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Some Late Cenozoic Sedimentary Formations of the Lower Omo Basin

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Geological and geomorphological studies in the lower Omo valley 1967–1968 have established a sedimentary sequence recording much of the late Cenozoic.

THE potential significance of the lower Omo valley for the palaeontology and stratigraphy of East Africa was first suspected by E. Suess in 1891 (ref. 1) on the basis of L. von Höhnel's observations. He placed the Omo Delta and Lake Rudolf within the Kenya Rift, emphasizing the palaeogeographic implications of the nilotic fauna. In 1896, the ill-fated Bottego Expedition explored the lower Omo valley and its geologist, M. Sacchi, recognized the widespread sedimentary series that cover the basin floor[2]. Sacchi's bouts with malaria hindered him from visiting the area of the fossiliferous Omo Beds, which were subsequently discovered by E. Brümpt in 1902 (ref. 3). This first fossil collection found its way to Paris and ultimately led to C. Arambourg's pioneer work during 1933 (ref. 4). He recognized the Omo Beds as lacustrine or fluvio-lacustrine deposits of apparent early Pleistocene age; they were unconformably overlain by late Pleistocene lacustrine beds. Detailed examination of the Omo Beds type area was begun by F. H. Brown in 1966 as a prelude to the systematic, multi-disciplinary studies of the international Omo Research Expedition to the Omo valley in 1967 (ref. 5) and 1968.

The expedition included teams from Kenya, France and the United States. Geological and geomorphological investigations were carried out by K. W. Butzer, F. H. Brown and J. de Heinzelin (Chicago group), and by J. Chavaillon (French group). This article outlines the stratigraphy and depositional history of those sedimentary formations studied by Butzer, including the late Pliocene Mursi and Nkalabong Formations, the late Pleistocene to mid-Holocene Kibish Formations, and the late Holocene Lobuni Beds. The radiocarbon dating of the Kibish is by Thurber.

Geological Setting

The lower Omo Basin is a tectonic depression, forming an extension of the Lake Rudolf trough (Fig. 1). The regional basement is formed by Pre-Cambrian metamorphics, primarily gneisses and amphibolites with intrusions of granite and pegmatite. In the Nkalabong Range, this basement complex is directly overlain by a thick sequence of extrusives, the lithological and stratigraphic details of which remain to be studied. Pending isotopic dates from Mt Nkalabong (F. H. Brown, in preparation; see also ref. 5), dating of the lavas of Turkana and the Ethiopian Plateau[6] suggests a Miocene to early Pliocene time range for the volcanics of the basin peripheries.

The essential topographic outlines of the lower Omo valley were formed by downwarping and downfaulting before deposition of the earliest known deltaic sediments,

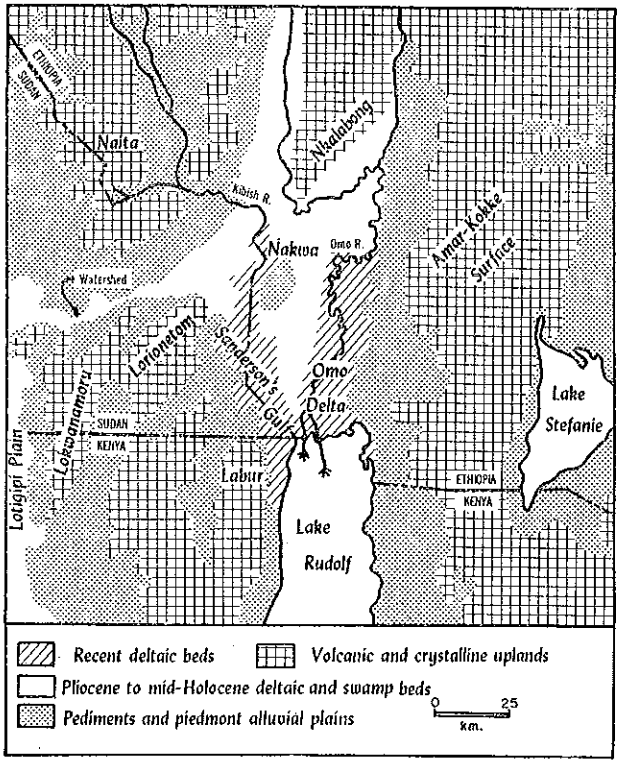

Fig. 1. The Lower Omo Basin.

well before 4 million yr ago. Block faulting upraised the Amar-Kokke Highland[7] to the east, between the Omo River and Lake Stefanie. West of the basin, a series of fault blocks was formed, dipping to the west[8]. At the scale of the Gemini IV photography these blocks appear to form part of a system of fractured, plunging folds. As a result, the country west and south-west of the lower Omo Basin has a marked basin-and-range topography, with a series of interconnected depressions that have intermittently linked the Omo–Rudolf trough to the Nile system.

There is only limited evidence as to the nature of geomorphologic processes in the lower Omo Basin during the Miocene and early Pliocene. A high planation surface can be recognized at a height of 900 to 1,200 m on the Amar–Kokke Horst. Its age must exceed that of the major deformation of the basin, but in all other respects its origin remains obscure. Younger planation surfaces that delimit the margins of the basin are pediments, cut into the peripheral highland masses and graded to about the same level as the local basin fill. Bevelling of these rock surfaces must have begun before deposition of the earliest deltaic sequence, because these beds are in part disposed on top of pediment-like footslopes of the western Nkalabong Range. Pedimentation, however, continued to modify the basin peripheries intermittently through the late Pliocene and the Pleistocene. The resulting forms converge, so that multiple levels or stages cannot be recognized on the basis of erosional criteria.

The Mursi Formation

The oldest sedimentary sequence within the basin is exposed south-west of the Nkalabong Range, at a height of 400 to 560 m (Fig. 2). It consists of 145 m of semiconformable deltaic and prodeltaic beds, overlain by 3–5 m of basalt that reaches a maximum thickness of at least 27 m. The base is not exposed, but it presumably rests on Mio-Pliocene extrusives. The type area is known as Yellow Sands (5° 24′ N, 35° 57′ E), located 85 km north of the present shores of Lake Rudolf. The designation Mursi is here adopted for this formation, after the name of the local tribe.

The Mursi Beds were first recognized as a sedimentary unit by the Kenya group of the expedition in 1967, and fossils were collected in the type area. No geological examination was caried out, however. In 1968, one of us (K. W. B.), assisted by Claudia Carr, studied the formation in detail, mapping the sediments of Yellow Sands at a scale of 1 : 10,500.

The basic stratigraphy of the formation can be summarized as follows (from bottom to top): *Member I.* Four beds with over 43 m of alternating thin and massive-bedded clays, silts and sands with intensive limonitic staining, horizons of sodium salts and gypsum lenses. One or more lenticles of tuffaceous silts. Horizontal, with terminal inclined beds, originally dipping to SW. *Member II.* Six beds with 24 m of alternating topset strata (sands, silts, clays) with several tuff-derived beds and a single, typical tuff unit. Intensive limonitic staining in most beds; sodium salts in lower units; massive ferruginous nodules in middle units. One or more gravel lenses among current-bedded sands mark the fossiliferous horizons (R. E. Leakey, in preparation). *Member III.* Six beds with 76 m of fairly homogeneous, horizontal strata of clays, silts, and sands with horizons of diffuse sodium salts or crystalline gypsum, as well as limonitic mottling. Some beds contain *Viviparus* and, locally, mammalian fauna. *Shiangoro Alteration Zone.* Red, baked sediment of Member III, consisting of a 1 m colour *B*-horizon (clay, with coarse angular blocky structure) and a 2 m *BC*-horizon (sandy loam), under a 1·5 m zone of thoroughly decomposed basalt. (Designation of Shiangoro after the native village at 5·24° N, 35° 57′ E, shown on the 1 : 250,000 topographic map, series *Y*501, Survey Office, Khartum, 1941.) *Member IV.* 27 m of olivine basalt

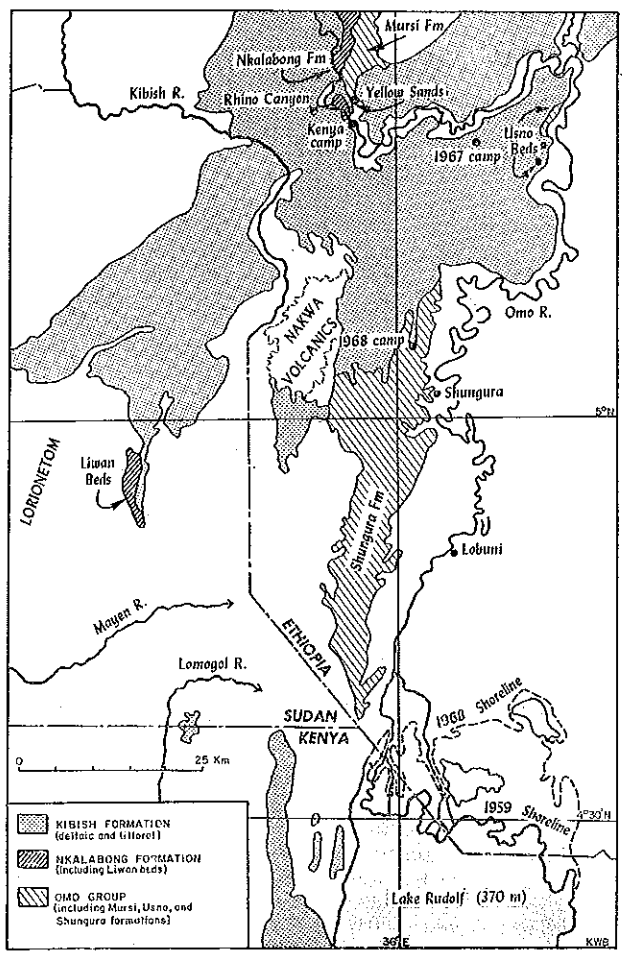

Fig. 2. Distribution of the major late Cenozoic sedimentary formations in a part of the Lower Omo Basin (simplified).

primarily massive or columnar. K/Ar dates 4·25 and 4·05 million yr (dated by G. H. Curtis and F. H. Brown, see ref. 5; further date pending by F. J. Fitch and J. A. Miller).

The Mursi Formation (Members I–III) records a sedimentary sequence from the delta of a primaeval Omo River and it seems that the delta-lake shoreline fluctuated repeatedly through an area approximately 80 to 100 km north of the modern delta-fringe. Nilotic Mollusca (*Corbicula*, *Viviparus*), fish (including *Lates niloticus*) and crocodile indicate hydrographic links with the Nile system presumably to the Umm Ruwaba Series of the Palaeo-Sudd Basin[9–11].

Major deformation of the Mursi Formation postdates the basalt, which is cut by a number of faults. At Yellow Sands the primary fault system strikes N 50° to 60° E, while a transverse fault system strikes N 15° W to N 15° E. Maximum vertical throws exceed 58 m while the cumulative displacement of normal faults exceeds 98 m and may possibly be in the order of 220 m. Most of the faults are normal, with the eastern side of the blocks downthrown.

The Omo Beds or Shungura Formation and the Usno Formation

Reinvestigation of the "classical" Omo Bed exposures was begun in 1966 by F. H. Brown, who showed that at least 330 m of sediments were present and that the structural complexity far exceeded anything that Arambourg had envisaged (F. H. Brown, unpublished report to the Wenner Gren Foundation, 1966). Additional work by Brown and Chavaillon in 1967 (results and K/Ar dating of the 1967 season are summarized by Brown in ref. 12, and by Howell in ref. 5; results of the French group are reported by Arambourg *et al.*[13]), and by de Heinzelin and Brown in 1968 has since shown the stratigraphic thickness to be in excess of 500 m, with neither the base nor the top of the sequence seen. These beds are now exposed over a considerable area (Fig. 2) ranging in height from 370 to 455 m. The type area which is extensively dissected is more restricted (about 75 km^2), forming a narrow belt between latitudes 5·0° and 5·10° N, part of which (north of about 5·4·20° N) marked the concession of the Chicago group during 1968. The structure and stratigraphy of this sector were mapped at a scale of about 1 : 10,000 by de Heinzelin.

The Omo Beds are analogous, in terms of facies, to both the Mursi and Usno Formations (see later). Clays, silts, sands and tuffs of deltaic or possibly prodeltaic origin are dominant, and de Heinzelin believes that periods of emergence are suggested by hydromorphic soils and possible aeolian features. No major disconformities are known. Ten tuffs are recognized as persistent stratigraphic markers (A through J upwards) while six further, subsidiary and less persistent tuffs (P through U upwards) occur at several points in the succession. Five K/Ar determinations are available on tuffs B_4, D and I_2, ranging in age from 3·75 to 1·81 million yr[12]. (Revisions of the generalized stratigraphy given in ref. 5, Fig. 2, now require the designation of the former tuff H as I.) This seems to indicate that the Omo Beds of the type area are younger than the Mursi Formation. The more specific designation Shungura Formation has been proposed, after the Bume village (5·3° N, 36·3° E) of that name[14]. This formation would span the terminal Upper Pliocene and most of the basal Pleistocene in terms of current views on the Phanerozoic time-scale.

The Shungura Formation was faulted extensively after deposition, and minor folding took place. There are at least three major and two minor normal faults. The slip planes of the major faults dip steeply eastwards, at angles of up to 65° or 70°; downthrusts may be as much as 100 m. The strike of the major faults is about 0° N–20° E and the fault blocks dip westwards at 8°–15°, occasionally as much as 25°. The minor faults commonly strike about 85° N–90° E and transect the type area to produce a series of compartmentalized blocks. De Heinzelin recognizes three, and possibly four, episodes of faulting.

Another sedimentary sequence, with certain similarities to the Mursi and Shungura Formations, was discovered at White Sands (5·18–20° N, 36·12° E) by the Chicago group in 1967. The geological succession was subsequently studied by de Heinzelin and Brown, with detailed sections and mapping of the eight different exposure areas (see ref. 5, Figs. 3–4). The semiconformable or disconformable sequence of deltaic beds, intercalated with coarse detrital units, has a stratigraphic thickness of some 200 m (now exposed in a range 415 to 458 m high). The sedimentary units at White Sands are designated as the Usno Formation, named after the major Omo tributary, north of the area. The stratigraphic column has been provisionally grouped into nine sequences[14].

The Usno Formation records repeated changes of facies apparently reflecting lateral shifts in position of the delta and floodplain of the Omo River (or a major tributary)—west or north of the exposure area—and a piedmont alluvial plain—to the east. The silts and clays are either deltaic or floodplain deposits, probably including prodeltaic beds; the sands and gravelly sands are fluvial and suggest alluvial fans or similar piedmont alluvia. The absence of contemporary deltaic beds at Yellow Sands may indicate that the Omo Delta was located farther south than it had been earlier. Again, nilotic Mollusca, fish (*Polypterus*, *Hydrocyon*) and crocodile would suggest prior or contemporary links with the Nile system. Faunal associations (F. C. Howell, in preparation) indicate that the Usno Formation is younger than the Mursi and that it is probably a lateral equivalent of part of the Shungura Formation.

After the close of the sedimentation period, the Usno Beds were disrupted by steep tensional faults with a general strike of N 25° E. The fault blocks dip 10° to 14° WNW.

The Nkalabong Formation

The oldest undeformed beds of the Lower Omo Basin are exposed west of the Nkalabong Range, primarily east of the Omo River between latitudes 5·23° N and 5·35° N ranging in height from 405 to 475 m. They are here designated as the Nkalabong Formation, after the moun-

Table 1. A LATE CENOZOIC STRATIGRAPHY OF THE LOWER OMO BASIN

Probable geological age	Isotopic dates	Rock units	Depositional environments
Holocene		Lobuni Beds	Deltaic, littoral
	^{14}C 5450–5750 yr	Kibish Fm. Mb. IV*b*	Deltaic, littoral
	^{14}C 7900–9500 yr	Kibish Fm. Mb. IV*a*	Deltaic, littoral
Middle/Upper Pleistocene		(Nakwa extrusions)	
	K/Ar "0" ^{14}C > 37,000 yr	Kibish Fm. Mb. III	Deltaic, prodeltaic
		Kibish Fm. Mb. II	Deltaic, prodeltaic
		Kibish Fm. Mb. I	Deltaic, prodeltaic
Lower Pleistocene to Upper Pliocene		(Several episodes of faulting in "Type Area")	
	K/Ar 1·81–3·75 m.y.	Shungura and Usno formations	Prodeltaic, deltaic, fluvial
		—?—	
	K/Ar 3·95 m.y.	Nkalabong Fm. Mb. III Mb. II Mb. I	Lacustrine Aeolian, fluvial Fluvial
		(Faulting in Nkalabong area)	
	K/Ar 4·05, 4·25 m.y.	Mursi Fm. Mb. IV Mbs. I–III	Basalt Deltaic, prodeltaic
		(Downwarping and downfaulting of Basin)	
Lower Pliocene to Lower Miocene		(Repeated volcanic episodes with massive extrusions of olivine basalts and rhyolites over erosional surface(s) on Basement Complex)	

tain range of that name. The type sections are located in Neusi Korongo (5·25·54° N, 35·36·11° E), an area first studi.d by Butzer in 1968, and geologically mapped at a scale of 1 : 10,500. The formation differs from all other sedimentary sequences in the basin in that deltaic beds are essentially absent. Instead, the 88 m of sediment consists of a complex succession of fluvial deposits, lapilli tuffs, and lacustrine beds. The Nkalabong Formation rests on weathered, denuded and dissected basalt of the Mursi Formation, a corrugated and step-faulted land surface, the segments of which dip 3° to the W and NW.

The sequence can be summarized from bottom to top:

Member I. Bed (*a*). 9 m. Current-bedded silts and clays of Omo River, channel directions SE to SSW. Bed (*b*). 26 m. Horizontal and current-bedded conglomerates of Omo River, with sandy tributary interdigitations; channel directions SSE to SW. Bed (*c*). 2 m. Calcreted sands rich in volcanic ash; surface intensively patinated.

Member II. Bed (*a*). 14 m. Horizontal and cross-bedded fluvial sands, filling valley floors. Bed (*b*). 0·5 m. Waterlaid tuff with coarse detritus. Bed (*c*). 18 m. Massive lapilli tuff, restricted to incised valleys.

Member III. Twelve beds with 19·5 m of topset clays, silts, and tuffs with a uniform 5° W dip. Topmost meter calcified (Calcorthid paleosol).

The former course of the Omo River can be inferred from the bedding directions of the Member I deposits; the major channel was located east of its present position in the type area. The lack of substantial gravel in the bed load of the modern Omo (at latitudes 5·00°–6·30° N) also suggests a period of greater stream competence for bed (*b*), Member I. Deposition of that member was followed by cutting of deep, narrow valleys across the western footslopes of the Nkalabong Range, draining in a westerly direction. The deposits of Member II which are primarily of aeolian facies, with limited colluvial reworking, do not suggest a local climate or palaeogeography significantly different from that of today. After a period of general erosion, the beds of Member III were deposited near the eastern shores of a lake, suggesting that the Omo Delta was located north of latitude 5·35° N, that is, more than 110 km north of modern Lake Rudolf. The uniform development of these fine grained and well sorted beds, with no local intercalations of coarse detritus, would seem to suggest a lack of torrential runoff from the western slopes of the Nkalabong Range, where present stream bed deposits range from coarse sands to sandy gravels.

Lacustrine beds, very similar in facies and development to Member III, are exposed along the eastern footslopes of the Lorionetom–Lokomarinyang Mts. between latitudes 4·54° N and 4·57° N, and ranging in height from 420 to 450 (Fig. 2). They exceed 25 m in thickness and are designated as the Liwan Beds.

There is no evidence for post-depositional deformation other than for a gentle tilting of the Nkalabong footslope region. Unfortunately, the Nkalabong Formation is non-fossiliferous except for rare but unidentifiable leaf impressions (examined by Claudia Carr) in the lapilli tuffs. Because these beds rest unconformably on the Mursi Formation and are overlain unconformably by the mid to late Pleistocene Kibish Formation (see later), their age can only be estimated in a general way. The original field inference that the Nkalabong Formation would be younger than the faulting of the Shungura and Usno Formations has not been confirmed by a K/Ar date of 3·95 m.y. from the lapilli tuff (Member II*b*) (see F. J. Fitch and J. A. Miller, p. 1143 of this issue). The relationship to the Shungura and Usno Formations may be sequential, as tentatively suggested by Table 1, although Member I may also represent a lateral facies change contemporary with the basal units of the Shungura Formation. If further isotopic dating proves the Nkalabong Formation to be of late Pliocene age, the faulting of the Shungura and Usno Formations must have been localized to a restricted part of the lower Omo Basin.

The Kibish Formation

The existence of widespread, horizontal sediments in the Lower Omo Basin has been known since Sacchi mentioned lacustrine beds of an ancient Lake Rudolf, and provided a rough map of their distribution[2]. Preliminary stratigraphic observations on these beds were made by F. H. Brown (Chicago group) and by R. E. Leakey (Kenya group) in 1967, before a systematic study by Butzer in 1967–68.

The Kibish Formation has been named after the police posts of that name (at 5·19° N, 35·53° E)[15]. Although widely exposed west of the Omo and Usno Rivers, good vertical exposures of these sediments, revealing the basal strata, are restricted to the gullied margins of the Omo floodplain between latitudes 5·18° and 5·35° N. The intensively dissected sectors adjacent to "Rhino Canyon" and "Kenya Camp" (5·23–24° N, 35·54–57° E) were chosen as the type area and geologically mapped by Butzer in 1968 at a scale of 1 : 11,000, on the basis of air photos taken by R. I. M. Campbell in 1967. These maps show four stratigraphic subdivisions (members) of the Kibish Formation, as well as the various units of the older formations.

On the basis of the field relations, corroborated by laboratory analyses and by thirteen radiocarbon dates by Thurber, the Kibish Formation is subdivided into four major units. Members I, II and III consist of delta-plain, delta-fringe and prodeltaic sediments. These interpretations are based on a semi-detailed study of the sediment facies and geomorphology of the modern Omo Delta, which has been partially exposed by retreat of Lake Rudolf and where most of these beds find counterparts among recent depositional environments. Accumulation of each member was followed by major dissection. Littoral deposits, with well developed geomorphologic forms, are more significant in Members IV*a* and IV*b* than in the earlier units. A number of dissected piedmont alluvia or fans, not included in the Kibish Formation, as here defined, are broadly contemporary with Members IV*a*, IV*b*.

Measured cumulative thickness of the Kibish Formation is 120·5 m, inferred thickness 130 m. The base rests on dissected, eroded and cemented units of the Nkalabong Formation. The sequence in the type area can be summarized as follows (from bottom to top):

Member I. Seven beds with 31 m of alternating clays, silts, sands, conglomerates and re-worked tuffs, in part with diffuse sodium salts or ferruginous horizons. Horizontal and often laminated or ripple-marked. Some vertebrate fossils, including two fossil hominid sites (see R. E. Leakey, K. W. B. and M. H. Day, page 1132 of this issue).

Member II. Two beds with 22·5 m thickness. A basal tuff followed by massive silts with ferruginous horizons, silicified wood, and fish, crocodile and hippo bone.

Member III. Twelve beds with 45·5 m of alternating clays, silts, sands and tuffs with some horizons of sodium salts or limonite. Horizontal, with terminal inclined beds. One or more lenses with *Melanoides* and *Unio* shell as well as mammalian and fish bone.

Member IVa. Five beds with 13·5 m of clays, silts, sands and gravels.

Member IVb. Five beds with 8 m of tuffs, clays, silts and sands.

Radiocarbon determinations have been made by Thurber from Members III, IV*a* and IV*b*. An *Etheria* bank from the penultimate bed of Member III gave "greater than 37,000 yr" (*L*-1203-*A*), *Unio* shell from a stratigraphically uncertain part of this member 26,700 ± 2,500 yr (*L*-1203-*F*). Radiocarbon ages of carbonates exceeding 20,000 yr are beyond the range of reliability and must be considered as minimum ages. Because there is no weathering horizon at the top of Member III, which is generally unconsolidated, and because the degree of compaction is no greater than that of Member IV, there are no geological reasons why the youngest beds of Member III should be substantially older than 37,000 yr. Basal units of Member IV*a* at White Sands, interpreted as wash and floodplain deposits, have a date of 9500 ± 150 BP (*L*-1203-*J*) on *Unio* shell; deltaic beds at Rhino Canyon have five *Unio* dates ranging from 9500–8650 BP (*L*-1203-*B*, 8650 ± 150 BP; *L*-1203-*C*, 9500 ± 150 BP; *L*-1203-*D*, 8700 ± 200 BP; *L*-1203-*E*, 8800 ± 200 BP; and *L*-1203-*M*, 9100 ± 300 BP); terminal littoral beds, in part attached (*Etheria* bank) to basalts of Mt. Nakwa, have a date of 7900 ± 150 BP (*L*-1203-*L*). Three *Unio* dates from Member IV*b* range from 5750–5450 BP (*L*-1203-*G*, 5700 ± 100 BP; *L*-1203-*I*, 5450 ± 100 BP; and *L*-1203-*K*, 5750 ± 100 BP), while an isolated date of 3250 ± 150 BP (*L*-1203-*H*) on mixed *Unio*, *Corbicula* and *Melanoides* shell from a high beach ridge may indicate a final high stand or transgression. Consequently, the sedimentation of Member IV*a* can be approximately dated 9700–7700 BP, Member IV*b* 5900–5300 BP.

The full palaeogeographical implications of the Kibish Formation can only be understood from the areal distribution of the beds. To this end, the surficial geology of the south-western quadrant of the Lower Omo Basin, an area of some 11,000 km^2, was mapped by helicopter air and ground survey at a scale of 1 : 100,000 in 1968 with the help of photogeologic interpretation (aerial photography, RAF, 1959). Four facies of the Kibish Formation were distinguished: (1) mixed fluvial and deltaic; (2) prodeltaic, swamp or lacustrine; (3) mixed lacustrine and littoral; and (4) beach ridges—in addition to the alluvial fans of broadly equivalent age. The geomorphological features related to Member IV*b* are still fresh and can be easily interpreted. On the basis of the areal distribution and stratigraphic sequences it can be deduced that the Omo Delta was centred 70 to 100 km north of its present position during each of the major depositional phases. The highest lying deposits of each member culminate in the range 450–455 m high, that is, 80–85 m above modern Lake Rudolf (370 m) and at about the level of the chain of swamps that now breach the watershed between the Omo–Rudolf Basin and the vast mudflats of the Lotigipi Plain to the west (Figs. 1 and 2). Distinct littoral forms at 435–455 m elevation can be followed south-westwards from the former Omo Delta to the drainage divide (R. C. Wakefield carried out an exploratory topographical survey of the Nile–Lotigipi–Rudolf watershed zone in 1938, but no results have been published other than his correction of the 1 : 250,000 East African map series (*Y*501, second edition, Survey Office, Khartum, 1941), sheets 78-*K*, *L*, *O* and *P*), and hydrographic links with the Nile system via the Pibor–Sobat drainage are indicated on faunal grounds[16,17], including the first appearance of the nilotic genus *Bithynia* in Member IV. (Of the Arambourg–Roger molluscan collection, made entirely from Member IV, seventeen species are nilotic, while the single endemic species is of nilotic origin. The fish and reptilian faunas are also nilotic.)

Each of the periods of deposition and high lake level suggest a long-term positive hydrological budget in the Omo–Rudolf Basin, either in response to greater rainfall over the Ethiopian catchment area and/or reduced evaporation over Lake Rudolf. Drier periods can be inferred from the intervals of non-deposition or erosion between Members III and IV*a* (a lengthy period prior to 9700 BP) and again between IV*a* and IV*b* (about 7700–5900 BP). Consequently, the period corresponding to the last Pleniglacial in higher latitudes appears to have been comparatively dry in the Omo–Rudolf Basin. (The later Pleistocene to mid-Holocene sedimentary sequences of the Nubian Nile Valley, reflecting largely the climatic changes of the northern and western parts of the Ethiopian Plateau, show analogies as well as some significant differences. See ref. 10.)

The Kibish Formation shows no evidence of deformation, despite the extrusion of the Nakwa tuffs and basalts (F. H. Brown and I. S. E. Carmichael, in preparation) after deposition of Member III and before deposition of Member IV*a*.

The Lobuni Beds

Alluvial, deltaic and littoral deposits of very recent age are found in different parts of the lower Omo Basin. Some of these surfaces remain functional, others appear to be essentially relict. These modern features are rather important in understanding the older sediments of the region because they provide analogies in terms of processes, sedimentology and forms. Consequently, the key modern depositional environment, the Omo Delta, was studied in some detail (K. W. B., assisted by Claudia Carr) during the 1968 season.

The recent or subrecent deposits of the lower Omo Basin include the typical floodplain alluvia of the Omo and Kibish river floodplains; the delta plain, delta fringe and prodeltaic beds of the Omo and Kibish Deltas; the mudflats of tectonic depressions such as Sanderson's Gulf, the Lotigipi and the Alabilab; the beach ridges and other littoral deposits around Lake Rudolf, Sanderson's Gulf, and the peripheries of the Omo Delta; and the extensive surfaces of piedmont alluvium fringing the lower Omo Basin and encroaching on the Omo Delta from the east. In spite of the variety of facies, these deposits can be provisionally and informally grouped as the Lobuni Beds, designated after the former delta bifurcation at Lobuni (4·50° N, 36·05° E). Estimates of the thickness of these deposits are not possible because there is little dissection and there are no borings.

The Lobuni Beds reflect modern geographical conditions, except that Lake Rudolf has transgressed as much as 45 km north and regressed as much as 10 km south of its present northern terminus (K. W. B., in preparation). The lake has never approached its overflow threshold, however, in spite of repeated, rapid and appreciable fluctuations of level to 30 m above and 5 m or more below that of the present. The molluscan and fish fauna remains nilotic, with limited endemism.

The Lobuni Beds are all distinctly younger than the beach ridges of the upland plains formed by Kibish Member IV. Consequently, they are separated from the last chronostratigraphic marker of the Kibish Formation (3250 BP ?) by a long period of dissection, perhaps by a millenium or two. Samples suitable for ^{14}C dating were not found in the Lobuni beach ridges so that no absolute dates are possible for the initial Lobuni sedimentation. "Contemporary" depositional patterns, however, probably exemplify the last two millenia.

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Early *Homo sapiens* Remains from the Omo River Region of South-west Ethiopia

Among the finds of the Kenya group (led by Mr Richard Leakey) of the 1967 International Palaeontological Research Expedition to the Omo River were three skulls and some skeletal material belonging to very early representatives of *Homo sapiens*. The sites of the two oldest skulls are no younger than mid-Upper Pleistocene and may be as old as late Middle Pleistocene. After a short account by Mr Leakey of some of the other fossils found by the expedition, and a description of the geology of the hominid sites by Professor Karl Butzer (a member of the US group), this article ends with a preliminary description of the human remains by Dr Michael H. Day.

Faunal Remains from the Omo Valley

The 1967 International Palaeontological Research Expedition to the Omo Valley was made possible through the interest and assistance of the Emperor of Ethiopia and his government. The expedition included three teams from Kenya, France and the United States. The fossils found by the Kenya team were recovered from a series of sediments known as the Kibish Formation. The human remains were found at the two sites, Site 1 (*KHS*) and Site 2 (*PHS*) marked on Fig. 1.

The Kibish deposits are not very fossiliferous and the specimens were recovered from a very large area. Unfortunately, the faunal assemblage is of little diagnostic value from a stratigraphic viewpoint.

A complete buffalo skeleton was collected *in situ* from the horizon in which the human skeleton Omo I was found. This buffalo differs slightly from *Syncerus caffer* and it may merit specific separation although it appears to have no characteristics that would preclude its being a direct ancestor to the living *Syncerus caffer* (personal communication from A. W. Gentry). Another bovid is represented by dental fragments the morphology of which recalls that of the *Syncerus/Homoicerus* stock; the occlusal features of these teeth being too advanced to fit *Pelorovis*. The Reduncini (reedbuck) are represented by a number of fragments, but there is insufficient material for positive identification.

Both *Ceratotherium simum* and *Diceros bicornis* are represented by individual teeth, the former being the more common. A primitive *Elephas loxodonta* occurs in Member I of the deposits and the occurrence of a very advanced *Elephas recki* has also been reported by the United States team (personal communication from F. H. Brown).

Primate material is scarce and the only two specimens collected are deeply embedded in a hard matrix and have yet to be fully examined. The specimens appear to be cercopithecoid; one could be a representative of the genus *Colobus* although it is larger than the representatives of either of the living species.

Very few stone tools were collected, all of which were surface finds with the exception of flake debris from the *KHS* excavation.

Omo I skeleton alone was associated with a small number of stone artefacts and some animal bone debris. Excavation of site *KHS* yielded some material *in situ* and established the provenance of the Omo 1 skeleton in terms of the stratigraphy of the Kibish deposits.

Above Member III of the deposits, sub-fossil mammal remains were noted in various localities. In the upper parts of the Kibish beds (Member IV*a*), several bone harpoon heads were found, usually associated with concentrations of *Etheria* and *Unio*.

All of the foregoing fossils are in process of further evaluation and it is hoped that these studies will result in more environmental information at a later date.

The Kenya team was supported by a grant from the Committee for Research and Exploration of the National Geographic Society, Washington DC.

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Geological Interpretation of Two Pleistocene Hominid Sites in the Lower Omo Basin*

THE fossil hominids described in the following article by Dr Day were recovered from sedimentary units defined as the Kibish Formation[1-3], which has five major subdivisions. The first three, Members I, II and III, consist of delta-plain, delta-fringe and prodeltaic sediments represented by a total of twenty-one stratigraphically significant beds, with a cumulative thickness of at least 108 m. Accumulation of each member was followed by major dissection. There are littoral deposits in Members IV*a* (at least 13·5 m) and IV*b* (at least 5 m). The upper part of Member III appears to lie just beyond the range of ^{14}C dating: an *Etheria* bank from the penultimate bed gave "greater than 37,000 yr" (*L*-1203-*A*), while *Unio* shell from a stratigraphically uncertain bed gave "26,600 yr or greater" (*L*-1203-*F*) (refs. 1–3). Member IV*a* can be dated about 9700–7700 BP by ^{14}C, Member IV*b* about 5900–5350 BP. The interval of non-deposition or erosion between Members III and IV*a* can be tentatively dated *circa* 35,000(?)–9700 BP, that between IV*a* and IV*b* about 7700–5900 BP.

The geology of the Kibish Formation type areas was mapped in 1968 at a scale of 1 : 11,000, using air photographs taken in 1967 by R. I. M. Campbell. A simplified and reduced extract of the area of the sites is given in Fig. 1. Wherever exposed, Member I rests disconformably on the cemented and dissected surface of the Late Pliocene Nkalabong Formation. The terminal units, which consist of consolidated lacustrine clays, silts and tuffs, are quite unlike those of the Kibish beds in terms of sediment properties and compaction.

The earliest deposits of Member I consist of 7·5 m of light grey, silty clay and appear to be prodeltaic (colours follow the *Munsell Soil Color Charts* for fresh sediment facies (dry state); all textures were determined by the hydrometer method[4]). They are covered by 1·5 m of light grey, laminated or ripple-bedded tuff of silt loam texture. This tuff is restricted in area, representing distributary channel or mouth-bars that are locally prominent because of their resistance to erosion. The tuff was followed by a variable series of up to 7 m of conglomerates, gravelly loams, and light grey, silt loams. Near Kenya Camp (Fig. 1) the gravel sequence increases in size and degree of rounding from base to top, culminating in a well rounded, coarse-grade conglomerate, transported primarily by sliding motions[5] in a river channel of higher competence than the modern Omo River. The basal units are rich in weathered rhyolite pebbles, but weathered pebbles are absent in the higher units while basalt almost completely replaces rhyolite as the primary pebble constituent. It seems that residual gravels of more local origin mark the first true fluvial beds while gravels transported over greater distances constitute the later beds.

Whereas the conglomerates were deposited in floodplain or delta channels, the second half of Member I is constituted largely of clays or loams of prodeltaic or delta-fringe origin. Exception to this are some distributary channel-beds that overlie a minor disconformity, representing a period of temporary emergence. The general stratigraphy of Member I can be summarized: (1) (base) 7·5 m; light grey, silty clay; (2) 1·6 m; light grey, laminated or ripple-marked tuff; (3) 6·5 m; intercalated conglomerates and light grey silt loams; (4) 0·5 m; white silt loam; (5) 11·5 m; very pale brown to pale brown, silty clay, silt loam and silty clay loam, with horizons of calcareous concretions or ferruginization; (6) 2·4 m; pale brown, current-bedded or ripple-marked, silty clay loam with limonitic staining; (7) (top) 1·0m; light yellowish brown, silty clay with secondary carbonate impregnation of dehydration cracks.

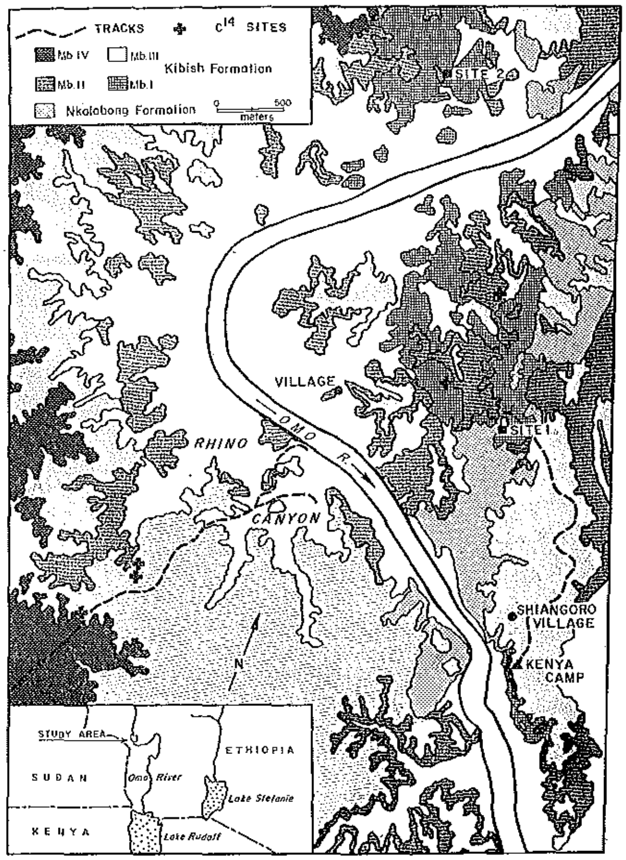

Fig. 1. Pleistocene stratigraphic units of the Kenya Camp-Rhino Canyon area (very generalized). Several small exposures of Members III and IV of the Kibish Formation have been omitted.

The major hominid site, *KHS*, is located 1·8 km north-west of Kenya Camp at 5° 24′ N, 35° 57′ E at 435 m (Fig. 1). The Leakey's trench, cut into the southern flank of a conical hill, records the upper part of Member I and the base of Member II (Fig. 2). Rapid denudation and a very incomplete vegetation mat has locally impeded the development of a mature soil and an incipient 10 cm (*A*)-horizon is frequently replaced by a 10 to 20 cm horizon of re-worked organic soil. Gradual leaching and surface transfer of primary salts from several of the strata, combined with capillary concentrations in the subsoil, have produced a pedogenic horizon of diffuse sodium salts with a thickness of 30 to 50 cm.

From bottom to top the strata are as follows (with reference to Fig. 2): (*a*) Over 3·00 m. Well stratified, very pale brown, silty clay; *p*H 7·6. Slightly hard with blocky structure. Terminated by clear, wavy boundary (consistence (dry), structure, horizon boundaries, and colour patterns are described according to the US Soil Survey terminology[4]). (Member I, bed 5.) (*b*) 0·15 m. Well stratified, light yellowish brown, silt loam with distinct, horizontal, reddish yellow limonitic staining; *p*H 8·3. Embed weakly to strongly cemented ferruginous–calcareous concretions of various sizes. Soft, with blocky structure and traces of diffuse, primary sodium salts. Clear, wavy boundary. (Member I, bed 5.) (*c*) 0·30 m. Well stratified, pale brown, silty clay; *p*H 8·0. Slightly

* Contribution No. 8, University of Chicago Group, Omo Research Expedition.

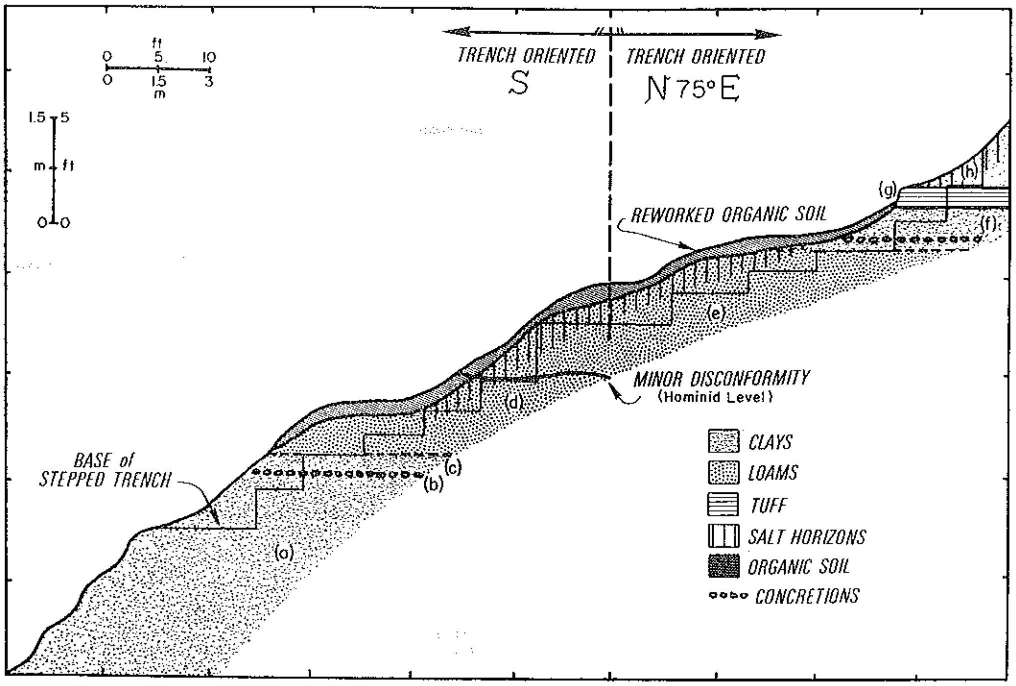

Fig. 2. Stratigraphy of the hominid site, *KHS*. Vertical exaggeration 2 : 1.

hard; blocky peds with pyrolusite staining. Clear, wavy boundary. (Member I, bed 5.) (*d*) 1·05 m. Well stratified, very pale brown, silty clay loam; *p*H 7·8. With a few fine but distinct, reddish yellow mottles and weakly cemented ferruginous microconcretions in sand grade. Biotite present among sands. Slightly hard and blocky; abrupt, wavy boundary suggests erosional truncation. (Member I, bed 5.) (*e*) 1·80 m. Well stratified, in part current or ripple-bedded, pale brown, silty clay loam with abundant and prominent, reddish yellow limonitic staining in form of subcontinuous horizons and fine mottles; *p*H 7·1. Slightly hard, blocky. Biotite, muscovite, amphiboles and pyroxenes among sand fraction, with wafery quartz grains of tuff origin. Truncated by abrupt, wavy boundary. (Member I, bed 6.) (*f*) 0·60 m. Laminated, light yellowish brown, clay with primary halite, and strongly cemented calcareous concretions with sodium salts (40 per cent $CaCO_3$; *p*H 7·8) that form subcontinuous horizons (up to 2 cm thick) or fill minor, vertical earch networks. The clay itself is non-calcareous, hard and has conchoidal structure; *p*H 6·9. Truncated by abrupt, smooth boundary. (Member I, bed 7.) (*g*) 0·30 m. Laminated, light grey tuff, primarily in 10–50 micron grade (silt loam) with some biotite in sand fraction; *p*H 7·0. Slightly hard with blocky to platy structure. Truncated by abrupt, wavy boundary. (Member II, bed 1.) (*h*) Over 1·00 m. Well stratified, pale brown, clay with primary sodium salts and gypsum; *p*H 7·3. Slightly hard with conchoidal structure. Grades up into some 20 m of alternating clays and silts, rich in salts, and with ferruginous horizons. (Member II, bed 2.)

Beds (*a*) to (*f*) mark the terminal stratigraphic subunits of Member I, beds (*g*) and (*h*) the base of Member II, Kibish Formation. With the exception of the concretionary horizons and certain clayey lenses, such as bed (*c*), each unit has stratigraphic meaning over areas of many square kilometres. The Omo I skeleton was found at the minor disconformity separating beds (*d*) and (*e*).

Very probably beds (*a*), (*b*) and (*c*) were deposited in a pro-deltaic environment, with the textural contrasts as well as carbonates or ferruginous horizons reflecting differences of water depth or impeded circulation (interdistributary bays ?). The texture and other characteristics of bed (*d*) are reminiscent of overbank silts associated with distributary levées in the delta fringe. The mottles follow root structures of reed or sedge vegetation, probably contemporary with the final phase of deposition. Bed (*e*), with its bedding properties and heavy mineral concentrations, is probably typical of distributary-channel or mouth deposits in the delta fringe. This interpretation is supported by the radiocarbon-dated *Etheria* bank*, which comes from the base of (*e*). Subsequent emergence is indicated by the ferruginized root structures. A pro-deltaic environment is once more strongly suggested by bed (*f*), the solubles of which impregnated a strongly dehydrated sediment at a much later date.

The local development of the tuff, in part grading into a coarse detritus on slopes of 20° or more, in part highly saline on absolutely horizontal surfaces, indicates subaqueous deposition in waters of variable depth and circulation, standing within the irregular topographic outlines of an old, dissected delta plain. The subsequent, massive sequence of bed (*h*), constituting the remainder of Member II, is characteristically pro-deltaic.

On the basis of this detailed analysis of the sedimentary sequence, there can be little doubt that the *KHS* site was occupied by man during a period of temporary emergence. The over and underlying deposits indicate a setting on shallow levées of the delta fringe. The sporadic presence of partially articulated mammalian bones at this horizon also suggests that the Omo distributaries were near by.

The second site, *PHS*, is located on the westerly side of the Omo valley, 4·8 km north-west of Kenya Camp at 5° 25·5′ N, 35° 55·5′ E, and at about 435 m (Site 2, Fig. 1). Unlike site *KHS*, where some bone and artefactual material was found geologically sealed in place, the skeletal remains (Omo II) at *PHS* (Site 2) were found spread over the side of a small clay residual, just next to a hill representing the upper half of Member I and the lower third of Member II. Although it was therefore not possible to determine the stratigraphic position with complete certainty, it is not likely that the bones have been exposed for long, or that they have been "lowered" appreciably through erosion of the underlying sediments. Consequently, the vertical position of the hominid can be related to the stratigraphic sequence exposed a few metres away and it is very probable that it comes from the top of unit (5) or the base of unit (6), Member I. The

* Shell was submitted by R. E. Leakey to both Geochron and Isotopes Inc. for ^{14}C dating.

same erosional disconformity is present here some 3 m below the characteristic tuff that marks the base of Member II. Because the sedimentary sequence is quite analogous, there seems little reason to question the assignment of the hominid Omo II at *PHS* to the same level as that of Omo I at *KHS*.

The stratigraphy and interpretation of the hominid sites have indicated that Members I, II and most or all of III antedate 35,000 BP, that is to say, the effective dating range of ^{14}C. The tuffs of these earlier units are too young for accurate dating by potassium–argon. Similarly, the faunal materials found *in situ* within the Kibish Formation cannot be dated precisely. Consequently, no firm date can be given for the hominid level.

In conclusion, the sites of Omo I and II both come from the same level, a minor disconformity in the upper third of Member I, Kibish Formation. The palaeo-environmental setting of both sites was within the former Omo delta fringe near the shores of a greatly expanded Lake Rudolf, approximately 65 m above modern lake level (370 m); the site *KHS* was possibly situated on a shallow levée. Members I and II predate the range of radiocarbon dating, while Member III probably terminated about 35,000 BP. This would indicate that the hominid level is no younger than mid-Upper Pleistocene but that it may be as old as late Middle Pleistocene.

The site of Omo III was not seen by myself, but seems to be related to Member III of the Kibish Formation (R. Leakey, personal communication).

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Omo Human Skeletal Remains

REMAINS of three adult individuals were recovered in large quantity by the Kenya group of the 1967 expedition and have been designated Omo I, Omo II and Omo III. All the material is very mineralized and, for the most part, undistorted and lacking in pathology. It has been difficult preparing the material for examination because of the hardness of adherent matrix and the degree of comminution of one skull and several of the long bones. A complete list of the material is given in Table 1.

Omo II (Site PHS)

This is the best calvaria of the three, the cranial vault being intact except for the right supraorbital region and a few small deficiencies in the parietal and occipital bones. The face is missing, as is a substantial part of the skull base including the basilar part of the occipital bone and the body of the sphenoid. Fortunately, both temporal bones and the nuchal portion of the occipital bone are preserved. The foramen magnum can be determined by its posterior and left lateral margins allowing identification of the opisthion.

The principal sutures are completely closed, although the ectocranial marks of the coronal, sagittal and lamboid sutures are still recognizable; thus it is possible to define the bregma, the lambda and the asterion of each side; it is less easy to define the pterion, but the sutural pattern here appears to be of the "human" type. If the state of sutural synostosis can fairly be compared with that of modern man, then the skull would appear to belong to an individual of advanced years. The cranium is heavily built with stout parietes and rugged muscle impressions. The maximum thickness of the parieto-mastoid region (on the angular torus of the parietal bone near the asterion) is 13 mm on the right and 13·5 mm on the left, and the maximum thickness in the region of the bregma is 9 mm.

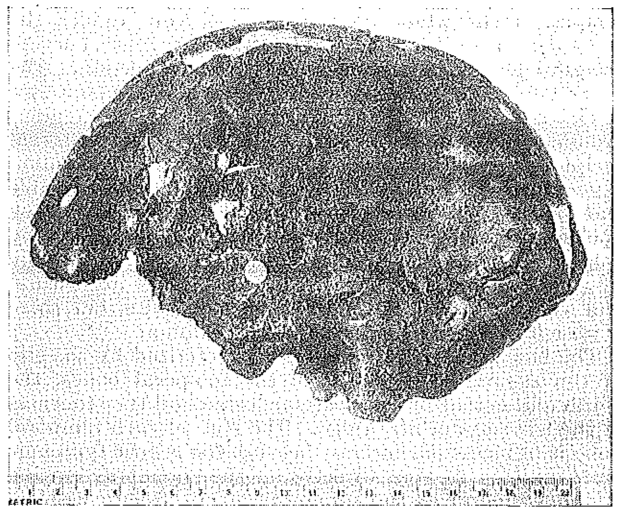

Fig. 3. Omo II calvaria, left lateral view.

In general form the skull is dolichocephalic. Its greatest length (glabella/opisthocranion, minimally reconstructed) is 215 mm; its greatest breadth (bimastoid) 145 mm. The Cranial Index is 67·5.

In lateral view (Fig. 3) the skull has several striking features, the most outstanding of which are the recession of the forehead, the size of the occipital torus and the flatness of the nuchal plane. The outline of the vault slopes almost directly backwards from the region of the glabella, the curve smoothly increasing to the bregma which appears to coincide with the vertex when the skull is orientated in the Frankfurt plane. Behind the bregma, the outline proceeds gently at first then dips evenly to the bulge of the external occipital protuberance by traversing a slight supratoral depression. The inion and the opisthocranion coincide. The occipital torus blends laterally with a marked supramastoid crest which in turn surmounts a prominent downturn mastoid process. The crest is continuous with the base of the zygomatic process of the temporal bone, and passes above the external auditory meatus as a low ridge. Above and behind the meatus on the left side there is a short linear depression in the region of the suprameatal triangle. The tympanic bone is extremely robust posteriorly and it encloses an elliptical meatus the principal axis of which is inclined forwards.

The supraorbital torus runs laterally to a thickened zygomatic process; this in turn gives rise to a prominent temporal ridge that sweeps posteriorly almost parallel with the vault outline, to rejoin the supramastoid crest. Surface erosion precludes its exact delineation throughout.

The frontal view of the Omo II skull reveals the lowness of the vault, the recession of the frontal region, the lateral bulging of the supramastoid crests and the presence on the vault of a sessile sagittal torus or keel (itself the subject of a shallow sagittal groove along part of its inter-parietal course) flanked by shallow parasagittal depressions. The glabella is broken away to reveal an endocast of the left frontal sinus. This sinus extends laterally into the orbital roof and backwards between the tables of the skull.

In occipital view the frontal outline is confirmed, and the supramastoid bulge is accentuated by the inturned direction of the mastoid processes. The most remarkable feature of this view, however, is the massive size of the occipital torus which spans the skull and divides the squamous part of the occipital bone into an upper, curved, occipital portion and a lower, flat, nuchal portion. The lower border of the torus overlaps the nuchal plane as a thick rolled edge that culminates medially in a triangular prominence the apex of which leads down to an external occipital crest that terminates at the foramen magnum. The impresses for the nuchal muscles are considerable and testify to the size of the nuchal muscle mass. The nuchal plane is separated from each mastoid process by a deeply incised digastric groove that is bounded medially by a prominent occipitomastoid crest. There are sutural and exsutural mastoid foramina on both sides, but there is no external evidence of parietal foramina.

The basal view of the skull is characterized by the size of the zygomatic processes of the temporal bones, the depth and extent of the artitular fossae and the stoutness of the left supraorbital ridge. The base of each temporal bone is of particular interest because the robust tympanic bone appears to abut directly on the squamous portion of the temporal at the squamotympanic fissure with no intervention of a tegmen tympani, while the vaginal portion of the tympanic plate surrounds a distinct styloid groove leading to the stylomastoid foramen. The styloid process is absent. Much of the foramen magnum is missing, including the occipital condyles; none the less, its postero-lateral quadrant is preserved on the left side and is thickened by a postcondylar tuberosity. As far as can be judged, the plane of the postcondylar part of the foramen faces downwards and forwards when the skull is orientated in the Frankfurt plane.

Internally, the skull is marked by a well defined frontal crest which leads back to a median sagittal ridge that, further posteriorly, develops a groove to house the superior sagittal sinus. The internal occipital protuberance is low and widely separated from the external occipital protuberance. Provisional estimates of the cranial capacity show a mean value of 1,435 cc $\pm$ 20 cc.

Omo I (Site KHS)

The skull of Omo I consists of an incomplete vault that includes parts of the occipital bone, both parietal bones and most of the frontal bone. Much of the right temporal bone, the right zygomatic bone, and three maxillary fragments are present. The mandible is represented by the symphysial region, part of the left side of the body, the right ramus, and the condylar process. Two tooth crowns belong to the right upper canine and the left lower first molar.

The superior sagittal suture is closed and entirely obliterated internally, but the coronal and lambdoid sutures are open wherever they are preserved. It is not possible to define the bregma, the lambda or the asterion with absolute confidence, but the glabella and the opisthion are both intact. While the skull is clearly adult, it may belong to a younger individual than Omo II. Similarly, while the vault is robust by modern human standards, it seems to be more lightly built than the Omo II calvaria. The maximum length of the Omo I skull is 210 mm (glabella/opisthocranion), and the glabella/inion length a little less, 207 mm, the opisthocranion being about 10 mm above the inion. The maximum breadth can only be estimated by doubling the half breadth, as much of the left side of the vault is missing. A provisional estimate of the greatest breadth is 144 mm (biparietal) producing a provisional Cranial Index of 68·5.

In lateral view (Fig. 4), the outline of the skull differs markedly from that of Omo II particularly in the occipital region. From the prominent glabella the contour passes gently backwards through a shallow supratoral sulcus and rises evenly to the vertex. Behind this point the curve steepens in the mid-parietal zone and descends smoothly to the inion which forms part of a moderate occipital torus that is undercut by the nuchal attachments. The occipital torus fades laterally and almost disappears before reaching the temporal region. The mastoid process is prominent and downturned.

In frontal view the Omo I skull shows a higher vault than Omo II, a receding forehead and an expanded parietal region. The supraorbital torus is prominent and

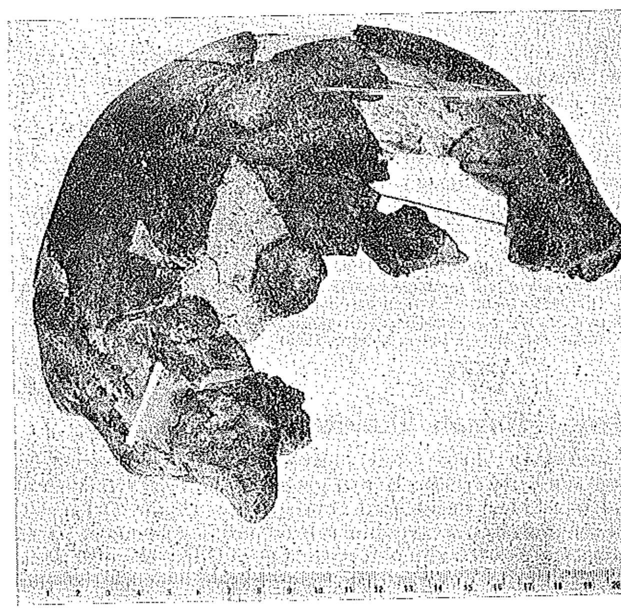

Fig. 4. Omo I calvaria, right lateral view.

Table 1. LIST OF THE OMO HUMAN SKELETAL MATERIAL

		Limb bones
OMO I	**Skull** Incomplete calvaria including frontal, parts of both parietals and occipital bone, and right temporal bone. **Facial skeleton** Right and left maxillary fragments, right zygomatic, symphysial region and part of the body of the mandible, right mandibular ramus and condyle. Teeth present include right upper canine crown and left lower first molar crown. **Vertebral column** Three cervical vertebrae and several cervical spinous processes. Three thoracic spinous processes, eight neural arch fragments and transverse processes. One lumbar neural arch and transverse process. Numerous rib fragments including nine rib heads.	**Upper limb** Complete left clavicle, two right clavicular fragments, both coracoid processes, almost complete left humerus, head and distal third right humerus, shaft of left radius, proximal end and part of shaft of right radius, proximal and distal ends of right ulna. (All of the following hand bones belong to the right side) Lunate, hook of hamate, ? head of first metacarpal, base and styloid process of third metacarpal, ? shaft fragment of fourth metacarpal, head of proximal phalanx, two bases of proximal phalanges, two intermediate phalanges, one base of a terminal phalanx. **Lower limb** Distal end of right femur, parts of the shafts of both tibiae, distal end of right tibia, distal end of right fibula. (All of the following foot bones belong to the right side) Navicular, medial cuneiform, intermediate cuneiform, cuboid, first metatarsal, second metatarsal base and shaft, fourth metatarsal base, first proximal phalanx, terminal phalangeal fragments.
OMO II	**Skull** Almost complete calvaria lacking face and part of the base.	——
OMO III	**Skull** Frontal fragment including the glabella, and a vault fragment.	——

In addition, there are 800 g of, as yet, unidentified fragments.

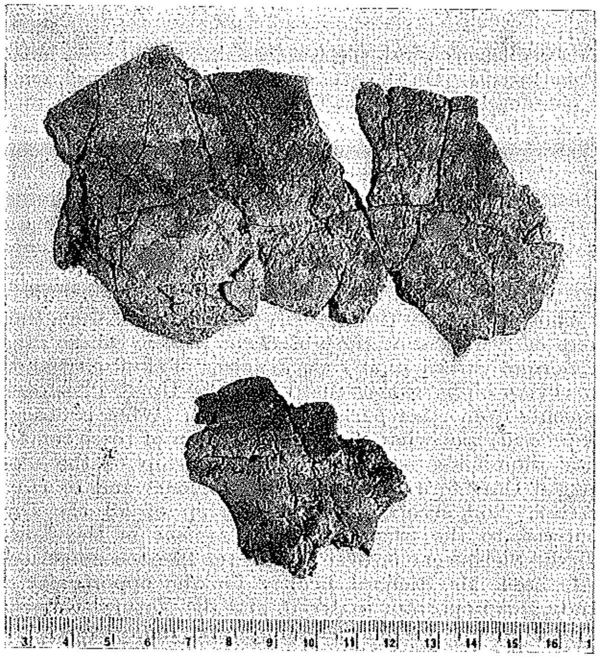

Fig. 5. Omo III skull fragments.

leads laterally to thickened zygomatic processes. On the right, the frontal bone is a little distorted making accurate reconstruction difficult. Both frontal sinuses are filled with hard matrix. The vault shows neither sagittal keel nor parasagittal flattenings, but it has a small depression of the outer table in the mid-frontal zone.

In occipital view the skull is well rounded and shows a restricted nuchal plane, modest nuchal markings and a lower inion than Omo II. The maximum breadth of the skull is low on the parietal bone. Paired parietal foramina are present, and an exsutural mastoid foramen on the right side.

The base of the skull is almost entirely missing, but the right temporal bone shows some interesting features. A fortunate break in the petrous temporal reveals a perfect endocast of the cochlea and exposes the semicircular canal system.

Much of the foramen magnum is missing, including both of the occipital condyles, but the opisthion and part of the left margin of the opening are present. This margin shows no post-condylar tuberosity. The plane of the post-condylar portion of the foramen magnum faces downwards and forwards when the skull is orientated in the Frankfurt plane.

Internally, the frontal crest is high and leads back for at least one third of the sagittal length of the frontal bone; beyond this the internal sagittal ridge is low and has a poorly defined groove. The internal occipital protuberance is set low and corresponds in position with the external occipital protuberance. The groove for the superior sagittal sinus is weak and joins the groove for the left transverse sinus. The cranial capacity of the Omo I skull can only be estimated from water displacement of an endocast of the fully restored and reconstructed cranium; however, at present there is no reason to believe that it will prove to be less than that of Omo II.

The facial bones are scanty and broken, but in general are of moderately robust structure; the maxillary fragments can be arranged in a U-shaped arcade to match the mandible. The symphysial portion of the mandible is of particular interest because it displays a well developed chin, posteriorly placed digastric impressions, single mental foramina and genial tubercles.

The canine tooth is heavily worn so that the incisive edge is flat with considerable exposure of the dentine. The labial surface is convex and the lingual surface, also worn, expanded towards the base. The crown of the tooth is robust by comparison with modern human teeth. (Crown dimensions—mesio-distal length 8·9 mm; bucco-lingual breadth 8·1 mm.)

The molar tooth is heavily worn and incomplete, lacking part of its distal half. Sufficient of the crown is retained, however, to identify five cusps and a Y-shaped fissure arrangement. There is no evidence of a buccal cingulum and none of secondary enamel wrinkling. (Crown dimensions—mesio-distal length, unobtainable; bucco-lingual breadth 11·5 mm.)

The post-cranial bones listed in Table 1 are parts of the skeleton of the upper limb girdle, the arm, the forearm and the right hand, as well as parts of the cervical, thoracic and lumbar portions of the vertebral column. The lower limb remains include parts of the right femur, both tibiae, the right fibula and the right foot. There are no recognizable parts of the pelvic girdle. The bones are fully adult, strongly built and carry commensurate muscular impressions. Anatomical examination has disclosed no features that can be said to be outside the range of normal variation of the post-cranial skeleton of modern man.

Omo III

The few remains of the third individual belong to the skull alone (Fig. 5). There is a left fronto-parietal frag-

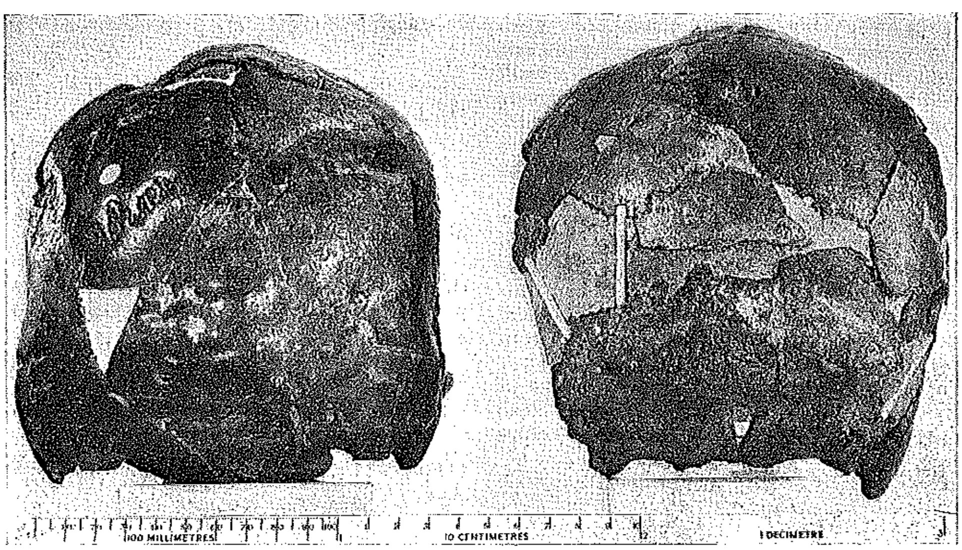

Fig. 6. Omo I (right) and Omo II (left) calvaria, compared in occipital view. Both skulls are orientated in the Frankfurt plane.

ment which includes the lower part of the fronto-parietal suture and the superior temporal line at its junction with the suture (the stephanion). The suture is closed, but it is still discernible on the ectocranial surface, suggesting that the individual was adult. The fragment is relatively thin, but this may be the result, at least in part, of weathering of the specimen. Internally, it is just possible to trace the larger meningeal vascular grooves.

The only other fragment consists of the glabellar region and includes part of the frontal bone, small parts of the frontal process of each maxilla and small parts of both nasal bones and the ethmoid bone. This fragment is heavily built, having a marked supraorbital torus divided by a weak glabellar depression; also, the receding forehead is separated from the torus by a shallow supratoral groove.

Assessment of the affinities of the Omo skeletal remains must depend eventually on intensive anatomical investigation coupled with wide comparative studies including multivariate statistical analysis. In particular, it is hoped to construct a discriminant function from cranial parameters that will assist in the grouping of these and other fossil skulls.

The anatomical evidence so far suggests that all the Omo specimens should be attributed to *Homo sapiens*, although all three skulls show a number of specialized features; also, the two major specimens show striking differences of skull form. The more complete calvaria, Omo II, has many features both in its general configuration and in its detailed anatomy, which is similar to the Solo skulls and, to a lesser extent, the Broken Hill skull, the Vertessöllös occipital, the Kanjero skulls, and even indeed *Homo erectus*. On the other hand, the Omo I skull, which is contemporaneous with Omo II, is more modern in its general form and can be reasonably compared with both the Swanscombe and Skuhl skulls. The presence of a chin, of relatively modern teeth, of a rounded occiput and of a considerable quantity of limb bones of modern human form supports this suggestion. The fragmentary remains of the later Omo III skull preclude any real assessment of its affinities at this time, but what resemblance it has lies with the more modern of the first two Omo skulls.

Thus we can say that, at this time in East Africa, there were early representatives of *Homo sapiens* whose range of normal variation, at least in terms of skull characters, was every bit as wide as that known for Upper Pleistocene sapients from other parts of the world. What is obscure at present, and what the full evaluation of these remains may illuminate, is, first, the relationship of the more rugged Omo form to other early sapients and to *Homo erectus*; and second, the relationship of all the Omo material to the origin of *Homo sapiens* in the Lower Middle Pleistocene or even the Lower Pleistocene periods.

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Age Determinations on Feldspar from the Lower Omo Basin

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Total degassing $^{40}Ar/^{39}Ar$ age determinations have been made on a concentrate of fresh feldspar from lapilli in a pumice–lapilli-tuff of the Nkalabong Fm., Lower Omo Basin, Ethiopia.

THE feldspar sample supplied to us for analysis was a separation from individual lapilli collected in the field by Professor K. W. Butzer from a pumice–lapilli-tuff in the Nkalabong Fm., Lower Omo Basin, Ethiopia. Contamination with any non-volcanic feldspar possibly present in the matrix was thus avoided. Examination of a bulk sample of the tuff provided by Mr F. H. Brown suggests that the tuff contains only fresh juvenile pumice lapilli. These lapilli show no signs of devitrification and there seems to be no reason why the feldspar ages should be discrepant in any way.

The feldspar concentrate being very small (of the order of 0·3 g), it was necessary to analyse it by the neutron irradiation total degassing $^{40}Ar/^{39}Ar$ method[1–3]. Because of the very young age of the feldspar the neutron-generated ^{37}Ar was utilized in order that a further correction for the presence of argon isotopes generated from calcium during irradiation could be applied (Table 1).

The average apparent total degassing $^{40}Ar/^{39}Ar$ age of 3·95 ± 0·11 m.y. obtained is regarded as a very close estimate of the age of eruption of this tuff. No factors which might cause discrepancy have been observed.

On the current Geological Society of London time-scale this age is "Pliocene". On the evidence from North America it would appear to be roughly equivalent to the early Blancan.

Table 1. ANALYTICAL RESULTS OF TOTAL DEGASSING $^{40}Ar/^{39}Ar$ AGE DETERMINATIONS

Sample	J	R^1	Q	Atmospheric contam. (per cent)	Apparent age and error (m.y.)	Average apparent age and error (m.y.)
Feldspar concentrate from Nkalabong Fm.	0·0755	0·274	0·002064	67·2	3·90 ± 0·10	3·95 ± 0·11
	0·0773	0·273	0·002110	67·1	3·99 ± 0·12	

USGS *P*-207 standard muscovite (age 81·3 m.y.) used as internal standard.

R^1, Ratio radiogenic ^{40}Ar to neutron induced ^{39}Ar (corrected for argon isotopes generated from calcium utilizing values of neutron induced ^{37}Ar).

Q, $e^{t/\tau^{-1}}$.

J, Constant of proportionality at reactor sites occupied by standards and corresponding samples.

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