Pliocene and Pleistocene Hominid-Bearing Sites from West of Lake Turkana, Kenya

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Pliocene and Pleistocene fossil localities near the western shoreline of Lake Turkana, ranging in age between 1 million and 3.5 million years in age, have produced important new hominid specimens including most of a *Homo erectus* skeleton and a relatively complete early robust australopithecine cranium. The lacustrine, fluviatile, and terrestrial strata are designated the Nachukui Formation, which is subdivided into eight members. The distribution of sedimentary facies within the Nachukui Formation suggests that, as today, the Labur and Murua Rith ranges formed the western margin of the basin and were drained by eastward-flowing rivers that fed into the forerunner of the present lake or a major river system. There is also stratigraphic evidence for tectonic movement during the deposition of these sediments. Twenty-three of the tuffs observed in the succession occur also in the Koobi Fora Formation east of the lake and in the Shungura Formation of the lower Omo Valley and permit precise correlation among these three localities. Forty-seven fossiliferous sites from West Turkana have yielded more than 1000 specimens of 93 mammalian species. The mammalian fossils represent nine sequential assemblages that augment information about faunal and environmental change from elsewhere in the basin.

The Lake Turkana basin, part of the eastern Rift Valley system of East Africa, is located at the western edge of the border between Kenya and Ethiopia. It has proved a prolific source of Miocene and Pliocene-Pleistocene fossils and has contributed much to understanding the evolution of terrestrial African faunas. Lengthy Plio-Pleistocene fossiliferous sequences in the lower Omo Valley provide a framework of potassium-argon dates and paleomagnetic data from which to calibrate and interpret faunal change both in the basin and farther afield (*1–3*). The Koobi Fora region has a less continuous Plio-Pleistocene succession but is also well dated (*4, 5*). The fossil assemblages from Koobi Fora supplement the Omo assemblages and provide samples from intervals that are unrecorded or only poorly documented from the latter (*6, 7*). Kanapoi, Ekora, and Lothagam to the southwest of the lake have yet to be dated precisely but have yielded important faunas of late Miocene and early Pliocene age (*8–10*). Earlier Miocene faunas are also known from the region (*11–14*).

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Late in 1980, National Museums of Kenya personnel surveyed exposures on the west side of Lake Turkana that lay between Kalakol (formerly Ferguson's Gulf) and Lowarengak and located sites that contained Plio-Pleistocene mammalian fossils and stone tools (Fig. 1). Further field reconnaissance in 1981 and 1982 established the basis for preliminary estimates of the biostratigraphy and chronostratigraphy of this new area (*15*). Large-scale aerial photographic coverage of the region was obtained in 1983 and collecting was initiated in 1984.

The region investigated lies between the settlements of Kalakol to the south and Kokuro to the north and is largely contained within a strip of land about 10 kilometers wide between the shore of Lake Turkana and prominent hills made up of rocks of Miocene or earlier age to the west. The region is delineated by latitudes 3°35′N and 4°30′N and longitudes 35°40′E and 35°55′E. Pliocene and Pleistocene sediments are exposed at elevations that range from about 372 m (the level of Lake Turkana) to 540 m. Much of the area is covered by late Pleistocene and Recent alluvium but many exposures of Pliocene and Pleistocene sediments crop out along stream courses near the lake or in low hills farther to the west.

Stratigraphy

The Nachukui Formation, which ranges in age from 0.7 million to 4.3 million years old, consists of poorly consolidated sandstones, siltstones, claystones, and conglomerates exposed west of Lake Turkana between latitudes 3°20′N and 4°20′N. It rests disconformably on, or is in fault contact with, Miocene volcanic rocks and intercalated sediments or Precambrian gneisses, or both. The formation has an aggregate thickness of 730 m and is named for the Laga Nachukui, a large ephemeral stream in the northern half of the area where outcrops typical of the upper half of the formation are exposed. The formation includes many tuffs (*16*), some of which have been previously recognized in the Koobi Fora Formation (where they were named) and in the Shungura Formation (where they were referred to by letter). Preexisting names have been used where possible. Thus Lokochot Tuff (A) implies that Tuff A of the Shungura Formation is considered correlative with the Lokochot Tuff exposed in the Koobi Fora and Nachukui formations. Because of the discontinuous nature of the exposures, no single type section exists for the strata of this region. However, each of the eight constituent members of the formation is defined in a single section, and each of these individual sections has been linked by analysis of volcanic ash layers. The stratotype of the formation is thus the composite stratotype of the constituent members (Fig. 2); these have been formally defined elsewhere (*16*). Correlations between members of the Nachukui Formation and those of the Shungura and Koobi Fora formations, and between tuffs of each of these, are also shown in Fig. 2.

The lowest, Lonyumun Member (91 m) of the Nachukui Formation is made up of those sediments that lie below the basal contact of the Moiti Tuff. It is a lateral extension of the Lonyumun Member of the Koobi Fora Formation (*17*) and consists dominantly of laminated lacustrine claystones with occasional beds of diatomite and thin sandstones. It is also lithologically similar to strata of the Muruongori Formation of the Lothagam area (*18*).

The Kataboi Member (46 m) consists of about 34 m of fluvial upward-fining cycles beginning with trough cross-bedded sandstones grading to silty claystones. The upper 12 m of the member consists of laminated or massive diatomite with well-preserved diatoms that correlate with diatomites of the Lokochot Member at Koobi Fora (*17*).

The Lomekwi Member (159 m) constitutes those strata that lie between the basal contact of the Tulu Bor Tuff (B) and the basal contact of the Lokalalei Tuff (D). The member is made up of two sharply contrasted lithologic associations; the basin margin association consists of volcanic clast conglomerates and massive, poorly sorted sandy siltstones, whereas the basinal association consists of quartz-rich sandstones that grade upward into siltstones and sandy claystones.

The Lokalalei Member (42 m) is defined as strata between the base of the Lokalalei Tuff (D) and the Kalochoro Tuff (F) and includes the Kokiselei Tuff (E). It is similar lithologically to the Lomekwi Member.

The Kalochoro Member (72 m) extends from the base of the Kalochoro Tuff (F) to the base of the KBS Tuff (H2). The lower 40 m of this member consists of upward-fining cycles similar to those

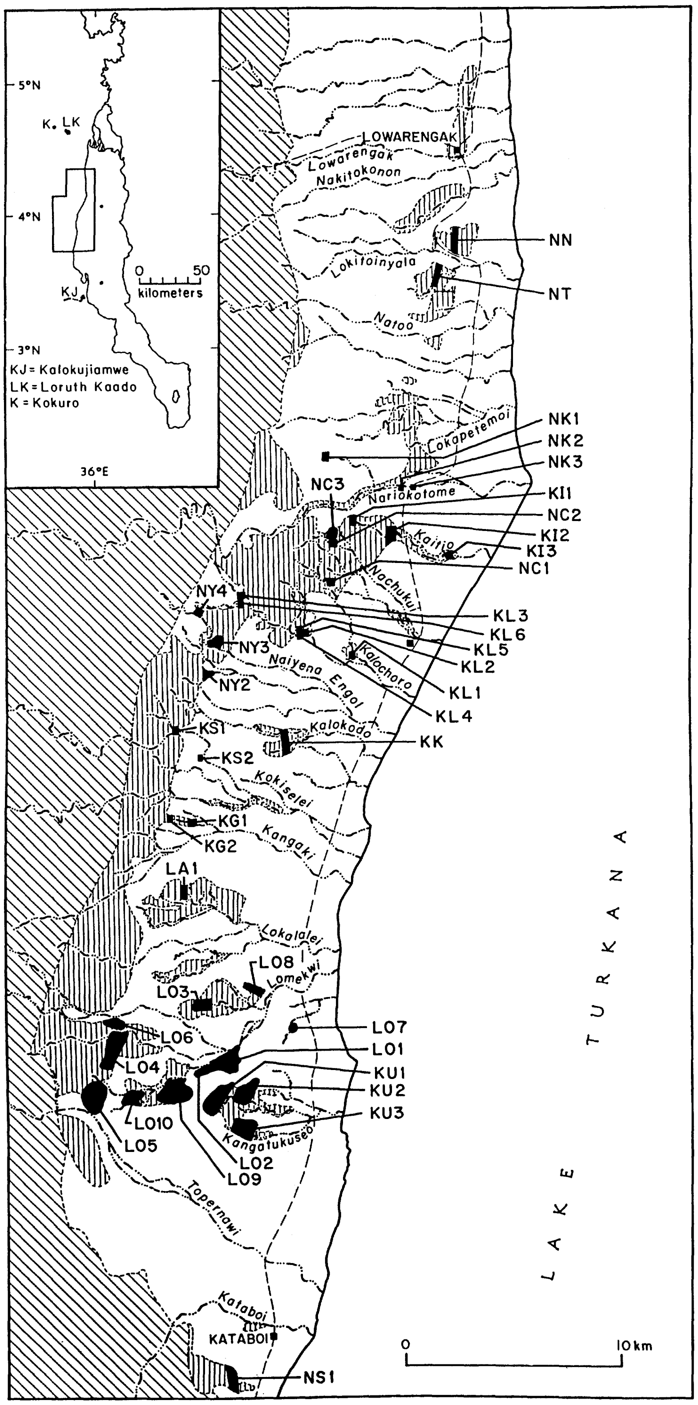

Fig. 1. Map of the West Turkana fossil localities. Unlabeled black squares represent settlements; vertical shading denotes exposures of the Nachukui Formation; diagonal shading represents Miocene and older rocks; solid shading indicates fossil localities (abbreviations are listed in Table 1).

Table 1. Stratigraphic positions of West Turkana vertebrate fossil sites.

Locality	Horizon	Member
Kaitio I (KI1)*	Above Nariokotome Tuff	Nariokotome
Kaitio II (KI2)	Above Okote Tuff	Natoo
Kaitio III (KI3)	Above Kokiselei Tuff	Kalochoro?
Kalochoro I (KL1)	Below Chari Tuff	Natoo
Kalochoro II (KL2)	Below Chari Tuff	Natoo
Kalochoro III (KL3)	Below Okote Tuff	Kaitio
Kalochoro IV (KL4)	Below KBS Tuff	Kalochoro
Kalochoro V (KL5)	Below Nariokotome Tuff	Natoo
Kalochoro VI (KL6)	Below Okote Tuff	Kaitio
Kalakodo (KK)	Below KBS Tuff	Kalochoro
Kangaki I (KG1)	Below KBS Tuff	Kalochoro
Kangaki II (KG2)	Below KBS Tuff	Kalochoro
Kangatakuseo I (KU1)	Below Lokalalei Tuff	Upper Lomekwi
Kangatukuseo II (KU2)	Below and just above Lokalalei Tuff	Upper Lomekwi/ Lokalalei
Kangatukuseo III (KU3)	Below Lokalalei Tuff	Upper Lomekwi
Kokiselei I (KS1)	Below Okote Tuff	Kaitio
Kokiselei II (KS2)	Below Okote Tuff	Kaitio
Lomekwi I (LO1)	Below Lokalalei Tuff	Upper Lomekwi
Lomekwi II (LO2)	Below Lokalalei Tuff	Upper Lomekwi
Lomekwi III (LO3)	Below Lokalalei Tuff	Upper Lomekwi
Lomekwi IV (LO4)	Just above Tulu Bor Tuff	Lower Lomekwi
Lomekwi V (LO5)	Just above Tulu Bor Tuff	Lower Lomekwi
Lomekwi VI (LO6)	Just below Tulu Bor Tuff	Kataboi
Lomekwi VII (LO7)	Above Lokalalei Tuff	Lokalalei
Lomekwi VIII (LO8)	Above Lokalalei Tuff	Lokalalei
Lomekwi IX (LO9)	Below Emekwi Tuff	Middle Lomekwi
Lomekwi X (LO10)	Below Emekwi Tuff	Middle Lomekwi
Lokalalei I (LA1)	Just above Kalochoro Tuff	Kalochoro
Loruth Kaado I (LK1)	Just below Tulu Bor Tuff	Kataboi
Loruth Kaado II (LK2)	Below Tulu Bor Tuff	Kataboi
Loruth Kaado III (LK3)	Above Okote Tuff	Natoo
Loruth Kaado IV (LK4)	Below Okote Tuff	Kaitio
Loruth Kaado V (LK5)	Indet.	Indet.
Nachukui I (NC1)	Above Chari Tuff	Nariokotome
Nachukui II (NC2)	Above Chari Tuff	Nariokotome
Nachukui III (NC3)	Above Chari Tuff	Nariokotome
Nasechebun I (NS1)	Below Tulu Bor Tuff	Kataboi
Nanyangakipi (NN)	Below/above Okote Tuff	Katio and Natoo
Nariokotome I (NK1)	Galana Boi Beds	
Nariokotome II (NK2)	Below Chari Tuff	Natoo
Nariokotome III (NK3)	Below Chari Tuff	Natoo
Nariokotome IV (NK4)	Below Chari Tuff	Natoo
Natoo (NT1)	Below Chari Tuff	Natoo
Naiyena Engol I (NY1)	Below Okote Tuff	Kaitio
Naiyena Engol II (NY2)	Below Okote Tuff	Kaitio
Naiyena Engol III (NY3)	Below Okote Tuff	Kaitio
Naiyena Engol IV (NY4)	Below Okote Tuff	Kaitio

*Abbreviations in parentheses.

of the Kataboi Member. The next 27 m consist dominantly of laminated claystones and siltstones that are overlain by 20 m of sandstone with minor interbedded volcanic pebble conglomerates.

The Kaitio Member (169 m) overlies the Kalochoro Member; its upper limit is the base of the Lower Koobi Fora Tuff. The member consists dominantly of laminated siltstones, claystones, and fine sandstones. Most of the fossils from this member derive from sandstones of the basin margin facies. The Malbe Tuff has been identified in several sections of the Kaitio Member.

The Natoo Member (75 m) constitutes those strata between the basal contact of the Lower Koobi Fora Tuff and the basal contact of the Lower Nariokotome Tuff. It is composed dominantly of fine sandstones grading upward into pale brown siltstones in 13 cycles, each with an average thickness of 5.8 m. The Chari Tuff (L) has been identified within this member.

Strata that lie above the basal contact of the Nariokotome Tuff but below Holocene strata are designated the Nariokotome Member (70 m). Lithologically it is dominated by conglomerates and sandstones with prominent cryptalgal stromatolite layers.

Plio-Pleistocene strata near Loruth Kaado (Fig. 1) have been only briefly surveyed but contain strata equivalent in age to the Lonyumun, Kataboi, Kaitio, and Natoo members of the Nachukui Formation.

Today the western margin of the Lake Turkana basin is formed by the low Labur and Murua Rith ranges. These provide the catchment for small ephemeral streams that drain eastward into Lake Turkana. These low western mountains are also cut through by several larger but still ephemeral rivers (the Lagas Kataboi, Topernawi, Kokiselei, Nariokotome) that have sources yet farther to the west. Distribution of the facies represented in the Nachukui Formation suggests a similar distribution of depositional environments along the western margin of the basin during the Plio-Pleistocene but with the streams sometimes draining into a major permanent river (the proto-Omo) rather than a lake. The upper courses of the larger local (eastward-draining) streams were characterized by extensive channel conglomerates and, during times when the lake was present, the vicinity of their mouths can be interpreted from the location of the stromatolite units. It is interesting that the western margin of the basin is well documented in the Nachukui Formation, but that the eastern margin is still only poorly known in the more laterally extensive Koobi Fora Formation.

Biostratigraphy

More than 1000 mammalian fossils, representing more than 90 species, have been recovered from the Nachukui Formation and the Loruth Kaado exposures. Most taxa have previously been documented from the Lake Turkana Basin though some primate, carnivore, hippo, and bovid species are either new or new to the region. Forty-seven sites yielding identifiable mammalian remains (Fig. 1) have been given names and are referred to by an abbreviated site designation consisting of two letters and a number, for example, LO3 (Table 1). This labeling system replaces the site numbering system (localities I to VII) employed previously (*15*).

No mammalian fossils have yet been recovered from the Lonyu-

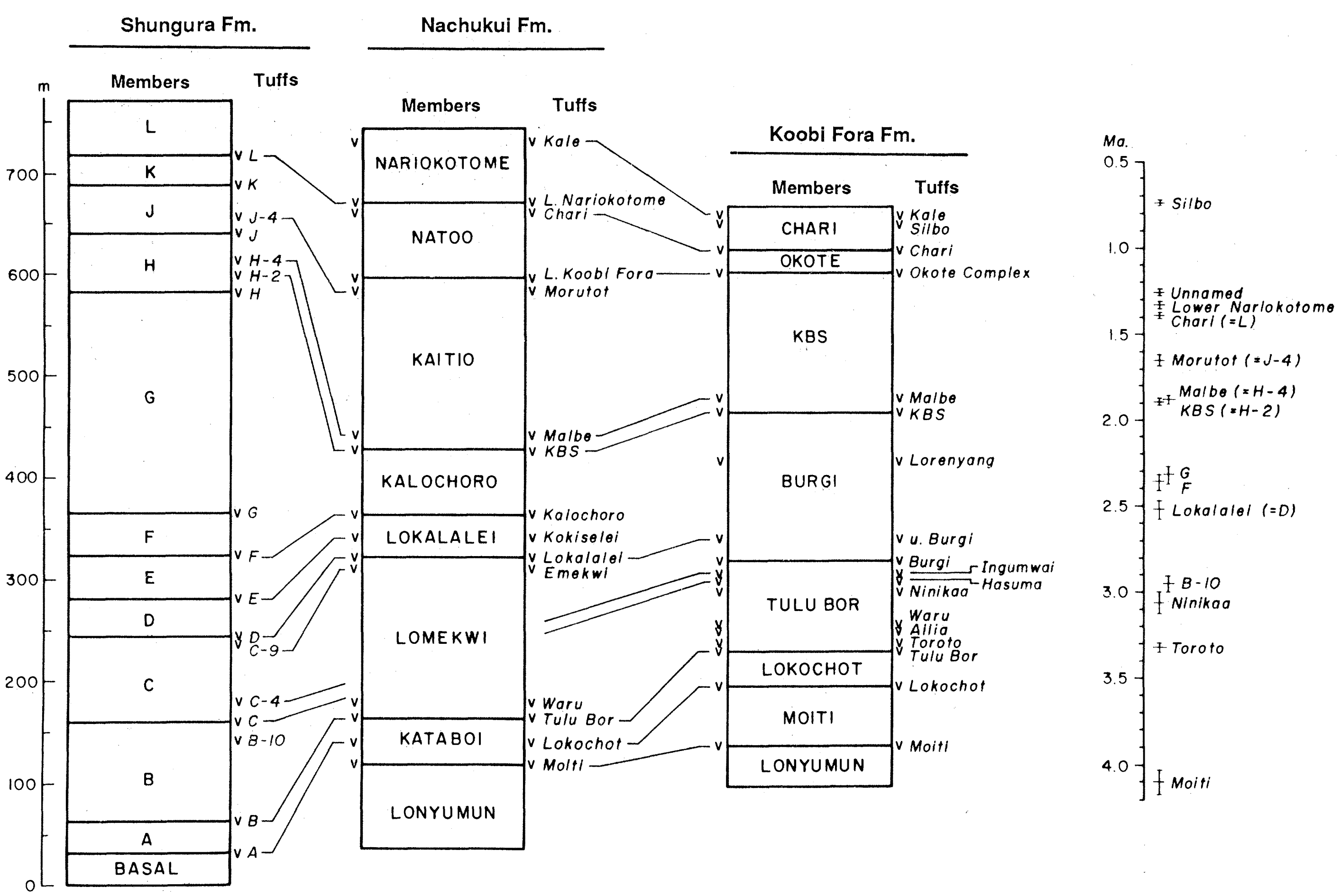

Fig. 2. Correlation diagram for the Shungura, Nachukui, and Koobi Fora formations. Note that the scale on the left, calibrating the thickness of these units, is unrelated to the time scale on the right.

mun Member west of Lake Turkana. The faunal samples constitute nine sequential assemblages—one from the Kataboi member, three from the Lomekwi Member, and one each from superjacent members. All may be correlated with assemblages from other parts of the basin but those from the Kataboi and Lokalalei members are not well documented from West Turkana whereas that from the Nariokotome Member is younger than most other faunas recovered from the Koobi Fora and Shungura formations. The distribution of taxa in the lower portion of the sequence is given in Table 2 and that in the upper part of the sequence in Table 3.

The Kataboi Member assemblage postdates those from the Omo Mursi Formation and the Moiti Member at Koobi Fora. Fossils have so far been recovered only from above the Lokochot Tuff and hence are of similar age to those from Shungura Member A and from the Lokochot Member of the Koobi Fora Formation. Impala and hippo species from the Kataboi Member differ from those from later horizons.

The lower Lomekwi Member assemblage is of similar age to those from the lower part of Shungura Member B and from the Tulu Bor Member at Koobi Fora. Several hominid specimens are known from this interval (*15*). *Theropithecus brumpti*, the common cercopithecoid, persists through the older part of the succession but *Parapapio ado* and *Parapapio* cf. *P. whitei* are also recorded from this interval. Two *Crocuta* species occur in this assemblage, one persisting to the middle Lomekwi Member. Elephants are represented by *Elephas recki brumpti* and *Loxodonta adaurora*; a single specimen of *Loxodonta exoptata* is known from LO4. *Notochoerus euilus* is the common suid but one specimen of *Not. scotti* was recovered from LO5 and representatives of *Nyanzachoerus, Kolpochoerus, Potamochoerus*, and *Metridiochoerus* also occur. *Hexaprotodon protamphibius* is the common hippo, replacing *Hippopotamus* cf. *H. kaisensis* found lower in the succession. Among the bovids, the alcelaphines and particularly the extinct impala *Aepyceros shungurae* predominate.

The middle Lomekwi Member assemblage from localities LO9 and LO10 is equivalent to faunas from the upper portions of Shungura Member B and the Tulu Bor Member. The saber-toothed *Dinofelis* cf. *D. barlowi* and the viverrids *Mungos dietrichi* and cf. *Civettictus* sp. are known only from the middle Lomekwi Member. The common suid is *Notochoerus scotti* but *Notochoerus euilus* makes its last appearance in this interval.

The assemblage from the upper Lomekwi Member at LO1–2, KU1, and KU3 is equivalent in age to faunas from Shungura Member C. Several specimens of *Australopithecus boisei* have been recovered from this interval (*19*). *Theropithecus brumpti* persists as the common cercopithecoid but *Parapapio* cf. *P. whitei* and *Paracolobus mutiwa* also occur. *Hyaena hyaena* makes its initial appearance in

Table 2. Fossil mammals from the lower part of the succession. The Xs denote species present.

Taxon	Assemblages*				
	1	2	3	4	5
Theropithecus brumpti		X	X	X	
Cercopithecidae large		X		X	
Cercopithicidae medium		X		X	
Cercopithecidae small		X		X	
Cercopithecidae indet.		X			
Parapapio ado		X			
Parapapio cf. *P. whitei*		X		X	
Paracolobus mutiwa				X	
Australopithecus boisei				X	
Hominidae indet.		X		X	
Crocuta sp. nov.		X	X		
cf. *Crocuta* sp.		X			
Hyaena hyaena				X	
Hyaenidae indet.				X	
Homotherium problematicus	X			X	
Dinofelis cf. *D. barlowi*			X		
Felidae				X	
Mungos dietrichi			X		
cf. *Civettictus* sp.			X		
Carnivora indet.		X	X	X	
Deinotherium bozasi	X	X	X	X	
Loxodonta adaurora	X	X			
Loxodonta exoptata		X			
Elephas recki brumpti		X	X	X	
E. recki shungurensis				X	X
Elephantidae indet.		X			
Hipparion hasumense	X	X	X	X	
Equidae indet.					X
Ceratotherium sp.		X	X	X	
Diceros bicornis		X	X	X	
Rhinocerotidae indet.	X	X			
Notochoerus euilis	X	X	X		
Not. scotti		X	X	X	
Nyanzachoerus kanamensis	X	X			
Kolpochoerus limnetes		X		X	X
Kolpochoerus majus				X	
Potamochoerus sp.		X			
Metridiochoerus andrewsi		X	X	X	X
Suidae indet.	X	X	X	X	
Hippopotamus cf. *H. kaisensis*	X				
Hexaprotodon protamphibius		X	X	X	
Camelus sp.				X	
Sivatherium maurusium	X			X	
Giraffa sp.		X	X	X	
Tragelaphus nakuae	X	X		X	X
Tragelaphus sp.					X
Tragelaphus scriptus		X		X	
Ugandax sp.?		X	X	X	X
Oryx sp.				X	
Hippotragini indet.		X			
Kobus sigmoidalis		X	X	X	X
Kobus oricornis	X	X		X	
Kobus sp. A		X		X	
Kobus sp. B			X	X	
Kobus sp. C				X	X
Kobus sp. D			X	X	
Kobus sp. indet.				X	
Menelikia lyrocera					X
Menelikia sp.				X	X
Reduncini large	X			X	
Reduncini medium		X	X	X	
Reduncini small		X		X	
Connochaetes sp. A				X	
Damaliscus sp.		X		X	
Parmularius sp.		X			
Alcelaphini large		X	X		X
Alcelaphini medium	X	X	X	X	
Alcelaphini small		X	X	X	
Aepyceros shungurae		X	X	X	X
Aepyceros sp.	X				
Antidorcas recki		X	X	X	
Gazella aff. *granti*	X			X	
Gazella cf. *janenschi*		X	X	X	
Gazella sp. indet.		X	X	X	
Caprini sp. A					X
Caprini sp. C			X		

*The numbers represent members (sites are in parentheses): 1, Kataboi (NS1, LK1, LK2, LO6); 2, lower Lomekwi (LO4, LO5); 3, middle Lomekwi (LO9, LO10); 4, upper Lomekwi (LO1, LO2, LO3, KU1, KU2, KU3); and 5, Lokalalei (KU2, LO7, LO8).

this interval. Elephants are represented by *E. recki shungurensis. Notochoerus scotti* is the common suid but *Kolpochoerus limnetes* and *Metridiochoerus andrewsi* are also present and their teeth display progressive changes from specimens recovered lower in the sequence. Reduncines are the most common bovids in this interval. LO3, on a northern branch of the Laga Lomekwi, is possibly slightly older than other faunas from this unit because of the presence of *E. recki brumpti* as well as *E. recki shungurensis*. A few fossils from KU2 derive from above the Lokalalei Tuff and hence belong to the Lokalalei Member.

The Lokalalei Member assemblage must be equivalent in age to Shungura members D or E, intervals of section that are unrepresented or unfossiliferous at Koobi Fora. The reduncine bovid *Menelikia lyrocera* makes its first appearance west of Lake Turkana at LO8, probably having evolved from the species of *Menelikia* common in the subjacent unit.

The Kalochoro Member assemblage is derived from fossiliferous horizons that lie above the Kalochoro Tuff (F). The reduncine bovid *Menelikia lyrocera* is common and has long lyrate horn cores like those from the middle portions of the Omo Shungura succession, in contrast to the shorter lyrate-horned form represented in the upper Burgi Member at Koobi Fora. The presence of *Equus* in this assemblage suggests age equivalence to the lower portion of Member G rather than Member F. *Theropithecus oswaldi, Hipparion* cf. *H. ethiopicum*, and *Aepyceros* cf. *A. melampus* replace *T. brumpti, H. hasumense*, and *A. shungurae*, respectively, whereas the greater kudu *Tragelaphus strepsiceros* supplants *T. nakuae* as the common tragelaphine. This assemblage is the youngest in which *Elephas recki shungurensis* and the hippo *Hexaprotodon protamphibius* appear. *Crocuta crocuta* and the jackal *Canis* cf. *C. mesomelas* occur for the first time west of Lake Turkana, but a larger canid (cf. *Lycaon* sp.) is known only from this interval. One hominid (*Homo habilis*) cranial fragment has been recovered from KG1.

The Kaitio Member assemblage is of equivalent age to those from

Table 3. Fossil vertebrates from the upper part of the succession. The Xs denote species present.

Taxon	Assemblages*				
	6	7	8	9	Galana Boi
Siluriformes			X		
Myliobatiformes			X		
Cyprinidae			X		
Characidae			X		
Pisces			X		
Crocodylus sp.	X				
Euthecodon brumpti	X		X	X	
Crocodylidae		X		X	
Trionyx sp.		X	X		
Aves	X	X	X		
Tatera sp.		X			
Hystrix sp.		X	X		X
Thryonomys sp.		X			X
Theropithecus oswaldi	X	X	X	X	
Theropithecus sp.		X			
Papio sp.					X
Cercopithecidea indet.		X			X
Australopithecus boisei		X			
Homo habilis	X				
Homo erectus			X		
Canis cf. *mesomelas*	X		X		
cf. *Lycaon* sp.	X				
Crocuta crocuta	X			X	
Hyaena hyaena	X	X			
Homotherium problematicus		X			
Carnivora indet.			X		
Deinotherium bozasi	X	X			
Loxodonta sp.		X			
Elephas recki shungurensis	X				
Elephas recki ileretensis		X			
Elephas recki recki				X	
Hipparion cornelianum		X			
Hipparion ethiopicum	X	X	X		
Equus sp.	X	X	X	X	
Equidae indet.	X	X	X		X
Diceros bicornis		X		X	
Ceratotherium simum		X	X	X	
Rhinocerotidae gen. indet.				X	
Notochoerus scotti	X	X			
Kolpochoerus limnetes	X	X	X	X	
Kolpochoerus majus				X	
Metridiochoerus andrewsi	X	X			
Metridiochoerus hopwoodi		X		X	
Metridiochoerus modestus		X		X	
Metridiochoerus compactus		X	X	X	
Potamochoerus porcus		X			X
Phacochoerus aethiopicus					X
Hexaprotodon protamphibius	X				
Hexaprotodon karumensis		X	X	X	
Hippopotamus gorgops		X	X	X	
Hippopotamus aethiopicus		X	X	X	
Hippopotamus amphibius				X	
Sivatherium maurusium	X		X		
Giraffa cf. *camelopardalis*				X	
Giraffa sp.	X		X		
Tragelaphus strepsiceros	X	X	X		
Tragelaphus scriptus		X		X	
Tragelaphus nakuae	X				
Tragelaphini sp.				X	
Syncerus cf. *caffer*				X	
Syncerus sp.	X				
Pelorovis sp. *nov.*		X			
Pelorovis sp.	X	X	X		
Hippotragus gigas		X			
Kobus ellipsiprymnus				X	
Kobus sigmoidalis			X		
Kobus sp.		X			
Kobus kob			X		
Kobus leche				X	
Menelikia lyrocera	X		X		
Reduncini large	X			X	
Reduncini medium	X	X	X	X	
Reduncini small	X	X	X	X	
Megalotragus sp.	X	X	X	X	
Connochaetes sp. nov.		X	X		
Damaliscus sp.		X	X		
Medium alcelaphini	X	X	X	X	
Small alcelaphini	X	X	X	X	
Aepyceros melampus	X	X	X	X	
Antidorcas recki	X	X			
Gazella janenschi		X	X		
Gazella praethomsoni	X		X		
Gazella sp.	X		X		
Caprini sp. A				X	
Caprini sp. B		X			
Caprini sp. C				X	
Caprini gen. indet.			X		

*The numbers represent members (sites are in parentheses): 6, Kalochoro (KK, KG, LA1); 7, Kaitio (KL3, KL4, KL6, LK4, NY2–4, KS1–2, NN); 8, Natoo (NT, LK3, KL1-2, KL5, NK3, KI2); and 9, Nariokotome (KI1, NC1–3). The Galana Boi Formation consists of Holocene lacustrine and fluviatile sediments.

the KBS Member at Koobi Fora and from Member H and lower Member J in the Shungura sequence. Carnivores are represented by *Hyaena hyaena* and *Homotherium problematicus*. Elephant specimens are uncommon but *Elephas recki ileretensis* and an undetermined species of *Loxodonta* have been recovered. Three different hippo species occur—*Hexaprotodon karumensis, Hippopotamus gorgops*, and *Hip. aethiopicus*—supplanting *Hex. protamphibius* of earlier horizons. Tragelaphines and alcelaphines are the commonest bovids from this interval except at KS1 where reduncines predominate. The wildebeest, *Connochaetes* sp. nov., appears for the first time in the West Turkana sequence and is clearly different from *Connochates* sp. A of the upper Lomekwi Member. *Australopithecus boisei* specimens have been recovered from sites in this unit.

The Natoo Member assemblage correlates with assemblages from the Okote Member at Koobi Fora and from upper Member J through lower Member L in the Shungura sequence. The NK3 has yielded two speciemens of *Homo erectus* (*20*). Alcelaphines are the commonest bovids from this interval. The commonest suid is the large and hypsodont *Metridiochoerus compactus*, known earlier in the succession from KL6 in the Kaitio Member.

The Nariokotome Member assemblage postdates others from the early Pleistocene succession at Koobi Fora and correlates partly with the uppermost part of Member L in the Shungura Formation. Species from West Turkana that are apparently restricted to this assemblage include *Elephas recki recki* and the extant (or similar) species *Hippopotamus amphibius, Giraffa* cf. *G. camelopardalis, Kobus ellipsiprymnus* and *Syncerus* cf. *S. caffer*.

The overall composition of the assemblages suggests environmental conditions that were cooler or more humid (or both) than those characterizing the region today. A major change in the represented primate, equid, hippo, and bovid species is encountered in the Kalochoro and Kaitio members. Similar change is documented also at equivalent intervals in the Koobi Fora and Shungura successions, where it has been interpreted as the result of increased regional aridity with the concomitant spread of savanna grassland in which alcelaphine bovids and the newly immigrant *Equus* species flourished and in which the extant African carnivore guild was established. Other less dramatic climatic fluctuations are suggested by the apparently cyclic changes observed in the proportions of bovid tribes represented in different intervals of the West Turkana succession. Although such changes could be related to worldwide climatic conditions, they might be better explained as the product of local tectonic activity which affected the basinal drainage and modified the available local habitats.

Discussion

The strata and assemblages from the West Turkana region are still being investigated but are clearly important for a number of reasons. The strata provide the first clear documentation of the western margin of the Lake Turkana basin, furnish intervals of section that were hitherto unrepresented in either the Koobi Fora or Shungura formations, and improve correlation between the fossiliferous horizons of the Shungura and Koobi Fora formations, with potential to eventually extend such correlation to Lothagam and Kanapoi. The Nachukui Formation adds appreciably to our understanding of the geologic history of the basin, pinpointing when lakes were present and documenting their fluctuations. A change in conglomerate lithology from volcanic to quartz clasts at Loruth Kaado provides evidence for tectonic uplift of the Labur Range between about 1.7 and 2.5 million years ago.

Mammalian assemblages from the Nachukui Formation augment those of similar age previously recovered from the Shungura and Koobi Fora formations, confirm the timing of the immigration of *Equus* species into the region, help refine previous interpretations of elephant (*21*) and suid (*22*) evolution in the Plio-Pleistocene of East Africa, and afford important potential for interpreting evolutionary changes in the basin's hippopotamid and bovid populations. The samples from horizons dated between 2 and 3 million years old, an interval of time poorly represented elsewhere in Africa except in the Shungura Formation, are particularly welcome. Significant contributions have been made to our understanding of early human evolution by the discovery of the most complete *Homo erectus* skeleton yet recovered (*20*) and by establishing the presence in East Africa of a hyper-robust australopithecine at about 2.5 million years ago (*19*). Further hominid specimens from the region are under investigation (*23*), as are stone artifacts from the Kalochoro and Natoo members (*24*).

The proportions of different bovid tribes represented in a fossil assemblage provide a useful indication of formerly prevailing habitats (*16, 25*). The bovid samples retrieved from the West Turkana fossil localities are of similar composition to those that might be found in the area today were the climate sufficiently humid to support perennial rivers. Thus, regardless of geologic age, closed habitat browsers such as tragelaphine bovids and impalas are abundant at West Turkana localities adjacent to the hills that form the western basin margin, water-frequenting reduncines predominate at localities that represent the courses of former tributary rivers, whereas open habitat grazers such as alcelaphines and antilopines are concentrated in those areas representing a lake shore or the flood plain of the ancestral Omo River. The samples from the Nachukui Formation are relatively small, but it will be interesting to see if such preliminary indications of community structure hold true for these and other mammalian groups when the rather larger samples from the Shungura and Koobi Fora formations are reexamined on a site-by-site basis.

It is apparent that although mammalian assemblages from the western (Nachukui Formation), eastern (Koobi Fora Formation) and northern (Shungura Formation) parts of the basin were simultaneously affected by regional climatic shifts, local habitats were sufficiently distinct ecologically to maintain persistent differences in the nature and abundance of represented species. The wealth of mammalian fossils from different parts of the Turkana basin, the large lateral extent of the basin, and the tight chronologic and stratigraphic control provided by the tuffs afford an opportunity to investigate paleocommunity structures and the habitat preferences of extinct species including those of hominids.

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Heavy-Electron Metals: New Highly Correlated States of Matter

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Heavy-electron metals exhibit highly correlated electronic behavior at liquid helium temperatures, with conduction-electron masses some hundred times the free-electron mass. Whether "normal," antiferromagnetic, or superconducting, their electronic behavior differs drastically from their ordinary metallic counterparts. The physical origin of the large mass and unusual superconducting and magnetic properties is the strong coupling between the conduction electrons and the local *f*-electron moment fluctuations characteristic of these materials.

THE DISCOVERY AND EXPLORATION OF HIGHLY CORRELATED states of condensed matter in this century have opened new chapters in physics. Recent examples include the superfluidity of ^{3}He (*1*) and the quantized Hall effect (*2*). In this article we review the properties of another set of new states, those found in heavy-electron systems, electrically conducting materials in which the conduction-electron specific heat is typically some 100 times larger than that found in most metals (*3*). As may be seen in Table 1, at low temperatures these systems either remain "normal," become antiferromagnetic, or become superconducting (*4–17*). Each of these highly correlated states displays properties that are dramatically different from their counterparts in ordinary metals.

At room temperatures and above, heavy-electron systems behave as a weakly interacting collection of *f*-electron moments and conduction electrons with quite ordinary masses; at low temperatures the *f*-electron moments become strongly coupled to the conduction electrons and to one another, and the conduction-electron effective mass is typically 10 to 100 times the bare electron mass (*3*). A number of these systems become superconducting, a quite surprising result given the fact that in ordinary superconductors a dilute concentration of magnetic impurities destroys superconductivity (*18*). Indeed in both UPt_3 (*19*) and URu_2Si_2 (*5*) recent experiments suggest that on lowering the temperature an antiferromagnetic transition is followed by a transition to the superconducting state, whereas in $U_{0.97}Th_{0.03}Be_{13}$ the order of the transitions is reversed (*9*). Moreover, we shall see that the physical mechanism responsible for superconductivity is an attractive interaction between electrons that results from a virtual exchange of local moment fluctuations, rather than the exchange of phonons that leads to superconductivity in ordinary metals.

Thus in heavy-electron systems one sees realized two long-

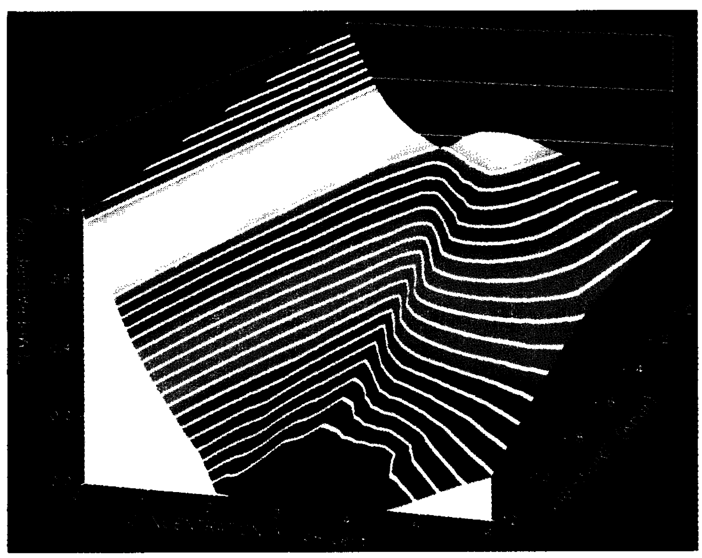

Fig. 1. The superconducting transition temperature (T_c) surface in pressure and concentration (x) space for $Th_xU_{1-x}Be_{13}$.

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