QUATERNARIA

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Tirage à part de
"QUATERNARIA" XI, Roma, 1969

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INTRODUCTION

The existence of old lacustrine deposits in the Lake Rudolf Basin was first recognized by Höhnel *et al.* (1891: 20f., 134) and subsequently confirmed by the work of M. Sacchi (Angelis and Millosevich, 1900) and E. Brumpt (Bourg de Bozas, 1903: 107ff.), Fuchs (1935, 1939), Champion (1937), and Arambourg (1943: 206f., 210f.). A part of these sediments, defined by Arambourg (1935, 1943: 180ff., 190ff., 207ff., 212f.) as the Omo Beds (also Fuchs, 1939) was subsequently faulted and folded. Younger deposits, broadly horizontal and undeformed, have been cursorily described by Fuchs (1934, 1939), who identified a sequence of shorelines on the western side of Lake Rudolf, between Losidok and Ferguson's Gulf. These range in elevation from 27 meters to 100 meters above the present level of the lake (*ca.* 370 meters). Fuchs believed that the oldest of these beaches, described as " Chellean " and " Acheulian " on the basis of a few scatterd artifacts, were Middle Pleistocene in age, while the youngest were attributed to the Upper Pleistocene. More recently, Whitworth (1966) has studied and described this same series of deposits, suggesting a late Pleistocene to Holocene age.

The younger undeformed lacustrine beds exposed in the Lake Rudolf Basin are characterized by a host of nilotic mollusca and fish (Roger, 1943; Fuchs, 1934, 1939; Whitworth, 1966; Thomson, 1966; also Worthington and Ricardo, 1935). Of the 18 molluscan species identified from these beds by Jean Roger, 10 are common to the Nile system and 17 to the Chad Basin (Arambourg, 1943: 209). For these reasons Fuchs (1934, 1939) and others have postulated an overflow of the Pleistocene lake across the plains of southeastern Sudan, towards the Sobat and the White Nile. Fuchs (1939) thought that the appearance of the nilotic fauna coincided with the highest, " Chellean " shoreline at + 100 meters and that internal drainage had been reestablished by the close of the Middle Pleistocene. On the other hand, Roger (1943: 145ff.) assumed indirect hydrographic links with

(*) Omo Research Expedition (University of Chicago), Contribution n. 6. A preliminary version of this paper was presented at the VIth Panafrican Congress of Prehistory, Dakar (December, 1967).

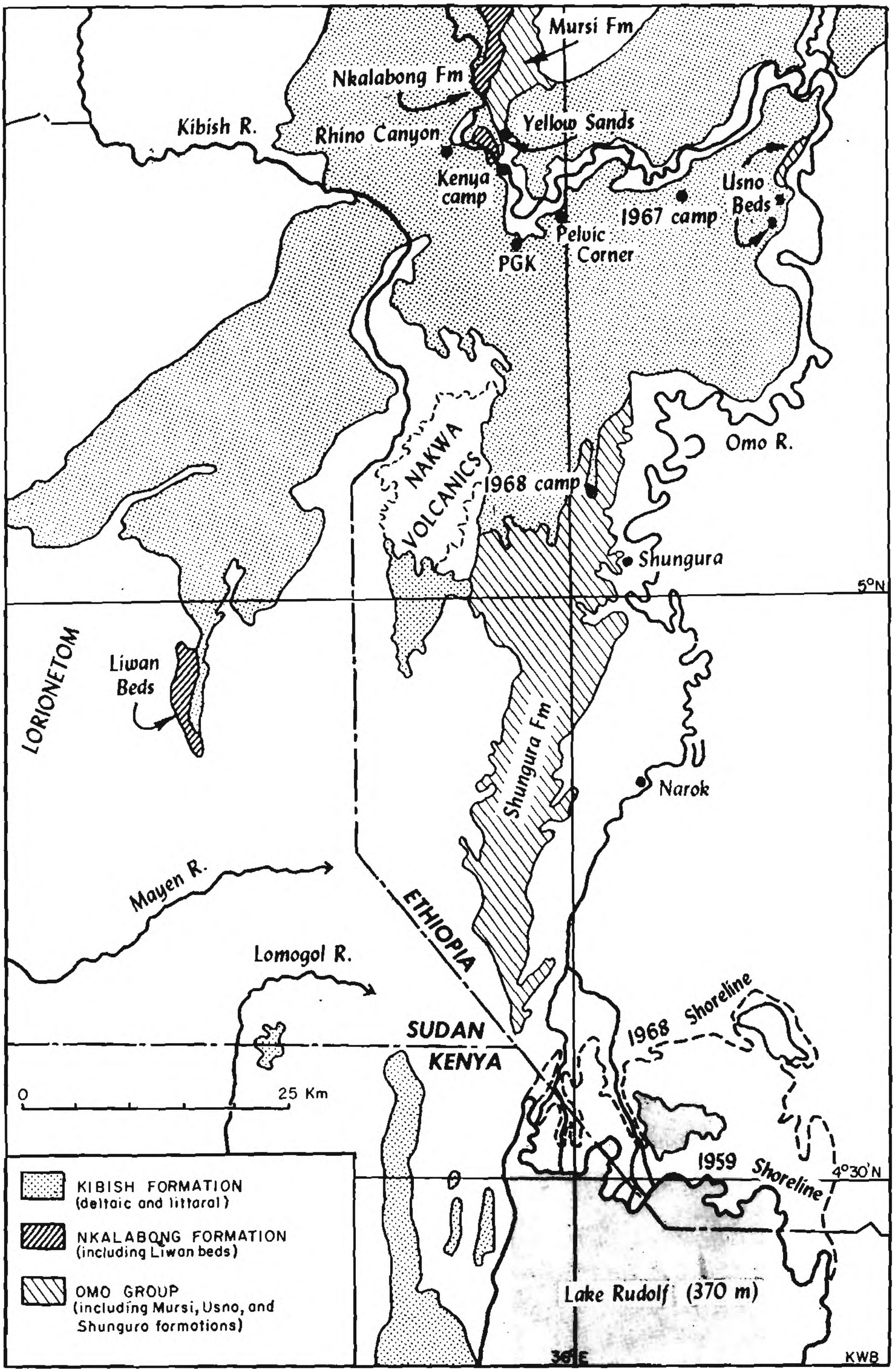

FIG. 1. - Late Pliocene to mid-Holocene surficial deposits of the Lower Omo Basin.

the entire East African lake system in early Pleistocene times, while further nilotic, sudanese and chadian forms would appear to have entered the Rudolf Basin during the late Pleistocene. Since the modern fauna of Lake Rudolf shows remarkably little endemism (also Worthington and Ricardo, 1935), and since there is a greater faunal similarity with the Nile River than with the other East African lakes, Roger (1943: 148) has suggested a very late rupture of the hydrographic connections between Lake Rudolf and the Nile.

The Omo Beds retained the interest of paleontologists over the years (see also Patterson, 1966), but the underformed lacustrine sediments west and east of Lake Rudolf have received little attention since the original reconnaissance studies between 1931 and 1934 (1). During 1967, Brown and Butzer discovered extensive well-exposed deposits of horizontal formations in the lower Omo Valley, at distances of 80 to 110 km north of Lake Rudolf (Fig. 1). Two stratigraphic entities can now be recognized in the area: (*a*) a series of older deposits, of late Pliocene age, designated as the Nkalabong Formation (Butzer and Thurber, 1969), and (*b*) a complex of younger deposits, defined as the Kibish Formation.

The Nkalabong Fm. has a maximum cumulative thickness of 88 meters and consists of a complex succession of fluvial deposits, lapilli tuffs, and lacustrine beds. The middle unit has an Ar^{39}/Ar^{40} date of 3.95 million yr. (Fitch and Miller, 1969). Wherever exposed, the base of the Nkalabong Fm. rests on faulted, weathered, denuded, and dissected basalt of the Mursi Formation (with K/Ar dates averaging 4.15 million yr., see Butzer and Thurber, 1969).

The Kibish Formation has been named after the Ethiopian police post of that name (at 5.19° N, 35.53° E). 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 subsequently mapped geologically 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 4 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 substantiated in part by 19 radiocarbon dates by Thurber, the Kibish Fm. is subdivided into 5 major units. Members I, II, and III consist of delta-plain, delta-fringe, and prodeltaic sediments. These interpretations are based on a semidetailed study of the sediment facies and geomorphology of the modern Omo Delta, which has been 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 geomor-

(1) Exceptions have been recent work of Whitworth (1966) and of the Geological Survey of Kenya, in particular the 1 :500,000 sheets « Northern Turkana Area », surveyed by J. Walsh and R. G. Dodson (1966), and « Area south of Lodwar », by R. G. Dodson (1966). These maps, however, only distinguish (a) Pleistocene to Recent lake beds; (b) Recent sandy soils; (c) Recent swamp soils, and (d) Recent lake deposits. The accompanying memoirs are due to be published in the immediate future.

phologic forms, are more significant in Members IVa and IVb than in the earlier units. A number of dissected piedmont alluvia or fans, not included in the Kibish Fm., as here defined, are broadly contemporary with Members IVa and IVb.

Measured cumulative thickness of the Kibish Fm. is 115 meters, inferred thickness about 130 meters. The base rests on dissected, eroded, and cemented units of the Nkalabong Formation.

MEMBER I

The oldest beds of the Kibish Formation have a cumulative stratigraphic thickness of 26.0 meters. The sediments extend vertically from below floodplain to 40 meters above it, a little to the northeast of Kenya Camp. Minimum thickness therefore can be assessed at 40 meters. The following beds are recognized and described according to the Wentworth classification, as resting on the Nkalabong Beds or on basalt outcrops of the Mursi Fm.:

(*a*) 7.5 meters (base). Light gray to pale brown, silty clay, clayey silt, or medium-sandy silt. Locally intercalated with conglomeratic lenses of basalt, rhyolite, chert and silicified rhyolite, and quartz gravel in the medium to coarse grade (0.6 to 6.0 cm.); basal conglomerates include strongly weathered pebbles with lenses of reddish brown, ferricreted sands.

(*b*) 1.6 meter. Light gray, laminated or ripple-marked tuff, with the texture of a fine-sandy silt. On the edge of the basalt flow, east of Kenya Camp, this tuff dips as much as 20°, embedding cobbles and boulders of weathered basalt. Partial cementation with irregular zones of calcareous concretions.

(*c*) 2.0 meters. Light gray to white, stratified, medium-sandy silt and silty sand, derived from tuffs; with lenses of dispersed pebbles of rounded basalt in medium to coarse gravel grades.

(*d*) 10.4 meters. Very pale brown, well-stratified or laminated, clayey silt, with thin beds of light yellowish brown, medium-sandy silt and pale brown, silty clay. Horizontal bands of limonitic staining as well as semicemented, ferruginous concretions are common to sandy lenses, related to bedding planes and former vertical cracks. Sodium salts and gypsum common in topmost 50 to 70 cm.

(*e*) 1.1 meter. Very pale brown, well-stratified, clayey silt, with limonitic mottling.

(*f*) 2.4 meters. Pale brown, well-stratified, in part crossbedded or ripple-marked clayey silt. Impregnated with salts, and intensively stained with limonite, particularly along bedding planes.

(*g*) 1.0 meter. Very pale to light yellowish brown, well-stratified or laminated, silty clay. Well developed horizontal zones of concretions and carbonate enrichment, grading laterally into beds with gypsum laminae.

The 7 stratigraphic subunits of Member I consist almost entirely of fine-grade, horizontal strata. The earliest beds (*a*) and (*b*) appear to have been primarily deposited in stream channels or in subaqueous settings near the mouth of the

Omo. Near Kenya Camp the gravel sequence attributed to unit (*a*) increases in size and degree of rounding from base to top, culminating in a well-rounded, coarse-grade conglomerate, transported primarily by sliding motions 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 make up the later beds. An extended period of emergence, with development of a Calcorthid paleosol, followed deposition of (*b*).

The second half of Member I is constituted largely of clays or silts of pro-deltaic or delta-fringe origin, that follow upon the initial fluvial deposits of bed (*c*). The textural contrasts as well as the carbonates or ferruginous horizons presumably reflect on differences of water depth or impeded circulation (interdistributary bays?). However, unit (*f*), 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 presence of Nile oyster (*Etheria elliptica*) bank. Subsequent emergence is indicated by ferruginized root structures, with prodeltaic conditions once more reflected in unit (*g*). The carbonates of (*g*) impregnated a network of dehydration cracks developed in a clayey sediment somewhat after its deposition.

The *Etheria* reef now has a Th^{230}/U^{234} date of around 130,000 (L-1303-J), and two C^{14} dates « greater than 39,900 yr. » were obtained earlier (R.E. Leakey, personal communication). Although a Th^{230}/U^{234} date for a mollusc cannot be accepted without reservation ([1]), it does suggest a late Middle or early Upper Pleistocene age. This is compatible with the geological evidence reported here as well as with the limited fauna of Member I (see Butzer, Day, and Leakey, 1969).

The discontinuous stratum (*e*) consists of well-stratified, silty clays with some distinct limonitic mottles and weakly-cemented microconcretions in the sand grade. These deposits are reminiscent of overbank silts associated with distributary levees in the delta fringe. The mottles follow root structures of reed or sedge vegetation, probably contemporary with the final phase of deposition. Resting upon the eroded surface were 2 hominid sites, identified as primitive *Homo sapiens* by M. H. Day (Butzer, Day and Leakey, 1969), near Kenya Camp. One of these sites included bones of *Syncerus caffer,* reedbuck and another unidentified bovid, some found *in situ*. Some 69 stone artifacts were also recovered, 9% of them waterworn. They are undiagnostic except possibly for 5 utilized or retouched

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([1]) The analytical precision of this result is 5000 years. However, molluscs have been shown to have open chemical systems with respect to uranium and its daughter products. Thus the accuracy of " ages " calculated from Th^{230}/U^{234} ratios is difficult to determine, and perhaps impossible, even with much more detailed work. The " age " reported here should perhaps be considered only as confirming the antiquity of the shells as indicated by radiocarbon and as some substantiation of the geologic interpretation. It should not be considered too seriously as an " age". See Thurber (1965) and Stearns and Thurber (1965) for a more detailed discussion of the problem.

Levallois flakes. No other archeological sites were found, although R. E. and Margaret Leakey collected a variety of scattered surface artifacts, of uncertain stratigraphy.

Member II

A moderately significant phase of downcutting by the Omo River succeeded upon the accumulation of Member I. The older beds were dissected to below 21 meters (relative to modern floodplain), indicating a vertical amplitude of over 19 meters for this period of degradation. Cutting by local tributaries appears to have been very restricted. Renewed aggradation is recorded by only 2 beds, with a cumulative stratigraphic thickness of 22.4 meters, and extending vertically from 21 meters to 40 meters above modern floodplain.

(*a*) 0.45 meters (base). Light gray, well-stratified to laminated tuff, with the texture of a well-sorted silt. In some areas impregnated with gypsum and sodium salts, and also including fine detritus in local, steeply-inclined (25-40°) beds.

(*b*) 21.9 meters. Very pale brown, silt clayey and pale brown, silt clayey, with uniform, horizontal bedding. Abundant ferruginous-siliceous concretions along bedding planes, with salts in basal meter or so.

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 massive sequence of unit (*b*) was probably deposited in shallow, standing waters, subject to repeated emergence, probably near the mouth of the former Omo-Delta. This is compatible with occurrences of silicified (drift?) wood, and fragments of fish, crocodile or hippopotamus.

No materials suitable for radiocarbon dating were recovered and archeological sites appear to be absent. However, an early Upper Pleistocene age can be inferred from the under- and overlying strata.

Approximately 25 meters of dissection by several channels of the Omo followed deposition of Member II. Downcutting extended to below 20 meters above modern floodplain.

Member III

The deposits of Member III extend from 20 to 47 meters above modern floodplain, indicating a total thickness of at least 27 meters. However, cumulative measured thickness northeast of Kenya Camp and in Rhino Canyon is 45.5 meters. The stratigraphic column, based on these two areas, is as follows:

(*a*) 6.0 meters (base). Light yellowish brown, stratified clayey silt interbedded with bands of brown to pale yellow conglomerate, consisting of derived concretions and some fine-grade basalt or quartz pebbles, in a matrix of silty coarse sand.

(*b*) 6.6 meters. Dark grayish brown, poorly stratified clay, interbedded with lenses of brown clayey silt. Some slickensides and local limonitic mottling.

(*c*) 7.0 meters. Pale brown, well-stratified to laminated silty clays, interbedded with lenses of clayey silt. Horizontal bands of yellowish-red limonitic staining common in sandier beds near top.

(*d*) 1.5 meters. Very pale brown, well-stratified, clayey silt and medium-sandy silt, with intensive reddish yellow limonitic staining. Top of bed locally calcreted, indicating a paleosol.

(*e*) 3.6 meters. Light gray, laminated tuff with the texture of a well-sorted silt, interbedded with laminae of clayey detritus. Calcrete zones near base.

(*f*) 4.0 meters. Brown, stratified, medium-grade sand with abundant calcareous nodules and root drip.

(*g*) 0.15 meters. Strong brown, stratified, coarse sandstone with very abundant impressions or partly decalcified shells of *Melanoides tuberculata* as well as fragments of *Unio*.

(*h*) 4.9 meters. Pale brown, stratified to laminated, clayey silt grading upward into silty clay, with increasing sodium salts and some limonitic staining.

(*i*) 1.8 meters. Brown, well-stratified to laminated, clayey or silty medium-sand, with limonitic staining and incipient ferruginous concretions.

(*j*) 1.0 meter. Alternating strata of (*i*) thin-bedded, pale brown, laminated, clayey silt, and (*ii*), massive, grayish brown, stratified, clayey silt rich in salts. Intensive reddish yellow, limonitic staining in most horizons.

(*k*) 4.2 meters. Dark yellowish brown to dark brown, well-stratified or cross-bedded, well-sorted, medium sand, interbedded with laminae of ferruginized clayey silt or thin lenses of brown, silty sandstone. Locally grades upwards into a fine to medium-grade pumice gravel in a matrix of pale yellow sands. *Etheria* bed *in situ.*

(*l*) 4.6 meters. Alternating, inclined beds (2 to 15°) of (*i*) dark gray, silty clay with diffuse salts and calcareous microconcretions, and (*ii*) brown, laminated, clayey silt. Reddish-yellow limonitic mottling.

The first two units occupy a network of broad, shallow channels, once diverging and converging along the axis of the modern Omo River north of latitude 5.21°. Texture and morphology suggest distributaries of a former delta. The clayey and silty beds of units (*c*) and (*d*) range up from channel fill to a broad mantle exposed through much of the study area. These extensive horizontal strata can best be related to accretion along the former delta-fringe. The subsequent tuff (*e*) is also widespread, and may possibly reflect on a prodeltaic environment. The calcareous horizon between (*d*) and (*e*) suggests a period of emergence and a Calcorthid paleosol.

Deposition of the tuff (*e*) was followed by a period of general erosion, with some downcutting, and the later beds rest disconformably on an undulating surface. The sequence of units (*f*) through (*e*) described above is extensively exposed over a wide area in the former delta. Beds (*h*) through (*j*) were deposited in shallow, standing waters near the mouth of this delta; the widespread sands, shell beds, or root drip of (*f*) and (*g*) suggest fluvial and/or littoral deposition; while beds (*k*) and (l) are distinctly fluvial, recording channel and levee beds. On a local scale, channel fills of medium-grade tuffaceous sand or fine wafery tuffs appear to have been laid down at about the same time as unit (*e*). A final period of emergence is indicated by the calcareous paleosol.

The *Etheria* of unit (*k*) has been dated at « greater than 37,000 yr. » by C^{14} and around 30,000 ± 500 P.B. by Th^{230}/U^{234} (L-1203-A) (²). In addition, *Unio* shell from a stratigraphically lower part of Member III gave a determination of 26,700 ± 2500 B.P. (L-1203-F), to be considered as a minimum age (³). This would suggest that Member III dates from the mid-Upper Pleistocene, probably from the Würm Interpleniglacial (see van der Hammen *et al.*, 1967). Such a date is not unreasonable since the limited mammalian fauna is essentially modern in aspect; no *in situ* archeology has been found, although some cranial fragments of a *Homo sapiens* may have come from this member (see Butzer, Day and Leakey, 1969).

Assuming that deposition of Member III terminated before 37,000 years B.P., a long period of dissection and erosion ensued, with local evidence of calcretion and patination, presumably under drier conditions (Butzer, 1970). During this time the Nakwa tuffs and basalts were extruded (see Brown and Carmichael, 1969). The amplitude of subsequent dissection is difficult to assess, but exceeded 15 meters in the White Sands area.

Member IVa

The youngest units of the Kibish Fm., Members IVa and IVb, are more difficult to delineate since deposits are relatively shallow, comprising a great variety of surficial deposits with frequent lateral variations of facies. An older generation, without morphological expression, can be recognized at three key localities. This is Member IVa.

In the Rhino Canyon area, the sequence is as follows:

(*a*) 0.1 meter (base). Brown, stratified sandy silt with masses of *Corbicula fluminalis, C. radiata, Melanoides tuberculata, Cleopatra pirothi, Cleopatra bulimoides,* and unionidae.

(*ii*) 0.6 meter. Grayish brown, poorly stratified, silty clay and clayey silt, with sodium salts.

(²) Note that the radiocarbon age and the Th^{230}/U^{234} age (30,000 ± 500) are not consistent with each other, the latter being significantly too young. This is a common problem with Th^{230}/U^{234} dates of molluscs. One should again rely more heavily on the geologic evidence for age with the radiocarbon date of > 37,000 being a firm minimum.

(³) One should note that carbonates are subject to contamination by exchange of CO_2 between their outer layers and the atmosphere. The possibility that this occurs makes the accuracy of all radiocarbon ages of carbonates greater than about 25,000 years old difficult to evaluate. If one has dated a series of samples which are contemporaneous, but give inconsistent results, the oldest should be taken as the best minimum age for the formation. If all give the same age, this should also be considered a minimum. In fact, the inconsistency indicates that L-1203-F is unacceptable as a " date ".

(*iii*) 1.3 meter. Pale brown, laminated silt and clayey silt, with bands of reddish yellow, limonitic staining. Scattered aquatic shells.

(*iv*) 0.1 meter. Shell bed as unit (*m*) (*i*).

(*v*) 0.2 meter. As unit (*m*) (*ii*).

(*vi*) 1.7 meter. As unit (*m*) (*iii*).

(*b*) 3.6 meters. Pale brown, stratified, silty medium sand with brown, calcareous-ferruginous concretionary bands and with root drip. Abundant *Corbicula fluminalis* with some *C. radiata* and *Unio* sp.

A C^{14} date of 8650 ± 150 B.P. (1-1203-B) was obtained from (*a*) (*i*) and one of 8700 ± 200 B.P. (L-1203-D) from (*a*) (*iv*). A lateral equivalent of unit (*a*), also from Rhino Canyon, gave 9500 ± 150 B.P. (L-1203-C), while a lateral equivalent of identical facies, south-east of Kenya Camp yielded 8900 ± 300 B.P. (L-1303-H). Unit (*b*) has a date of 8800 ± 200 B.P. (L-1203-E) ([4]).

Another sequence of deposits can be recognized north of Kenya Camp:

(A) 0.9 meter. Pale brown, stratified, clayey silt.

(B) 1.1 meter. Light gray, well-stratified to laminated tuff, with the texture of a well-sorted silt.

(C) 0.3 meter. Pale brown, well-stratified gravelly coarse sand with calcareous cement (18% $CaCO_3$) and limonitic staining. The pebbles consist of fine-grade quartz with some basalt or rhyolite. Local *Etheria* banks. Grades laterally into a coarse sand rich in *Corbicula fluminalis*, with some *Unio* sp., and *Melanoides tuberculata*.

(D) 0.9 meter. Pale brown, well stratified, partly inclined or crossbedded, clayey silt with derived concretions and shells from (C).

A date of 9100 ± 300 B.P. (L-1203-M) has been obtained from *Corbicula* in bed (C) and a further date is pending from an *Etheria* bank.

This unit contains a number of bone harpoons and stone artifacts. The conglomerate yielded 2 unrolled, amygdaloid hand-axes and a 16 cm. long harpoon, barbed on one side. The latter was found by R.E. Leakey, who also found 8 broken harpoon points, barbed on one or two sides, on the surface, as well as another handaxe (with matrix attached), in the sandy facies.

A third sequence is present at White Sands (5.21° N, 36.12° E). The column represented here is as follows:

(α) 1.6 meter. Pale brown to light brown, well-stratified coarse sands with quartz granules or lenses of fine-grade quartz gravel; grading up into grayish brown

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([4]) Although the radiocarbon ages reported here should be consistent with each other, comparisons with other determinations should be made with caution because of the possibility that carbon dioxide in the lake used to build the mollusc shells was not completely equilibrated with the atmosphere. From a knowledge of the lake chemistry (Beadle, 1932), and morphology, and an understanding of the physical processes of exchange (Thurber and Broecker, in press), one may predict that the C^{14}/C^{12} in the lake waters is within 90% of that in the atmosphere. The ages reported here are calculated with the assumption that the lake water would give an "age" of 400 years. The true ages may, however, be as much as 800 years younger.

silty medium-sand, interbedded with laminae of sandy clay. Abundant limonitic mottling. Some root casts and bone fragments.

(β) 2.0 meters. Very dark gray, medium-sandy clay, with secondary quartz sand admixture in dehydration crack network of a former vertisol. Grades laterally into light gray to olive gray, medium-sandy clay.

(*ii*) 0.85 meter. Grayish brown, stratified, sandy silt, with sporadic basal lenses of medium-grade, subrounded and chemically-frosted quartz gravel.

(γ) 1.05 meter. · Alternating well-stratified beds:

(*i*) 0.45 meter. Light gray, stratified clayey medium-sand with thin gravel bands of fine quartz and coarse, rolled diatomite derived from the Omo Beds.

(*ii*) 0.35 meter. Pale brown, well-stratified, clayey coarse sand with inclined bedding.

(*iii*) 0 to 0.25 meter. Light browninsh gray, clayey coarse-sand forming a 1-2 meter wide rill-channel filling. With extensive reddish yellow limonitic staining of ped faces, and abundant shells of *Melanoides tuberculata,* some *Unio* sp., and occasional *Corbicula fluminalis.*

(*iv*) 0.30 meter. Alternating beds of light gray, medium-sandy silt and light brownish gray, clayey silt, interspersed with zones of quartz or diatomite pebbles.

(δ) 4.5 meters. White to light gray, laminated, mixed tuff with clayey silt texture. Abundant *Melanoides tuberculata in situ.*

(ε) 1.7 meters. Pale brown, stratified medium-sandy silt, some with shell debris and abundant *Melanoides tuberculata,* some *Corbicula fluminalis,* and rare *Unio* sp., *Cleopatra bulimoides,* and *Planorbis* or *Bulinus* sp.

(ζ) 1.5 meters. Pale brown, stratified, silty medium-sand or sandy silt, with zones of quartz granules. This bed frequently weathers to a fine gravel lag; elsewhere it may exhibit a 35 to 40 centimeter, pale brown to yellowish brown, mulliform A-horizon (AC-profile).

Unio shell from (γ) (*iii*) gave a date of 9500 ± 150 B.P. (L-1203-J), but unit (ε) has not yet been dated in order to determine whether or not beds (δ) to (ζ) still belong to the same stratigraphic complex. Unit (ζ) contains some artifacts, including Levallois and non-Levallois flakes, points, small bifaces, and possible basalt manuports. These may have been in functional association with fish bone (*Clarias* sp., *Lates niloticus*).

Interpretation of the depositional environments of these three sequences is essential to a reconstruction of the stratigraphic column for Member IVa. In the view of Butzer, beds (α)-(γ) and (A)-(D) are primarily fluvial, possibly marking the initial lake transgression up the Omo River floodplain (*ca.* 9500-9000 B.P.). Subsequently, beds (*a*) and (*b*) may record a littoral environment at the time of highest lake level (*ca.* 9000-8600 B.P.). The ensuing regression appears to have been recorded by successive beach ridges at lower elevations, including an *Etheria* bank in position of growth on basalts of the Nakwa (Kuraz) Hills (7900 ± 150 B.P., L 1203-L). If this interpretation is accepted, the thickness of Member IVa at the White Sands and Rhino Canyon type sites would be some 13 meters.

The period of sedimentation can be approximately dated between 9700 and 7700 B.P., suggesting a duration of 25,000 years or more for the preceding period of non-deposition. Subsequent dissection in the U.S. Camp and White Sands area probably exceeded 30 meters.

Member IVb

The stratigraphic column of Member IVb is still uncertain since a number of potential type sites remain to be dated by C^{14} in order to confirm the geological stratigraphy. Sequences at any one site are shallow, seldom more than 5 to 8 meters at a maximum.

A transgressive, gravelly sandstone near Todenyang, from a little below to as much as 15 meters above the modern level of Lake Rudolf, gave a C^{14} date of 6600 ± 150 B.P. (L-1303-D) on mixed shell. High beach ridges, marking a maximum of the succeding transgression, include *Unio* shell which at PGK gave 5700 ± 100 B.P. (L-1203-G). Similar shell, in a position of growth in a massive and widespread tuff B — extending from PGK to White Sands — gave 5750 ± 100 B.P. (L-1203-K). Finally, littoral shell beds overlying deltaic sands at Pelvic Corner have been dated at 5450 ± 100 B.P. (L-1203-I).

The stratigraphy of this last site deserves mention, in view of its archeological materials:

(*i*) Over 2.5 meters (base). Alternating 10 to 15 centimeter strata of (*i*) brown to yellowish brown, stratifield, sandy silt and clayey silt, and (*ii*) pale brown, well-stratified or crossbedded, silty coarse sand with rolled molluscan fragments.

(*ii*) 0.8 meter. Brown, stratified, silty coarse sand with dispersed shells or proliferations of *Melanoides tuberculata, Corbicula fluminalis, Cleopatra pirothi, Viviparus* and unionidae (L-1203-I).

(*iii*) 0.4 meter. Brown stratified, silty coarse sand with stratified shells as (*ii*).

Whereas the basal unit (*i*) is clearly fluvial, with some channel beds, the upper strata (*ii*) and (*iii*) dip at 2° towards the modern Omo River and suggest a littoral origin. Cultural materials have weathered out from the base of (*iii*) or the top of (*ii*). They include fragments of a human skeleton (currently being studied by M. H. Day), several basalt manuports, abundant chert *débitage,* a few scrapers and blades, a lunate, a micro-tranchet, and abundant coarse pottery. In addition to human bone there are remains of buffalo (*Syncerus*), hyppopotamus, an equid, antilope, fish, and a possible tortoise (Lynn Fichter, *personal communication*). All of the bone is thoroughly mineralized, and the skull and longbones of the hominid are smashed just like those of the mammals, possibly suggesting cannibalism (Jean de Heinzelin, *personal communication*).

A terminal age for Member IVb has not yet been fixed. One high beach ridge yielded a date of 3250 ± 150 B.P. (L-1203-H) on mixed shell, and other such ridges remain to be dated. One lake maximum dates *ca.* 5900-5300 B.P., but the whole period of sedimentation may span a longer time range from *ca.* 6500 to 3000 B.P. Subsequent dissection in the Rhino Canyon area has exceeded 45 meters.

Significance of the Kibish Formation

The full paleogeographical implications of the Kibish Formation can only be understood from the areal distribution of the beds. To this end, the surficial geology of the southwestern quadrant of the Lower Omo Basin, an area of some 11,000 km., 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 IVb 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 meters, that is, 80 to 85 meters 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. Distinct littoral forms at 435-455 m. elevation can be followed southwestwards from the former Omo Delta to the drainage divide, and hydrographic links with the Nile system via the Pibor-Sobat drainage are indicated on faunal grounds (see Fuchs, 1934, 1939; Roger, 1943) [5].

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 IVa and again between IVa and IVb. Consequently, the period corresponding to the last Pleniglacial in higher latitudes

Table I. — SUMMARY STRATIGRAPHY OF THE KIBISH FORMATION.

Member	Number of Beds	Measured Cumulative Thickness	Minimum Amplitude of Subsequent Dissection	Approximate Age (or Correlation)
IVb	—	*ca.* 8	45	6500-3000 B.P.
IVa	(5)	13.1	30	9700-7700 B.P.
III	12	45.4	15	terminated before 30,000 B.P.
II	2	22.4	25	Early Upper Pleistocene (?)
I	7	26.0	19	Late Middle Pleistocene (?)
Total . . .	23	115.0		

(5) 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.

appears to have been comparatively dry in the Omo-Rudolf Basin, while much of the early and mid-Holocene was relatively moist. Similarly the last Interpleniglacial and two earlier phases in the late Middle to Early Pleistocene time range were also moist. It is still premature to relate these to specific units of the higher latitude glacial sequence. However, the late 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 Butzer and Hansen, 1968).

The Kibish Fm. provides one of the longest and most detailed stratigraphic columns for the later Pleistocene and Holocene in Africa (Table I). After completion of all the related studies, this sedimentary sequence may prove suitable as a time-stratigraphic norm for the later Quaternary of East Africa.

ACKNOWLEDGEMENTS

These field studies were supported by grant GS-1471 of the National Science Foundation and by supplementary grants from the Wenner-Gren Foundation to F. Clark Howell (University of Chicago). Much of the sedimentological work was carried out by B. G. Gladfelter and Claudia Carr (University of Chicago) while J. A. Kirchner drafted the map. The radiocarbon and thorium-uranium determinations were made possible by grants GA-1346 and GA-1648 of the National Science Foundation. Richard Pardi and John Goddard assisted with the analyses. Finally, we are grateful to the Imperial Ethiopian Government and the Institut Ethiopien d'Archéologie for their efforts to facilitate the field work.

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ZUSAMMENFASSUNG

Die Kibish-Bildungen (Delta-, Litoral- und Fluvialfazies) des unteren Omo Beckens bestehen aus 4 Abteilungen (Members), deren Gesamtmächtigkeit 120 m. beträgt. Die unterste Abteilung (Member I), mit einer Th/U Bestimmung von 130.000 J.v.H., hat eine Mächtigkeit von 31 m.; Abteilung II beträgt 22 m., Abteilung III 46 m. Letztere hat C^{14} Datierungen von « mehr als 37.000 » und 26.700 v.H. sowie eine Th/U Bestimmung von 30.000 v.H. Ein langer Abschnitt ohne Ablagerung, etwa 25.000-9.700 v.H., wurde abgelöst durch Aufschüttung der Abteilungen IVa (*ca.* 9700-7700 v.H.) und IVb (*ca.* 6500-3000 v.H.), mit einer Gesamtmächtigkeit von etwa 21 m. Die Zeitabschnitte aktiver Sedimentation waren mit einem hohen Niveau des Rudolfsees verknüpft. Die Ablagerung von delta, fluvialen und

ufernahen Bildungen bis zu +80-85 m. erfolgte in Zeiten feuchteren Klimas. Einschneidungsabschnitte deuten andererseits auf niedrige Stände des Rudolfsees, d.h. ein relativ trockenes Klima, mehr mit dem heutigen zu vergleichen.

RIASSUNTO

La formazione dell'Omo, di tipo deltizio, litorale e fluviale, include 4 membri, con uno spessore stratigrafico totale di 120 m. Il più antico, il membro I, ha uno spessore di 31 m. e sembra risalire al Pleistocene superiore antico. Il membro II ha uno spessore di 22 m.; il membro III di 46 m. Per una parte terminale di quest'ultimo si ha una datazione al C 14 di « più di 37.000 anni ». Un lungo intervallo in cui non vi fu sedimentazione, circa 35.000-9.700 B.P., fu seguito dal modellamento dei membri IV-a (circa 9.700-7.700 B.P.) e IV-b (circa 6.500-3.000 B.P.), per uno spessore totale di circa 21 m. I periodi di deposizione hanno corrisposto ad un alto livello del Lago Rodolfo, con accumulazioni deltizie, litorali e alluvionali ad un'altezza di +80-85 m., in una fase di clima relativamente umido. Gli intervalli di non-deposizione e dissezione, d'altro canto, indicano bassi livelli del lago ed un clima relativamente secco, più vicino a quello attuale.