminary description of this locality noted the presence of an *in situ* fragmentary hominid maxilla and surface artifacts and faunal remains in a lake margin context (Shipman *et al.*, 1983). The purpose of this paper is to summarize our findings about the geology, taphonomy, fauna, and evidence of hominids at Lainyamok and, in particular, to re-examine the initial interpretation of hominid butchery activities at this locality.

Geologic background and chronology

The Lainyamok sediments occupy a small graben approximately 35 m deep and 500 m wide and are exposed over an area of about 1.5 km². The sequence consists of 9 m of interbedded lacustrine silts, tuffaceous silts, poorly-developed soils and carbonate layers which were deposited in lake and lake margin settings (Figure 2). A brief description of the strata and their interpretation follows:

—Magadi Trachyte: lowest unit in the sequence.

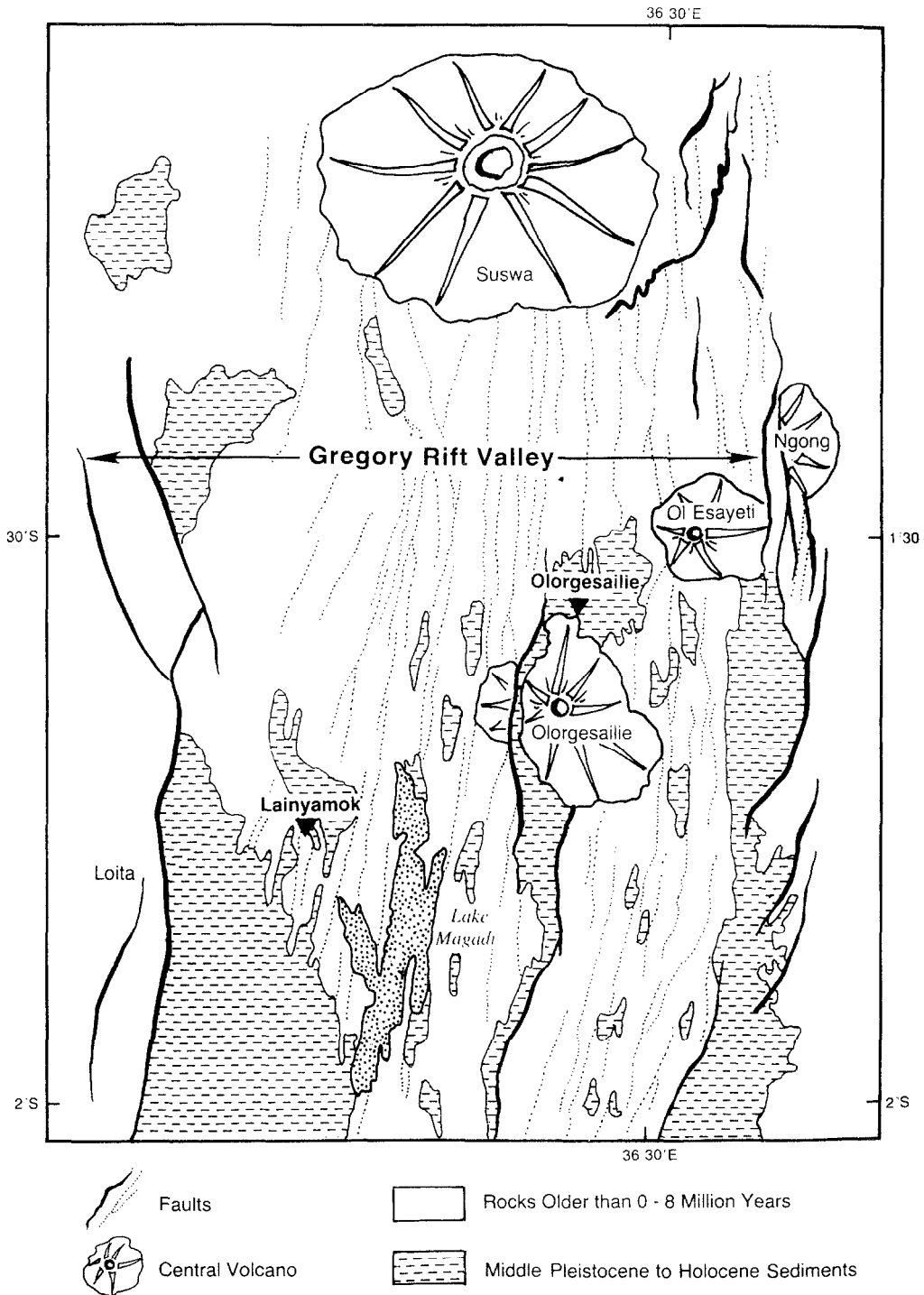


Figure 1. A map of the southern Kenya rift. The locations of Lainyamok, Olorgesailie, Lake Magadi, and major volcanic cones are indicated.

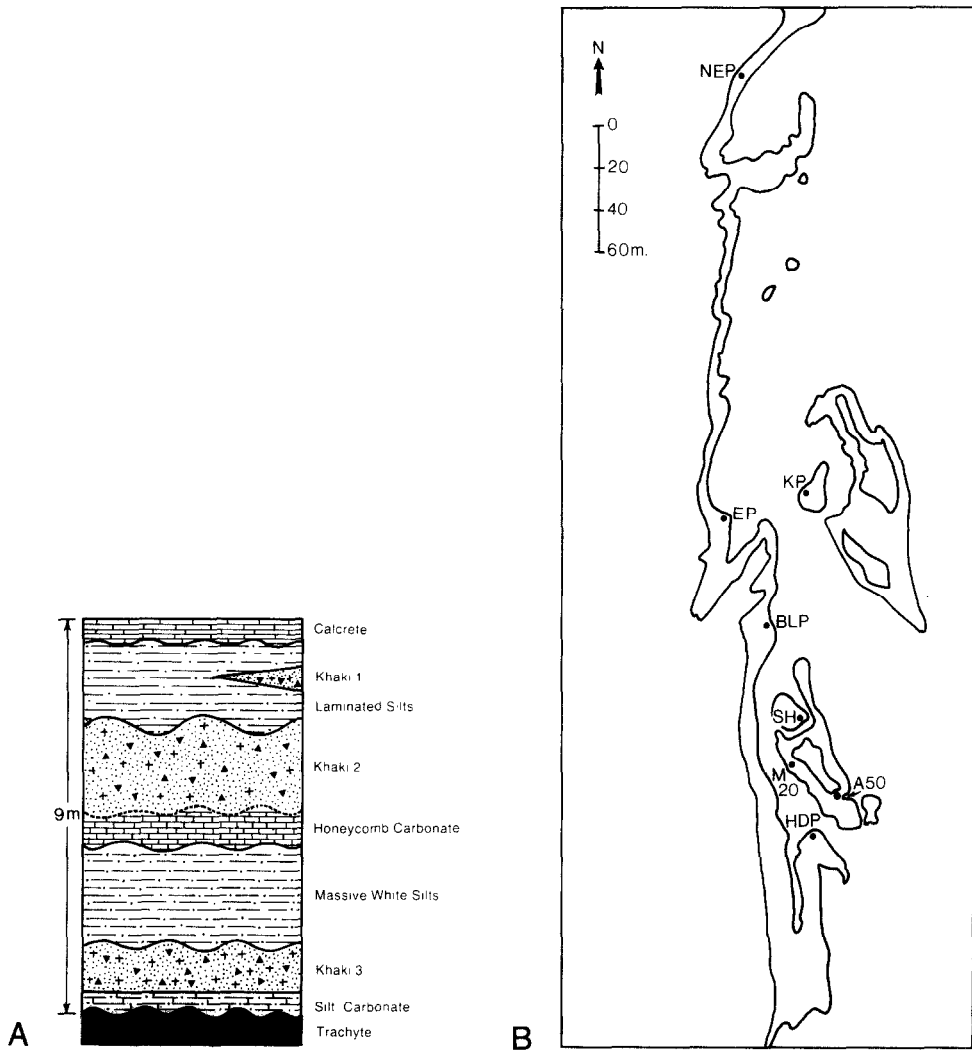


Figure 2. A, general stratigraphic section of the Lainyamok sediments. B, plan view of the Khaki layer exposures and locations of *in situ* bone patches.

—Carbonate boxwork: 20 cm thick deposit of carbonate laminae developed around clasts of silt, similar to the Honeycomb layer (described below); evaporative origin.

—Khaki 3: 1 m thick tuffaceous sandy silt located in the middle to lower portions of the massive white silts on an eroded contact; observed in the central to northern exposures. This unit consists of both massive and graded beds and is probably of fluvial origin during subaerial exposure of the white silts.

—Massive white silts: 2–3 m thick; contains infrequent fragments of fossil fish; lacustrine in origin but deposition interrupted by periodic drying episodes evidenced by mud cracks seen on sediment surfaces.

—Honeycomb layer: a carbonate boxwork structure developed around small, closely

spaced (1 cm) fractures in the top 20–60 cm of the massive white silts in the northern exposures. Abundant fossil fish remains are preserved in this part of the carbonate. In the southern exposures, the honeycomb layer thins to 0–20 cm and is developed in a silt matrix that surrounds clasts of siltstone and claystone. The top of the honeycomb layer in the south is capped by 1–2 cm finely laminated carbonate which covers the tops and sides of mudcrack structures. Carbonate deposition was likely the result of evaporative processes occurring at a periodically immersed lake margin.

—Khaki 2: poorly sorted, massive silt, 1–2.5 m thick, which contains abundant rounded fragments and cobbles of Magadi Trachyte; abundant zircon is most likely derived from alteration of volcanic glass. The base of this layer contains numerous clasts of the underlying honeycomb and white silt layers. Artifacts and abundant faunal remains are preserved. This stratum is interpreted as a subaerially deposited mudflow (see below).

—Laminated silts: 1–2 m of silts which are variable in nature. In places, these silts are finely laminated and contain fish fossils indicative of a lacustrine origin; in other places, the silts are more massive and show signs of soil formation (root casts, burrowing). Some of the soil development is modern but some development probably occurred during temporary regression of the paleo-lake.

—Khaki 1: massive siltstone, 50 cm thick, which occurs in the middle of the laminated silts noted above; subaerial mud flow.

—Capping calcrete: at the top of the section a 15 cm thick carbonate horizon, probably evaporative in origin.

The Magadi Trachytes, which occur extensively over the southern Kenya rift, are a series of flows dated at 1.81–0.72 Ma (Baker, 1958; Baker *et al.*, 1971; Baker & Mitchell, 1976). K-Ar dates of 0.89 ± 0.05 Ma and 0.92 ± 0.02 Ma for the trachyte in the Lainyamok graben confirm that it is the Magadi Trachyte at the base of this sequence (A. Deino & R. Drake, *pers. comm.*). Although the main fossiliferous layer (Khaki 2) does contain significant tuffaceous material and fresh crystals of anorthoclase, considerable contamination of this layer by feldspars derived from much older sediments is evident by K-Ar dates in excess of 23 Ma (Deino & Drake, *pers. comm.*). Paleomagnetic polarity was determined on oriented samples, and all exhibited normal polarities with progressive thermal demagnetization up to temperatures of 630°C. Thus, the age of the Lainyamok sediments above the trachyte is less than 0.73 Ma.

The Khaki 1 layer, a subaerial mudflow above the main fossiliferous horizon, is also contaminated by old volcanic material. However, single fresh crystals isolated by laser techniques and analyzed by Ar-Ar provide a range of 0.34–0.41 Ma (Deino, *pers. comm.*). An average of 0.38 Ma represents a firm upper limit for the main fossiliferous bed (Khaki 2) at Lainyamok.

The chemistry of feldspars has proved useful in distinguishing different tuffaceous horizons in the East African rift, particularly in the Omo-Turkana region (Brown & Nash, 1976). In our analysis the underlying assumption was that feldspars in a single tuffaceous horizon should be roughly constant in composition or have compositions that reflect the evolution of a magma during an eruptive phase. Electron microprobe determinations of feldspar composition were performed on several nearby tuff horizons possibly correlated with the Khaki layers at Lainyamok. Feldspars in the Khaki 2 sediments exhibit a unique chemical composition with similarities to the Magadi Trachyte and to Member 9 of the Olorgesailie Formation (Figure 3). Of these two sources of comparison, the latter

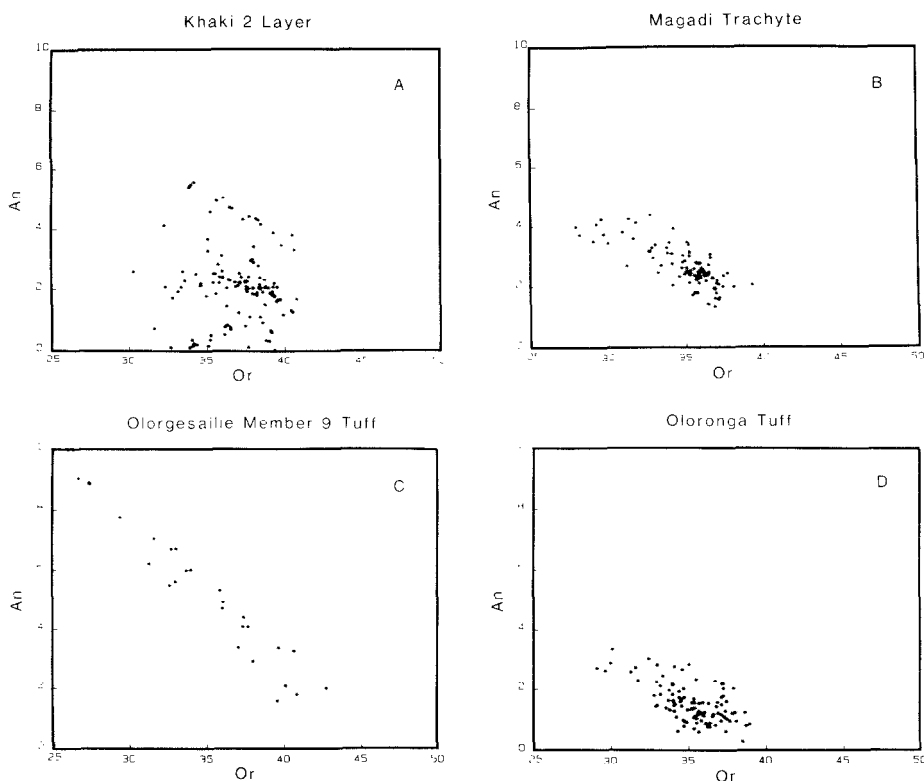


Figure 3. Plots of Anorthite (An) vs. Orthoclase (Or) components of feldspars from: A, the Khaki 2 layer (Lainyamok); B, Magadi Trachyte; C, Olorgesailie Member 9; and D, a tuff from the Oloronga Beds. Note that the trend of the high An feldspars in the Khaki 2 layer corresponds with the trend of the Olorgesailie Member 9 tuff.

represents the youngest unit, dated approximately 0.70 Ma (Bye *et al.*, 1987). If indeed the Khaki 2 layer contains feldspars of similar origin to those of Olorgesailie Member 9, it implies that the main fossiliferous unit at Lainyamok is 0.70 Ma or younger.

This lower age limit is supported by faunal comparisons. The Lainyamok fauna does not include archaic, extinct species present in Olorgesailie Members 1 and 7 (*Theropithecus oswaldi*, *Elephas recki*, *Hipparion libycum*, *Equus oldowayensis*, *Metridiochoerus* sp., *Hippopotamus gorgops*, *Giraffa gracilis*, *Pelorovis* sp., and probably *Sivatherium maurusium*: Koch, 1986). A closer comparison can be made with the fauna from Olorgesailie Member 11, which takes on a more modern character, although it involves far fewer specimens than Members 1 and 7. Member 11 at Olorgesailie is bracketed by K-Ar determinations between 0.70 Ma (Member 10; Bye *et al.*, 1987) and 0.56 ± 0.06 Ma, which is a single, provisional Ar-Ar date obtained from Member 12 pumice (Deino, *pers. comm.*).

In addition to Ar-Ar results from the Khaki 1 layer noted above, an upper limit estimate on the age of fossils from Lainyamok can be based on evidence about the structural history of the southern Kenya rift. Excavation at the contact between the sediments and the eastern graben wall at Lainyamok demonstrates that deposition of the lake beds

immediately below the Khaki 2 layer preceded faulting that led to graben formation: the contacts between sedimentary layers are deformed upward closer to the graben wall. Lainyamok is part of a complex of north-south trending grabens that occur west of Lake Magadi. Tectonic activity causing the formation of these grabens occurred during grid faulting that took place throughout the southern Kenya rift (Fairhead *et al.*, 1972; Crossley, 1979). Following Baker & Mitchell (1976), the best estimate for the last phase of grid faulting is the final part of the Olorgesailie sequence. Chemical analyses of glass separates from the upper beds at Olorgesailie are similar to those from OI Doinyo Nyokie, *ca.* 0.60 Ma (Bye *et al.*, 1987). A 0.56 Ma date for Member 12 (noted above) represents an approximate youngest age for the upper members at Olorgesailie. Therefore, this is considered a provisional upper limit for the bottom to middle part of the Lainyamok sequence. This upper age estimate would not apply if grid faulting continued later west of Magadi than to the north (at Olorgesailie) (*cf.* Crossley, 1979).

An age range between 0.70 and 0.56 Ma for the main fossiliferous unit at Lainyamok would make these sediments contemporaneous with the upper Oloronga Beds known from the margins of Lake Magadi (Baker, 1958). For these beds Eugster (1981) offers estimates from over 0.8 Ma to contemporaneous with the latest part of the Olorgesailie sequence; Crossley (1979) gives an age of 600 000 years for the Oloronga Beds. Baker (1958) characterized the Oloronga Beds as volcanic mudflows deposited during faulting of the southern Kenya rift. The Lainyamok deposits, specifically the Khaki layers, are also best described as mudflows containing primarily volcanic materials. In addition, isolated outcrops of fossiliferous, olive-green, massive deposits, similar to the Khaki 2 layer, can be traced eastward to Oloronga outcrops identified by Eugster (1981). Given these similarities of structural history and lithology, the Lainyamok sediments probably represent a western extension of the Oloronga Beds, as suggested previously by Shipman *et al.* (1983). Since the tuffaceous sediments at Lainyamok for the most part represent mudflows (see below) in which materials from a wide area and age range were mixed together, a strong correlation specifically with the Oloronga tuffs is not to be expected. This provisional association of Lainyamok with the Oloronga Beds also implies an early Middle Pleistocene age for this locality.

The stone artifact evidence from Lainyamok is consistent with this interpretation. The artifacts associated with the Khaki 2 layer largely consist of technologically simple flakes and core fragments, while several artifacts associated with the overlying laminated silts and related soils exhibit prepared core technique. The absence of such Middle Stone Age elements in Khaki 2 and their presence higher in the stratigraphic sequence suggest an upper age limit of late Middle Pleistocene for the Khaki 2 layer, based on archeological evidence alone.

An early Middle Pleistocene age estimate, 0.70–0.56 Ma, implied by the foregoing evidence provides a restricted time frame for Lainyamok; however, we emphasize that the upper age limit remains provisional until more information about the geologic history of the southern Kenya rift is known, particularly the detailed correlations among west Magadi, the Oloronga Beds, and Olorgesailie.

The butchery hypothesis

In 1976, Bishop's geological team collected approximately 200 fossils from Lainyamok. These fossils were mainly surface finds, though one specimen found *in situ* was a fragment of

hominid maxilla (right P⁴-M²) (Shipman *et al.*, 1983). Bishop's brief geologic reconnaissance showed that numerous animal bones and stone tools were associated with a lake margin setting. The fossil finds on or eroding from the surface of the Khaki 2 layer were distributed in small clusters with barren areas in between. The most striking feature of these bone patches was the occurrence of multiple skeletal elements from single animals, including articulated units. This type of spatial distribution of bones resembles single animal scatters that typify animal death sites, the butchery sites of modern hunter-gatherers, and presumed butchery sites of Pleistocene age (Clark & Haynes, 1970; Hill, 1975; Gifford, 1977). Bishop's survey recovered a wide size range of mammals with a variety of small and medium-size ungulates and several species of carnivore. This initial survey team also reported that stone artifacts came from the same layer as the fossils.

Thus, Lainyamok appeared to offer abundant Middle Pleistocene faunal remains and artifacts that had been deposited in an environment sufficiently quiet to leave articulated elements and spatially associated bones of single carcasses undisturbed. This kind of situation for the Middle Pleistocene is extremely rare because most sites from this period, including those in Africa, occur in fluvial/channel contexts. The distribution of fossil animals on the surface and the presence of abundant stone artifacts suggested that Lainyamok might preserve places where hominids had butchered carcasses, especially of small and medium-size prey animals (Shipman *et al.*, 1983). This hypothesis was important to test because there is minimal archeological evidence that Lower or Middle Pleistocene hominids organized their activities in the types of spatially discrete areas generally assumed to characterize hunter-gatherers—e.g., butchery, factory, and home-base sites. Thus, excavation and further analysis were conducted specifically to assess whether spatially discrete butchery sites were preserved at Lainyamok.

Based on ethnographic studies and ideas developed from modern butchery, we made five predictions about what would be found in excavation if kill or butchery sites were present at Lainyamok:

- (1) We expected stone artifacts and the animal bones to be associated with one another, reflecting the use of artifacts in processing the animals from which the bones were derived.
- (2) Stone tool cut marks on bones also would have to be found. We predicted that these cut marks ought to be in locations which indicate any of the necessary steps in the butchery process (e.g., Guilday *et al.*, 1962; Binford, 1981).
- (3) If, in fact, animals were butchered at their death sites, excavations should reveal scatters of bones belonging to single animals relatively isolated from other such scatters. That is, considerably less mixing of elements from different carcasses would occur than does at Type C sites known from the early Pleistocene of Africa, which preserve bones of numerous and diverse mammal species associated with stone artifacts (cf. Isaac & Crader, 1981). Such a spatial arrangement would also imply that the sites had a relatively high degree of integrity and resolution, which is necessary if indeed single episodes of hominid activity were involved (Binford, 1981).
- (4) Moreover, we expected that hominids would have butchered primarily ungulates. Even if carnivores were preserved, we would still predict that traces of butchery activities would be focused on ungulates.
- (5) A final test prediction of this hypothesis, and a crucial prerequisite of all interpretations of hominid activity from archeological remains, was that excavated

Table 1 Relative representation of major taxonomic groups of large mammals (2 kg) in Lainyamok surface collection (1984 and previous collection). The number of individual specimens (NISP) is given for each species

Taxon	NISP	Percentage of specimens	Number of species
Bovidae		65%	15
<i>Antidorcas</i> sp.	1		
<i>Gazella granti</i>	5		
<i>Gazella thomsoni</i>	3		
<i>Litocranius walleri</i>	1		
Antilopini indet.	4		
<i>Aepyceros</i> sp.	4		
<i>Damaliscus lunatus</i>	3		
<i>Damaliscus hunteri</i>	1		
<i>Connochaetes</i> sp.	2		
Alcelphini indet.	7		
<i>Hippotragus equinus</i>	2		
<i>Oryx</i> sp.	4		
<i>Kobus</i> sp.	2		
<i>Taurotragus oryx</i>	12		
Bovini indet.	1		
<i>Madoqua</i> sp.	6		
Cephalophini indet.	1		
Bovidae indet.	313		
Equidae		13%	2
<i>Equus grevyi</i>	35		
<i>Equus burchelli</i>	21		
<i>Equus</i> sp.	20		
Carnivora		9%	12
<i>Canis mesomelas</i>	2		
<i>Canis adustus</i>	5		
<i>Canis</i> sp.	2		
Canid indet.	1		
<i>Otocyon</i> sp.	8		
<i>Mellivora capensis</i>	2		
<i>Herpestes ichneuman</i>	2		
<i>Ichneumia</i> sp.	1		
<i>Crocuta</i> sp.	3		
<i>Hyaena hyaena</i>	1		
<i>Panthera leo</i>	3		
<i>Panthera pardus</i>	2		
<i>Felis caracal</i>	2		
<i>Felis libyca</i>	11		
Felid indet.	1		
Carnivora indet.	4		
Suidae		<1%	1
<i>Potamochoerus porcus</i>	1		
Suidae indet.	1		
Giraffidae		<1%	1
<i>Giraffa camelopardalis</i>	3		
<i>Giraffa</i> sp.	1		
Hippopotamidae		<1%	1
<i>Hippopotamus</i> sp.	1		

Table 1—continued

Taxon	NISP	Percentage of specimens	Number of species
Cercopithecidae		<1%	1
<i>Papio</i> sp.	5		
Elephantidae		<1%	1
indet.	1		
Orycteropodidae		5%	1
<i>Orycteropus afer</i>	30		
Small mammals		5%	4
<i>Pedetes</i> sp.	7		
<i>Thryonomys</i> sp.	2		
Rodentia indet.	10		
<i>Lepus capensis</i>	2		
<i>Procavia</i> sp.	6		
Mammalia indeterminate	123		
Total mammal specimens	691		
Non-mammal specimens:	$n = 89$		

assemblages of stone tools and animal bones would show little evidence of disturbance by depositional processes.

These predictions represent stringent criteria for recognizing butchery sites and extend the characteristics of such sites evaluated by Clark & Haynes (1970).

Procedures and results

During 1984, all surface artifacts and bones were collected in the vicinity of Khaki 2 exposure (0.07 km²). Surface material was collected in 20 × 20 m units marked on a grid map of the site. After surface collection was completed, numerous patches and isolated instances of *in situ* bone were excavated. Concentrations of materials obtained in excavation from the Khaki 2 layer were plotted in three dimensions, dips and orientations of specimens were measured, and the sediment was sieved using 1 cm and 1 mm mesh screens.

A total of 2147 cores, flakes, and core fragments was collected from the surface, spread over an area of 28 800 m². Densities ranged from 0 artifacts per 400 m² to 189 per 400 m². Only 9% of the artifacts were directly associated with the laminated and paleosol silts above the Khaki 2 layer; the remainder occurred on or immediately below Khaki 2.

From an area of 31 200 m², over 6600 bone specimens were collected, though most of these represented fragments of bones broken after exposure by erosion of the Khaki 2 layer. The 691 specimens identified as large mammals (>2 kg in live body weight) represent a rather diverse fauna (Table 1). Bovids are represented by 15 species and comprise 65% of the specimens recognized to family level. There is also a surprising array of carnivores, which comprise 12 species, 9% of the specimens identified to family level, and approximately 20% of the minimum number of individuals (MNI) represented in the

Table 2 The number of bone specimens excavated from the Khaki 2 layer: 92% of the total number of excavated specimens occurred in eight bone patches

Excavation site	Bone specimens
1 Equid patch (EP)	150
2 Skeleton Hill (SH)	142
3 M20 Patch (M20)	70
4 Karen's Patch (KP)	48
5 North End Patch (NEP)	37
6 Bovid Leg Patch (BLP)	16
7 Hunting Dog Patch (HDP)	15
8 A50 Patch (A50)	9
	487
<i>Other excavations</i>	
Ndetei's Patch	3
Hominid Ridge	24
Other isolated specimens	17
	44
<i>Total</i>	531

Table 3 Approximate area of concentration, number of specimens, minimum number of elements (MNE), minimum number of individuals (MNI), and the number of species represented in the eight bone patches from Lainyamok

Excavation	Area (m ²)	Specimens	MNE	MNI	Species
EP	1.5	150	117	21	11
SH	1.5	142	45	15	13
M20	0.36	70	31	9	6
KP	0.18	48	30	6	5
NEP	0.59	37	26	7	6
BLP	0.43	16	14	5	4
HDP	0.23	15	10	6	6
A50	0.09	9	9	5	4

surface collection. This MNI figure is surprising since the Carnivora make up approximately 1–3% of large mammal individuals in African savannas today.

Excavated material was used to test the butchery site hypothesis. Extensive scraping and brushing of the top 5–10 cm of the Khaki 2 erosion slope was used to search for *in situ* bone or stone material, which was then excavated in detail. Despite the large quantity of stone artifacts on the surface and extensive testing and excavation of the Khaki 2 layer, only 12 artifacts were found *in situ*. These specimens were widely separated from each other, and only 3 of the 12 were found in or near excavated patches of bones. Based on this result, the litter of artifacts found on the surface evidently reflects extensive erosion which exposed relatively indestructible stone artifacts that had been widely scattered through the Khaki 2 layer.

Eight patches of bone (Table 2) excavated primarily from the lower third of the Khaki 2 layer provided 92% of all *in situ* faunal remains (excluding several hundred unidentifiable fragments obtained during sieving). Concentrations of bone ranged from 9 to 150

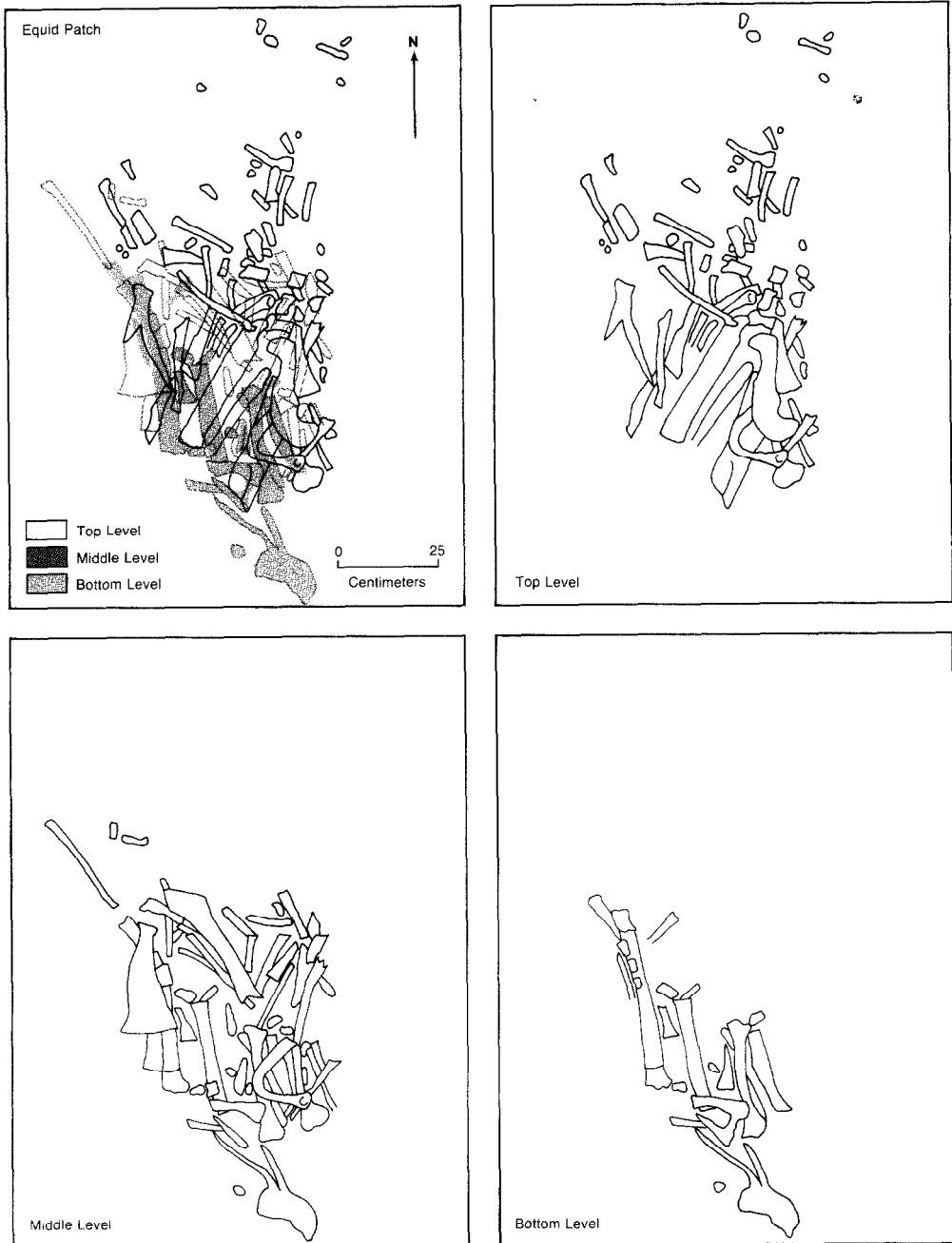


Figure 4. Site plan of the Equid Patch bone cluster. The drawing in the upper left represents all bone specimens found in this cluster. In the accompanying site plans, this cluster is separated into three levels according to depth. The elongated nature of the cluster and the preferred orientations of bones can be observed.

specimens per patch. Another 44 specimens were found dispersed throughout the Khaki 2 layer, isolated from other bones (Table 2). Only three bones preserved possible cut marks. However, none of these instances proved to exhibit conclusive microscopic evidence of a stone tool cut mark. Therefore, not only is there a lack of cut mark patterning that could relate to butchery (prediction 2), but there is not even clear evidence of intentional use of tools on bones by hominids.

Table 3 shows data from the eight bone clusters. Excavations of three of these—Equid Patch (EP), Skeleton Hill Patch (SK), and M20 Patch—revealed particularly dense and spatially well delimited concentrations of bones representing a variety of species. For instance at the Equid Patch, 150 specimens from at least 21 individuals and 11 different species were confined mainly to an area just over 1 meter long, 50 cm wide, and about 20 cm deep (Figure 4). In each concentration, bones were found in contact with one another, usually confined within a deposit less than 1 square meter in area and 10–20 cm thick. Isolated, single animal scatters did not occur in excavation, contrary to prediction 3. Articulated bones were fairly common; for example, a set of seven articulated vertebrae and an articulated humerus and radioulna were found at the Equid Patch. Yet such bones were always clustered with the bones of other species. The finds located in the original surface survey—articulated bones and spatially associated bones of particular species—evidently do not represent the isolated remains of individual animals.

With regard to prediction 4, carnivore fossils were generally common in excavation, as on the surface, and were highly abundant in some accumulations. They ranged from 0% to 29% of the MNI in the eight bone patches. Thus, the fourth prediction of the butchery site hypothesis is not met.

The last prediction concerns depositional context. Indeed, Lainyamok was part of an ancient lake basin, and the fossils and artifacts were deposited near the margin of a lake. Lacustrine silts are prevalent in the northern part of the locality, where the fossiliferous Khaki 2 layer lies above it. However, the Khaki 2 layer is a thick, unstratified silty unit which contains small rock fragments and cobbles (10–30 cm in length) dispersed throughout. The cobbles, largely made up of Magadi Trachyte, are found at a variety of orientations, including vertical or end on, which is not expected if the cobbles had settled on a land surface prior to burial. Furthermore, above the lacustrine sediments (massive white silts) in the northern part of the graben, small chunks of lake bed have been incorporated into the base of Khaki 2. The lack of any sedimentary structure, poor sorting, and the inclusion of cobbles and underlying sediments in Khaki 2 strongly suggests that this unit is a subaerial mudflow deposited with high energy and possibly rapidly. The evidence argues against the possibility of a more gradual accumulation of the Khaki layer, e.g., in an alluvial floodplain context. Thus, evidence of disturbance during sedimentation is found, contrary to prediction 5 of the butchery site hypothesis.

Reinterpretation of Lainyamok

Based on evidence for a debris flow mode of deposition of Khaki 2, it appears that cobbles, rock fragments, artifacts and bones lying on the landscape in the vicinity of Lainyamok were picked up and deposited by a viscous flow or slumping of sediments into a lake basin from highlands formed as a result of extensive faulting in the southern Kenya rift during the Middle Pleistocene. Layers that show these criteria for debris flows occur in pockets

Table 4 Percentage of isolated long bone ends ($\leq 1/3$ of diaphysis) vs. ends with greater than one-third of the diaphysis for all long bone specimens that possess at least a portion of articular end

Excavation	Number of long bone specimens	Isolated ends	Ends with $> 1/3$ shaft
EP	61	21%	79%
SH	20	10%	90%
M20	10	40%	60%
KP	4	50%	50%
NEP	8	25%	75%
BLP	4	25%	75%
HDP	5	60%	40%
A50	4	0%	100%
Total	116	23%	77%

Table 5 Percentage of diaphysis fragments which represent cylinders in the eight bone patches from Lainyamok

Excavation	Number of diaphysis fragments	Cylinders
EP	24	42%
SH	66	17%
M20	29	10%
KP	14	78%
NEP	5	40%
BLP	3	33%
HDP	3	0%
A50	0	—
Total	144	26%

throughout the west side of Lake Magadi. It is primarily these layers where fossils are preserved.

The debris flow interpretation satisfactorily explains the general scatter of isolated bones and artifacts in the Khaki 2 layer. But did this mode of deposition produce the widely spaced, dense, and clearly delimited clusters of bones excavated at Lainyamok?

Evidence that carnivores were involved in collecting these bones provides the primary clue to our taphonomic interpretation of the bone clusters. In particular, the bones found in patches exhibit damage and taxonomic patterns that characterize accumulations made by hyenas, based on data and descriptive reports of bone assemblages produced by *Crocuta* and *Hyaena* and by other carnivores in general (Sutcliffe, 1970; Klein, 1975; Binford, 1981; Brain, 1981; Hill, 1981; Potts, 1982, 1988).

First, hyenas and other carnivores are known to gnaw off the ends of long bones. As a result, in carnivore accumulations, isolated long bone ends tend to be less common than ends with more than one-third of the diaphysis attached. In the eight bone patches at Lainyamok isolated ends comprise only 23% of all long bone ends (Table 4). In comparison, a modern bone assemblage ($n = 98$ long bone specimens) produced by spotted hyenas from Amboseli, Kenya, exhibits 37% isolated ends (Potts, 1988), whereas the

Table 6 Percentage of complete long bones and of complete radii, metacarpals, and metatarsals for Lainyamok and assemblages produced by known agencies

Assemblage	Process of accumulation	Minimum number (MNE) of long bones	Percentage complete	Percentage complete radii & metapodials
Lainyamok (EP & SH)	—	97	33%	27%
Lainyamok (8 patches)	—	151	28%	21%
Amboseli den ¹	Spotted hyenas	203	30%	25%
Verdigre quarry ²	Fluvial	2471	13%	11%
Kung San campsites ³	Hunter-gatherers	162*	1.9%	1%
Khwee San campsite ⁴	Hunter-gatherers	200*	0%	0%

* Number of long bone specimens

¹ Potts, 1988

² Voorhies, 1969

³ Yellen, 1977

⁴ Bunn, 1982

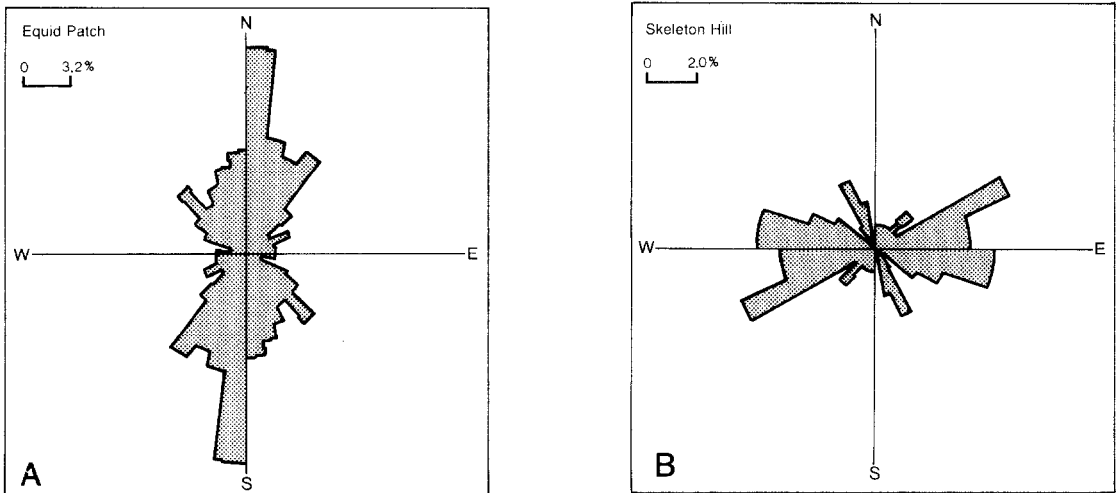


Figure 5. Rose diagrams of bone orientations for A, Equid Patch and B, Skeleton Hill. Preferred orientations of bone specimens can be noted in these accumulations, the two largest bone patches from Lainyamok.

majority, and occasionally all, of the long bone ends from human-made bone assemblages represent isolated ends (Binford, 1981). Furthermore, tubular diaphyses which are missing both articular ends, or cylinders, are also a product of epiphysis-first attack of long bones by carnivores. This feature of carnivore-collected bone assemblages is also demonstrable at Lainyamok. Cylinders represent 26% of all diaphysis fragments in the eight bone patches; they constitute 42% of such fragments in the largest bone accumulation at Lainyamok (EP) (Table 5). Overall, the majority of identifiable types of bone damage observed in the Lainyamok assemblages is attributable to carnivores. Of 165 specimens on which detailed damage information was recorded, 113 (68%) exhibited characteristic forms of carnivore damage, especially punctures, scooping out of cancellous bone, tooth scoring, and long bone cylinders.

Second, hyenas are known to preferentially break certain long bones of ungulates and to

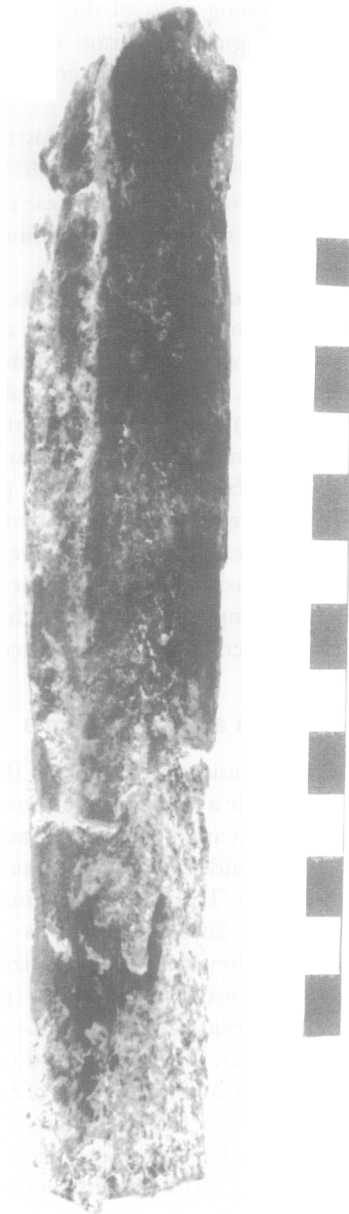


Figure 6. Hominid femur (KNM-WM 13350) from Lainyamok, posterior view. Total length = 177 mm. Mid-shaft dimensions: anterior-posterior = 31.3 mm; medial-lateral = 32.2 mm.

leave others, especially metapodials and radii, unbroken; this is seen, for example, in the modern spotted hyena den at Amboseli, Kenya (Hill, 1981; Potts, 1982, 1988). In the two largest bone assemblages at Lainyamok (EP and SH), complete metapodials and radii are exceptionally well represented, comprising 27% of the minimum number of long bone elements (which is statistically indistinguishable from the 25% in the Amboseli hyena den). Data presented in Table 6 suggest that bone accumulations produced by fluvial processes or human activity do not exhibit this pattern.

Finally, the high frequency of carnivores at Lainyamok further suggests that the primary bone collector was a carnivore (cf. Klein, 1975; Brain, 1981). An average of 12% of the MNI in the eight bone patches are carnivores; in five of these patches, carnivores represent 14% or more of the total MNI, though it must be kept in mind that the MNI sample sizes are small (range: 5–21).

In short, these data indicate that hyenas (or some other bone-collecting, burrow-using carnivore) probably introduced bones into the Khaki 2 layer after the sediments had been deposited and prior to the deposition of higher stratigraphic layers (since there is no microstratigraphic evidence of infilling). The distribution of finds in elongated patches with preferred orientations (Figures 4, 5) indeed is consistent with deposition of bones in den passageways, as each of the three living species of hyena are capable of doing (Sutcliffe, 1970; Klein, 1975; Mills & Mills, 1977; Skinner *et al.*, 1980; personal observation).

To summarize, the evidence from excavations at Lainyamok contradicts the first four predictions of the butchery site hypothesis. Our alternative interpretation involves the action of two different means of bone deposition in sequence at Lainyamok—first, by debris flow and later by carnivores. The latter implies that most of the excavated bones (the eight clusters) were in primary context (prediction 5) but unrelated to hominid activity.

Discussion and conclusions

In light of these revised interpretations and destruction of the butchery site hypothesis, what information does Lainyamok provide about early hominids and their ecology? In fact, hominids were clearly present in the Lainyamok vicinity. In addition to the maxillary teeth recovered by the previous survey, a hominid femoral shaft was excavated from the Skeleton Hill Patch (KNM-WM 13350) (Figure 6). The midshaft region of a left femur is preserved. A prominent *linea aspera* disappears distally. There is no indication of proximal platymeria, the presence of which is believed to characterize the femora of *Homo erectus* (Day, 1971). However, the midshaft regions of *Homo* femora (*pre-sapiens*) often have about equal anterior–posterior and medial–lateral dimensions (Leakey *et al.*, 1978, p. 180), as does the Lainyamok femur (see Figure 6). There is no indication of anterior bowing or build-up of a pilaster, which generally characterize femora of *Homo sapiens*. The Lainyamok specimen shows closest similarities to two femoral shafts from East Turkana (Okote Member, Koobi Fora Formation) which have not been ascribed to any particular taxon (KNM-ER 1807 and 1809) (Leakey *et al.*, 1978). Unfortunately, all three specimens have only the diaphysis preserved.

More important to issues of early hominid activities and paleoecology is that Lainyamok enables comparisons with hominid localities that are approximately contemporaneous. Comparison between Lainyamok and Olororgesailie, for example, suggests that ecological overlap between hominids and large carnivores was not as intense during the Middle Pleistocene as it was prior to 1.7 Ma in East Africa. Evidence from sites at Olduvai Gorge

dated 1.70–1.85 Ma indicates that hominids and carnivores exploited similar animal species, were attracted to the same body parts, overlapped spatially, and interacted directly on occasion (Potts, 1982, 1984, 1988). Later in time, Lainyamok and Olorgesailie present a different picture. At Lainyamok hominid activities appear to have been rare; mammalian carnivores were diverse and common; at least one carnivore species, probably either *Crocota* or *Hyaena* (both of which are preserved in the surface collection), was an active collector and chewer of bones; no prey species larger than a single immature giraffe is known in the excavated fauna, nor is there any sign of bone collecting activities by hominids. In contrast, hominids were comparatively very active in the Olorgesailie area; carnivore fossils are extremely rare; carnivore damage to bones appears to be rare; and large animals (e.g., *Elephas*, *Hippopotamus*) are common (Koch, 1986; Isaac, 1977). Recent excavations at Olorgesailie (Potts, in prep.) further suggest that hominids and carnivores did not closely overlap in their use of the landscape, in contrast to Olduvai. Understanding the precise ecological roles of early hominids is thus enhanced by comparisons to ecological zones in which hominids left little evidence of their activities.

Finally, the Lainyamok fauna is well preserved and includes diagnostic parts (i.e., crania) that will help to define Middle Pleistocene faunas in East Africa. For example, a complete cranium of a blesbok (*Damaliscus dorcas*) was excavated from EP and is the only definite record of this species in East Africa. The fauna is more modern in appearance than that from Bed IV Olduvai and Olorgesailie Members 1–7. Thus, Lainyamok probably records a Middle Pleistocene fauna that followed a period of relatively high species turnover and migration in Africa. The activities of hominids and the events that occurred in hominid evolution during this period of transition have yet to be clearly documented.

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