

# Early *Homo erectus* skeleton from west Lake Turkana, Kenya

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*The most complete early hominid skeleton ever found was discovered at Nariokotome III, west Lake Turkana, Kenya, and excavated in situ in sediments dated close to 1.6 Myr. The specimen, KNM-WT 15000, is a male Homo erectus that died at 12 ± 1 years of age, as judged by human standards, but was already 1.68 m tall. Although human-like in many respects, this specimen documents important anatomical differences between H. erectus and modern humans for the first time.*

DURING the course of palaeontological exploration on the west side of Lake Turkana, Bw. Kamoya Kimeu found a small fragment of hominid frontal bone exposed on the surface at the site of Nariokotome III, on the south bank of the Nariokotome River. The approximate latitude and longitude of the site are 4°08' N, 35°54' E (Fig. 1). Near the site the Plio-Pleistocene beds strike N 7° E and dip 5° to the west. Exposures are reasonably good along the south bank of the Nariokotome where a section was measured to establish the stratigraphic position of the hominid (Fig. 2). Several tuffs occur within this section that have been correlated with tuffs elsewhere in the Turkana Basin on the basis of their chemical composition. The hominid derives from a siltstone that immediately overlies a tuff identified as a component ash of the Okote Tuff complex of the Koobi Fora Formation. The age of this tuff is ~1.65 Myr<sup>1,2</sup>. An ash that correlates with Tuff L of the Shungura Formation (Chari Tuff of the Koobi Fora Formation) dated at 1.39 Myr<sup>3,4</sup> lies 34 m above the hominid level. An un-named tuff dated at 1.33 Myr<sup>4</sup> lies 46 m above the specimen. Thus, the hominid is probably very close to 1.6 Myr in age.

The strata consist predominantly of pale yellowish-brown sandstones and siltstones and very pale yellowish-brown to medium-brown siltstones. The sandstones and siltstones are either laminated or massive. The tuff that underlies the hominid fills cracks in an underlying sandy siltstone and contains small-to-medium-scale trough crossbeds truncated at their tops and overlain by siltstone. A small lens of fine tuffaceous sand that lies ~1 m above the hominid level contains abundant amphioxea and amphistrongyla of freshwater sponges. A tuff that lies 6.7 m above the hominid level contains reworked molluscs at the base and a sandstone 13.8 m above the hominid is capped by an ostracod-rich layer 10 cm thick. Mammalian fossils are rare at this locality, the most abundant vertebrate fossils being parts of small and large fish. The depositional environment was evidently an alluvial plain of low relief, consistent with the fossil fauna in the section. It is likely that the plain was only slightly higher in elevation than a lake which existed nearby, such that with only minor changes in lake level, typical lacustrine forms (for example, ostracods, molluscs) could invade the area.

Twenty-five other vertebrate-bearing sites were located and collected during the 1984 season. Individual sites were labelled by the name of the ephemeral river draining their exposures and were further numbered sequentially in order of their discovery (Table 1). As at Koobi Fora, the Okote Tuff was used as a marker horizon in the subdivision of the fossiliferous succession. Fossil assemblages were retrieved from horizons a short depth below the Okote Tuff at five localities and slightly above it at eight localities (see Table 2). Appreciably fewer taxa are represented at these new localities than at equivalent places at Koobi Fora, but this may be an artefact of sample size. The distribution of identifiable species at sites on both sides of the lake, specifically the presence of *Deinotherium bozasi*, *Elephas recki ileretensis*, *Diceros bicornis*, *Metridiochoerus andrewsi* and

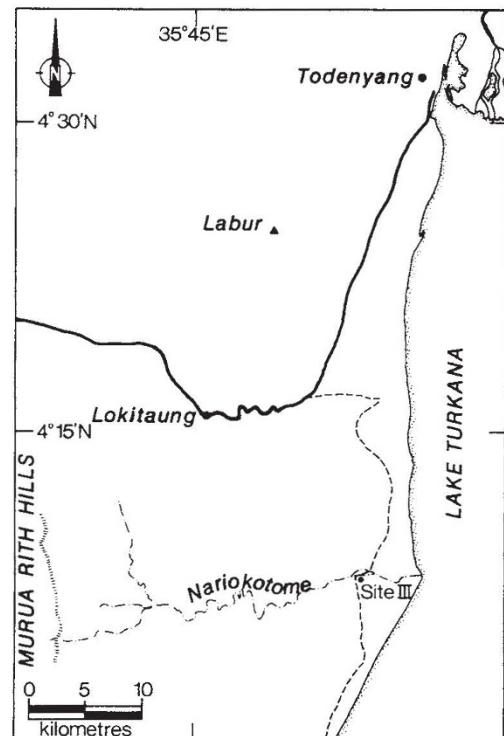


Fig. 1 Map of northern Kenya to show location of site Nariokotome III.

*Gazella janenschii* only at horizons below the Okote tuff and *Metridiochoerus compactus* only at horizons above this tuff, provides a measure of correlative support for geochemical analyses of the tephra. *Tragelaphus scriptus* is the only species from this part of the section on the west side of the lake that is not represented yet at Koobi Fora.

Following the initial discovery, screening and washing of surface float and pebble lag led to the recovery of most of the hominid calvaria. The facial skeleton was found just eroding out from tuffaceous sediments. Excavation of an area ~5 × 6 m has led so far to the recovery of the mandible, several isolated teeth and much of the postcranial skeleton. A list of the parts found so far is given in Table 3. The site plan of the excavation (Fig. 3) shows that the skeleton was dispersed before final sedimentary burial. The bones were found in a layer of tuffaceous silt of variable thickness deposited on a more indurated, flat-lying tuffaceous sand with orange root casts. The top of the fossiliferous horizon shows many signs of bioturbation and several of the bones were found broken or lying in positions suggesting that they had been trampled by large mammals. The

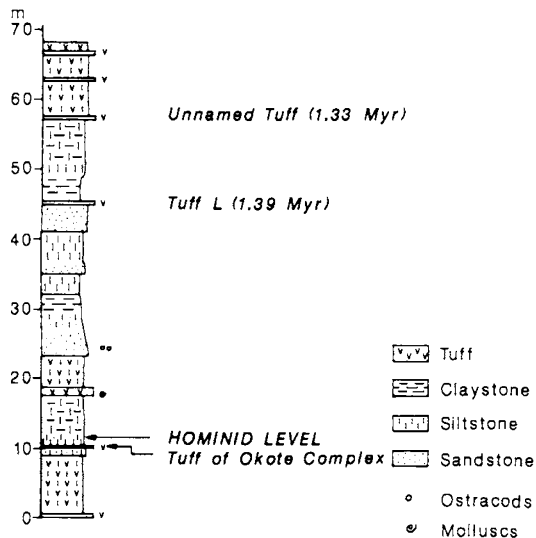


Fig. 2 Section at site Nariokotome III to show stratigraphic position of KNM-WT 15000.

general alignment of the long bones, separation of elements once in close articulation and the linear dispersal of the skeleton over at least 7 m, indicate minor water transport (see Fig. 3). Postmortem damage is seen and some parts of the bones are crushed, particularly where there is much cancellous tissue. There are no signs of carnivore or scavenger damage and the only pathology is a minor amount of alveolar resorption on the right mandibular body which took place before the right  $dm_2$  was shed. The only other fauna found so far in the fossiliferous bed are many opercula of the swamp snail *Pila*, a few bones of the catfish *Synodontis* and two fragments of indeterminate large mammal bone, although equid and pygmy hippopotamus remains were found on the surface here.

The cranium has been assembled from about 70 pieces. The only main pieces missing are the nasals, ethmoid, lacrimals, central parts of the supraorbital tori, parts of the sphenoid and some parts of the vault, the two largest being bits of the right frontal near bregma and right parietal near lambda. The sutures were all unfused. The facial skeleton was positioned on the braincase by using the mandible. The mandible is undistorted, but the calvaria has a slight overall plastic deformation with the upper part displaced to the left. Only a preliminary cranial reconstruction has been possible so far and the capacity has not been measured. Table 4 lists the teeth found so far and their measurements. They are all close to the mean size recorded for *Homo erectus* from Zhoukoudian<sup>5</sup>. The M3 germs will have to be examined radiologically. Several of the teeth were excavated separately and returned to their alveoli. The alveoli for the deciduous upper canines are still visible lateral to the permanent canine alveoli, and the left upper canine was in the process of erupting. The degree of root development of the isolated teeth, the tooth wear stages and the eruption stage are equivalent to that in  $12 \pm 1$ -year-old modern human males<sup>6</sup>. The canines erupted later than the M2s, and although this is not usual, it is a known human condition<sup>7</sup>. The dental age is matched in the postcranial skeleton where all epiphyses are unfused and the incongruity between growth-plate surfaces suggests that much further growth would have been possible. The cranium does not show strong tori, temporal or nuchal lines because it was immature at death. Despite this, its tori are thicker, its palate broader and its facial skeleton bigger and more massive than those of the presumed female cranium KNM-ER 3733 (ref. 8), which is from a roughly equivalent time horizon in the same basin. We take this to mean that there was probably considerable sexual dimorphism in the crania of early *H. erectus*. It is conceivable that this individual, had it lived to maturity, might have developed as strong and robust a cranium as that of Olduvai Hominid 9 (ref. 9).

Table 1 Fossiliferous sites west of Lake Turkana

Locality	Abbreviation	Horizon
Kaitio I	KI I	Indet.
Kaitio 11	KI 11	Indet.
Kalachoro I	KL I	Below Chari Tuff
Kalachoro II	KL II	Below Chari Tuff
Kalachoro III	KL III	Below Okote Tuff
Kalachoro IV	KL IV	Indet.
Kalachoro V	KL V	Below Chari Tuff
Kalachoro VI	KL VI	Below Okote Tuff
Kalakodo	KK	Below KBS Tuff
Kangaki	KG I	Below KBS Tuff
Kangaki II	KG II	Below KBS Tuff
Loruth Kaado I	LK I	Below Tulu Bor Tuff
Loruth Kaado II	LK II	Below Tulu Bor Tuff
Loruth Kaado III	LK III	Below Chari Tuff
Loruth Kaado IV	LK IV	Below Okote Tuff
Nachakui I	NC I	Above Chari Tuff
Nachakui II	NC II	Above Chari Tuff
Nachakui III	NC III	Indet.
Nanyangakipi	NN	Just below/above Okote Tuff
Nariokotome I	NK I	Galana Boi Beds
Nariokotome II	NK II	Below Chari Tuff
Nariokotome III	NK III	Immediately above Okote Tuff
Nariokotome IV	NK IV	Below Chari Tuff
Natoo	NT	Below Okote Tuff
Nyaena Engol I	NY I	Below Okote Tuff
Nyaena Engol II	NY I	Indet.

Indet., indeterminate horizon.

Previous *H. erectus* postcranial material has been either fragmentary, not definitely associated, disputed as to species or diseased. From Trinil, Indonesia<sup>10</sup>, there are several fragmentary and one complete (but pathological) femora. Despite the fact that it was these specimens that led to the species name, there are doubts as to whether they are *H. erectus*<sup>11</sup> with the most recent consensus being that they probably are not. Until recently the only *H. erectus* postcranial bones from China were from Zhoukoudian<sup>12</sup> and these were very fragmentary, with no complete lengths or articular surfaces. The reported clavicle is probably not even primate<sup>13</sup>. Recent newspaper accounts report an *H. erectus* cranium, innominate, ulna, three vertebrae, a rib, some hand and foot bones, a patella and a partial innominate from Yingkou, Liaoning Province, China, which are said to be 200,000 yr old<sup>14,15</sup>.

*H. erectus* postcrania have also been found at Olduvai Gorge, Tanzania, and East Turkana, Kenya. An associated fragmentary left innominate and femoral shaft (OH 28) from Bed IV Olduvai have been described as belonging to this species<sup>16</sup>. Tibial and femoral shafts (OH 34) from Bed III Olduvai<sup>17</sup> may belong, but are so badly eroded that their analytical value is slight. An undescribed ulna (OH 36) from Bed II Olduvai has also been attributed to this species<sup>13</sup>. There are many postcranial bones from East Turkana<sup>18,19</sup>. Only one is definitely associated with complete enough cranial remains to be absolutely certain of attribution and, unfortunately, that individual had suffered from a disease which affected the postcranial skeleton<sup>19,20</sup>. The East Turkana specimens are mainly isolated and/or fragmentary.

The finding of KNM-WT 15000 will allow not only the study of the morphology and proportions of this individual, but also allow former attributions and enhance the analytical value of very many other isolated or fragmentary specimens. Recognizing that the excavation has yet to be completed and that this will probably result in the recovery of more parts, a complete assessment of this individual will not yet be attempted. There are, however, some points which can confidently be made. The stature of the individual has been estimated by using regression equations developed on modern human adult males<sup>21</sup> to be 1.68 m (caucasian) or 1.64 m (blacks). This individual would not have been quite that tall, because the cranium does not have the great height of modern *Homo sapiens*. Despite the young age of the individual, the length of the long bones are very close

Table 2 Faunal list

Taxon	West Turkana		East Turkana	
	KLIII, KLIV, LKIV, NY, NN	NT, LKIII, KLI, KLII, KLV, NKIII	Below Okote	Above Okote
<i>Pisces</i>	✓	✓	✓	✓
<i>Crocodylus</i> sp.		✓	✓	✓
<i>Euthecodon brumpti</i>		✓	✓	✓
<i>Trionyx</i> sp.	✓	✓	✓	✓
<i>Geochelone</i> sp.		✓	✓	✓
<i>Aves</i>	✓	✓	✓	✓
<i>Hystrix</i> sp.		✓	✓	✓
<i>Theropithecus oswaldi</i>	✓	✓	✓	✓
<i>Homo erectus</i>		✓	✓	✓
<i>Canis</i> sp.	✓		✓	
<i>Carnivora</i> gen. indet.		✓		
<i>Deinotherium bozasi</i>	✓		✓	
<i>Elephas recki ileretensis</i>	✓		✓	
<i>Elephas recki recki</i>		✓		✓
<i>Hipparion ethiopicum</i>		✓	×	×
<i>Equus koobiforensis</i>	✓	✓	✓	
<i>Diceros bicornis</i>	✓		✓	
<i>Ceratotherium simum</i>	✓		✓	✓
<i>Metridiochoerus andrewsi</i>	✓		✓	
<i>Metridiochoerus modestus</i>	✓		✓	✓
<i>Metridiochoerus compactus</i>		✓		✓
<i>Kolpochoerus limnetes</i>		✓	✓	✓
<i>Hexaprotodon karumensis</i>	✓	✓	✓	✓
<i>Hippopotamus gorgops</i>	✓	✓	✓	✓
<i>Hippopotamus aethiopicus</i>	✓	✓	✓	✓
<i>Aepyceros</i> sp.	✓	✓	✓	✓
<i>Megalotragus</i> sp.		✓	✓	✓
<i>Connochaetes</i> sp.	✓	×	✓	✓
<i>Damaliscus</i> sp.	✓	✓	✓	✓
<i>Pelorovis</i> sp.	✓	✓	✓	✓
<i>Pelorovis olduwayensis</i>		×	✓	✓
<i>Syncerus caffer</i>	×	×	×	
<i>Tragelaphus strepsiceros</i>	✓	✓	✓	✓
<i>Tragelaphus scriptus</i>	✓			
<i>Menelikia lyrocera</i>		✓	✓	✓
<i>Kobus sigmoidalis</i>	✓		✓	✓
<i>Kobus kob</i>		✓	✓	✓
<i>Kobus leche</i>		?	✓	✓
<i>Antidorcas recki</i>	✓		✓	✓
<i>Gazella janenschi</i>	✓		✓	✓
<i>Gazella praethomsoni</i>	✓		✓	✓
<i>Gazella</i> sp.		✓		

✓, Species present; ×, comparable species present; ?, stratigraphic position uncertain.

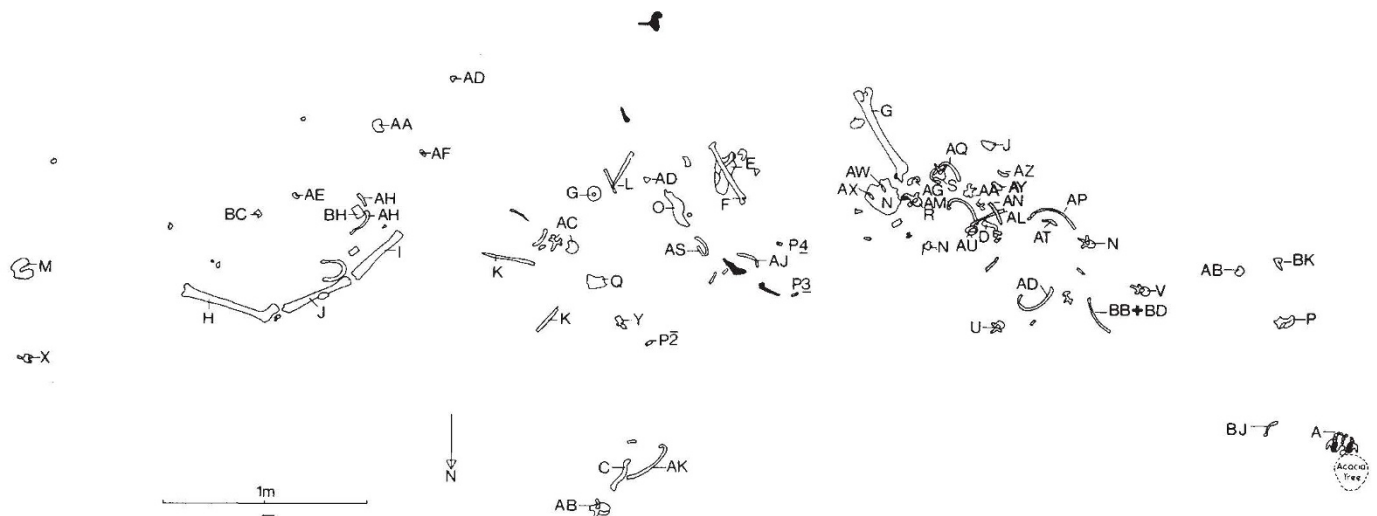


Fig. 3 Detail of site plan showing distribution of *H. erectus* bones. Major hominid parts are as lettered in Table 3. Non-hominid bones, mostly fish, are in solid.

Table 3 Skeletal parts of KNM-WT 15000

Cranium (A)	Right rib 4 (AI, BD, BE)
Mandible (B)	Right rib 5 fragment (BJ)
Cervical vertebra 7 (R)	Right rib 6 (AL)
Thoracic vertebra 1 (S)	Left rib 7 (AP)
Thoracic vertebra 2 (T)	Right rib 7 (AK)
Thoracic vertebra 3 (U)	Left rib 8 (AU)
Thoracic vertebra 6 or 7, spine and laminae (BI)	Right rib 8 (AM)
Thoracic vertebra 8 (V)	Left rib 9 (AO)
Thoracic vertebra 9 (W)	Right rib 9 (AS)
Thoracic vertebra 10 (X)	Right rib 10 (AJ)
Thoracic vertebra 11 (Y)	Left rib 11 (AN)
Lumbar vertebra 1, body and right lamina and inferior facet (AR, BA)	Left clavicle (C)
Lumbar vertebra 2 (AA, AV)	Right clavicle (D)
Lumbar vertebra 3, pedicle laminae and spine (Z)	Left scapula, spine and axillary border (BK, BL)
Lumbar vertebra 4 (AB)	Right scapula (E)
Lumbar vertebra 5 (AC)	Right humerus (F)
Sacral vertebra 1 (AD)	Left ilium (L, BF, BG)
Sacral vertebra 3, laminae and spine (BB)	Left ischium (Q)
Sacral vertebra, right half (BC)	Right ilium (O)
Sacral vertebra 5 (AE)	Right ischium (P)
Coccygeal vertebra 1 (AF)	Right pubic fragments (AW, AX)
Left rib 1 (AG)	Left femur (G)
Right rib 1 (AY, AZ)	Right femur (H, M)
Left rib 2 (AQ)	Left tibia (I)
Right rib 2 (AH)	Right tibia (J)
Left rib 3 (AT)	Left fibula (K, BH)
	Right fibula (L)

to the means for white North American adult males given by Schultz in 1937 (ref. 22). We have examined casts and originals of other early *H. erectus* postcranial bones and find that all of them are large. Stini<sup>23</sup> noted current secular trends of increase in body size in many human populations and wondered whether the trend was revealing a genetic potential left over from early hunter and gatherer ancestors. The new *H. erectus* data support this hypothesis.

The vertebrae show some interesting differences from those of modern humans. The spinous processes on all vertebrae recovered so far are relatively longer and less inclined inferiorly than their modern counterparts and the laminae are much less broad. This means that the marked imbrication of the laminae and spines of adjacent vertebrae (particularly the thoracic series) so typical of *H. sapiens* is much less marked. The vertebral foramen is smaller relative to vertebral body size in the lower cervical and thoracic series, unlike that of modern humans, but about the same in the lumbar series. The inferior articular facets of the fifth lumbar vertebra face almost directly anteriorly and are slightly concave, in contrast to the usual human condition in which the surfaces face laterally and are cylindrically convex<sup>24</sup>.

Although we have yet to recover sufficient parts of the pubic bones to complete a full reconstruction, the innominates are very similar indeed to OH 28 and KNM-ER 3228 (refs 16, 25), but the strong iliac pillar had not yet developed. The sacrum is represented by S1 and S5, the spine of S3 and half of S4. Although we can reasonably estimate the sacral width, precise alignment with the pelvis must wait for the recovery of S2. There was a remarkable degree of iliac flare<sup>26</sup>; this flare is concordant with the extremely long femoral necks, which are relatively as long as those of robust australopithecines<sup>26</sup>. The biomechanical advantage of the abductor mechanism<sup>26</sup> was much enhanced relative to the condition in *H. sapiens*. The biomechanical neck length of 85 mm is well over 3 s.d. from the mean of a sample of *H. sapiens*<sup>26</sup>. As well as having a long femoral neck, the neck-shaft angle is very small at 110°, being 5 s.d.s from the mean of the same *H. sapiens* population. The femoral head diameter at 44.0 mm is almost exactly on an *H. sapiens* mean<sup>27</sup> and scales with femoral length in the same way as *H. sapiens* and *Australopithecus boisei*<sup>28</sup>.

Martin<sup>29</sup>, following a stimulating discussion of human and great ape brain growth, suggested that early *H. erectus* could

have produced their adult brain sizes by modification of the rate and/or extent of fetal growth without any need for significant postnatal postponement of fetal growth patterns as found in humans. This is dependent, however, on *H. erectus* pelvis having allowed the birth of an infant as large as those of *H. sapiens*. Modern human populations show little, if any, sexual dimorphism in the absolute width of the sacrum<sup>30</sup>, a major determinant of pelvic inlet size. The interacetabular distance in WT 15000 is very small and surely correlated both with the great iliac flare and long femoral necks. It seems likely to us that early *H. erectus* birth-canal diameters would have been significantly smaller than in *H. sapiens* and that passage of a modern-sized, full-term fetus would have been impossible. The continuation after birth of fetal growth rates, found only in

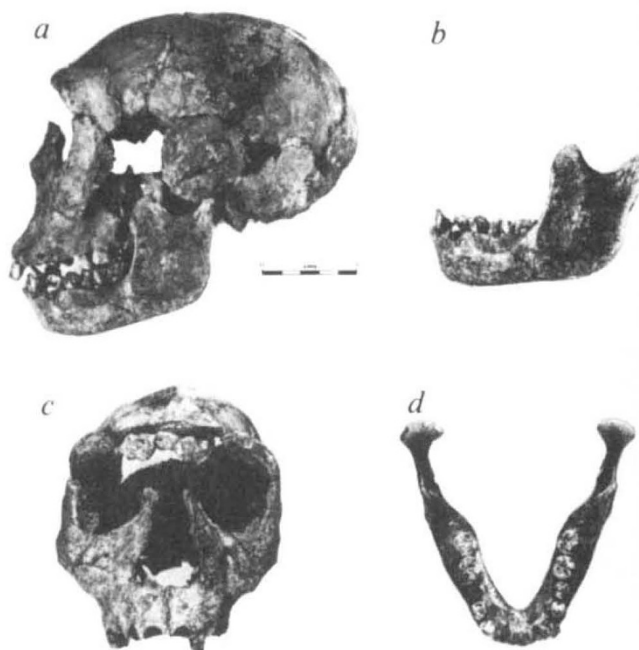


Fig. 4 KNM-WT 15000. a, Left lateral view of skull; b, left lateral view of mandible; c, frontal view of cranium; and d, occlusal view of mandible.

**Table 4** Tooth measurements (mm)

	Right		Left	
	Mesiodistal	Buccolingual	Mesiodistal	Buccolingual
Mandible				
C	8.8	9.0	8.6	9.4
P <sub>3</sub>	9.0	10.1	8.5	10.1
P <sub>4</sub>	—	—	9.0	9.5
M <sub>1</sub>	11.9	11.1	12.2	10.9
M <sub>2</sub>	12.4	11.4	12.2	11.5
Maxilla				
I <sup>2</sup>	7.9	8.5	7.9	8.3
P <sup>3</sup>	8.3	11.5	—	—
P <sup>4</sup>	8.2	11.5	—	—
M <sup>1</sup>	12.2	11.8	11.1	11.8
M <sup>2</sup>	12.5	12.6	13.3	11.7

humans, must have been part of the developmental mechanism of *H. erectus*. Already then, by 1.6 Myr ago, the secondarily altricial condition (which leads to increased infant dependency) must have been present.

This skeleton has already shown that our views of early

*H. erectus* morphology must be modified. With the possibility of finding more parts when the excavation is continued and with further analysis, KNM-WT 15000 will provide a firmer foundation for the identification and understanding of unassociated postcranial bones and early hominid growth patterns. Except for those representing the latest stages of our evolution, it is also the first fossil hominoid, let alone hominid, in which brain and body size can be measured accurately on the same individual. These two crucial variables, on which so much speculation about human origins and behaviour has been based, can now be determined for at least one individual early hominid.

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## LETTERS TO NATURE

### Age of the Okote Tuff Complex at Koobi Fora, Kenya

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The Okote Tuff Complex crops out in the Koobi Fora region next to the north-eastern shores of Lake Turkana, northern Kenya. It occurs in the upper part of the ~450 m thick, essentially flat lying, Plio-Pleistocene sequence of fluvial, deltaic and lacustrine sediments comprising the Koobi Fora Formation<sup>1-3</sup>. Many important archaeological sites and hominid fossils, including the *Homo erectus* finds discussed in the accompanying papers<sup>4,5</sup>, are stratigraphically close to the level of the Okote Tuff Complex<sup>6</sup> or its correlatives, so that its precise numerical age is of great interest. Previously published isotopic ages, mainly by the <sup>40</sup>Ar/<sup>39</sup>Ar dating technique, exhibited a very wide scatter<sup>7</sup>. Here we report comprehensive K-Ar data showing that pumices within one of the tuffs of the Okote Tuff Complex have an age of  $1.64 \pm 0.03$  Myr, which is in the earliest Pleistocene<sup>8</sup>.

The type locality for the Okote Tuff Complex is within area 131, adjacent to Karari Ridge, 20-km east of Lake Turkana (Fig. 1). The unit was formally named by Findlater<sup>2</sup> and discussed further by Cerling and Brown<sup>3</sup>. A stratigraphical section measured in this area is shown in Fig. 2, after ref. 5. The Okote Tuff Complex lies about mid-way between the KBS and Chari Tuffs which, in area 131, are separated by ~40 m of section consisting mainly of river channel sands together with some flood plain silts and clays. The Complex has yet to be defined and described in detail. In the field it consists of several sandy

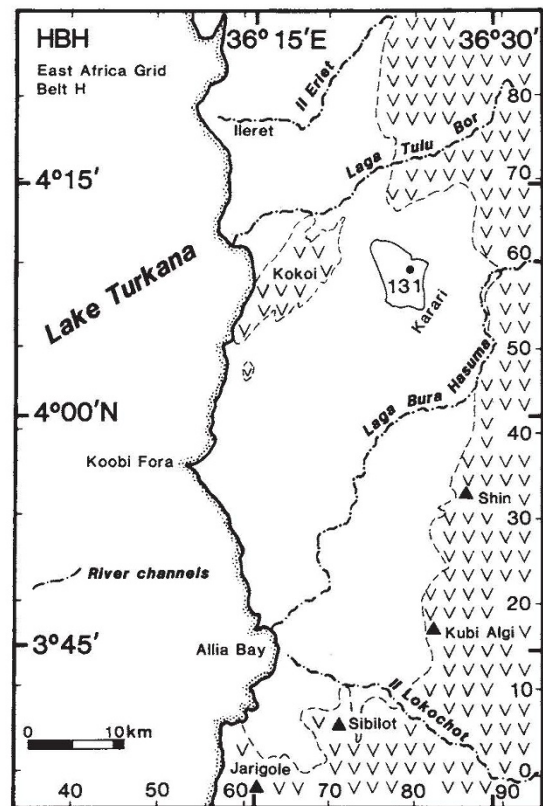


Fig. 1 Outcrop of the Koobi Fora Formation adjacent to the shores of Lake Turkana is indicated by blank area. Type locality for the Okote Tuff Complex is shown by filled circle within fossil collection area 131. Local basement, dominantly Neogene volcanics, is indicated by pattern.