GEOMORPHOLOGICAL OBSERVATIONS IN THE LOWER OMO BASIN, SOUTHWESTERN ETHIOPIA

With 2 figures, 6 photos and 1 table

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Introduction

The Omo is the largest river of western Ethiopia, with a drainage basin of almost 70 000 sp. km. The river flows 1 000 km. from latitude 9° 22' N to the shores of Lake Rudolf at 4° 29' N. The watershed of the main catchment area, north of about 6° latitude, lies at elevations of 2 000 to 4 000 m and the Omo descends rapidly through a series of canyons and deeply-incised valleys onto a broad tectonic depression that merges with the northern end of the Rudolf trough (Fig. 1). The level of this non-outlet lake, with an area of 7 700 sq. km., is at about 370 m. This gives the drainage basin considerable potential energy and the river has a mean gradient of 27:10 000.

The upper and middle Omo drainage shows striking geometric arrangements of its principal streams within a topographic matrix of great shield volcanoes. This suggests successive accretions of the headwater segments of rivers that once drained to the Sobat and Blue Nile Rivers, prior to the Miocene extrusion of the volcanic domes that now crown the Ethiopian Plateau. The lower third of the basin is aligned with the quasi-rectilinear shorelines that bound the northern half of Lake Rudolf. Deep sedimentary fills and younger extrusives cover the broad floors of this sector, defining a complex tectonic depression known as the Lower Omo Basin.

This geomorphologic entity ranges from the arid shores of Lake Rudolf to the semiarid mountain fringe, with elevations of 1 000 to 2 000 m or more. By extrapolation of climatic observations from northern Kenya, supplemented by short-term local records from different sources, annual precipitation values of about 400 to 600 mm can be inferred. Rainfall comes primarily in the form of thundershowers during April or May and, in the high country north of latitude 5 or 6°, during July or August. As a result, the Omo is an exotic stream in its lower basin and its two major affluents, the Kibish and Usno Rivers, are generally dry during the low-sun season. Minor stream networks are correspondingly poorly integrated, with radial highland drainage failing on broad piedmont slopes (see Fig. 2).

Field Studies in the Lower Omo Basin

Geomorphological research in southwestern Ethiopia has been largely limited to the comments of explorers and surveyors. L. v. HÖHNEL, who discovered Lake Rudolf in 1888, made useful observations on the Omo Delta and supplied sufficient field data for E. SUESS to infer the basic nature ot the Rift Valley in this part of Ethiopia (HÖHNEL et al., 1891). The Bottego Expedition established the relationship of the Omo River and Lake Rudolf in 1896 while its geologist, M. SACCHI, first recognized widespread lacustrine deposits in the lower basin

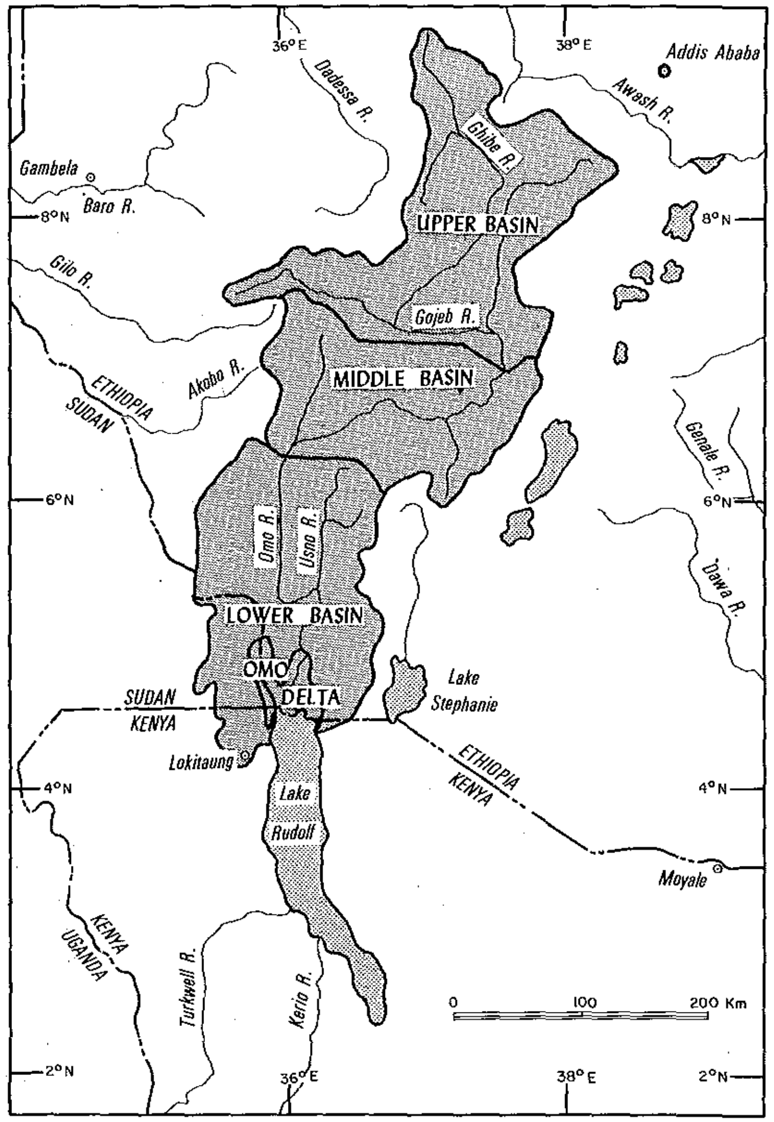

Fig. 1: The Omo Basin and Lake Rudolf.

(D'OSSAT and MILLOSEVICH, 1900). In 1902 the fossiliferous Plio-Pleistocene Omo Beds were discovered by E. BRUMPT (BOURG DE BOZAS, 1903), leading to widespread interest among paleontologists. Extensive topographic mapping accompanied the first delimitations between Ethiopia and Kenya in 1903 (MAUD, 1904) and again in 1908 (GWYNN, 1911). Thereafter this frontier area remained essentially closed except for the major paleontological expedition of C. ARAMBOURG in 1932-33 (ARAMBOURG, 1943-48). Italian efforts after 1936 were restricted to some reconnaissance by M. MARCHETTI and by the ZAVATTARI Expedition, the results of which were incorporated into DAINELLI's (1943) fundamental study on the geology of Ethiopia (see also MOHR, 1964, 1968).

The British campaign of 1940-41 led to extensive but incomplete aerial photography, followed up by partial air photo coverage (at about 1:77 500) in 1957-59. The only attempt at semi-detailed topographic mapping, the Kenya 1:100 000 series (Y 633, 1961), was based on these photos. Since 1965 a joint U. S. A. -Ethiopian mapping project has been engaged in low-level photography, the results of which remain unavailable. As a result the only existing or accessible maps and air photos are currently restricted to the border zone adjacent to the Sudan and Kenya frontier.

During September-October of 1966, F. H. BROWN initiated systematic geological work in the Omo Beds, preliminary to an international expedition (U. S. A., France, Kenya) that studied the Lower Omo Basin for a total of almost 7 months during 1967-68 (see HOWELL, 1968) with ongoing work in 1969. The „American" contingent was led by F. CLARK HOWELL (University of Chicago) and included 3 earth scientists: F. H. BROWN (Berkeley), J. DE HEINZELIN (Rijksuniversiteit-Gent), and myself. I was responsible for the geomorphology and a part of the stratigraphic work. As a result of HOWELL'S earlier field experience (1959) in the almost inaccessible Omo Basin, and thanks to the generosity of the National Science Foundation, a Hughes-300 helicopter was chartered for most of the time. The general mobility as well as the aerial perspective provided by a helicopter over difficult or almost unmotorable terrain proved indispensable for the geomorphological work. Consequently I was able to map the surficial deposits of an area of 11 000 sq. km. at 1:100 000 with the help of the available air photos, and of certain, more restricted „type" areas (65 sq. km.) at 1:11 000 with special air photos taken by R. I. M. CAMPBELL from a Piper Cherokee aircraft in 1967.

The paper will outline, in preliminary fashion, the major geomorphological characteristics of the Lower Omo Basin. A preliminary stratigraphy of the sedimentary formations, radiometrically fixed by suites of potassium-argon and radiocarbon dates, has already been outlined (HOWELL, 1968; BUTZER and THURBER, 1969). Sedimentological analyses are still underway in the laboratory, so precluding a more detailed discussion of the soils here. Similarly, the intensive plant-ecological work of CLAUDIA CARR remains to be fully evaluated before a climato-geomorphological synthesis can be attempted.

The Tertiary Origin of the Basin

The regional basement of this part of East Africa is formed by Precambrian metamorphics, primarily gneisses with intrusions of granite and pegmatite. These crystalline rocks appear to have been bevelled by one or more periods of planation during late Cretaceous to early Tertiary times (see SAGGERSON and BAKER, 1965), prior to accumulation of the first known sedimentaries. These are the Turkana Grits, a suite of up to 300 meters of coarse arcosic sandstones, grits, and quartz conglomerates (WALSH and DODSON, 1966; FUCHS, 1939; ARAMBOURG, 1943). The sand grains include subrounded quartz, altered feldspars, micas, and ferromagnesians derived from the Precambrian „Basement Complex" and probably deposited in a terrestrial or lacustrine environment. The Turkana Grits are locally intercalated with and then overlain by a massive series of extrusive vulcanics, totalling at least 1500 meters in thickness. Basalts and rhyolites are dominant, with limited development of phonolites, nephelinites, and andesites. Potassium-argon dates suggest that these extrusives range in age from late Oligocene to late Miocene or early Pliocene (REILLY et al., 1966; MOHR, 1968).

Downwarping of the floor of the Eastern or Kenya Rift Valley seems to have begun by early Miocene times, but major faulting and folding in the Lake Rudolf area appears to date from the Pliocene (see also McCALL et al., 1967). Be this as it may, the Lower Omo Basin had been created along essentially modern lines during the first part of the Pliocene period. The Miocene extrusives and the underlying crystalline rocks of the Basement Complex were downwarped and downfaulted prior to the deposition of the earliest known deltaic sequence, over 4.25 million years ago. Block-faulting upraised the Amar-Kokke horst to the east, between the Omo River and Lake Stefanie (SCHOTTENLOHER, 1938). West of the basin a series of fault blocks were formed that appear to form part of a system of fractured, plunging folds. As a result the country west and southwest 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.

The Mountain Peripheries

The margins of the lower Omo valley are demarcated by massifs of volcanic rocks that rise about 1000 to 1500 m above the basin floors. These ranges or mountain blocks are individually delimited by complex fracture zones, some of which can be observed or directly inferred (see Fig. 2).

The mountain groups to the north (Nkalabong), northwest (Ilibai, Donyiro, Naita) and west (Lorionetom, Lokwanamoru) of the Lower Omo Basin (Fig. 2) are broadly similar in terms of geomorphology. With exception of the granitic plug of Mt. Naita and olivine basalts well-developed in the southern part of Lorionetom, these mountains are primarily built of rhyolite flows (see HOWELL, 1968; BROWN, in preparation; ARAMBOURG, 1943; FUCHS, 1939) The uplands proper consist of ridges and rolling platforms, with average slopes of 5-10°. These are offset from the footslope regions by steep midslopes, with individual slope segments and facets ranging from 25 to 90°, but averaging about 35-45°. Irregular platforms of limited development are commonly found along these midslopes, between the steep-sided, stream-cut incisions that lace the mountain flanks (photo 1). Most or all of these benches result from resistant lava units. Footslopes are normally pedimented or mantled by extensive spreads of coarse-grained alluvium. Where the footslope regions are abruptly limited by major faults, as along the southeast edge of Nkalabong, alluvial fans or cones, generally of Holocene age, are developed (photo 1). Where the footslopes are broad and the inevitable fracture zones are masked by alluvial spreads, pediments are better developed and one or more generations of dissected fans or other alluvia may be present. Generalized slope in the piedmont regions varies from 0.5 to 5°.

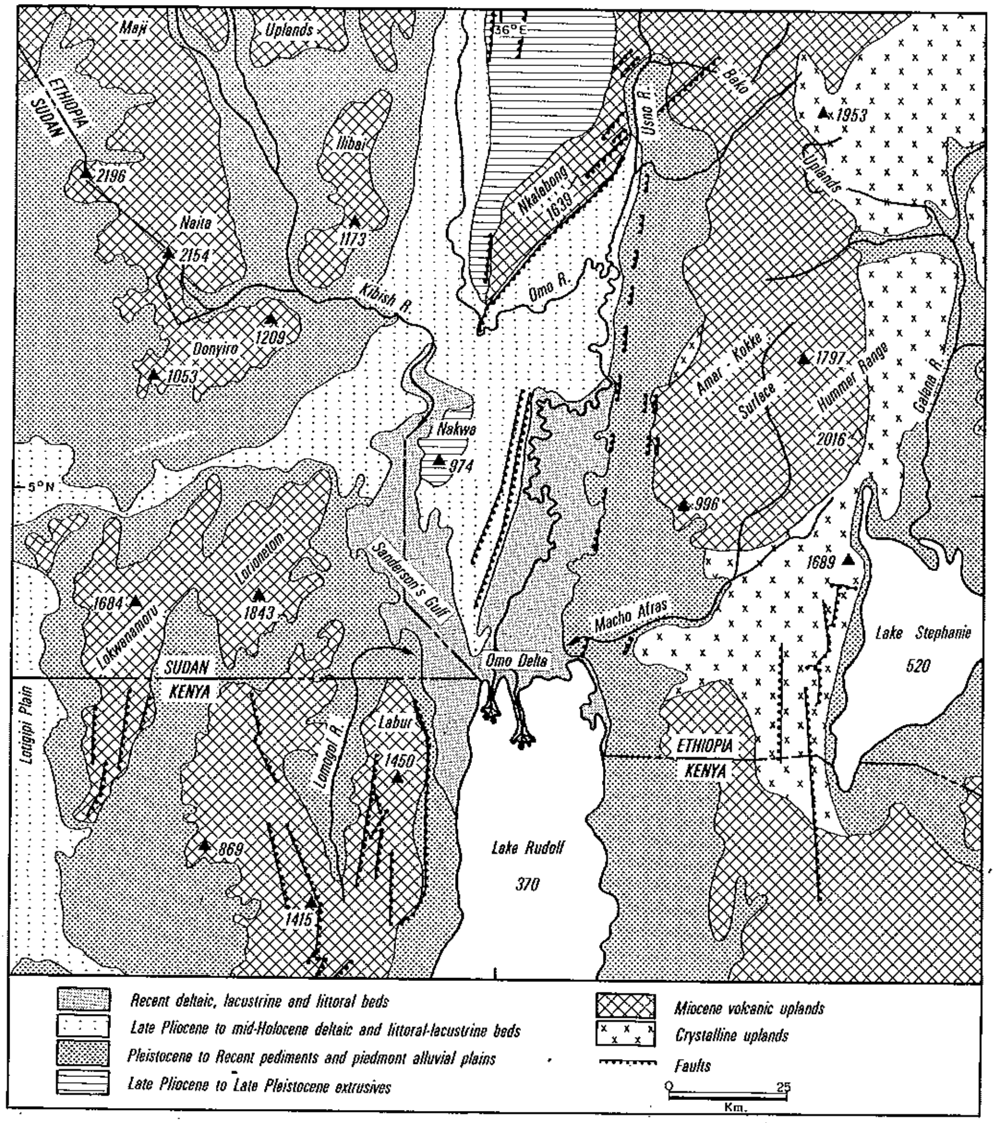

Fig. 2: Geomorphology of the Lower Omo Basin. Structural features, in part after WALSH and DODSON (1966), are incomplete and provisional. Delimitation of the Basement Complex and vulcanic uplands east of the Omo Basin is approximate only.

Deep soil mantles that may once have developed on the mountain massifs have long been eroded. Cobbles and boulders of weathered rhyolite now litter even the smoother surfaces, and great talus aprons and cones are characteristic of the hillsides. Although partly fixed by grass and tree vegetation, these talus mantles are not immobile and render climbing difficult. Everywhere there are reworked vestiges of a former cover of loamy, reddish brown (5YR 5/3, dry) soils. These occur as a 5-10 cm veneer among the lag-strewn uplands, or as a heterogeneous matrix to the talus sheets. Recent humification has darkened these relict soils and non-calcareous, alkaline, brown (7.5 YR 4/2, 5/4, dry), silt loams are characteristic of more typical exposures.

The uplands to the east of the Lower Omo Basin (Fig. 2) are somethat different. Characteristically they form an intermediate-or low-level plateau, extending from the Amar-Kokke horst southwards along the eastern margins of the Rudolf trough. Most striking of these plateaus is the Amar-Kokke planation surface (photo 2), cut across rhyolitic rocks that mantle outcrops of the Basement Complex. Residual masses stud this 900-1200 m, probably complex, surface, while intensive dissection has further increased the relief. The highlands to the east (Hummer Range, 1500-2000 m) and northeast (Bako Uplands) rise sharply above the Amar-Kokke surface, their prominence possibly accentuated by fault displacements. The western periphery, to the pediments and piedmont alluvia of the Omo lowlands, is steeply dissected and demarcated by a complex of *en échelon* faults. The upland between Lakes Rudolf and Stefanie falls off gently to the west from a smaller horst block (1000 m) just west of Stefanie. Erosional development of the Macho Afas drainage has been a dominant factor here, stripping the volcanic mantle rocks and developing great alluvial fans adjacent to the Omo Delta. Further south, in Kenya, rhyolites and basalts form a desert plateau (at 600-900 m), its western margin mantled by intensively dissected and denuded lacustrine and littoral deposits of a higher Lake Rudolf.

In general, whereas the rhyolitic surfaces tend to be sub-horizontal, reflecting lava stratification, the metamorphic basement erodes in an irregular fashion with dikes of resistant rocks assuming great prominence. Unlike the rougher highlands, the Amar-Kokke horst, in particular the irregular upland plains in the high Macho Afas drainage, have moderately extensive soil mantles. These are utilized by the Amar tribe and provide the resource base for localized areas of agricultural landscape. Rubefied soils appear to be dominant, although colluvial reworking is common in bedrock areas with rolling topography.

Pediments and Piedmont Alluvia

Perhaps the most striking zonal aspect of the regional geomorphology is the broad development of typical pediment surfaces, intergrading with alluvial fans or piedmont alluvial plains. Commonly these footslope forms attain a width of 10-20 km or more.

The pediments may occasionally be cut in older alluvium, but generally cut across bedrock (photo 3). Lightly veneered by sandy alluvium, they are crisscrossed by anastomosing rills and are best developed where no major streams emerge from the highland flanks or where bedrock hills have been disassociated from the major highland groups. Most of the pediments remain functional, although they are older than the different generations of alluvium that normally rest on a rock-cut base. Several levels of strongly-dissected pediments, formerly cut across metamorphic rocks, can be recognized north and south of the Macho Afas. Since they are 100 to 200 m higher than the highest exposures of late Pliocene sediments of the basin floor, these may well be of mid-Pliocene age. Elsewhere the pediments are graded to about the same level as the basin-floor fill. Bevelling of these rock surfaces must have begun prior to deposition of the earliest deltaic sequence, at least 4.25 million yr old, since these beds are in part disposed on top of pediment-like footslopes of the western Nkalabong Range. However, pedimentation 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 piedmont alluvia are best developed adjacent to the larger, episodic streams draining the highlands. Although younger than most of the pediments, the alluvia are more informative. So for example, east of Lorionetom (see Fig. 2 and photo 3), two major generations of gravelly piedmont alluvia can be tentatively assigned to the late Pleistocene; they rest disconformably on late Pliocene lacustrine tuffs and are overlain by early Holocene littoral and lacustrine formations of Lake Rudolf. A degraded brown paleosol was formed on both alluvia prior to this early Holocene transgression. Original profile depth was 2.5-4.0 m, with strong brown (7.5 YR 5/6, dry) loams or clay loams in the (B)-horizon. Parent material was basalt, rhyolite and chert gravel in a matrix of sand, mainly quartz but with ferromagnesian minerals. North of the Macho Afas (see Fig. 2) there are intensively dissected fragments of at least one generation of rubefied alluvium. Here the truncated (B) and (B)C-horizons exceed 1.9 m in depth, with a yellowish red (5 YR 5/6, dry) loam developed in coarse, arcosic quartz sands or sandy gravels. In both areas younger alluvial spreads, where undisturbed, show less intensive late Holocene zonal soil profiles: a 60-centimeter A_1-horizon of brown (7.5 YR 5/4, dry) loam, moderately rooted and mull, under savanna grassland, and immediately over a C_1. There are no free carbonates; pH values are neutral or slightly alkaline (6.5-7.4); 14Å peaks in the clay mineral diffractograms indicate montmorillonite.

The paleosols must consequently record periods of longer or more intensive chemical weathering since they contrast strongly with the zonal soil profiles found at lower elevations (under 1500 m) today. At least two generations are indicated east of Lorionetom (photo 3) where, in addition to the late Pleistocene paleosol described above, derived *Rotlehm* sediments of reddish brown (5 YR 5/3, dry), clay loams are found at the base of the late Pliocene lacustrine beds. The younger, Pleistocene paleosol was subject to mechanical eluviation of fines after biochemical weathering came to a standstill; a little later, secondary calcification produced a 5-cm Ca-horizon at -25 to-30 cm depth within the former (B), still before the close of the Pleistocene. The partly-decomposed pebbles in the top 30 cm of these profiles have frequently been split *in situ* by salt-hydration; surface lag is normally patinated.

The geomorphologic and pedogenetic record of the piedmont environments suggests that late Cenozoic climate has generally been on the dry side. The geomorphologic record indicates alternating pediment-cutting, aggradation of coarse alluvial spreads (by higher competence rills and strams), and fill-dissection (by lower competence watercourses). The equally variable pedogenetic record suggests contrasting trends such as rubefaction with intensive pedogenesis; non-calcic grassland soil-formation; secondary calcification; salt-weathering;

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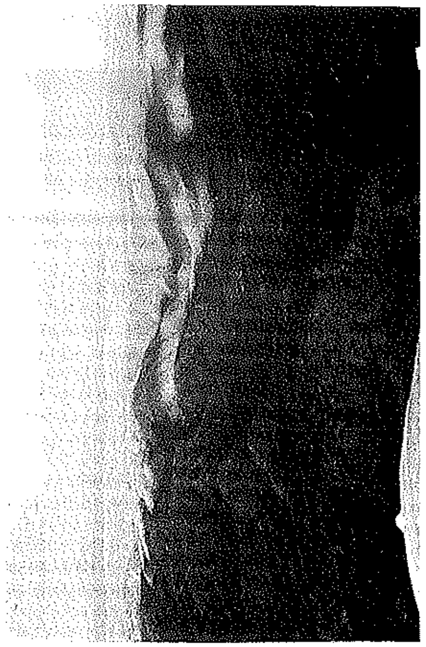

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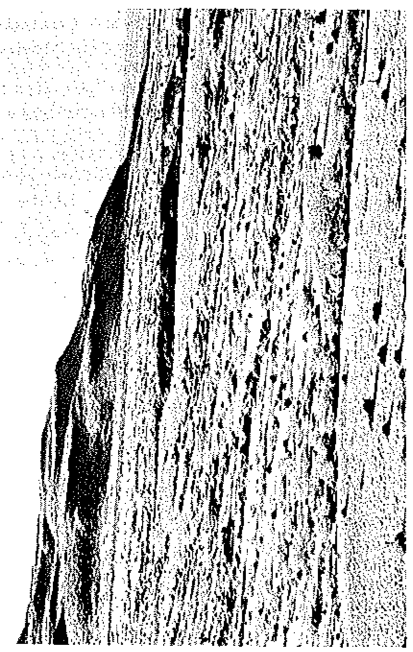

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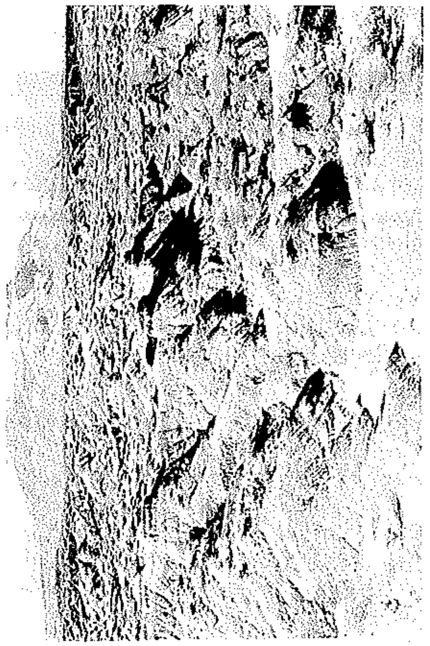

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Photo 1: Dissected fault scarp with Holocene alluvial fan (southeastern face of Nkalabong Range).

Photo 2: Amar-Kokke planation surface (smooth horizontal crests in middle background) with Bako Uplands rising abruptly at horizon. Dissected western margins in foreground (shadows).

Photo 3: Inclined pediment east of Lorionetom, cut across basalts and mantled with late Pleistocene piedmont alluvia (facing north).

Photo 4: Badland erosion in late Pliocene Mursi beds, Nkalabong Range in background (facing northeast).

Photo 5: Tilted fault-blocks of Plio-Pleistocene Omo Beds, with resistant tuff strata creating cuesta forms (facing southwest). An example of structurally-controlled dissection along fringes of Omo floodplain.

Photo 6: Meander train of Omo River upstream of Usno confluence. The riverine forest and partly-flooded alluvial flats are sharply offset from early Holocene Kibish beds (mixed fluvial-deltaic, with channel traces still apparent) in foreground.

and patination. This would suggest that ecological conditions have at different times been subhumid, semiarid, or arid.

The Dissected Littoral-Lacustrine Plains

The Floor of the Lower Omo Basin, between the fringe zone of pediments and piedmont alluvia, is filled by several massive series of sediments. The age, stratigraphy, and facies of this depositional sequence are summarized in Table I, after BUTZER and THURBER (1969), HOWELL (1958), and FITCH and MILLER (1969 a, b). The deposits range from strongly deformed Plio-Pleistocene beds (photos 4, 5) to younger undeformed strata of mid-Pleistocene to mid-Holocene age. With exception of lava flows and eolian tuffs, all belong to the Omo River and a formerly more extended Lake Rudolf. They are, then, in good part a reflection of climate in the upper and middle Omo drainage, rather than of regional processes. Nonetheless, periods of high lake level reflect a longterm positive hydrological balance over the entire Omo-Rudolf basin. Since Omo discharge provides by far the greatest part of the annual influx into Lake Rudolf today, a high lake indicates greater rainfall over the Ethiopian catchment of the Omo and/ or reduced evaporation over Lake Rudolf. The terminal deposits of each aggradational unit (Table I) culminate in the 450-455 m elevation range, i.e., 80-85 m above modern Lake Rudolf, and at about the elevation of the Omo-Lotigipi threshhold (north of Lokwanamoru). From there repeated hydrographic links to the Nile system, via the Pibor-Sobat River are indicated by the nilotic molluscan, fish, and reptilian faunas characteristic of Lake Rudolf since the late Pliocene (see BUTZER and THURBER, 1969; ROGER, 1943; WORTHINGTON and RICARDO, 1935). Consequently each of the depositional phases in Table I records periods of comparatively moist climate for the basin as a whole (see BUTZER and HANSEN, 1968, for discussion of the Sobat and Blue Nile headwaters).

Surface expression of the non-functional deltaic, prodeltaic and littoral sediments in the Lower Omo Basin (see Fig. 2) is largerly restricted to those of the youngest Kibish deposits. The Omo Beds are widely exposed west of the modern Omo Delta and a variety of older beds are dissected along the Omo floodplain fringes, southwest of the Nkalabong Range (see BUTZER and THURBER, 1969, Fig. 2). Elsewhere, however, littoral, delta-fringe or shallow-lake deposits of unit IV of the Kibish Formation constitute the land surface. The following surface forms are characteristic for these recent surficial deposits: (a) Long, sinuous beach ridges of coarse sand, with a relief of 3 to 9 m. These ridges often occur in multiple belts and may locally pass into spits. Former lagoonal mudflats may be located in their rear, occasionally replaced by low, fossil sand dunes of transverse („W"), blow-out, and barkhan types. All of these features find close contemporary analogues along the windward shores of Lake Rudolf. (b) Extensive prodeltaic and lacustrine mudflats of brown silty clays. The montmorillonitic clays and, to a lesser extent, the primary sodium salts, favor development of great polygonal crack networks. (c) Mixed fluvio-littoral beds, without ridge-like relief. Piedmont alluvia in some areas were deposited into standing waters and partly reworked by wave-action. These consist of well-stra-

Table 1: Late Cenozoic Sedimentary Units of the Lower Omo Basin

Formations and Members, Thickness and Facies, Absolute Ages (if determined)	Correlation
Narok Beds (deltaic, lacustrine, littoral) (contemporary)	Late HOLOCENE
Erosion	
Kibish Fm., IVb (8 m; littoral, deltaic) (ca. 5900-5300 B.P.)	Middle HOLOCENE
Erosion	
Kibish Fm., IVa (13.1 m; littoral, deltaic) (ca. 9700-7700 B. P.)	Early HOLOCENE
Erosion. Extrusion of Nakwa Basalts and tuffs.	
Kibish Fm., III (45.4 m deltaic, prodeltaic) (terminated 35 000 (?) B.P.)	MIDDLE/UPPER
Erosion	
Kibish Fm., II (22.4 m; deltaic, prodeltaic)	PLEISTOCENE
Erosion	
Kibish Fm., I (26.1 m; deltaic, prodeltaic)	
Erosion	
At least 3 episodes of faulting, probably localized	
Omo Beds (over 500 m, basal units possibly laterally interdigited with Nkalabong Fm.; fluvial, deltaic, prodeltaic) (ca. 3.75-1.8 mill. yr.)	LOWER
	PLEISTOCENE
Nkalabong Fm., III (18 m; lacustrine)	
Erosion	
Nkalabong Fm., II (32.5 m; some fluvial beds; eolian tuff dated 3.95 mill. yr.)	TO
Erosion	
Nkalabong Fm., I (37 m; alluvial beds and reworked terminal tuffs)	
Erosion	
Faulting, possibly localized	UPPER
Extrusion of basalts (ca. 4.25 mill. yr.)	PLIOCENE
Mursi Beds, I-III (143 m; deltaic, prodeltaic)	

tified horizontal or cross-bedded sands or gravels, with pockets or lenses of littoral shells *(Melanoides, Corbicula, Unio)*.

The greater part of the high-lying, littoral-lacustrine plain is undissected and poorly drained. Local relief over 5-kilometer squares may be less than 5 m, and slopes are well under 0.5°. Zonal soils are consequently replaced by dark grayish brown (10 YR 4/2) clays of v e r t i s o l type (see DUDAL, 1965), frequently exhibiting some degree of salinity. Major and minor crack networks penetrate to depths of 50-120 cm during the dry season, while inundation and surface water-logging are commonplace after the rains. Gullying is prominent in the soft deltaic sediments exposed along the margins of the Omo floodplain, where local relief may be in excess of 40 m (photo 4). Extensive badlands are developed in some sectors, the most impressive of which are among the exhumed, cuestaform, tilted fault-blocks of the Omo Beds (photo 5).

The youngest evidence of vulcanism in the Lower Omo Basin is the extrusion of the Nakwa tuffs and basalts, a chain of some 20 ejecta cones, several of which remain unbreached (BROWN and CARMICHAEL, 1969). Overall relief of the group exceeds 500 m. These eruptions are younger than unit III, older than unit IVa of the Kibish Formation; they are, therefore, of terminal Pleistocene age.

The Omo Floodplain and Delta

The Omo River flows within a typical convex floodplain with meander belts, natural levees, point-bar ridges and swales, flood basins with bachswamps and gathering streams, and marked by numerous abandoned channels and a few oxbow lakes (photo 6). Broad alluvial spreads or reworked older materials are graded to the floodplain margins. Floodplain width is in the order of 4-5 km, that of the fringing forest about 2 km; the low-water channel averages 120-150 m across. The Usno floodplain is quite similar, although on a much smaller scale (channel width 20-30 m).

In actual fact the floodplain is largely non-functional today. The 1967 and 1968 flood crests remained several meters below the Omo levees, although both years were exceptionally wet throughout East Africa. Further evidence is given by the recent undercutting of the levees in both convex and concave meander bends, while laterally-graded alluvial spreads have been subject to dissection. Instead, modern flood accretion has been responsible for aggrading a silt berm at 3 to 4 m below the levees against which these berms are embanked. There can be little doubt that the Omo floodplain south of about 5° 30' N has been subject to net dissection over a period of at least several decades, presumably as a result of the rapid fall of Lake Rudolf by 17 m between 1899 and the 1930's (BUTZER, in preparation). During the last few years, apparently since the rapid, 4-meter rise of the lake since 1962, the river is actively aggrading. This can be deduced from contemporary berms now commonly embanked against undercut levees.

Local relief between the flood basins and channel levees is generally about 1-2 m, and slopes here almost never exceed 0.5°. Atypical floodplain soils are developed on the silty clay loams of the levees, deep-cracking vertisols (60-70 % clay fraction) in the silty clays of the flood basins.

The delta plain of the Omo consists in large part of abandoned deltaic environments in which the modern river occupies and periodically floods only a very small segment. Meanders are poorly developed and the channel functions primarily as a drainage line cut down rapidly into the emerging delta since about 1900. Repeated channel bifurcation and delta formation can be discerned from the abandoned distributary channels and their related levees, while gathering streams drain the former interdistributary basins and lagoonal mudflats. As a consequence the delta plain is generally well-drained, and soil development is very limited. Buried vertisols can, however, locally be seen under a recent mantle of silt, where the fine nature of the subsurface deposits is shown by giant crack networks – fissures over 4.5 m deep, 1 to 1.5 m wide, and often extending up to 200 m in length.

The delta fringe has been largely submerged since 1962 so that the contemporary shoreline has an exaggerated birdfoot profile. A mosaic of seasonal or permanent marshes, partly fed by seepage, partly by overbank discharge, and partly linked to the expanding interdistributary bays, is now developing in the lower part of the delta plain. Shoreline features due to cuspate remodelling by wave and current action were apparent on the 1959 air photos but are now submerged.

The Kibish River and Sanderson's Gulf

The Kibish River derives its waters from the Maji Uplands; overbank discharge periodically deposits flood silts along the shallow channel developed where this seasonal stream crosses the piedmont zone. Downstream, the channel in increasingly incised into the deltaic formations of the basin floor and there is next to no floodplain. Northwest of Nakwa the river begins to bifurcate into a maze of dispersal channels, marking two former sub-deltas, separated by a zone of gathering streams. Coarse sands are characteristic of the Kibish channel at low water, although fine silts and clays are deposited across the broad delta plains.

The Kibish Delta grades over, almost imperceptibly, into the mudflats once described as „Sanderson's Gulf". This synclinal depression was an embayment of Lake Rudolf as late as 1920, linked by an interbarrier inlet among the beach ridges and local dunes of the lakeshore. In more recent years the Omo River overflows into the lower part of the „gulf" at flood stage, while the upper parts may be temporarily inundated by the Kibish River. Low beach ridges fringe the western, windward margins of the former „gulf".

Cracking, dark clay vertisols are characteristic of the Kibish Delta and the northern part of Sanderson's Gulf. There are no typical soils in the lower-lying regions, although salt efflorescences or great polygonal crack networks may be widespread.

A Synopsis of Regional Geomorphologic Events

A provisional geomorphologic history of the Lower Omo Basin can now be summarized on the basin of the above thematic discussion and with specific reference to the regional stratigraphy (Table 1, BUTZER and THURBER, 1969, BUTZER et al., 1970);

(1) Repeated vulcanic episodes with extrusions of basalts and rhyolites over pre-existing erosional surfaces. Early Miocene to early Pliocene.

(2) Planation of the polygenetic Amar-Kokke surface (at 900-1200 m). Early Pliocene?

(3) Major downwarping and downfaulting, climaxing in creation of the Lower Omo Basin. Early to mid-Pliocene?

(4) Cutting of 2 or more pediment surfaces east of the Omo Delta (at 500-600 m). Mid-Pliocene.

(5) Piedmont alluvia from Nkalabong Range intercalated with the ortherwise deltaic Mursi Formation; partly concurrent with long-term pedimentation along basin peripheries that continued intermittently through phase (11). Lake Rudolf level high, at or a little below the Omo-Lotigipi-Nile watersheds. Basalt extrusions along the footslopes of Nkalabong Range. Late Pliocene (before 4.25 million yr).

(6) Faulting of the Mursi Fm., followed by major dissection.
(7) Formation of deep, reddish paleosol; intensive chemical weathering. Late Pliocene.
(8) Gravel aggradation (in northern basin) by higher-competence Omo River with interdigitation of coarse sands from local streams; deltaic sedimentation in southern part of basin (earliest units of Omo Beds?). (Nkalabong Fm., unit I). Tuffs indicate continuing vulcanic activity in Mt Nkalabong area.
(9) Deep dissection by Omo River and its intermittent tributaries, terminated by restricted aggradation of local watercourses. (Nkalabong Fm., unit II). Lapilli tuff dated 3.95 million yr. Late Pliocene.
(10) Rapid rise of Lake Rudolf to 460 m or more. Lacustrine conditions prevailing over basin floor, with mouth of Omo River north of 5^{o} 35' N. Fine-grained littoral-lacustrine deposits suggest an effective local vegetation mat, with little torrential runoff. (Nkalabong Fm., unit III).
(11) Massive piedmont alluvia from Amar-Kokke uplands repeatedly intercalated with the otherwise deltaic Omo Beds; pedimentation active along basin peripheries. Lake Rudolf level generally high, but with several major regressions. 9 K/Ar dates 3.75-1.81 million yr. Late Pliocene to Early Pleistocene.
(12) Several phases of faulting in Omo Beds; gentle tilting of western footslopes of Mt Nkalabong. Late Lower Pleistocene (?).
(13) Major dissection of Omo Basin sedimentary fill, following lake regression. Mid-Pleistocene.
(12) Gravel deposition by higher-competence Omo River, contemporary with aggradation of coarse piedmont alluvia; terminated by extensive deltaic sedimentation in basin. Th/U date 130,000yr. Late Middle or early Upper Pleistocene (Kibish Fm., unit I).
(13) Dissection and lake regression.
(14) Lake transgression with deltaic sedimentation in basin; little evidence of local geomorphologic activity. Early or Mid-Upper Pleistocene. (Kibish Fm., unit II).
(15) Dissection and lake regression.
(16) Lake transgression, with initial aggradation of coarse piedmont alluvia. Extensive deltaic sedimentation (Kibish Fm., unit III), apparently contemporary (in its later phases) with development of a deep paleosol. Mid-Upper Pleistocene (terminating ca. 35 000 B.P. on basis of C^{14} date ,,greater than" 37,000 and Th/U date 30,000 yr.)
(17) Long period of low lake level and gradual dissection. Pedogenetic calcification and salt-hydration appear to be indicated at about this time and suggest dry local climate. Extrusion of Nakwa volcanics. Late Upper Pleistocene (ca. 35 000-10 000 B.P.).
(18) Lake transgression, with extensive deltaic and lacustrine deposition (Kibish Fm., units IVa and IVb), locally interdigiting with piedmont alluvia and interrupted by brief interval of dissection with lower lake level. Early to mid-Holocene (ca. 10 000-5 000 B.P., dated by 16 C^{14} determinations).
(19) Dissection and lake regression. Late Holocene.
(20) Aggradation of contemporary floodplains, delta plains and shoreline forms (Narok Beds).

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