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CORRELATIONS BETWEEN LANDFORMS, ~~SOIL~~ AND VEGETATION IN SOUTHWEST UGANDA

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Abstract

In a subhumid to semiarid equatorial area of southwest Uganda, landscape development proceeded in phases dictated by differential upwarp within a major continental uparching and by differential lithology. A phase of considerable upwarp and deformation followed by a prolonged pause caused the dissection of the initial (pre-Tertiary?) planed Rwampara Surface and the differentiation of a lower planed Gayaza Surface in the proto-Katonga basin, throughout most of the area. Resumption of continuous moderate tilting resulted in the differentiation of a third - Sanga Syrface which, in its turn, was dissected mainly through lithological differentiation by the last erosional phase oflowland expansion. The landscape, consequently, consists of upland formed of resistant lithology and preserving on its crests remnants of three consecutive levels, and of lowland developed upon incompetent lithology.

The relatively rapid development of a planed lowland surface allowed for relatively early deceleration of geomorphic processes, deep weathering and retardation of pedogenesis, while upland was being constantly dissected. Active dissection of the upland prevented the preservation of extensive remnants of ancient laterite duricrusts upon crests and enabled constant active pedogenesis. As a result soils of the older upland surfaces are of a more youthfull character than those of the younger lowland surface. The former are relatively unstable, actively forming soils which reflect the current climatic environment. The latter are sedentary, developed on pre-weathered material and preserve properties of a former, more humid climate. In the lowland periphery, where soils are relatively younger and accretion of material from eroding upland slopes occurs, these qualities are modified and lowland soils are more similar to upland soils.

Vegetation is correlated to this pattern of soil distribution. Under present climatic conditions the predominant formation on deep

well-drained soils is that of a compound-leaf Savanna with a wide-spread thicket element. Within the macro-climatic frame communities are controlled by interaction of moisture availability, base saturation and reaction in the soils. Consequently, communities on upland soils resemble those of foothill pediments and lower interfluve slopes in mid-lowland due to the similar chemical properties of high base saturation and mild acidity. They differ from communities of mid-lowland interfluves where soils are strongly leached and acid. Where upland crest soils are relatively better supplied with moisture, such as in the heavier soils of broad crests, they carry communities which are found in the lowland only on especially favourable sites such as depositional fans at gully mouths.

CONTENTS

INTRODUCTION: THE STUDY AREA

Choice and Location

The choice of the area for the present study was guided by two main principles.

It was thought that in order to be able to study as large a range of correlations as possible, an area must be chosen where the greatest variety of morphological features can be found in the closest proximity. Furthermore, it was thought that for this purpose it would be best to look for an area in which the greatest number of the erosion-surfaces, recognized or postulated in Uganda, can be found in close juxtaposition. An inclusion of one of the older surfaces seemed desirable in order to study, if possible, any influence the relative age of the morphological feature may have.

The second principle was based on the assumption that in order to study influences of landforms on the distribution of vegetation, it would be necessary to eliminate, as much as possible, the climatic effect. This meant the restriction of the study to a more or less homogeneous climatic region. Another basic assumption was that the study of the subject would bring better results in areas where a decisive limiting factor of the climatic environment is relatively marginal, so as to emphasize changes caused by topographical features and soils. The most decisive limiting factor in the equatorial region being moisture, it seemed necessary to choose a relatively dry area.

The driest parts of Uganda are situated, according to the available rainfall data, in the district of Karamoja, in the north-eastern part of the country. The mean annual rainfall in this area is in some parts, lower than 20 inches, while almost the whole of the district receives less than 35 inches annually. Another dry area, of less than 35 inches mean annual rainfall, is situated at the bottom of the Rift Valley, around Lakes Albert, Edward and George.

Both these areas are of relatively uniform landscape and have little variety of geomorphological features. Also, no more than two of the postulated erosion-surfaces could be found there in close juxtaposition.

It seemed, therefore, necessary to choose a third area which, though not as dry as the two former - having up to 45 inches of mean annual rainfall - contains within its limits a greater range of geomorphological variety and at least three (possibly four) of the five postulated erosion-surfaces (Maps 4,4a).

This area forms a part of an easily definable climatic region of Uganda in Eastern Ankole and the neighbouring western Masaka, being, as it is, a region of drier savanna country bordered on three sides by regions of higher rainfall and semi-evergreen forest or woodland. It is, in fact, a continuation of a similar climatic region in the Karagwe province of north-western Tanganyika and eastern Ruanda.

Within this region there are two centres of greater aridity in which the mean annual rainfall is less than 35 inches. Of these the southern one seemed to be more suitable because of the more variable landscape and greater possibility of distinguishing a number of erosion surfaces.

The actual size and limits of the study area within this chosen region were to some degree imposed by time and technical limitations. Scarcity of all-weather roads made most of the area accessible only on foot or only in the dry seasons. The nature of the subject when combined with lack of any help in actual field work, limited the area that could be covered in a suitable manner. So that in fact the limits of the area were reached, rather than predetermined, in the time available. But they were reached from several chosen centres which seemed to be representative of the various natural complexes present.

The present study, thus, embraces an area of rectangular form about fifty miles long, from north to south, and forty miles wide - i.e. roughly, an area of 2000 square miles.

It is bounded, approximately, by longitudes 30° 40' and 31° 12' East and latitudes 0° 22' and 1° 00' South. Its southern boundary coincides, throughout most of its length, with the Uganda-Tanganyika border. More exactly it is bounded by the longitudinal grid-lines 240 and 300 and the latitudinal grid-lines 9890 and 9960 in zone 36 M of the UTM Grid.

Geology

(Maps 1&2*; tables 1&2)
Sections 1-8 *

The geology of the area shares the characteristic feature of the East African Inland Plateau namely - the enormous stratigraphical gap between the predominant Precambrian formations and the late Cainozoic and Recent, mostly unconsolidated, deposits of aggraded valleys and drowned lowlands. A special position should be assigned to the remnants of laterite sheets acting as ironstone caprocks, which may be of different ages but apparently, according to most authorities, are not older than early-Tertiary.

The Precambrian is represented within the area by three formations: the Basement Complex and the Toro and Karagwe-Ankolean Systems.

Basement Complex

Basement Complex rocks are exposed due to the stripping of presumed former metasedimentary cover in about a third of the area. In fact, the inclusion of these rocks within the Basement Complex may be at least partially erroneous and it is possible that they embrace also rocks of younger age absorbed and incorporated by late metasomatic activity. This is implied by the wholly granitoid nature of this formation within the area, comprising none of the paragneissess, metacalcareous or metaquartzitic and charnockitic rocks and the basic masses which characterize this formation elsewhere. Furthermore, the granitoids of this formation present, in the area, a certain pattern of distribution and structural evidence indicating a relatively late process of granitization of pre-existing metamorphics.

The centre of this magmatic activity was, apparently, in the area of the Ishura lowland, where the most advanced stage of the process in the form of

* Maps and sections - in end-pocket

coarsely porphyritic granite, is represented. To the south, on the margin of the lowland, the granite appears to be overlain by a successive narrow belt of granodiorite and granulite representing the replacement sequence of granitization. The pattern is less clear on the northern flank of this centre, where granite is still predominent, but occurrences of orthogneiss and of gneissose granite perhaps point to another sequence. Similarly to the east of the porphyritic granite, outcrops of intermixed fine-grained granite and granodiorite appear in the Buyojwa inlier of the Koki Hills. Since granitization appears to have affected metamorphic rocks and not the earlier Basement sedimentaries, it must have been a relatively late occurrence. However, late as it may have been, Phillips (1959 ~~ibid~~., p.26) maintains that structural evidence suggests that it occurred long before the deposition of the sedimentary formations.

Structural evidence of magmatic activity is present in the form of shearing and silification, pointing to the fact that tectonic activity recurred even after exposure and solidification (Phillips, 1959). Shear foliation coincides approximately with the primary foliation of the granite (ibid. p.22) i.e. - with the main trend of strike prevalent in all the ancient African shields - N. to NW. while the major joints seem to be coincident with the cross-trend or, in any case, to intersect the strike of foliation. Shear zones grade, as silification progresses and recrystallization continues, from granulated granite with lenses and stringers of quartz through silicified rock with bands of grains and elongated masses and veins of coarsely crystalline quartz to very large bodies of this tectonic quartz. Thus, parallel quartz belts of greater or lesser extent or regularity, occur within the granite following the main (Ishura-Nyabushozi lowland) or the cross trend (Kazinga lowland) or appear in isolated masses.

Toro and Karagwe-Ankolean Systems

The Toro System* is only poorly represented in the area. Consisting entirely (within the area) of incompetent quartz-sericite schists with subordinate muscovite-schists. The areas supposedly underlain by them are poor in outcrops and deeply buried by soils and alluvial deposits. According to the available information (Geological Survey of Uganda 1:250000, Mbarara Sheet; Sheet 87 (Rakai) 1:100000) they underlie the western and southern parts of the Masha arena and the Bwarkasani lowland in the southwest.

While the Toro age schists are regarded as a product of regional deformation of unsorted arenaceous and argillaceous material, the overlying, basal quartz-muscovite and muscovite schists of the Karagwe-Ankolean System are thought to have resulted from the transformation of shales and, perhaps, micaceous sandstones. Consequently, a gradation can be discerned from the schists to the overlying succession of arenaceous and argillaceous horizons. Mica-schists pass into quartz-mica-schists, then into micaceous quartzites interbedded with mica-schists, schistose quartzites with micaceous laminae and schistose phyllites and finally, into quartzites and phyllites. There is also a horizontal gradation of metamorphism from west to east and apparently also to northeast and north. It involves, apparently, mainly the argillaceous members of the succession while the vertical grade affects mainly

*(Combe, 1945). Pallister & Barnes (1954) suggest that since the sediments included in this formation have never been adequately defined except as older than the Karagwe-Ankolean and younger than the Basement Complex, they should not, as yet, be elevated to a System.

the arenaceous members. The interaction of both gradation series results in a complicated lithologic pattern, in which upper horizons in the west have a higher metamorphic grade than lower horizons in the east. Beyond a certain eastern and north-eastern limit, metamorphic change appears only in arenaceous members due to vertical grade. Argillaceous rocks grade from phyllites and slates into shales and mudstones.

While it is possible to draw a generalized boundary between predominance of shale or mudstones and that of phyllite it is often very difficult to distinguish between highly recrystallized shales or cleaved mudstones and the lower grades of phyllites. Also, both mudstones and shales are locally associated with phyllites. Gradation of arenaceous rocks appears to be independent of the original nature of the sandstones. In the lower grades, the original quartz grains are still discernible in the interstitial material which was recrystallized into sericite and microgranular quartz and at times still contains relics of felspar. The higher grades produce massive medium-grained quartzites composed of distinct colourless quartz grains in a white silica matrix with few sericite and muscovite flakes. The highest grade, found in the west, produces blue-white, entirely recrystallized quartzite, in which no cementing matrix is present. Even here some detrital muscovite flakes may be found lying parallel to the bedding.

It is, however, the successional pattern, as preserved today, and structural peculiarities in each part of the System, that determine the present lithological characteristics. Differences in succession reflect both initial differences in thickness, with a general eastward and northward shallowing of ancient basins, and subsequent tectonics and resultant differential erosion of upper horizons. A tentative successional scheme is presented in table 1 to illustrate this. The Rwampara-Gayaza succession is, perhaps, correlated in its lowest horizon of quartzite with the uppermost horizon of the Kasumba Syncline, but the relations between both areas are obscure. Structurally, the Karagwe-Ankolean System may be divided into two or three complexes (Map 2). The Rwampara-Gayaza-Nshara area is dominated by simple, ramified and sub-parallel major folds of both trends which, in the study-area, tend to be more longitudinal. They constitute a northern extension of similar structures in Karagwe (Tanganyika) which swing sharply back to the northeast to connect with the more complex structure of the Isingiro area (Combe, 1932). This structural complex is based on two major synclinal structures, pitching in opposite directions in a latitudinal cross-trend, from a central main-trend anticlinal structure at the approximate junction between the Kasumba and Rugaga hillmasses. The Kasumba Syncline pitches southwestwards towards the Karagwe structure, with its axis expressed in the Bigasha lowland; the Rugaga or Kakoma Syncline pitches northeastwards towards Koki, with its axis possibly expressed in the lower Nyakagera valley. There seems to be no doubt that the Koki structure is a shallower, broader continuation of this major Isingiro eyncline (Phillips, 1959), though the elements of such a continuation can be discerned only with difficulty. In both areas the major structures are associated with a system of subsidiary and minor structures of varying pattern and magnitude which makes for a very complex lithological and structural features (Map 2).

Table 1 : A Scheme of Karagwe-Ankolean Succession

A. Rwampara-Gayaza Area

Nshungezi-Kambeizi		Bungura		Gayaza	
a	b	a	b	a	b
Phyllite	3400*				
Quartzite	1800				
Phyllite	6000	Phyllite	8000*		
Quartzite	2400	Quartzite	3400	Phyllite	1000*
				Quartzite	200
Phyllite	300	Phyllite	1400	Phyllite	1500
Quartzite	300				
Phyllite	500				
Quartzite	3400	Quartzite	3000	Quartzite	300
				Phyllite	500
				Quartzite	400
Phyllite	?	Phyllite	?	?	?

B. Isingiro Area

Kasumba Syncline

a	b
Quartzite	9000*
Schistose Phyllite and Quartzite	200
Quartzite	2400
Schistose Phyllite and Quartzite	800
Mica Schist	1000

Rugaga Syncline

a	b
Phyllite and Quartzite	5800*
Quartzite	800
Phyllite and Quartzite	1100
Quartzite	5600
Mica Schist	2400
Quartzite	400
Mica Schist	800
Quartzite	1200
Mica Schist	7000
Quartzite	2500

a. Rock Type
b. Approximate thickness in feet
* Denuded upper horizon

Table 2

Chemical Composition of Rocks*

	1	2	3	4	5
Serial No.	21,054	20,182	20,183	20,184	20,185
%					
SiO_2	72.21	67.00	70.00	72.00	70.96
TiO_2	0.63	0.38	0.16	0.15	0.12
Al_2O_3	19.29	19.82	15.64	13.83	15.84
Fe_2O_3	0.61	1.52	0.70	1.65	1.15
FeO	-	1.96	1.40	1.62	1.40
MnO	Trace	0.02	0.03	0.17	0.02
MgO	0.29	1.05	1.75	1.40	0.70
CaO	0.38	1.98	1.98	2.47	2.47
Na_2O	0.50	2.29	2.19	2.46	2.87
K_2O	1.81	1.78	1.97	1.67	1.41
H_2O+	3.54	2.45	3.00	1.94	1.80
H_2O-	0.18	0.46	0.40	0.27	0.33
P_2O_5	0.33	0.08	0.23	-	0.08
	99.77	100.79	99.79	99.63	99.15

*Geological Survey of Uganda - Rock Analysis from the Eastern Ankole Western Masaka area (in litt.)

1. Phyllite, Kisai, Koki (sheet 87) C. Du Bois 1959
2. Fine grained granulite, Lake Kachera area (sheet 87) C. Du Bois 1959
3. Marginal type granite " " " " " W.J. Phillips 1959
4. Foliated granite " " " " " " " "
5. Granite, Kabale, Koki " " " " " " " "

Physiography

Relief and Drainage (Map 3)

In general, the area is divided into two topographic units: a high dissected, plateau-like upland and a relatively low undulating country with flat-floored valleys. The two units are separated by a prominent slope, 300-1,100 ft high with an average slope usually exceeding 15° and a pediment slope of about 5° or less at the base. Both high and low ground are subject to a regional east directed slope, much more prominent in the upland. The lowest part of area is situated in the south, where the Kagera valley is incised below 4,000' a.s.l. But generally, main drainage lines in the lowland have a consistent altitude between 4,000' and 4,100' a.s.l. Lowland interfluves are mostly 4,100-4,300' a.s.l. but on watersheds may reach 4,500' a.s.l. Only in a narrow belt along the western margin of the area lowland altitude is, on the average, about 100-200 ft higher. Isolated ridges and low hills within the lowland, whose disposition is clearly adjusted to geology and not to drainage pattern, may be higher than 4,500 ft a.s.l. but none, except in the western margin, exceeds 4,700 ft (Nyabishozi Hill in the Masha arena). Upland altitude is much more variable and summits rise in the south from 5,096 ft a.s.l. in the eastern part of the area (Kinota, Western Koki) to over 5,900 ft a.s.l. in the western part (Bungara, Eastern Rwampara). Where upland extends longitudinally there is also a decrease in upland summit altitude in a northward direction. In northwestern Koki summits are just over 4,800 ft (Kabula) and in Central Nyabushozi - over 4,700 ft (Omukate). General crest levels are usually 100-300 ft below summit elevations and considering the relative uniformity of lowland altitude the amplitude of available relief ranges between 600 and 1,800'

Except for its northwestern corner, the study-area embraces parts of two catchment basins, both tributary to Lake Victoria. They are separated by a watershed which runs along the main ridge of the southern upland, dividing runoff to the south into the Kagera River from that to the north into an extensive drowned latitudinal valley choked with swamps and flanked by a series of larger and smaller lakes, in lateral valleys. The largest of these are the Nakivali, Mburo and Kachera and, beyond the limits of the area - Lake Kijanebalola flooding the lower end of the main valley. The surfaces of Lakes Nakivali and Mburo stand at about 4,060 ft a.s.l., that of Kachera at 4,040 ft a.s.l. and of Kijanebalola - at 4,025 ft a.s.l. With a distance of approximately 30 miles between Lakes Nakivali and Kijanebalola, the gradient is very small and there is scarcely any flow through the papyrus chocked valley. This is also evident from the fact that alone among the large lakes the Kijanebalola, at the lowest part of the basin, dries up completely at times, which suggests that it is mainly dependent on its own catchment area. Consequently, even though the whole Lake System is regarded as directly tributary to Lake Victoria through the Kibale River which drains the Kijanebalola basin it is, in fact, an internal drainage basin. The level of the western lakes is fairly constant, probably due to the Ruizi River with its extensive catchment basin, which is the only perennial and unaggraded, and the largest tributary of the Lake System. Another significant peculiarity of this basin is the nature of its watersheds which are obviously little related to the present drainage. Even the southern watershed, clearly, an ancient one, is either fully or partially breached in at least three places, of which the through-valley of the Orichinga is the most prominent one. After very heavy rains, especially after several consecutive years of heavy rainfall, water from Lake Nakivali revives this drainage line and flows down it to the Kagera.

Physiographic Units

A physiographic regionalization of the area, based on the prevalent views on its geomorphic nature, must start with an attempt to place the area within a larger scale of physiographic pattern (Map 4). According to the brief but admirable scheme of physiographic regions proposed by McMaster (1962) for Uganda, the study-area embraces parts of two major regions: the Katonga Plateau (including the Koki Hills) and the Southwestern Highlands: of the former - the southwestern part of the Katonga Plateau proper subregion and the western part of the Koki Hills subregion; of the latter - the eastern part of the Ankole ridges and downlands subregion. The basic division between two regions is unquestionably sound though the reasons for details are unavoidably obscure. It seems more proper, on geological and geomorphological grounds to detach the Koki Hills subregion, that for some reason is supposed to include also the Isingiro Hills, from the entirely different Katonga Plateau and attach it to the Ankole ridges and downlands subregion. This subregion which may be designated also as the South Ankolean Highland subregion can be further differentiated according to the proportion of upland, its altitudinal range and orographic character into several units: the South Ankolean Highlands - including the Rwampara Mountains, and the Isingiro Hills; the Koki Hills; the Northern Downlands and Outliers - including the alternating arenas or arena-like lowlands, their flanking and intervening upland masses and features and the Nshara upland; the Inter-Upland Valleys - like the Orichinga and the Nyabubare - which almost completely intersect the South Ankole Highland, as lowland gaps; and the Southern Downlands embracing the Arenas and lowlands flanking the South Ankolean Highlands on the south. Each of these units possess a certain specific combination of geomorphic features and geological fundament. Each can also be fitted into one or more of the erosion-surface schemes postulated for Uganda. In the Katonga Plateau, differentiation is more difficult but several complexes of geomorphic features and geologic control may be distinguished (Map 4a).

Climate

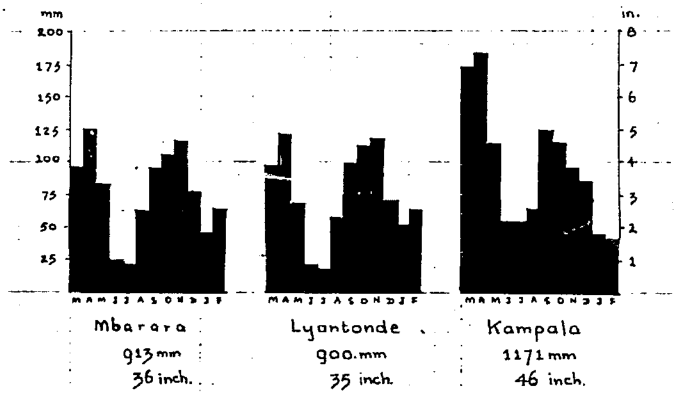
Data of elements of climate in the area are available from only two stations: Mbarara and Lyantonde, both either marginal to the area or just beyond its limits. Rain gauges were supposed to be stationed at Rugaga, within the area, and in Kiruhura close to its northern limit, but information collected in these localities were stated to be unavailable. Consequently, in regards to the study-area the rainfall maps of Uganda, published by the East African Meteorological Department, probably depict an extrapolation from data of surrounding areas. Data gathered from various sources, none of them referring directly to the area or to climate, are not always in agreement with that supplied by the maps and it appears also that data compiled from mean monthly rainfall maps is not in complete agreement with the mean annual rainfall map (Map 5 ; Table 4).

Temperature

Temperature varies very little during the year, its main variation being due to altitude. Seasonal fluctuations of mean monthly temperature do not exceed 1.0° C with the coolest seasons in June-July and November-December and the warmest months in March-April and August-September. Since there is no direct record of temperature from elevations in the area higher than that of Mbarara, an estimate of altitudinal fall of temperature had to be extrapolated from other areas. Mean annual temperature data from stations at various elevations in Uganda reveal a definite influence of alitiude. It is, however, not a "remarkably regular" influence as maintained by McMaster (1962). There appear to be at least one critical altitudinal level at which the rate of temperature fall changes abruptly. Below 3,500 ft a.s.l. the rate of temperature fall appears to be in the order of 0.8-1. 0°C per 1,000 ft. Above 4,500 ft a.s.l. mean annual temperature drops by approximately 3°C/1,000 ft. If this calculation is applicable to the area then mean annual temperatures of the upland will be in the range of 17° - 19°C, and those of the lowlands 20 - 22°C. An indirect and partial confirmation for this limit is given by Snowden (1953) who, while following Henderson (1949) in delimiting the Tropical Zone at 5,500 ft a.s.l., maintains that change of vegetation from tropical to subtropical communities commences at 4,500 ft a.s.l., so that the interval of 4,500 - 5,500 ft a.s.l., represents a transitional climatic belt.

Rainfall and moisture supply

Rainfall is characterized by the bimodal distribution typical of the zone of inter-tropical convergence. In this the climatic regime of the area compares closely with other equatorial regions of the country (Fig. 1), all having their rainy seasons in March-May and September-Nov-



mm
200
175
150
125
100
75
50
25
in.
8
7
6
5
4
3
2
1
M A M J J A S O N D J F
Mbarara
913 mm
36 inch.
Lyantonde
900 mm
35 inch.
Kampala
1171 mm
46 inch.

Fig. 1

ember. A more exact definition of rainfall regime depends on determination of the terms 'rainy' and 'dry' season, which apparently differs between regions. Thus, in Buganda the term 'rainy season' appears to apply to those months in which mean rainfall exceeds 100 mm. (4"). It is only in this case that the designations of 'Long Rains' (mid-March to mid-May) and 'Short Rains' (September to early October) can be applied. However, it seems difficult to use the same limit in relation to the study-area.

It is a characteristic feature of equatorial Uganda climate that in areas not affected by Lake Victoria the second rainy season exceeds the first. In the westernmost stations this involves both more protracted rains and higher monthly peaks. In the region of the study-area, however, the higher peaks occur in the first season, although they do not exceed those of the second in the same measure as in the Lake region. The greater amount of rain in the second season derives, consequently from a greater duration. Adopting the 100 mm., limit the rainy seasons will be very short: the first, only one month (April) and the second - two (October-November). An arbitary lowering of the limit to 75 mm., which appears to fit the present region better, will make the first rainy season 2-3 months long and the second 3-4 months long.

Table 3

	Wet Season March-May	Dry Season June-August	Wet Season September-November	Dry Season December-February
Mbarara (mm/in.)	303.4(11.94)	108.2(4.25)	316.6(12.46)	185.0(7.28)
Lyantonde (mm/in.)	286.2(11.26)	98.8(3.89)	329.8(12.98)	185.2(7.29)

The mean annual rainfall map (Map 5) of the region is slightly modified from that prepared by the Uganda Region of the East African Meterological Department. The modifications involved concern mainly the depiction of a 30" isohyet in the south-central part of the study-area extending from the Western Isingiro to Western Koki and northward to the Nakivali-Mburo area. They also concern the indication of lesser certainty of the isohyets to the east of the study-area, shown by broken lines. The first results from an isolated record of 25 - 30" of mean annual rainfall at Rugaga (Harrop, 1960) and from comparison with rainfall maps of Tanganyika and Rwanda, both showing areas with less than 30" mean annual rainfall adjacent to the Uganda border. The second expresses doubt as to the validity of rainfall data from Rakai*which caused the inexplicable westward extention of the isohyets in the Koki Hills area and may

* The map is based on information available up to 1956, i.e. a record of only 5 years from Rakai. By 1964 the mean annual rainfall at that station (over 55" in the map) has been modified to 47".

have modified the depicted pattern of rainfall within the area.

The climatological position of the area, as part of an extensive zone, recording less than 40" p.a. and trending roughly south-south-west to north-north-east from Karagwe and eastern Rwanda to southwest Mengo, emerges clearly. In this zone the study-area constitutes the northern part of the southern centre of greater aridity. The patterns of annual and monthly rainfall distribution provide an explanation to the existence of this subhumid region.* The equatorial zone of Uganda is affected by two main sources of rainbearing air movements, both apparently controlled by the migration and configuration of the I.T.C.Z. : the south-east trade from the southwestern Indian Ocean and the westerly South Atlantic Tm airmasses. In both cases, these originally moist airmasses are much modified while transversing extensive continental areas. Nevertheless the south-east trade, although it has a shorter distance to travel is apparently more modified than the westerly Atlantic airmass by the time they reach Uganda. This is presumably due to greater loss of moisture on ascent of the East African Plateau (and possibly - in Madagascar) whereas the

*The validity of the following explanation has been questioned in relation to meteorological interpretation, but still appears to constitute the best basis for a climatic exposition.

latitudinal course of the Atlantic air carries it over the humid equatorial forest of the Congo basin. The passage by the southeast trade of the great expanse of Lake Victoria replenishes its depleted moisture, but the northward deflection with approach to the equator limits the effect of this resuscitation to a relatively narrow belt along the western shore of the lake. At the same time, the westerly flow of South Atlantic air is forced to release its moisture and prevented from extending its influence eastwards by the longitudinal alignment of the Rift shoulder. The Eastern Ankole-Western Masaka climatic zone represents, therefore, a gap between the spheres of relatively abundant moisture supply.

The seasonal pattern is, therefore, clearly apparent. April is the rainiest month all over East Africa (over 2") marking the passage of the I.T.C.Z. over the equator and the full effect of both sources of moisture on the equatorial zone of Uganda. It is also indicative of the heating of the larger mass of the latitudinally aligned northern-hemi-continent and, consequently, of the relative enhancement of the southeastern source of rainbearing air movement. In September, when the heating of the smaller, southern half, of the continent commences, the southward curving of the I.T.C.Z. results in the relative ascendancy of the Atlantic airmass, which attains its farthest eastward incursion in October. At that time the centre of relative aridity is situated on the shores of the lake. It is this pattern which explains the relative enhancement of rainfall of the second wet season in Western Uganda. Dry seasons occur when moisture supply from both sources is weakened at the solstices. The greater intensity of the northern solstice drawing the South Atlantic air northwards and the southeast trade into the monsoonal system of southern Asia, results in a more pronounced dry season in June-July than in January-February.

It is the dry season of June-July, in which average rainfall falls below the limit of ecological efficiency (25 mm.) (Philips, J. 1958), added to the general variability and low reliability (9:1 confidence limit: less than 40" in all the zone; less than 30" in the centres of relative aridity) of annual rainfall (Manning 1951, 1956; Glover et al, 1954) that determine the ecological nature of the area. The rainy seasons provide little or no effective moisture surplus to carry plant growth through the dry seasons (Sansom, 1954). Consequently, woody vegetation acquires a specific semi-deciduous aspect, and grass cover is dominated by communities of relatively short grasses.

Within the limits of the study-area, orographic effect on rainfall appears to be limited to the Rwampara Mountains and, perhaps, to a slight föhn effect, east of the Rwampara, increasing the aridity of the Isingiro area. The main climatic differentiation concerns the rainfall gradient from the south central part towards the periphery. While the details of the various isohyets are apparently only tentative for lack of sufficient meteorological data, the pattern of vegetational and floristic distribution appears to support at least a northward gradient of increase in rainfall.

Table 4

Meteorological data for two stations in the area

	Mbarara (4734 ft a.s.l.)								Lyantonde 4150 ft asl	
Temperature					Relative Humidity % (6yrs)		Rainfall (60 yrs)		Rainfall (25 yrs)	
	Yrs. of record	C°	F°		0600	1200	mm.	inch	mm.	inch
Mean annual	21	20.0	68.0	January	86	55	44.3	1.74	51.9	2.04
				February	86	53	63.2	2.49	63.1	2.48
Mean annual maxim.	7	26.2	97.2	March	85	56	96.5	3.80	97.5	3.84
				April	87	60	124.9	4.92	120.6	4.75
" " minim.	7	13.0	55.4	May	85	59	82.0	3.23	68.1	2.68
				June	83	48	24.6	0.97	21.5	0.85
Highest recorded	21	33.3	92.0	July	78	43	21.0	0.83	19.8	0.78
				August	80	46	62.6	2.46	57.5	2.26
Lowest record	21	10.0	50.0	Sept.	82	57	96.3	3.79	99.1	3.90
				October	83	62	105.0	4.13	112.8	4.44
Highest monthly mean* (April)	7	19.0	66.2	November	86	65	115.3	4.54	117.9	4.64
				December	87	55	77.5	3.05	70.2	2.76
Lowest monthly mean* (July)	7	18,0	64.4	Year	84	55	913.2	35.95	900.0	35.42

East African Meteorological Department, Uganda Region (in litt., 1965)

* The discrepancy in relation to mean annual temperature is due to difference in number of record years. The mean annual temperature for the last seven record years (1958-1964) is 18.7°C.

Geomorphology and Soils

Geologic Control of Landscape Pattern

Elements of landscape pattern

The landscape of the region between Lake Victoria and the Rift Valley is very clearly differentiated into two distinct elements which may be described as 'upland' and 'lowland' systems of relief features:

1. The upland element includes relief features whose relative elevation above the adjacent lowland usually exceeds 300 ft., and which tend to have relatively flat crests and steep slopes. Crests of proximate features are apparently accordant at one or several levels.
2. The lowland element is represented by foothill pediments and low interfluve ridges separated by wide, flat-floored valleys. Crest elevation is, usually, less than 300 ft., above the valley floors and slopes are gentle to moderate. Crest-form is variable and may be bevelled, domed, gently rounded or "tor" - topped.

It is the differential spatial relationship between these elements and the differential nature of the features of each element that give each part of the region its distinctive character and form the basis of physiographic regionalization within it. The study area, as stated, extends across a transition between two such physiographic regions, one of which is dominated by certain types of upland and the other - by certain types of lowland. The transition is expressed in the presence of an intermediate belt of country in which upland and lowland alternate both as landscape units and as individual features.

The differentiation into elements and their spatial relationships and resultant landscape pattern, correlate very closely with the geologic pattern. Upland is formed mainly by sedimentary or metasedimentary formations which, in the present case, belong exclusively to the Karagwe-Ankolean System. Lowland is formed, as a rule, by granitoid rocks, whether intrusive or of the Basement Complex, and by the schists of the Toro System or those basal to the Karagwe-Ankolean System. Where upland features consist of granitoid rocks or schists they are preserved by a cap-rock of laterite duricrust.

Landscape patterns reflect the extent and continuity of the sedimentary cover over the underlying plutonic or schistose basement. The transitional character of the landscape appears to reflect a decrease in the absolute or relative* ~~(II)~~ original thickness of the resistant sediments and metasediments. Another possible factor affecting the pattern is the metamorphic grade of the sediments influencing their relative competence. The pattern of the landscape of the study-area, no doubt indicates the graduality

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* ~~(II)~~ relative thickness - the position of the contact between the resistant and non-resistant formations in relation to the controlling bass-level.

implied by these factors. The South Ankolean Highland and the Koki Hills, occupying the southern part and the eastern margin of the area form an extensive and continuous belt of upland representing an extensive and continuous area of thick Karagwe-Ankolean formations. The Nyabushozi or Katonga plateau in the northern part of the area is an extensive lowland underlain by Basement granitoid rocks. In between these two belts, in the intermediate zone, upland units and features represent discontinuous remnants of a thin metasedimentary cover while the lowland units and features represent exposed plutonic or schistose formations.

The extent and geographic position of upland and lowland units, thus correlates with the original magnitude of metasedimentary and sedimentary cover. The extent and position of lowland units reflects the degree of the stripping of this cover. Consequently, the diversity of lowland landscape can be recognised, not so much on the basis of their extent as on that of lithologic and structural diversity and consequent geomorphic evolution. The extent of upland units is, on the other hand, a decisive characteristic of the landscape and the above correlation is reflected in the existence of two major types of upland landscape: blocks of upland in which upland features are contiguous over an extensive area and represent areas where the original absolute or relative magnitude of the sedimentary cover has been considerable; residual upland in which upland features are separated by various extent of lowland features and representing areas where the original cover has been of smaller proportions.

Lithologic and structural control

Further variability of landscape within these generalized types of elements is conditioned both by lithologic diversity and structural nature.

Lithologic diversity is associated with differential weatherability and the suspectibility of the different lithologic components of the landscape is clearly reflected in the topographic pattern and the nature of the landforms. Naturally, effect of lithologic and structural control is much more prominent in the resistant stratified sedimentary formations than in the incompetent massive plutonic ones. Consequently diversification of lowland landscapes is less conspicuous than that of upland and they should be classified on a different level and treated separately.

A tentative order of suspectibility of the area's component lithology estimated on the basis of the existing relief is represented in a series of decreasing weatherability and erodibility, as follows*:

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*The table is based on average available relief as calculated from planimeter measurements of altitudinal intervals.

Upland Lithology		Lowland Lithology	
arenaceous	argillaceous	plutonic	metamorphic
Coarse-grained quartzite		Tectonic quartzite	
	Phyllite	Coarse-grained massive granite	
	Slate	Granodiorite	
Fine-grained quartzite		Foliated granite	
		Gneissose granite	
	Shale		Granulite
	Mudstone		Quartz-schist
			Mica-schist
Schistose and micaceous quartzite			

Laterite is not included in the above table since it occupies a special position in relation to weatherability and erodibility. Due to its specific genesis and relatively small age it is always present in small amounts in comparison to other lithologic formations and occupies only certain sites. Consequently, while the magnitude of any lithologic formation has bearing only on the sum of its weatherability, in a laterite duricrust it appears to be as important as the specific weatherability. Evidence from the area suggests that a laterite duricrust acquires the geomorphic significance of a protective caprock only where its thickness exceeds certain limits, presumably dependent on the competence of the underlying rock. Actually it is rarely possible to determine these limits in the field, since thickness itself is usually related, among other factors, to the weatherability of the underlying rock. It is, for instance, reasonable to assume that incompetent rocks such as granitoids and schists will be scarcely comparable in resistance even to a very thin laterite crust. In fact, a laterite crust appears to be the only type of rock which preserves upland features in areas of exposed plutonic and schistose rocks, but attains over them, almost invariably, considerable thickness. On the other hand, evidence from the study-area shows that on quartzite, thickness of laterite is usually small. Even where it does reach considerable proportions there are clear indications to the fact that it is not the competence of the crust which protects the crest of a quartzite hill, but that of the quartzite which preserves the crust. Presumably, to attain a resistance comparable to that of quartzite, a laterite crust should be very thick. As to the competence of laterite in relation to other lithologic formations, situated between these two extremes, the impression gained from the evidence of the study-area is that a laterite crust, 3-4' thick, is approximately intermediate in competence between phyllite and shale.

Coarsely crystalline quartzite also occupies a special position in relation to the competence of other rocks. Its position at the head of the competence - series is somewhat deceptive. Not only is it the most insoluble of rocks but the difference between it and the next rock in the series - phyllite, is much greater than that between phyllite and shale. Its very high resistance makes quartzite one of the most important factors in the moulding of the landscapes. It forms, in fact, the framework of the upland. Upland features formed of quartzite or of other lithologic formations interbedded by a considerable number of quartzite strata or by few massive beds of quartzite are, usually, higher than comparable* features formed of phyllites, shales or mudstones alone. In the lowland, where quartzite outcrops occupy a much smaller area, either interbedded with the Karagwe-Ankolean basal schists or as tectonic veins in the plutonic basement, it always stands out above the surrounding country and its relative abundance, area and pattern may serve as one of the criteria for distinguishing types of lowland.

Geologic control of upland features

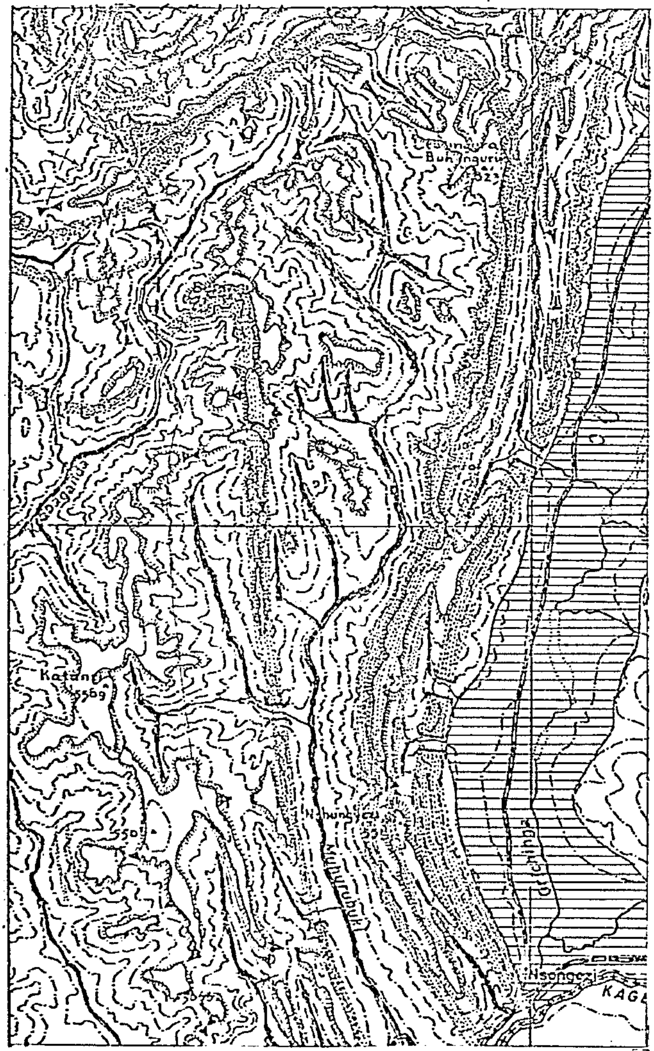
The proportion of quartzite in the lithologic succession is a leading factor in the determination of upland pattern. Where it dominates the succession, it preserves, besides altitude, the topographic continuity of the orographic pattern throughout the upland block. Ridges are formed

*Comparable - aligned in parallel to the axis of the maximum regional upwarp so that its effect may be disregarded.

rather than separate hills and crests are usually continuous. Where interrupted, either by cols or by an abrupt break in slope, the interruption is never profound enough to disrupt the unity of the ridge. This pattern of interconnected, continuous and contiguous ridges forms what may be termed an upland mass (Fig. 2). Where quartzite is absent or scarce, i.e. - where the argillaceous succession includes only few, thin and discontinuous quartzite beds, the topographic continuity of the pattern is disrupted. Former ridges are dissected into series of hills aligned along the ridge-line but separated by sharply defined cols. Most of the South Ankolean Highland blocks form upland masses. The Koki Hills, on the other hand, are mostly "hill-series", as is the Chamburara upland block (Fig. 3) and perhaps, also, the upland features of the Lower Ruizi basin in the Nshara block.

Structural control is added to that of lithology in the further diversification of landscape patterns. The upland mass type of landscape is found in two main combinations of structural design and lithological succession: in the first geologic type, a mixed succession of phyllite and quartzite, in which the latter is subordinate (40-45% in the thickest succession) is arranged in a system of simply ramified major folds extending over considerable distances and usually devoid of subsidiary folding. The

Upland mass : Eastern Rwampara



quartzite band · crest · crest-line slope

strike valley · quartzite-band breach

major fold structures

lowland

1:100000

0 1 2 3 km

Fig. 2

Hill Series : Chamburara hillmass

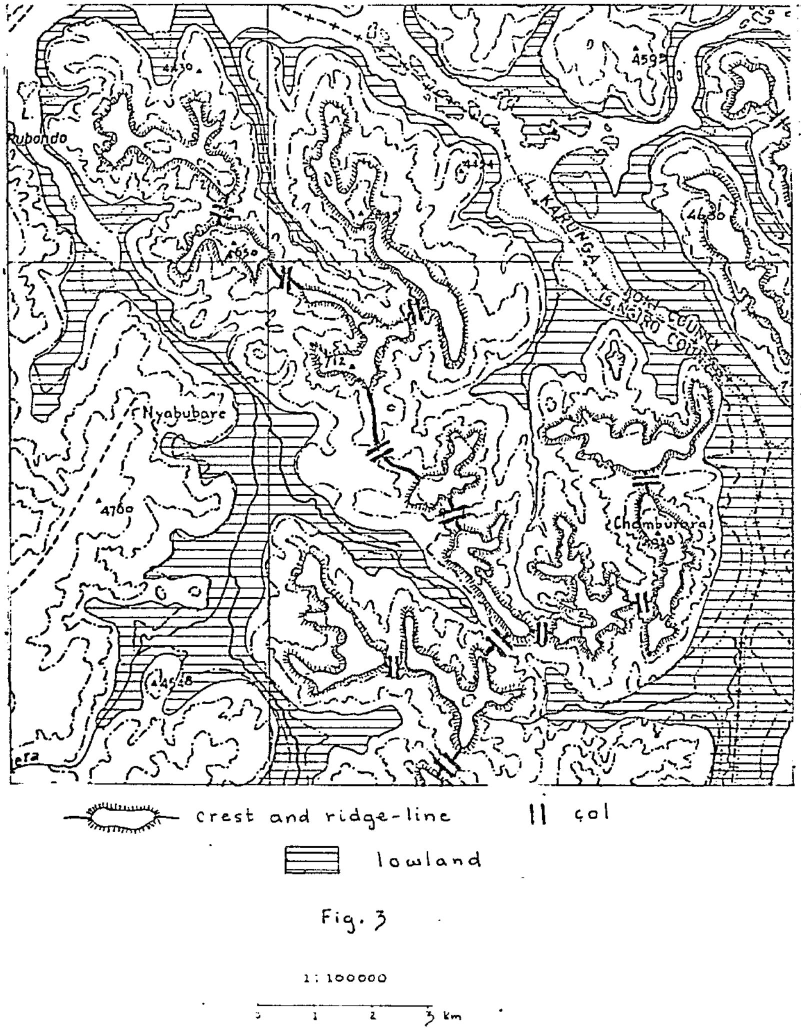
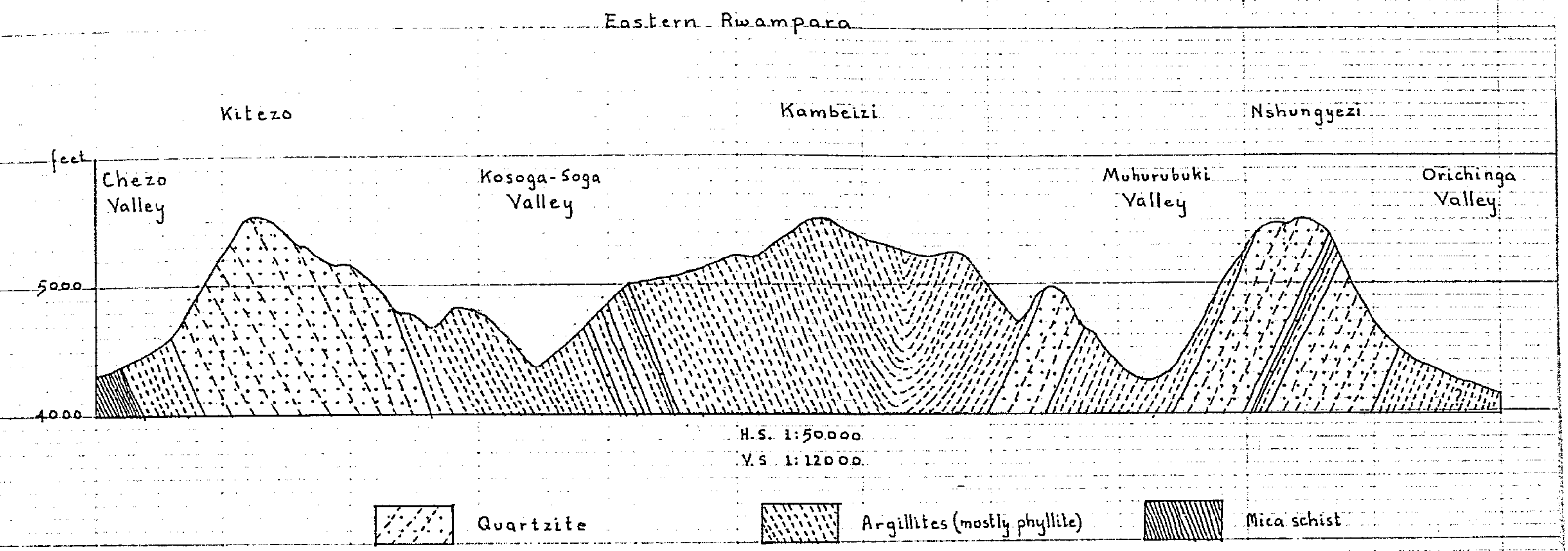


Fig. 3

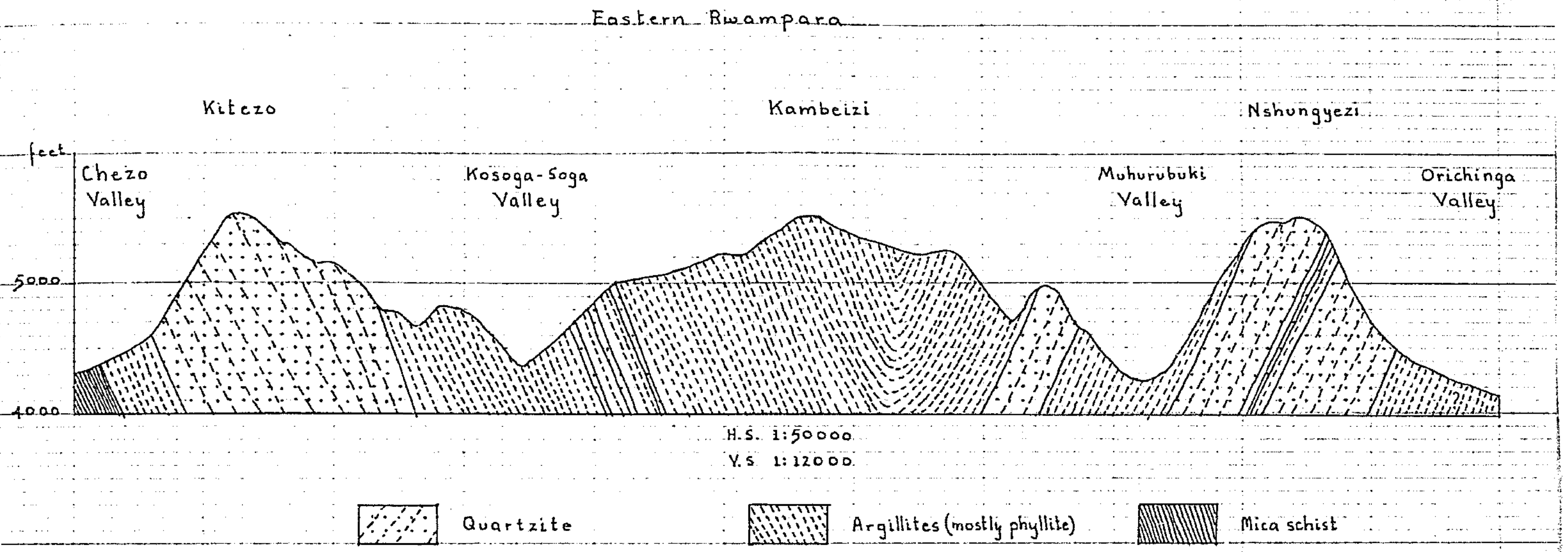
type is exemplified by the Rwampara Mountains. In the second type, exemplified by the Isingiro Hills, quartzite predominates in the succession (95-97% to 53-60% in the upper part of the succession above the basal, lowland, schists) which is arranged in a complex synclinal structure, composed of many divergent, main and cross-trend subsidiary folds. Though the geology of the Isingiro Hills is not yet fully clarified the overall impression is that it represents the lower part of the Karagwe-Ankolean succession, denuded of the predominately argillaceous Rwampara succession. The few, limited, patches of phyllites overlying the quartzites in minor synclinal structures and the increasing extent of upper phyllites towards the eastern parts of the Isingiro Hills, where the major structure and the succession as a whole become shallower, seem to support this possibility. Another complicating feature of the geology is the fact that within the succession the metamorphic grade of the quartzite is not uniform with several strata approaching sandstone.

Structural control is, of course, more readily evident in the first type of geology. The relief is clearly inverted with the major synclines forming groups of high ridges whose crests are supported by quartzite, usually in several successive beds (Fig. 4). Anticlines, constitute the intervals between these ridge-groups. Where a platonic core



Inverted Relief in the Gayaza-Bugamba Syncline

Fig. 4



Inverted Relief in the Gayaza-Bugamba Syncline

Fig. 4

surrounded by a schistose aureole intrudes into the anticlines, lowland embayments may be formed within the upland mass. Individual ridges within the synclinal structures are usually separated by upland subsequent valleys in the less competent phyllites. Both ridges and valleys are, thus, conditioned by the strike of the structure and tend to be long and narrow, (Fig. 2). Faulting appears to exert little control probably because the effect of differential lithology tends to erase or mask it. Only in few cases can the topographic pattern be related to a fault-line origin and this only where the strike of the fault happens to coincide with the strike of a quartzite bed on the upthrow side. The effect of structure is less apparent in the more complex geology and homogeneous lithology of the Isingiro Hills. The orographic pattern does not conform with the major structure and structural control is observable to a limited degree in only a few places where spur and valley patterns reveal a subsidiary fold structure. While there is some correlation between the pattern and the strikes of the quartzite strata, the complexity of the structure makes it much less regular than in the previous case with the ridges broader and shorter. Towards the periphery of the hill-masses, however, the thinning out of the resistant succession and the inter-bedding of less resistant strata such as phyllite, schistose phyllite and schist causes the pattern to be more similar to that of residual upland. The effect of faulting is more apparent in this geological type where faults may exceed the dimensions of many minor structures or transect the larger ones. The main influence appears to be in creating lines of weakness along which denudation may breach a resistant stratum and act upon a less resistant one (Fig.5). In fact, a considerable part of the dissection seems to be controlled to some degree by faulting.

Manifestations of structural control in the 'hill-series' type of upland, such as the Koki Hills are, as indicated by the scarcity of quartzite, limited and can be observed mainly on a local scale. Minor folds associated with outcrops of quartzite occasionally determine the configuration of slopes and crests and the location of spurs and gullies (e.g. Chamburara Hill). Larger anticlinal structures in shallow parts of the succession may cause the exposure of the plutonic or schistose foundation and the formation of a lowland unit within the upland (the Burakati and Buyojwa inliers, Phillips, 1959). In major, very extensive, structural systems with a consistent trend of a strike and dip, an outcrop of a quartzite bed extending over great distances results in a long ridge-line breached into a continuous series of elongated, narrow-crested ridges (Kamengo-Kayonza ridge line). On the whole, however, the nature of the

Ngarama hillmass: Kikoma and Karuruma Valleys

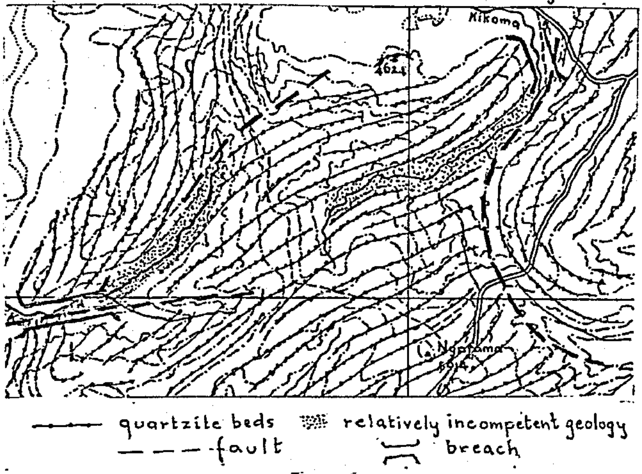
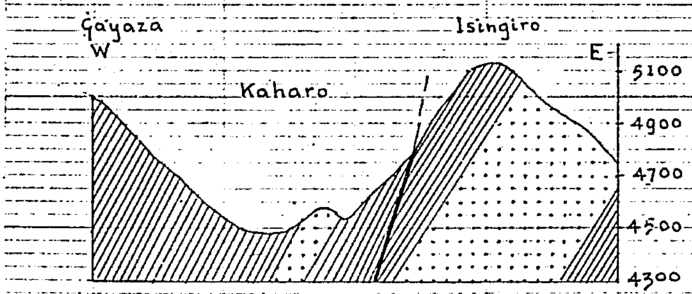


Fig 5.

1:100000

0 1 2 3 km



H. S. 1: 25000
V. S. 1: 6000

Fig. 13

lithology - usually of comparatively low metamorphic grade - tends to obscure structural control.

Fragmentary evidence renders the interpretation of structure in the residual upland at best difficult and tentative. Specific circumstances connected with the lesser magnitude of the sedimentary sheet, undoubtedly condition the formation of specific upland features but geological control by this formation is at times difficult to discern. One of the major characteristics of this belt of residual upland is the intrusion or doming of granite into the sedimentary succession and the creation of a schistose aureole or - originally - a schistose envelope in its basal part. This relative uplift of the base of the resistant succession has brought about the formation of enclosed or semi-enclosed areas of low ground which Wayland (1921) has termed 'arenas'. Plummer (1960) suggests that the intrusion is connected with an extensive doming or with a broad anticlinal structure flanked by synclines. Where situated between two such domes these flanking synclines are characteristically narrow and their axes swing around the dome structures. The small breadth of the synclines results in the breaching of the resistant metasediments preserved in them and the break-up of the original ridge into a range of hills separated by gaps of lowland or very low cols. Where thick quartzite beds are situated in the upper part of the local succession the individual hills may attain a considerable relative elevation. The Nyamitsindo ridge-line separating the Masha arena from the Lower Ruizi basin and the Bihunya-Kabulangire-Kishasha range, separating the Masha and Mbarara arenas, exemplify this situation. (Figs. 6,7).

Another type of residual upland is exemplified by the Lower Ruizi basin itself and by the Sanga Hills to the north of it. It is characterized by the separation of upland features by tracts of lowland - usually, pediment-flanked, flat-floored valleys. The upland features of the Lower Ruizi basin differ from those of the Sanga Hills in the preservation of an orographic pattern. The hills are as yet aligned along the original ridge-lines as they are in the 'hill-series' type of upland blocks, but the ridge-lines are separated by lowland pedimented valleys. The Sanga Hills are situated on the margin of the sedimentary sheet, where its thickness is, apparently, smaller. Accordingly the orographic pattern has been at least partially disrupted and the individual hills no longer have a consistent topographic coherence along ridge-lines. Towards the margin of the Basement, where the basal schists are exposed, the northernmost Sanga Hills have special geologic traits which distinguish them from other upland features within this unit. They are either composed of tectonic quartz or preserved by

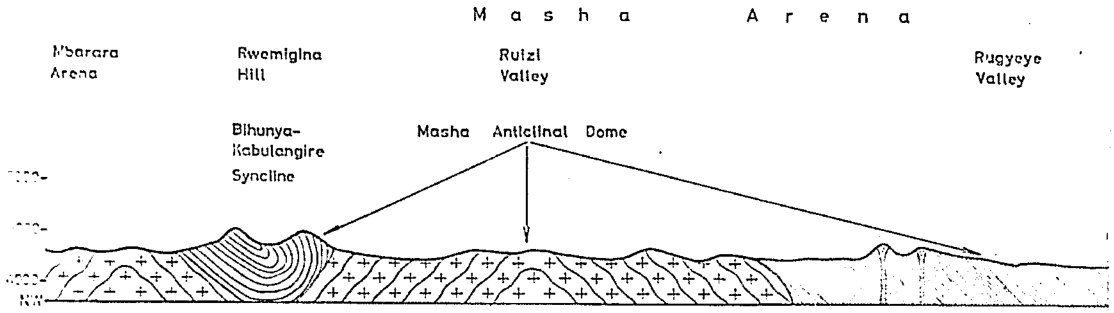

Masha Arena
M'barara Arena
Rwemigina Hill
Ruizi Valley
Rugyeye Valley
Bihunya-Kabulangire Syncline
Masha Anticlinal Dome
NW

Fig. 6

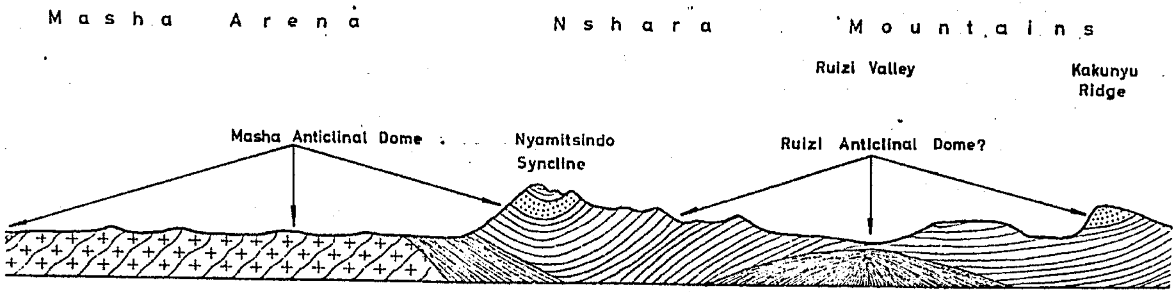

Masha Arena
Nshara
Mountains
Ruizi Valley
Kakunyu Ridge
Masha Anticlinal Dome
Nyamitsindo Syncline
Ruizi Anticlinal Dome?

Fig. 7

a fairly thick laterite crust. Such a crust is a common characteristic of most features in this type of residual upland but in the northern Sanga Hills it is the sole reason for the preservation of upland features on the highly incompetent schists.

Separating the Lower Ruizi basin from the Sanga Hills is the Ntarwete - Kakunyu ridge, constituting a singular and outstanding feature of the residual upland. Whereas, in the Lower Ruizi basin and the Sanga Hills metasedimentary quartzite is entirely absent, the succession in this ridge consists of a very thick quartzite stratum overlying a mixed sequence of argillite and quartzite. The upper quartzite forms the whole of the twenty miles long broad crest and confers on the ridge its outstanding altitude and continuity.

The structural basis of these landscape units is as yet attended by doubts, though Plummer's as yet unpublished report may include as explanation of it. The Lower Ruizi basin represents, perhaps,a preliminary phase in the production of another arena. It has the basic topographic attributes of such a structure and the argillite of the low ground or, perhaps, even the soils of the lowland valleys may be underlain by a schistose mantle at no great depth. The Ntarwete-Kakunyu ridge, bounding the basin on the north and east, does not, apparently, represent a single simple structure as does the Nyamitsindo syncline bounding it on the south and west. Plummer (1960) implies that it consists of a system of parallel major folds. Only the flanking members of this system, the longitudinal ridges of Ntarwete on the east and Kishakazi-Chai on the west, are fully represented, whereas the intermediate ones are observable only partially in the meandering lineament of the latitudinal Kakunyu ridge. Plummer also implies that the Ntarwete fold assemblage is related to the folded structures of the Rwampara and Gayaza to the south, but the relation is as yet obscure.

A few isolated features appear solitary within the lowland. The majority of them are situated north of the Sanga Hills in the central part of the Katonga divide. The pattern of their distribution, however, does not coincide with the latitudinal alignment of the divide. On the contrary, with other similar features to the north of the study-area, up to Kiruhura in central Nyabushozi, the pattern is decidedly longitudinal, along the higher midrib of Nyabushozi separating the Mbuga lowland on the west from the Eastern Nyabushozi lowland on the east. Common to all these hills is the thick laterite crust surmounting a deeply weathered layer of granitic or gneissose rock (e.g. Omukate). A somewhat different type of a solitary upland feature is represented by the Warukiri Hill on the border of the Ishura lowland, east of Lake Mburo. Laterite protects, here, basal mica-schists but is apparently bolstered by a fairly extensive outcrop of quartzite. The principal difference, however, is in the location of the feature aside from the main divide of the lowland which, characteristically, carries no laterite even at higher elevations.

Geologically conditioned upland landforms

Slope form and dissection

A closer investigation than the present one is necessary in order to isolate the numerous factors and various ways in which geology affects the evolution of slope forms and upland valleys. Even rock-types as grouped above, cannot be used as a key for classifying and explaining these forms, since no single rock-type is entirely homogeneous within one upland unit or one type of succession. The complexity of some structures also causes numerous variations in form, difficult to classify and isolate. Consequently generalizations of geologic effects have many exceptions and are, necessarily, schematic.

Nonetheless geologic heterogeneity does not obscure differential effect of major geologic assemblages. It thus seems possible to base generalizations of slope form and erosional development on the disposition of the major upland rock-types, namely - quartzites and argillites within the macrostructural frame and on their specific weatherability as conditioned by chemical composition and microstructural properties.

Metasedimentary quartzites of the upland, besides being extremely insoluble are also massively bedded and possess an open joint lattice. Consequently, quartzite outcrops tend to break-up into boulders and generally coarse waste, which in turn decomposes directly into grains. Variations in metamorphic grade are reflected in the size of primary waste fragments so that a rock approaching sandstone decomposes directly into grains. Rate of weathering and erosion, thus, changes with the change of metamorphic grade which is expressed, in certain cases, in an admixture of soluble micaceous minerals and acquisition of schistose microstructure. Argillites, though including several rock-types, have as a group a close-latticed interstice pattern, beside being chemically more soluble than quartzite. They decompose into a comparatively fine waste at a speedier rate. Shale and mudstone tend to disintegrate as a whole, directly into very fine waste, while phyllites and slates first break into fragments along interstice planes.

Under the climatic conditions of the area, the ratio of waste production to waste removal is apparently low on unprotected slopes whose angle exceeds a certain limit (approximately 10° - 15°). Fine waste is speedily removed leaving the bedrock of the backslope relatively bare as it is deposited on the gentle footslope. Coarse waste of large fragments, blocks and boulders, on the other hand, is retained upon the slope, mantling the bedrock, preserving a high angle of rest and maintaining a relatively abrupt angle with the footlope. A Coarse Waste mantle on the slope serves also to impede the removal of finer waste, obstructing its downslope erosion and protecting it in the inter-fragmental spaces. Such accumulations of finer waste may promote denser vegetation and consequent differential weathering and formation of bench-like flattening of the slope. Such slight flattenings may be formed also through differential subsidence of the coarse waste with removal of supporting finer waste.

The main process of upland dissection and slope evolution is gully erosion and development. Gully distribution on slope is primarily related, as observed by Savigear (1960), to their steepness, but also appears to have a strong direct geologic control. Contary to Savigear's (ibid) evidence from West Africa the differentiation of gully-distribution into linear and irregular patterns is not simply governed by respective bedded and massive structures. Both types appear on subhorizontally bedded slopes and are related directly to macrostructure and lithology or indirectly through the geological effect on the average angle of slope.

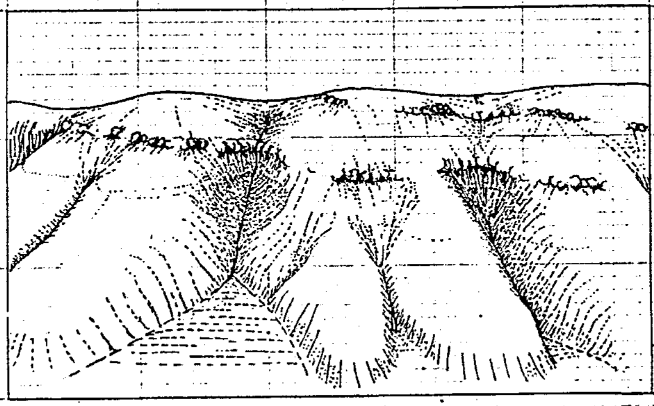
Strike-slopes are, as a rule, prominently steeper than those cut across the trend of the strike. This results presumably from the fact that slopes cut across the strike are usually shorter and present a larger surface to erosive action. The phenomenon is apparent mainly in simple structures where the strike trend has a consistent continuity over considerable distances. A conspicuous example is derived from the comparison of the outer eastern slope of the Rwampara Mountains with the northern and southern ridge ends. The fluted aspect of the steep strike-slopes, incised by a sub-parallel linear pattern of gullies, is a characteristic landscape feature of the area. It is less apparent in a complex structure or where lithology prevents consistent coincidence of strike trend and slope lineament. Nevertheless, wherever such coincidence occurs, even over short distances the slope are characteristically steep and fluted. Generally speaking then, simple structures of major sub-parallel folds show a linear pattern of initial gully and a subsequent upland dissection while complex structures of minor folds show an irregular pattern.

The basic difference in the nature of slopes formed on quartzite and argillites entail differential gully development and upland dissection. On a theoretically homogeneous quartzite slope with a steep angle of rest of the debris mass against a convex bedrock face, gullying starts by abstraction of runnels winding through the waste-mass. Usually the waste-mass does not cover the whole of the bed-rock face. A scarp-like outcrop of a quartzite-bed is left above it, at the junction of the backslope and the crestslope. The scarp-like effect is also conducive to the initiation of gullying by the concentration of seepage through the open interstice and the break of angle. Gullying is, thus, unequal, its initiation being dependent on angle and height of slope and massiveness of the out-crop bed.

The process of gullying is initiated by incision into the waste-mass and downcutting until the bedrock is reached. Obviously this phase is attained earlier on the upslope part of the debris cover, where the thickness of the waste-mass is small. The downslope diminution in the rate of downcutting is matched by a similar diminution in the rate of lateral erosion into the less resistant debris at the flanks of the gully.

Simultaneous headward erosion from the outlet of the gully on the footslope will impart to the well-developed gully a characteristic profile and form. It will possess a funnel-shaped cliffed gully-head and a fan-shaped outlet, with a narrowing cross-section in between. Where the cliff-like quartzite at the gully head is initially absent, backward erosion of the gully-head will encroach on the crestslope in a shallow depression of converging incisions and steepen abruptly at the eroded junction with the backslope, (Fig. 8). Where gully dissection is closely spaced waste mass is soon consumed by lateral erosion and the bedrock of the gully interfluves is graded to reflect the profile of the gullies to which it is tributary. Where spacing is wider, the interfluve may develop new independent gullies or evolve through continuing waste-production and runnel erosion. There is, thus, a continuous retreat of the whole face of the slope without fundamental change in the average angle, effected by continuous discrepancy in the rate of backward and lateral erosion of constant or intermittent gullies, until the crest is consumed and different conditions of height and angle attain.

On a theoretically homogeneous argillite slope, gullies may be initially of a linear pattern on steep strike slopes though argillite strike slopes are on the average less steep than on quartzite and gullies are more widely spaced. Since waste cover never attains considerable quantities the rate of downcutting and backward erosion is not subject to change and lateral erosion gains upon it only after the profile is graded. Consequently, gullies on argillaceous slopes soon develop into valleys dissecting the upland mass and the contin-



Gully forms on a slope with an alternate succession of quartzite and argillites
Fig. 8-9

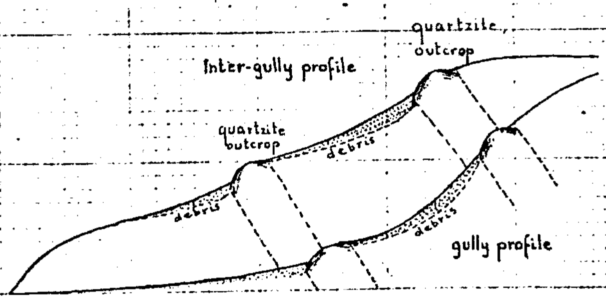


Fig. 10

uity of slope lineament is disrupted. Gully heads are not cliffed as a rule and usually ascend smoothly up into the crestslopes (Fig. 9). Since the microstructure of argillites is rarely evenly spaced, lateral erosion in headward eroding gullies soon favours perpendicularly trending weaker belts, especially if they coincide with the strike so that regularity of dissection pattern is not destroyed. Instead of the approximately simultaneous and equal erosion of the whole front of a quartzite slope, the argillaceous slope is reduced by deep dissection and fragmentation into progressively smaller upland features, attacked and consumed on all sides.

As observed, lithologically homogeneous slopes are rarely met with and the preceding outline of geological effects on slope form and evolution is largely theoretical and schematic. It serves only as a basis for an attempt at classification of actual slope forms.

In simple structures such as the Rwampara Mountains and the Gayaza hillmass, strike-slope forms derive from the nature of the succession which is either alternate quartzite and argillite beds or wholly argillaceous in the centre of the structure. The alternate succession, however, differs in nature as to number of quartzite beds and their thickness and slope forms differ accordingly. Variations of alternate successions may be abstracted into three generalized types. In the first, the thickness of beds of different rock-types does not differ significantly and several quartzite strata outcrop on a single slope. In the other two types the succession consists of one very thick quartzite stratum which either underlays or tops an argillaceous layer of lesser dimensions, which may be interbedded by thin quartzite strata.

In the first type, well-exemplified in the northwestern slope of the Gayaza hillmass, intergully profiles represent a composite of several elements. Each element consists of an upper quartzite outcrop, surmounting a backslope of debris and a gentler slope of underlying argillites, terminating at the outcrop of the next quartzite band. The gentler slope of the argillaceous layer may enable deposition of finer waste as a footslope. Angles of the different facets of each element obviously depend on the surface area of each rock-type outcrop, the higher value being associated with the smaller area. Gully profiles are less affected by the lithological alternation and are, as may be expected, controlled by the quartzite members of the succession. Since the dip of the strata in these structures is quite steep the overall development of the profiles is characterized not by parallel retreat of elements and facets but by a diagonal downward regression coinciding with the angle of dip. In consequence, a quartzite facet on the interfluves correlates with a lower outcrop in the gully bed (Fig. 10).

Dissection of the upland in such alternate successions follows a breach of a higher quartzite band by the gully and capture of the crestslope drainage. There is then a change in incision pattern at right angles to the direction of the initial gully and following the subsequent trend of the argillaceous band. With the retreat of slope some remnants of the lowest quartzite band may be preserved in the positions of former interfluves, as outliers to the mass, or as semi-isolated parallel ridges.

Similar outliers conditioned by relatively thin quartzite bands occur where these form part of a lower succession underlying a massive quartzite band. The Ntarwete ridge of the Nshara Mountains, is an example of such a succession. Slope forms are dominated by the upper quartzite, whose debris partially covers the underlying argillites and produces a typical quartzite slope, except for the several outliers revealing the alternate nature of lower successions. In the opposite case, such as the Nshungyezi ridge, where quartzite forms the lower $\frac{3}{4}$ of the succession, the slope differs from the typical quartzite slope in the absence of the characteristic quartzite scarp and the presence of a smoothly convex upper slope similar to that found in an alternate succession. The altitudinal limits of the upland within the area, usually preclude the preservation of another complete quartzite band above this argillaceous bed, in such a type of succession. Remnants of such a band occur forming as a rule part of the crest, and in certain cases they are represented by abberant crest-elements, clearly controlled by lithology.

Forms of slope and dissection on complex structures are mostly difficult to explain. In part this is due to the fact that the complex structures of the area possess special lithologic characteristics and in this respect are entirely different from the simpler structures. The lithology of the predominantly arenaceous succession in the Isingiro Hills is, apparently, much more heterogeneous than the arenaceous members in the Rwampara, Gayaza and Nshara upland. Lithological reaction to geomorphic processes though similar in details, results in different landforms. Minor structures explain many peculiarities of form and dissection but not all of them. Lesser resistance of lower grade or schistose arenaceous strata and admixture of susceptible minerals explain other peculiarities but do not combine with structural characteristics to form a comprehensive explanation. Some of these inexplicable features are probably derived from geomorphic evolution which has erased geological diversity and no doubt the still incomplete knowledge of geological detail hampers understanding too. Similar problems arise in the predominantly argillaceous succession of the Koki hills which are composed from relatively incompetent shales and mudstones. But in these areas geology is better known and the general impression is that peculiarities of landform derive mainly from geomorphic evolution of the landscape and are geologically conditioned only in few cases such as the straight range of narrow ridges produced by an isolated thin quartzite band east of Kinota and the Buyojwa lowland inlier derived from the exposure of granodiorite basement in an eroded anticline.

In the Isingiro Hills, slope profiles and valleys forms are influenced to some degree by a lesser mean altitude which may presumably represent a result of both geomorphic history and less competent geology, but on the whole the mechanism of their development seems to combine processes typical both to resistant and non-resistant lithology. Where some slopes are formed on uniformly resistant strata, such as the slopes of the Karuruma valley and the western slopes of the Wemeriti ridge, the profile is essentially similar to the generalized type outlined above, except that its average angle is closer to that of the argillaceous slopes and it has only intermittent scarp-features. Apparently, however, this is not a widespread occurrence. Usually angles of slope are noticeably lower than can be expected on resistant rocks and gullying is comparatively widely spaced. Although coarse waste mantles most slopes, it is thinner and of smaller fragment-size and is frequently supported by an outcrop of resistant rock at the base of the slope. The prevalence of deep dissection, guided irregularly by minor structures and faults and the occurrence of semi-isolated spurs and outliers add to the evidence of successional heterogeneity.

A special type of slope is produced in the area by the occurence of thick duricrust cappings on individual hills. Such occurrences, as will be discussed below, are concentrated in certain parts of the study area, where comparatively thick laterite is found mainly on argillaceous hills but also, in one case at least, on a hill formed by a quartzite vein. In both cases the profile of the hill-slopes differs significantly from the classic laterite profile described in Buganda and found within the northern lowlands of the area. While possessing a nearly flat crest and lacking the typically convex upper slopes of other upland features of the area, the laterite scarp, never very high, is always situated a certain distance away from the edge of the crest (Fig. 32*). The general impression is that the thick laterite cappings found on these hills have both a speedier rate and a different mode of erosion than the underlying bedrock. The duri-

* p. 184

crust certainly forms a scarp-like edge which tends to disintegrate into coarse fragments and blocks. It is eroded away through the retreat of this scarp, and this retreat has overtaken the retreat of the underlying bedrock slope. As can be deduced from this feature the laterite crust in these cases is not associated with the typical underlying mottled and pallid zones and rests directly on fresh rock. This fact, of course, has important bearing on the origin of the thick crust.

Upland valleys

Upland valleys differ from the lowland valleys which penetrate or intersect the upland mainly by the absence of easily recognizable valley floor pediments as different from footslopes of deposited fine waste. Except in major strike valleys or denuded minor anticlinal structures, upland valleys lack even footslopes and appear youthful in section. In most cases even major wide-floored upland valleys have ungraded long profiles, with one or several knickpoints.

As observed most of upland valleys are geologically controlled as evident especially in simple structures. Drainage pattern can be easily correlated with the strike of argillaceous bands in alternate successions or of comparatively incompetent lithology in more homogeneous successions. Knickpoints in these subsequent stream-beds are, in most cases, correlated with change of direction and a breach of a resistant bed. In the complex structure of the Isingiro Hills, geological control is also evident in most cases, with the valleys correlated with faults, with minor anticlines or with the strike of a relatively incompetent bed. However, as stated, geological conditioning cannot explain the pattern or form of all the valleys.. The only area in which dissection pattern and form appears to be only subordinately correlated with geology is the Koki Hills where, as observed, lithological incompetence obscures geological control.

Cross-section of the strike-valleys dissecting the alternate succession are markedly asymmetrical. Valley sides on the "consequent" flank are usually more gently sloping than on the "obsequent" flank. Differential resistance and erosion on both flanks is associated with downward lateral migration of the stream bed, increasing the asymmetrical effect. Where the valley crosses the strike of a resistant band it narrows and its cross-section tends to be more symmetrical as are most valleys at right angle to the strike (Fig. 11-12). Faults coincident with strike reverse the profile of the cross-section where they are aligned along the "consequent" slope as in part of the Koharo valley of the Gayaza hillmass or accentuate it if they are aligned along the "obsequent" slope (Fig. 13*). The lack of data on details of geology prevents accurate analysis of valley forms in the Isingiro Hills at the present stage but on the whole it seems that there is a wide range of variation in lithologic competence and valley forms derive from differential interplay of lithological and complex structural characteristics. Structure may have a prominent effect on the slope of one flank of the valley, where it is cut across a resistant stratum, while the opposite slope on a less competent stratum, structural effect may be entirely obscured. This is apparent, for example, in the Mikoma and Kararuma valleys. The only case in which a structural feature exerts consistent, though by no means general, influence on valley form is, as observed above, where a fault creates a weak line

* p. 47

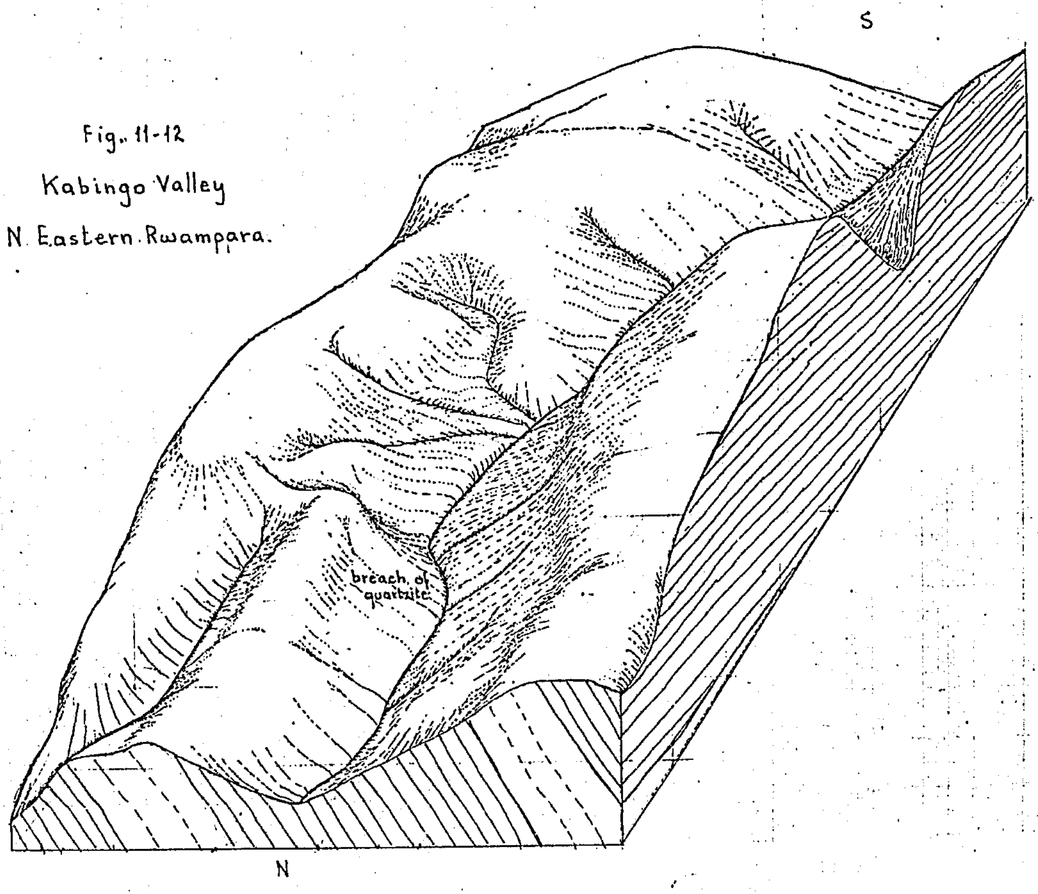


Fig. 11-12
Kabingo Valley
N. Eastern Rwampara.

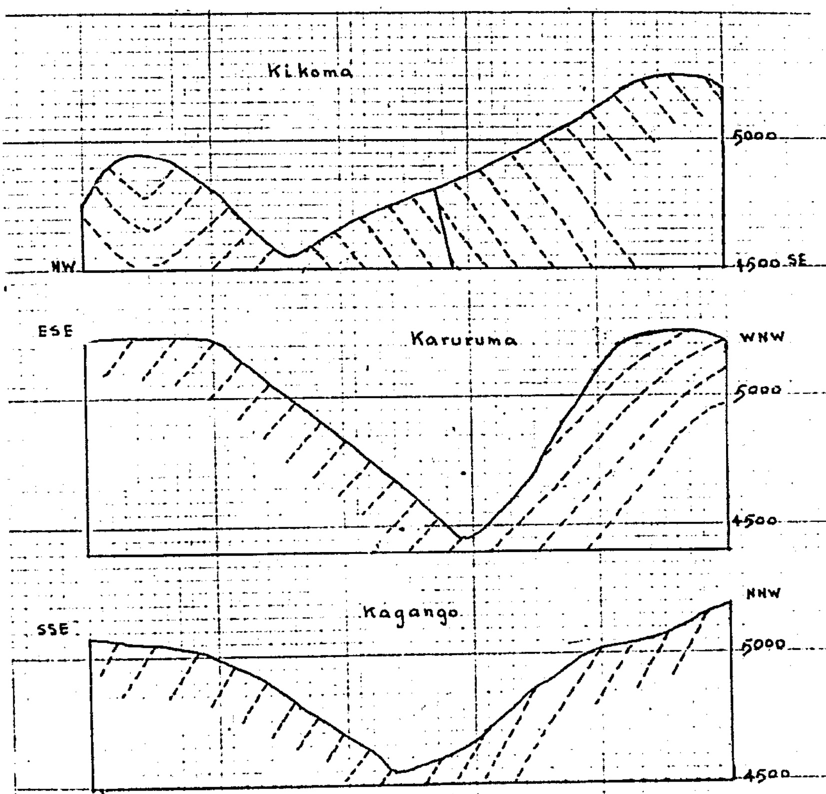
across a resistant stratum to a succeeding less-resistant one. Against the background of factors independent of local geology, such as differential local base-levels in the surrounding lowland and changes in climatically conditioned geomorphic processes, the wealth of variety in valley-form necessitates closer scrutiny for adequate generalization, (Fig. 14).

Geologic control of lowland features

Combination of incompetent lithology and the absence of macrostructure against a background of prolonged geomorphic evolution, tends to minimise the effect of geology in lowland landscapes. Geomorphic differences between lowland units and features of diverse geologic nature are, thus, never of the same order as those of the upland and the landscape of the lowland is essentially similar in the whole of the study area.

Resemblance of lowland landscapes results from geomorphic evolution of similarly incompetent lithology and the development of a very deep weathered mantle which equalizes lithologic diversity and masks structural peculiarities. Nonetheless initial geologic diversity can be discerned in the nature of several geomorphic features and in their pattern of distribution.

Lowland, as observed, is formed over two main types of lithology - basement granitoids and overlying schists of the sedimentary systems. On the whole, it appears that the schistose lowlands, e.g. the Nakivali - Mburo and the Ikariro - Bwarkasani lowlands, have a more subdued relief than those formed on basement rocks. Certainly, relative altitude is less diverse and drainage pattern more regular and these consistent



Valley forms in the Western Isingiro
H.S 1:25000
V.S. 1:6000
Fig. 14

characteristics cannot be related solely to the pattern of geomorphic evolution. The schists underlying the lowland form, as mentioned, the basal part of the Karagwe-Ankolean succession and the Toro System probably representing argillaceous strata metamorphosed over an igneous basement. Consequently, quartzite bands may be interbedded with them, etched out as ridges rising above the surrounding lowland. Prominent examples are the Mulambiro ridge in the eastern Nakivali lowland, south of Lake Ruma, which is separated by almost two miles of lowland from the Rugaga hillmass to the south, or the Mbala ridge in the western Ikariro lowland south of the Rugaga hillmass. A less prominent example, situated closer to upland units is the Rwambisengera-Biharwa range of low hills in the south-western part of the Masha arena, at the foot of the Rwampara Mountains. It represents a basal stratum of the Toro System, separating it from the plutonic inlier of the arena. Generally speaking, however, all these intra-lowland quartzite ridges, except perhaps, the Biharwa Hills, are much less altitudinally prominent than could have been expected by their lithology. The basal quartzite of the Karagwe-Ankolean system, outcropping broadly north and northwest of Lake Kazuma and between it and Lake Bwala, is not very noticeable in the relief. In any case it does not result in greater relative relief than that of the porphyritic granite to the north of it. This is, possibly, due to the nature of metamorphism within the schistose zone and the closer proximity to the underlying igneous activity.

Schistose lowlands are perhaps genetically related to arena-lowlands which usually have a metamorphic schistose aureole of varying extent.

It is possible that they represent an intermediate stage in the geomorphic development of an arena, following the erosion of overlying phyllitic strata and preceding the exposure of the underlying plutonic core. An earlier stage is perhaps represented, as already observed, by the Lower Ruizi basin. The possibility is attested by a strong similarity in the nature of the upland slopes, surrounding both arenas and schistose lowlands all of which show consistence of angle, height and lineament indicating equivalent development in spite of geological diversity. In true arenas, where the granitic core is exposed, mean relative relief is greater than that of schistose lowlands, attaining as much as 350 ft as compared with 200-250 ft in schistose lowlands. The irregularity of the drainage pattern which may be associated also with the more massive nature of the lithology is even more noticeable. The schistose aureoles of arenas and schistose zones at the margin of the sedimentary cover are characterized, on the other hand, by the occasional presence of quartz veins, probably intruding from the underlying basement through the thinning cover of schists. As a rule they form sharply conspicuous ridges that may attain a relative relief of over 400 ft. The Nyabishozi Hill in the Masha arena is a conspicuous example within the study-area; another example is the Kyibega Hill, the westernmost of the Sanga Hills.

In the granitoid lowlands quartz veins and other outcrops of tectonic quartzite are disposed in belts following the tectonic trends of the structure. Most of them are aligned along the main trend forming ridges or ranges of prominent hills characterized by smoothly curved crests. Some of these belts can be traced over long distances as for instance, the Buringhanira ridge, in the eastern Ishura lowland, west of Lyantonde. The number or density of such belts, their continuity and trend may be used as criteria for classifying granitoid lowlands, since their expression in the relief is very conspicuous and characteristic. Thus, the Mbuga lowland in the northwestern part of the area beside being of more subdued relief is characterized by relatively few quartz veins following the cross-trend to the NNE, while the Ishura lowland in the centre of the area is transacted by as many as seven belts (Philips, 1959) of quartzite, some of them continuous over more than five miles and all following the main-trend between NW and NNW. The Nyabushozi lowland reveals intermediate characteristics.

A feature which distinguishes arena lowlands from other granitoid lowlands is associated with outcrops of the bedrock and the formation of a "tor" -like inselberg landscape. The evolution of these landforms has been investigated and discussed elsewhere. The most applicable theories, both based on Linton (1955) are Savigear's (1960) in West Africa and Ollier's (1960) in Uganda. "Tors" or other types of bedrock outcrops rarely appear in arena lowlands of the study area. They are abundant in the Ishura-Nyabushozi lowland and possess a discernible regularity of distribution. Measurements of joint and foliation planes and density in the granitoid rocks are insufficient to attempt a study of this distribution, but the application of Linton's theory seems very appropriate. In the Ishura lowland disposition of hill-top "tors" is closely correlated with the predominant tectonic trend and thus - with the distribution of quartz ridges, usually appearing on intervening ridges. In the Mbuga lowland they are considerably less abundant, both cases being accordant with the distribution and abundance of quartz veins. Absence or scarcity of outcrops in the arena lowlands of the area (they are abundant in other arenas, such as the Chitwe arena in south Ankole), are probably related to more homogeneous close-latticed microstructure of the granite and to younger erosional history.

The Nature and Distribution of Levels

The differentiation of landscape into two major elements - upland and lowland - and the indication that each of those elements is characterized by a relatively planed surface, brings to the fore one of the major problems of geomorphological study in Uganda and in Africa as a whole. The significance of planed surfaces and their evolution to the present study is obvious. The main aspect of correlation between landforms, soils and vegetation is associated with the differentiation of level and inclined surfaces and sites. Multiplicity of altitudinal level surfaces may indicate also differences in age and implies the attendant diversity in the genesis and nature of associated soils and the consequent differentiation of vegetation.

In the preceding chapter the importance of geological control as a primary factor in the differentiation of the main elements of relief and of types of landforms within them, is discussed. At the same time it was implied that there are many manifestations of general landscapes and of individual landforms that cannot be explained by geology alone or by geology at all. Most of these are associated with the level and apparently accordant crests of upland features and the presence of different levels of crests on geologically similar features and, consequently, indicate the effacement of geological differences through prolonged geomorphic evolution and the formation of one or more planed surfaces truncating competent and incompetent lithology at the same level.

The following chapter is concerned with the elucidation of the nature and distribution of these planed surfaces in the study-area. But since this elucidation is based on extensive previous work, it is necessary to precede it by a review of relevant ideas and theories.

Erosion Surfaces and Landscape Evolution - review and comment

The study of African geomorphology has always been and still is concerned mainly with aspects of cyclic landscape evolution as reflected in the characteristic presence, in any one region, of a number of distinct surfaces separated by scarps of varying heights and prominence. No doubt, the maintenance of this focus of interest stems from the lack of general agreement in the interpretation of these surfaces and the solution of the problems involved in it. These include the number of stages or cycles represented, the mode of origin and development of the surfaces, their dating and correlation from one region to another and their interrelations within w each region and, also, the nature and significance of surface deposits, notably, laterite.

1. Uganda's "Classical" Surfaces (Table 5, p.77)

(a) <u>The sequence of surfaces</u>

The concept of a sequence of stages in the evolution of Uganda's landscape was introduced by Wayland (1920, 1921, 1926) who later established the existence of three major stages. These he originally thought to have been terminated in the formation of peneplains and, accordingly, designated as PI, PII and PIII (1931, 1933, 1934). This sequence was accepted and supported with further evidence by Combe (1932, 1943) working in South Ankole and, later, by Pallister (1954), working in Buganda. It was also extrapolated by Lepersonne (1949, 1956) to the area of Northwestern Congo and adjacent parts of Uganda. McConnell (1955) attempting a country-wide correlation recognised five surfaces (four - within the area relevant to the present subject), which appeared to conform to the continent-wide sequence and chronology established by Dixey (1939, 1943, 1946, 1955, 1956b) and L.C.King (1948, 1951, 1953, 1962) who subsequently quoted McConnell in support of their postulations. While this continent-wide, five-stage sequence appears to have gained fairly general acceptance by the beginning of the present decade (B.C. King, 1958), McConnell's views were immediately opposed within Uganda itself. It was, however, only the validity of one of his surfaces that was challenged and there seemed to exist considerable agreement as to the validity of the other four. At the same time it was realized that postulation of surfaces in Uganda and in Africa as a whole, encounter serious difficulties which cannot be met by the prevalent views.

(b) Limitations of surface correlation

It was established already by Wayland (1929) and other early workers that the landsurface in western Uganda has been strongly deformed by warping associated with the formation of the Western Rift. Being of regional extent only, the deformation obviously presents difficulties in fitting the regional surfaces within the continental sequence. Moreover, the differential upwarp of the Rift shoulder and downwarp of the Lake Victoria basin render the correlation of discontinuous and isolated surface relicts a highly uncertain, if not an impossible task even within one region. Another basic difficulty results from the fact that many residuals of older surfaces have been preserved on resistant formations. This is especially conspicuous in southwestern Uganda where the two distinct relief units of upland and lowland are associated, respectively, with highly resistant phyllites and quartzites and with easily weatherable granitoids and schists. The older surfaces (Wayland's PI and McConnell's Ankole and Koki surfaces) are identified exclusively on the metasedimentary upland crests while the younger ones are recognized mainly on schistose and plutonic lowlands. Where a higher surface is cut across a more competent lithology than a lower, adjacent one, a "step up in altitude" does not necessarily mean "a step back in time". It is on both these grounds that Pallister, who adopted McConnell's nomenclature for his youngest surfaces and extended the Acholi surface to the flat-bottomed valleys of Mengo (1956b, 1959, 1960), objected to the Koki surface which, he maintained, represented an upwarped and a lithologically segregated part of the Buganda Surface, (1956c).

Undoubtedly the differential weathering and erosion and differential warping can result in a multilevel topography devoid of cyclic significance. This was clearly appreciated by L.C. King and Dixey who, consequently, considered the cycles they recognised as major stages applicable on a continental scale and regarded at least the higher residuals as reflecting multiple-levelling of surfaces upwarped on a regional scale. It has, thus, long been recognised that in regions of tectonic instability the absolute altitude is of very limited value in correlation of surfaces and that other additional criteria should be used in their identification and characterisation. Among these the association of surfaces with laterite was early regarded as being significant.

(c) The Association of Laterite

The significance attached to the association of laterite with erosion-surfaces springs from the prevalent view as to the nature of laterization. According to this a thick accumulation of lateritic materials occurs only where the surface has undergone prolonged plantation. The presence of flat-lying thick laterite sheete upon upland crests, thus, clearly indicates the existence of a former planed surface and the plotting of laterite residuals becomes, in fact, the plotting of an ancient peneplain or pediplain. The occurrence of thick laterite duricrust as cappings of flat-topped hills is one of the most prominent landscape features of the lakeside region of Uganda. Wayland, Pallister and McConnell all associated thick laterite with the same PII or Buganda Surface and McConnell associated it also with his Koki Surface. All three agree also that the younger surface (PIII; Tanganyika Surface) is associated with Laterite of a different nature; while the Buganda Surface laterite represents relicts of an extensive sheet subsequently dissected, exposed and hardened into a massive ironstone duri-

Table 5: Uganda Surfaces

Wayland 1931,1934 Uganda	Combe 1932 Ankole	Ruhe 1954 Eastern Congo	McConnell 1955 Uganda	Lepersonne 1956 Eastern Congo	Pallister 1956 Mengo	De Swardt & Trendall,1961 De Swardt,1964 Uganda	Doornkamp & Temple,1966 Masaka-Ankole
PI End-Cretaceous over 4700 ft partially laterized	PI ? over 5500ft		Ankole Jurassic over 5000ft un-laterized	PI ? Jurassic Cretaceous 5100-5700 ft	Buta-Bulaga ? Cretaceous 5000-5200 ft ?un-laterized	Upper Laterite	Marangara-Singiro ? Pre-Tertiary over 7000 ft (unwarped)
	PII (Buganda) 4900-5400ft	Mid-Tertiary over 4300 ft	Koki Cretaceous 4600-4800ft thickly laterized	PII Miocene 3600-4400ft	Buganda Mid-Tertiary thickly laterized - - - - - - - upwarped or lithologic- ally differentia- ted 4600-4800ft	Cretaceous Early Tertiary 3300-8000 ft thickly laterized	Upland Landscape ? Eocene-Early Oligocene (? pre- Tertiary) 4300-7000 ft
PII Oligocene 4300-4400ft thickly laterized			Buganda Mid-Tertiary 4200-4400ft thickly laterized		downwarped 4100-4200ft		
PIII Pliocene 3400-4000ft partially laterized	PIII ? 4200-4700ft	End-Tertiary under 4300ft	Tanganyika End-Tertiary 3500-3800ft partially laterized	PIII End-Tertiary 2400-3300ft	Tanganyika End-Tertiary 3500-4000ft partially laterized	Lower Laterite Mid-Tertiary 1800-5400ft partially laterized	Lowland Landscape Late-Oligocene Mid-Pleistocene 3500-4700 ft (upwarped)
			Acholi Lower Pleistocene 3000-3500ft un-laterized		Acholi Early Pleistocene 3000-3500ft un-laterized (aggradational surface)	Wide Valley Bottoms Mid-Tertiary 1600-5200ft un-laterized	Infill Landscape Mid-Late Pleistocene 3000-4200 ft (up-warped)

crust, the laterite of the lower surface is still found within the original soil-regolith profile. The surface being only imperfectly planed as yet, laterite occurs only where topography is favourable. It is thick only where it is flattened and is well-indurated only where the surface is dissected by the younger, valley, cycle. Agreement is less clearly stated as to the laterite on the older surface: but it does appear to exist. Wayland associates laterite with his PI surface but considers it to be present only is patches (1934); Pallister does not mention laterite in relation to his Buta-Bulaga surface, as he does in relation to the lower surfaces (1960); McConnell states that his Ankole Surface "does not as a rule carry laterite" (1955).

Even if none of the three workers referred to it, a general picture of surface laterite relations does appear to emerge from these observations. The original laterite cover of the older surface has been, at least partially, eroded and its stripping did not affect the preservation of the surface itself. This seems to indicate that the bedrock across which the surface has been cut is more resistant than the original laterite cover. The intermediate surface, on the other hand, is represented only where the original laterite cover has been preserved. Wherever it was stripped away the surface was speedily modified (Pallister 1956a,b). Laterite on the younger surface is not, as yet, fully developed. It is apparent that laterite is regarded by these authors only as a supplementary criterion. The decisive criterion remains the altidunal disposition of the surfaces, and the topographical discontinuities between them. This is reflected mainly in McConnell's assertion of similarity between the nature of laterite on both the Koki and Buganda Surfaces. It is the dependence on altitude, whether relative or absolute, as a decisive criterion that provoked the main criticisms of the "Classical Uganda Surfaces".

2. Recent Approaches

(a) The two-surface concept

As outlined above landscape in Uganda falls into two distinct groups of landforms. In a survey of a limited area it is always one major upland crest surface that it apparent. Other even surfaces are usually limited in area and may be identified either on the few features rising above the general crest level, or on bevelled spurs and foothill fringes below it. When the prevalence of this dual aspect of the landscape is added to the difficulties in correlation entailed by tectonic instability and lithologic differentiation it is not suprising that serious doubts were stirred as to the validity of the "Classical" surfaces. These doubts were entertained even by some of the earlier writers like Willis (1936) and Solomon (1939) who, mainly on tectonic grounds, disputed the existence of evidence for more than two major surfaces. Later, Ruhe (1954, 1956) reached similar conclusions and formulated long-recognised views in a thesis that seems to be shared by many recent workers. He points out the inadequacy of altitude as a criterion of correlation in regions of tectonic instability and the importance of surface continuity, constancy of relations between surfaces and anology of surface deposits.

(b) Laterite surfaces

The same thesis was independently developed by De Swardt and Trendall (1961) and De Swardt (1964) who attributed a major significance to the nature and distribution of laterite. This is reflected in the avoidance of the term 'erosion surface' and the substitution of 'laterite surface' in its stead. They recognise two such surfaces of laterite accumulations: (1) an Upper Laterite - characterised by a uniformly distributed thick ironstone duricrust of primary origin and relatively old age (2) a Lower Laterite - characterised by unevenly distributed thinner and less indurated accumulations, largely of secondary origin and younger age. To these they added a younger erosion surface dissecting the Lower Laterite and lacking altogether, designated as the Flat-Bottomed Valleys surface. Obviously this surface is equivalent to the Acholi Surface as defined by Pallister while the Lower Laterite corresponds to the Tanganyika Surface of Pallister and McConnell or to Wayland's PIII. The Upper Laterite, however, is stated to embrace all other, older surfaces - Waylands PI and PII, Pallister's Buta-Bulaga and Buganda and McConnell's Ankole, Koki and Buganda surfaces. This considerable altitudinal range attributed to a single surface is envisaged not only on an interregional (difference of approximately 4000 ft between Buganda and Kigezi) but also on an intra-regional and even a local scale (500-700 ft in Koki, Ankole and Kigezi within individual topographic units). Regional deformation while constituting an important factor is not regarded as the cause for the great altitudinal range of this surface. In fact, it is denied that several surfaces can be distinguised within the upland and that any evidence of an ancient planed surface, if it ever existed, has survived. The basic premise for this assertion is the presence of a thick laterite sheet upon this upper surface regarded as, virtually, diagnostic (and, consequently evidence asserting lack of laterite is emphatically denied, cf. 1961, p. 41; 1964, p. 323). Laterite is considered to represent the residue of a gradually eroded great mass of overlying rock. This is regarded as the only possible source of such a great amount of lateritic materials and it is argued that the lowering of the landsurface during the cycle that resulted in the laterite accumulation was of the order of "hundreds if not thousands of feet" (ibid, 1961, p.44). Differences in amount of reelief, in different parts of the surface are, presumably, attributed to difference in lithologic competence. It is probable, accordingly, that the resistant Karagwe-Ankolean sediments always effected a greater relief than the Basement Complex and Intrusive granitoids and that the ancient relief at the start of the cycle was not much different than the present one.

The uniform presence of a thick laterite sheet upon a highly uneven surface, is, thus an essential premise of the hypothesis. The existence of remnants of several bevels within the upland, and consequently, the possibility of a single laterite sheet simultaneously blanketing several pre-existing surfaces, is rejected: it is asserted that a statistical treatment of summit elevations showed no maxima and produced no rational pattern of such surfaces. Moreover, it is stated that "though it shows considerable relief the older laterite surface is remarkably smooth and there are no marked breaks in slope, except at the margins of extensive quartzite outcrops". Considering the local scale of this very uneven relief this would mean that laterite is regarded as accumulating thickly through gradual lowering, on quite steep slopes. This view, which is contrary to previous concepts of laterization, is supported by examples from Buganda where differences of about 100 ft in the elevations of laterite surfaces are asserted to exist on individual residuals and from Ankole, where Phillips (1959) is cited in evidence of 300-400 ft differences in thick laterite sheet elevations over single remnants. Since the main tectonic events in the area are supposed to have occurred after the three surfaces were already in existence, it is suggested that the breaks in slope separating the two laterite surfaces and the flat-bottomed valleys are related to cessation of laterization and incision of f drainage caused by change from humid to arid conditions.

(c) Landscape surfaces

Recently Doornkamp and Temple (1966), adopting the same principles reached similar conclusions as to the number of stages represented in southwest Uganda. Their approach and their conclusion as to the evolution of the landscape are, however, different from those presented above. Laterite is scarcely mentioned and evidently if any significance is attached to it, it is only of secondary importance. The "upland landscape" corresponding in extent to the above Upper Laterite, is regarded as representing residuals of an ancient initial surface. It is envisaged as having some relief and even carrying few modified residuals of a former surface but it is a subdued late-mature relief, entirely different both in amount and form from the present one. The lowland surface corresponding to the Lower Laterite is regarded as a product of an erosion-cycle initiated by regional uplift associated with the formation of the Rift Valley. Tectonic movements are, thus, considered to have occurred since mid-Tertiary times, if not earlier, and to have caused the sequence of stages in landscape evolution. There is no attempt to correlate these stages with the continental sequence suggested by Dixey and L.C. King or to regard them as having more than a regional significance. It is recognised that the upland landscape has a multi-level aspect but it is attributed to differential warping within the regional uplift and to lithologic differentiation. Only one major tectonic phase is envisaged (the upland landscape being treated as an initial one) and is regarded as being prolonged (? late Oligocene - later Pleistocene) and concurrent with the development of the lowland landscape. The third surface, the infill or aggradation landscape, is consequent upon reversal of previous drainage by continuing rise of the uplift axis.

3. Problems of landscape evolution

(a) Mode of surface development

Divergence of opinion as to the mode of surface development in Africa does not, except in one case, transcend the generally conceded concept of cyclic evolution. Within the limits of this concept the main point of dispute is identical with the more general geomorphic controversy between the Davisian and Penckian schools of thought, in itself based, partially at least, on data derived from Africa. A summary of this controversy, in relation to Africa, has been provided by B.C. King (1957, 1958) and need not be reviewed here except for one observation that appears to indicate the need for an open mind toward both schools of thought. Studies of different areas in Africa, among them that of Pallister in Uganda (1956a,b) suggest that "whereas scarp retreat may be important in the earlier stages of the evolution of a new erosion surface, the later stages will conform more closely to the pattern of the 'normal' cycle, once remnants of the older surface have been eliminated from the divides (cf. Dixey, 1955, p.272)" (ibid, 1957, p.674).

B.C. King does not mention a somewhat different view on the mode of surface development originating in Uganda. This view was first presented by Wayland (1934) who introduced the term "etchplain" to indicate the result of a rapid stripping, upon uplift, of a thick mantle of deeply weathered, easily eroded, rock and exposure of the underlying, relatively even, basal surface of fresh rock. This relative eveness of the "etchplain" necessitates the assumption of an initial, stable, planed surface to allow for the uniform depth of weathering. Accordingly Wayland suggested tentatively that his PI represented a peneplain while both PII and PIII were etchplains. The view was adopted by Willis (1936) who used the term "etching" to describe the process culminating in the "etchplain". Notwithstanding Thornbury's (1954) doubts as to the applicability of the process on a regional scale, the hypothesis - at times modified - seemed to have gained several, more recent, adherents. Pallister (1960,p.27) considered the term, if not its exact intended meaning, to be "peculiarly apt for Mengo". Ollier (1960) used the hypothesis as a basic for his views on inselberg formation in Uganda. He modified it, however, very significantly in assuming that the soft rotted rock mantle is not virtually stripped to expose extensively the basal surface but is eroded away, mostly through incision and slope retreat of laterite capped hills, exposing only irregularities of the basal surface. The modification is better suited to meet the facts of the Uganda lowland landscape but tends to make the hypothesis of doubtful value. Nevertheless, Thomas (1965) empasizes the importance of deep weathering and etching in the geomorphology of tropical environments, basing himself mainly on observations in southwestern Nigeria. Earlier, Bakker and Levelt (1964) extended the concept to ancient landforms in Europe. It should be noted that all writers, including also Berry and Ruxton (1959) refer, when they speak of the deep weathering and its geomorphological consequences, mainly to areas underlain by granitoid rocks. These seems to be no allusion to deep weathering of less weatherable rocks of the type found in southwest Uganda.

The exception, mentioned above, to the cyclic concept of landscape evolution, is the hypothesis of 'Apparent Peneplains' presented by Trendall (1962). According to this hypothesis, the laterite-capped, flat crests of Buganda hills do not represent preserved remnants of an ancient, planed, erosion-surface. Each one of the hills, together with the surrounding pediments is regarded as a single inevitable product of a continuous interplay between two concurrent processes of erosion - laterization and surface wash, both causing a general but differential lowering of the landsurface. The flat crests, in other words, are not related to some ancient base-level but to the same one with which the foothill pediments are associated; the scarp and slope separating them do not indicate a separation of two stages in evolution but of a predominance of laterization from a predominance of surface wash. The combined process was initiated by a long-past major lowering of base-level and involved progressive flattening of interfluves associated with progressive accumulation of laterite, and gradual steepening of convex slopes. A point of equilibrium is finally reached when flattness of crest prevents further surface wash (removal of non-lateritic solubles) and exposure and hardening of the thick edge of the laterite accumulation above the slope prevents further down-wearing. Beyond this point the present typical profile develops - flat, laterite-capped crest, scarp of the duricrust and the concave back-wearing slope. Landscape is, thus, entirely divorced from the concept of cyclic evolution unless a very ancient previous cycle is postulated terminating in an even peneplain hundreds of feet higher than the present hill crests and of which, of course, no evidence survived.

It may be noted that although the hypothesis accords in many respects with the postulated propounded by De Swardt and Trendall (1961) it differs significantly in uniting the Upper and Lower Laterites within one cycle. The difference between them is one of phases of the same process: the Lower Laterite has been presumably formed after equilibrium was attained and slope retreat began. There are several other characteristics accruing from this hypothesis that should be noted. Flattening of convex interfluves associated with laterization and selective removal of soluble rock constituents necessarily means that the thickness of residual laterite is greatest in the centre of the crest, where the greatest amount of rock was removed. The process is conceived as applied to an area underlain by granite and its rate and amount are calculated according to the composition of these rocks. It appears to fit also, at a slower rate, the hill-forms common to the Karagwe-Ankolean metasediments (convex upper slopes, thin laterite edge below crest-line) in those few cases where the hills are lithologically homogeneous and the surrounding pediments are cut across the same lithology. It is difficult to fit the theory to the more common cases where the lithology of the pediments and the hills differs sharply, but it certainly accounts for the great relief of a single surface extending on different lithologies.

(b) Dating the surfaces

In absence of direct evidence, the "classical" surfaces of Uganda were usually referred to the Tertiary deposits, bearing Burdigalian mammal fossils and overlying unconformably the Pre-Cambrian rock-surface in Kavirondo Gulf. This datum was early correlated by Wayland (1929) with the PII Buganda Surface in Uganda which - he considered - has been formed by late Oligocene times. Accordingly, PI was dated comparatively 'on general grounds' as end-Cretaceous (Wayland, 1931, p.8) and PIII/Tanganyika Surface - as Pliocene (1934, p.78). Despite some difference of opinion as to whether the datum surface underlies the Miocene deposits or truncates them (B.C. King, 1957, p. 678, citing Kent, 1944, Dixey, 1945 and Shackleton, 1951), agreement with this comparative chronology seems to have been fairly general. Willis (1936) regarded the Buganda surface as 'late' Tertiary, either Miocene or Pliocene. Dixey (1944, 1946) correlated it with the main mid-Tertiary or sub-Miocene peneplain he identified in Central Africa; Pallister (1960) also accepted this basic chronology, tentatively dating his Buta-Bulaga surface - by analogy - as late-Cretaceous or early Tertiary, the Buganda Surface - as mid-Tertiary and the Tanganyika Surface - as end-Tertiary or Pliocene. Similarly, McConnell (1955) ascribed to his surfaces the following ages: Ankole-Jurassic; Koki-Cretaceous; Buganda-mid-Tertiary; Tanganyika-end-Tertiary and Acholi-Lower Pleistocene.

The discovery of a Lower Miocene fauna in the volcanics of Napak by Bishop (1958, 1961) at Kadam, initiated a reappraisal of the chronology outlined above. It was found that the surface underlying the volcanics, designated as the "Kyoga" surface by Trendall, is unlikely to be correlated with any surface higher than the PIII/Tanganyika surface. Since it is shown to have existed already in Miocene times (De Swardt and Trendall, 1961, p.21), the older Buganda Surface may prove to be pre-Miocene and possibly Pre-Tertiary. The Kyoga/Tanganyika surface has been modified by pediplanation (and laterization ?) <u>since</u> late Tertiary up to the present, as evidenced by the presence of 50-150 ft high 'pedestals' of Precambrian basement preserved under the subvolcanic sediments (Bishop, 1966). As Bishop points out, if such a rate of modification is accepted, a considerable re-investigation of erosion-surfaces formation will be necessary before former, unburied remnants of surfaces can be considered as virtually unmodified.

Consequent upon these conclusions, the correlation of the Kavirondo subvolcanic surface with the Buganda surface was subjected to severe criticism. Bishop (1962, 1966), brings convincing arguments that the evidence for correlation is insufficient in itself and also in view of the tectonic and volcanic history of the region. His arguments imply that the surface is entirely unsuitable to serve as a datum for any chronological determination. The conclusions outlined above are also corroborated by recent evidence from the Western Rift. It is generally recognised that the surface represented on the uplifted Rift shoulder corresponds to the PIII/Tanganyika surface regarded as end-Tertiary. It was considered that the Plio-Pleistocene rifting has downthrown a part of this surface into the floor of the Rift Valley where it was, subsequently, covered by younger sediments. Results of the surveys in 1956 (Harris et al, 1956) suggest that the Plio-Pleistocene deposits of the Rift Valley rest upon pre-Pliocene sediments and not upon Precambrian basement which underlies only the latter. This indicates a probable pre Miocene age for both the rifting and the Tanganyika surface.

Both de Swardt and Trendall (1961, 1964) and Doornkamp and Temple agree in their postulations with this revised chronology. De Swart's Lower Laterite is stated to represent a modified Kyoga (=Tanganyika) surface except of course, that the modification is ascribed to laterization and the surface is regarded as a laterite surface. In other words, insofar as the laterite is used to define the surfaces their age is younger than that of the original, unmodified, erosion-surface. The Kyoga erosion-surface underlying the volcanics, on which laterite has nowhere been proved, was probably defined in pre-Miocene while the laterized present surface is younger than Miocene and is still in the process of formation. Similarly Doornkamp and Temple have assigned a late Oligocene age to the initiation of their lowland landscape which attained its present state by mid-late Pleistocene, and an early Tertiary or, possibly, a pre-Tertiary age to their upland landscape (Buganda surface).

(c) Drainage Pattern

It has been long recognised (W.C. Simmons in Wayland 1931, p. 41) that drainage pattern in Uganda reflects an antecedent system, originally directed westwards and subsequently reversed and modified by the uplift of the Western Rift Shoulder. Reversal and downwarp have caused the impounding of Lake Victoria and the drowning of what is regarded as the former upper parts of the two main systems of Southwestern Uganda - the Katanga and Kagera Rivers. The main continental watershed, preceding the uplift, is placed east of the lake and somewhat to the west of the Eastern Rift (Teale 1950, Cooke 1958, B.C. King 1958, Bishop 1966).

While there is almost a complete agreement with this interpretation, since it is clearly supported by the west-directed pattern of drainage, it still involves several problems of detail, especially as to the drainage of south-western Uganda. These seem to be associated with the striking inconsistency of drainage pattern with geologic arrangement as reflected in the relief. In an early publication Dixey (1946) who apparently agreed with the postulation of westward-flowing drainage in Uganda, expressed doubt as to the general possibility of east-west drainage lines traversing the ancient high country on the western flank of the Rift Valley and consequently deduced that it is probable that the west-directed Uganda drainage was tributary to the Nile, which is consistent with his views on the early origin of the Rift. Although Dixey did not refer to the eastern flank of the Rift, the same doubt may be applied to it, in the highland areas of Ankole. In fact Trendall (1962) raises just this question in regard to the Ruizi and Kagera Rivers, both possessing a much greater relief in their lower parts than in the upper parts of their basins. This doubt is also consistent with his view of an initial surface of considerable relief. It is obvious, however, that such a consistent and pronounced lack of adjustment of drainage to geology as is found in the region can be explained only by superimposition from an initially planed surface on which geological diversity has been smoothed out.

This was recognised by Doornkamp and Temple (1966) who based their interpretation on a single initial late-mature surface, subsequently uplifted and warped. However, this interpreation, presented as a general outline, is necessarily simplified. It assumes, for instance, that the present drainage pattern is basically the same as that of the initial surface. The modifications recognised are all related to uplift and warping and subsequent reversal and infill. They involve mainly the changes produced in the proto-Ruizi and proto-Orichinga systems of drainage which cannot be doubted. Except for these basins the alignment of stream courses and watersheds is regarded as virtually unchanged since at least early Oligocene. It is only the direction of flow and the affinity of ~~criteria~~ category of basins that has changed.

Examples relevant to the study area are, the present lower course of the Kagera, from Nsongezi to the Lake and the present divide between the Katonga-Mpanga and the Nakivali-Kijanebalola lake system. In both cases the present alignment is regarded as virtually identical with the initial one. In the case of the divide it is at present very tenuously defined across a lowland and quite frequently and broadly breached by wide shallow valleys. Moreover, the disposition of flat crested upland features, presumed to represent remnants of the initial surface, does not coincide with the latitudinal alignment of the watershed. On the contrary, they appear to extend across it, far to the north. The lower course of the Kagera is at present incised into lacstrine deposits of an ancient arm of Lake Victoria. While it is apparent that this arm had flooded a pre-existing valley, there is no direct evidence as to the original direction of this valley or its nature. It is, perhaps, due to this fact that Heinzelin (1962) followed by Gautier (1965) traced the upper course of the proto-Kagera approximately in its present south-north alignment and related its present lower course to a tributary of the northwestard flowing upper proto-Katonga. In this, of course, these writers ignore or deny the validity of the evidence on the submerged channels shown by soundings in Lake Victoria. According to Teale (1950) the Kagera mouth is linked by such a channel to the Mara River on the opposite shore of the Lake.

The fact that both these examples are associated with areas of lowland and, thus, of incompetent lithology appears to be significant. Preservation of an antecedent virtually unmodified drainage pattern during a very long period of uplift may well be envisaged where it has been superimposed upon a very resistant lithology whose rate of uplift or warping was slower than the rate of downcutting. It may be possibly preserved, in a more modified form, where incompetent lithology was exposed at a relatively late stage and is consequently of relatively limited extent (e.g. - arenas) so that available time and effect of proximate superimposed drainage would have enabled only little modification. Even in both these cases the amount of modification would depend on variable factors like differential warping, differential resistance and proximity and intensity of successive new base levels.

Where exposure of plutonic and schistose rocks and consequent lowland landscape are extensive it is reasonable to assume that the incompetent lithology was devoid of resistant cover already on the initial planed surface or possessed only a thin cover stripped at an early stage of the uplift. It would seem that in such a case there is a possibility that an antecedent drainage pattern, even if initially superimposed in an unmodified form, will be subsequently modified with shifts of divide and stream alignment and even a change of pattern on less than a regional scale. This would be especially true if uplift and differential warping were intermittent and multi-phasal allowing for phases of stability and surface development. Modifications of drainage pattern would occur, in this case, through the relatively rapid denudation of newly exposed areas of the unevenly underlying basal or basement rocks.

It must also be noted, in this connection, that the initial surface must be regarded as possessing some amount of relief.

Doornkamp and Temple admit to the possibility of as much as 900 ft of relative relief on their initial surface, seemingly because some of the features they regard as remnants of this surface still possess this relief even within a single remnant (e.g. the Nshungyezi-Burunga ridge in the East Rwampara). It may be expected that the greater amount of relief on the initial surface will be associated with the more resistant lithology. It is also obvious that watersheds will be associated with the greater relief and since the postulated surface is late-mature and its drainage well-integrated it can be assumed that major divides will tend to be associated with the location of greater relief. Thus, the alignment of the major proto-Katanga - proto-Kagera divide across an area of incompetent rocks, and the tracing of the main course of the proto-Kagera across the area of very competent rocks and the greatest relative relief must be doubtful. It appears more reasonable to suppose that the major divide has shifted northwards due to later modification of lowland drainage and that the proto-Kagera did not constitute as major an artery on the initial surface as it was supposed to, or in other words - that the proto-Kagera did not originate in the ancient continental divide but somewhere to the south, in approximately the same direction from which its upper part flows at present. Note may be taken of Dixey's (1946) mention of a mid-Tertiary divide in Tanganyika trending from the vicinity of Tabora towards the western flank of the present Eastern Rift - e.g. - towards the ancient continental divide. Its western continuation is not known but it might have had some connection with the upper proto-Kagera. The evidence of the channels on the bottom of Lake Victoria does not appear to this writer to be conclusive in itself and neither does it fit with the coastal morphology of the lake as well as does the postulation of a northward trend for the former drainage.

Surfaces and Levels in the Study-Area

Considerations of Uplift and Warping

It is obvious that knowledge of the nature and magnitude of tectonic events is essential to the understanding of surface evolution. Theories on the sequence of surface in southwestern Uganda have, undoubtedly, failed in many cases to take proper account of tectonic instability or to state the measure of influence it may have had. Altitudinal correlation seems to have been too much depended upon in postulation of erosion-surfaces and consequently justified criticism were induced that may have caused too extreme a rejection of these theories.

An antecedent drainage pattern is, no doubt, a significant clue to the occurrence of uplift. But, as intimated, it must be employed with caution. It can be used to estimate the nature and magnitude of regional uplift only where the lithology upon which it imprinted itself is similarly resistant throughout the region impressed by the uplift and where such an imprint is clearly unadjusted to geology. Where these circumstances do not obtain on a regional scale it will be possible to ascertain the magnitude of the uplift only locally, where they do. The differentiality of regional uplift and warping will be then difficult to ascertain and application of other lines of investigation seriously hampered. Where lithology is similarly resistant across the uplifted region, valuable data may be derived from the study of relative altitudes. In cases where antecedent drainage is clearly present throughout the area of resistant lithology, relative altitudes will enable an estimate of the position of the pre-uplift surface and permit calculations of uplift and differential warping. Otherwise use of altitudinal data must rest on certain pre-suppositions. It must be assumed that the surfaces whose altitude is being measured and compared represent remnants of the initial pre-uplift surface or that the amount of crest lowering by erosion has been infinitesemal. Furthermore, a straightforward comparison rests on the assumption that uplift was continuous and not intermittent or that in case it was intermittent and intermediate surfaces developed, the compared surfaces do not represent them and are all remnants of the initial, pre-uplift, surface alone.

Relevant views of uplift and warping

Most views on the geomorphic evolution of Africa, expounded on a continental scale mainly by Dixey and L.C. King, envisage a prolonged stage of continent-wide stability culminating, by early Cainozoic, with an enormous, extremely smooth peneplain or pediplain upon which limited remnants of an earlier, Mesozoic planation were preserved mainly on divides (L.C. King, 1962, 1967). This continent-wide, uniform surface is regarded as a useful datum for the definition and delimitation of later or earlier surfaces. Cooke (1958) agrees with Willis' (1936) early estimate that the general inclination of this surface amounted to about 1ft/mile and calculated that the elevation of the continental divide on this surface, at present in the region of the Eastern Rift, was ~~almost~~ about 1600 ft a.s.l. A simple calculation of the average inclination, puts this surface in southwestern Uganda between 1300 ft in the Masaka area and 1200 ft a.s.l. in the Rift shoulder area of Western Ankole.

The tectonic events that have led to the deformation of this 'African' or mid-Tertiary surface and its subsequent dissection and erosion are envisaged by L.C. King as a series of broad, 'cymatogenic', upwarpings within each of which differential warping controlled geomorphic evolution on a regional scale. In the region relevant to the present study, differential warping consisted, according to the evidence, of the upwarping of the Rift shoulder and the downwarping, beginning at a later stage, of the Lake Victoria basin. Theoretically, then, a certain belt of country in the western Lakeside region, remained, over and above the general uplift, at approximately the same relative altitude. Since general uplift may be regarded as roughly uniform on a regional scale, this belt may be used as a regional datum. It appears, therefore, that the main problem associated with the estimate of regional upwarp rests in the identification of upland remnants in this datum belt with the surface preserved in the area of maximum uplift on the Rift shoulder. If such an identification is possibly an estimate of uplift magnitude is easy to attain. Furthermore, since different upland and lowland levels are easily distinguished by geomorphic characteristics as separate erosion surfaces, the differential measure of altitudinal interval between them clearly indicates differential warping.

Doornkamp and Temple (1966) have shown convincingly how a table of mean comparable altitudes of upland and lowland at selected locations along a profile of the upwarped region, may be used to establish a rough estimate of relative uplift and differential warping. But, their conclusions rest on the unsubstantiated assumption of identity between the Masaka upland level (lakeside region) at 4300 ft a.s.l. and the Rift shoulder upland level at 6600 ft. Such an assumption, representative of the two-level concept in the theory of Uganda's landscape evolution is, of course, at variance with the 'classical' postulations. The authors suggest that this initial surface is equivalent to the 'classical' Buganda Surface or L.C. King's 'African' (early-Cainozoic) surface. Except for two isolated quartzite summits (Singiro and Marangara) they recognise no remnants of former cycles such as Wayland's PI, McConnell's 'Ankole' or L.C. King's 'Gondwana' and 'post-Gondwana' Mesozoic surfaces, in the area of the Rift shoulder of West Ankole.

That such a view may be merited in regards to this limited belt of maximum uplift is evident in the two examples cited by the authors. The drainage pattern of the Kasharara, Kandekye and upper Ruizi rivers show complete inadjustment with geologic pattern and cannot be explained except by superimposition from a planed surface. Since upland features in the area of superimposition possess only a single accordant crest-level it is reasonable to assume that this level represents the initial surface. It must be noted, however, that these examples are the only undoubtful ones in the belt of maximum uplift in West Ankole. It is only in these cases that a west-directed drainage pattern is superimposed upon resistant lithology and traverses the strike of the structures. In other, apparently similar cases in this area inadjustment to structure is associated exclusively with incompetent lithology and a lowland landscape and definite conclusions as to the original alignment and nature of the drainage are impossible. There are other, less conspicuous occurrences of superimposition in resistant upland landscape, notably in the Sanga Hills and the Nshara Mountains. In these cases, however, the nature of the structure is not clear as yet and the upland landscape possesses a multi-level aspect. It is therefore not certain that superimposition was initiated on the initial planed surface and the altitude of the upland crests cannot be used to estimate the amount of uplift. In the other parts of the region the drainage pattern ~~has~~ in the resistant upland is clearly adjusted to lithology and structure and may not be regarded as antecedent or as reasonable proof of an initial planed surface and may not be used in estimates of uplift magnitude. Therefore, the assumption that the early-Cainozoic planed surface is represented on upland crests throughout the region cannot, to the writer's opinion be considered as proved by evidence of superimposition. Reasonable certainty exists only in regards to the limited area of the maximal uplift. In other parts of the region additional evidence must be examined.

At the other end of Doornkamp and Temple's profile, in the Masaka area, identity of present upland crest-level with the initial, pre-uplift surface, is even less clear. As presented in their table, the vertical interval between the Masaka upland surface and that in the vicinity of Lake Kijanebalola in Eastern Koki, is about 500 ft. This vertical difference, however, is not gradually attained over the 15 miles of latitudinal distance between these localities, as would be expected if a differential uplift is involved. It is attained through an abrupt, high escarpment coincident with the lithological boundary of the Koki Hills. The elevation of the upland features in the intervening area is markedly accordant with that of the Masaka upland up to the foot of the escarpment. Differences in competence between the Masaka plutonics and the Koki quartizes and argillites, no doubt contributed to the altitudinal differences and theoretically, at least, it is possible to assume that both levels represent the same surface. But certainly only planation could have obliterated effects of uplift at the foot of the escarpment and resulted in such a consistent accordance of crests. Such a planation must have occurred after the initiation of the uplift and was caused by it. It also preceded the initiation of the lowland surface. This must at least cast doubt as to the identity of the Masaka upland surface with the initial surface and on its validity as a datum surface. The solution to this problem may lie in the adoption of Trendall's 'apparent peneplain' theory (1962) and the estimate of the possible original elevation of the upland according to the thickness of laterite cappings, or it may be achieved by the application of evidence from other parts of the profile.

A correct choice of a profile intended for examination of uplift and warping seems to be highly important. The example cited above of the Masaka area reveals the way in which a profile of diverse lithology may prove misleading. Since effects of factors other than uplift and warping must be excluded as much as possible, the best profile for study would be one cutting across a continuous formation of resistant lithology. Doornkamp and Temple's profile is, therefore, the only possible one in the region, except for the area east of Koki. Any other profile of the area will be transecting areas of extensive lowland with relatively few residual upland features, in which estimate of uplift is either impossible or wrought with uncertainties. However, an examination of a single profile may obscure significant features of the tectonic event such as a possible differentiality of warping in more than one direction or the possibility of uplift being continuous in one part of the region and intermittent in another. When the single profile represents a possible area of greater relief and watershed on the initial surface, as is the case in question, such dangers are accentuated. The necessity of being confired to a single profile must, therefore, be compensated by examination of supplementary data from other parts of the uplifted region. An example from the region may illustrate this point.

If the warping of the region is judged to have been differential only along the latitudinal axis, it is reasonable to assume that longitudinal axes, parallel to that of maximum uplift will represent approximately equal magnitudes of warping. The upland features of Central Nyabushozi preserved on plutonic rocks and the Eastern Rwampara Mountains are aligned on such a longitudinal axis and are both regarded by adherents of the two-surface concept as remnants of the same initial surface. Yet, the mean altitude of the former is about 4700 ft a.s.l. and that of the latter - about 5700 ft a.s.l. on the main watershed ridge. This difference implies several possibilities. The initial surface may have possessed a considerable relative relief of at least 1000 ft. In this case, it certainly possessed a considerable northward average inclination of 33 ft/mile which contrasts sharply with the supposed smoothness of the surface. Upwarping may have been differential also along this longitudinal axis and, lastly, the compared upland features may represent distinct erosion-surfaces of continental, regional or local dimensions resulting from a major cycle or from stable phases of an intermittent uplift within one cycle. A combination of all or two sets of circumstances, all of which suggest northward drainage and southward erosion, is also possible, of course.

It also seems that a generalized profile of the sort dictated by the scope of Doornkamp and Temple's paper, based on only five locations in a hundred miles, may possibly conceal significant features of the landsurface and that a more detailed profile is needed to clarify the nature of uplift and warping and their effect on surface development (Table 6; Figs 16, 17).

Analysis of the Upland Profile

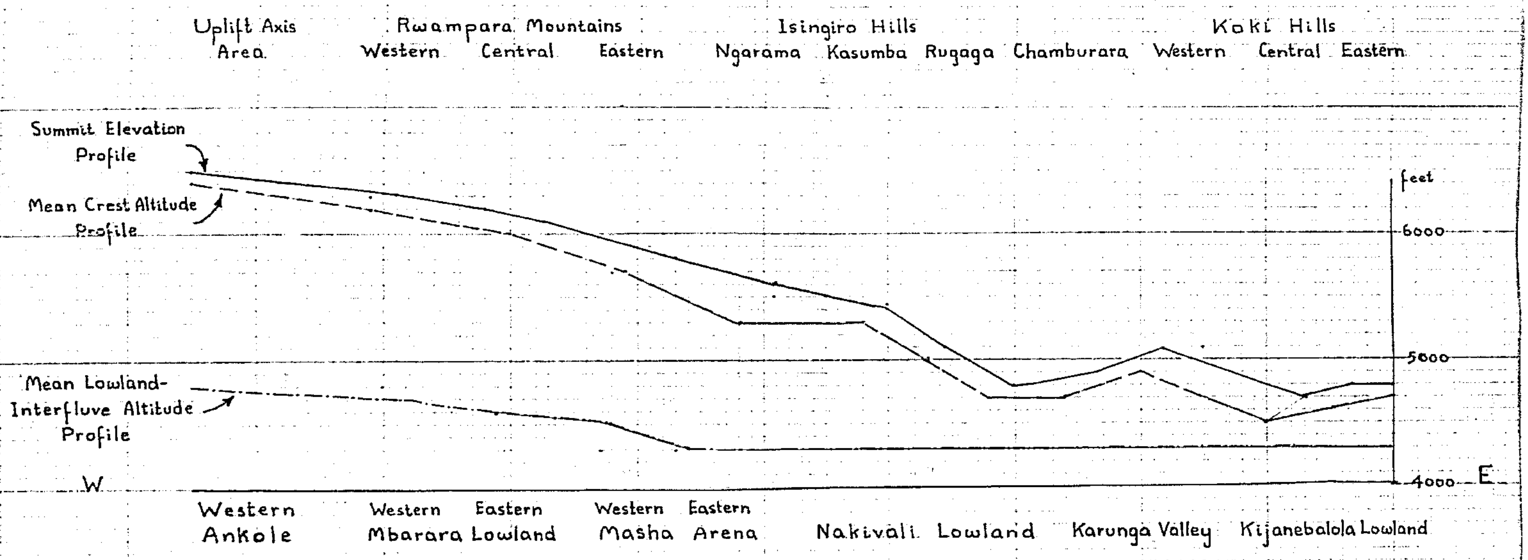
A profile of a differentially upwarped region about a hundred miles long, outlined by remnants of the original surface, may be reasonably expected to present a smooth curve, probably steepening at some intermediate point and possibly flattening out again in the area of maximum uplift. Any breaks in such a profile must be related to factors other than regional uplift unless a very complicated and unlikely differential warping is assumed.

Several such breaks are apparent in the profile of the present Kagera-Ruizi watershed and its postulated extensions. The most prominent of these are associated with abrupt descents of mean upland surface in two areas - Central Koki and the Chamburara-Eastern Rugaga upland units. In neither case lithological causes can be invoked. Whereas the shales and mudstones of Central Koki, poor as they are in interbedded quartzite, are probably less resistant than the quart-

Table 6 : Altitudinal Profiles in the Southern Part of Southwest Uganda

Upland profile along the Kagera-Ruizi divide							Lowland profile along the Lake System-Ruizi axis				Upland/Lowland Difference	
	Mean crest altitude			Summit altitude								
Upland Unit	ft.a.s.l.	Ascent/ Descent ft	ft/m	ft.a.s.l.	rise	ft/m	Lowland Unit	ft.a.s.l.	Rise	ft/m	ft	Increase/ Decrease
Eastern Koki	4700			4824								
Central Koki	4500	-200	20	–			Kijane-balola	4300			200	
Western Koki	4900	+400	40	5096	+272	15	Karunga	4300	–	–	600	+400
Chamburara	4700	-200	33	–							400	-200
Eastern Rugaga	4700	–	–	–			Nakivali				400	–
Western Rugaga	5000	+300	60	5114	+18	2	Lowland	4300	–	–	700	+300
Kasumba	5300	+300	60	5440	+326	82					1000	+300
Ngarama	5300	–	–	5616	+176	20					1000	–
Eastern Rwampara	5600	+400	44	5823	+207	25	Eastern Masha	4300	–	–	1100	+100
							Western Masha	4500	+200	33	1500	+400
Central Rwampara	6000	+300	33	6071	+248	25	Eastern	4600	+100	11	1400	-100
Western Rwampara	6200	+200	18	6325	+254	19	Western Mbarara	4700	+100	14	1500	+100
Kiara	6400	+200	12	6484	+159	14	Ruizi	4800	+100	6	1600	+100
		Total rise 1700 ft	Mean Rate 20		Total rise 1660 ft	Mean rate 20			Total rise 500 ft	Mean rate 6		Total increase 1400 ft

Fig. 16



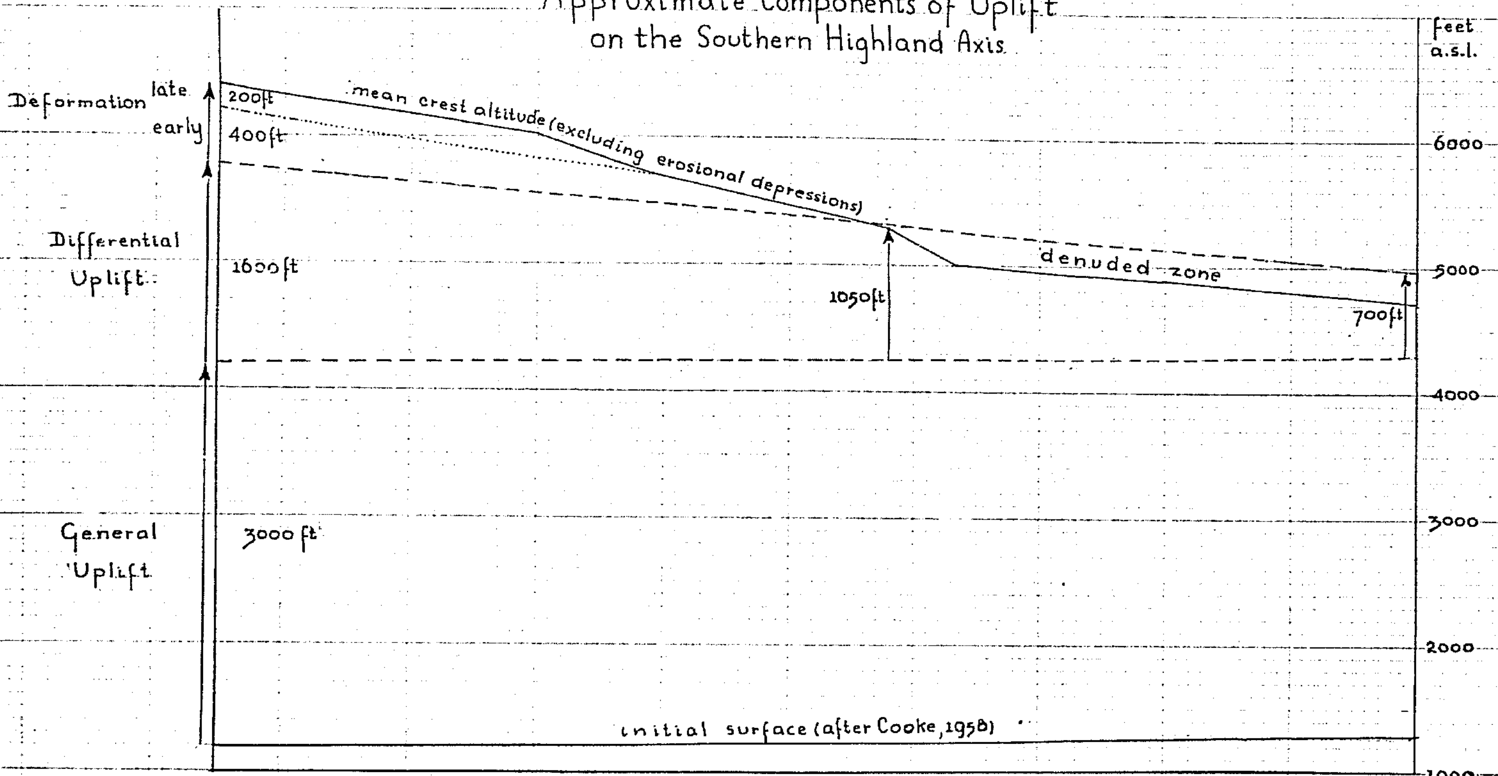
Profiles of Mean Crest and Interfluve Altitude and Summit Elevations on the Southern Highland Axis

H.S. 1:633,600

V.S. 1:12,000

Fig. 17

Approximate Components of Uplift on the Southern Highland Axis



H.S. 1:633,600

V.S. 1:12,000

zite heights of Eastern Koki and the more phyllitic hill series of Western Koki, their relatively low upland crest-level is clearly accordant with a similar level in both these areas. In other words, the upland of Western and to a lesser degree Eastern Koki is distinctly differentiated into two well-defined levels (also Phillips,1958) of which the lower one, at times abutting against the slope of the higher, accords in mean altitude with the Central Koki upland. In the Chamburara-Eastern Rugaga area the absence of lithological control is even more conspicuous. The Chamburara hill-series do not differ lithologically from the Western Koki hill-series, whose mean crest altitude is about 200 ft higher. At the same time they differ altogether from the predominantly quartzitic Eastern Rugaga ridges which are of the same mean altitude. Moreover, the topographically continuous and geologically similar upland of Western Rugaga is appreciably higher as a result of a rather abrupt rise of landsurface. In both cases accordance of upland crests is not as even as in the Masaka area and there is a slight inclination of upland surface towards central axes, but since there is no geological evidence of minor downwarps an erosional origin must be presumed in the period between the initiation of uplift and development of the lowland surface.

Other prominent irregularities distorting the smooth curve of uplift are associated with breaks between the Western Rugaga and Kasumba hillmasses and between the Ngarama hillmass and Eastern Rwampara Mountains. A comparison between profiles of summit elevations and of mean upland altitude reveals that whereas the latter break is smoothed out in the summit profile the former is conspicuous in both profiles. The difference is associated with the fact that summit elevation in the Ngarama hillmass exceeds mean crest altitude by about 300 ft while in all other, flanking, upland units the difference is only about 100 ft. Similarly to the Masaka-Koki transition the sharp rise in both summit and mean altitude between Western Rugaga and Kasumba is attained by a high escarpment also coinciding with a lithological boundary though not as profound. In the same way crest altitude of Western Rugaga shows no apparent effect of uplift up to the foot of the escarpment (a distance of 7 miles) and must again indicate erosional leveling.

A combination of summit and mean altitude profiles reflects in fact two stages of landsurface development. The summit profile may be expected to represent a position closer to that induced by the upwarp and the mean altitude profile - to impart an impression of the way the uplifted landsurface was further modified through factors other than upwarp. In the case of the Western Isingiro (Kasumba and Ngarama hillmasses)the summit profile indicates that the transition from Western Rugaga coincides with the steepening of upwarp curve while the transition to Eastern Rwampara forms a smooth continuation of that steepening. Exclusion of the erosionally induced depressions in Central Koki and Chamburara-Eastern Rugaga areas, will show that there exists a consistent rate of rise of less than 10 ft/mile from Eastern Koki, through Western Koki to Western Rugaga. From Western Rugaga westwards the rate of rise is approximately doubled up to Central Rwampara where it reverts to the original amount in the area of maximum uplift.

The position of Western Isingiro in such a critical area of the upwarp may be expected to be reflected in the nature of the evolving landscape. And, indeed, the profile of mean crest altitude expresses a complex situation whose explanation is not easy to formulate. It reflects an eastward descending, steplike pattern of surfaces consisting of the Eastern Rwampara at 5700 a.s.l., the Western Isingiro at 5300 ft a.sl and of Western Rugaga at 5000 ft a.s.l. Undoubtedly the differential nature of geology may have contributed to the altitudinal interval between Eastern Rwampara and Western Isingiro since - as indicated - the arenaceous succession of Isingiro is, on the whole, less competent than the alternate succession of the Rwampara. But there is no geological difference between West Isingiro and Western Rugaga and the differential altitude must be related to the effect of the sharp steepening of the upwarp alone. Another complicating factor is the absence of upland continuity between Western Isingiro and the Rwampara associated with the specific nature of the Orichinga Valley.

This valley which at present forms a very sharply defined lowland gap traversing the southern highland, and an intermittent direct link between the Ruizi - Lake Systems drainage and the Kagera River, imparts a strong impression of superimposition. It is, probably, this impression that has led to the generally held view that the Lake System drainage was tributary to the proto-Kagera upon the pre-uplift surface. Yet, the Orichinga Valley clearly coincides with a geological boundary, separating the longitudinal major structures of the Eastern Rwampara alternate succession from the complex latitudinal structure of the Isingiro arenaceous succession. The structural relationships of these two units have not yet been explained and therefore, the geological nature of the valley is as yet unclarified. Its underlying lithology is assumed to be argillaceous but the exact nature of it is uncertain due to absence of outcrops; its transitional structural character is also in doubt. It is known, however, that the northern continuation of the Orichinga - the Muke valley - represents a denuded anticlinal structure and thus, lends weight to a suggestion of relating the Orichinga Valley to a belt of geological weakness. The possibility arises, then, that the impression of superimposition is deceptive. It may be conceived that the valley was initiated by a relatively rapid headward erosion controlled by the belt of comparatively incompetent geology. With uplift a greater development than that of similar adjacent drainage lines ensued which subsequently resulted in a breach of the upland into the lowland beyond. Such a breach would have inevitably established a new, lower, base-level for the lowland and possibly initiated a large scale modification of its drainage pattern. This points to a possible late development of the lake-system drainage and to a possible humble origin of the Orichinga on the initial surface.

A rapid development of the Orichinga upon intermittent up warp would have been controlled by the differential geology of its flanks. The less resistant eastern - Ngarama-flank would have been more profoundly modified in one of several levels, while the resistant Rwampara flank would develop into an escarpment-like slope. In the Ngarama any remnant of the original surface would, thus, tend to be preserved away from the immediate vicinity of the valley floor while in the Rwampara it may adjoin the escarpment to the present.

Evidence of other landscape units

The example of Central Nyabushozi, cited above, illustrates the comparative unreliability of residual upland features and extensive lowland landscapes, as evidence for definite conclusions on the nature of upwarp and its effects. But, as observed, these features provide valuable information to supplement the evidence of the continuous upland in the southern part of the region.

1. The Lowlands

The profile of the lowland along the Lake System-Ruizi axis, based on mean altitude of interfluves, as shown by Doornkamp and Temple, enables a rough estimate of differential warping to be made. Since it represents the product of a relatively late stage in the upwarp, any irregularities that come out must be regarded as evidence of late tectonics or late geomorphic development - later than the development of the general lowland landscape. Thus, even Doornkamp and Temple's simplified profile reveals a significant differentiality. The rate of land-surface rise from the Lake Kijanebalola area to the Lake Nakivali area is very slight (approx. 6 ft/mile) but further west it is more than tripled for 30 miles, up to Lake Munyere area, and then flattens again in the belt of maximal uplift. This accords quite well with the differential rise of the adjacent upland. A more detailed profile adds to the accuracy of this basic pattern (Fig. 16).

In the eastern half of the profile, the lowland areas along the whole Lake System have approximately the same mean altitude of interfluves, with no discernible westward rise. The rise of low-land surface along this axis begins with the tranition from the Lake System to the Masha arena and is especially prominent in the arena itself. This accelerated rate of rise decreases considerably again in the Mbarara Lowland and even more so in West Ankole. Lithology must have contributed to this differential rise. The transition between the eastern and western parts of the Masha arena coincides with the lithological boundary between aureole mica-schists and the exposed granitic core; the Nakivali lowland which barely rises at all, is formed wholly upon basal schists. It is clear, however, that the abrupt rise within the Masha arena cannot be attributed to lithological differentiation alone. The fact that the Mbrara lowland, to the west of Masha and also formed on schists, maintains a substantial rise up to the maximum uplift, though at a reduced rate, is indicative of the major role of upwarp. Therefore, there seems to be little doubt that the area of the Masha arena coincides with the location of a considerable buckling effect in the process of upwarp. It suggests that upwarping continued after the development of the lowland surface reached an advanced stage and that the buckling at this stage occurred in a somewhat different area than the early buckling of the upland. Another impression imparted by the lowland profile, is that the Nakivali-Mburo lowland was also formed at a late stage, after the lowland surface was well-developed. It seems to have been formed by further modification of the lowland surface towards a southwestern base-level, and subsequently, differentially uplifted so that its west-directed gradient was reduced to eveness of interfluves and reversal of the drainage.

No similar deviations from a gentle westward rise can be observed in the northern lowlands of Nyabushozi and Mbuga-Bubale. The rate of rise increases from 7 ft/mile in the transition between Eastern and Central Nyabushozi to 8 ft/mile between the latter and the Mbuga-Bubale lowland. Further west it acquires a greater rate of 14 ft/mile to the foot of the Buhweju highland. If rise of landsurface is indicative of the nature of uplift, this would suggest that differentiality of upwarp was effected not only in an east-west direction but also between the southern part of the region and its north and centre. The buckling effect of the lowland upwarp does not, in any case, extend into the present area of the northern lowlands.

2. <u>Residual upland</u>

Residual upland, having no latitudinal continuity, provides only partial evidence of landsurface rise. This evidence is further complicated by effect of differential lithology, and since mean crest altitude of residuals represents a relatively small area, it may reflect lithological effect over that of upwarp. Many residuals are preserved due to thick resistant quartzite and, consequently, can not be compared with distant argillaceous residuals. Yet, even accounting for these difficulties the overall impression is that, as with the lowland, effect of upwarp is less noticeable in the residual upland than in the southern upland blocks. Thus, while Western Koki has a summit elevation of close to 5,100 ft and a mean crest altitude of 4,900 ft, the residual Nshara Mts, 20 miles to the west are, 5,500ft and 5,000 ft. (The highest summits are two obviously residual quartzite heights, rising 300 ft above the adjacent crest level). Comparison of the northern part of Western Koki with the latitudinally equivalent Sanga Hills, shows similar relations on a lower level. On the other hand, comparison between the Nshara residuals and those of the Bihunya-Kabulangire range with a summit elevation of 5,600 ft and a mean crest altitude of 5,200 ft, reveals a much greater rate of rise. This may, perhaps, be attributed to a northward extension of the late buckling effect in the Masha area. A similar rise in the northern ridges of the Rwampara, on the southern side of Masha (Rwebihungo and Kashaka ridges and the Rubeya quartzite mass), seems to support this suggestion.

Both these landscape units of residual upland possess a longitudinal continuity with the southern upland blocks and may, therefore, provide evidence as to the nature of the upwarp and its effect. The Bihunya-Kabulangire range reveals a gradual rise of crest altitude from a pronounced lowland gap in the area of Kabale, both for a short distance southwards and throughout the range, northwards. If the premise of alignment along an area of late buckling is correct, then the Kabale gap or its higher precursor must have existed at an earlier stage, and the prevalent view that the headwaters of the proto-Ruizi originated in this range must be re-examined. The possibility that the Kabale gap represents a former headward breach of the narrow range by the proto-Ruizi, formed long before buckling and reversal, implies that a local reversal of drainage unrelated to tectonics may have occurred within the arena due to erosional change of base-level.

The extensive residual Nshara upland presents an entirely different pattern. It is continuous across the Rugyeye lowland gap (draining the Masha arena at present) with the Gayaza Hill mass which is a structural continuation of the Rwampara and contiguous with it. The Gayaza hill mass and the high Nshara features have comparable mean crest altitudes of 5,000-5,100 ft over a longitudinal distance of about fifteen miles. As previously mentioned, several quartzite heights, representing residuals of a modified former level rise to about 300 ft above it (Nyamitsindo, Ihunga and Kakunyu). The Gayaza hill mass thus abuts against the northern slope of the Eastern Rwampara main ridge with a rather abrupt change of 600-700 ft in mean crest altitude. A similar change may be clearly observed in a fringe of foothills and spurs of the Eastern Rwampara to the west of Gayaza, where a very marked accordance of even crests exists at a similar mean altitude of 5,000-5,100 ft.

Another, lower, level of mean altitude can be distinguished, as observed, in the Sanga Hills and the isolated upland features of Central Nyabushozi. Features of a similar mean altitude of 4,700-4,800 ft, either in the form of distinct upland features or as erosional benches, can be found throughout this belt of residual upland. They are concentrated mainly in the Sanga-Nyabushozi area, in the Lower Ruizi basin and in the area to the north and east of the Gayaza hill mass (Bugarama ridge, etc.). Common to this level is the gradual rise of surface towards the higher ridges of the previous surface, terminating in a well-marked break of slope and an abrupt rise of several hundred feet which, in contrast to the higher surface is always associated with a massive band of quartzite. This regular pattern is at times complicated by the existence of several thinner quartzite bands below the massive upper band, as in the northern slope of the Kakunyu ridge.

There is, thus in the Gayaza-Nshara area, a pattern of three distinct surfaces whose separate levels are clearly erosional in origin since they truncate diverse lithology (lower level) and are differentiated upon similar geology (two upper levels): the Eastern Rwampara main ridge level - 5,700ft a.s.l., the Gayaza-Ntarwete-Kakunyu level - 500-5100 ft a.s.l.; and the Nyabushozi-Sanga-Bugarama level - 4700 - 4800 ft a.s.l. The remarkable accordance of even crests in each level, especially that of the intermediate level as it abuts the slope of the upper one, probably led Combe (1932) to postulate his famous 'two-peneplain' concept of this area. It points, in any case, to an erosional development which occurred later than a possible early differential upwarp or buckling along the longitudinal axis of this area and was unaffected by any possible late differential upwarp or buckling.

3. The Koki Hills

The Koki Hills, with a similar longitudinal extent, present a more complex pattern. Three levels of crest elevation can also be distinguished here, but their altitudinal relationships and spatial pattern are not as clearly defined or as regularly arranged. The upper level, at a mean altitude of 4,900 ft a.s.l., and discernible only in Western Koki, merges gradually with an intermediate level, at 4,700-4,800 ft, in the northern part of Western Koki, and in the Chamburara area. At the same time it rises quite abruptly above the low level at 4,500-4,600 ft. In Eastern and Central Koki, where the higher level is absent, there is a gradual merging of the lower levels and any abrupt breaks between them are clearly attributable to lithology. These lower surfaces lack the conspicuous accordance of flat crests which characterise the upper levels of the Gayaza-Nshara area. As mentioned, they have a perceptible inclination towards median axes.

The upper level may be, possibly, correlated with the intermediate level of the Gayaza-Nshara area. But such a correlation can be valid only if no significant differential upwarp occurred in the intervening area, either during the formation of this level or later. The two lower levels can be correlated with the lower level in the Gayaza-Nshara area as remnants of a single uneven surface resulting from a continuous regional uplift moderately differential in an east-west direction. The lower Koki level thus represents a well advanced modification of the extensive upper Koki level (equivalent to the Gayaza-Nshara intermediate level). On this surface the Chamburara-Eastern Rugaga and the Central-Eastern Koki areas represented the upper parts of a broad erosional depression trending northwest. Its middle part should be sought in the Ishura and Eastern Nyabushozi lowlands as is, perhaps, indicated by the isolated upland feature of Warukiri (4,500 ft) at the margin of the Ishura lowland. The lower level in the Gayaza-Nshara area, represents in this case the elevated western fringe of the depression rising towards the residuals of the higher level or on the divide. The noticeable break between the levels in some areas of Western Koki, notably on the flanks of the drowned lowland gap connecting the Karunga and Kijanebalola lowlands across Western Koki, seems to indicate a later stage, corresponding to newly developed base-levels and changes in drainage pattern. The differential nature of the geology and the consequent differential rate of geomorphic evolution between the sedimentary upper parts of this depression and its plutonic middle and lower parts, may have a bearing on the development of this later stage and the resultant modification of both these areas.

4. <u>The Southern Highlands</u>

A longitudinal profile of the southern highlands in the Eastern Rwampara Mts. or the Western Isingiro Hills reveals a conspicuous asymmetry of relief on either side of the main divide ridge. In both cases the main ridge is situated in the northern part of the upland block and the orographic pattern of the subsidiary ridges consists of short ridges or absence of ridges on the northern side and long, extensive ridges on the southern side. On the northern side the upland terminates in an abrupt high slope, while on the southern side there is a gradual lowering of crest-surface over a long distance. The crest altitude at the southern end of the upland block may be as low as 4,900-5,000 ft. a.s.l., e.g. - about 800-900 ft below that of the main ridge. The gradual lowering of crest elevation is most apparent where the longitudinal orographic pattern is controlled by structure and where coincident quartzite bands preserve the continuity of the subsidiary ridge. Where argillites predominate and where the structural pattern swings into a latitudinal trend, deep dissection distorts the gradual slope of the crests which becomes apparent only as an average value.

While the crest surface reveals no differentiation into distinct levels and no significant breaks in slope except where local lithological control is evident, such a differentiation appears in the upland valleys, notably in the Muhurubuki valley. This is a strike valley following an argillaceous band between the Nshungyezi-Chewiro quartzite ridge on the east and the Katanzi-Buhingu ridge on the west. Along its western flank there is a bench-like series of flat-crested spurs, diverging from the Katanzi-Buhingu ridge and abutting against its western slope. The crest surface of these spurs slopes southward in close conformity with both adjacent ridge crest and thalweg gradients, but at an intermediate elevation. Similar features are to be found in the upper Kyabaganda valley but since this valley has only a short upland course there are only few of them.

It appears, therefore, that geomorphic evolution differed considerably on both sides of Rwampara main ridge. The erosional phase activated by an early stage in the upwarp seems to have been independent on each side of the divide. In other words, the formation of the intermediate Gayaza-Nshara surface was subject to an entirely different base-level than that of the spur-level in the Muhurubuki valley and there was no direct drainage link between both sides of the watershed. This casts further doubt on the role of the Orichinga valley as an initially major drainage line. It also implies that the southward slope of the crest-surface represents a similar slope of the initial surface on which the proto-Muhurubuki already formed a shallow valley along the same argillaceous band. Therefore upwarp along the longitudinal axis of the Eastern Rwampara was not differential. The dissociation or very indirect connection of the northern and southern drainage systems is evident also in the absence on the southern side of any parallel to the third, lowest, Gayaza-Nshara level. Since this level, as suggested, did not result from a relatively abrupt buckling followed by a stable period, but from a moderate continuous regional uplift, the effect of the distant new base-level did not penetrate into the southern basin.

The nature of the initial surface south of the Rwampara divide is undoubtedly related to the proto-Kagera drainage. But the premise of a considerable relief in this area of the initial surface, associated with resistant lithology and a major watershed, does not favour the vew that the present alignment of the river was a major course at that time. The structural pattern of the Karagwe-Ankolean system in this area involves an extended southward trend of the Isingiro synclinal axis into the Karagwe region of Tanganyika where it joins the Eastern Rwampara axis in a sharp northward swing. This indicates an extensive continuous area of resistant geology.

Judging by the slope of crest-surfaces in the Rwampara and Karagwe this area could not have been entirely planed and there are no grounds to assume that it was already traversed by a major drainage line. It appears more reasonable to presume that the surface sloped towards a subsidiary stream, directed across the structure by the general westward slope of the land surface but originating within the area of uneven resistant lithology.

Conclusions on uplift and upwarping

1. The tectonic activity which has affected the region at present between Lake Victoria and the Western Rift, was part of an extensive arching of the crust in East and Central Africa, which initiated, on a continental scale, the erosion cycle culminating in the development of the lowland element. The effect of the arching within the limits of the region may be regarded as consisting of two elements: a general uplift uniformly affecting the whole region (if Cooke's estimate is accepted this general uplift must have been in the order of 3,000 ft) as part of the continental arching; a regional, differential warping above this general uplift, which decided the nature of the cycle within the region.
2. The initial, pre-uplift, surface was part of the continental slope and as such possessed a general west directed inclination and drainage pattern. But actual inclinations and drainage within the region were controlled by the dispositions of watersheds in relation to regional base-levels. Watersheds reflected areas of resistant geology which retained a certain amount of relative relief. Consequently, the node of the main watersheds was located in the area at present represented by the South Ankolean Highland.

The region was divided into two major but unequal drainage basins. The largest part of the region drained into the proto-Katonga, which formed a regional base-level at the northern margin of the region. Most of the drainage of this basin was direct, flowing northward, but apparently part of it, draining the southeast of the region, was indirect flowing south and southeast into tributaries of the proto-Katonga, in the region of the present Lake Victoria. The western and southwestern parts of the region drained into the northwest directed proto-Kagera, possibly remotely connected to the proto-Katonga. Thus, the major divide on the initial surface had a predominantly longitudinal alignment, with two main subsidiary divides branching from it latitudinally along the present axis of the South Ankolean Highland: the eastern one separating the direct and indirect drainage of the proto-Katonga; the western-the direct proto-Kagera drainage from that of its tributary - the proto-Ruizi.

Regional slopes were, therefore, asymmetric already on the initial surface: with the highest divide area located in the southern part of the region, the northern slope was very long and gentle and the southern shorter and steeper, probably of the same order as that represented by the present crest-level on the southern slope of the highland. It is difficult to visualise the manner in which these regional slopes were imposed upon the general continental slope to the west. The relative relief in the area of the southern divides was not such as to disrupt the general late-mature aspect of the surface but a very smooth, low-relief planation, equally truncating competent and incompetent geology has apparently advanced only to the western margin of the region, from the direction of the continental base-level.

3. Upwarp above the general uplift has been irregularly differential. It appears to have occurred in two forms: a regional differential upwarp which raised the western margin of the region by about 1,000 ft in excess of the eastern margin; and a buckling effect of a less than regional scale which uplifted the southwestern part of the region in excess of the regional upwarp by a total amount of about 600 ft. There is evidence that the regional upwarp was differential also on a longitudinal axis, i.e. - that the southern divide area was uplifted in excess of the uplift in the Katonga base-level area, but an estimate of this differential necessitates an investigation of other regions to the north. Generally it appears to have had a more extensive spatial scale and a lesser magnitude than the latitudinal differential. Defomation appears to have occurred twice - in an early phase and at a very late phase of the upwarp. The early deformation affected a larger area and was of greater magnitude, possible causing an excess of upwarp of up to 400 ft in the area west of Kasumba. The late deformation seems to have affected the area west of Masha with an upwarp of no more than 200 ft. Regional upwarp appears to have been intermittent in at least two phases with a fairly prolonged stable period between them. The first phase culminated in the early extensive deformation and was slow enough to permit antecedence at least in the western margin of the region. The second phase was apparently continuous and slow throughout most of its duration allowing the progressive expansion of the lowland surface. Only towards its end further deformation and concurrent or subsequent acceleration of upwarp occurred.

4. This complex sequence of tectonic development resulted in the differentiation of several surface-levels which may be regarded as phases of a single major cycle of a continental scale (Map 6).

a. Of the initial early-Cainozoic (?end-Cretaceous), pre-uplift, surface only those parts associated with the most resistant geology and, thus, with the greatest relief, have been preserved. No remnants of this surface are to be found to the north of the Rwampara-West Isingiro main ridge or to the east of the Kasumba main ridge. While it is by no means possible to assume that at present this Rwampara surface represents an unmodified remnant of the initial surface, as will be discussed below, it appears that it retains a relative relief not much different from the original one.

b. The phase of stability following the first stage of upwarp and deformation enabled the development of an extendive surface controlled by the base-level of the proto-Katonga to the north and east. Relicts of this surface can be identified at present in the upper level in Western Koki and the Western Rugaga, in the intermediate level of the Gayaza-Nshara area and the northern fringes of the Rwampara and perhaps also in the higher hills of the Bihunya-Kabulangire range. Planation of this Gayaza surface appears to have been fairly advanced except for several modified residuals of the initial surface preserved on resistant quartzite, and, probably a general gentle inclination towards the north and east. In the proto-Kagera basin the development of this surface did not advance beyond the formation of new valley-floor levels due to indirect and remote control of the new base-level.

c. With the initiation of the second stage of upwarp a new surface began to develop along the main drainage lines which were still predominantly directed northward or eastward to the proto-Katonga and its tributaries. It is probable that the development of this Sanga surface was simultaneous with the progressive expansion of the lowland as the uneven underlying basement granitoids and basal schists became exposed. Since upwarp was continuous, even if of small magnitude, prominent scarps separating the developing surface from the former one are found only where lithological differentiation obtained, as between the lowland surface and upland features or where massive quartzite formed part of the Gayaza surface. Continuous upwarp also prevented advanced planation of the Sanga surface so that a noticeable rise towards the divide areas was retained. Where the underlying basement was exposed in the early phases of development, over domes or in the lower parts of the region, new erosional controls obtained which may have induced an accelerated rate of development or even changes in drainage pattern.

d. As the expansion of the lowland surface attained a well-advanced stage and remnants of the Sanga surface were reduced to margins of former residuals and divide areas, the erosional development of the lowland became progressively more subject to the control of lithological differences within it, and of newly evolving base-levels. It appears to the writer that the breach of the southern upland, at this stage, by the Orichinga, bringing into control the closer and lower Kagera base-level, brought about a very profound modification of the drainage pattern, affecting in the first phase the less competent mica schists flanking the upland on the north and later the already deeply weathered Ishura lowland.

A capture of drainage on such a scale caused the migration of the major divide northwards, to a possible alignment across Central Nyabushozi; it probably resulted in the dissection of the Sanga surface, the antecedence of drainage across the present Sanga Hills and the capture of the upper part of the Mbuga-Bubale drainage. Possibly it also reversed the drainage of the Masha arena through a newly formed breach in the Rugyeye gap, but there are indications that this may have occurred earlier, before the breach by the Orichinga. That the latter may have been the case is attested by the topography of the Sanga surface in the Lower Ruizi basin and on the flanks of the Rugyeye, which is showing an eastward directed relief pattern. In this case, two stages in the development of the drainage system in this area must be envisaged. The first did not involve a change in the regional base-level but only a change in the rate of erosion due to the rapid southward expansion of the Ishura lowland whose rate of planation must have been faster than that on the surrounding sedimentary formations. Such a development may have resulted both in the evolution of the eastward trending drainage of the Masha arena dnd the Lower Ruizi and, as intimated above, the capture of the Central Koki drainage by that of the Chamburara-Eastern Rugaga area. Only in the second stage did the breach of Orichinga modify the drainage to its present pattern by a complete change in regional base-level. The whole of this phase of erosional development of the lowland may be regarded as part of a regional or even continental stage of evolution which has caused a general valley incision below the lowland level. It corresponds, therefore, to Pallister's Acholi surface (1960) or, De Swardt's "Valley Bottom" surface (1961). The cause of this incision, which nowhere is very deep, is not clear.

Pallister, by adopting McConnell's nomenclature, (1955) intimates that Rift faulting and formation of the new Nile base-level may have initiated this phase. This seems to be supported by Doornkamp and Temple. De Swardt and Trendall (1961, p.55) state that "it is difficult to visualize the conditions under which the flat-bottomed valleys were initiated", a difficulty perhaps due to their basic conclusion that the phase was completed before the main movements along the Western Rift.

e. The last stage of landscape evolution involved the acceleration of differential warping, especially along the axis, or the area west of the Masha arena, where it was associated with a moderate deformation. Accelerated upwarping brought about the drastic reduction of gradients in the stream courses, the reversal of the whole drainage system east of Rift shoulder, and the consequent aggradation and ponding back of the Lake-System. It is not known if the accelerated upwarp was associated with deformation also in other parts of Uganda, but there seems to be no doubt that deformation, even if relatively slight, became a significant factor in the evolution of the drainage system in the area west of the Masha arena. There is a very definite belt of country in the western part of the arena in which gradients of small valleys have been reduced almost to nil and into which headward erosion of the more steeply graded parts of the drainage to the east have not yet reached. On the other hand, the major artery of the Lower Ruizi has already breached the divide of the Bihunya-Kabulangire range in an as yet ungraded course, and captured the whole drainage basin of the Ruizi in the Mbarara Lowland and beyond. There is evidence (Doornkamp and Temple, 1966), that prior to this capture the reversal and ponding up caused the formation in its old headwater valleys of a "Lake Ruizi", subsequently drained through the new breach.

Deformation in this area would explain the deep incision of the Ruizi River south and east of Mbarara and the relatively light aggradation or even complete absence of aggradation in the major, east-directed valleys of the central Masha arena in contrast to the heavily aggraded, tributaries. Absence of deformation above the differential upwarp to the east of Masha, would explain the very indefinite nature of the drainage in the Lake System, with its extremely low gradient and intermittent renewal of connection with the Kagera. In the Kagera basin itself reversal of drainage wrought even more profound changes. If Cooke's (1958) admittedly superficial impression, that the terraces of Nsongezi and Kikagati were controlled not by Lake Victoria but by a presumed "Lake Kagera" to the west, proves correct, then the development of the present Kagera system has been similar to that of the Ruizi. A first stage of upwarp resulted in the ponding back in the headwater valleys and only further differential warping, including the downwarp of the Lake Victoria basin initiated reversal of flow, the draining of the "Lake Kagera" and the drowning of the Lake Victoria basin.

Altimetric Analysis and Laterite Levels

The existence of a multi-level topography and the sequential pattern of its evolution, are essential factors in the understanding of soil and vegetation correlations. At the same time they have been lately the subject of disagreement among geomorphologists investigating the area and very strong doubts have been cast upon the validity of previously postulated surfaces and on the possibility of outlining the pattern of their evolution.

As reviewed above, most of the recent investigators in the relevant region have come to uphold the concept of a 'two-surface' landscape, asserting that, on a regional scale, no more than two of the major continental cycles of erosion have affected the landscape. However, the issue between this school of thought and previous ones is not decisive in the present context. It is not the correlation of surfaces on a regional or a continental scale that is the concern of the present subject but the validity of their existence within the studied area. Their presence seems impossible to refute according to field evidence. Combe's (1932) view as to the existence of a "two-peneplain" topography was founded on such evidence and subsequently reaffirmed (ibid, 1943). Certainly, as asserted by Doornkamp and Temple (1966), this multi-level topography may be envisaged as the result of a phased development within one major cycle, implying that due to the regional extent of tectonic instability the various levels do not necessarily correlate with surfaces outside the region.

Of the other adherents of the "two-surface" concepts only De Swardt and Trendall have closely investigated the relevant area and it is their conclusions which strongly oppose the view of a multi-level topography. As outlined above their conclusion rests on two main points of evidence: the uniform nature of laterite on all upland levels and a statistical treatment of heights of summits and smooth-topped hills. It is asserted by these authors that "even after corrections were made for tilting, no rational picture emerged and the senior author was forced to conclude that he was dealing with a single, uneven older surface without any relics of flat surfaces of any extent" (1961, p.44).

Since De Swardt and Trendall's as yet unpublished, and De Swardt's (1964) papers propounded an entirely new approach to the nature of the landscape in southwestern Uganda and since their views rejected what to the writer seemed to be implied by his subjective view of the field evidence it was thought necessary to recheck their assertions in order to find out in what degree they apply to the investigated area. The rechecking consisted, thus, of a survey of laterite both as to its nature and its altitudinal distribution and of an altimetric analysis of topography.

Altimetric Analysis

Sample Area

As observed by Clarke (1966) it is obvious that regions of warping could present considerable problems of interpretation by altimetric analysis. It is, therefore, necessary to eliminate as much as possible the probable effects of warping, mainly by choosing a sample area aligned along the axis of the minimal tilting. In the present case this indicates a choice of area along the longitudinal axis of the region, which, as observed, has undergone differential warping to a lesser degree than the latitudinal one. Since there is no argument about the validity of the lowland as a distinct erosion surface the analysis may be confined to upland surfaces. It is also reasonable to select an area within which the whole range of possible upland surfaces should be included. Whereas the effect of upwarp prevents straightforward comparison between areas along different longitudinal axes and corrections for tilt can be only theoretical, an element of subjectivity is unavoidable in the choice of a sample area. This area must not be of a too extensive latitudinal width and the interpretation of the analysis must take account of the possible effects of warping.

Subject to these stipulations there seems to be only one choice within the study area. It is that same area in which the "two-peneplain" topography was, presumably, recognised by Combe and in which, it seems, visual judgements are not hampered by deceptive appearances due to combined effects of perspective and distance. It includes the Eastern Rwampara Mts, their northern foothill fringe, the Gayaza hill mass and the Nshara upland to the north. (Map 7). If the postulation of a very small amount of upwarp in the area east of Masha during the secondstage of uplift is correct, then the ten miles maximum width of this area prevents the need for substantial correction for tilt, since the differential obtained within the area falls short of the available contour interval.

Method and preliminary consideration

Altimetric analysis by any method depends on the availability of topographic maps of sufficiently large scale, and the scale of 1:50000 which is the largest available for the area is deemed sufficient for the purpose. On the other hand spot heights whether instrumentally measured or otherwise, are not uniformly distributed and sparse. Consequently, any method depending on frequencies of spot or summit heights, such as was presumably used by De Swardt and Trendall (no details of the method were given by the authors), could not be depended upon, and a much more laborious method of area measurement had to be chosen.

Since the aim of any altimetric analysis is to demonstrate the existence of surfaces or levels and since the generally accepted premise is that remnants of such levels are represented by crests of present topographic features an attempt was made to confine measurements to crest surfaces alone (in the present case - upland crest surfaces). This was done by the systematic mapping of all upland crests within the sample area, with the help of air-photographs and verification in the field. With outlines of crests traced upon the topographic maps it was possible to measure the area enclosed between each of two hundred-feet contours, with the aid of a planimeter. Within continuous crest surfaces units of measurement were defined by a limit of slope angle as expressed by the intercontour interval. An interval of less than 5 mm was regarded as a break in the crest-surface continuity and excluded from the calculation; and the separated parts were measured independently.

In such a way a series of tables was obtained, each representing a discrete and relatively small crest-surface area. These tables were subject to comparison and regroupings within their landscape units and among different units in order to attain one or several reasonable patterns. In order to do this certain preliminary assumptions had to be made concerning the amplitude of relief upon the measured surfaces. No definite limits of postulated relative relief have been set for different degrees of planation and definitions of amounts of relative relief on a planed surface are highly variable within certain limits. It seemed, however, reasonable to assume that a surface with a predominance of relative relief not exceeding 300 ft may be regarded as planed. Where crest-surfaces possessing such a relief within a certain class of contour intervals can be correlated upon widely separated upland features of the sample area, there exists a strong case for regarding them as parts of a single planed surface.

It is, however, possible that crest surfaces do not represent remnants of a planed surface and in this case no predominance of a 300 ft class of contour-intervals can be expected to show in the tables or the associated histograms. This may be also true in the case of a planed surface subject to continuous uplift where no consistent scarp emerged to separate it from the new surface. Such surfaces may be expected, however, to retain some pattern of relief in accordance with the drainage pattern existent upon them. Consequently, altimetric analysis should reveal local patterns of sloping surfaces controlled by some central drainage line. It must also be remembered that totals of intercontour areas may be deceptive if several surfaces are present since it is logical to expect each older surface to be represented by a lesser total area. It is therefore the lower levels which tend to stand out in a frequency diagram of the total area, at times obscuring the existence of an upper, older level. This may be further complicated by the fact that the junction of two surfaces is usually not abrupt and even a classically planed surface may be expected to have a certain rise towards it.

Discussion and interpretation of the histograms

The histograms are presented in a sequence which, it is hoped, will demonstrate the procedure that has led to the identification of separate surfaces. Discrete surfaces are identified by percentage peaks of intercontour area separated by well defined gaps of lower percentages. Any uneven surface when devoid of a cyclic pattern will tend to have a single peak at some level, but the peak will merge in a smooth curve with the other intercontour intervals. In contrast, a histogram of a single planed surface, will have a prominent peak flanked by rather abrupt dips in the percentage curve. It appears that the main problem associated with these generalisations is that of defining the altitudinal class-intervals, allowable within the term of a planed surface. The vertical interval of 100 ft, afforded by the available maps, would seem to be very low and, as observed, there is no authoritative definition of any accepted limit of relative relief within planed surfaces. Consequently such limits were arbitarily fixed in two parallel criteria. A surface possessing a relative relief of no more than 300 ft in no less than ⅔ of its area and of 200 ft in no less than half its area, was considered to represent a reasonably planed surface. It was felt that the use of such a double criterion will serve to eliminate any inconsistencies due to incalculable factors of geomorphic evolution.

The histograms may be divided into three groups. The purpose of the first group, which consists of histograms representing the

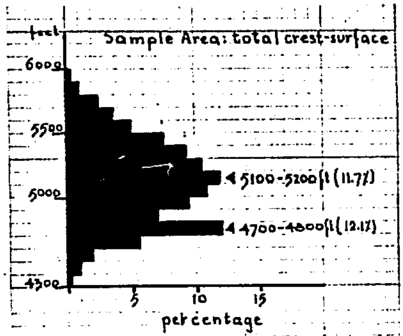


Fig. 18

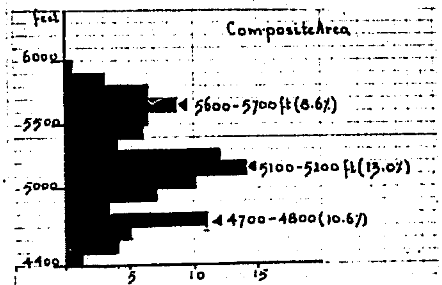


Fig. 19

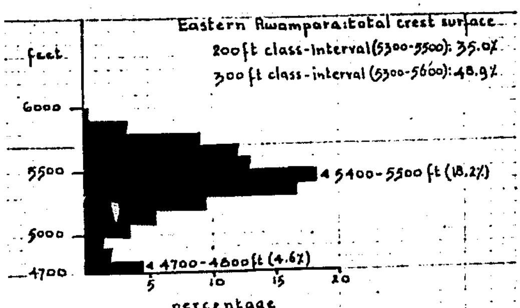


Fig. 20

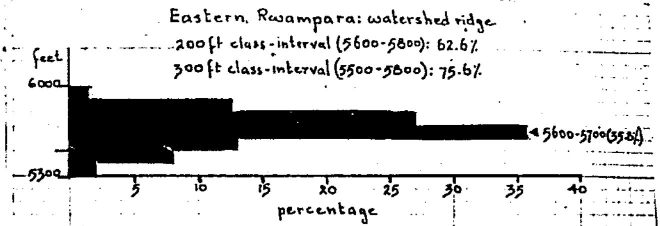


Fig. 21

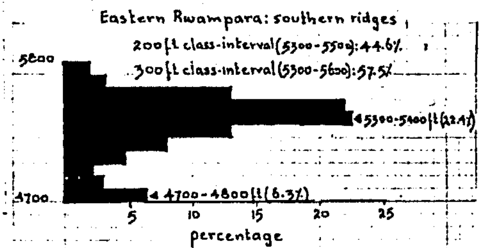


Fig. 22

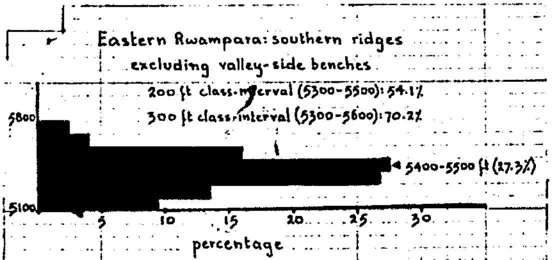


Fig. 22a

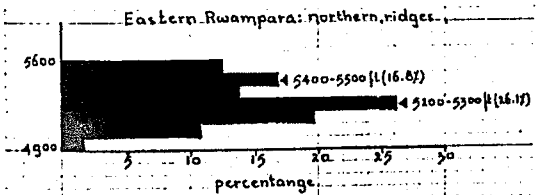


Fig. 23

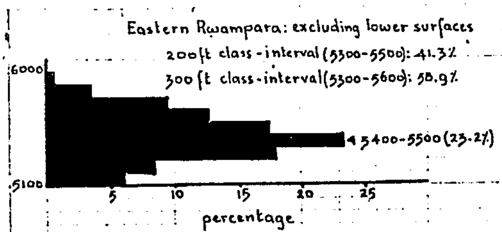


Fig. 20a

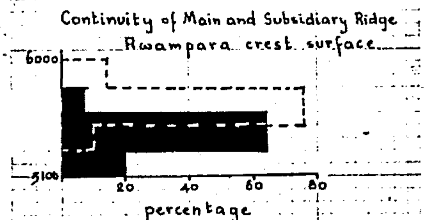


Fig. 24

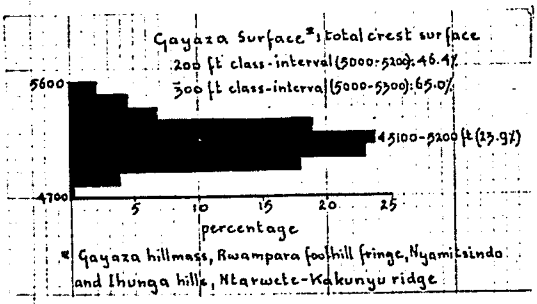


Fig. 25

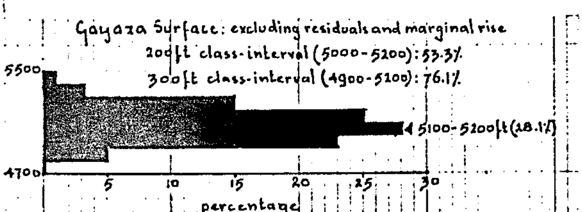


Fig. 26

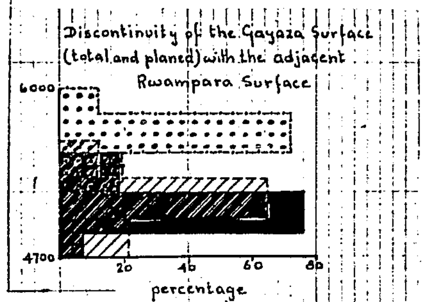
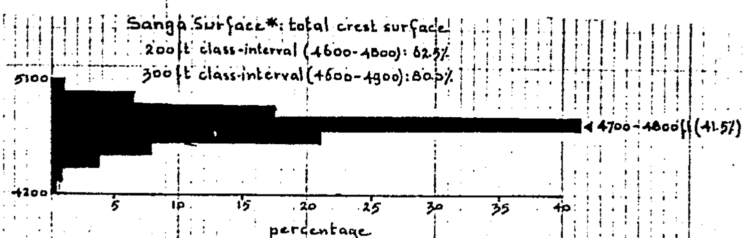


Fig. 27



* Sanga hills, Lower Ruizi basin, Mpororo spurs, Bugarama ridge

Fig. 28

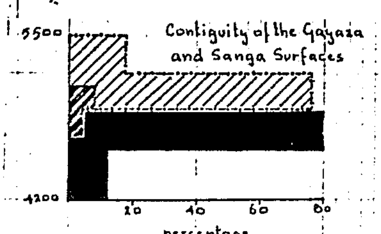


Fig. 29

total crest surface of the sample area and of a limited composite part of it, is to show the emergence of several distinct surfaces within the area. The second group, which consists of more than half of the number of the histograms, represents one physiographic unit within the sample area - the Eastern Rwampara Mts. This unit presents the greatest difficulties in analysis, and necessitated a greater number of combinations. It is assumed that it can serve as an example of the principles and, therefore, makes it unnecessary to treat the simpler physiographic units in as much detail. These units are represented in the third group of histograms. Since they are units of residual upland, crest features representing distinct surfaces are scattered over and intermixed throughout a large area. The emergence of these surfaces in the histogram of the total area made it unnecessary to present a separate histogram of the total residual upland and it was also deemed unnecessary to include all the histograms of the separate features. Consequently, only the concluding histograms of each surface area presented.

It can be seen already in the histogram representing the total crest surface of the sample area (Fig. 18), that two class-intervals stand out as peaks with the higher one less prominent and less well-defined. Such a pattern may represent an expected decrease in area of progressively older surfaces and, thus, does not invalidate the probability of two surfaces. In the same way, the gradual decrease in percentage of higher intervals may be deceptive and conceal the presence of an older, higher surface, represented by a relatively small area. The obvious way to overcome this difficulty is to examine a smaller, representative area and the most logical choice within the sample area seems to be that landscape in which a multi-level topography is visually prominent in the field, namely that extending from the watershed ridge of the Eastern Rwampara northward, down to the Rugyeye lowland (Map 7).

In the histogram representing this landscape (Fig. 19) the third, upper, peak emerges very clearly with well-defined 300 ft intervals between the three peaks. The lower peak's reduced percentage is, no doubt, due to exclusion of a large proportion of the lower surface's area from the histogram. ~~If this is taken into account the graduality in the area from the histogram.~~ If this is taken into account the graduality in the area of successive surfaces is quite distinct. The highest of these three peaks represents exclusively the watershed ridge of the Rwampara and is not only the least prominent but also the least well-defined. The relatively high percentage of the intervals adjoining this peak, and the lack of a conspicuous southern limit to the ridge, indicate that the physiographic unit of which it forms a part merits a closer investigation.

The histogram of the total Eastern Rwampara crest-area (Fig. 20) shows two peaks of which the subsidiary one represents the lowest inter contour interval and is separated from the main peak by as much as 600 ft. This points to the probability that it represents an entirely separate surface that should be excluded from the histogram. In such a case the histogram shows a single peak and, consequently, lends itslef to an examination according to the predetermined criteria of surface definition. Since the limits set by these criteria are not met with, a further specification of the unit is necessary. The Eastern Rwampara Mts consist of three main topographic elements: the watershed ridge, the southern subsidiary ridges and the northern subsidiary ridges and foothill spurs. The indicating continuity of the crest surface between these elements (Fig. 24). It appears that the only conclusion that can be drawn from these facts is that the crest-surface of the Eastern Rwampara does not represent a former planed surface, but an inclined one, perhaps indicating an area of greater relief on a regionally planed surface.

The features of the sample area which produced the intermediate peak on the composite histogram and the higher peak on the total area histogram, whose combined crest-surface has been termed above - the Gayaza Surface, are grouped together to produce a single peak histogram (Fig. 25), but fail by a narrow margin to attain the predetermined limits. A closer investigation of the component features, shows that lower class-intervals cannot be reasonably separated on any geomorphical grounds. On the other hand, the higher class-intervals appear to be produced by two distinct topographic elements: high summits of hills rising prominently above general crest-level or of isolated residual upland features, and a belt of sloping crests at the junction with the northern slope of the Rwampara. The first element can be regarded, on lithological grounds, as representing modified residuals of a higher surface. The second - as a rise of the surface towards the junction with the slope of that higher surface. If these elements are excluded, the resultant histogram (Fig. 26) depicts a surface within the assumed limits. An examination of the relationship between this Gayaza surface and the adjacent part of the Rwampara surface, according to the 300 ft class-interval criterion (Fig. 27) reveals a clear discontinuity of 200 ft with the total Gayaza surface and of 300 ft with the planed Gayaza surface.

This discontinuity is regarded as indicating both the distinction of the two surfaces and the circumstances of their differentiation (tectonic stability following uplift and deformation).

The histogram combining the features of the lowest surface (Fig. 28) shows the remarkable planation attained by this Sanga surface as a whole. It is however, deceptive as to the details of the surface, in the sense that the amount of planation revealed in each physiographic unit of the surface in much less pronounced and it is only the average values that produce the outstanding predominance of certain class-intervals. Furthermore, each physiographic unit appears to lend itslef, by the distribution of its component features to a rational pattern of altitudinal belts, roughly semi-concentric on low area (Map 7). Again, an examination of the relationship with the higher Gayaza surface, shows contiguity of dominant class-intervals (Fig. 29). The picture that emerges is of a new cycle dissecting a surface planed in a former cycle under conditions of continuous slow uplift (indicated by the contiguity of the surfaces). The different physiographic units in which this new surface dominates, would seem to have been marginal to the main planation, representing a marginal belt of rising landsurface or subsidiary headwater drainage basins whose surface slopes gently from the outlet of the basin and its main drainage line, to its watershed.

In conclusion it appears, therefore, that altimetric analysis reveals the existence in the sample area, of three surfaces disposed in a pattern which lends itself to reasonable explanation:

1. The Rwampara Surface which is inclined southwards rising from approx. 5,100 ft to over 5,900 ft a.s.l. with only 59% of its area within the 300 ft limit of the 5,300-5,600 ft interval. It

possibly represents an area of initially considerable relief upon resistant lithology.

2. The Gayaza Surface is adjacent to the former on the north and separated from it by a pronounced vertical discontinuity, denoting a period of stability during its development. Except for a few modified residuals of the former surface and a rise towards the juncture with its slope, it is a fairly even surface having more than 75% of its area within the class-interval of 4,900-5,200 ft a.s.l.

3. The Sanga Surface represented by numerous, relatively small, residuals, shows a general accordance of crest levels within the class-interval of 4,600-4,900 ft a.s.l. and is, thus, altitudinally contiguous with the former surface, denoting development concurrent with continuous uplift. It may represent marginal parts of the main activity of the cycle.

In other parts of the area the Rwampara surface is represented only in the Western Isingiro where it is much lower indicating, perhaps, an eastward inclination of this surface in addition to the southward inclination; or representing modified residuals of this surface. Otherwise only the equivalents of the Gayaza and Sanga surfaces are represented and, taking into account tilt and deformation, and differential geomorphic control, it is possible to discern a reasonable and explainable pattern of their distribution.

The Nature and Distribution of Laterite

Aspects of Laterization and Development of Laterite

In the light of the various, at times contradictory, assertions made as to the nature and distribution of laterite in the area and the differences in the interpretation of its significance, it seems necessary to precede the discussion of this phenomenon with a review of the basic concepts and theories concerning laterite upon which the present study was based.

Aspects of Laterization

1. Concepts of Laterization

Common to all theories of laterization is the concept of the individualization of primary parent-rock constituents by hydrolysis with the consequent exportation of soluble base-compounds and, significantly, silica and the accumulation of secondary sesquioxides in their hydrated form. Laterization is, therefore, essentially a process of solution and subsequent leaching. The accumulating lateritic materials donnot represent a simple, direct residue but a secondary product of rock-constituents altered by hydrolysis.

As emphasised by Prescott and Pendleton (1952) laterization is envisaged both as a weathering and a pedogenetic process. In the first instance lateritic materials represent a secondary insoluble residue of a certain volume of rock; in the second - an illuvial soil-regolith horizon. The implication is that laterization is not necessarily concurrent with weathering, and may form a late stage realised only after soil formation is well-advanced.

Another implication is that laterization does not necessarily consist of exportation of non-lateritic materials and retention of lateritic materials. It may involve, following individualisation, the mobilization, migration and translocated precipitation of lateritic materials, whether within the original soil profile or without it. Related to these concepts, though by no means identical with them is the concept of relative and absolute lateritic accumulation developed by D'Hoore (1954). He defined a selective accumulation *in situ* as relative and that resulting from lateral provenance of lateritic materials ("oblique leaching") as absolute. Maignien (1958) defines this concept as follows – the accumulation of lateritic materials results from two distinct processes: (1) relative accumulation - the exportation of soluble constituents; (2) absolute accumulation - the importation of mobilized lateritic materials.

2. Mobility of lateritic materials

Since the leaching of soluble base compounds by the ordinary hydrolytic action of water, carbonic acid and organic acids is a feature common to all humid climates, laterization is characterized principally by the mobility of combined silica in relation to that of Al and Fe hydroxides. Combined silica is, as a rule, electronegatively charged in electrolytic solution while hydrated sesquioxides are amphoteric, tending towards the electropositive state. Consequently, under aerobic conditions, silica is mobilised by alkaline hydrolysis while hydroxides are mobilized by acid hydrolysis. Therefore, laterization can, at least theoretically, attain completion only in an alkaline medium under atmospheric influence. Under the conditions of abundant moisture supply and prolonged stability of landsurface, which are conducive to excessive leaching and thorough impoverishment in base compounds, such circumstances are limited to weathering zones and areas of deposition above groundwater level and to environments favouring intensive mineralization of organic matter. While an acid medium increases the mobility of lateritic materials, the measure of this mobility differs between the different compounds. On the whole, Fe compounds and minerals are mobilized at a higher pH value of medium reaction than Al compounds and minerals which, in predominantly acid environments, means that iron is more soluble and mobile than Al (Prescott and Pendleton, 1952). The implication of this differential specific solubility is that mobilized Al compounds will tend to be precipitated under a greater range of conditions than Fe compounds. Where oblique leaching prevails, they will tend to accumulate closer to their source and to be less dependent on the mobility of water and, therefore, on topography. Iron compounds, on the other hand, will be transported further away and their precipitate will be scarce on steeply inclined surfaces. This means that primary laterite will show a greater proportion of Al constituents than secondary laterite.

3. Composition and alteration of lateritic materials

The evidence of numerous observations shows that composition of laterite and lateritic materials is not as simple as suggested by the classical concept of laterization. The end-products of the process as envisaged by this concept are either hydroxides or free oxides of Al and Fe and the greater their proportion the more characteristic and advanced the stage of the process was considered to be. Consequently much significance was attached to the SiO_2/R_2O_3 ratio in the composition of laterite and lateritic soils and in the definition of climatic limits of laterization. It was discovered however, that what may be called the diagnostic compounds of laterite are consistently associated with the prevalence of clay-minerals, especially alumosilicate minerals. As Maignien (1958) points out - due to their electropositive state, hydroxides tend to combine with the electronegative silica and be fixed in colloidal silicate clay*. This partaking of clay minerals in the composition of lateritic materials has been explained in two different ways:

(a) One school of thought regards the individualization of free hydroxides as only the first stage in the process of laterization. It is postulated that the next stage consists of new synthesis ("neoformation") of the clay-mineral kaolinite by resilication of the mineral Al-hydroxide-gibbsite. Kaolinite is regarded as the end-product of laterization representing a stable state of equilibrium unalterable by further laterization (Waegemans, 1951). Such a process can be expressed in the following schematized sequence:

acid hydrolysis

(1) $K_2O.Al_2O_3.6SiO_2 + H_2O \longrightarrow Al_2O_3.6SiO_2.H_2O + KOH \searrow$ exported base

orthoclase — acid alumosolicate

alkaline hydrolysis

(2) $Al_2O_3.6SiO_2H_2O + 2H_2O \longrightarrow Al_2O_3.3H_2O + 6SiO_2 \searrow$ exported silica

acid alumosilicate — gibbsite

resilication

(3) $Al_2O_3.3H_2O + 2SiO_2 \longrightarrow Al_2O_3.2SiO_2 2H_2O + H_2O \searrow$ exported water

gibbsite — kaolinite

* Maignien, consequently, maintains that mobility of hydroxides depends on their ability to associate with certain (unspecified) soil substances, forming with them electronegative complexes indifferent to silica or any other electrolyte.

Where a mildly alkaline medium already exists, kaolinite is presumed to be formed directly on the hydrolysis of the primary mineral (Harrison, 1934)

(1) $K_2O.Al_2O_3.6SiO + 3H_2O \longrightarrow Al_2O_3.2SiO_2.2H_2O + 4SiO_2 + 2KOH$

Both gibbsite and kaolinite favour ferruginization in the form of absorbed thin layers of hydrated iron oxides, probably microcrystalline geothite (Fripiat and Gastauche, cited in Alexander and Cady, 1962). With the addition of residual limonite and haematite, it represents the lateritic iron element and accounts for the red colour of the clay.

(b) The formation of secondary alumosilicate clay minerals in the katamorphic and pedogenetic processes is, however, a common feature of all humid climates. According to the other school of thought laterization as a process active under humid tropical climate is distinguished from processes in temperate climates by the instability of kaolinite. This view envisages, therefore, a further step in the process of alteration, consisting of the dissolution of alumosilicate clay into its component hydroxides and silica and of hydroxides into their component alumina and water. Laterization is, thus, represented as a process of progressive degradation by leaching, reaching a more advanced stage than katamorphism under temperate conditions in enabling the complete removal of silica and possibly water.

acid hydrolysis

(2) $K_2O.Al_2O_3.6SiO_2 + H_2O \longrightarrow Al_2O_3.6SiO_2.H_2O + 2KOH \searrow$

orthoclase — acid alumosilicate — exported base

alkaline hydrolysis

(3) $Al_2O_3.6SiO_2.H_2O + H_2O \longrightarrow Al_2O_3.2SiO_2.2H_2O + 4SiO_2 \searrow$

acid alumosilicate — kaolinite — exported silica

(4) $Al_2O_3.3H_2O + H_2O \longrightarrow Al_2O_3 + 4H_2O$

gibbsite — alumina

According to both interpretations, kaolinite and, consequently, combined silica, form an important component of lateritic materials. To this may be added a considerable amount of uncombined silica, usually in the form of residual or recrystallized quartz. This would suggest that the SiO_2/R_2O_3 ratio is not a reliable quantitative criterion of defining laterite (Mohr and Van Baren, 1954) or correlating laterization with rainfall (Glangeaud 1941; Vine, 1949). Moreover, it is considered that this ratio cannot be used in the study of Katamorphic laterization since analytical techniques are now regarded as insufficient for comparison of parent rocks and derived clays (Rougerie 1958) and it appears, therefore, that the value of this criterion is becoming progressively more doubtful.

Predominance of Kaolinite in the mineral composition of lateritic materials is attested by numerous clay-mineral analysis and normative calculations of mineral composition of laterite samples. But there are other instances which show predominance of gibbsits and goethite and even the occurence of certain amounts of free alumina and iron-oxides (e.g. Mohr and Van Baren 1954; Alexander and Cady, 1962). The fact that all these samples originated in regions of very high rainfall suggests that association of Kaolinite with laterite lends itself to a certain distributional pattern which corrèlates with climatic differentaiation, and tends to lend weight to the theory of progressive degradation. It implies that changes in the proportions of different clay minerals may indicate not only stages in a unifirm process but also variations of the process, dictated by the variations in the environment of the process.

Another aspect of the composition of lateritic materials concerns the relative importance of Al and Fe compounds. It would appear that while the quantity of aluminium compounds and minerals may far exceed that of iron compounds in the composition it is the iron compounds which are associated with all forms and manifestations of laterization and, consequently, may be regarded as diagnostic of the process (Alexander and Cady, 1962). Since iron compounds are, presumably, more mobile than aluminium compounds, they gradually gain ascendance over them in the composition of lateritic materials with the decrease in amount and increase of intermittence of moisture supply.

4. Environment of laterization

It follows from the above that variation in the amount and distribution of moisture supply effect a differentiation of laterization into roughly two main forms which may, perhaps, be designated after Aubert's (1954) terminology of lateritic soils - ferrallitization and ferruginization. Ferralitization, defined as occurring under a regime of abundant and continuous or semi-continuous rainfall, involves mobilization of both aluminium and iron hydroxides and in its original definition, inherent in the term was the diagnostic presence of free alumina. Ferruginization, on the other hand, occurs where rainfall is lower* and especially where ~~the~~

* ~~(a)~~ According to Rougerie (1959) - lower than 60 inches of annual rainfall

the rainfall seasons are contrasting. The effect of leaching is less profound and it is mainly the more mobile iron compounds that are affected.

The use of a climatic factor as a decisive criterion in definition of laterization forms emphasizes their zonal nature and, no doubt, laterization on the whole, is a zonal phenomenon. There is, however, some difference of opinion as to the validity of its subzonal differentiation into ferrallitic and ferruginous components. Since laterization, as observed, is essentially a process activated by movement of water, it cannot proceed typically in intrazonal situations where drainage is either impeded or too rapid. In the first case, soluble compounds cannot be removed from the profile and oxidation, favouring immobilization of lateritic materials, may be retarded; in the second-erosion prevents the development of the profile itself.

It is, therefore, only where drainage is free that differentiation into a "ferrallitic" and a "ferruginous" environment can take place. A "ferrallitic" environment presupposes a fairly continuous hydrolysis and, under undisturbed conditions, a fairly dense, shady, forest cover. These conditions ensure an uninterrupted and relatively rapid process of weathering and an undisturbed and rapid decomposition of litter. Both these processes bring about a constant supply of liberated or individualized base compounds from weathering rock and mineralized organic matter. In young and, consequently, relatively shallow soils, where the effects of these processes might merge and be distributed throughout the profile, conditions for an alkaline hydrolysis are obtained and typical accumulation of sesquioxides and exportation of silica are effected. As the weathering zone descends with the deepening of the soil mantle, a gradual change in conditions ensues. The supply of newly liberated bases is no longer available throughout the profile and the increased volume of water permeating the soil mass dilutes the soil solution. Consequently, alkalinity weakens.

Where rainfall is very high and its distribution equal these conditions of weakly alkaline hydrolysis are retained. Medium reaction becomes acid enough to make migration of silica difficult. At the same time, intensive hydration of sesquioxides raises their isoelectric points and, consequently, affords more opportunity for their combination with the electronegative silica into clay minerals or ferro-siliceous complexes. It appears, therefore, that in the state of equilibrium achieved under these conditions the product of laterization is not laterite but kaolinitic clay with absorbed iron-minerals. More typical ferrallitization occurs, apparently, where rainfall is not excessive and is unequally distributed. In the less rainy seasons there is a slower and more discontinuous movement of water and occasionally a temporary dehydration. Alkalinity is enhanced and better conditions for exportation of silica and precipitation of hydroxides are created. In the more rainy seasons, a more acid reaction and, thus, greater mobility of hydroxides prevail. This alternation of conditions brings about a concentration of hydroxides in a certain preferential horizon and a differentiation of the profile into several horizons. The horizon of concentration will develop into a lateritic horizon though, probably with a larger proportion of clay than of individualized sesquioxides.

The ideal environment for laterization and development of laterite appears to be that in which there is a definite alternation of rainy and dry seasons. Even where total rainfall is relatively high hydrolysis is more or less interrupted. Vegetational cover allows direct effect of insolation on decomposing litter with the resultant inhibition of bacterial activity. This, when added to the larger proportion of grassy vegetation, induces a more rapid humification and a slower mineralization than under forest. It is also under these conditions that fluctuations of ground water table are most pronounced.

In the rainy seasons the hydrolysis effected is very acid. Where soils are young and shallow the humic acids may penetrate to the base of the profile and in deep, aged soils they augment the acidity caused by the reasons stated above. Where total rainfall is high this entails the mobilization and exportation of both aluminous and ferrous hydroxides. Where rainfall is lower only the more mobile iron compounds are exported. They are precipitated in the weathering zone, where the supply of bases overbalances the acidity, or at the upper limit of raised alkaline water-table, carrying bases from up from the weathering zone. Possibly, in the transition periods between the rainy and dry seasons, when penetration of humic acids is inhibited and the concentration of solutions grows, alkaline reaction is asserted for a certain time. It would certainly be more pronounced in the weathering zone and at the upper limit of the water-table, thus allowing for the release of silica from the clay minerals and its removal from the lateritic horizon. In the upper horizons, however, it would be weaker and enable formation of alumosilicate clay.

In the dry season, with percolation ceasing and water-table falling, hydrolysis virtually stops and the only movement of soil-water is, perhaps, capillary, though this is possible only where the ground water-table does not fall below a certain depth.

In any case, the dessication of the soil-regolith profile facilitates prolonged oxidation and immobilization of hydroxides in the lateritic horizon.

This is an environment in which soils are more subject to truncation by erosion, exposure of the lateritic horizon and its hardening into laterite. This is also the climatic regime under which the transition from a "ferrallitic" to a "ferruginous" environment occurs. It is difficult to fix a climatic boundary between the two. According to D'Hoore (1964, p.96) "ferruginous" or "fersiallitic" soils are found between isohyets 500-1200 mm (19.5-47.5 inches). Rougerie (1958, p.204) states similarly that ferruginous soils replace ferrallitic in the regions having 1000-1500 mm (39.0-59.0 inches), while Maignien (1958, pp 107-110) describes ferruginous profiles from areas having 30-50 inches. At the same time, in Uganda, Chenery (1960, p.19) classifies within the rainfall range of 20"-40" both "ferruginous tropical soils" and ferrallitic soils (including the intermediate ferrisols). It wouls seem that beside total rainfall, this boundary depends also on the length of the dry season (including the difference between the equatorial regime of two dry seasons and the tropical regime of one long dry season), on elevation, which may change the effective value of rainfall, and on the geomorphic-climatic history in the sense that ferrallitic soils in a subhumid area may represent products of former climatic conditions.

It seems that as total rainfall falls below 35-40 inches hydrolysis becomes weak and infrequent causing only the individualization of bases and some iron compounds. Laterization does not proceed beyond formation of clay, probably also incompletely kaolinized. Silica is retained and hydroxides of iron do not concentrate in a preferential horizon. When rainfall is over 20" there is still accumulation of hydroxides and even precipitation of iron in concretions but scarcity of water favours dispersion of liberated iron hydroxides through impregnation or absorption on clay minerals.

Development of laterites and its geomorphic significance

1. The 'laterite profile' and the derivation of lateritic materials

One of the commonly recognized field properties of laterite or of a lateritic horizon is its association with a characteristic profile. The term 'laterite profile' is not usually applied to the whole of the soil-regolith profile in which lateritic materials accumulate in a certain horizon. Its application is restricted to that part of the profile which includes the lateritic horizon and underlays it. It can, therefore, be recognized also after the soil horizons above the laterite have been stripped away. Indeed, it was in this form that the 'laterite profile' was originally recognized, described and interpreted by J. Walther (1915).

The nature of this profile is well-known and needs no descriptive elaboration in the present context. It does, however, involve certain properties which seem to have bearing on the present subject. Of these, the relative thickness of the two main horizons of the profile - the lateritic horizon and the 'pallid zone' - is associated with two interreleted aspects of geomorphic significance: the mode of accumulation and the derivation of lateritic materials.

The 'pallid zone' of the 'laterite profile' represents, without any doubt, the mass of weathered rock from which most of the constituents have been leached leaving an almost wholly kaolinitic residue. This is indicated by the many instances in which structural characteristics of the parent-rock are preserved in this zone despite the profound chemical and mineralogical alterations, and by the presence of transitional zones between it and overlying laterite ("mottled zone") and the underlying parent rock. Since the thickness of the laterite is usually much smaller than that of the underlying pallid zone, it is reasonable to assume that the lateritic materials originated in it. Indeed, it is difficult of account for the large amount of iron concentrated within the lateritic horizon, on the one hand, and the paucity of iron in the pallid zone, on the other unless its origin is postulated in the great volume of underlying rock (Trendall, 1962).

No doubt, in part, ~~of~~ the lateritic materials are derived from the overlying soil horizons through the agency of percolating rainwater but the very small relative magnitude of soil mantle, usually much smaller than that of the lateritic horizon itself, can account only for a very slight portion of the accumulated laterite. If, then, the main source of lateritic materials is in the underlying rock, represented by the leached 'pallid zone', their only possible agency of upward vertical transport from the weathered rock to the lateritic horizon is a fluctuating groundwater surface. The leaching of the rock is, presumably, achieved by Alkaline hydrolysis under anaerobic conditions. Their precipitation occurs where rising water-table carrying them in solution comes under atmospheric, oxidizing, influence, assuming of course, that the lateritic horizon is permeable to such an influence.

It would appear that where groundwater forms an undulating surface under an uneven landsurface, lateral movement of the water will greatly inhibit the accumulation of precipitated lateritic materials or restrict it to the summits and depressions of the groundwater surface. Apparently, then, an accumulation of a thick and extensive lateritic horizon cannot occur where the upper limit of the water-table fluctuation does not reach the zone of atmospheric influence or where lansurface form and lithology do not preclude lateral movement of ground water. In other words, the differentiation of a 'laterite profile', especially one with a thick lateritic horizon and 'pallid zone', would occur on a relatively even surface, at a late stage of the erosion-cycle, with the attendant slow rate of lateral groundwater movement and waste removal and the consequent deep weathering (Prescott and Pendleton, 1952).

2. <u>The theory of laterization as an agent of landscape development</u>

This, apparently widely accepted principle of the theory of laterization has been lately challenged by De Swardt and Trendall in their joint (1961) and separate (Trendall, 1962; De Swardt, 1964) papers. They maintain that the volume of the 'pallid zone' is often insufficient to account for the quantity of iron contained in the laterite overlying it. Trendall (1962) has calculated that, assuming a 30% loss during laterization, 20 feet of granite are needed to account for the iron contained in 1 foot of laterite. With an average thickness of 30 feet, the massive Buganda laterites indicate, according to this calculation, a lowering of the surface by approx. 600 ft. The process of laterization is, therefore, envisaged as associated with a gradual downward migration of the 'laterite profile' resulting from the removal of solubles from the underlying rock, erosion by surface wash and progressive weathering in depth. It is activated both by percolating rainwater and fluctuating groundwater, with the latter, presumably, forming the decisive mechanism.

The calculations involved are based on the assumption that the laterite is uniformly residual and accumulation uniformly relative. This, however, may not always be the case. At any one place accumulated lateritic materials may be of diverse origin and genesis, i.e. - partly imported and even secondary. The measure of genetic heterogeneity would be dependent on the evolving pattern and form of the surface upon which laterization proceeded or the one developing in the following cycle. Problems of derivation arise especially where thick laterite overlies fresh rock or a rock-type defficient in lateritic elements (e.g. quartzite). In such cases a lateral provenance must be invoked or a denuded overlay of a different rock-type - an assumption which does not always conform with the geological evidence. In any case, such possibilities would make calculations of the amount of consumed rock according to the thickness of laterite, much more complicated.

With these qualifications in mind, the theory of derivation of lateritic materials from a relatively large volume of rock and of the progressive downward migration of the 'laterite profile' has much to commend it. It is the geomorphic conclusions derived from it that appear doubtful or, rather, inconsistent. Lateral removal of non-lateritic constituents of the consumed rock volume is an essential factor in the theory and it implies control by some base-level. Laterization is, therefore, coincident with an erosional cycle. The initiation of this erosion-laterization cycle did not necessarily occur only on an uplifted planed surface, though the postulation of such an initial surface would much simplify the explanation of lateritic accumulation (as demonstrated by Trendall (1962) in his idealized description of the process. But while it is reasonable to assume the initiation of this cycle on a very uneven surface, it is difficult to see how such a cycle can be presumed to culminate in a thick accumulation of laterite on a surface nearly as uneven as that of the present day (De Swardt and Trendall, 1961; De Swardt, 1964).

Trendall, in his theory of 'apparent peneplains', based on the flat-lying laterites of Buganda's hill-tops necessarily does not support such a conclusion. Yet, in regard to southwestern Uganda where landscape is more vaired due to differential lithology, a theory of physiographic development is propounded by De Swardt and Trendall (ibid.) which envisages the formation of a thick laterite uniformly upon a very uneven surface. It appears, that these authors view the landscape lowering, not in the usual terms of a geomorphic cycle, but as a process of simultaneous, parallel lowering of available relief and of the associated 'laterite profile'. Thick laterite is thought, therefore, to have been formed on quite steep slopes and, as observed, evidence of sloping laterite is presented and assertions of patchy presence or absence of laterite are emphatically denied. The occurrence of laterite is discussed in the following section and at this point the theoretical problem of laterite on slopes, and the evidence presented in support will be considered further.

From the theoretical point of view, it appears to the writer that De Swardt's and Trendall's view of the geomorphic process associated with laterization is based upon too literal an interpretation of the term 'residual laterite'. De Swardt himself notes that the progressive lowering of the 'laterite profile' involves constant solution and redeposition of lateritic materials in depth and replacement of the leached and porous rocks below (ibid. 1964). A phase of solution is, of course, essential also for the individualization of the secondary lateritic materials from the primary minerals of the parent-rock. However short is this phase of solution, it indicates that lateritic materials do not represent a direct insoluble residue of the parent-rock and are subject to the mobility of the solvent medium. Over periods of geological duration (Trendall calculated the duration of accumulation for Buganda at approx. 30 million years, ibid. 1962) even the shortest phase of solution will result in migration downslope. Presumably, on moderate and gentle slopes accumulation can occur but even in such a case its thickness will depend on the angle of slope and it will be always relatively thicker downslope. On a slope whose angle exceeds a certain limit, no long-term accumulation of the order of Buganda's laterites can be envisaged. When this basic consideration is added to the inconsistencies entailed by the invocation of a major role for a fluctuating groundwater level under a very uneven surface and the difficulties involved in accepting the concept of landscape lowering without substantial reduction of available relief and angle of slope, this view of the physiographic evolution of southwest Uganda becomes very doubtful.

As to the evidence presented to support the validity of sloping thick laterite (see p.215), it appears that it is, at least in part, erroneous or misinterpreted. Without personally examining the evidence from Buganda two possibilities which may have been overlooked, suggest themselves to the writer. Pallister (1959) has suggested that the thickness of Buganda laterites at outcrop "is deceptive owing to recent laterisation which causes a marked thickening adjacent to a cliff face or large vertical exposures" (ibid. p.47.) On the other hand, as suggested above, laterite may be heterogeneous on a single relict and subject to differential erosion conducive to the formation of a considerable slope within the thickness of the laterite (It must be noted that the evidence concerns hardened laterite and not a lateritic horizon within the original profile). As to the evidence from southwest Uganda it concerns the Rugega hillmass whose crests, according to Phillips (1959) are entirely blanketed by a continuous laterite sheet. Even if such an assertion is fully justified, Phillips fails to indicate the thickness of this sheet. Moreover, the extent of this supposedly single relict, between the highest and the lowest points of the laterite sheet, is 5-9 miles, which with a difference of 300-400 ft, means a rise of 40-60 ft/mile or an average of $^1/16$ - scarcely a considerable slope.

Another aspect of Trendall's theory of laterization as an agent of landscape development, which appears in need of further consideration concerns the nature of the pallid zone in relation to the thickness of laterite accumulation. According to this theory, it is essential that the laterite profile as a whole should migrate downwards unchanged, and the thickness of the pallid zone, indicating the major source of iron-compounds, be directly related to the amplitude of groundwater fluctuations. This appears very doubtful where the depth of this zone is of in the order of hundreds of feet (see p.168 for Trendall's evidence from the Masaka District). Since any fluctuation of groundwater beneath a lateritic horizon presupposes its permeability, whatever thickness it attains (presuming the view that laterization is associated with lowering of the surface) it appears more reasonable to assume that deep weathering results from a prolonged state of planation and deep saturation by groundwater with a gently undulating surface under a stable planed land surface. Another possibility is that the weathering in depth of the pallid zone occurred through free leaching consequent upon dissection of the surface and the laterite. This, however, seems less likely since free leaching in great depths can be envisaged only where the water-table is lowered considerably, i.e. - under high but areally limited residuals. There exists, then, a possibility that the leaching will be under aerobic conditions and consequently the residue will consist also of iron-oxides. Pallid zones are distinguished, however, even at great depth by their relative paucity of iron.

It appears, therefore, that some revision of the theory of laterization is necessary to account for the great depth of some pallid zones, but on the whole the existence of such zones points again to the close association of laterization with a planed or a gently rolling surface.

3. Hardening and reversal of hardening

The genesis of laterite proceeds within a soil-regolith profile of which it forms a lower horizon, usually illuvial. Since the primary pedogenetic process of laterization involves gradual accumulation of lateritic materials, the lateri~~zation~~tic horizon attains its characteristic properties progressively. Consequently the widely recognized distinction between laterite and lateritic soils depends on certain quantitative and qualitative properties whose most pronounced expression is the ability of laterite to harden on exposure.

Hardening of a lateritic horizon depends on enrichment, either absolute or relative, in iron compounds. It appears that the amount necessary to ensure hardening depends on the nature of the medium in which they accumulate - a coarse-grained material with a smaller specific surface necessitates a lesser quantity than a fine-grained medium. Hardening seems to involve crystallization and dehydration of mobile, amorphous or microcrystalline, hydrated iron-oxides under conditions of exposure to alternate wetting and drying, perhaps accompanied by reduction and reoxidation (Alexander and Cady, 1962). More specifically, the process seems to involve progressive decrease of kaolinite and increase of crystalline goethite and haematite as well as gibbsite. There is evidence that suggests that these are not only relative changes - through the importation of iron - but are due also to destruction of kaolinite.

As hardening constitutes a gradual process it may be found in various stages indicated, apparently, by the relative amount of kaolinite. There seems to be no clear evidence as to the duration of the hardening process. Undoubtedly the rate of hardening differs with conditions and once it has attained a certain degree, laterite might retain its composition and structure even after these conditions no longer obtain. Consequently, it would be impossible to determine the relative age of hard laterite possessing similar composition and structure.

Hardening of laterite is usually regarded as an irreversible process, and the erosion of a massive laterite crust is generally believed to involve only mechanical disintegration at the exposed edges. There are, however, indications that under certain circumstances, physico-chemical reversal of hardening may take place. Alexander and Cady (ibid.) mention examples of crust softening by rehydration indicated by decrease in amount of gibbsite and ~~in~~ increase of kaolinite, perhaps through resilication. Such a reversal involves also disappearance of boehmite (a product of hardening of free alumina) and reduction of haematite into geothite and limonite. It appears from these examples that reversal takes place only after the mechanical disintegration of the massive crust into small fragments, or where it comes under water (presumably reduction reversing the effect of immobilizing oxidation). It is doubtful whether rehydration and resilication can be as active and rapid without disintegration and where the crust is situated on high, well-drained sites.

In any case rehydration is not considered to be the main cause of reversal. It is the establishment of vegetation which is regarded as the most important agency of crust break-up and reversal of hardening. The products of vegetation decomposition combined with a large moisture supply can bring about the solution of iron, and to some extent - [illegible], compounds by complexing (chelation) with organic matter (Bloomfield, 1953, 1955; Maignien, 1958) and under certain circumstances, presumably, by lowering the pH. Establishment of vegetation on hardened laterite is, however, closely connected with the problem of laterite as a parent-material in pedogenesis. In most cases, it appears, soils derived from a thick upland laterite crust, are relatively shallow and skeletal and, indeed, it is difficult to envisage the development of any other type of soil on such a poor parent material. Alexander and Cady maintain that "All soils over a disintegrating crust show additions of wind-blown, water transported or colluvial external material" and admit that "for a crust to break up... it seems that some overlay or additional material that can supply nutrients and hold water for vegetation is almost essential".

Associated with the hardening of laterite is the minor problem of definition of laterite. There is still some confusion in the literature as to the use of the term when applied to the different products of the different phases in the process of laterization. It is clear, however , that from the point of view of geomorphic and pedogenetic significance a clear distinction must be made between the lateritic horizon within the original soil-regolith profile which consists of a relatively soft, friable, earth-like material, and the hard, rock-like material, resulting on the exposure of dessication of this horizon. It must be noted, however, that between these two extremes there are intermediate forms, indicating both intermediate phases and variations of process. Concentrations of lateritic materials in an illuvial horizon are not the only form of laterization. Precipitation of lateritic materials, namely-iron compounds, often takes the form of concretions within the soil medium, at times around soil gels or around small fragments of unweathered rock. Such concentrations of concretionary material can attain considerable hardness and resistance to weathering, but if they are not cemented by a lateritic matrix into a massive hardpan, they cannot possess the geomorphic and pedogenetic significance of a laterite crust.

The Nature of Laterite

Occurrence of Laterite

The occurrence of lateritic accumulation in lowlands

In lowlands of the study-area, mottled, clayey subsoil horizons and their indurated exposed equivalents occur only sparsely and are confined in their distribution to incised edges of drainage lines. In most cases the measure of induration of these outcrops is relatively small and it becomes progressively less with depth. Also in most cases such outcrops can be clearly related to existing soil profiles and consequently regarded as products of contemporary or sub-recent laterization, at least of younger age than the lowland surface under which they exist. This is the lateritic accumulation referred to by De Swardt and Trendall (1961) as the "Lower Laterite" and, as indicated by them, it is at least partially of secondary origin, with the source of its materials in the older, higher accumulation. It is only if the unhardened lateritic material is included under the term of 'laterite' that De Swardt and Trendall's statement that laterite is extensively developed in the Orichinga Valley (ibid. p.47) is valid. Low scarps of indurated outcrops, do exist at the edge of the present valley-floor, but only in one case, on the eastern side of the Muko valley (the northern continuation of the Orichinga), can the material be, somewhat doubtfully described as hard ironstone.

Plummer (1960) mentions few other outcrops of this type and maintains that only a few limited outcrops of lowland laterite have been recorded in the area covered by Sheet 86 of the geological map which includes most of the lowland in the study area. Phillips (1959) mentions and depicts only a very few cases of lowland laterite in the area surveyed by him and included in the present study-area. He relates them to a young surface of comparatively recent origin. The conclusion that lowland laterite accumulations are usually of relatively recent origin and of rare occurrence in the area, was confirmed in the course of the present study. ~~Occurrence in the area, was confirmed in the course of the present study~~. Occurrences were found to be limited to edges of drainage lines in relatively close proximity to eroding slopes, or to formerly inundated flats (e.g. the north-eastern shore of Lake Mburo). The fact that lateritic accumulations are not found in the centres of extensive lowlands may be explained by the deep weathering and prolonged leaching of such areas.

Since the greatest proportion of lowland lateritic accumulations exist within their original soil profiles and largely retain soil-like properties, their geomorphic and pedogenic significance in the present context is comparatively small. Consequently, the usage of the term 'laterite' in the present study follows that adhered to in the memoirs of the Research Division of the Ministry of Agriculture of Uganda (Chenery, 1960). According to this definition, the term 'laterite' applies to "ferruginous rocks which are.... hard (that is, they cannot be broken in the hand or when dropped)" and occur as "sheet and/or erratic ironstone" (ibid., pp.29-30).

Evidence of laterite on the upland

A consideration of laterite involves three main aspects: the pattern of its distribution, its form of occurrence and the nature of the laterite profile, namely the thickness of the laterite horizon and the presence or absence of 'mottled' and 'pallid' zones. An examination of the evidence may start with the negative statement that there is no specific evidence in the literature of a case of a 'pallid' zone underlying laterite on sedimentary rocks within the limits of the study area. One case is cited by De Swardt and Trendall (1961, p.30) from an unspecified locality in the Koki Hills (Masaka District) where shales are stated to have been altered by leaching into fine quartz and kaolin to the depth of 200 ft below the laterite. Indirect evidence is supplied by Phillips (1959) in the Rakai geological map, where Kaolin is depicted as present in the Buganda Hill in northern Koki.

As observed (Table ; p.) Wayland (1934) maintained that his PI, presumably represented on the crests of the Ankole Highlands, carries only patches of laterite. McConnell (1955) asserted that the same surface ("Ankole Surface") 'does not as a rule carry laterite' and that, on the other hand, the "Koki Surface" carries 'thick laterite'. It is of interest to note that both these assertions are denied by other investigators. De Swardt and Trendall (1961, p.41) and De Swardt (1964, p.323), basing their view on

Plummer's testimony, state that McConnell's assertion of the absence of laterite on the Ankole Surface is incorrect and that, in fact, it carries a thick laterite cover. On the other hand, Radwanski (1960, p.34), while describing the soils of the Koki Hills, negates McConnell's assertion of thick laterite on the 'Koki Surface'. He states that 'laterite as such, is not present on the crests of the Koki Hills. He admits only to the presence of a surface crust of iron-oxides and a few laterite boulders which he regards as relics of an older, and now removed, sheet of laterite. The thin surface crust is, in his opinion, a secondary product derived from the disintegration of the old sheet.

McConnell does not specify the exact value he assigns to the designation of 'thick laterite'. De Swardt and Trendall, on the other hand, state that the thickness of the 'Upper Laterite' (including McConnell's 'Ankole' and 'Koki' surface) is 'probably between ten and thirty feet' (op.cit. p.28). More directly related to the study-area is the evidence presneted by Plummer, Phillips and Harrop (1960). Plummer's treatment of the subject of laterite is almost entirely concerned with its geomorphic significance. The description of its distribution is stated in altitudinal terms but imparts the impression of a uniform spatial presence on upland features. He refers to the nature of the laterite only in the preamble where he states in general terms that its thickness is "of a score of feet or more" (op.cit., p.12).V makes such a thickness difficult to credit. Plummer's evidence (in. litt.) cited by De Swardt and Trendall, viz., that south and east of Mbarara he found laterite to be so extensively developed that it masked the underlying geology and seriously hampered mapping, seems barely sufficient to justify their implied conclusion that laterite is uniformly present and thick. A three-feet thick cover of laterite, even a three-feet

V However, indirectly his evidence implies that laterite cover cannot be every where, uniformly over a score of feet thick. The mention of lines of quartzite boulders jutting through the laterite cover (opp. cit., p.14) deep mantle of soil, mask the bedrock geology as effectively as a 30-feet thick cover.

Harrop's evidence, while more clearly presented than Plummer's is part of a general soil survey of the whole Western Region and, therefore, necessarily brief, generalized and lacking in detail. He testifies to the presence of thick laterite on the higher crests of the Rwampara (e.g. Karamrani), but, at the same time, states that on lower ridges laterite remnants are only sporadically present and then - less well-developed than on the higher ridges. It may be significant that the type-profile of the upper member in the relevant soil catena (Bugamba Catena), shows phyllite as underlying the C-horizon, with no laterite in any of the horizons. In the Isingiro Hills, on the other hand, laterite is stated to be present at the base of the crest soil-series (Rugaga Series). The type-profile shows disintegrating laterite in the lowest horizon and the presence of a continuous sheet of underlying laterite appears to have been deduced from the frequent outcroppings of sheet patches on the periphery of the crests. At the same time the occurrence of laterite under the soils of this series is admitted to be difficult to account for on pedological grounds. As to the presence and nature of laterite on other upland units, Harrop - by correlating them with the Koki Hills - appears to accept Radwanski's version (ibid. pp.34-38).

Lastly, Phillips devotes a brief section to the distribution of laterite in the eastern part of the region, but he also is concerned mainly with the geomorphic aspects of altitudinal distribution and alludes to the nature of laterite only in stating that it is cellular and, in several places, thick. He does not specify how thick, it is (1959, p.3). However, he identifies laterite almost universally, though not equally, throughout his area. The consistency of laterite association with crests decreases noticeably from the Rugaga hill mass to Eastern Koki, but even so the frequency and extent of laterite relicts on the Koki hill-tops is such as to contradict Radwanski's evidence, unless they signify no more than the presence of lateritic residues.

There are, thus, two contradictory statements of evidence as to the presence of laterite in the upland of the area. That presented by McConnell, Radwanski and Harrop who, either directly of by implication, maintain that laterite is not universally present, at least not in the form of a thick, continuous sheet, and that presented by Phillips, Plummer and De Swardt and Trendall who, again directly or by implication, maintain that the whole upland surface is uniformly covered by a thick laterite sheet. An important corollary of this last view is the recognition of the existence of such a sheet over the slopes connecting the different levels of the upland crest-surface. As observed, it is a basic premise of the 'Laterite Surfaces' concept, that it should exist on slopes. Plummer also cites many cases in which the laterite sheet extends over sharp breaks of slope, and is continuous between levels, but apparently also recognizes that this is not a universal phenomenon and that "a sharp break in slope is not conducive to laterization" (opp.cit., p.19). Phillips mentions many cases in which laterite extends on to slopes and has an inclined surface, but it is never stated to connect two crest levels, which are treated as separate surfaces with, presumably, separate development of laterite.

In an attempt to evaluate these contradictory views, two points seem to be of importance: the context in which the observations producing the evidence were made and the curious fact that all of those upholding the second view are geologists while of the three upholding the first - two are pedologists. Of all investigators only De Swardt and Trendall were specifically concerned with laterite. On the other hand, only Plummer and Phillips were specifically concerned with the relevant area and surveyed it in detail. McConnell and De Swardt and Trendall were dealing with the problem on a country-wide scale while for Radwanski and Harrop the area was only a part of a wider survey. Understandably, the wider the scale of the study the less detailed are the observations, the greater the depenience on isolated examples and second-hand evidence and, perhaps, the greater is the tendency to generalize from observations in another area or region.

It is necessary, at the same time, to keep in mind the basic differences between geological and pedological surveys. A geological survey depends mainly on superficial outcrops and its purpose is identificatory and interpretative. Laterite is, usually, of secondary importance to bedrock from the lithological, petrographic and structural points of view. A soil survey depends on sample-pits and transects of profiles and its purpose is classificatory and analytical. Laterite is a factor of prime importance in the classification of tropical soils according to profiles and pedogenetic processes. Its nature, as to morphology and composition and the structure of its profile, is of more significance to pedologists to whom it represents either part of the soil profile or a parent-material, than to geologists to whom, in a geological survey, it represents merely another surface deposit. It may be important to note again that the only case, in the area, in which laterite was identified in a type-profile of soil, it was described as disintegrating, its thickness was not specified and the whole phenonmenon of laterite underlying a deep profile of a fairly fertile soil, was deemed to be very problematical. Lastly, McConnell may have been incorrect in stating that laterite was absent 'as a rule' from the Ankole Surface, but it is difficult to assume that he made his assertion without any observational foundation and that laterite is present everywhere on this surface.

Forms of Laterite Occurrence

In the course of the present study it became clear that although laterite as defined above, is found almost universally upon surfaces, it definitely does not blanket them uniformly. The continuous sheets completely capping the crests of upland features, which are so typical of the Buganda landscape, are confined in the study-area to certain landscape units and certain altitudinal limits. Even where found, complete conformity with crest area is present in only certain cases and the thickness of the sheet is usually lower than the average thirty feet of Buganda laterite.

The laterite found in the area is conspicuously heterogeneous both morphologically and genetically. It is found in continuous sheets and erratically, its accumulation can be either absolute or relative and its origin - primary or secondary. Since all these attributes seem to lend themselves to a topographical and altitudinal pattern, the described forms of occurrence are classified in this way. (Figs.30-32).

1. Laterite on the upper surfaces

a. Crest laterite

Relicts of a massive laterite sheet occur on the flattened part of the Rwampara Surface crests. Those examined are of relatively limited extent (the largest being approximately two acres in area), and possess a fairly rounded form and lack bounding scarps. Consequently, their presence on the crest can be discerned only by the noticeable steepening of their slopes in comparison to the general crest surface. Their thickness seems to accord with Plummer's estimate of about a score of feet, but this appears to include a certain thickness of a weathered zone preserved beneath the laterite. The presence of laterite blocks and fragments on the slopes and at the base of the relict and the disposition of encroaching vegetation in an irregularly linear pattern of fissures and cracks imparts an impression of a dismantling mass, considerably modified from its original form. Furthermore, a fairly extensive belt of a relatively superficial ferruginous pavements surrounds the relict, on the adjacent flat crest surface and extends up its lower, gentler, slope, probably representing a secondary colluvial accumulation.

Relicts of this type were found only in a very few places, on the southern ridges of the Eastern Rwampara. In all probability many others exist, perhaps of greater dimensions, The presence of an extensive, thick, sheet of laterite on the Karamrani ridge appears from the evidence to be indisputable. But whether or not such relicts exist in great number and cover considerable crest-surface areas, there is no doubt that large tracts of the Rwampara Surface crest-area are entirely devoid of such a form of occurrence. This seems to apply with even greater emphasis to the crests of the Gayaza Surface where, it is believed, no such relicts exist at all. Field evidence within the study-area thus indicates that a statement of the presence of a continuous sheet of thick laterite upon the Rwampara Hts imparts an entirely erroneous impression which, as will be argued, is not borne out by the facts of soil and vegetational distribution. Consequently, Wayland's original assertion of patches of laterite, seems to accord with the observational evidence better than any other assertion. The existence of the laterite sheet on the Karamrani may simply indicate a better preservation upon the higher parts of the watershed ridge.

b. Crest-slope laterite

Of much greater frequency and almost universal appearance on both the Rwampara and Gayaza Surfaces is the type of laterite pavement associated with the periphery of the crests, usually at the edge of the crest-slope. These pavements have, as a rule, a slightly inclined surface (2° - 5°), which may conform with or be of somewhat lower angle than the crest slope. In all observed cases such pavements emerge from beneath a soil mantle and thus, when they appear on both sides of the crest, impart the impression of a continuous sheet of laterite underlying the soil and blanketing the crest. There is, however, strong ecvidence to the contrary: the thickness of the laterite at the edge of the pavement, never exceeded, in the observed cases, 3 ft. The edge itself, never forms a scarp and always peters out before the top of the steeper hill-side slope is reached; in some instances laterite was observed to lap around outcropping boulders of quartzites. At the edges and in excavations, laterite is seen to rest directly on fresh bedrock with no mottled or pallid zones underlying it. The morphology of laterite shows discernible structure of pisoliths imbedded in a laminar matrix. Lastly, soil pits (see Fig.33b) along a section from the crest to the outcrop of the pavement show a progressive downslope compaction of the illuvial horizon and increase in ferruginous mottling and in concentration of concretionary nodules. On top of the crest, though it may be as much as fifty feet higher than the pavement outcrop, disintegrating phyllite is reached at a depth of fifty-sixty inches or less.

There seems, therefore, to be little doubt that the laterite pavements do not represent the edges of a laterite cap or any relative accumulation, but result from an absolute accumulation of obliquely leached, mobilized, lateritic materials of the soil mantle whose transport is engendered by the convexity of the crest surface. It is a process which, probably, has been active since the development of the soil and is still active at present as is evident in iron-rich water gathering in the hollows excavated for the purpose. Presumably, then, the relative duration of the process can be roughly estimated by the relative thickness of the pavement, and with it - the amount of rock transformed into soil on the crest slope since its beginning and the differential duration of pedogenesis on different lithologies and topographic units. With the retreat of the hillside slope and the progressive truncation of the soil profile, the exposed, retreating edge of the lateritic horizon hardens into an ironstone pavement. It is significant that no later-ite scarps are created by this retreat and that the angle of the pavement's edge is lower than that of the hillside slope. The evident current mobilization of iron-compounds, both in the percolating water and in the ferruginous coatings on underlying bedrock, also lends force to the suggestion that the pavement laterite, whether inherently or because of incomplete hardening process, is less competent than the underlying rock. It is also obvious that the sole origin of the lateritic materials in the crest's soil mantle imposes a limit on the possible amount of accumulation. Where slope retreat is assumed to predominate overwhelmingly over crest lowering the volume of crest soil available as a source of lateritic material, never very large on high relief, is constantly on the decrease. Consequently, no thick sheets of laterite can be expected on such a relief, unless the premise of relative accumulation on steep slope is accepted. The relatively meagre and incompetent pavements cannot have the effect of "freezing the landscape" and it is undoubtedly the lithological attributes of the bedrock that affect the measure of the relief.

c. <u>Fragments of laterite</u>

The statement of the universal occurrence of laterite on the upper upland crest surfaces cannot apply, therefore, to sheet or pavement laterite which are limited to certain sites and occur intermittently. It is the erratic laterite in the form of disconnected fragments that make its occurrence universal. The morphology and shape of the fragments, as distinct from those of erratic concretionary nodules, clearly indicates that they have their origin in sheet or pavement laterite. They are found mainly in two generalized size-groups: irregularly polygonal blocks usually larger than 15" across, and irregularly shaped gravel usually less than 4" across. Laterite blocks can be always associated with present or former thick sheets of the type described above. It appears that the mode of disintegration of such sheets involves cracking into large blocks falling away from the edges of the sheet and subsequently disintegrating into gravel which are gradually dissolved. Presumably gravel can be formed directly too from the vesicular and heterogeneously composed sheet laterite. In contrast pavement laterite does not appear to produce much gravel-sized fragments and no blocks of pavement laterite morphology or composition were found. Those fragments which can be related to pavement laterite are on the whole, of smaller size and rounder form and the most abundant products of pavement disintegration are very hard concretionary nodules.

It is reasonable to assume that angular gravel of vesicular structure, wherever it is found, originates in the dismantling of very hard and relatively thick sheets of laterite of the same vesicular morphology and not in the pisolithic-laminar ~~laterite~~ laterite pavements. Consequently the fact that such angular gravel is found dispersed not only in the vicinity of relicts of such sheets, but throughout the profile of the crest soils, seems to be of great significance, since it indicates the possible former blanketing of both the Rwampara and Gayaza surfaces by thick laterite sheets. An attempt to draw definite conclusions from the pattern of fragment dispersion in soil-profiles throughout the area was unsuccessful because of the lack of time for detailed counting and measuring of fragments in a much larger number of crest soil-pits than were necessary for soil survey and samples. Yet, while available profiles appeared to reveal no consistent pattern of dispersion, some generalized facts did emerge. Laterite fragments are not specifically concentrated in any one soil horizon but in most cases tend to be more abundant in the upper horizons than in the lower;

on the whole it seems that soils of the Rwampara Surface crests contain more laterite gravel than those of the Gayaza Surface. Again, a more accurate and detailed statistical survey is necessary to verify these impressions but if they are correct then the first fact possibly indicates the gradual dispersion of the gravel in the soil downwards from the surface and in any case, negates the suggestion that the soil was formed from the laterite. The second fact implies that the original laterite on the Gayaza Surface was not as thick as that of the Rwampara Surface.

2. Laterite on Slopes

a. Fragments of laterite

As may be expected, fragments of laterite, as angular gravel and concretionary pisoliths abound on hillside slopes, both on the surface and in the predominantly shallow soil profiles or as part of the debris. Blocks of laterite are found too but in relatively few numbers. There can be little doubt that all gravel and blocks originated on the crests and probably also a large part of the pisolithic nodules. As with the distribution of laterite fragments on crests, a closer investigation is needed before any significant pattern can be established, but the expected increase in number of fragments, both on flattenings of the slope and along gully beds is easily discernible. It would appear that on steep quartzitic slopes the larger blocks of laterite are more or less integrated with general coarse waste-mass while on the bare argillaceous slopes they tend to stay on the surface. Laterite gravel is subject to a dispersal pattern intermediate between those of coarse and fine waste and is found scattered on the surface or within the waste-mass on the steeper slopes and concentrated in larger amounts, exposed or buried, at the head of the gentler slopes.

b. Laterite crusts and patches

However, the main problem of laterite occurrence on slopes concerns not the erratic fragments whose allochthonous origin can hardly be in question, but the existence of continuous accumulations which are professed to blanket slopes completely and thickly and, in consequence, to indicate continuity of geomorphic evolution. It is, undoubtedly, true that relative accumulation of lateritic materials may occur on surfaces which have some measure of slope. The limiting angle which will allow such an accumulation will depend on the nature and quantity of the mobilized lateritic compounds and, therefore, on the lithologic and climatic environment. It is also reasonable to assume that an absolute accumulation will have a lower limiting angle since it presupposes the prolonged solution of compounds which in a relative accumulation may have only a very brief phase of mobility. Obviously, as observed, the higher the angle of slope the smaller is the amount that can accumulate and beyond a certain limit, it is doubtful that more than a very thin veneer of lateritic coating will be formed. As far as is known to the present writer no specific investigation into this problem of laterite on slopes has been made up to the present ~~and evidence of thick laterite on steep slopes has been made up to the present~~ and evidence of thick laterite on steep slopes is either absent or doubtful.

Sheets of continuous laterite occur on most slopes of the two upper surfaces in the area and in some cases are almost continuous between them, as far as was observed (e.g. the Kagarama slope towards the Cayaza hillmass). In most instances, however, such sheets extend only partly down the slope and their downslope limit is clearly correlated with the angle of slope. On steep upper slopes of massive quartzite ridges they rarely descend beyond the edge of the crest slope and where present are usually continuous with the crest-slope pavements. On more moderate slopes of the argillaceous ridges or on the less competent, arenaceous ridges of the Isingiro Hills, they may extend as far as 300-400 ft below the crest level (in isolated cases, such as the northern slope of the Isozi Hill, a laterite crust appears to be continuous down to 600 ft below the crest) usually along the upper parts of gully interfluves. Below this downslope limit of continuous laterite, only discontinuous patches whose extent appears to be clearly related to slope faceting, is found until the foot of the slope is reached.

No general correlation of the distribution of these sheets with limits of slope inclination is possible except in a negative sense namely, that they do not exist, apparently on angles of slope exceeding 20° - 25°. The fact that they are found on such slopes only in isolated cases does not diminish the validity of the problem, and their presence in explicable only if their nature is closely examined. The observational evidence in the study-area reveals that these are by no means thick relative accumulations. While apparently of varying thickness, it never exceeds a few inches, as is amply evident by the projection of stones and waste gravel through the crust. It appears that the thicker accumulations are to be found where bedrock produced a small flatter facet and the general effect is of laterite smoothing the irregularities of the slope surface producing a very characteristic texture on air-photographs comparable to that of bare rock. Furthermore, the numerous inclusions of rock and laterite fragments imbedded in the crust and the typical laminated morphology with the foreign inclusions forming nuclei of concretions, undoubtedly indicate absolute accumulation possibly largely of secondary origin.

This is, then, a thin crust of lateritic material carried downslope in solution and originating probably either in disintegrating crest accumulations or in leached crest soils. Its redeposition on the slope is possibly aided by irregularities of bedrock and waste cover and never attains a considerable thickness after smoothing these irregularities. It is not easy to account for the presence of these crusts on some slopes and their absence on others or for their different extents on similarly inclined slopes unless they are assumed to be continuously destroyed by erosion and reformed by deposition with the balance controlled by the differential amount of supply on the crest. On the whole, however, it should be emphasized again that the phenomenon of continuous superficial crusts on slopes is relatively limited in extent and that, as a rule, the larger parts of slopes are devoid of such crusts and are either bare, covered with debris or carry skeletal soils.

Nonetheless, even steep bare slopes are laterized to some degree. Usually this takes the form of thin ferruginous coating on the slope surface. The measure of this ferruginization apparently depends on the amount of surface available for adsorption and deposition. Since steep slopes are usually bare of soil cover laterization is most noticeable in waste-masses and occurrence of steeply rising, heavily ferruginized scree slopes is quite common on the flanks of massive quartzite ridges.

Generally speaking, therefore, the observed evidence from the study-area does not support the assertion that there exist thickly laterized steep slopes, indicating a fossilized relief of considerable amplitude. The deceptive impression of such a relief can be conceivably gained through the existence of continuous cover of lateritic crusts, but closer scrutiny shows these to be only superficial and probably of current formation.

c. Subsoil laterization on slopes

As described above slopes formed on an alternate succession of quartzite and argillites possess prominent elements of steeper and flatter facets and that the flatter facets may have an accumulation of finer waste which develops into a soil profile. These mid-slope soils are associated with a subsidiary form of laterization consisting of an intermixture of relative and absolute accumulation of both primary and secondary lateritic materials. Since the soils are relatively shallow and in some cases obviously young,

Laterite on the Upper Surfaces

Crest

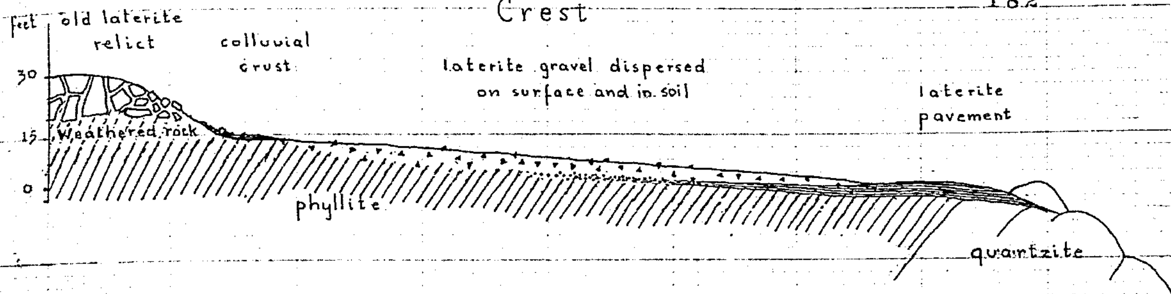


Fig. 30

Slope

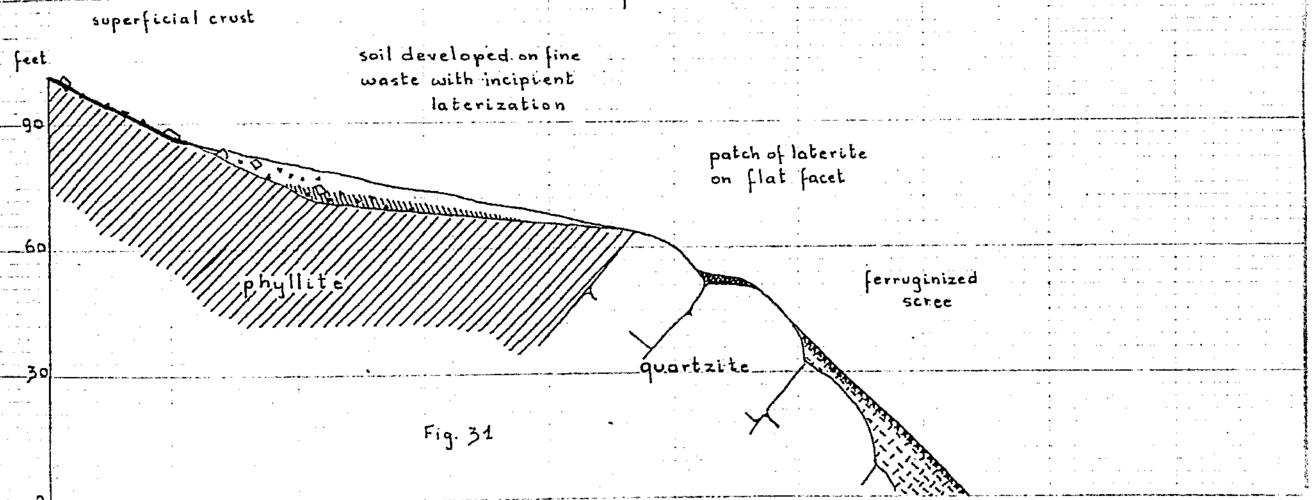


Fig. 31

both in base content and in poorly developed horizons, it is reasonable to assume that the presence of a well-differentiated, heavily mottled, clayey subsoil horizon is largely due to the percolation of iron-rich water from upslope. But undoubtedly *in situ* weathering and leaching also takes part in this incipient laterization. It is doubtful, however, that the process will attain completion under the conditions of severe erosional activity encroaching on three sides of the spur unless woody vegetation is allowed to develop undisturbed.

3. Lower level laterite

Laterite on the Sanga surface crests rests, as intimated above, on two types of lithology - metasedimentary or sedimentary, resistant formations and schistose or plutonic incompetent rocks which, within the study-area carry laterite only in a few instances. The laterite carried on the basal micaschists or Basement granitoids has, as was already observed, the general form and properties as has the typical Buganda laterite: a thick flat-lying cap of ironstone underlain by mottled and pallid zones with sharp breaks at the edge of the sheet and smoothly inclined, well-developed pediments below the scarps. In a few cases, laterite-capped hills of mica-schist, situated at the edge of the basal exposure of the sedimentary sheet (e.g. Sanga Hills) preserve uncommonly steep and high slopes. The concentration of several such hills in a limited area and the close proximity of resistant formations indicate a relatively young downcutting and a fairly early stage in the retreat of slopes.

The similarity of this type of laterite to that of the well-studied Buganda laterite and its relative scarcity in the study-area, make it unnecessary to describe it in detail. It is the laterite found on the resistant upland features of the Sanga Surface that constitute the main point of interest in the study-area, in that they are entirely different from both the laterites of the upper levels and those found on incompetent rocks.

Laterite on the Lower Suraface

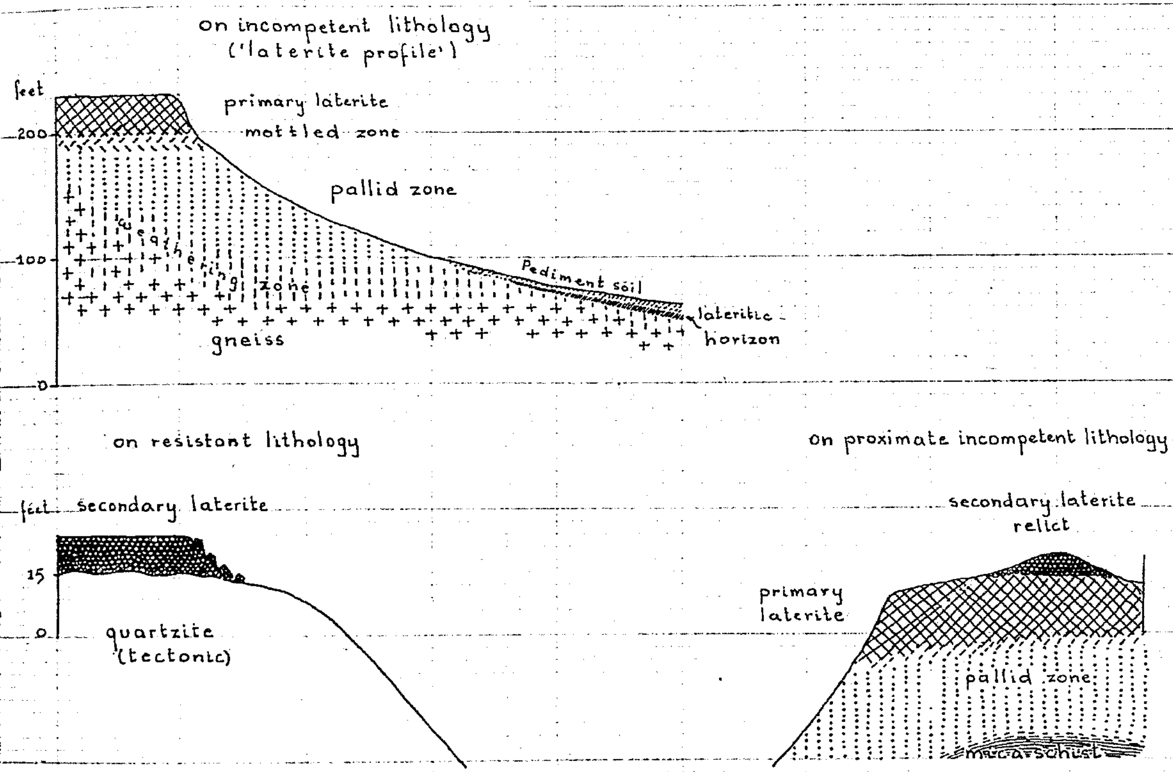


Fig. 32

Mention has been made of the main attributes of form of these laterites: the continuous sheets covering all or parts of the crest-surface of individual upland features and attaining as much as ten feet in thickness. It was also mentioned that these flat laterite caps have quite prominent scarp-like slopes which usually rise steeply at some distance back from the edge of the bedrock crest and have no weathered zone underlying them. To these attributes should be added morphological characteristics distinguishable already in the field, which emphasize the different nature of this type of laterite. On superficial examination the laterite seems entirely pisolithic differing from the concretionary pavement laterite of the higher surfaces in lacking any noticeable amount of cementing matrix. It is also of much darker red-brown, almost black, colour and the individual concretions are much less regularly shaped than the well-rounded or ovoid concretions of the pavement laterite. These laterite caps disintegrate into large blocks, similarly to the sheet relicts on the Rwampara Surface, but somewhat smaller in size and of less regular form. No discernible fissures indicating the complete dismantling of the mass, are present and disintegration is confined to the scarp-like edges.

It appears evident, even according to field characteristics alone, that this type does not represent a relative accumulation in situ in the classical mode of laterite formation. The gross morphology of the laterite points to absolute accumulation in a fashion different from that found in pavement laterite or in slope crusts, which suggests concretionary precipitation around minute, regularly shaped nuclei or around very large angular fragments. As will be shown (p. 198), the laterite cap, evidently represents a thoroughly laterized lower part of a deep soil-regolith profile, probably developed on a low-lying pediplaned surface.

In some special cases, this type of laterite is found together on the same feature with the vesicular type of laterite which apparently developed by relative accumulation in situ and overlies a weathered zone. In one such case (e.g. Hill 4691 opposite Kyibega in the Sanga Hills) the pisolithic laterite overlies the thicker vesicular laterite in a modified patch on the higher part of the crest and its origin as the soil cover of the underlying laterite is clearly evident.

Properties of Laterite types

Laboratory examination of laterite samples representing the different types determined by field characteristics consisted of a chemical analysis and a megascopic inspection of gross morphology and structure. Financial considerations forced a choice between chemical analysis and differential thermal analysis of mineral composition. It was decided to choose the first since it appeared possible to determine approximate normative mineral composition from the chemical analysis and it was thought that these would enable better comparative interpretation. An attempt to make thin-sections proved unsuccessful for lack of experience.

The same considerations prevented the examination of more than ten samples of laterite of which no more than three represented the same general type. This is a very small number and, consequently, the result should be interpreted with caution and may not have general applications. Nevertheless, as will be seen, they produce a rational picture, which accords with the conclusions derived from field characteristics and it was reasoned that since the study is not concerned with laterite specifically, the results may be regarded as sufficient for the present purpose.

Description and morphology of the samples

Rwampara Surface laterite.

1a1

A fragment broken from inner face of a fissure in a dismantling sheet of thick laterite, on phyllite. Buhingu (Buhingu-Katanzi ridge) altitude approx. 5,700' a.s.l.

It has an overall pale reddish-brown mottled appearance with numerous channels and cavities of varying size. Some cavities are filled with a lighter-coloured, ochre, material; the larger ones are visibly coated with a rust-coloured hard veneer. Other parts are blotched with a variety of brown colours, from very dark to very light yellowish-red. The darker spots have definite, irregularly round shapes and appear to be very well-cemented concretions with distorted boundaries. The lighter areas are mottled with rust-coloured patches. The exposed part of the fragment is much darker in colour than the freshly broken face. On the whole it has the appearance of a cellular slag ('structure scoriacée', Maignien 1958).

A substantial element of clay in the composition of the fragment, seems to be indicated by the lighter patches and areas with more brittle texture. But, in the main, clay appears to be enclosed by iron-oxides, and the darker, concretion-like areas point to an extensive replacement of alumosilicate clay by iron-compounds (Alexander & Cady, 1962). At the same time, differences in colour, from yellowish to dark-brown, apparently represent a decreasing grade of hydration of iron compounds (Maignien, 1958). The origin and significance of the cavities and channels, are open to question. If vesicular laterite originates in the activity of termites, as suggested by Prescott and Pendleton (1952), then the property has no significance except as a purely fortuitous diagnostic feature of this specific type of laterite since no other type has it to the same degree. If, on the other hand, vesicularity indicates a specific phase in the process of accumulation or a form of post-hardening differential weathering, then the suggestion of a process of replacement of kaolinitic clay by iron-compounds and, thus, of a relative accumulation is much strengthened.

The impression imparted by the morphology of this sample is, therefore, of a thick relative accumulation, in situ, of primary lateritic materials, by the process of progressive replacement in depth of a clayey weathering zone and a downward migration of the profile. The very small depth of the weathered zone under the laterite and the relatively inconsiderable thickness of the laterite itself, suggests the doubtful role of a great amplitude in the fluctuation of groundwater table in general laterization, but it may also indicate an inclination of the surface on which laterization occurred in the present case.

1a2

A fragment broken from a block of laterite lying on the surface of a slope rising above the crest-level; on quartzite. Kanywagongi (Kshungyezi-Chewiro ridge), altitude approx. 5,300 ft. a.s.l.

Very similar to the former sample in morphology, except that it appears to be more concretionary, and, on the whole, darker in colour pointing both to a somewhat larger iron content and a lesser grade of hydratation of iron-oxides. No evidence of a weathered zone is found in the locality and the underlying bedrock appears to be massive quartzite. The somewhat higher iron content despite the erratic nature of the occurrence, may, consequently, be related to an initial lower position of the surface on the southward-inclined slope of the Rwampara or of the lateritic horizon within the profile. Yet, according to this superficial impression the increase in iron content is very slight. Otherwise the same considerations apply as to the previous sample. Moreover, the fact that this erratic block was found on the surface, high above a local exposure of pavement laterite, indicates that the increase in iron content, if it exists, is due to initial enrichment and not a late lateral provenance.

1c1

Laterite gravel from a depth of 29" in a soil-pit, on phyllite, Mt. Kagarama (Main Ridge), altitude approx. 5,700' a.s.l.

Also closely resembles sample 1a1, in general morphology. There are, however, significance differences. Contrary to 1a2, iron content is lower, fracture planes are lighter in colour and most of the channels are filled with ochre-coloured material. Examination under magnification reveals a possible higher content of crystalline quartz in the lighter areas; there are only relatively few dark concretionary bodies.

The impression is, therefore, that a certain amount of the iron content has been leached from the gravel, leaving at least a greater residue of insoluble, initial or recrystallized quartz. It is possible that the increased quartz and the lesser iron content are initial and related to precipitation in an arenaceous or mixed parent-material. However, the nature of the sample - an erratic gravel found within an upper horizon of an <u>in situ</u> soil profile - indicates that leaching and solution have had some effect on it.

<u>Gayaza Surface laterite</u>

1c2

Laterite gravel from a depth of 12" in a soil-pit, on arenaceous bedrock; Kazya Hill (Kasumba Hill mass), altitude approx. 5,050' a.s.l.

Similar to 1c1 both in shape (smoothed edges of angularity), colour and texture. Again, decrease in iron and increase in quartz is noted, but here an arenaceous origin is more evident, although it is in this area that Combe (1943) noted argillaceous beds intervening in the arenaceous succession.

1b1

Fragment broken from edge of a laterite pavement on phyllite. Icingiro Hill (Gayaza hillmass); altitude approx. 5,150' a.s.l.

Concretionary bodies of round or ovoid shape possess what looks like definite boundaries. Some of them have a smooth discontinuity with the surrounding matrix, but others do not ~~show the~~ show the same nodular character and do not stand out in relief on the broken surface of the fragment. Other inclusions of the matrix consist of irregularly shaped small bodies, all coated with iron-oxides but have no distinct discontinuity from the surrounding matrix. Of the several which were dissected two had nuclei of tiny rock fragments, apparently phyllite, and another - a large quartz grain. The matrix itself is very dense, but in the vicinity of the inclusions is porous with numerous small holes. Where continuous, it is heteromorphous both as to colour and texture. On the whole, it is of a much redder brown than in previous samples but shows mottling of darker and lighter shades. The lighter coloured patches are of a coarser texture and are apparently more crystalline. The darker areas look amorphous or very fine-grained. The outer part of the fragment shows a discernible laminar structure.

This type of morphology appears to be similar to that mentioned by D'Hoore (1954) as typical of an absolute accumulation, except that in his example from the Cote D'Ivoire (Boundoukou) detrital fragments of old laterite seem to be very abundant and the origin of the absolute accumulation is unquestionably secondary. In the present case it is perhaps only partially secondary since, as mentioned above, transect profiles along a similar crest (Gayaza) show a gradual increase of laterization in both massive and concretionary form, which appears to indicate a primary origin in the leaching of soils.

The formation of this type of laterite appears to consist of two parallel processes, both involving solution, migration and subsequent precipitation of iron-oxides. One process involves the precipitation on detrital relatively coarse nuclei of consecutive layers of iron-oxides. The second - the progressive adsorption and impregnation of the soil clay fraction by an increasing amount of migrating iron-oxides. It appears, therefore, that definite nodules within the laterite indicate an earlier stage in the process, when their present location was situated in a higher position along the transect. Less definite concretionary bodies indicate different degrees of concretion "frozen" by hardening on the exposure of the lateritic horizon by slope retreat. Differentiation of the matrix material appears to indicate, besides greater degree of ferruginization, also variable concentration of detrital or recrystallized quartz. The significance of the laminar structure in the outer part of the fragment seems obvious - it points to post-hardening accretion of iron solution and deposition on the exposed surface probably at the margin of the soil mantle.

The conditions under which such a form of laterization may occur can be clearly envisaged. Considerable solution of iron by the leaching of a soil profile points to some acidity of the medium. The apparent differentiality in the solution of the aluminium and iron sesquioxides indicated by the relative high degree of ferruginization, points to a moderately acid medium or to a relatively low temperature - in other words, to a fersiallitic environment. Where the weathering zone is situated at no great depth, as on these crests, the acidity of the medium could originate only in an upper source, namely - in the decomposition of vegetation under conditions of lower temperature or greater effect of radiation. These indicate a higher elevation or a sparser vegetation cover (greater aridity) and point to conditions developed at a later stage of the area's history. The convexity of the crest slope, which was possibly somewhat steeper formerly than at present (see p. 176), and the shallowness of the soil caused the soil-profile to be permeated with the leaching mildly acid solvent down to the weathering zone. Consequently, at the head of the slope, where the amount of leached iron is still meagre, a laterization takes the form of isolated concretions and mottles of iron ~~is still meagre, a laterization takes the form of isolated concretions [illegible] of iron~~ in the lower horizon. Downslope, however, with the accumulating amount of leached materials, impregnation of the clayey subsoil increases. Towards the edge of crest slope, where soil cover is shallower and vegetation more sparse, acidity is diminished and accumulation occurs. When the crest slope was steeper a larger proportion of the dissolved iron was carried over the edge of the crest-slope, but with the slow flattening of the slope due to weathering, pedogenesis and erosion, a growing proportion of it is deposited on the edge of the retreating back slope, hardening into a pavement as it is being exposed by soil erosion (Fig.33).

1b2

Fragment broken from the upper side of a waterhole in a laterite pavement. Apparently at a juncture of a quartzite outcrop and overlying phyllite beds. Gayaza ridge; altitude approx. 4,950' a.s.l.

Similar to 1b1 except that it appears even richer in iron and includes large quartzite and laterite fragments. There is also a relatively large channel, but apart from that the appearance of the fragment is in no way similar to that of the vesicular laterite. The laterite fragment imbedded in the matrix is clearly detrital, having a pale brown, mottled colour entirely different from the red shade of the matrix and quite definite boundaries with the iron-oxide coat. Similarly to the previous sample it has a smooth glossy outer face over a laminated crust.

1b3

A fragment broken from the side of another waterhole in a laterite pavement on an arenaceous bedrock, Lumma Hill (Kasumba hillmass); altitude approx. 5,300' a.s.l.

Differs from previous samples considerably. It is less red in colour and is appreciably more crystalline in texture with a considerable proportion of light quartzose areas. The pavement from

Genesis of laterite pavements on the Gayaza hillmass: early dissection

I. Ferrallitic environment

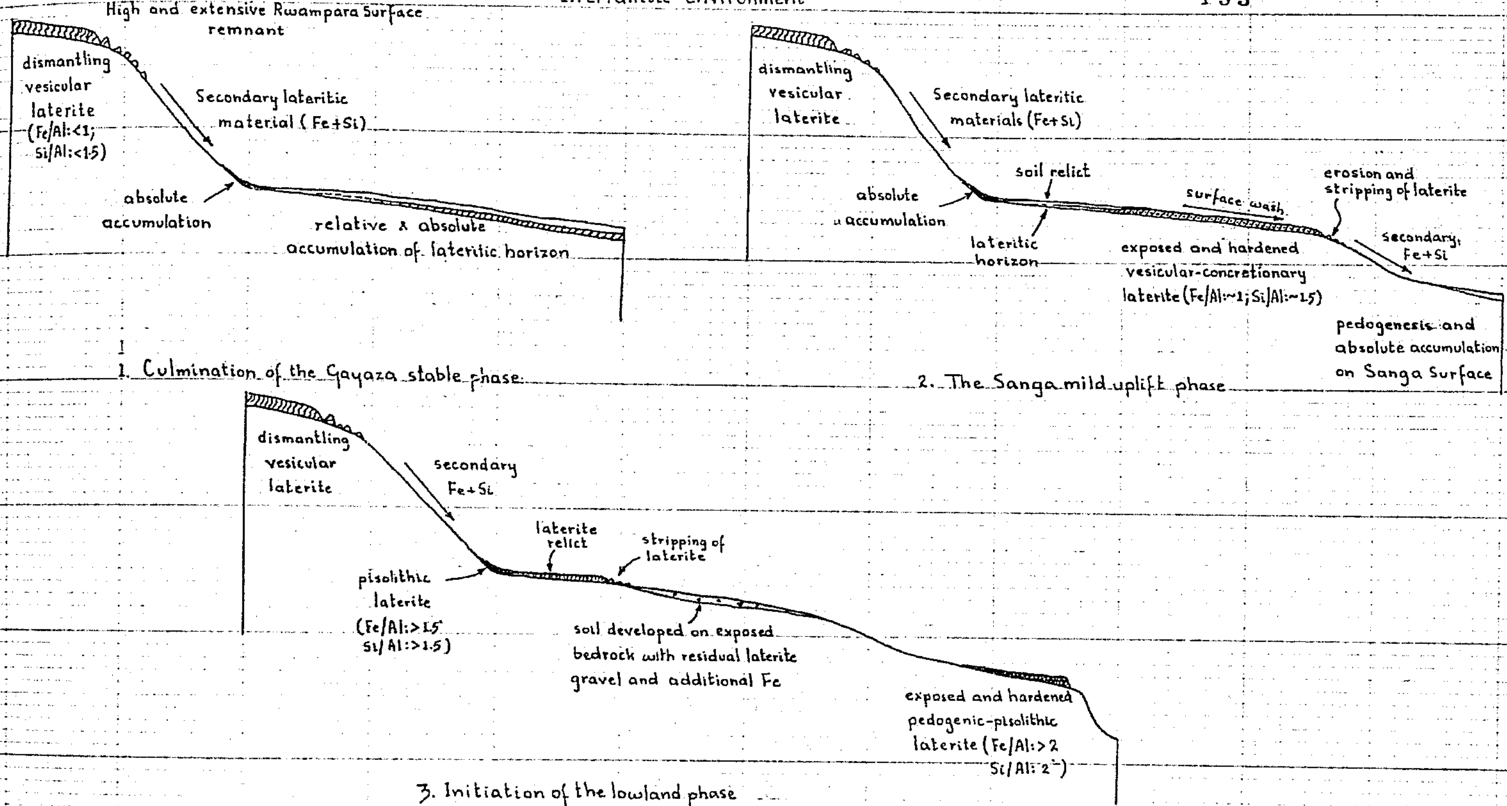
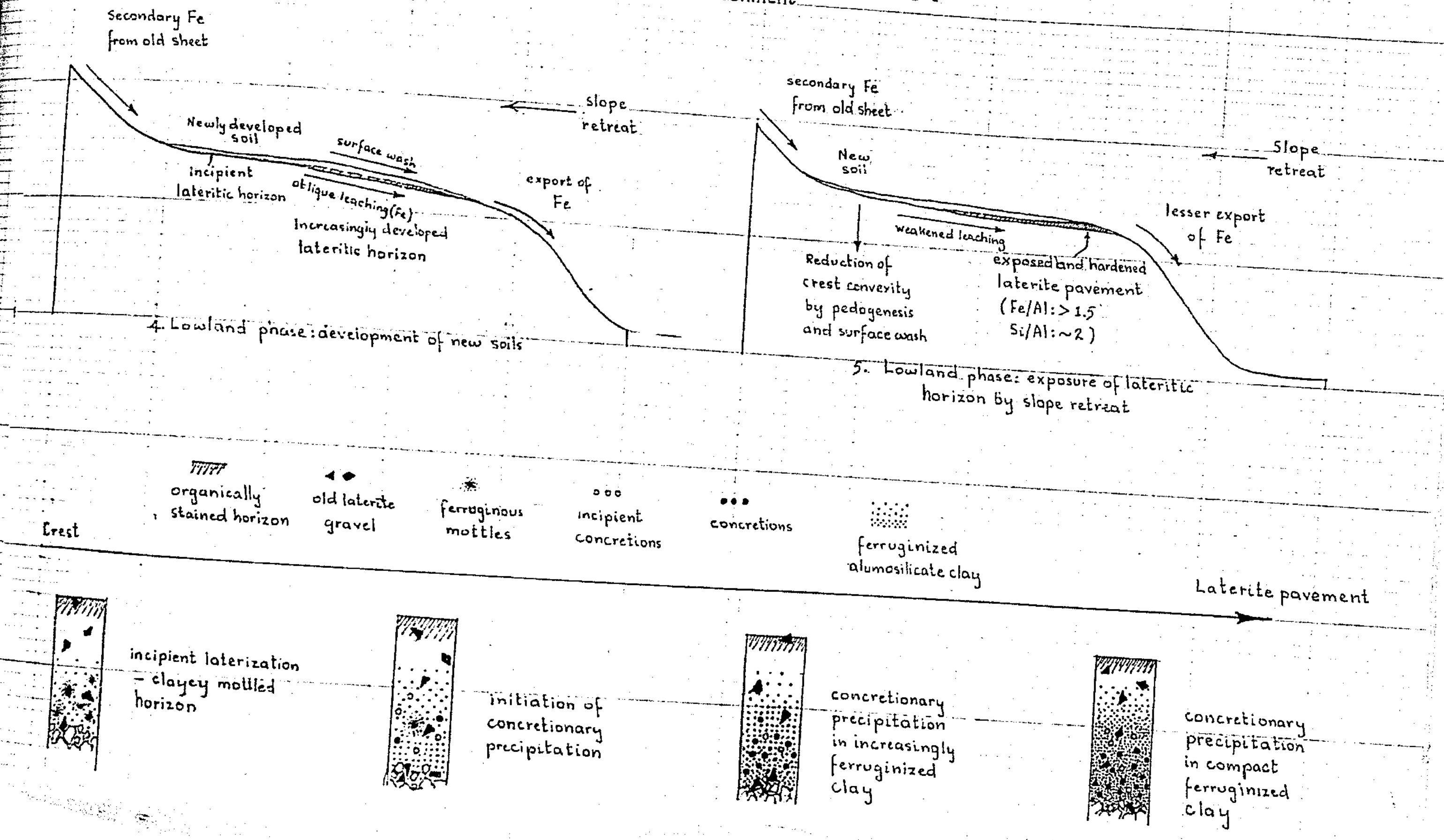


Fig. 33a

Fig. 33b

II. Fer-siallitic environment



which it has been taken is exposed to a larger extent and lacks the smooth glossy surface apparent in the former pavements. Laminar structure appears to be absent in the outer part of the fragment and no large inclusions of foreign bodies can be discerned, but otherwise the morphology of the fragment is similar to that of the previous samples.

Interpretation of this fragment appears difficult. The apparent higher content of crystalline quartz and the possible lesser content of iron may be related to the arenaceous parent material, but this explanation cannot account for the source of whatever quantity of iron that exists unless this is assumed to be an old relative primary accumulation, or that the arenaceous parent material is richer in iron than quartzite usually is. It's general position on the edge of the crest-slope, it's emergence from beneath a fairly deep soil mantle, and the absence of any discernible weathered zone also argue against this being a relict of old laterite. Yet, an apparent absence of current laterization, the high absolute elevation and a fairly prominent scarp edge indicate, perhaps, a relatively old age for this pavement, originating in the first soil mantle developed after the stripping of old laterite from the surface. At present it has only a small extent of crest area at the back of it and thus a limited provenance of material. The slope below it, is very moderate, formed by a broad shallow headwater valley of the Kagango whose abrupt change of gradient downstream indicates an early development on the Gayaza Surface or the modified Rwampara Surface. This pavement may consequently represent the upper part of an early lateritic horizon, extending westward and by now much reduced (Fig. 34).

Genesis of laterite pavements on the Kasumba hillmass: late dissection

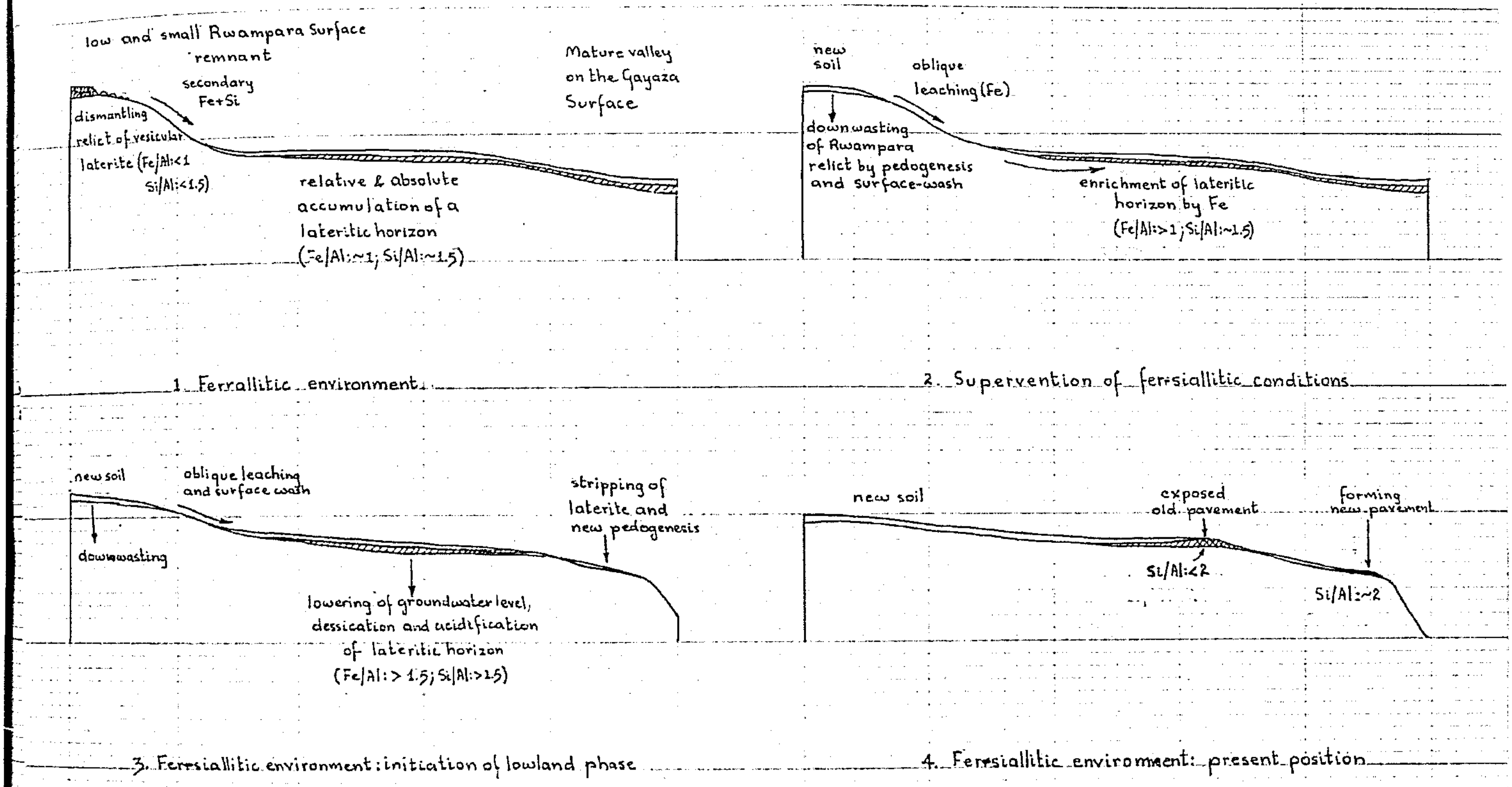


Fig. 34

[illegible] Surface Laterite

Ja1

A fragment of a lateritic block lying on the surface of a scarp of a thick (approx. 10ft) laterite sheet, on tectonic quartzite at Kyibaga Hill ([illegible] Hills); altitude approx. 4,700' a.s.l.

The shape of the fragment is considerably less angular than in previous samples. It breaks off in an irregularly semi-rounded mass and it is very dark brown, nearly black, in colour. It consists of an agglomeration of cemented, irregularly rounded pellets or pisoliths which can be shown to be concretionary by the discernible concentricity of precipitated iron laminae around small nuclei of a friable clayey material. Cementation occurs by fusion of contact points between pisoliths and there is no continuous matrix. ~~The mass, is, therefore, very porous with a large amount of inter-pisoliths and there is no continuous matrix.~~ The mass is, therefore, very porous with a large amount of inter-pisolith space. Some of this space is infilled with material of much lighter yellow-brown or reddish colour, clearly a late infill, having sharp boundaries with the pisoliths. Foreign inclusions include numerous and at times large quartzite crystals, but no detrital laterite.

The clay nuclei of the pisoliths suggest that this is laterite formed by precipitation of iron-oxides in a soil mass and around [illegible] nuclei. Since it is inconceivable that the amount of iron stored in the sheet could have originated in the directly underlying [illegible] which is composed of coarsely crystalline, almost uncontaminated quartz, it is clearly an absolute secondary accumulation. [illegible] been formed by lateral provenance of iron-rich solutions which permeated an existing soil mantle, apparently, in this specific case, of lateral origin itself. Probably the present sheet represents the sub-A-horizon part of the original profile and the infill found in the inter-pisolith spaces originated in the eluvial horizon of the soil.

Jab

A fragment broken from the base of a laterite sheet similar to the previous sample (approx. 7ft thick), on phyllite (possibly phyllitic shale), Nyamaranda Hill (Mange Hills); altitude approx. 4,700' a.s.l.

Differs from the previous sample in having a larger size of the pisoliths and an almost complete infilling of much smaller inter-pisolith spaces. Also, the boundaries of the pisoliths are very weak, at times almost indistinguishable except by a change of colour. Quartzite inclusions are replaced by much smaller fragments of argillites, and the content of quartz in the infills appears to be much smaller.

These differences can be related either to position in the profile or to the nature of the soil parent material. The absence of an abrupt juncture of sheet and bedrock, present in the previous case suggests the origin of the initial soil in the underlying rock. However, here also there cannot be doubt that most of the iron is of allochthonous, secondary origin, and was precipitated in an existing soil mantle. At the same time, current with the permeation of the soil by iron-rich solution through lateral provenance, was the differentiation of horizons within the profile with a greater accumulation in the illuvial soil horizon, and consequently, larger concretions. This was related also with the normal eluviation of clay from the upper horizons and the infill of the inter-pisolith spaces.

3b1

A fragment of a primary laterite sheet (approx. 15ft), broken off scarp face, on gneissose granite (?) at Omukate Hill (Central Nyabushozi); altitude approx. 4,700 ft.

The colour of the fresh face is paler than in any previous sample and vesicularity is very pronounced. The laterite consists of a very few reddish concretions in a yellow-brown matrix with even lighter patches, very clearly crystalline. Channels are either filled with whitish, brittle material, showing no crystallinity or empty and coated with rusty brown ferrugnized crust, plainly laminar.

The appearance of the whole sheet - flatness of crest and scarp edge above long, smooth pediments, the evidence of highly kaolinitic pink stained, soils lower down on the dissected southern, steeper slope of the hill and the indubitable high clay content in the sample itself clearly suggest a relative <u>in situ</u> accumulation of primary materials, of the classic type and profile. Pisolithic structure appears to be related to a greater proportion of crystalline quartz in granitoid rocks and the precipitation of iron in the weathered, quartz - rich kaolinitic clay.

<u>Chemical and Mineral Composition of Samples</u>

The results of a chemical analysis for five oxides and combined water are presented in Table a, followed by calculated mineral composition. Several molar ratios of selected oxides and minerals were also calculated in order to stress significant differences and similarities which are, in some cases, obscured in the percentage composition.

It may be noted that in all the samples some residue is not accounted for. This residue is probably assignable both to the vagaries of the analysis and to those compounds whose content was not sought - mainly MnO and P_2O_5 but probably also some very small amounts of alkalies.

Table 7: Composition of laterite

	Rwampara Surface			Gayaza Surface				Sanga Surface		
	sheet laterite		gravel	gravel	pavement laterite			on quartzite	on phyllite	on granite
Chemical Composition	$1a_1$	$1a_2$	$1c_1$	$1c_2$	$1b_1$	$1b_2$	$1b_3$	$3a_1$	$3a_2$	3b
% SiO_2	21.10	20.59	23.90	25.47	24.58	24.62	25.78	22.30	20.18	21.55
Al_2O_3	29.18	27.57	28.68	28.58	15.80	15.01	15.42	13.91	14.56	22.56
Fe_2O_3	31.03	32.76	28.84	27.87	46.04	47.30	47.32	49.86	49.74	40.18
FeO	0.98	1.42	0.93	0.96	0.48	0.46	0.52	-	0.49	0.92
TiO_2	1.08	1.63	1.05	1.07	0.57	0.52	0.59	-	0.53	1.03
H_2O	15.49	14.79	15.40	15.13	10.52	10.40	9.81	9.93	10.06	12.86
	98.86	98.75	98.80	99.08	97.99	98.31	99.44	96.00	95.56	98.10
Mineral Composition (normative)										
Kaolinite	41	40	43	44	40	38	34	35	37	41
Gibbsite	20	18	18	17	-	-	3	-	-	9
Geothite	29	31	32	31	49	50	40	50	52	38
Haematite	5	5	-	-	2	2	11	5	3	6
Ilmenite	2	3	2	2	1	1	1	-	1	2
Quartz	2	2	4	5	6	7	10	6	3	2
Molar Ratios (combined silica)										
SiO_2/Al_2O_3	1.11	1.15	1.18	1.22	2.00	2.00	1.75	2.00	2.00	1.48
SiO_2/R_2O_3	0.67	0.65	0.74	0.75	0.70	0.69	0.59	0.61	0.63	0.69
Fe_2O_3/Al_2O_3	0.68	0.76	0.64	0.62	1.86	2.00	1.95	2.29	2.17	1.13
Kaolinite/Gibbsite	1.55	1.67	1.80	1.96	-	-	8.68	-	-	3.51

The limitations of normative mineral composition are well known calculated as it is on the basis of a predetermined estimate of mineral consituents. It is, however, a controversal problem whether estimates of mineral percentages based on D.T.A. or x-ray Diffraction Analysis can provide more accurate data.

It is apparent from the data presented in the table that properties of the samples are not differentiated in conformity with the surface upon which they were taken. There are differences between samples taken on the same surface and similarities between samples from different surfaces. This fact casts doubt upon the premise of uniformity of laterite type on the one hand and on that of correlation of laterite type with surface age, on the other.

1. Gibbsite-rich samples

Samples containing more than 25% alumina of which a considerable part is in hydroxide form and not combined with silica to form kaolinite, present a quite distinct group. The high content of gibbsite is emphasized by the very low silica/alumina and kaolinite/gibbsite ratios, the first well below 1.5 and the other - below 2.0. Corrollaries of this property are the relatively low content of iron-oxides (expressed in a ferric oxide/alumina ratio of less than 1.0) and the high content of combined water related mainly to the hydrated alumina minerals.

As observed a high content of gibbsite can be related either to an early stage of lateritic weathering, prior to resilication into kaolinite or to a late stage of decomposition of kaolinite. In both cases presence of gibbsite indicates a silica/alumina ratio which is thought to be correlated with high rainfall (e.g. - Mohr and van Baren, 1954). Direct formation of gibbsite by weathering of acid rocks is closely followed by resilication into kaolinite (Aubert, 1941, 1944, 1954; Alexander et al. 1942) but where conditions of neutral or alkaline medium or of impeded oxidation exist due to thorough mineralization of organic matter and continuous saturation by excessive rainfall, genesis of kaolinite is inhibited by greater exportation of silica. A greater amount of gibbsite is retained. Similar conditions, on the other hand, enhance the decomposition of kaolinite and, thus, increase the proportion of gibbsite (D'Hoore, 1954). It appears, therefore, that whatever the genetic position of gibbsite, a high proportion of gibbsite in the composition of laterite indicates a certain range of environmental conditions prevalent during the period that laterization was chemically active, probably before the lateritic horizon was exposed and irreversibly hardened (see p. on reversal and hardening). It is, therefore, suggested that the laterite represented by this group of samples was formed in a different, more ferrallitic environment than the present one and under different conditions than those influencing the formation of laterite represented by other samples. Although iron content appears to be somewhat high for a typically ferrallitic environment (Mohr & van Baren, 1954), there are several examples in the literature of laterite currently forming in such an environment that have a comparable composition (Maignien, 1958; Alexander & Cady, 1962).

There are, however, differences within the group which must be noted. In fact, the four samples may be grouped in two pairs differing as to amount of silica and iron-oxide - one is designated by 1a representing fragments broken from larger masses of laterite, the other - 1c - erratic gravel, probably detached by disintegration of formerly continuous laterite and found within the soil profile. It is, of course, difficult to envisage and impossible to calculate the influences to which the erratic gravel was subject since their detachment from the original accumulation. It is reasonable to assume that on the type of resistant lithology with which the other pair of the group is associated, in the soil in which the gravel were found, and with the relatively larger surface they present, the action of solvents, enhanced by products of vegetation decomposition, was more pronounced. Such an action would result in the leaching of iron compounds and the proportionate increase of aluminium constituents. This is apparently what caused the relatively lower iron content in the gravel samples, which is the lowest among all the samples. Apparently also, it was the acid medium engendered by better drainage and organic decomposition consequent upon the dissection of the laterite and formation of soil which inhibited further degradation of kaolin and somewhat raised the initial kaolinite/gibbsite ratio. Relevant to these aspects of laterite gravel composition is the problem of the origin of the sample from the Gayaza Surface. Its similarity to the other gravel sample is, indeed, very close and the specific properties mentioned above are even more emphasized in it. As may have already been surmised from the foregoing, it is a basic premise of the present interpretation that the laterite gravel was found virtually <u>in situ</u> in the sense that there is little likelihood of it having been transported from a younger surface. This is affirmed by the fundamental chemical and mineralogical similarity of the gravel with the sheet laterite, namely - the relatively high proportion of alumina or gibbsite and the low proportion of iron-oxide. There exists, however, the possibility that sample $1c_2$ originated in the higher, older, Rwampara Surface, whose modified remnants still exist or have once existed in close proximity to the locality in which it was taken. Since, as observed, no definite relicts of the initial, primary laterite of the Gayaza Surface have been identified, there is no direct evidence of its nature, and it is impossible to determine if the similarity of the two gravel samples indicates similarity of the initial laterite on the two surfaces or the origin of $1c_2$ in the Rwampara Surface laterite. At the same time, circumstantial evidence in the form of a great amount of laterite gravel of the same morphological type, differing profoundly from the adjacent pavement laterite, which is to be found throughout the area of the Gayaza Surface, even where transfer from the upper surface is much less likely, points to the possibility that the initial Gayaza Surface laterite was similar in type and, probably, composition to that of the Rwampara Surface.

If this assumption is correct, it is the samples of the 1_a type that should be regarded as representing the initial laterite more closely. Yet, even if this laterite was similar on both upper surfaces there were bound to be some differences. Considering the general similarity of lithology, of both surfaces, an identical amount of original lateritic materials should be presumed. The amount of iron present in samples taken on the Rwampara watershed or close to it, could be regarded only as the result of relative accumulation. A rough calculation of minimal values* shows that the thickness of approximately ten feet of laterite originated in at least 800 ft of rock consumed during the cycle producing the Rwampara Surface. Furthermore, considering the position and the nature of the laterite relicts on present crests it is doubtful whether ten feet represent the original thickness. Lowering of the surface during the Gayaza phase was much less than this and consequently it must be surmised that the thickness of initial laterite on it was relatively meagre even if supply of secondary materials from the disintegrating upper sheet is taken into account.

To conclude, this group of samples appears to represent a primary laterite formed through relative accumulation under a different climate than the present, possibly in the period previous to the rise of the Rift shoulder to its present elevation. The samples supply no evidence as to whether this laterite developed separately on each of the two upper surfaces or simultaneously on both surfaces subsequent to the stripping of the Rwampara initial laterite. In this latter case provision must be made for a considerable lowering of the Rwampara Surface during the Gayaza phase. However, considering the length of time involved according to the views now prevalent and the evidence of lithological

* based on an amount of Fe_2O_3 in phyllite, on low density of laterite (2.7) and on minimal loss (30%).

control - it appears more likely that the stripping of the Rwampara laterite was concurrent with the development of the Gayaza Surface and its laterite sheet, to which it probably contributed secondary material.

2. Pavement laterite samples

The compositions of pavement laterites differ sharply from those of the previous group in several significant aspects. Alumina content is, on the average, 13% less and the decline - as can be seen - is assignable mainly to the absence or a low proportion of gibbsite while the percentage of kaolinite is less by only an average of 4-5%. The latter is reflected in a noticeable increase in proportion of silica and the parallel silica/alumina ratio. It should be noted, however, that if comparison between the groups excludes the possibly abnormal gravel samples a substantial increase in crystalline silica is shown. Since no gibbsite is present in two of the samples this increase cannot be assigned to the decomposition of kaolinite and is possibly residual quartz or results from the recrystallization of amorphous silica on exposure of in a mildly acid medium. Parallel to a decrease in alumina is a very noticeable increase in ferric oxide percentage (agerage 15% increase compared to samples 1a).

The absence or paucity of gibbsite combined with a relatively high content of kaolinite may be relatdd to several environmental complexes. It may indicate relative accumulation under conditions of excessive rainfall, on a very well-drained site and under deep soils, where the medium is acid enough to inhibit exportation of silica but where hydration of aluminium sesquioxide raises its isoelectric point sufficiently to enhance its combination with silica (Rougerie, 1958). In such circumstances the chances are that iron-oxides accumulating by adsorption as minerals to the alumosilicate clay, being of much greater solubility and constituting only a very small proportion of the parent rock (0.6% as against 19% of alumina in phyllite), wil not exceed the amount of Kaolinite. On the other hand, an absolute high proportion of kaolinite can result also under fersiallitic conditions where an alkaline medium is asserted only intermittently and only in deep-seated weathering zones. Usually, and especially in the rainy seasons, it is either acid or very mildly alkaline, favouring the formation of alumosilicate clay. At the same time rainfall is usually insufficient to induce a low enough pH for mobilization of aluminium hydroxides and it is only the more mobile iron compounds that are exported. The composition represented in the samples of the pavement laterite, with iron-oxide minerals exceeding the amount of alumosilicate clay, clearly points to an addition of iron and an absolute accumulation. Consequently, a fersiallitic environment in which iron is mobilized, transported and precipitated in a kaolinitic matrix, is clearly indicated. This supports the evidence of the morphology of the samples which also suggests that lateral supply of iron is still current. The conclusion is, thus, reached that pavement laterite results from both lateral and vertical provenance of lateritic materials and is, therefore, an absolute accumulation effected in a fersiallitic environment such as the presnnt one. Since absolute accumulation of lateritic materials must be associated with some relief, it seems reasonable that the formation of the present pavements began later than the dissection of the surface upon which they are found. The fersiallitic nature of their composition marks their probable origin in the period following the rise of the Rift shoulder and the curtailment of moisture supply (possibly also - some lowering of mean temperature due to uplift) which, as observed, means a rather late phase in the geomorphic history of the region. The amount of iron-oxide stored in the average thickness of a pavement conforms with the possible amount of rock consumed during the Gayaza phase. However, since the nature of the laterite does not indicate a relative accumulation and does indicate an environment prevailing much later than the Gayaza phase, there cannot be any doubt that much of it is secondarily derived from the disintegration of the initial laterite of the surface and only partly from the weathering of the exposed bedrock.

Sample $1b_3$, clearly represents a different type of laterite than the other two samples of pavement laterite, although it has similar basic properties of lower alumina and higher ferric oxide content which place it in the same category. The main differences appear to be the presence of a small proportion of gibbsite and a relatively large proportion of dehydrated iron-oxide in the mineral form of haematite; a somewhat larger proportion of crystalline silica may also be of significance. As stated, it appears difficult to explain these characteristics in view of the foregoing discussion of the other pavement samples. As described in the previous section (p.195) it is the geomorphic position of the pavement that may provide a tentative explanation to the composition of the sample. As asserted in that section this pavement may be older than those represented by the other samples, and may have been formed at the first stage of dissection of the Gayaza Surface and in closer proximity to modified remnants of the Rwampara Surface. Such an assertion would make the character of this sample, appear more explicable. Presence of gibbsite is apparently assignable to decomposition of kaolinite and not to alteration of primary minerals, since other characteristics point to the absolute nature of the accumulation. If this is the case then addition of quartz indicates recrystallization of silica released from kaolinite. The exposure of the laterite possibly resulted in a greater dehydration of goethite into haematite.

But this interpretation cannot be regarded as sufficient since it does not explain the sequence of environmental conditions that enable such a development. An old pavement, possibly connected with the modification of the Rwampara Surface and not with a late dissection of the Gayaza Surface, implies formation under ferrallitic conditions and, thus, contradicts the high percentage of iron, or implies that all the foregoing interpretation of other samples is faulty. If, on the other hand, the initial accumulation of this pavement proceeded under fersiallitic conditions as implied by its basic composition, it cannot be much older than other pavements, and the differences in particular aspects of the composition are not explained. The answer to this conflicting evidence lies, perhaps in the complicated geomorphic nature of the locality.

As can be seen, the Burama Hill on the western crest-slope of which the pavement is located, is part of the Kasumba main ridge, This ridge, was regarded as situated close to the margin of the early, larger, deformation of the landsurface which resulted in the initiation of the Gayaza phase. It, consequently, represents a modified part of the initial Rwampara Surface, perhaps preserved in less modified form on the higher summits of the ridge (Kiarhuti and Chitanda). The vertical difference between the initial surface and the newly formed Gayaza Surface, developed in a stable phase, was much smaller in this area than further west, due to lesser relative deformation. Consequently, the initial relative accumulation on the adjacent Gayaza Surface could not have been very great. As suggested by the nature of the surface in the western part of the Kasumba hillmass - the extensive flat-crested ridges and the shallow broad head valleys between them contrasted by the narrow deep valleys separating them lower down - and by the absence of any remnants of the lower Sanga Surface in the drainage basin, the dissection of the Gayaza Surface came rather late, probably at a late stage of the lowland phase, when the breach of the Kasumba-Karagwe watershed caused the change of erosional orientation towards the southeast. It is conceivable, therefore, that the initial relative laterite accumulation of the surface was not exposed and stripped off, before fersiallitic conditions prevailed, as in other areas, but remained in the original profile and absolute enrichment in iron associated with replacement of kaolinite was superimposed upon it. Before the lowland phase penetrated the existing mature valleys, slower erosion and drainage, a groundwater table nearer to the surface and possibly a denser vegetation with relict characteristics of a former climate, may have somewhat modified the ferrsiallitic environment, and prevented acidification of the medium. But the comparatively abrupt change in local base-level, with the resultant deep downcutting of valleys prevailing over slope-retreat and consumation of crests, must have drastically changed drainage conditions, causing a comparatively abrupt lowering of ground water level, and at least an intermittent dessication of the lateritic horizon. Enhanced leaching due to lowering of groundwater table, under extensive, bevelled crests, still carrying dense vegetation, may have caused some desilication of kaolinite, and, perhaps, ferrosiliceous compounds. Intermittent dessication brought about the dehydration of goethite and perhaps, amorphous iron-oxides into mineral haematite, lowering the isoelectric points of all hydroxides to prevent their recombination with the increasingly less mobile silica and, thus, to favour its crystallization into secondary quartz.

In conclusion, the foregoing interpretation suggests that laterite pavements exist in two genetic forms. One occurs on the western remnants of the upper surfaces, controlled by the northward erosional orientation where deformation resulted in a greater altitudinal interval between them and where dissection of the Gayaza Surface began much earlier, already by the Sanga phase. This earlier dissection resulted in smaller remnants retained between arena-type basins and which were consequently subject to earlier exposure and more complete stripping of the initial laterite. The early initiation of slope retreat of arena walls which proceeded concurrently with the stripping of initial laterite, soil formation and new laterization, caused a constant removal of the forming laterite pavement. Consequently, any existing pavement reflects a relatively young formation related to the crest back of it and the arena slope below its front. This genetic character is reflected in its composition.

The second form of pavement is connected to those parts of the upper surfaces in which the erosional development is in a much earlier stage, with downcutting as yet ungraded to the local base-level and where the vertical interval between the surfaces was initially much smaller. In such areas, the late advent of dissection has probably never succeeded in even exposing the initial lateritic horizon. The change of environmental conditions caused the enrichment of this horizon in iron by absolute accumulation probably derived from the modification of Rwampara Surface remnants. Late dissection did not allow, as yet, for the exposure of this laterite but caused changes in its composition. Consequently pavements of this type which are exposed at present represent not an entirely new formation related to newly developed soils, but an old lateritic horizon transformed by change of environment and new dissection. Hence their specific morphology and composition, their greater thickness in relation to other pavements, and their disposition at the foot of remnants of the Rwampara Surface and not on the edge of the Gayaza Surface crest-slopes. Consequently they are more restricted in distribution.

3. Lower surface laterite samples

Samples of laterite from continuous sheets on the Sanga Surface are clearly differentiated into two types: 3a, representing laterite on resistant metasedimentary or tectonic rocks and 3b that on incompetent plutonic rocks.

a. Samples from laterite over resistent lithology

Compared with the previous group these samples show even higher content of iron and lower of alumina. Gibbsite is absent and consequently silica percentage is lower though the SiO_2/Al_2O_3 ratio is the same. The ferric oxide/alumina ratio is also higher which expresses a lower proportion of kaolinite but the difference, though significant, is not great.

It would have been possibly difficult to differentiate between these samples and the first two pavement laterite samples, without referring to the morphological evidence. But once the key to the nature of the laterite is provided by that evidence, both the similarities and the differences between these two groups become explicable. Similarities such as enumerated above and also the higher percentage of goethite in relation to kaolinite, must be related to a similar mode of origin in an absolute accumulation - in a lateral provenance of mobilized iron-compounds and subsequent precipitation in an existing matrix. Indeed, considering the large source of iron available for the formation of this laterite, comprising the larger part of the decomposing Gayaza Surface laterite, compared with the limited source of the pavement laterite to which only newly formed soils and a smaller proportion of the initial laterite was available, a greater proportion of iron-oxid and iron minerals may have been expected. That this is not the case may be attributed to partly the fact that in the specific cases from which the samples were taken, the available source was relatively restricted (residual upland). But it appears possible that the more important reason is related to the type of environment in which this accumulation occurred. Evidence shows (D'Hoore 1954, Maignien, 1958) that as a rule an absolute accumulation, in whatever environment, is always more ferruginous than a relative accumulation, but in a ferrallitic environment the percentage of alumina is higher than in a fersiallitic and ferruginous environment. ~~Conceivably, then, the percentage of~~

~~alumina is higher than in a ferrallitic and ferruginous environment~~. Conceivably, then, the percentage of ferric oxide would have far exceeded 50% if the formation of this Sanga Surface laterite did not occur in a ferrallitic environment.

The differences between the 3a and the $1b_{1-2}$ samples are apparently related to the nature of the matrix in which iron was precipitated and its influence on the processes of iron transport and dispersion. An illuvial horizon within a soil profile represents an entirely different matrix than a complete soil profile permeated from an outside source. More detailed and numerous sampling than the present one would have probably shown in what way this soil profile was differentiated by the combined outside transport and <u>in situ</u> processes. Some indication of this is given by the difference between $3a_1$ and $3a_2$, with a slightly greater proportion of both kaolinite and goethite possibly resulting from the illuviation of clay and greater adsorption of mineral iron hydroxide. Conceivably the sample is not representative and a more profound difference in the same trend may be the rule. The composition, both chemical and mechanical, of higher soil horizons is reflected mainly by the morphology of the laterite - the greater inter-pisolith space from which finer particles, not impregnated by iron have been leached downwards. Nuclei of pisoliths are small peds and coarse particles as indicated by a greater amount of quartz. In both samples, the non-analysed residue is larger than in any other sample, representing, probably, unweathered or partially weathered minerals retained in the ped-nuclei and absent in a typically lateritic horizon. It can be seen, at the same time that reduction of alumina and kaolinite, compared to content of young pavement laterite is relatively small and a somewhat greater proportion of haematite may be attributed to greater age and to dehydration on the dissection of the Sanga Surface.

b. <u>Sample from laterite over incompetent lithology</u>

A comparative examination of the composition of all samples will show that despite some very great differences there is a basic similarity between sample 3_b and those designated as 1_a. This is clearly expressed in the ratios of the major constituents. Silica/alumina ratio is still below 1.5, ferric oxide/alumina ratio is above 1.0, but not very much so and, in any case, far lower than in any other sample. In addition, percentage of goethite does not exceed that of kaolinite. It thus appears that the conclusion of a relative primary accumulation derived from morphological and general field evidence, is well supported by the chemical and mineralogical data. Differences between these two groups can be attributed mainly to the fundamental difference between the rocks from which the laterites were derived and perhaps also to differences of environment and age. As can be seen from the available data on composition of rocks, granite contains less alumina, about three times as much ferric oxide and about 2.5 times as much siliceous base minerals, as phyllite (also much more ferrous oxide). Granite has, consequently, a higher SiO_2/Al_2O_3 molar ratio than phyllite and its greater weatherability under tropical conditions releases combined silica in a greater amount and at a greater rate. Weathering of granite is, therefore, mainly kaolinitic and amount of initial gibbsite is lower. It is reasonable to assume that the gibbsite contained in the sample is mostly a product of desilication consequent upon the change in drainage conditions which followed the dissection of the Sanga Surface by the lowland phase, in an environment that was still more ferrallitic than the present one. The relatively (compared with 1a sample) high iron content can be entirely residual, representing a lowering of the surface during the Sanga phase by approximately 300 ft, an amount in general accordance with the mean vertical difference between the Gayaza and Sanga Surfaces.

Altitudinal Distribution of Laterite

It is evident from the descriptive and analytical data presented in the preceding sections that the altitudinal distribution of laterite is significant more in its results than in the nature of its geomorphic causes. If it is deemed necessary to devote a section to this aspect, it is mainly because several investigators of the relevant area assert the universal or almost universal presence of a continuous laterite capping on upland crests. It is not the purpose of this section to refute this assertion but to show that an assertion of the presence of laterite, even when continuously and uniformly thick does not necessarily imply that the crests and the slopes it is supposed to blanket all represent the same erosion surface or even a small number of them. This will be doan through an examination and discussion of the views and data presented by these authors themselves.

There exists a major division of opinion between De Swardt and Trendall (1961) on the one hand and Plummer (1960) and Phillips (1959) on the other as to the meaning that should be attached to the presence of laterite at different levels of the upland. De Swardt and Trendall maintain that continuity of thick laterite over sharp breaks between levels points to the possibility of an initial single very uneven surface and the lack of positive results from an altimetric analysis proves it with finality. Both Plummer and Phillips recognize the existence of two upland surfaces (Phillips' third, lowest surface, is associated almost exclusively with the Lake Victoria lowland) but while Phillips apparently considers that the laterite formed separately on each of them and, thus, differs in age according to the surface with which it is associated, Plummer, who also recognizes continuity of that laterite over sharp breaks in slopes, maintains that it is all of contemporary age and has balnketed simultaneously pre-existing surfaces. However, both of them agree that at least one of their surfaces had a very considerable relief.

De Swardt and Trendall's concept of the single 'Upper Laterite'

Since these authors' view diverges from the one offered in the present study on fundamental points of evidence - both observational, concerning the universality and uniformity of upland laterite, and analytical - concerning the interpretation of an altimetric analysis, it appears that there is no way of comparing the views. It should be noted at the same time, that the concept of a single 'Upper Laterite' is formulated not on the strength of observational evidence alone but on the results of the analysis.

There are, however, two aspects of their stated view which have relevance to the present context. De Swardt states correctly as a basic argument, the view "that major and persistent breaks in slope above a well-integrated drainage system can be correlated regardless of variations in absolute altitude or relief" (1964), p. 318). In this he, of course, refers mainly to the relationship between upland and lowland, and, no doubt, the principle applies on a country-wide scale, possibly even to the correlation of the upper surfaces in West Ankole and Southern Mengo. Yet, the principle must apply on a smaller scale also to intermediate breaks of slope caused by differential upwarp. On a regional scale these are as major and as persistent as that between upland and lowland in general, on a country-wide scale. The fact that beyond the upwarped region they do not exist by no means invalidates their correlation within the region.

De Swardt and Trendall's refutation of the multi-level aspect of the landscape in southwest Uganda differs radically from the apparent landscape which,appears impossible to ignore, as can be also deduced from the conclusions reached by all other workers in the area. One of the first to observe the area closely was Combe (1932), whose evidence and conclusions of a "two peneplain topography" (ibid. p.8.) are constantly being referred to by later authors.

Apparently the evidence provided by his detailed and discerning observations is also impossible to ignore. De Swardt and Trendall assert that it was the "hill-and-pediment.topography that had led Combe to conclude that two peneplains are present"(ibid. p.44), which is in fact an assertion that conforms with their own view. This is manifestly incorrect since Combe states clearly that the lower peneplain is represented by the crests of hills and ridges along the edge of the Rwampara and Nshara Mts. "which rise to a remarkably even, bench-like surface" (Combe, 1932, p.7.). He could not have meant that these refer to lowland pediments or to pediments "preserved on narrow sloping spurs" (De Swardt and Trendall, 1961, p.48).

The concept of two upland Laterite Surfaces or Levels.

Plummer and Phillips surveyed between them the whole of the area included in the present study, Phillips studying the part east of the Kasumba hillmass and Plummer that west of it. As observed, they both recognized two laterite surfaces within De Swardt and Trendall's single "Upper Laterite". Phillips placed most of his "oldest" surface at altitudes varying between 4,500 ft and 5,100 ft a.s.l. and his "intermediate" surface between 4,300 ft and 4,600 ft a.s.l., thus allowing for a respective relief of 600 ft and 300 ft. Plummer placed his "upper laterite surface" at 4,700-5,900 ft (within the study area) and his "lower laterite surface" at 4,400-5,000 ft a.s.l. - i.e. a respective relief of 1,200 and 600 ft. The difference in mean absolute altitude is, no doubt, attributable to differential upwarp. The mean distance between the areas in which these surfaces were identified allows for a landsurface rise of approx. 15 ft/mile which accords with the average between the calculated 10 ft/mile in the eastern part and 20 ft/mile in the western part of the area.

It can be noted that amplitude of relief doubles both with the age of the postulated surfaces and with the westward rise. While Phillips gives no explanation of the uneveness of his upper surface, Plummer explains the greater uneveness of his surfaces. He visualizes his upper surface as representing a landscape of resistant lithology which has never been affected by complete planation. It rises above the margin of an extensive planed surface which has a gentle regional slope and is tentatively identified as the peripherial part of the Buganda Surface. It is, at present, represented by the "lower laterite surface". In this way, Plummer reduces the available relief of De Swardt and Trendall's "Upper Laterite" by about 300 ft, but still envisages it as a very uneven surface. This would have provided a plausible explanation if Plummer's description of his surfaces presnnted a rational pattern.

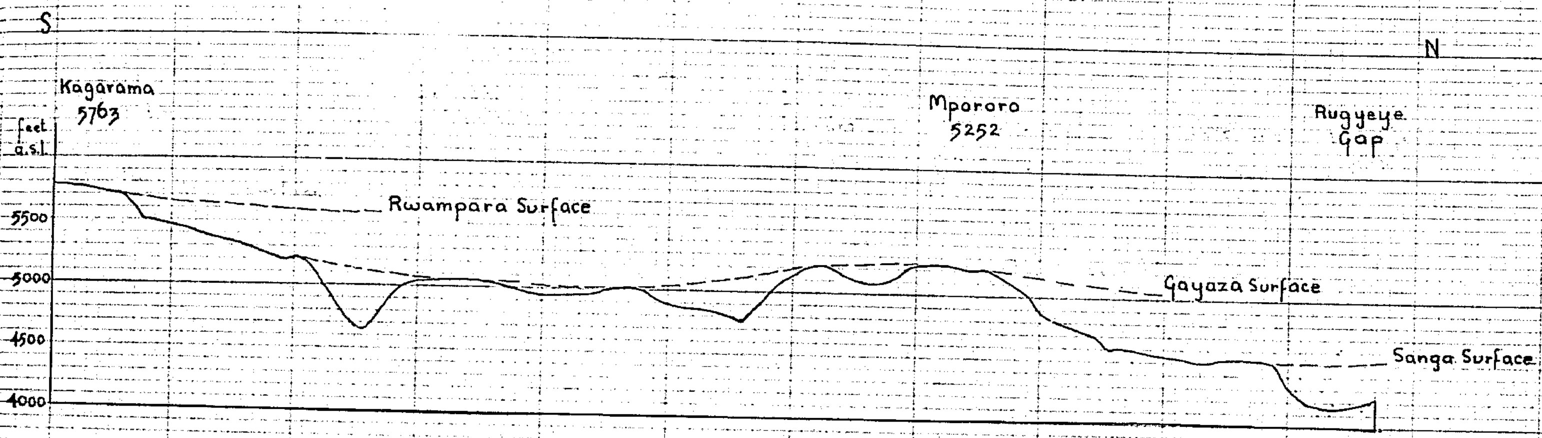
It appears that Plummer defined his surfaces from within the same area as has been used as a sample-area for the altimetric analysis in the present study (Map 7), which, as observed, seems to provide the best choice. However, he apparently divided it into two parts: a southern one including the Eastern Rwampara, its northern foothill fringe and the Gayaza hillmass; and a northern one - including the Nshara area. For each of these he applies entirely different altitudinal criteria for which no explanation is offered.

In the southern part, Plummer emphasizes the sharp break of slope on the laterite surface north of Kagarama and states that "this fall is accentuated by the entirely bevelled nature of the laterite latterly described (i.e. - on the crests of Rwampara(s northern foothill fringe) in contrast to the higher irregular surface of the Rwampara". In contrast to De Swardt and Trendall, he agrees that it was this "sharp fall that had led Combe, Wayland and others to suggest two peneplain surfaces in this area" (1960, pp. 14-15). Obviously, then, Plummer considers that the Rwampara crest-laterite which stands at 5,500-5,900 ft a.s.l., represents the 'upper laterite surface' while the lower foothill fringe and, apparently, also the Gayaza hillmass, backed by this 'sharp fall' and standing at 4,900-5,300 ft a.s.l., represent the 'lower laterite surface.'

In the northern part of the area, howdver, Plummer defines as part of his 'lower' surface, the bevelled laterite relicts in the Lower Ruizi basin, the bench-like laterite abutting the slopes of the Ntarwete-Kakunyu ridge and the flat crest-laterite on the Kpororo spurs. On all these features laterite stands predominantly at 4,500-4,800 ft a.s.l., i.e. - 400 ft lower than on the Gayaza hillmass which is defined in the same surface. At the same time, the crest laterite on the Ntarwete-Kakunyu ridge standing at approximately the same elevation as on the Gayaza hillmass is regarded as the 'upper surface'. It appears, thus, that the Kpororo spurs at 4,500-4,700 ft a.s.l., which are the only localities where the two parts of the area are contiguous, have two well-defined surfaces rising above them: the Gayaza hillmass at 4,900-5,200 ft and the Rwampara main ridge - at 5,600-5,900 ft a.s.l. (Fig. 35). They consequently cannot be fitted into Plummer's scheme of two surfaces. When added to the fact that postulation of differential upwarp along the longitudinal axis of the area would entail the assumption of a rate of rise exceeding 40 ft/mile, this discrepancy in surface definition would seem to refute the postulation of two surfaces. A sequence of three surfaces such as was outlined above, appears, therefore, better suited to explain the pattern of the landscape.

In the area surveyed by Phillips, the sequence propounded in the present work envisages only two surfaces and is, thus, in general agreement with Phillips' postulations. The main, and basic, difference between the views, apart from that concerning the distribution and significance of laterite, is that the present view envisages a greater relief on the lower surface in this area and a much lesser one on the upper surface. Phillips defines his laterite surfaces very briefly and peremptorily. As with Plummer, his definitions appear to be based on altitudinal relationships of more or less proximate features and, where present, on presumed continuity of laterite. The boundary between the surfaces is placed, flexibly, between 4,450 ft and 4,650 ft a.s.l., without apparent consideration of the possible effects of tilting. Since most of the features carrying laterite are of relatively limited area and widely discontinuous, the determination of the surface is, in most

Surfaces on the Gayaza Divide Axis



H.S. 1: 79,200

V.S. 1: 12,000

Fig. 35

cases, not associated with any sharp breaks of slope. As a result, many inexplicable definitions occur and the inclusion of certain features within one of the two surfaces appears rather arbitrary. In some cases, a small vertical interval of a hundred feet is regarded as decisive despite profound lithological differentiation (e.g. Namimbi Hill); in others a much greater interval of 400 ft on homogeneous lithology is not regarded as sufficient for the differentiation of two surfaces (e.g. southern spurs of the Rugaga hillmass). In some cases the upper surface is identified at the same elevation as a lower surface situated much to the east of it (e.g. Mbale ridge) and in others it is much higher than the same surface to the west of it, even when the latter is identified on a more resistant lithology (e.g. Kinota, approx. 5,100 ft on shale, and Nyabubare, at approx. 4,550 ft, on quartzite). On the whole, there appears to be an overlap of apprriximately 200 ft between the surfaces, without any rational pattern to explain it.

It appears to the writer, consequently, that Phillips' doubts as to the unity of his lower surface are best applied to his upper one. An assumption of an uneven lower surface with a wider altitudinal range than postulated by him, would make it comparable to Plummer's lower surface and contribute to a more rational regional pattern. It would seem that in his placement of the intersurface boundary Phillips was misled by his interpretation of the nature and significance of laterite. If like Plummer, he had assumed a late blanketing by laterite of pre-existing surfaces he would have, probably, discerned the topographic discontinuity between Eastern and Western Rugaga, in the areas of Nyaruhuzi and Nyakagera. Admittedly this is not as prominent a discontinuity as that between the Rwampara main-ridge and the Gayaza hillmass but it is comparable to that between the crest of the Ntarwete-Kakunyu ridge and those of the Lower Ruizi basin. Where no lithological boundary is involved such a break can be envisaged as a result of moderate continuous uplift, which would also explain the wide altitudinal range of the lower surface. Furthermore, the association of this break on the crest of the only extensive single feature of the area with the fact that the altitudinal interval below this break overlaps widely throughout the area with the interval assigned by Phillips to the lower surface, favours the placement of the intersurface boundary at the higher interval of 4,800-4,900 ft.

It can be concluded, therefore, that the concept of a uniformly laterized upland crest-surface, does not necessarily contradict the concept of a multi-level landscape, and that previous concepts of two levels can be proved erroneous or interpreted differently. Continuity of laterite between levels and over breaks in slope can be interpreted as a late simultaneous blanketing or by heterogeneity - with the laterite on the slopes and on the lower surface differing as to age, thickness or origin. In either case, the proof of existence of discrete surfaces of any extent or grade is independent of the presence of laterite and should be sought in other criteria.

The present view differs from that of Plummer and Phillips in that it maintains ~~ains~~ that under conditions of pronounced uplift and formation of high relief and residual landforms of resistant lithology it is unlikely that laterite of whatever origin and age will be preserved intact.

Conclusions as to the geomorphic relations of Laterite

1. The geomorphic significance of laterite

The interpretation of the evidence presented in the previous sections entail a reconsideration of the geomorphic significance usually attached to laterite.

If the previously outlined pattern of upland surfaces, is correct, laterite cannot be used as a decisive criterion for their definition. The two upper surfaces show no significant difference in the distribution and nature of laterite types found on them. In both, laterite cover is patchy, erratic or residual; in both current laterization is evident and laterite pavements appear to be of later origin than the soil mantle; in both, what may be old laterite is at least partly residual and indicates lesser competence than the underlying bedrock. It cannot, therefore, be regarded as preserving or 'freezing' the original surface on which it was formed. The unavoidable conclusion from the evidence is that, on the contrary, it is the resistant bedrock across which the surface was cut, that preserved whatever relicts or residue of a former laterite sheet that have persisted to the present.

Much of this applies also to the lower surface, where many features of resistant lithology reveal only residues of laterite. However, a great number of features representing this upland surface do carry thick sheets of laterite. But these appear in a pattern clearly controlled by lithology and proximity of features of a higher surface. Where they exist on resistant lithology they are apparently of predominantly secondary origin and their relation to the underlying bedrock is fundamentally the same as on the upper surfaces. Variety of origin and nature of form of occurrence thus, prevents the use of laterite as a criterion for the identification of a single lower surface.

It is , consequently, a basic argument arising from the present study that on the present evidence laterite cannot prove the existence of several surfaces. Upland bedrock lithology is considered to represent a more significant geomorphic factor than the laterite covering it and, therefore, it is the existence of surfaces tha t explains the distribution of laterite and not that of the laterite which defines the existence of surfaces. Moreover, the nature and distributional patterns of laterite are regarded as necessary corollaries of the concept of multi-phased evolution of the landscape.

2. Laterite and landscape evolution

a. Laterite on the initial surface

The premise of an initial planed surface of a relatively low absolute elevation and a west-directed gentle continental slope existing in early Tertiary times, appears to be corroborated by the nature of laterite relicts and residues found on the Rwampara Surface. The accumulation is relatively thick and if vesicularity can be accepted as evidence, it is a relative accumulation produced during the planation of the surface by progressive downward migration of the laterite profile. The relatively large proportion of aluminium compounds and that of gibbsite in the alumosilicate clay indicate at least a moderately ferrallitic environment which may be expected at the altitude of the surface and its exposure to western, relatively humid air masses.

However, the thickness of the laterite and, even more so, of its underlying weathered zone, are much smaller than may have been expected on a very mature surface ofpprolonged development. This can be, probably, attributed, in part, to the fact that present relicts are found on what may have been the greatest relief of the initial surface and, in fact, on the then existing watershed. But it would appear that this cannot be the whole answer and as pointed out previously (p.162) a modification of the theory of primary laterization, especially in regard to the movement of lateritic materials through the 'pallid zone' is required.

b. <u>Effect of landscape evolution on laterite of the upper upland surfaces</u>

The subsequent geomorphic history ~~on laterite~~ appears to have been controlled, basically, by the differential erodibility of laterite in relation to that of the underlying bedrock. The fact that large tracts of the crest area are bare of laterite cover indicates the relative incompetence of laterite and it is, therefore, reasonable to assume that upon uplift and the initiation of a new erosional phase laterite would have tended to be stripped off the elevated surface. It is also conceivable that after the stripping of the laterite sheet the effect of erosion on the underlying resistant bedrock will have been much slower, and the crest-surface may have been little affected. Certainly, this is not a rapid process and laterite ironstone is still a relatively resistant rock. The stripping of a laterite sheet was, then a gradual and prolonged process and proceeded unequally, depending on the nature of the laterite itself - its composition and thickness - and on extraneous geomorphic factors. However, it did proceed independently of the geomorphic evolution of the underlying bedrock.

Of the extraneous geomorphic factors which affect the stripping of laterite, the orientation of the erosional phase is undoubtedly important. In the present case erosion is envisaged as advancing from the north and east and later also from the southeast. The southern slope of the Rwampara (initial) Surface was affected only at a late stage of the first erosional phase and, consequently, relatively little. Laterite was, therefore, better preserved on this southern slope than on the northern one. Since uplift consisted also of differential upwarp and deformation, the new altitudinal disposition of any part of the surface in relation to erosional orientation should be taken into account too. Thus, the initial surface in the Western Isingiro area was situated lower down on the slope of the deformation than in the Eastern Rwampara area, and consequently laterite was probably stripped off it to a greater extent and at a speedier rate.

The laterization that was associated with the development of the Gayaza Surface during this erosional phase, was probably of the same general type as the laterization of the initial surface. It proceeded during a stable phase to a relatively mature state and it is possible that general uplift has not yet elevated the land-surface enough to cause a profound change in the ferrallitic environment, either as regards to average temperatures or accessibility of atmospheric moisture. The essential features of the Chemical process were, therefore, similar - a relative accumulation of a primary lateritic horizon with the associated ferruginization of secondary alumosilicate clay. There were bound to be, however, also fundamental differences. As observed, the Gayaza Surface has never attained perfect planation; it was probably less perfect than that of the initial surface since the available stable period was apparently shorter. Moreover, the amount of available rock provided by differential uplift was possibly less than that available to the major cycle of the initial surface. The relicts of this surface represent either the very margin of the original, at the juncture with the slope of the higher surface, or relatively restricted residuals. In the marginal area of the surface, which was the last to develop, laterization was probably relatively weak. It appears, therefore, that the laterite associated with the culmination of the stable erosional phase was of lesser thickness, had a larger proportion of clay minerals and a lesser one of gibbsite in relation to kaolinite. At the same time, the existence, for this surface, of a source of secondary lateritic materials in the disintegrating higher sheet, could have caused a greater amount of ferruginization in the marginal areas. These properties would indicate a speedier stripping of laterite on this surface than on the Rwampara Surface. It is even conceivable that on the dissection of the Gayaza Surface in the next phase of uplift, smaller relicts of its laterite sheet were preserved than of the already long-eroding Rwampara sheet.

The stripping of primary laterite cover proceeded, as indicated by present processes, largely through the disintegration of its edges, apparently by differential solution of constituents. Consequently, the products of disintegration take the form of both fragments of different size and compounds carried in solution. The newly stripped crest surface may, thus, carry as a residue, a large number of fragments, mostly of gravel size but also a few blocks and a ferruginous crust of re-precipiated lateritic materials as coatings on the bedrock surface. Most of the disintegrated material will be carried downslope both in fragments and dissolved to provide additional secondary material for the laterization of lower surfaces. The newly exposed bedrock surface is then subject to renewed weathering and soil formation in which, probably, a proportion of the residual clay from the laterite also takes part.

With new pedogenesis is associated also new laterization. It appears probable that with the continuing moderate uplift some level of balance was attained between soil formation and erosion so that present soils do not represent the initial environment of pedogenesis on crests. Contemporary soils represent, most likely, development since cessation of uplift and renewed prevalence of slope retreat. They also represent a new environmental complex created by high absolute elevation and a reduced supply of moisture caused by the shadow of the newly uplifted Rift shoulder. In such an environment ferrisolic conditions prevail enhanced by the inhibited decomposition of organic litter and, therefore, by a more acid medium. Laterization takes the form of an absolute accumulation through the leaching of the soil profile by percolating rainwater and the convexity of the crest periphery makes this largely an oblique leaching leading to the formation of laterite pavements at the eroded edge of the soil mantle. Consequently, laterite pavements are relatively young, strongly ferruginized both in pisolithic concretions and by adsorption, but also having a considerable proportion of clay which is largely kaolinitic. It is possible that a large proportion of the more soluble iron is carried over the edge of the crest slope and consequently the proportion of residual clay is greater in this form of crest laterite than it would have been on a flat surface. It also means that an accumulation of this type has even a lower limit than the present soil mantle indicates and, therefore, thick pavements may represent results of several successive profiles, and added material from disintegrating old laterite.

c. Laterization of the lower upland surface

As indicated, the development of the Sanga Surface was much more complex than that of the Gayaza Surface. It occurred concurrently with continuous uplift; it was probably also concurrent with the expansion of the lowland surface and it affected heterogeneous lithology. Orientation of erosion in this phase was still directed northward and eastward with an added southeastern direction. Large areas of incompetent lithology were exposed whereas resistant rocks became gradually confined to the margins of the new surface. No doubt surface development on the incompetent basement rocks gained on that of the resistant margins and headwater basins and became more planed and mature at an earlier stage. Primary laterization associated with and followed by deep weathering prevailed and a typical laterite profile developed. Apparently advanced planation and deep weathering embraced also part of the less resistant sedimentary formation - i.e. the shale and mudstones of northern Koki, in that area of the sedimentary formation situated at the juncture of the northern and eastern erosional orientations.

On the resistant marginal area, which was of greater relief and general surface inclination and of lesser weatherability, primary laterization was inhibited and apparently did not advance much beyond development of a soil mantle. This mantle became deeper as the surface developed but was not associated with deep weathering or primary laterization. It was associated, however, with a very intensive process of secondary laterization by material derived from the disintegration and dissolution of older primary and secondary laterite of the proximate remnants of the Gayaza Surface. This secondary laterization proceeded through progressive impregnation of the whole soil profile, by iron-oxides which were precipitated on soil particles and small rock fragments, forming an almost totally pisolithic laterite. Continuous provenance of lateritic materials probably inhibited a clear differentiation of horizons, although the two distinct horizons which were reocg-nized may not represent the whole scope of differentiation and, probably an upper soil horizon, less impregnated, is now absent through truncation. In any case, differentiation of lateritic horizons was not sufficient to create differential erodibility in the relicts of this secondary laterite and at present they appear as uniformly thick, flat-topped sheets.

The dissection of the Sanga Surface does not appear to have resulted from any prominent tectonic event. It was a progressive process, possibly concurrent with the formation of the surface itself, but had an increasing rate on incompetent lithology caused by a rapid "etching" of the deeply weathered rocks, once the laterite covered interfluves were consumed, and by reorientation of drainage which was either consequent on the etching or due to breaching of former watersheds and the creation of new ones. Consequently, only very few relicts of laterite on this surface were preserved in the area of incompetent rocks, mostly where previous watersheds coincide with the general disposition of the newly evolved ones. Preservation was much better where resistant lithology prevented rapid undercutting of the sheet and consequently depended more on the nature of the laterite itself. As was shown, (Fig.32), remnants of pisolithic secondary laterite are sometimes found on top of a primary relict preserving a crest of a schistose of plutonic feature situated at not too great a distance from the source of the secondary laterite. It is reasonable to assume that the thickness of this secondary laterite diminishes with the distance from the source, and that where resistant lithology extended far away from the remnants of the Gayaza surface, or where such remnants were of relatively small extent the meagre cover of secondary laterite was stripped away.

This applied especially to the hill-series type of topography prevalent in areas where sedimentary formations are of low metamorphic grade and individual crest features are of small extent. In such areas, notably the Koki Hills, a more advanced planation and deep weathering occurred too, as intimated, and preservation of laterite cover undercut by erosion of weathered zones is less likely. Consequently, many upland features of this surface are bare of laterite in the Koki area. However, the late stripping of this surface and the small extent of crests did not allow the development of deep and mature soil-cover, except where a weathered zone was exposed over less resistant lithology. So that crest soils of the Koki Hills are usually more skeletal than those of the stripped Gayaza and Rwampara Surfaces and laterite is mostly scanty, residual and secondary, derived from the dismantling of former sheets.

3. Laterization and landsurface

As observed above in the introduction to the chapter on laterite there exists a limit to the depth of the soil-regolith profile at which laterite can accumulate, since access of atmospheric influence is necessary to ensure precipitation of lateritic materials in the mildly alkaline medium of the weathering zone. No definite limit has been determined for the depth of possible accumulation, but it seems that it cannot exceed the order of a few tens of feet. It is, consequently, possible to assume that a laterite sheet represents a surface which was not more than a few tens of feet higher, before the upper soil horizons were stripped off. Moreover, since stripping of soil cover and exposure and hardening to laterite coincide with the inception of new erosional conditions, an exposed laterite sheet can be regarded as marking the culmination of a cycle or an erosional phase.

It is, however, the accumulation of primary lateritic materials that indicates the associated cycle of erosion and when thickness of laterite is used to estimate the amount of rock consumed during that cycle, care should be taken to exclude any thickness that can be attributed to a secondary and extraneous origin. It should be noted that nowhere within the investigated area was any lateritic accumulation observed to exceed 10-15 feet in thickness on resistant lithology. With the original soil cover the whole profile is unlikely to have exceeded forty feet on the initial Rwampara Surface. The difference between the mean altitudes of the Rwampara and Gayaza Surfaces which is about 500-600 ft and the low content of iron in phyllites* ~~(n)~~ and quartzites, indicate that primary laterite on the Gayaza Surface could not have been

(*) next page

very thick, especially if considerable loss of iron through run-off and erosion is taken into account. Indeed, wherever in the area bare crests indicate a late stripping of old laterite cover, the original surface must have been only very slightly modified.

The situation is at least theoretically different where early stripping has allowed the development of a mature soil mantle, Without supporting evidence it is impossible to assume that existing soil represents the result of initial pedogenesis - that initiated by the stripping of the laterite. Where old surfaces are postulated and uplift is invoked it is probable that present soil mantle represents only a current stage in a long process of interaction between pedogenesis and erosion. It is very difficult, therefore, to estimate the amount of crest lowering involved in soil-formation since the dissection of the surface and the stripping of the laterite, and only a tentative and very rough idea may be formulated on the strength of circumstantial evidence.

One line of such evidence concerns the depth of present crest-soils, which rarely exceeds 4-5 ft. There are several reasons to believe that it has never been much greater. Centres of crests, where soils tend to be the deepest were, probably, last to be stripped of laterite and this stage is unlikely to have been attained before a very close drainage pattern, of the present order, has developed and restricted crest area. This apparently, occurred only after the lowland surface attained approximately its present pattern which, as observed, was long before uplift petered out. If such a close drainage system already existed, overbalancing of erosion by soil formation after cessation of uplift, could not have been very considerable. In other words, inherent in the association of pedogenesis with stripping of old laterite is also its association

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(n) An average of 0.22% Fe_2O_3 according to samples from Koki analysed by C. Du Bois 1959 (Geological Survey of Uganda, in Litt.).

with sites susceptible to erosion. Since the ratio of soil production to soil erosion must have been lower than at present during uplift, crest soil mantle is unlikely to have been much deeper than it is at present. Pavement laterite derived from newly formed crest-soils contains too large a quantity of iron-oxides to have all originated even in the deepest soil profile existing at present and it may be roughly calculated* thatthe average thickness of pavement laterite necessitated the leaching of a soil depth of more than twenty feet, but less than thirty. A similar calculation in regards to the volume of rock represented by this depth of soil showed that thirty feet of soil resulted from no more than forty feet of rock**. These may be regarded as maximal values since no account is taken of Fe_2O_3 and TiO supplied by disintegrating old laterite, which was, probably, of considerable amount.

It appears, therefore, that present crest surface on resistant lithology represents a modification of the original surface by an amount of crest lowering well below a hundred feet. Within the contour intervals available for the area a modification of this magnitude, which has, undoubtedly, been less than the maximal value in large parts of the crest area, cannot have much influence on the conclusions outlined above.

Soils of the Study-Area

The study of the soils in the area was undertaken under the

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* Calculation is based on analytical data on Fe_2O_3 content in pavement laterite (approx. 40%) and in present soils (approx. 15%) on the Rwampara surface, with an estimated loss of 30%. Measured density of laterite was 2.7; and of soil 0.5.

** Based on content of insoluble ilmenite (TiO·FeO) in soil (3.3%) and in phyllite (0.62%; density - 2.5).

basic premise that soil would prove to be the connecting link between landforms and vegetation and, consequently, their study would help resolve the correlations between them. Previous perusal of the available literature on the general subject of geomorphical relations of soils and vegetation (~~Saint~~, Wooldridge, 1950; Stephens 1956; Mulcahy 1959, 1960; Mulcahy & Hingston 1961) has led to the formulation of a preliminary hypothesis that age of surface isuusually expressed in the nature of the soils it carries, and, consequently, in the nature of its vegetation. It was thought that since landscape in Uganda can be differentiated into, at least, two surfaces of different ages, the basic aspect of correlation between landform and vegetation will concern the depleted nature of both soils and vegetation on the higher, older surface or surfaces. With one exception there appeared to exist no evidence or theory contradicting this tentative hypothesis in relation to climatically homogeneous areas in Uganda. Or, more properly, where rainfall and temperature data show no substantial orographic influence, soils and vegetation on upland (in the sense defined above), seemed always to be more impoverished than on lowland. It was realized, of course, that depletion in most cases is due to erosional processes and not to deterioration through prolonged leaching and laterization. The evidence of thick continuous laterite over upland surfaces was regarded as supporting this supposition.

The exception mentioned above concerned the soils covering the crests of the Isingiro Hills, Gayaza hillmass and some of the Rwampara crests and defined by Harrop (1960) as the Rugaga Series. As observed already, this series was purported to have developed on a thick sheet of disintegrating laterite, "though not necessarily from" it (Ibid., p.37). It is pointed out that their lack of stability and resistance to erosion and their relative richness in exchangeable bases do not indicate their residual nature and old age. Vegetational evidence to comply with this seemingly aberrant case is only partial. In the survey of vegetation of the relevant area (Langdale-Brown, 1960) and the associated vegetation map, part of the Rugaga Series appears to carry a potential climax much more luxurious than that envisaged on the surrounding lowland, but this is apparently related to altitude and not to pedological attributes. Consequently, since this appeared to be an isolated case of unsupported evidence, stated (in relation to soil) to be problematical, it was not considered to bear decisively on the general hypothesis.

It was, therefore, noted with surprise that field evidence largely contradicts this hypothesis.. This was first noted in relation to vegetation on what was defined here as the Gayaza Surface which was found to be, where least disturbed, more luxurious and rich in species than the similar community in the adjacent lowland. The Rwampara Surface did not present exactly the same picture, but where soil was preserved on it and vegetation less distubed, it still presented a richer vegetational aspect than the lowland. It was also noted that the crests of the Gayaza and, partially, also the Rwampara Surface constitute the primary agricultural concentrations in the area, and the centres of coffee growing, a feature, it is believed, nowhere else to be found in Uganda except in purely mountainous regions. Even when it is realized that these concentrations resulted perhaps largely from certain historical circumstances (the famous sleeping-sickness epidemic in the beginning of the present century) the existence of crest soils suitable to support them was reasoned to pose a fundamental problem in the present study.

Classification of Tropical Soils

The endeavours of pedologists to attain a "natural" classification of soils in tropical Africa, have been based on two lines of approach dictated at least partially, by the nature of the laboratory work employed. The Franco-Belgian approach is based principally on detailed chemical and mineral analysis and field characteristics are used only as secondary criteria for subdivision. Conclusions as to the nature of soil taxons, consequently, enable the formulation of sound genetic concepts. There is no doubt that such an approach is the best possible even if the inductive genetic concepts derived from it necessarily represent subjective interpretation. Unfortunately, such an approach is not always practical on financial grounds and pedologists frequently have to base their classifications on field characteristics alone or with the addition of only routine laboratory examination.

This has been mostly the case in East Africa, where only very few chemical and clay-mineral analyses of soils are available. Since Milne (1935) formulated the 'catena' concept in East Africa, pedologists in that region have tended to adopt the topographic-geomorphic approach to soil classification. There is, of course, a fundamental difference between a purely topographic application of the 'catena' concept, and a geomorphic interpretation of topography-soil associations. In the first case the 'catena' is used as a mapping-unit, devoid of any genetic connotations; the members of the unit have no genetic relationships, and simply indicate a recurrent sequence of certain soil-types on similar topography. A geomorphic interpretation of soil catenas, is based on the concept of the soil taxon or the mapping-unit as an integrated part of the landscape unit (Avery, 1956) and since landscape units represent stages in an evolutionary process, a soil catena is regarded as a replacement sequence.

No doubt this concept of a soil taxon as a geographic or 'landschaft' unit, associated with a certain natural complex, facilitates inferences concerning many aspects of the nature of the soil and its genetic character, e.g. - drainage conditions, depth, profile development, degree of weathering, age, organic matter content, vegetation and even argicultural potential. This is especially true where geomorphic evolution is postulated to have been cyclic or phasal and topography consists of several well-differentiated levels of differing ages but fundamentally similar evolutionary patterns.

It is the tendency of present soil-taxonomists to avoid genetic criteria in soil classifications and to base themselves on purely objective field characteristics and laboratory date (as expressed mainly by the U.S. Dept. of Agric. systems of classification, 1960, 1965). It would seem that this approach, fully justified at present within the limits of pedology, will relegate soils to a purely descriptive position in the study of landscape complexes. It is preferable, therefore, to accept the deficiencies of genetic classifications which are associated with the subjective nature of the judgements and postulations rather than dispense with the use of soils as an interpretive component.

Most likely the best system of classification for the needs of the present study would have been one which combines detailed laboratory examinations with a geomorphic approach. ~~As intimated, a geomorphic approach.~~ As intimated, a geomorphic approach forms the basis of many classification schemes in East Africa, but all of these lack sufficient laboratory data to make any sound genetic concepts possible. An attempt by Gethin Jones (1957) to construct a genetic classification of East African soils, was based on the genetic criterion of presence or absence of laterite (hard ironstone). As observed by Chenery (1960) this is not a satisfactory criterion (without sufficient analytical data) since it does not differentiate between current and millions of years old pedogenetic processes. On the other hand, the Belgian pedologists (D'Hoore, 1959, 1964; Sys, 1959) based their classification scheme on the nature of clay minerals and oxide ratios, which strongly reflect the process of soil genesis. The geographical implications of this scheme are mainly climatic and only secondarily geomorphic, but as a pedological genetic classification it has everything to recommend it (Chenery, 1960).

Of the many schemes of classification which could be applied to the soils of the study-area only a few will be reviewed. Analytical information from these soils includes some mineralogical data but no data on chemical composition. Consequently it is difficult to fit them accurately into genetic schemes based on both mineralogical and chemical composition. However, some reference to the Belgian scheme can be made and therefore, it will be briefly reviewed in relation to relevant soil types.

Genetic classification schemes

Sys's classification of Congolese Soils (1959)

The classification consists of seven taxons or categories in a descending order of magnitude based on criteria of decreasing importance. The largest taxon - the order - is defined by the degree of weathering (nature of dominant clay minerals) and the nature of the profile as expressed in the succession of pedogenic horizons. The degree of weathering differentiates, in the first place, between weathered and unweathered parent materials including in the second category raw mineral, hydromorphic and organic soils. Weathered soils are differentiated, in the first order, according to type of B-horizon into podzolic and non-podzolic soils. The non-podzolic soils are classified into two types of weathering - kaolinitic and non-kaolinitic. Kaolinitic soils or kaolisols include all the soils formed on mostly or completely weathered materials, with the greater part of the clay fraction comprising kaolinite and free oxides.

The non-kaolinitic soils (less than 50% kaolinite in the clay fraction), are divided into four orders according to the nature of the profile, of the A_1-horizon - whether margalic (dark, montmorillonite rich) or non-margalic, and of the B.-horizon - whether textural (clay illuviation), structural (only clay skins; polyhedral structure) or consistent (structure less, devoid of distinct clay content): recent soils (A-C, A-D profile with a non-margalic A_1 horizon,) black soils (A-C, A-D, A-B-C or A-B-D profiles with a margalic A_1 horizon,) brown soils (A-B-C or A-B-D profiles with a structural or consistent B horizon) recent textural soils (A-B-C or A-B-D profile with a textural B-horizon). Of these the recent soils are probably represented in the area on steep slopes and bare rocky surfaces and the black soils - possibly in soils developed on alluvium of aggraded but uninundated valley floors.

It is, however, mainly the kaolisols which pose problems of identification and interpretation apart from comprising the most extensive and characteristic soils of well-drained sites in tropical regions. The criteria chosen by Sys to differentiate the order of the Kaolisols into sub-orders are associated with the relation of their characteristics to climate, mainly in the pedoclimatic expression. Three groups are distinguished, firstly, according to the degree of dessication of the pr0file: hydro-kaolisols which are intermittently waterlogged and never dry out entirely; xero-kaolisols which undergo a very marked dessication of the profile (saturation of the adsorbing complex in lower horizons - over 50%) and an intermediate group comprising two groups of suborders: the hygro-kaolisols whose profile is neither waterlogged nor dired out during the year (25% saturation in lower horizons) and hygro-xero-kaolisols - whose profile dried out temporarily, with the wilting point attained for at least one month during the year (50% saturation). Each of these groups is divided according to pedoclimatic temperature expressed by the development of a humic A_1-horizon.

Since the hydro-kaolisols are defined as showing a gley horizon their differentiation from hydromorphic soils is probably only a matter of degree. With the available data it is, consequently, difficult, to determine if any of the hydromorphic soils represented in the area can be defined as hydro-kaolisols. Elevation in the study-area is nowhere high enough to produce a really cold pedoclimate with the resultant pronouncedly humic A_1-horizon.* It is possible, however, that at higher elevations, some kind of integrade into humic kaolisols may exist. Hygro-kaolisols are developed typically in a very humid climate and under a very dense forest and consequently should not be expected to occur in the study-area. Xero-kaolisols may be present in the lowlands in the centre of the area, where annual rain fall is less than 35" and accretion of bases from adjacent upland is unlikely. In other parts of the area, soils will be probably all hygro-xero-kaolisols.

Definition of Great Groups of soils is independent of that of sub-orders, in that both hygro-and hygro-xero-kaolosils may consist of the same Great Groups. The general criterion for distinguishing Great Groups is the mechanical, chemical and mineralogical nature of certain genetic horizons and the succession of horizons in the various suborders. There is, however, a general conformity of the Groups with macroclimatic conditions and they are apparently subject to a zonal pattern of distribution. Thus, in order of increasing moisture supply the sequence of Great Groups, is, as follows:

1. <u>Tropical Ferruginious soils</u>. Apparently synonymous with the xero-

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* Sys states that the lower limit of humic soils varies between 4,200 and 5,200 ft a.s.l. north of $6^{o}N$. It would be expected to be higher closer to the equator as the study area is.

kaolisols of which suborder they form the only Great Group. They are considered to represent active pedogenesis in a relatively dry (less than 35") tropical climate. Weak leaching is expressed in either a high silt/clay ratio (>0.15), in the lower horizons, an appreciable reserve of weatherable minerals in the sand fraction or the occasional presence of a B-textural (illuvial) horizon without a corresponding A_2 (eluvial) horizon. The clay fraction is mostly kaolinitic with free oxides but contains also 2/1 lattice clay. Saturation of the adsorbing complex is 75%. Gibbsite is absent (SiO_2/Al_2O_3:~2 or>2). This is a well-defined group, appearing also in the French classification ("sols ferrugineux tropicaux"; Aubert, 1954), and denotes specific environmental conditions, differing from those of other zonal tropical soils.

2. Ferrisols. This group is obviously transitional to the next group and is also considered to represent active pedogenesis but in a more humid environment. Ferrisols differ from the previous group by presence of a B-structural horizon with clay-skins, by a lower silt/clay ratio but not lower than 0.15 or by a lower reserve of weatherable minerals in the sand fraction (but not less than 10%). The clay fraction consists of more than 50% kaolinite and free oxides and may include gibbsite (SiO_2/Al_2O_3: ~2 or<2). Saturation of the adsorbing complex is 50%. In the French classification (ibid.) the group is included in the "sols ferrallitiques" and possibly represents slightly ferrallitic soils("sols faiblement ferrallitiques").

3. Ferralsols. Regarded as representing reduced or halted pedogenesis. They still contain an appreciable amount of clay (>20%) but the silt/clay ratio is<0.15; the mineral reserve is slight or absent and a B-structural horizon with distinct clay skins is absent. Horizons are only slightly differentiated but occasionally, a leached A_2 horizon is present without a corresponding B-textural horizon. This is indicative not only of intensive

leaching but also of deep weathering. The clay fraction which is predominantly kaolinitic includes appreciable quantities of free oxides and, frequently, gibbsite (SiO_2/Al_2O_3:<2). Saturation of the adsorbing complex is 25-50%. ("sols ferrallitiques typiques").

4. Rego-ferrals. This group represents conditions of intensive leaching of ferralsols. Consequently amount of clay is very low (<20%) in the upper part of the deep soil-profiles and mineral reserve is very slight or absent. Correspondingly, both exchange capacity and saturation of the adsorbing complex are very low (<25%). The soil profile consists consequently of A-C or A-D horizons with no B-horizon of any kind. They correspond to the "sols ferrallitiques lessivés" of the French classification (ibid.).

Apart from these soil groups both humic ferrisols and ferralsols are recognized as Great Groups where the usually weak A_1 horizon is replaced by a marked one, thicker than 10 cm., very dark and with >2% carbon content.

The general climatic associations of these groups restricts possible representation in the study-area to ferrisols and ferruginous soils with the possible addition of humic ferrisols at higher elevations. A more detailed discussion of the application of these categories to the soils of the study-area will follow an exposition of the analytical data of these soils.

Each Great Group is regarded as comprising several Small Groups one of which represents the type of (orthotype) and the others - intergrades with other taxons. Thus, the Orthotype ferrisol is distinguished from the ferralsol intergrade by having more than 50% of the B-structural unit surface covered with a clay skin. The Orthotype ferralsol is distinguished from its rego-ferral intergrade by having more than 25% of clay in the upper 1.m.

It is only in the following category - that of the Great Family - that the lithological nature of the parent rock is used as a distinguishing criterion, whereas geomorphic position comes only next as a defining criterion for the Small Family.

D'Hoore's System for the Soil Map of Africa (1959, 1964)

This system is very similar to the former, especially as to the classification of the basic - Great Group - taxons of the kaolisols. The differences between the systems are associated mainly with the greater scope of applications and the related need to impart greater flexibility and to rely on schemes based on different principles. The principal results of this are the elevation of the lithological and colour criteria to a higher category - parallel to that of Sys's Small Group and the reduction of certain taxons, e.g. the humic and rego-ferral Groups, to a lower category.

There are also several instances in which details of chemical and other criteria differ or an additional criterion is defined. Thus, cation exchange capacity of the clay fraction is stated to be below 20 me/100 gr in ferralsols, over 15 me/100 gr in ferrisols and higher than that in ferruginous soils. Saturation of the adsorbing complex in lower horizons is defined for ferruginous soils as exceeding 40%, for ferrisols as below 50% and for ferralsols as below 40%.

Charter's interim scheme for the classification of tropical soils (Brammer, 1956).

Charter's classification, devised originally for West Africa, is less comprehensive than the Belgian systems but appears to cover all the types of soils which have relevance to the study-area. His approach is genetic in a more classical, Russian-school way, based as it is on Neustrev's famous formula of "Soil= $\int$ climate, vegetation, relief and drainage, parent material and age. It is, therefore, founded largely on field and environmental characteristics, and the simplest chemical data - mainly pH.

The first category or taxon - the order - is defined according to the predominating influence of one or two of the factors comprising the above formula. Four orders are, consequently, distinguished:

I Climatophytic Earths - whose characteristics are determined predominantly by climate and vegetation. They correspond to the classic Zonal group of soils.

II Topoclimatic Earths - Combined effect of relief and climate, namely - montane soils at altitudes exceeding 10,000 ft, in the tropics.

III Topohydric Earths - Combined effect of relief and drainage, namely - impeded drainage on relatively low ground. Include most of soils formerly defined as Intrazonal.

IV Lithochronic Earths - Characteristics determined mainly by parent rock and/or age - namely, resistance, inertness or extreme youth of parent material. Equivalent to Azonal and certain Intrazonal soils. On the suborder level, each of the orders is subdivided according to different criteria. Since the problems associated with the soils of the study area are related to those included under Charter's Climatophytic Earths, the present review will be limited to this group.

Climatophytic Earths are subdivided according to the degree of leaching into two suborders:

A. Hygropeds - soils in which percolating rainwater leaches the whole depth of the profile, to groundwater level. Correspond to the old term of Pedalfers.

B. Xeropeds - soils under low precipitation, in which percolation does not connect with groundwater level. Correspond to Pedocals. Strictly speaking, xeropeds must be scarce in the tropics. Even where rainfall is low, it is heavy and provides enough water to permeate the whole profile. Moreover, even in the contemporary very arid tropics wetter climates prevailed in the near geological past and are reflected in the present soils. It appears, however, useful in view of the former schemes to retain this taxon, in the present classification, under a more flexible definition in order to differentiate between the two main tropical environments. In such a case hygropeds will correspond to Sys's hygro-and hygro-xero-kaolisols and xeropeds - to his xero-kaolisols.

Hygropeds are divided into two Great Groups according to the reaction values throughout the soil profile, regarded as expressing the differentiation of soils in active state of pedogenesis (rapid release of bases counteracting the effect of leaching and, therefore, a neutral to slightly acid reaction throughout the profile) - Basisols, from soils in reduced or halted state of pedogenesis (acid reaction at least below topsoil) - Latosols. It is considered that under high rainfall (80 inches) latosols develop directly from basic rocks so that basisols occur mainly as relatively young soils under more moderate rainfall or very briefly, over acid rocks, under high rainfall. Another characteristic of latosols is the weak differntiation of profile horizons especially the B.-horizon. The development of an authentic B-horizon is regarded as indicating a change into another taxon, usually into Topophydric Earth on a planed surface. Clearly, then, Latosols correspond, generally to the Belgian Ferralsols, and Basisols to the Belgian Ferrisols.

Each of the two Great Groups is subdivided into two pairs of groups. In Latosols these pairs are clearly differentiated according to the amount of rainfall under which they occur. Oxysols occur under high rainfall (70") and are, therefore, strongly leached showing pH values decreasing from 5.0 at the weathering zone to 4.0 at the surface. Cation exchange capacity is low due to leaching of clay, but having developed normally under rain-forest, organic matter content is relatively high, and dispersed deeply within the profile. Ochrosols are associated with lower rainfall and differ from basisols in being old and deep and consequently more leached, acid and poor in clay, pH values below the topsoil and above the weathering zone range between 4.5 and 5.5, usually in a reverse direction to that in oxysols.

Subdivision of basisols is less clearly defined and is based mainly on the colour of the solum. Red basisols are designated as Rubrisols and brown - as Brunosols. There is a tendency for rubrisols to occur under higher rainfall than the brunosols, indicating a more profound leaching of bases and weatherable minerals, but the difference in colour may also indicate the effect of differential parent material - richer or poorer in iron.

The criterion for further subdivision into groups is type of vegetation: Forest, savannah or thorn-thicket, each indicating certain climatic conditions, usually - amount of rainfall. Obviously, the normal vegetation of oxysols is rainforest and when found under savannah, it is only a derived one. Ochrosols may be found under forest where rainfall is 40-70" under broad-leaved savannah woodland (30-50") and under thorn-thicket (apparently including compound-leaved savannah; 15-30"). Under forest pH values in the upper topsoil may reach 6.0-7.0 due to increased mineralization of organic matter, but fall rapidly to 4.5-5.0 through the rest of the profile. Under savannah there is no such fall and a value of pH 5.5 is retained throughout the profile. Under thorn-thicket inhibition of bacterial activity by direct insolation lowers the topsoil pH to 5.5-6.0 and that of the lower horizons to 5.0-5.5. Similar tendencies are apparent also in rubrisols and brunosols.

Xeropeds are subdivided according to conventional groupings - Reddish Prairie, Reddish Chestnut, Reddish-brown, Red Desert and Desert soils - without any attempt to reassess this classification.

Of the taxons defined in this classification the Savannah and thorn-thicket ochrosols, savannah and thorn-thicket rubisols and the savannah brunosols are possibly represented within the study area. It can be seen, consequently, that although there exists a general correspondence of Large Groups between Charter's and Sys's classifications there is no equivalence and that the different criteria of definition set somewhat different limits to the taxons.

Geographic classification

Scott's scheme for East Africa (1960)

This scheme which is based mainly on Gethin Jones and Scott's soil maps of Kenya and Tanganyika (1959) and on the Soil Survey of Uganda reviewed in the next section, is included under the present heading mainly due to the fact that genetic taxons are regarded as members of topographic sequences and as the representing stages of geomorphic evolution and are mapped, accordingly, on the 'catena' principle. Otherwise, the scheme is based on the effects of the drainage and climatic factors and, in common with many other British schemes in Africa, depends on field characteristics and routine laboratory data. The basic taxon - the Great Group - is defined following the American usage, according to the nature of the profile - the main features being colour, texture, structure and consistency of horizons, together with amounts or organic matter, soluble salts, calcareous and iron concretions etc., site characteristics and topography in conjunction with physical and chemical properties. These criteria are used flexibly, a certain set being selected to define each Great Group.

The first separation of soils, by inference, is made between raw mineral soils (litho- and regosols) and weathered soils. These last are divided according to their drainage into five categories in order of increasing impediment, from well- to poorly-drained soils., The well-drained soils are subdivided into four rainfall categories: Humid (40"), sub-humid (30-40"), semi-arid (20-30") and arid (< 20"). It is recognized that these categories are broad and may be further subdivided according to the effect of rainfall on base saturation and total base content. Of the 14 Great Soil Groups included in these categories not only the four of the subhumid region which falls within the rainfall range of the area but also the last three of those included in the humid region seem to be relevant in the present context.

The 36 Great Groups which comprise the scheme are arranged for the whole of East Africa, in nine generalized groups of soil-topography associations.

The groups reflect gradation and nature of relief commencing with highly dissected to broad ridge topography through ridge to gently unduating topography and gently undulating to level, and terminating with level to depressed and with redissected topography. Special groups are assigned to specific relief elements such as inselbergs which may appear in several groups and to combinations of climate, parent rock and relative stage of geomorphic evolution within each group, enabling the construction of evolutionary sequences according to different climatic conditons and parent rock and perhaps even reflecting changes in climatic conditions.

The association depicted for the region including the study-area is defined in the group of highly dissected to broad ridge topography and consists of three Great Groups: crests of high ridges with shallow stony soils and rock outcrops; slopes and broad lower ridges with yellow-red sandy clay-loams (humid region) and valley floors with alluvium, lacustrine deposits and swamps. This is, of course, a very much generalized outline and the simplified topographic components are, perhaps, justified at the scale used. It is, however, clear that an erroneous climatic definition has been applied and that the same topographic combination should have been associated with a drier climate.

The Soil Survey of Uganda (Chenery et al., 1959-60)

This in fact, was not destined to synthesize a natural system of classification but only to provide a practical, convenient scheme stated to be directed mainly at non-pedologists. Consequently, it represents essentially a simplified, genetically non-committal list of soils.

The primary division of soils is not related to any pedological criterion but is based on the postulated classic erosion-surfaces. Only where the scheme of surfaces could not be applied or where soils are clearly related to lithology as independent of geomorphology, were other primary divisions defined. It is argued, as observed, that from division into geomorphic levels many pedologic characteristics can be inferred and that, therefore, the division is a natural one. Further sub-division is not comprehensive and where it exists it is usually defined according to parent rock or major genetic properties (rock and skeletal soils, young alluvial soils, pre-weathered soils etc.). The basic units are series and catenas which are delimited as geographic units and defined by both pedological properties and site characteristics.

The system suffers from several deficiencies, apart from the lack of detailed chemical and mineralogical data. It is based on a geomorphic scheme which is, by no means, proved or even generally accepted. Consequently significant implications of the primary division, mainly those related to the age of soils and paleoclimatic or paleogeomorphic influences (presence and nature of laterite etc.) may be incorrect. The absence of a comprehensive sub-division of primary categories according to some pedologic criterion related to environments tends to make the system clumsy and unenlightening. Each primary division consequently, appears as a long list of geographic appellations which may represent soils pedologically widely different.

On the other hand, the system has many advantages for relatively small-scale studies especially such as are not concerned solely with soils, and, therefore, attains its stated purpose. The non-genetic geographic approach has, of course, the advantage of objectivity once the implications of erosion-surface groupings are accepted as being flexible. And the geographic association of basic units helps in the recognition of local soil patterns.

Several basic units of this survey related to several surfaces occur within the study area or are related to its soils. Since these are the most detailed pedologic units available for the study-area they will be discussed in detail at a later stage.

Soils of the Study-Area

The examination of soils was undertaken in a number of soil-pits dug at selected points along certain transects. The transects were drawn so as to include two or more distinct levels of landsurface with at least one transect to each upland-lowland geological complex. Pit localities were selected on both lithological and vegetational grounds so as to cover both the possible types of parent material and the apparent vegetational assemblages. Consequently, transects represent merely a general direction along which pits are aligned. In each pit the profile was described and from most of them samples were taken from each of the distinct horizons. Samples of representative profiles were examined in the laboratory for base content, exchange capacity, base saturation and pH. A limited selected number of samples from lower horizons were subjected to clay-mineral and mechanical analyses. (For description and comments on representative soil profiles - see Appendix I.)

Laboratory Examination of Soils

The results of laboratory examinations of representative profiles will be presented, as were the profiles themselves, according to the geomorphological units on which they were taken. In this

way, the physical and chemical properties of the soils will show the trends in relation to their geomorphological position, and any departures from these trends. A fundamental fact emerges from such an exposition, namely, that soils are not necessarily of the same age as the surface on which they occur and that they present strong evidence to suggest that considerable erosional modification has taken place. Another emerging fact is that parent material exerts effect only on the lowest level, that of texture and colour and that higher level properties derived from pedogenetic processes are determined by climate, topography and the sequence of geomorphic evolution.
The analytical data from comparable locations in the study-area presented by Harrop (1960) is included for comparison. It can be seen that very great differences exist in the results especially as to content of exchangeable cations, exchange capacity and base saturation and also mechanical analysis. No satisfactory explanation has been found for this discrepancy. The reason should be sought perhaps in the different laboratory methods, but it should also be noted that a similar discrepancy appears when Harrop's data are compared with those presented by Radwanski (1960) on some common soils (Mawogola and Buruli Catenas). In any case, the discrepancy does not obscure the fact that trends of properties shown by Harrop's data are fundamentally similar to those of the data presented here.

Table 8: Analytical Data for Soil Samples

Surface/site	Soil type	Depth in.	Mechanical Analysis(%)* sand	silt	clay	pH	Exchangeable Cations (m.e.%) Ca	Mg	K	Na	Mn	Sum	C.E.C. m.e.	Base Satur. %	P p.p.m.	Organ. C	Soil Mineralogy (DTA, X-ray diff.) Sand	Silt	Clay
Rwampara	IA2	5	25	13	62	5.2	5.6	2.3	0.4	0.1	0.3	8.7	33.6	25	16	4.8	Kaolinite +	Kaolinite + Quartz ++	Kaolinite [illegible] cps
Crest Slope		25	18	13	69	4.7	2.0	0.2	0.7	0.1	0.1	3.1	29.4	10	8	1.0	Quartz +++	Feldspar ++ Ilmenite Tr.	Illite 67cps
		40	15	12	73	4.8	0.8	0.2	0.4	0.2	0.01	1.6	15.9	10	5	0.5	Ilmenite +		14A°*** 65cps
Gayaza	IBI	5	78	10	12	5.9	15.8	5.5	0.9	0.1	0.7	23.0	29.5	79	250	3.2			
Crest		8	74	8	18	6.9	18.4	5.6	0.8	0.1	0.2	25.1	28.3	88	250	2.8			
		20	71	4	25	6.6	11.8	6.6	1.3	0.1	1.1	20.9	24.0	87	250	2.0			
		30	54	12	34	7.0	6.4	3.6	2.0	0.0	0.7	12.7	19.8	64	250	1.5			
		40	44	13	43	7.0	4.6	2.7	1.8	0.0	0.4	9.5	15.8	60	96	0.6			
	Rugaga (Harrop, 1960)	8	50	11	39	6.6	7.8	5.0	0.6	0.0	Tr	13.4	17.4	77	19	2.1			
		18	50	10	40	6.5	9.2	3.9	0.4	0.0	0.02	13.5	16.5	82	17	1.3			
		30	56	12	32	7.0	10.3	3.8	0.3	0.0	0.02	14.4	16.5	87	56	1.3			
		42	56	10	34	7.3	9.2	3.7	0.4	0.0	0.02	13.3	13.3	100	57	0.9			
	IB2	8	29	13	58	7.2	6.4	1.0	0.8	0.1	0.4	8.7	24.5	39	5	2.0	Quartz	Kaolinite + Quartz +++	Kaolinite 68%
		30	22	9	69	6.6	4.8	1.0	1.0	0.1	0.3	7.2	19.6	35	4	12		Feldspar + Ilmenite +	
	Ksingire (Harrop, 1960)	9	77	8	15	6.5	9.8	1.4	0.2	0.0	0.0	11.4	15.0	76	42.5	2.4			
		18	73	4	23	6.2	6.6	3.1	0.6	0.0	0.0	10.3	13.6	76	16.5	0.6			
		28	63	6	29	6.0	5.5	3.5	0.7	0.0	0.0	9.7	13.8	70	51	1.5			

	IB3	5	46	16	38	5.3	2.8	1.0	0.6	0.1	0.2	4.7	22.4	20	5	2.2	Kaolinite +	Kaolinite +	Kaolinite + 153cps***
		15	26	19	55	5.0	2.0	0.2	0.7	0.1	0.02	3.0	26.6	11	2	1.2	Quartz +++	Quartz +++	Illite 63cps
		30	40	25	35	5.4	1.2	0.1	0.3	0.3	0.02	1.9	13.6	14	2	0.4	Olmenite +	Ilmenite	14A° 51cps
Slope	ICI	10	66	9	25	4.8	1.2	0.2	0.6	0.1	0.1	2.2	15.7	13	12	1.7			
		18	76	15	9	4.9	0.4	0.2	0.5	0.1	0.01	1.2	9.8	12	2	1.0			
	Isingiro (Harrop,1960)	8	70	7	23	6.4	12.6	5.0	2.3	0.0	0.02	19.9	24.6	81	1600	3.9			
		28	54	5	41	6.6	8.1	1.7	2.	0.0	0.0	12.5	16.4	76	370	1.3			
Lowland foothill pediment	IIA1	5	35	38	27	5.7	2.8	0.6	0.9	0.1	0.2	4.6	12.9	34	5	2.9	Quartz +++	Quartz +++	Kaolinite 53%
		15	30	36	34	5.2	1.2	0.2	0.4	0.1	0.2	2.1	8.2	23	5	1.4	Feldspar Tr	Feldspar +	Illite 47%
		30	23	31	46	6.1	3.2	0.8	0.5	0.1	0.02	4.6	11.3	41	2	0.2			
	Mbarara (Harrop, 1960)	6	64	15	21	6.4	13.6	7.5	1.3	0.0	0.0	22.4	25.0	90	143	3.9			
		15	66	11	23	5.3	5.0	2.8	0.7	0.0	0.01	8.5	11.1	77	113	1.6			
		25	65	9	26	5.2	2.9	1.6	0.4	0.0	0.04	4.9	8.3	59	39	0.5			
		36	61	11	28	5.1	3.2	1.0	0.5	0.0	0.04	4.8	7.5	64	27	0.3			
		48	59	11	30	5.5	2.3	1.3	0.5	0.0	0.03	4.1	6.8	61	13	0.2			
mid-lowland pediment	IIB2	8	63	15	22	5.9	2.0	0.2	0.8	0.1	0.0	3.1	8.9	35	2	1.8	Quartz +++	Kaolinite + Illite +	Kaolinite 60%
		30	39	19	42	4.5	0.8	0.2	0.2	0.1	0.0	1.3	9.2	14	0	0.5	Feldspar ++	Quartz +++ Feldspar ++	Illite 40%

	Nawogola	4	71	6	23	6.2	3.0	1.4	0.6	0.0	0.0	5.0	7.9	63	24	1.9
	(Harrop, 1960)	8	65	12	23	5.8	2.0	1.2	0.5	0.0	0.0	3.7	7.2	51	10	1.1
		18	55	12	33	5.4	0.6	0.9	0.5	0.0	0.0	2.0	5.8	34	3	0.7
		30	53	6	41	5.3	0.5	0.9	0.9	0.0	0.0	2.3	6.6	35	6	0.6
		42	59	10	41	5.4	0.3	0.6	1.3	0.0	0.0	2.2	6.3	35	9	0.4
Flat floored	IIC1	4	61	18	21	5.4	4.8	3.0	0.6	0.0	0.1	8.5	15.0	57	24	3.2
valleys		12	52	20	28	5.1	3.2	1.6	0.3	0.3	0.1	5.5	11.7	47	14	1.9
		30	48	10	42	4.8	7.0	2.9	0.2	1.0	0.0	11.1	15.4	72	14	0.8
		45	53	10	37	5.2	7.4	2.3	0.2	1.0	0.0	10.9	15.6	70	31	0.3

* Sand 50m – 2mm; silt: 2 – 50m; Clay 2m

** Mineral intermediate between chlorite and mentmorillarite

*** No percentage estimate was given. Counts per Second are presented as a measure of proportion with different backgrounds at 14°20: IA2 – 38cps; IB3 – 34cps. A very tentative estimate of the respective percentages is: IA2 – Ka. 68%; Ill. 24%; 14A° – 18%; IB3 – Ka. 43%; Ill. 30%; 14A° – 27%.

The analyses were performed by Mr. A. Theisson of the Scott's (National) Agricultural Laboratories in Nairobi.

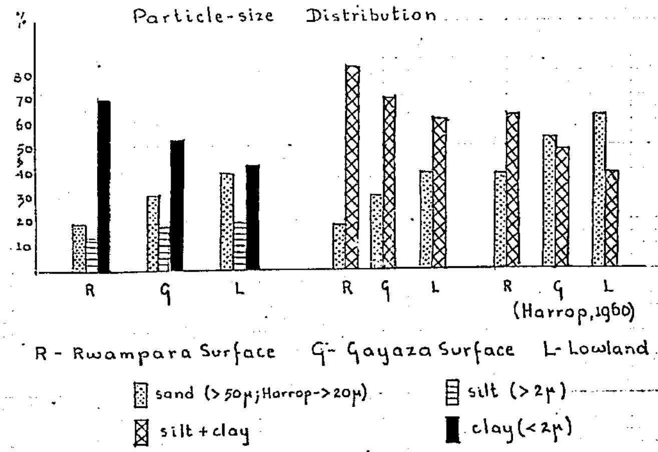

Fig. 36

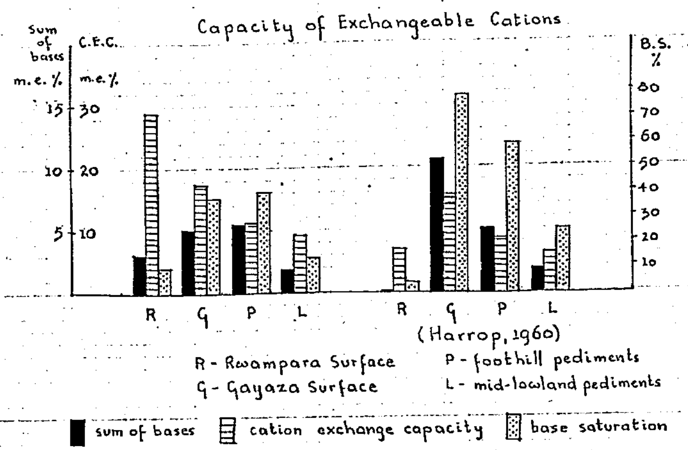

Fig. 37

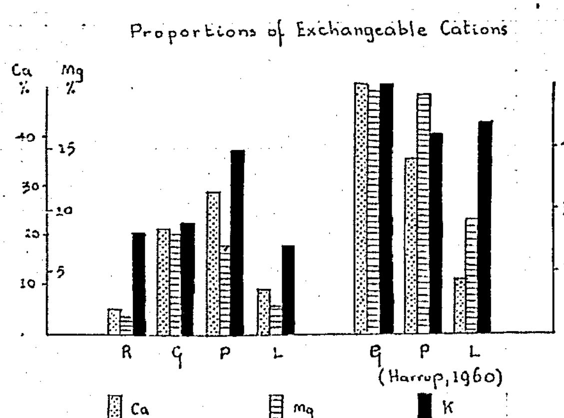

Fig. 38

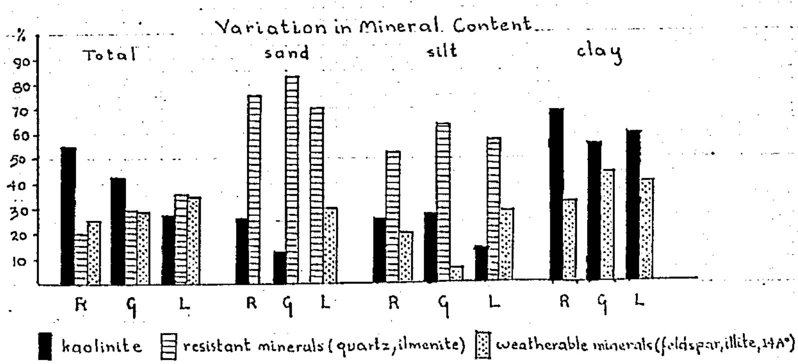

Fig. 39

1. Particle-size distribution

If aberrant soil types such as the very young soils on arenaceous rocks, or soils supplied laterally with leached materials in crest depressions, at foothills or on valley floors, are excluded from calculation a definite trend towards increasing sandiness and siltiness and a decrease in clay, with the mean elevation of the surface, as illustrated in Fig. 36 . The values shown are for an approximately equal depth of soil (25-35"). Those for surface horizons are not shown, but although they are in general more sandy, they follow the same trend. Harrop's data, for similar depths, show the same trend only if the fine fractions are combined. This is, probably, a result of differences in both analytical techniques and fraction definition.*

There can be little doubt, since mature soils on both arenaceous and argillaceous parent rock are included, that the greater sandiness of lowland soil suggests their stronger leaching.

The effect of leaching on particle-size distribution within the profile appears to depend also on site characteristics in relation to drainage. In sedentary soils affected by vertical percolation alone or whose internal lateral drainage is moderate, there appears to exist a general increase of clay with depth. In such soils the characteristic profile is an A-C one, with the illuvial horizon in the C-zone and without noticeable differentiation of the B-horizon. In soils of excessive internal,

* i.e. The Uganda's soil survey definition of silt is narrower (2-20 μ) than that adopted in the present work (2 - 50 μ).

lateral-downslope drainage such as those situated above a fairly steep slope or in soils subject to import of material by surface-wash, clay tends to form a higher proportion in upper, usually the subtopsoil A_1-horizons. These properties are associated with a specific distribution of exchange capacity within the profile.

2. Soil reaction

Apart from aberrant cases connected with special site conditions or, perhaps, with special climatic conditions, there appears a well-defined correlation between soil reaction and surface relations of soils. Generally, lower horizons (25-35") of upland-crest soils are less acid than those of lowland surfaces. A prominent exception to this rule is the soils of the Rwampara Surface (IA_2) showing a pronounced acidity already in the surface topsoil. With only one sample to judge from, the apparent reason for this, supported by high organic content and type of vegetation cover, is predominance of humification over mineralization of organic matter due to higher altitude. A more satisfactory reason may be provided by more detailed knowledge of distribution of effective rainfall. It is possible that rainfall on the Rwampara Mountains is higher and more efficient. In such a case, low pH values will be caused by greater leaching and lower base saturation. Such a possibility is supported by the fact that on the Gayaza Surface, samples from the western part of the area (Gayaza hillmass) which is supposed to receive higher rainfall, are more acid than those from the dry centre of the area, although not as acid as the Rwampara soils.

On the Gayaza Surface the mean pH value for soils at a depth of 25-30" is 6.4 (including Harrop's samples which have the same range of values). If the western samples are excluded the mean value rises to 6.6. The only exceptions are the very shallow skeletal soils on slopes (e.g. IC1) which have values below 5.0. Soils on the Lowland Surface (also including Harrop's samples) have, at the same depth, a mean pH value of 5.0. An exception to this are the soils found at the foot of the granite tors which may have pH exceeding 6.0 due to the proximity of weathering rock.

Within the profiles themselves, the trend of pH value is closely related to base saturation and consequently, tends to be relatively high in the topsoil containing mineralizing organic matter, falls perceptibly in the A_{1-3} horizon and B-horizon where it is present, and then rises gradually or abruptly, depending on the degree of leaching, as weathering parent rock is approached. The exceptions to this normal trend are soils in which the lateral supply of bases is excessive (IB1, Rugaga; also the 'tor-base' soils, see Harrop, 1960, Appendix p.13) and in which pH values rise from the surface down to the base of the profile or even fall sharply after reaching a certain maximum in a sub-topsoil horizon.

3. Exchange capacity, base saturation and the content of exchangeable cations.

Exchange capacity, dependent as it is on clay content and mineral nature shows a definite trend towards decrease with the elevation of the surface (Fig. 37). Correlations of base content and base saturation are more complicated. According to Harrop's data there is a parallel decrease in both values from the Gayaza Surface (Rugaga and Isingiro Series) to the lowland. On the Rwampara Surface from which he presents data only from the somewhat skeletal and leached Bugamba Catena, all three values are very low except at the surface. The data gathered in the present work differs in showing a high exchange capacity in the Rwampara Surface soils and an upward decrease only in base content and saturation. Furthermore, this decrease is smaller than that shown by Harrop's data (38% decrease in base content; 74% decrease in saturation as compared with Harrop's nearly 100% decrease in both values). On the other hand the specific position of soils on foothill pediments as relatively base-rich lowland soils, shown in both cases, is enhanced in the values shown in the present work. There is a small increase in both base content and saturation of foothill pediment soils in relation to those of the Gayaza Surface.

This increase is due to a constant supply of calcium and potassium from the upper surfaces, as illustrated in Fig. 38. Magnesium, which occupied the second place in the proportion of metal-iron constituents, is apparently less subject to leaching. The proportions of exchangeable cations show the same trend as the total base content, rising to a peak in the soils of the foothill pediments (Ca,K) or of the Gayaza Surface crests (Mg) and illustrating again the specific character of the Rwampara Surface leached, acid soils. Harrop's data also parallel the trend shown by total base content, of decrease in the three metal-ions from the Gayaza Surface, through foothill pediments to mid-lowland pediments.

It appears therefore that the data gained from two sources agree as to the fundamental difference between the soils of the Gayaza Surface and those of lowland pediments which are not subject to extraneous supply of soluble bases; the soils of the upper surface have a higher base content, a greater exchange capacity and a higher base saturation of the exchange complex. Dearth of data prevents an accurate assessment of the nature of the Rwampara crest soil which is undoubtedly different from that of the Gayaza Surface soils. The difference between the two data sources as to the nature of the foothill pediments may indicate that an intermediate character is more representative of average properties of this soil type and that since the trend of increase in the values of these properties is not very pronounced, it does not distort the general trend.

4. Soil mineralogy.

The results of the mineral analysis of a number of subsoils show a consistent high proportion of unweathered or partially weathered minerals, besides the expected, pre-dominant kaolinite. The mineral composition of the soils appears to be related more to the nature of the parent rock than to surface disposition but undoubtedly it is also dependent on the degree and form of weathering. The presence of illite indicates a partial weathering of micas, probably of the slowly weathering muscovite or biotite; 14A°, restricted to soils on phyllite, possibly results from the weathering of both muscovite and chlorite, a constitutent of phyllite. These minerals, however, indicate only partial weathering of which the further step is the loss of potassium from the illite and 14A° and the formation of kaolinite. Felspars apparently represent unweathered minerals.

The distribution of soil minerals shows (Fig.39) a certain trend which is expressed by a general increase of weatherable minerals and a parallel decrease of resistant minerals with decreasing surface elevations. This may mean that the lowland surface is either at an earlier stage of weathering or that it is less leached. Unfortunately very few other mineral analyses of Uganda soils are available for comparison. Those presented by Chenery (1960) concern soils under different climatic and geomorphic conditions and relate only to the clay fractions. It is, however, of significance that all those lowland soil-samples containing more than 10% of weatherable minerals are from lower members of the catenas or from alluvial series. The high proportion of weatherable minerals in the lowland, especially mid-lowland and soils, is surprising when taken in conjunction with the strong field evidence of deep weathering and the accepted views on the two-cycle tropical pedogenesis (Ollier, 1959). The 'tor' landscape associated with the area in which the sample was taken, and the numerous exposed deep kaolinite profiles, strongly suggest that the soils have been formed on pre-weathered materials from which most of the weatherable minerals have been long removed and bases for plant nutrition can no longer be released (Ollier and Radwanski 1959). This is well-attested by the very low base content of the soils and their greater acidity, exemplified also by the relevant sample (IB2). Consequently, the high proportion of weatherable minerals in the same sample is difficult to explain and no satisfactory answer has been found.

However, several facts should be kept in mind: as described previously the IB2 profile rests on weathered parent material at no great depth and the parent material itself is not entirely kaolinized. It is conceivable, therefore, that this specific profile, sited on the upper slope, is of relatively late development, following the stripping of weathered mantle, with the weathering bedrock still not far below the surface. The fact does not explain however, the acidity of the soil and the low base content and the problem cannot be resolved until many other analyses of this soil type are undertaken. It is the opinion of the present writer that all the other evidence presented here, indicating the relative poverty of mid-lowland soils in fine-fraction content and exchangeable cations and the low capacity of its exchange complex, outweighs the single mineralogical evidence and suggests that these soils have been more thoroughly leached than the upland-crest soils and are apparently in a retarded state of pedogenesis.

The Nature and Geomorphic Relations of the Soils

An Attempt at classification

In view of the preceding data of soil properties, it appears that the classification proposed in the Survey of soils in the Western Province of Uganda (Harrop, 1960) needs only few modifications on the series level, within the limits of the study-area.

While it seems obvious that the two types of the Rwampara crest soils are genetically related, the shallow, IA_1 type representing a younger or a slope-sited phase of IA_2, it appears necessary to distinguish the crest-soils of the Rwampara Surface from those of the Ggyaza Surface which closely parallel Harrop's Rugaga Series, and define them in a separate unit. The identification of these two types in the Memoirs, appear to be based solely on the definition of the surfaces on which they are found as parts of the same Ankole Surface. While this definition may be correct in the sense that these are surfaces of an approximately similar age, it is very doubtful, even on general theoretical grounds, if soils upon them are necessarily identical. No laboratory data are given to support this identification and an incongruous pattern emerges from it, in which the crest-member of one Catena - the Bugamba - appears as the uppermost member of another - the Isingiro Catena. As was discussed above, on the other hand, the soils parallel to those of the Isingiro Catena show gradation from shallow lithosols to quite deep latosols. It was recognised that topographical and lithological diversity can result in variation of gradation series quite apart from diversity imposed by age and past influences. At least two types of a fairly advanced stage in such a sequence were described (IB1; IB4). It is also admitted that differences between well-developed crest soils and crest-slope and shallow soils are pronounced. Yet, surely similarities in chemical properties (high base content, exchange capacity and base saturation etc.) justify the conclusion that genetic relations are closer between the Rugaga Series type and the Isingiro Catena type than between the former and the Bugamba type.

Consequently, the dividing line should be placed between two groups of series: Rwampara-Bugamba and Rugaga-Isingiro. The first series in each group indicates the crest-soil - more mature, differentiated and leached; the second - the shallower phase whose development is either more recent or inhibited by topographical or lithological circumstances. The intermediate stages have been partially but not sufficiently identified in the Isingiro Hills, and appear to differ with topographical-lithological complexes. An attempt to name these units meets with certain difficulties of classification and terminology. It is an accepted usage in genetic soil classifications to separate shallow, skeletal soils, reflecting mainly the parent-rock properties from the potential products of their further pedogenesis at the order level, on the basic premise that genetic classifications should refer to pedogenetic factors as expressed in soil properties and not to possible but necessarily at least partially hypothetical evolutionary sequences.

There is no doubt that certain soils defined in Harrop's Isingiro Catena are lithosols. Their separation from other skeletal soils on slopes (compare IC1) which are not defined or mapped in the Memoirs is presumably based on the arenaceous parent material, while the existence of an unrelated crest-soil Series in their midst is ascribed to an underlying laterite sheet. It is, however, certain and attested in the Memoirs, that not all the soils included in this unit are genuine lithosols. On gentler slopes they appear to possess characteristics of young but already well-developed soils, influenced also by other factors than parent materials. It seems, therefore, that only the shallow slope-soils should be classed as lithosols and separated on a high order level while the crest-soils of all phases of development should be grouped together as a unit consisting of variants which are defined according to stage of development and soil properties.

The other difficulties encountered concern the usage of the term "catena" and the geomorphic relationships of the soils. No doubt the use of the term "catena" to define the Isingiro soils has desisive technical advantages since it enables simplified mapping. It is justified as long as it is understood that it has no genetic implications and does not include the whole topographic sequence from crest to foothill pediment and to lowland drainage line.

These implications are very misleading when related to upland-lowland sequences in south-west Uganda where pediment soils are related to upland crest soils only in secondary and derived properties. It appears that in this area the usage of the term should be best restricted to either crest or lowland sequences and the two separated by lithosol units defined by the parent rock.

As observed, groupings of soils on the basis of postulated surfaces may be erroneous as to implied soil properties and variety. The only consistent relationship between surface levels and soils appears to apply to general differences between upland soils on crests and in lowlands and even in these cases there are exceptions to the rule. Thus, if it may be stated that as a rule upland crest-soils show properties implying more active current pedogenesis than those of the lowland and are consequently better supplied with plant nutrients, the statement does not include soils on residual upland crests which are usually skeletal and acid, and poor in nutrients representing lithosols developed after stripping of a former soil mantle. Furthermore, as shown by the foregoing exposition, distribution of soil-types does not correlate with different upland levels. The deep soils of the Rwampara Surface are of two types, one found on the crests of the Rwampara Mountains themselves and the other on relicts, of this Surface in Western Isingiro. Differentiation seems to result from climatic and topographical circumstancew, or perhaps parent material and not from the age of the surface. In other words, a geomorphic classification of soils may be based on landform and relief but not on geomorphic history, since soils, especially on elevated and dissected old surfaces, may have no relation to its initial nature.

Another modification of the Soil Survey classification appears to be necessary in relation to the study area. It is doubtful whether the definition of the Mbarara Catena as presented in the Memoirs and exemplified by a single profile can be extended to as large an area as depicted on the associated map. It would appear that such a definition should be restricted to a relatively narrow foothill pediment fringe, where the influence of transported, dissolved and suspended material from the actively weathering and eroding adjacent upland slopes engenders specific soil properties. At some distance away from the retreating upland slopes, where lowland soils are older, base content falls sharply (11B1-2), acidity is greater and sandiness increases. Probably, the extent of foothill pediment soils is very restricted where extensive lowlands are present and it is only in inter-upland lowland tracts such as the Orichinga and Nyabubare Valleys or the valleys among the Sanga Hills, that these soils are prevalent. A similar case is presented by the Nyabushozi Catena which is stated to be differentiated primarily in order to introduce the shallow soils on the laterite sheets of upland crests. In other respects these soils resemble closely, in low base content and acidity, other mid-lowland soils and do not include any parallel of the foothill pediment soils since erosion of the crest laterites does not contribute any additional bases.

Considerations of genetic classification

Chenery in his introduction to the Soil Survey of Uganda (1960) attempted a genetic classification of the series defined in the survey, according to both the Belgian and Charter's systems. Of the series mentioned above he includes all except the Isingiro Catena among the Ferralsols: the Bugamba, Mbarara and the "Red" Koki soils are classed as orthotype ferralsols according to Sys, or as red ferralsols on undifferentiated rock, according to D'Hoore; the Mawogola and the Brown Koki Soils are classed as Tropical Brown Intergrade and the Nyabushozi soils, as Regoferal Intergrade. All the latter three series are classed as yellow-brown ferralsols on undifferentiated rocks, in D'Hoore's system. The ferralsols correspond, according to Chenery, to Charter's Savanna Ochrosols. The Isingiro soils (as are Radwanski's Tolero Series) are classed as Lithosols (D'Hoore), recent tropical soils (Sys) or lithopeds (Charter). The Bukara soils (of aggraded valley floors) are given a special high category within these systems, due to the high content of dioctahedral mica in their clay fraction. They are designated as Micasols and related to Sys's humic hygro-xero-kaolisols and to Charter's latosols.

The predominance of kaolinite in the clay fraction of all analysed soils, undoubtedly places all the well-drained soils of relatively level sites in the kaolisol order, even if no evidence of the subsidiary criterion of free-oxide content is available. These are typically tropical soils whose kaolinitic weathering is conditioned by the prevalence of climatic circumstances over other factors and can be classed, on this general definition with Charter's Climatophytic (≠"Zonal") soils. Greater difficulties, however, attend concurrence with Chenery's classification on the sub-order level. On the general climatic criterion of present annual rainfall the soils of the area could be classified as ferralsols only if they are assumed to represent reworked and redistributed soils formed under different climatic conditions. Otherwise, a rainfall of less than 1000mm p.a. in the whole of the area (except a very limited part in the northwestern corner) and of less than 900mm in most of it, would indicate the prevalence of fersiallitic (ferruginous tropical) soils, or at the most ferrisols. However, mineral and chemical properties indicate that the soils belong to more than one of these three suborders or great family groups.

It appears that a distinction should be made between the mineralogical and chemical evidence whose implications as diagnostic properties, seem contradictory. Mineralogical evidence points to a general appreciable reserve of weatherable minerals, exceeding 25% of the average mineral content of all soils. As observed, this reserve increases with decrease of surface elevation. This property is paralleled by the weatherable mineral content of the sand fraction which exceeds the diagnostic limit of 10% only in the mid-lowland soils.

The proportion of kaolinite in the clay fraction exceeds 50% in all Kaolisols (except for one very specifically sited upland profile where it exceeds 40% - see 1B3). Mineralogical evidence, consequently, tends to support the inclusion of lowland soils in the fersiallitic or ferrisolic great family group and those of the upland within the ferrallitic group of within a ferrallitic intergrade of the ferrisols. However, as observed, mineralogical evidence from mid-lowland soils is regarded here as insufficient and probably unrepresentative and more weight should be assigned to chemical and morphological evidence.

Silt/clay ratio in averages of soil types, including those of the Soil Survey, exceed 0.15 and, thus according to Sys's criteria, excludes their definition as ferralsols. It should be noted, however, that according to Harrop's data (1960), the mid-lowland soils of the Nyabushozi and Mawogola Catenas show an average ratio of 0.23 and some of the profiles show ratios below 0.15. If D'Hoore's diagnostic limit of $<$ 0.25 is accepted then mid-lowland soils must be classified as ferralsols. Data of chemical analysis corroborate such a definition. Harrop's data on the exchange capacity of mid-lowland soils cannot be applied to D'Hoore's criteria since they do not show a separate exchange capacity of the clay-fraction. Data from analyses of the present work, however, show that the exchange capacity of mid-lowland soils is very close (21%) to D'Hoore's diagnostic limit for ferrallitic soils (20%). Base-saturation values are below the limit for ferrallitic soils (40%) according to both sources.

If, then, the tentative mineralogical evidence is added to the chemical one, there is a strong case for Chenery's classification of the Mawogola Catena as a ferralsol tropical brown intergrade according to Sys's system and as a yellow-brown ferralsol according to D'Hoore's system. It is doubtful, however, if the Nyabushozi Catena can be separated from this unit as a rego-ferral intergrade since there is no evidence of the diagnostic feature of a very leached layer at 10-40", with less than 20% clay.

There is, of course, a trend towards a downward increase of clay proportion, and in one profile it is as low as 21% in the upper sub-topsoil, but there is no sharp lower limit to the leached layer and the trend as such is common to most soils in the area including those defined in Mawogola Catena. Consequently, it appears that chemical similarities between the two groups are more significant than morphological differences and the soils should be united in the ferrallitic tropical brown intergrade.

The Mbarara-type foothill pediment soils are more difficult to define according to those criteria. Mineralogical data indicate less than 10% of weatherable minerals in the sand fraction but silt/clay ratio much exceeds 0.15 according to data from both sources. Exchange capacity of the clay fraction is 24% which is close to but above the limit for ferralsols. Base-saturation at 41% in the B-horizon and 23% in the A-horizon is close to or below the ferralsol limit (40%) according to the data of the present work, but much exceeds it according to Harrop's data (approximately 60%). The nature of horizon-sequence and chemistry in the profile suggests that contrary to mid-lowland soils, this soil-type may be still undergoing pedogenesis (increase of base content and pH value in the lowest horizon) and that it is affected by importation of material from the adjacent slope. In view of all these facts the classification of this soil-type will depend on the importance attached to different properties. This is largely, as is the case in all genetic classifications, a matter for subjective judgement.

It appears clear that the soil is close in properties to ferralsols and it is the high silt/clay ratio, the indication of active pedogenesis and Harrop's evidence of high base saturation that prevent its definition as such. It is also clear that these soils cannot be classified as fersiallitic due to very low weatherable mineral reserve in the sand fraction, the low exchange capacity of the clay fraction and the evidence produced here of base saturation values lower than 50%. The definition of ferrisol, however, appears to fit the properties of the soil on all counts according both to D'Hoore and Sys's systems, if the qualifications of this definition are kept in mind. Thus, according to these systems, to define a soil as a ferrisol it is not necessary that a high silt/clay ratio will be associated with a high reserve of weatherable minerals in the sand fraction or with a B-structural horizon with distinct clay-skins. It is only necessary that it should be associated with a base saturation value of 40-50%, a clay-fraction exchange capacity of over 15 m.e 100 gr. and a state of pedogenesis that is more active than in ferralsols but retarded compared with that of fersiallitic soils. A corollary of the relatively low base-saturation are the relatively low pH values which are intermediate between those of the same horizons in ferralsols and fersiallitic soils. In the case of active pedogenesis this value may rise abruptly in the C-horizon. It appears to the writer that this combination of properties is more significant than Harrop's data on high base saturation which are not correlated with high pH values. It seems possible that the degree of saturation in his sample-profile should be attributed to accretion of material from the adjacent slopes as is also indicated by the morphology and chemistry of his profile's horizon-sequence. Therefore, both data sources do not indicate that the foothill-pediment soils are true ferralsols as Chenery maintains. According to Sys's system they may fall within the definition of a ferrisol-intergrade approaching fersiallitic soils.

If similar considerations are attached to upland-crest soils a very sharp division will emerge between the mature soils of the Rwampara Surface and those of the Gayaza. The divergence of mineralogical and chemical evidence appears to be greater in the upland soils than in the lowland. On both surfaces the sand fraction contains no reserve of weatherable minerals, yet, on both of them silt/clay ratio exceeds the limit of 0.15, averaging 0.25 according to Harrop's data and 0.31 according to the present data. At the same time, clay-fraction exchange-capacity exceeds the limit of 25%, averaging 36%. On the Rwampara Surface these values are lower, averaging 0.18 for silt/clay ratio and 32% for clay-fraction exchange capacity. Taken separately the Gayaza Surface soils show respective values of 0.40 (0.25 according to Harrop) and 39%. In any case, all these values fail to corroborate the implications of the ferrallitic nature imparted by the absence of weatherable minerals in the sand fraction.

While, as observed, the trends shown by chemical data of both sources are similar, they differ very significantly in relation to diagnostic criteria. Base saturation in the 25-35" horizon of the Gayaza Surface soils averages 78%, according to Harrop, and only 38% according to the present data. Harrop's data corroborate the other chemical and mechanical properties in defining the soils as non-ferralsols while the present data fail to do so by a narrow margin. This contradictory evidence on diagnostic properties makes it necessary to consider other features which were not defined in the Belgian systems as diagnostic.

The nature of the sites which characterize these soils should be kept in mind. All are situated on crests, usually on crest slopes and are, consequently, subject both to alternate excessive leaching and drying and to some accretion of materials from upslope. At the same time they reveal definite evidence of active pedogenesis by the consistent increase of both pH and base saturation values in the lowest horizons of the profiles. The much greater saturation values shown by Harrop's data are due both to higher base and lower clay content. But Harrop's data are, in fact, derived from two profiles of which the one, as remarked, is sited at the foot of a considerable slope and the other represents a relatively shallow, early stage in the development of the crest soils. Consequently, both may have a higher base content and a lower clay content than should be expected from the average crest soil. On the other hand, the data gathered in the present work represent widely different sites and circumstances, from a hollow in the crest where base saturation is more than 70% and clay content - less than 30% to soil at the top edge of an open-jointed quartzite scarp, where base saturation in the same horizon is 11%, and clay content is over 50%. In either case the number of samples is too small to be representative but it would appear from the consideration of the sites, which were chosen during the present study to represent variety, that would the choice have been random, the average characteristic soil profile representing most of the soil area should have been richer in bases and poorer in clay than the average of the sampled profiles. It appears, therefore, to the writer that a mean value between Harrop's and the present data's base-saturation values is more representative than both. Such a mean of 58% base saturation is more in accord with the high silt/clay ratio and clay fraction exchange capacity and places the Gayaza Surface crest soils within the definition of fersiallitic soils, according to the chemical and morphological criteria.

As to the mineral evidence which appears to contradict such a definition it was already observed that the mineral composition of soils is representative of the nature of the parent rock especially where the soils are in a state of very active pedogenesis and relatively young. It would do well to remember that the samples analyzed for minerals were taken from soils developed upon highly metamorphosed rocks, of very high resistance to weathering. It is a petrographic characteristic of such rocks that by the far greatest part of their weatherable mineral constituents are very fine grained and relatively resistant (muscovite, sericite, etc.) while whatever small quantity of coarse weatherable minerals that may be included consists of relatively incompetent ones (feldspars etc.). It is reasonable to expect that the coarse fraction of the soils developed on such rocks, will consist entirely of very resistant minerals (quartz, ilmenite, zircon etc.) and perhaps a small proportion of weatherable minerals already altered to the very resistant secondary kaolinite. It appears, therefore, that mineralogical criteria for classification of soils must be adjusted to the nature of the parent-rock and cannot be applied in a generalized fashion, especially where soils are in state of active pedogenesis and on freely leached sites. On highly metamorphosed sedimentaries the reserve of weatherable minerals in the sand fraction cannot constitute a reliable criterion and furthermore, the general reserve of such minerals should be assessed on a different basis than that of soils on incompetent plutonics.

Similar considerations apply also to the Rwampara Surface soil which is distinguished by higher clay content and general exchange capacity. There is no doubt, however, that while their general reserve of weatherable minerals is not much smaller than that of the Gayaza Surface soils the Rwampara Surface soils are much more leached and acid, and except for a silt/clay ratio somewhat higher than the limit for ferralsols they fit into this category better than any other upland soil. It even appears that their state of pedogenesis is more retarded than that of the Gayaza Surface soils. However, the single sample-profile of these soils is certainly insufficient for generalizations especially with the specific site conditions that are involved. The relatively high elevation and the possible greater efficiency of precipitation combined with the rapid drying out which is characteristic of all narrow crest sites, perhaps contributed to the greater leaching and acidity and the elimination of evidence of active pedogenesis.

Retarded mineralization of organic matter due to both lower temperature and rapid drying will probably enhance these features. If the site is situated, as implied by altitude, above the limit of the subtropical montane zone (Snowden, 1953) the nature of the soils may indicate an intergrade between the Gayaza Surface type of soils and montane soils of the humid subtropical type. The possibility that the properties of the soil derive from greater age compared to that of the Gayaza Surface and not from different environmental conditions appears to be mitigated by the nature of a younger soil on the Rwampara Surface exemplified in Harrop's Bugamba profile (1960, append, p.9) which shows the same trend towards very low base content and saturation and very strong acidity. In view of the high organic Carbon content ($> 4\%$)

in the topsoil, the closest definition that applies to the mature Rwampara soils appears to be that of humic Kaolisols. In the Soil Survey's scheme of classification they seem to approach the type of soils found on the lower crests of the Kigezi Mountains and defined as members of Kabole Catena.

Another group of Kaolisols present in the area corresponds very closely to Radwanski's Koki Catena (1960). No samples of these soils were taken in the present study, but a comparison of field characteristics showed that Radwanski's profiles and the soils found in Western Koki are essentially the same except that in the "Brown" (mid-slope) member of the Catena appears to be dominant and the "yellow" (low-slope) member - is relatively limited in area. The taxonomic position of the Catena is, consequently, determined according to Radwanski's data (ibid, appendix pp. 2-3). In contrast to the lowlands to the west, where the foothill pediments are long and gently sloping, the pediments in Koki are relatively short and steep, especially in their upper parts. Moreover, the slopes of the upland at their back are much lower. These peculiarities have, apparently, a very fundamental effect on the nature of the pediment soils. Accretion of material from the slopes is smaller, the soils are more intensively leached and the more clearly differentiated in a catenary sequence determined by differential freedom of internal drainage. They are consequently poorer in base-content, their base-saturation is lower and their reaction more acid. These diagnostic properties place all the three members within the ferralsols as orthotype (Koki "Red" and "Yellow") or as intergrade approaching ferrisols (Koki "Brown"). However, they are certainly different ferralsols than those found in mid-lowland areas. They are developed on fresh rock and not on pre-weathered material and they are, apparently, still in a state of active pedogenesis at least the lower members of the Catena. It would appear, therefore, that pending the availability of additional reliable data, their definition as ferralsols must be qualified. These are not old resorted soils retaining properties of former environments. Their ferrallitic nature is derived from specific geomorphic conditions and does not express the climatic environment.

A scheme of soil classification

In view of the considerations outlined in the previous sections the soils of the study-area lend themselves to the following classification. (Map 8).

I. Lithosols

1. Tolero Series* (Tl)

Shallow (2-20") black to dark brown humose loams over disintegrating metasedimentary or sedimentary rocks of the Karagwe-Ankolean System. Profile - not differentiated or weakly differentiated. Usually includes relic laterite gravel and occasionally a secondary ferruginous crust on rock-rubble.

Occur on level crests of the residual upland, at 4400-5600' a.s.l. and under 30-45" p.a. rainfall. Drainage of the profile is usually free, occasionally slow on the central parts of crests of larger residuals. In these cases the soil approaches Recent Tropical Soils.

Exchange capacity and base saturation are high: respectively 20-30 m.e. % and > 50%. Reaction is slightly acid to neutral**. Texture-dependent on parent material: sandy loams over arenaceous rocks (sand--50-70%); loams to clay loams (sand--30-50%) on argillaceous rocks of various metamorphic grades. Silt/clay ratio always exceeds 0.20. Organic carbon content exceeds 4%.

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* For all notes -- see end of section.

2. Sanga Series (Sa)

Shallow to moderately shallow (10-20") dark brown humose sandy to sandy clay loams over thick laterite sheets. Profile - not differentiated or weakly differentiated.

Occur on flat remnants of massive laterite, at 4400-4800' a.s.l. and under 30-45" p.a. rainfall. Drainage is usually free.

Exchange capacity is very low: 10-15 m.e.% in the upper horizons and < 10 m.e.% in the lower horizon; but base saturation is high (> 50%). Reaction is medium to slightly acid. Silt/clay ratio exceeds 0.20. Organic Carbon content is less than 2%.

3. Kateti Series (Kt)

Very shallow (< 10") black to dark brown humose sandy loams over quartzites and phyllites.

Occur on narrow sloping crests and moderate to steep slopes, at most elevations and under all rainfall conditions of the area. Drainage is excessive. Some deep pockets occur between boulders of outcrops where moisture retention is good.

Low exchange capacity (< 15 m.e.%) and base saturation (< 20%) and very strongly acid reaction. Silt/clay: < 0.20, but sand fraction is 60-80%.

II. Recent Tropical Soils

4. Bugamba Series (Bu)

Shallow to moderately shallow (10-20") dark to reddish-brown sandy or silty loams with a black to dark-brown humose topsoil over quartzite and phyllites. Weakly differentiated or A-C profiles. Usually includes relic laterite gravel.

Occurs on level or convex, usually narrow crests or edges of broad ridges, at 5500-5900' a.s.l. and under > 35" p.a. rainfall. Drainage of the profile is usually free to somewhat excessive.

Low cation exchange capacity (< 15 m.e.%) and very low base saturation (< 20%). Very strongly acid. Silt/clay: > 0.20, and sand fraction varies according to parent material: 30-70%. Organic Carbon: > 4%.

5. <u>Isingiro Series</u> (Is)

Shallow to moderately deep (10-14") black to dark brown and reddish-brown, humose sandy to clay loams, over arenaceous rocks of various metamorphic grades and argillaceous contamination. Profile represents various phases of development from skeletal to A-C and weakly A-B-C. Includes relic laterite gravel and incipient to moderately developed lateritic horizon.

Occur on level to convex crests of narrow to moderately broad ridges at 4700-5200' a.s.l. and under 25-30" p.a. rainfall. Drainage is usually free or moderate in mid-broad crests, where soils approach fersiallitic soils.

Exchange capacity is moderate to high (10-30 m.e.%) and base saturation is high (> 50%). Slightly acid, Silt/clay: > 0.20. Sand fraction content varying: 50-80%. Organic Carbon: > 2%.

III. Kaolisols

A. Fersiallitic (tropical ferruginous) soils

6. Rugaga Series (Ru)

Moderately deep (3.5 ft.) reddish-brown clay loams over argillaceous and arenaceous rocks. A-C and A-B-C horizon profiles. Include relic laterite gravel. Lateritic horizon, from incipient to well-developed, is occasionally present. Current or subrecent laterite outcrops are occasional on crest periphery.

Occur on level to convex crests of broad ridges, at 5000-5600' a.s.l. and under 25-40" p.a. rainfall. Drainage is moderate to slow.

High exchange capacity (20-30 me.%) and base saturation (> 50%). Neutral reaction. Silt/clay: > 0.20; Sand fraction: 30-40%. Organic Carbon: > 3%.

Possibly related and intergraded with the Isingiro Series.

B. Ferrisols

7. Mbarara* Series (Mb)

Moderately deep to deep (> 3 ft.) reddish brown over yellowish red loams and sandy loams, over mica-schists and medium and fine-grained granites. A-C and A-Bs-C horizon profiles. Occasional well-developed lateritic horizons of current and subrecent laterization outcropping along incised drainage lines.

Occur on gently sloping foothill pediments or, in a modified form, on interfluves of small arenas, at 4000-46000' a.s.l.

and under all rainfall conditions within the area. Drainage is slow and a catenary sequence is not differentiated except in overlying depositional fans at gully mouths.

Exchange capacity is moderate (10-20 m.e.%) and so is base saturation (40-50%), but reaction is medium to strongly acid in the sub-topsoil horizons. Silt/clay: > 0.20; sand fraction: 30-50%; Organic Carbon: 1-2%.

Due to an absence of clay-skins in the Bs horizon and the relatively high reserve of weatherable minerals in the sand fractions, the series probably represents an integrade approaching fersiallitic soils.

C. Ferralsols

8. Mawogola* Catena (Ma)

A catenary sequence of soil series on mid-lowland interfluves under the whole range of annual rainfall within the area. Developed mostly on preweathered, resorted and reworked material derived from coarse-grained granitoids. Appreciable content of weatherable minerals in the sand fraction of some associates may indicate an intgrade approaching tropical brown soils.

a. "Tor-base" Series

Moderately shallow to moderately deep (1-4 ft.) dark brown to reddish-brown sandy and gritty loams. Occur near base of "tor" outcrops at 4300-4600' a.s.l. A-C profiles; laterization absent. Drainage free to moderate. Exchange capacity - very low (< 10 m.e.%)

and base saturation high (> 50%) while reaction is medium to strongly acid. Silt/clay: 70.20; Sand fraction: 50-70%; Organic Carbon: 1-2%.

b. "Crest" Series

Moderately shallow to moderately deep (1-3 ft.) dark brown reddish-brown to reddish-brown sandy and gravelly loams. A-C profiles and stone-lines. Laterization absent. Occur on eroded interfluve crests and crest slopes at 4300-4500' a.s.l. Drainage is somewhat excessive.

Exchange capacity and base-saturation are very low (< 10 m.e.%; < 20%) and reaction very strongly acid. Silt/clay: < 0.20; Sand fraction: 30-60%; Organic Carbon: < 1%.

c. "Medium" Series

Deep (> 4 ft.) dark reddish-brown over yellowish-red sandy loams and loams with an A-C horizon profile and stonelines. Laterization is absent or slight. Occur on level, broad interfluve crests or on gentle interfluve slopes at 4200-4400 ft. a.s.l. Drainage is somewhat excessive.

Exchange capacity and base saturation are low (< 15 m.e.%; < 40%) and reaction very strongly acid. Silt/clay: < 0.20; sand 50-80%; Organic Carbon : < 1%.

d. "Hillwash"* Series

Deep (> 4 ft.) dark brown over yellow loamy sand and sand with an A-C horizon profile and stonelines. Laterization is absent.

Occur on lower interfluve slopes at 4100 - 4300 ft. a.s.l. Drainage is somewhat excessive.

Exchange capacity and base saturation are low (< 20 m.e.%; < 40%) and reaction is strongly to medium acid. Silt/clay: < 0.15; sand: 80-95%; organic Carbon: < 1%.

9. Koki Catena* (Ki)

A catenary sequence on narrow steep pediments under 35-40" p.a. rainfall. Developed on medium and low-grade phyllites, shales and mudstones, partly preweathered. Due to high silt/clay ratio and high base saturation in some of the associates, the soils may represent an intergrade approaching ferrisols.

a. "Red"* Series

Deep (> 4 ft.) yellowish red clays with an A-B+-C horizon profile. Laterization very slight or absent. Occur on upper, steeper pediment slopes at 4400-4700 ft. a.s.l. Drainage free to moderate.

Exchange capacity and base saturation very low (< 10 m.e.%; < 20%) and reaction strongly to medium acid. Silt/clay: < 0.20; sand: 30-50%; organic Carbon: 1-2%.

b. "Brown"* Series

Moderately deep to deep (> 3 ft.) brown to yellow-brown silty clays with an A-C or weakly A-B-C horizon profile; laterization is absent. Occur on middle, gentler, pediment slopes, at 4400-4700 ft. a.s.l. Drainage is moderate to slow.

Exchange capacity is low (< 15 m.e.%) but base saturation is moderate (> 40%). Reaction is strongly to medium acid. Silt/clay: 0.20; sand: 50-60%; organic Carbon: 2-3%.

c. "Yellow"* Series

Moderately shallow to moderately deep (2-4 ft.), pale-yellow silty clays with an A-C or weakly differentiated A-B-C horizon profiles. Laterization - very slight or absent. Occur on lower pediment slopes at 4000-4400 ft. a.s.l. Drainage is moderate to slow.

Exchange capacity and base saturation are low (< 15 m.e.%; < 40%) and reaction - very strongly acid. Silt/clay and sand: not determined; organic Carbon: 1-2%.

III. Humic Kaolisols

10. Rwampara Series (Rw)

Moderately shallow to moderately deep (2-4 ft.) dark brown to dark reddish-brown humus silty clays and clays over phyllites and quartzites. A-C or A-Bt-C horizon profiles. Relic laterite gravel; occur on level or convex crests on moderately broad ridges at 5600-5900 ft. a.s.l. and under > 35" p.a. rainfall. Drainage is free to moderate.

High exchange capacity (20-30 m.e.%) but low base saturation (< 15%) and very strongly acid. Silt/clay: 0.15-0.20; sand: 10-30%; organic Carbon: > 5%.

IV. Micasols*** or hydromorphic alluvial soils

11. Bukara* Series (Ba)

Moderately deep to deep (> 3 ft.) black sandy clay loams over dark-grey clays, developed on fluvial and lacustrine alluvium. Weakly A-C horizon profiles.

Occur on flat valley-floors, at 4000-4300 ft. a.s.l. under the whole range of annual rainfall within the area. Seasonally water-logged to slow draining.

C.E.C. moderate to high (10-50 m.e.%) and base saturation very high (50-100%), but very strongly to strongly acid; except in shallow phases where lowest horizon may be only slightly acid. Silt/clay: 0.15 - 0.55; sand: 45-75%; organic C: > 4%.

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* Nomenclature retained from Soil Survey of Uganda (Harrop, Radwansky, 1960).

** pH terminology according to USDA:

Extremely acid	below 4.5	Slightly acid	6.1-6.5
Very strongly acid	4.5-5.0	Neutral	6.6-7.3
Strongly acid	5.1-5.5	Mildly alkaline	7.4-7.8
Medium acid	5.6-6.0	Moderately alkaline	7.9-8.4

*** A definition introduced by Chenery (1960) who maintains that the very high proportion of dioctahedral mica in the clay fraction of these and other (Ntendule and Kabira Series) Uganda soils necessitates their definition in a new Great Group category.

All data except Organic Carbon content represent sub-soil horizons. Organic Carbon content represents topsoil alone.

Soil Relationships

Soil - laterite relationships

The significance of the differentiation between laterite and a lateritic horizon in relation to soils appears obvious. It was observed in the previous sections that current or subrecent lateritic horizons, still integrated within their original soil profile, are relatively infrequently within the study-area and are confined mainly to two types of soils--crest soils and foothill pediment soils. In both these types, lateritic accumulation appears to be largely absolute, through oblique leaching and on the pediments it is also largely secondary with the derivation of the lateritic materials being mainly in the adjoining upland. Even on these sites lateritic horizons are by no means frequent and appear to be associated both with the proximity of an extraneous source and with late geomorphic-pedogenetic development.

Where soils have developed on pre-weathered material, already well-leached of lateritic materials, laterization is slight and scarce, as in lowland developed at an earlier stage.

It is not, however, the earth-like lateritic horizons buried under relatively recent soils that pose the main problem of soil-laterite relationships, but the hard laterite sheets and crusts, entirely transformed in morphological character after being stripped of the original soil cover. Little is known of the role of hard laterite as a parent material in pedogenesis. What is known of the nature of hard laterite and its chemical and mineralogical composition suggests that reversal of hardening and pedogenesis on thick laterites would result in a soil composed mainly of alumosilicate clay, iron compounds and quartz, and devoid of any weatherable primary or secondary minerals except, possibly, in a very small amount representing relic minerals or soil gels formerly encapsulated within iron-concretions in the laterite. Presumably, in time such a soil may become more or less differentiated into horizons by a downward migration, under suitable conditions, of the more mobile compounds, although the probable compact clayey texture of such a soil makes it doubtful if the process will be rapid.

However, the reversal of hardening and soil formation from hard laterite are usually associated with the encroachment of vegetation and [illegible] decomposition of its litter, which constitutes a significant source [illegible] bases and nutrients. Conceivably, a specific successional sere may [illegible] about the gradual improvement of soil conditions at least in the [illegible] horizons and result in a stable nutritional cycle, of the type [illegible] in the highly leached rainforest soils. In such a case, it would [illegible] reasonable to expect that the sub-topsoil horizons will be still similar in chemical and mineral composition to the laterite. Reduction and chelation by organic matter will be confined mainly to the humic upper horizons and at any event would result in a downward gradient of decreasing base saturation and pH values. Also no primary or partially weathered minerals can be expected in such a theoretical soil.

Of the 138 catenas, series and complexes defined in the Soil Survey of Uganda (Chenery, 1960), only 3 are specifically stated to have laterite residues or sheet ironstone as parent material. In one of these--the Nzia Series from Buganda--the soil is skeletal and very thin differing from skeletal soils on bare bedrock in being more clayey and of reddish-brown colour. The other two units are the Rugaga Series which has been discussed above and the crest member of the Nyabushozi Catena. In both cases, fairly deep (over 3 ft.) soils are stated to exist upon sheet ironstone, both profiles showing a downward increase in base saturation and pH values and a relatively high base-content in the subsoil (over 6 m.e.% in the Nyabushozi soil and over 12 m.e.% in the Rugaga soil). In fact, in the three criteria, these soils, and especially the Rugaga soils, exceed the values shown by most other units of kaolisols. Furthermore, in both cases it is stated by Harrop (1960) who defined these units, that no satisfactory explanation has been found for their peculiar nature in relation to the underlying massive laterite.

Of other relatively recent work dealing with soil-laterite relations in Africa, those of Maignien (1958) and Alexander and Cady (1962) in West Africa appear to be the most authoritative. Both recognize that hardening of laterite can be reversed into soil formation and bring several examples of soils developed on hard laterite. Maignien confines himself to descriptions of the profiles which are never deeper than approximately 30 cm. and include a relatively large proportion of isolated laterite blocks. Alexander and Cady present as many as eight samples of such soils with profiles varying in depth from 10 to 60 cm., i.e.-- none over 2 ft. deep. Only four profiles of those overlying hard laterite (and not laterized rock waste) were analyzed for exchangeable cations and only in three of these was exchange capacity determined. In all four, base content does not exceed 6.1 m.e.% (ibid. p.48) and in three--1.1 m.e.% (ibid. pp. 26, 40). Base saturation in the three profiles does not exceed 20% and is 5-6% in two of the profiles. Reaction in the sub-topsoil horizons does not exceed pH 5.4 and clay-mineral analyses of these show only secondary and primary resistant minerals containing no bases. The conclusion reached by the authors in view of these facts is, as already observed, that for a laterite crust to break up and develop into soil, "it seems that some overlay or additional material that can supply nutrients and hold water for vegetation is almost essential." (ibid. p. 12.)

There are, consequently, three possible explanations to account for the base-rich, saturated and neutral or only slightly acid soils of the Rugaga Series and the Nyabushozi "crest" type. If it is maintained that laterite constitutes the parent materials of these soils, one possibility of explaining the nature of the soils is in assuming that this parent material contained relatively large amounts of encapsulated weatherable minerals. There seems to exist no evidence of such amounts either in the laterite samples from the area (see Table 7 ; p.200) or any examples listed in the literature. Content of alkalies in 19 samples of hard laterite analysed by Alexander and Cady (1962) ranged between 0.22 and 1.25%, averaging 0.36%. Six samples analysed by Maignien (1958) show a range of 0.28 - 0.88%, averaging 0.54%. It seems, therefore, highly unlikely that the exchangeable bases in the soils derived from the laterite itself. The only other answer is a possible accretion of extraneous material.

Accretion of material rich in bases may come from two sources--a higher adjacent weathering surface or a proximate centre of volcanic activity. The location of the type-profile of the Nyabushozi soil precludes the first possibility since the nearest weathering slope of a higher surface is situated approximately 15 miles away with extensive tracts of lowland intervening. It was already observed that the Rugaga type-profile is, on the contrary, located at the foot of such a slope and it was argued that its high base-content and saturation may be assigned to this fact. However, the nearest profile examined in the present study, and located on the highest crest of the hillmass, although not as rich in bases and as saturated, still shows the highest base content and saturation than any other soils in the area. The nearest higher slope is 5 miles away. Consequently while accretion of extraneous material into the Rugaga type profile is probable, it does not signify that it enriched an intrinsically poor soil profile.

The invocation of accretion by volcanic ash presupposes a gradual increase of accretionary material in the direction of the centre of volcanic activity. The closest volcanic centres that can be related to the study area are the Bufumbira volcanoes, 30-100 miles to the southwest, on the Rwanda-Congo border, and the Kicwamba area 50-70 miles to the northwest, in northwestern Ankole. It is sufficient to indicate that while the soils derived from the volcanic rocks in these soils have (at a depth of 25-30") an average base content of 18 m.e.% (3.8-29.2), a mean saturation of 76% (25-100), and a mean pH value of 6.8, the upland soils derived from adjacent precambrian rocks show respective average values of: 0.09 (0.0-0.20), 1.4 (0.0-3.3) and 4.5 (5.1-5.1). Lowland soils intervening between the study area and both volcanic centres show higher mean values, especially where rainfall is relatively low but they do not compare with the higher mean values of upland crest soils of the Rugaga type. Thus, even considering that the data are supplied by very few samples, there appears to be no evidence of accretion of volcanic materials between the study-area and the volcanic centres, although volcanic activity in these centres is comparatively recent (Combe, 1933; Holmes and Harwood, 1937; Holmes, 1942, 1942, 1950, 1952).

It was suggested above that for the Rugaga-type soils the solution of the problem appears to rest in an erroneous impression of the distribution and nature of laterite on the surface carrying these soils. That, in fact, the soils did not derive from a massive sheet of laterite but from the underlying rock subsequent to the stripping of the sheet. As to the Nyabushozi-type soils, no similar solution can be offered. The writer has not been able to observe the site of the type-profile for that soil and in all cases of massive laterite which have been observed in the area, soil cover was scant and the soil itself plainly skeletal.

However, the description of the type-profile (Harrop, 1960, p. 55) does not specifically state that it overlies massive laterite. The soil is described generally as shallow, dark-humose loam overlying laterite rubble, which in the description of the profile is asserted to represent disintegrating laterite. This may mean that the rubble represents only residues of an eroded sheet. The soil-type is similar to recent soils derived from bedrock, and the high base and phosphorous content may be assigned, as in those soils, to high content of organic matter and excessive drainage causing prolonged dessication during each year.

These arguments, envisaging the soil as derived from recently exposed fresh rock subsequent to the stripping of the massive laterite sheet, do not explain several phenomena such as the concentration of laterite rubble in the lowest horizon and the apparent absence of a "pallid zone" usually present under massive laterite on incompetent rocks. Consequently, in regards to this soil-type, the writer agrees with Harrop's statement that "no satisfactory explanation can be given that might apply generally" (ibid.) concerning the tendency for hill-crest soils to be richer in bases and phosphorous.

The geomorphic relationships of soils

Soil-Surface correlations (a generalization)

The evidence of soil distribution and the genetic implications of soil properties as presented in the previous sections can be generalized in the following points:-

1. In general, soil characteristics are correlated with contemporary intensity of geomorphic processes rather than with the postulated relative age of the surface. Soils in an initial or active state of pedogenesis are associated, therefore, with landforms connected with strong dissection, resistant lithology, and a generally youthful landscape while soils in a retarded or halted state of pedogenesis are associated with a mature landscape in which geomorphic processes have decelerated. In the circumstances of the geological pattern of the area, where incompetent lithology is, as a rule, disposed low down the stratigraphical column, such a correlation is clearly unrelated to the time factor. A late erosion surface, cut across the incompetent lithology may attain maturity, deceleration of geomorphic processes and retardation of pedogenesis before an earlier surface of resistant lithology has passed the youthful stage. Thus, properties and distribution of soils

in the area reflect the degree of stability imposed by the geomorphic ratio of waste production to waste removal. Where rate of weathering exceeds the rate of erosion, soils will be sedentary and their present character will reflect the length of time since they attained stability. Where reverse conditions prevail, soils will be unstable and their present character will reflect the balance of erosion over pedogenesis.

2. The exceptions to this rule concern the intervention of two factors. Climatic altitudinal zonation induced by uplift appears to have resulted in at least one pedological boundary situated roughly in the interval between 5600 and 5700' a.s.l. No doubt influence of elevation upon the nature of soils is enhanced in the particular case by a greater amount of rainfall and where this amount is lower the altitudinal transition will occur at a higher elevation. Above this limit, soil properties are modified by greater efficiency of moisture supply and a retarded decomposition of organic matter resulting in greater intensity of leaching and stronger acidity of the medium. Probably the altitudinal transition is gradual and leached acid soils appear in particular sites also at a lower elevation. Certain topographic relationships also tend to result in soil properties which do not conform to the generalization. Where such relations are determined by contrasting lithology as in pediments formed on incompetent rocks at the foot of resistant retreating slopes, soil characteristics are governed not only by the relative youthfulness of the pediment landform but also by the adjoining slope. Since the topography of the pediment conforms to the incompetence of the underlying bedrock the transported material from the adjacent

eroding upland is retained within the soils and enhances their general similarity to upland, actively evolving soils. Where, on the other hand, the formation of foothill pediments occur in a uniform, relatively resistant lithology and is controlled by erosional factors alone, they tend to be shorter and steeper. Consequently, internal drainage is somewhat excessive and soils, while still actively evolving tend to be more leached and acid than upland soils. Such a tendency is enhanced by higher rainfall and affected by the nature of the lithology and drainage. Impoverishment of base content, low saturation and strong acidity are enhanced, therefore, where either drainage is excessive or where parent rock is already partially leached.

3. The pattern of soil-surface correlation consists, therefore, of three levels:-

a) The lowland level on which three soil-types emerge: mid-lowland soils developed in material differentially pre-weathered in a former cycle or phase and differentially stripped in the following phase; Foothill-pediment soils on incompetent but unweathered lithology and backed by high-grade metasediments; Foothill pediment soils on low-grade metasediments and sediments which are in part leached. The first and last types consist of catenary sequences differentiated according to freedom of drainage, measure of stripping of deeply weathered parent material in the first case and measure of leaching of the parent material in the second. The second soil-type does not show pronounced catenary differentiation due to relative uniformity of parent material and drainage conditions.

b) The intermediate upland level on which soils constitute an evolutionary sequence dependent on the angle of the crest-slope. On the least inclined parts of the crest a mature, moderately drained, but actively forming soil emerges. Where crest area is limited and slope angles are greater the nature of the soil varies from raw lithosols to an already differentiated recent soil. The nature of this evolutionary sequence varies according to lithology and drainage. In all soils of this level a relatively low amount of rainfall contributes to enrichment in bases.

c) The high upland level on which climatic circumstances tend to counter-balance the relative youthfulness of the soils by more profound leaching and lesser mineralization of organic matter. These tendencies appear in all the stages of soil development which, as on the intermediate level, are controlled by the angle of slope and the nature of lithology.

A Pattern of Landscape Evolution

(Conclusion to the Chapter on Geomorphology and Soils)

A Synopsis of Surface Development

Controls of surface development

The exposition of landscape evolution presented in the present study is based on the assumption that all or most of the study-area was covered, at the initial phase of evolution, by a certain thickness of metasedimentary or sedimentary formations. It is an essential argument of this exposition, derived from the clearly apparent differential competence between sedimentary and plutonic formations in the area, that this resistant sedimentary cover was thickest in the belt now occupied by the South Ankolean Highland and Koki Hills and thinned out gradually northwards. Such an initial geologic pattern would indicate that the present geological pattern resulted from the differential removal of the sedimentary cover, controlled by its differential thickness and structure. Since incompetent lithology is disposed uniformly at the base of the stratigraphic column, its effect on the evolution of the landscape became apparent only at a progressively later stage with the southward growing thickness of the resistant cover. In other words, this means that development of the lowest surface in the area advanced in a general southward direction. The measure and extent of this advance was, of course, subject to the irregularities in the topography of the incompetent basement but the general pattern of northward removal of the resistant cover is well attested by the present geomorphological and geological patterns.

While lowland lithology is relatively little differentiated in degree of incompetence and its reflection in the landscape is comparatively meagre, resulting in slight differences between the major groups of granitoids and schists, the expression of differential competence of upland lithology is much more pronounced. This differentiality appears to depend mainly on metamorphic grade and the nature of the structure so that high grade metasediments disposed in many major, steeply dipping, folded structures appear to be the most resistant while unmetamorphosed sediments in indistinct broad shallow structures are the least resistant. This differentiality is expressed in the degree of dissection of upland landforms and the associated preservation of crest surfaces. However, in contrast to the vertical stratigraphic differentiation of competence which determined the relative extent of lowland and upland, the metamorphic-structural differentiation is mainly horizontal decreasing both eastward and northward. Consequently, the amount of upland dissection as controlled by lithology increases in both directions and appears to have constituted a significant factor in landscape development.

Geological control is expressed, therefore, in the emergence during the geomorphic evolution of the landscape of several physiographic units differentiated according to the competence of their lithology and by the age and extent of former landscapes preserved upon them. Thus, lowland, representing the latest major stage of landscape evolution is wholly developed upon basal incompetent lithology and is only slightly and shallowly dissected by later stages. In the upland, developed on more resistant lithology, the least resistant mudstones and shales in indistinct major structures, produce the most dissected type of landscape consisting of relatively low individual upland features separated by gaps of lowland and preserving only remnants of the latest phase of upland landscape evolution. Low-grade metasedimentaries in more distinctive structures produce the hill-series type of topography where lowland gaps finger only between ridge-line groups of features on which small remnants or modified remnants of an early stage of upland evolution are preserved. Metasediments of intermediate grade or of relatively meagre thickness produce high hill-masses or residuals, on which remnants of the early stage predominate with occasional remnants or modified remnants of the earliest stage. The high-grade metasediments arranged in major folded structures, produce the highest mountain blocks of the area preserving remnants of the initial stage of evolution.

The view propounded in the present study is that the evolution of the upland landscape in southwest Uganda was initiated by what L.C. King (1967) described as the 'cymatogenic' uplift leading eventually to the formation of the Rift Valley. It envisages, previous to that uplift, an initial mature surface of continental extent possibly identical with King's African Surface. It is, however, unlikely on the present view, that this initial surface evolved only by Lower Miocene as was maintained by the classic postulation. It appears to this writer that the time that should be allowed to account for the envisaged evolutionary sequence indicates a much earlier age for the initial surface and the initiation of cymatogenic uplift,-- possibly pre-Tertiary. It must be remembered that initiation of uplift need not have coincided with rifting. More probably uplift preceded rifting by a long period. On the other hand, rifting, when it did occur, was not necessarily associated with immediate uplift of the rift shoulder and reversal of westward drainage. This probably occurred only at a very late, relatively recent, stage of the uplift. There is strong evidence that rift and downfaulting occurred at a much earlier period than previously supposed. According to Bishop (1966), "the age of the initial rift-faulting is still rather uncertain, but is probably pre-Miocene at least and may well be older still" (ibid. p. 171). If Dixey's (1956) views on the early origin of the regional upwarp associated with the Western Rift and the Ruwenzori block and his evidence from the Southern Rift are added to this, it appears that a strong case for a pre-Tertiary initiation of the cymatogenic uplift does exist.

A possible different interpretation is that the older stages of landscape development preceded the initiation of uplift and that their present remnants existed probably in a greater extent, on the initial, pre-uplift surface. Such an interpretation would extend the geological time available for the development of the different surfaces enough to regard each stage as a major cycle on a continental scale. It would also necessitate the postulation of continental origins of changes in base-levels, probably the same as stipulated by L.C. King. In other words, such an interpretation would bring the postulated sequence of development closer to the classical scheme of Uganda Surfaces with a revised dating.

This interpretation is not implied by the evidence from the study-area. The writer believes that the reasonable possibility of a very early initiation of uplift is sufficient to account for the evolutionary sequence within the study-area. It must be kept in mind that the differentiation of surfaces is envisaged on a limited regional scale and that the causes of this differentiation are attributed to a regional differentiality of upwarp within the general cymatogenic uplift. That is to say that the controlling base-levels of each new phase are envisaged within the region itself or only slightly outside it, so that the extent of the surfaces developed in each phase is relatively limited. Furthermore, the altitudinal interval between any two consecutive surfaces, indicating the degree of the associated differential upwarp, does not exceed within the study-area, the average values of 600 ft. between first two upland surfaces and of 400 ft. between the second and the third. This interval may be greater between the lowest upland surface and the lowland but in this case it is accounted for by the great difference in lithologic competence. No attempt has been made to correlate these surfaces with surfaces outside the region and tentatively they are assumed to represent phases of a major cycle initiated by the general cymatogenic uplift. This means that the lowland surface represents the culminating phase of the major cycle.

If it is identical with lowland and pediment surfaces defined in other parts of Uganda it may be equivalent to McConnell's (1955) and Pallister's (1960) Tanganyika Surface or Bishop's (1966) Kasubi Surface, differing from them in that its development did not terminate by end-Tertiary times, but continued far into the Pleistocene, for as long as uplift continued. Such a concept of phasal development within a major, very prolonged cycle, involves the possibility that the uppermost level in the area, representing remnants of the initial surface, may be equivalent to the much lower, lakeside Buganda Surface. However, the present study does not provide sufficient evidence for a country-wide correlation of surfaces. It only establishes that the landscape of the area developed in several distinct phases which may or may not be correlated with phases beyond its limits.

The sequence of phases

1) The initial (Rwampara) phase. The initial surface is envisaged as part of a continent-wide mature landscape with a slight westward inclination. It is regarded as having had preserved on it a measure of relief correlated with the pattern of geologic competence. Since metamorphic grade and structural resistance show a definite trend of southward and westward increase, it is considered that the highest relative relief within the study-area was located in the southwest, forming a highland mass which embraced the present areas of the Rwampara, Western Isingiro and Kargawe. A rough calculation* shows

* Based on assumed datum levels in the lakeside area, calculated to account for thickness of laterite, and on distances from postulated regional base-levels in the Katonga and Lake Victoria areas.

that in its highest parts this mass may have attained in relation to the mean surface level, an available relief of 1000-1500 ft. It had a variable, but generally slight, northward and eastward slope which, probably, did not exceed the rate of 20 ft./mile. Most of the surface consequently drained northward towards the proto-Katonga. A small area possibly drained eastward or south-eastward into a tributary system of the proto-Katonga. Only the western margin and the southwestern-highland part, apparently belonged to a different catchment area--that of the proto-Kagera. While this drainage system appears to have been also remotely tributary to the main proto-Katonga system, its basin within the resistant highland was only subsidiary. Consequently, being subject to a relatively proximate local base-level it effected greater slope gradients within the highland, as indicated by the altitudinal disposition of present surface remnants (approx. 50 ft./mile).

2) First (Gayaza) phase. The first phase of landscape evolution was initiated by beginning of uplift. Within the area, the uplift consisted of general differential warping, uplifting the western margin of the area by approximately 200 ft. in excess of the eastern margin, and of differential deformation which affected only the area west of the present Rugaga hill mass, adding, at thewestern margin,another 200 ft. to the uplift. Uplift was followed by a prolonged pause during which a very extensive levelled surface emerged in the proto-Katonga basin producing notched scarps in the flanks of the deformed area. Where deformation was small, as on its eastern margin, the scarp was relatively low;

where it was greater, as in the Eastern Rwampara, the scarp may have attained a height of 500-600 ft. In the eastern part of the highland, in present area of Western Isingiro, where both erosional orientations coincided, levelling breached the watershed, isolating and partly modifying remnants of the initial surface from the main mass of the highland. However, the levelling, possibly enhanced by other factors such as structural weakness, apparently did not disrupt the existing drainage pattern, so that the lowered area was retained within the proto-Kagera basin. In the more resistant part of the basin, however, the erosional phase did not progress beyond the formation of sloping valley floor surfaces, possibly due to the fact that change of northern regional base-level in the proto-Katonga was very remote and the drainage was not affected by closer eastern base-levels. The extensive levelled Gayaza Surface whose present remnants on resistant lithology show a relative relief not exceeding 300 ft. was, probably, even more subdued where cut across less competent low-grade or unmetamorphosed sediments in the north and northeast. On the other hand, where massive quartzites occurred, several modified remnants of the initial surface rose 200-300 ft. above the general level. Correspondingly, it is possible that already at this stage the precursors of the arenas, such as the Masha and Ishura, formed depressions in the surface where basal schists were already exposed. In relation to the Masha arena it is difficult to say whether it belonged to the proto-Ruizi or to the proto-Katonga catchments.

3) Second (Sanga) phase. This phase was initiated by the resumption of uplift. Compared with the previous phase it was, probably, shorter and involved no deformations so that east-west differential did not exceed 100 ft. Moreover, differential warping was continuous and erosional development already affected extensive exposed areas of incompetent basal lithology. The pattern of the new surface was, consequently, less uniform and lithological differentiation more pronounced than on the previous surface. On extensively exposed, relatively or absolutely incompetent lithology, planation was advanced, associated with relative, primary, laterization and very deep weathering (Ishura, Nyabushozi, Mbuga-Bubale, Northern Koki). Here the surface was the lowest, approximately 400-500 ft. lower than the Gayaza Surface, with few exposed quartzite ridges already rising slightly above it. On more resistant lithology the surface sloped gently up to join the Gayaza Surface in a noticeable break of slope; low scarps emerged only where induced by differential lithology. Usually this part of the surface was represented in headwater drainage basins such as the present Lower Ruizi and the Masha and Ikariro arenas which, perhaps then resembled the Lower Ruizi basin's present state. Of similar dimensions although of different pattern were two elongated sloping basins in the Eastern Rugaga-Chamburara and the Central Koki areas. They developed along existing northwest directed drainage lines on intermediate lithology and limited remnants of the Gayaza Surface were preserved on the Western Koki watershed between them. There is no indication that this phase penetrated the proto-Kagera catchment so that drainage pattern remained essentially the same.

4. Third (Lowland) phase. It is not clear what event caused the initiation of this phase. Possibly, the cause lies beyond the limits of the area, perhaps associated with a stage of differential warping that affected uniformly the whole region or at least the part including the study-area. A significant lowering of regional base-level occurred without a noticeable effect on differential upwarping within the area. The associated erosional phase affected mainly basal incompetent lithology, in part deeply weathered, and consequently proceeded at a relatively rapid rate modifying profoundly the lowland surface and expanding it at the expense of the older upland, probably by inducing predominance of slope retreat. Landscape evolution was, therefore, much more complex than previously. Several stages may be discerned, marked mainly by profound changes of drainage patterns:

(a) A rapid but still partial stripping of the weathered mantle over incompetent lithology of the proto-Katonga catchment caused the elimination of most of the Sanga Surface in these areas and its restriction to marginal areas of resistant lithology and few laterite caps on watersheds. A lithologically induced scarp began to emerge between the surfaces. The highest irregularities of the basal surface were etched as "tors" and quartzite ridges; and where drainage lines reached the unweathered or less weathered base, lateral erosion produced typical flat floored valleys. Abrupt readjustment of local base-levels induced by this rapid erosion, caused two significant changes in drainage pattern: the upper part of the Central Koki drainage basin was captured by the Chamburara (Karunga) drainage across the Western Koki watershed. This is attested by numerous levelled benches abutting the slopes of the capture channel and the Chamburara and Western Koki hill masses at a similar level, approximately 100-200 ft. lower than the Sanga Surface remnants. This capture, probably due to the greater southward extent of the Ishura lowland, resulted in the lowering and initiation of the present Kijanebalola basin; the other change concerned the breach of the highland watershed south of Kasumba and the capture by the present Lower Kagera of the headwater, subsidiary, basins of the proto-Kagera, represented today by the Orichniga and Bigasha systems. The effect of lowland stripping was probably enhanced in this case by the cumulative effect of differential upwarp and the proximity of regional base-level. The capture resulted in the dissection of the up till then intact Gayaza Surface of Western Isingiro.

(b) The main occurrence at this stage was the breach by the Orichinga of the already tenuous Bugarama-Isozi watershed, probably due to the effect of the newly established southeastern base-level. This breach, exposing to this relatively vigorous base-level the extensive areas of incompetent mica-schists of the present Nakival-Mburo lowland and the as yet not entirely stripped weathered mantle of the present Ishura lowland, resulted in the complete reorientation of the drainage system and the profound modification of the lowland surface in the centre of the area. The newly-formed southern low ground caused the acceleration of weathered mantle stripping, the destruction of former lowland-divides and even the capture of north-directed drainage across the resistant remnants of the Sanga Surface (e.g. that of the Mazinga-

Mbuga System by the Nyarutegura). It resulted consequently, in the migration of the watershed from the southern highland axis to a northern mid-lowland alignment, where it is still gapped by several wide valley floors. It also caused the incision, below the lowland surface, of the present drainage pattern, the precursor of the present Lake Systems which was, however, still directed westwards and had no connection with the proto-Ruizi system.

(c) Warping, which up to this stage had been slow and possessed a small east-west differential, began suddenly to accelerate--probably in late-Middle Pleistocene (Bishop and Posnansky, 1960). Acceleration was associated with a second deformation of the area west of Masha, adding 200 ft. to the 100 ft. east-west differential of warping attained during the lowland phase. A readjustment of drainage occurred in the western parts of the Masha arena and Lower Ruizi basin, associated possibly with the final exposure of the granitoid core in the former, a westward expansion of the latter, and the breaching of the Bihunya-Kabulangire range into the Mbarara arena.

This outline is, of course, tentative. Details of lowland surface development may have occurred at different stages than implied by it or processes may have been continuous from one stage to another. Thus, possibly, the capture of northward drainage across the Sanga Hills and development of the present Mburo-Kisimbi drainage pattern may have occurred mainly in the stage of deformation. The evolution of the Lake-System drainage pattern may have continued throughout the last stage. Or, more significantly, the capture of the Orichinga-Bigasha drainage by the Lower Kagera may have resulted, already in this phase, in the lowering of the Nsongezi-Kikagati gorge and capture of the Eastern Rwampara drainage by the eastward drainage. Such an occurrence, as that in western Masha and possibly aligned on the same deformational axis, prepared the way for the future capture of the Proto-Kagera system which was prevented at this stage only by insufficient differential warping.

5. Fourth (Aggradation) phase. The acceleration of differential warping across the rising Rift shoulder, finally resulted in drastic reduction of drainage gradients and reversal of its direction. Aggradation of valleys followed, and the widespread drowning of the drainage system. Usually, latitudinally aligned drainage lines were more extensively aggraded and drowned than those longitudinally aligned, which explains some very shallow alluvial deposits in very wide valleys. In some cases aggradation and ponding back of headwater basins was followed by capture and draining by east-directed drainage, prominently that of "Lake Ruizi" by the Lower Ruizi; or that of "Lake Kagera" by the Lower Kagera, through the Nsongezi-Kikagati gorge. In both cases, capture and draining of new upstream drainage were followed by ponding back, lower down the new drainage systems--the Lake System in the case of the Ruizi and Lake Victoria in the case of the Kagera. The extensive ponding-up of the Lake Victoria basin reached the limits of the study-area only in the extreme south, along the Kagera valley, up to Nsongezi, and probably left its mark on the main drainage lines of the Ikariro

lowland. Otherwise, the last phases of the upwarp, terminating in the recession of Lake Victoria to its present shores, left no distinct impression on the study-area.

The Sequence of Surface Deposits

The relations of laterization and pedogenesis to landscape evolution are summarized in Table 9 , in which an attempt was made to emphasize the main points of sequence. It is, necessarily, a largely hypothetical scheme, especially concerning the sequence of former soils, but this necessity of hypothesis emphasizes the principle that in a highly dissected and tectonically unstable landscape, one cannot expect to find age correlations between surfaces and their deposits. The summary attempts to emphasizeanother principle--that the nature of surface deposits depends not on geomorphic features alone but also on macroclimatic environment. Where surface is relatively stable and little disturbed by geomorphic processes, relic influences of former environments may be preserved in surface deposits. Otherwise, they reflect only the contemporary environmental conditions.

A much more detailed and specific study is needed in order to work out the actual environmental sequence in the study-area. The present summary intends only to emphasize the fact that there was a significant change of environmental conditions of surface-deposit formation. The long period of prevalence of ferrallitic conditions should be regarded, consequently, as a strongly generalized interpretation. It is well-known

TABLE 9 : RELATIONSHIPS BETWEEN SOILS AND LANDSCAPE EVOLUTION

		Resistant lithology		Incompetent lithology			
		Rwampara	Gayaza	Sanga	Lowland		
ferrallitic environment	1	Stripping of ferrallitic soil; exposure and hardening of relatively accumulated, primary lateritic horizon.	Surface formation; ferrallitic pedogenesis; absolute/relative accumulation of secondary/primary lateritic horizon.	-	-	dissection by down-cutting and crest lowering followed by planation.	uplift followed by stable phase.
	2	Stripping of laterite; new ferrallitic pedogenesis; P/E<1	Stripping of soil cover; exposure and hardening of lateritic horizon.	Surface formation: ferrallitic pedogenesis. inclined surface: absolute accumulation of secondary lateritic horizon. planed surface: relative accumulation of primary lateritic horizon. Deep weathering.	-	resistant lithology: down-cutting and crest-lowering; incompetent lithology: planation.	mild continuous uplift.
	3	Rise to montane elevations; stripping of laterite; new humic intergrade pedogenesis P/E<1	Stripping of laterite; new ferrallitic pedogenesis; P/E<1	Stripping of soil cover; exposure and hardening of lateritic horizon.	Surface formation; rapid partial stripping of weathered mantle; ferrallitic pedogenesis on pre-weathered material; absence of laterization; P/E~1		
fersiallitic environment	4	as in phase 3; except P/E~1	Completion of old laterite stripping; new fersiallitic pedogenesis; formation of pavement laterite P/E~1 Residuals: P/E<1; skeletal pedogenesis.	Differential stripping of laterite (thinner crusts removed); skeletal pedogenesis on hard laterite and resistant lithology.	Expansion of surface; new fersiallitic pedogenesis on foothill pediments; brown soil intergrade pedogenesis in mid-lowland soils P/E>1	growing prevalence of slope retreat.	dwindling and termination of uplift.
		evolutionary sequence of humic intergrade kaolisols 1. Bugamba-recent 2. Rwampara-mature	evolutionary sequence of fersiallitic soils 1. Isingiro-recent 2. Rugaga-mature skeletal soils on residuals 3. Tolero	skeletal soils 1. Tolero-on resistant bedrock 2. Sanga-on hard laterite	Pattern of leached soils 1. Ferrallitic-brown soil intergrade (Mawogola)-mid-lowland 2. Ferrallitic-ferrisolic intergrade (Koki)-steep short pediments 3. Ferrisols (Mbarara)-gentle long pediments.		

P/E: pedogenesis/erosion ratio

that since early Tertiary several alterations of climatic conditions occurred, at least westward of the present region (Cahen, 1954; Cahen and Leperssonne, 1956), but it is impossible to correlate them with any accuracy with the available evidence of the present region. While the nature of laterite relics on the Rwampara Surface may point to ferrallitic conditions at an early stage of the geomorphic history, the next evidence of such conditions is provided by the nature of soils on the relatively late mid-lowland areas. Consequently the intervening period may have witnessed several alternations of conditions from humid-ferrallitic to arid-fersiallitic and back, without any evidence having been preserved in the land surface or its deposits.

The summary also obscures some points of detail such as the predominant influence of local geomorphic and other environmental factors over the general macroclimatic factor. This may result in specific deposit characteristics which do not conform with the general climatic environment. Thus, the Koki soils show ferrallitic properties under a subhumid climate, and foothill pediments show ferrisolic properties under a semi-arid climate. In addition, the summary may tend to impart the impression of abrupt changes, of restriction of processes to a certain phase or their prevalence throughout some phase. In fact, transitions between phases should be regarded as very gradual and processes of deposit formation as variable in duration, at times continuing into another phase than that in which they are indicated or as prevalent only during part of it. A final point to note is that present characteristics of soil units or specific surfaces are subject not only to catenary differentiation but also to a spatial, geographical pattern. Their definition, therefore, is generalized and it is doubtful, for instance, if all mid-lowland soils have developed on equally pre-weathered material and that they are, consequently, equally ferrallitic.

V E G E T A T I O N

The Nature of the Vegetation

Types of Vegetation

Invariably, attempts at classification of vegetation involve a preliminary problem similar to that encountered in pedological classification, namely -- whether the classification should be based on objective field evidence alone or should it represent genetic postulations derived from this evidence. In relation to African vegetation, such postulations are often quite difficult, as certain types of vegetation may be natural in one area and induced in another. Frequently, also, the absence of relic evidence of a different vegetation makes it difficult to judge the genetic position of the existing vegetation and to decide whether it is natural or derived. It is, consequently, the dearth of evidence that often prevents the elaboration of "natural" classification, embracing more varied sources of information, and the lesser the detail, the greater is the tendency to avoid genetic postulations and base classification on physiognomy.

Although literature concerning the vegetation of Uganda is quite numerous it is mostly concerned with very limited areas or specific types of vegetation and almost none of it can be directly related to the study-area or to its prevalent vegetation types. However, Uganda is also as yet the only country in East Africa which has received an overall survey of vegetation. A relatively short but very illuminating treatise, laying emphasis on grass communities was presented by Snowden (1953). A much more detailed and relatively recent survey was presented as a series of the Memoirs of the Research Division in the Ministry of Agriculture of Uganda (Langdale-Brown, 1959-60; Wilson, 1960). Vegetation types of the area were, consequently, studied mainly on the basis of these two works.

Major physiognomic types.

Most of previous classifications of East African vegetation appear to have been influenced by Schimper's (1898) concept of three major vegetation zones, of three basic formation types:- woodland, grassland, and desert and of two kinds of formation -- climatic and edaphic. The types defined by these classifications were named accordingly, adapted to combinations found in the relevant area with various additional environmental criteria, usually -- moisture supply and altitude, for subsidiary subdivision (e.g. Chipp in Tansley and Chipp, 1926; Burtt-Davey, 1938; Greenway, 1943). Snowden was apparently also influenced by this approach, but the smaller scope of his survey enabled him to formulate a more detailed division of major types based on physiognomic-botanical features. It appears that through this division he also attempted a climatic differentiation indicating a genetic classification in the sense that his formations were also climatic climaxes. He differentiated in the first category between vegetation of plains and hills (below 1680 m. altitude) including all tropical formations, and montane vegetation including subtropical, temperate and alpine formations. According to his map, montane vegetation is not represented within the study-area although the highland there exceeds the altitudinal limit he set for tropical vegetation. Of the tropical formations, according to this map, only two are represented within the area: the Acacia and Mixed Woodland formation which occupies most of it and the Evergreen Forest formation occupying only the eastern margin and probably indicating the transition to the humid lakeside region.

As some others before him, Snowden avoids the usage of the term "savanna"; possibly in response to the controversy and doubts attached to it and expressed shortly before by Aubreville (1949). Apparently since then views on the application and usage of the term have become more crystallized. Langdale-Brown's survey accepts the term as designating a definite vegetation type of both a genetic and a physiognomic application, indicating that it can be applied both to natural-climatic and edaphic-climaxes and to induced vegetation and that it is a very useful descriptive term in regards to African vegetation. In that, as in all his classification, Langdale-Brown follows mainly the Yangambi physiognomic system which was outlined as a provisional general scheme for the vegetation of the whole of Africa south of the Sahara (CSA/C.C.T.A., 1956). He also uses this physiognomic system as a descriptive basis for a natural successional classification.

It is a characteristic result of such an approach that formations defined on a physiognomic basis and those defined on a genetic basis are identical and are composed of the same communities. It is only the allocation of the communities to different formations that distinguishes the physiognomic from the genetic system. This implies that secondary vegetation induced by anthropogenic factors can have only a certain range of physiognomic formational expression, a range dictated by environmental conditions. The conclusion appears to be of much significance in relation to African vegetation since it rejects the view that any vegetation-type on the formational level, and certainly on the formation-group level, such as the savanna, can be wholly derivational. Langdale-Brown also modifies the Yangambi system in that he unites the Wooded and Tree Savanna formations regarding them possibly as representing different grades of disturbance of the same community. Although the same reasoning can be applied also to grass savanna the physiognomic difference is much more profound and in some cases a grass savanna has no genetic connection with the other types.

Langdale-Brown distinguishes within the study-area mainly two physiognomic formations or subformational vegetation types: Compound-leaf Savanna Woodland (Acacia) and Tree Savanna of the type associated mainly with Themeda grass spp. and Grass Savanna of the types dominated mainly by Themeda and by Hyparrhenia grass spp. The former predominates on lowland interfluves, some upland crests (Isingiro and part of Koki) and also in some wide, seasonally inundated, valleys (Nyabushozi and Ikariro lowlands, Bigasha and Orichinga Valleys). Of the latter, that dominated by Themeda is prevalent on most upland crests and slopes and also in some valleys (Lyamtonde-Kachera area); that dominated by Hyparrhenia is prevalent in some lowlands (Nyabushozi, Nakivali). It is significant that members of two other formations are recognized on very small areas: a Deciduous Thicket on termite mounds and relics of a Medium Altitude Moist semi-Deciduous Forest in the Rwampara Mountains. Other formations are found on sites with impeded drainage: Aquatic Grassland (eastern part of the Lake System) and Herb Swamp (Lake System).

Successional classification

Snowden (1953) indicates the successional relationships of grass communities by grouping them on a formational level in certain types. He also, points occasionally to successional relations between the different communities of the same formation. Although he does not discuss successional implications in detail these implications are quite clear, indicating his opinion that the climatic climax throughout most of the area is an Acacia and Mixed Woodland formation which is associated only with the sub-humid or semi-arid regions of equatorial Uganda, namely, the southern part of the western Rift Valley and the Katonga Plateau.

Langdale-Brown (1959-60) dissertates much more elaborate views on the genetic nature of Uganda's vegetation. He recognizes for the whole of Uganda 26 or 27 natural climax types equivalent to physiognomic formations which he groups in 7 formation-groups corresponding to the formation-groups of the Yangambi classification, namely: forests (including thickets) at low and medium altitudes; forests at high altitudes; edaphic forests; woodland; savanna; steppe and grassland. Of these, no less than four formation-groups and eight climax-types are represented, according to his maps, within the study-area:

Forests and Thickets at Low and Medium Altitudes

A. Moist Semi-Deciduous Forest

B. Forest-Savanna Transition

C. Semi-Evergreen Thicket

D. Deciduous Thicket

Edaphic Forests and Thickets

L. Seasonal Swamp Thicket

Savanna

R. Compound leaf Savanna Woodland and Tree Savanna

S. Grass Savanna

Grassland

X. Aquatic grassland

Y. Herb Swamp

A. The Moist Semi-Deciduous Forest (Albizia-Markhamia type) is depicted as forming a mosaic with Grass Savanna in the Eastern and Central Rwampara. It is not described in the survey nor is it differentiated as to the occurrence of the subformational type. In other parts of Uganda this latter forms quite extensive relics, especially in Mubende and Toro districts and also in western Mengo and southern Bunyoro. In the study-area it is represented by very limited relics, if at all, probably in well-protected valley sites, and its significance appears to be mainly in indicating more favourable moisture supply and efficiency.

B. The Forest-Savanna Transition Climax type is represented in the area only by a derived community oß pediments of the mid- and north Western Koki Hills, probably indicating especially favourable moisture-supply sites in the transitional belt to the Lakeside region.

C. Semi-Evergreen Thicket is also represented only by derived communities and is depicted as occurring in several different environmental complexes: on upland crests of the Isingiro and Gayaza hill masses, where it dominates a mosaic with grassland savanna, indicating, apparently, relatively favourable crest-soil conditions at medium altitudes; on pediments of narrow lowland valleys in the northern foothills of the Rwampara, probably indicating better moisture and nutrient supply in protected sites; on lowland interfluves of the Mbarara arena indicating higher rainfull area and, possibly also a favourable soil-topography complex.

D. Deciduous Thicket is represented in the area by its natural climax community only on termite mounds, but this and the presence of associated characteristic species elsewhere is apparently regarded as indicating the potential climax of most of the lowlands of the study-area and also some parts of upland crests. It is difficult to determine exact correlations for this climax-type since its depicted distribution does not coincide with any single isohyet or group of soil series. Generally however, it appears to correspond in distribution with Snowden's Acacia and Mixed Woodland formation although it extends farther north in the

Rift Valley and exists also in limited areas of lakeside pediments in the Kyoga basin. It is, therefore, similarly, a vegetation-type restricted to sub-humid-semi-arid regions of Uganda's equatorial zone.

L. Seasonal Swamp Thicket is depicted within the area as being confined to wide valley floors of the eastern Ishura lowland, draining eastward to Lake Kachera. The reasons for this are not quite clear. It appears also to be generally restricted to the equatorial zone where its distribution on seasonally inundated valley floors depends apparently on the balance of interaction between amount of rainfall (length of double inundation) and the moisture regime of the alluvial clay soils. This is, however, a very general characterization which does not explain the details of distribution.

E. Compound leaf Savanna climax-type is regarded as being restricted to the wider flat floored valleys of the Kagera catchment area and Central Nyabushozi. As far as can be surmised from the distributional pattern, this climax-type is more edaphic than climatic although it is rarely found where rainfall exceeds 50 inches. It is generally confined to lowland and appears to be related to sandy soils. A tentative correlation seems to exist between its distribution on these soils with rainfall and drainage conditions. Thus, it occupies sandy interfluves only where rainfall exceeds 35 - 40 inches. Otherwise it is confined to seasonally inundated valley floors where waterlogging is slight and brief but moisture supply is adequate.

S. Grass Savanna is second only to Deciduous Thicket in extent in the study-area. It predominates on upland crests of both the Rwampara and the Sanga Surfaces and also on the residual features of the Gayaza Surface. It also predominates on all upland slopes in heavily aggraded and seasonally inundated valley floors. These last appear to differ from the L and R valley-floor climax types in being more waterlogged during the year due to heavier aggradation and longer inundation (higher rainfall or lower, flatter position). Clearly, on upland crests and slopes this climax-type results from shallow skeletal soils, either due to excessive erosion or to the nature of the parent rock (high-grade quartzite and ironstone) interacting with low rainfall. Where excessive erosion appears to be the sole cause (as in the Rwampara and the wetter parts of the Koki Hills) it is controversial if the vegetation-type can be regarded as a climatic climax.

X. Aquatic grassland climax-type is confined in the study-area to the Kijanebalola-Karunga part of the Lake System and the shores of Lake Kachera. Apparently it indicates the shallower swamp phases or those valley floors which are inundated most of the year. It appears to be related to certain topographic circumstances along drainage lines, which prevent rapid progressive silting up (e.g. absence of substantial up-stream gradient or small catchment, or shallow but relatively fast flow) combined with a sufficient rainfall (35 - 55") to ensure a permanently high water-table and prolonged, seasonal inundation. However, it appears uncertain if it can be regarded as a climax. It may represent a seral stage to seasonal swamp thicket, or forest.

Y. Herb swamp climax-type characterizes the deeper swamp phases of the Lake System and indicates a permanence of inundation in the lowest parts of the relief where drainage is strongly impeded.

Environmental Considerations

General climatic and edaphic relationships

Influence of climate is, therefore, the decisive factor in both physiognomic and genetic nature of vegetation types in the study-area.

On the formational level, both aspects are related to a low annual rainfall of 25 - 45". On a sub-formational level, the physiognomic type of Acacia Woodland Savanna associated with Themeda grass and the potential climax of Deciduous Thicket as distinct from floristically different deciduous thickets in other parts of East Africa (e.g. the Itigi thicket of the Central Province of Tanganyika; see Phillips, 1929, 1931), they appear to be related to an equatorial seasonal regime which allows for a better distribution of the available moisture supply and the restriction of the dry season, in which precipitation falls below the ecological minimum for growth, to no more than two consecutive months.

Within these limits of yearly rainfall (to 45") and seasonal regime, prominent variations in vegetation-type appear to be related to edaphic rather than to climatic factors. There is some indication of variability between the western and eastern transition belts. It appears that the dominant vegetation-types, especially the physiognomic types, are found to the west of the study-areas under higher rainfall than to the east of it. Acacia-Themeda woodland savanna occurs in western and northwestern Ankole under a yearly rainfall exceeding 45" and occasionally 50". In Masaka, to the east, they are found in areas with over 40" p.a. only on very dry sites. On the other hand, moist Acacia Woodland Savanna associated with more demanding grasses (Hyparrhenia, Beckeropsis, etc.) of the Forest and Forest/Savanna Transition climax-types are found in the Koki Hills under less than 35" p.a., while in western Ankole they never occur under less than 40". This is, perhaps, due to change in diurnal distribution of rainfall. In the Lakeside region and over the Lake a pattern of nocturnal maximum of rainfall prevails while in the inland regions there is a fairly general early afternoon peak. The transition to the east of the study-area, into the zone of Lake influence, is quite rapid as indicated by amounts of rainfall. It is possible, therefore, that greater effectiveness of available rainfall, especially on favourable sites, is expressed in vegetation. A slight climatic influence is possibly discernable in slope exposition, with the west and south-facing slopes having a denser vegetation than east and north-facing slopes. This denser vegetation may also include species not found on east and north facing slopes but never to the degree of causing a change in vegetation-type or even community. This may be due mainly to the direction of the prevailing rain-bearing winds. However, the tendency is very slight and is commonly obscured by other factors so that its existence as a uniform and consistent phenomenon is in doubt. A much more prominent climatic factor is associated with altitude. This is apparent mainly in climax-typesand only where edaphic factors are favourable. As observed, the prevalently present climax-type in the Rwampara Mountains is Grass-Savanna but this is due mainly to excessive erosion and relics of moist semi-Deciduous Forest indicate the possible original climax-type. On the other hand, where relatively deep soils are preserved on the broad crests of the Isingiro and Gayaza hillmasses, a special derived community of the Semi-Evergreen Thicket climax-type exists which differs from lowland communities of the same climax-type.

Relationships between vegetation and soils are apparently not correlated with soil units as such but with certain soil properties. Most important among these are drainage and moisture regime which seem to outweigh other edaphic factors. Consequently, a very conspicuous differentiation of several levels is apparent between vegetation-types on sites of different drainage properties and moisture regime. Where drainage conditions are extreme, considerably impeded or excessive, vegetation types are differentiated on a high formational or sub-formational level. On the degree of extremity depends whether the differentiation is only physiognomic or also successional. Thus, vegetation of gullies of moderate slopes is very much different from that on gully interfluves. But if the gully is wide or still very shallow, and is only relatively more moist than the adjacent slopes, the difference in vegetation is mainly physiognomic — a dense woodland instead of a tree savanna. Where gullies are deep and narrow and their moisture regime differs drastically from that of the exposed slopes, a dense thicket of an entirely different floristic composition develops in them. Or, where flat valleys are inundated only very briefly during the year and the water holding capacity of the alluvial deposits is low, a grass savanna may develop differing profoundly in physiognomy from that of the adjacent interfluves, but the climax-type may be common to both. Where, on the other hand, drainage is more impeded, inundation prolonged or soil characteristics allow for a permanently high standing water-table, the climax-type of the valley-floor would be different from that of the interfluves. Other factors which appear to influence vegetation, some of them closely associated with drainage conditions and difficult to distinguish, usually affect vegetation on a lower level, only rarely above that of the community or a variant of a community. This is expressed mainly by a change of floristic composition, frequently of no more than a shift in sub-dominance status between members of the community. Soil reaction, for instance, often associated with excessive drainage and leaching, may cause the increase or the new appearance of certain tree species. Texture, also often associated with drainage conditions and soil reaction, may result as indicated above, in a specific climax-type. Nutrient status is another factor, effecting a shift of sub-dominance and even a considerable reduction in frequency of certain species. Generally, then, distribution of vegetation types and communities does not correlate with that of soil units as defined above but rather with the interaction of certain of their properties.

The Anthropogenic factor

Of the 20 communities identified by Langdale-Brown (1960) in the study-area, only four, two of them palustrine, are regarded as climax communities; three others are defined as seral stages following cessation of disturbance (two are stages immediately preceding climax). All the other thirteen communities are defined as fire climaxes.

Burning of the savanna grass at the end of both or one of the dry seasons is a wide-spread and well-established practice used for the purposes of cultivation and grazing or at times it is done quite arbitrarily. Burning is not necessarily annual but according to Langdale-Brown's survey the communities occupying the largest part of the study-area are annually burnt; some others are regularly burnt and only the climax vegetation is wholly or mostly free of fire. Undoubtedly the gradation from annual to regular and to occasional and sporadic fires is expressed in a gradation of vegetation such that the communities subject to annual or regular fire are the most profoundly modified. However, obviously the effects of fire, whatever its frequency, are not spatially uniform. They depend largely upon the density of fire foci which reflect density of population and agricultural or pastoral practices. Under an equatorial seasonal regime with only one of the relatively short dry seasons inducing a complete wilting of perennial grasses, the concept of fires sweeping across wide expanses of savannas from few starting points appears rather doubtful. The density of population in the study-area averages approximately 20 per sq. mile (over 80 per sq. ml. for the whole of Ankole and over 100 per sq. ml. for the whole of Masaka) and it is largely concentrated (approx. 70%) on the Isingiro and Gayaza hillmasses, the adjacent parts of the Rwampara Mountains and Orichinga Valley, the Western margin of the Masha arena and the adjacent Mbarara arena; and in the northern part of West Koki. These concentrations occupy no more than 20% of the area, which means that over the greater part of the area, average density is as low as 8 per sq. ml.* Pastoral practices, however, involve burning out of proportion to the density of population, and the lowlands of the study-area have been for a very long time part of the pasture lands of the Bahima. Yet, even at present, large parts of the lowlands are heavily infested by tse-tse and it is only relatively recently that herds started descending from the Isingiro Hills to pastures in the adjacent lowlands. In the writer's experience of two consecutive dry seasons in the area, burning appeared to be very limited both in frequency of foci and in the extent to which it spread from each focus.

Associated with burning are cultivation and grazing. Cultivation and settlement are also associated with wide-spread cutting of woody vegetation. But the same limitations of extent and frequency as pertained to burning apply to these. In fact, the influence of these factors appears to be very decisive in the vicinity of concentrated settlement, where vegetation is profoundly affected, but is relatively

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* Calculations are based on results of the 1959 census. At the time of the study a very considerable additional number of Rwandan refugees had settled in the area, but extension of the settled area was confined mostly to the Orichinga Valley.

slight where settlements are few and small, as in most of the lowlands of the area. In most of the study-area cultivated land constitutes less than 5% on the average (MacMasters, 1962) and in the lowlands it is much less than that. Consequently, as with the associated factor of burning, the effect of these factors should be considered differentially according to specific circumstances and generalizations should be undertaken with care.

It is, however, necessary to take into account the cumulative effects of these factors over a prolonged period for which little is known as to distribution and density of population and grazing herds. Apparently the general pattern of present density and distribution has been in existence only since the beginning of the century. Prior to that settlement of the lowlands at the foot of the major upland blocks in the south, had been denser. It is doubtful, however, if general numbers of population were much greater. It is only the numbers of cattle which were, possibly, much higher. In view of the shifts and changes in the prolonged human occupation, the present status of the vegetation depends obviously on the rate of regeneration and availability of locally extinct constituents of original communities. Generally, the meagre historical evidence indicates that the vegetation of the southern lowlands may have been of a lower physiognomy status than at present (see Stanley, 1878), with tree savannas or grassland savannas predominating where extensive tracts of wooded savannas exist at present. A more accurate estimate of regeneration may be gained from a comparison of areas cleared of vegetation as a measure in combating tse-tse (G. morsitans) in the western part of the area. These clearings were undertaken during the period between 1931 and 1937 (Langlands, in litt.) and the degree of regeneration in thirty years can be assessed, especially where no human settlements exist, by comparison with adjacent uncleared areas. In general, it can be stated, without any qualification, that differences between the vegetation of cleared and adjacent uncleared areas is apparent only in minor details (see Appendix) and considering the method of clearing, involving an almost complete elimination of woody vegetation, and the lack of any evidence of human activity in some of these areas, the secondary status of these communities seems in need of careful reconsideration.

Vegetation of the Study-Area

Method and Preliminary Considerations

The survey of vegetation in the study-area was undertaken with the basic object of distinguishing relationships of vegetation-types of different orders with physiographic elements of different order and form. It had the great advantage of being able to base itself on an already existent and fairly detailed survey, but it was conducted under very grave disadvantages ensuing from a lack of specialist and manual help and an allocation of time that was rather short for its needs. An essential requirement of such a survey is a thorough acquaintance with the flora which is very difficult and time-consuming to acquire when no specialized help is available. The methods of the survey had to be devised, therefore, to collect the necessary data in the minimum of time available after sufficient acquaintance with the flora was attained.

As a result of these considerations, field methods were based on descriptions of apparently uniform stands of vegetation on both sides of traverse lines routed along roads, motorable tracks and occasional footpaths, from which side trips were taken where deemed necessary. All motorable tracks and roads within the area were traversed and many cross-country trips on footpaths. When data was assembled from the whole of the area provisional groupings of vegetation were outlined. A second survey was then carried out where gaps appeared to exist or where uncertainties were involved. Stands were chosen where apparent changes in the vegetation were noted and where obvious transitions between landforms occurred.

In each chosen stand the following salient features were noted: species composition in each stratum of the community, their estimated relative cover-abundance and physiognomic details (height, spacing and aerial cover). After the revision of the groupings, involving also corrections in floristic identification (where identification depended on floral characteristics), several transects were undertaken in what were defined as type-localities, and several more detailed observations carried out in typical stands according to adaptations of the quadrate method. An attempt was thus made to combine certain aspects of the Zürich-Montpelier approach (Braun-Blanquet, 1951) with those used by Trapnell (1937, 1943). In view of the fact that the major problems in correlation between vegetation and landforms, seemed to be associated with differences between upland-crest and lowland vegetation, less attention was devoted to vegetation on the slopes and valley floors or to such types as appeared to be climatically conditioned.

Vegetation units of the Study Area

The major units of vegetation and their distribution

As observed the non-aquatic vegetation of the study area comprises two major physiognomic units on a formation-group level: savanna and closed forest at medium altitude, the latter being represented only by thicket. Of these two units savannas are by far the more prevalent and include the whole range of savanna formations - wooded savanna, tree savanna and grass savanna. Thickets are represented only by components or by communities restricted to specific sites usually of small extent. However, many savanna communities include a large proportion of thicket elements, which tend to congregate in small groups, in certain situations and these, consequently, impart a thicket-like aspect to the savanna.

Apart from the physiognomic differentiation based upon synusial relationships, i.e. the relative proportion of the tree and grass layers, the savannas of the area are physiognomically and floristically differentiated into two major subformational units: a compound-leaf savanna dominated by species of Acacia and a mixed, broad-compound leaf savanna dominated mainly by the compound-leaf Albizia spp. and by the broadleaf Combretum spp., but occasionally by others. The distinction is a broad one since both units contain elements and communities related to other formations or sub-formations, of which those of the thicket are the most prominent. What makes the distinction very conspicuous is the exclusive association of each of these units with a major aspect of the landscape or, more properly, with a major group of soils: compound-leaf savannas are associated with level surfaces, carrying relatively deep, weathered soils; mixed savannas are associated with slopes carrying skeletal, shallow soils. This differentiation of the tree layer is paralleled by the differentiation of the grass layer, but since grasses and herbs respond to a different scale of environmental factors than woody vegetation, the grass layer associated with slopes is more uniform than that on level surfaces due to the greater uniformity of edaphic factors in skeletal, unstable soils.

As stated, this physiognomic-floristic differentiation of vegetation is independent of the physiognomic-synusial one and tree or grass savanna may be associated either with compound-leaf or mixed savanna, according to their woody components. Such an association is a relatively simple task with the uniform grass layer on the skeletal soils where grasslands devoid of woody vegetation may be presumed to be associates of the mixed savanna on general ecologic grounds. The task is more complicated or conjectural on level surfaces, where the grass layer is more variable, but in general it can be said that except where the altitudinal factor is involved, all physiognomic types on well-drained and on the less poorly drained level surfaces have an affinity with the compound-leaf savanna.

An affinity of this kind may express two types of successional relationships: edaphic and anthropogenic and, of course, a combination of both. A purely edaphic successional, "catenary" sequence of physiognomic types indicates a gradual change in the nature of edaphic factors, generally due to topography. It is, consequently, associated mainly with the more variable level surfaces or with transition between the broad habitats of the two subformations. The anthropogenic successional sequence indicates a degree of disturbance or regeneration after cessation of disturbance, and is the main factor of physiognomic change. Anthropogenic factors may, however, aggravate edaphic conditions and cause physiognomic change indirectly. They can also cause an extreme deterioration of edaphic conditions which will drastically affect the rate of succession.

Genetic relationships of vegetation must be, of course, related to a certain time-scale and a certain, usually macroclimatic, environmental modality. The assessment of the potential vegetation of the area must, therefore, be undertaken only in relation to anthropogenic disturbance and its consequences. Within such a frame of reference, the general impression imparted by the nature of the vegetation is that in most cases tree or grass savannas on level surfaces carrying relatively deep soils, are genetically related to compound leaf savanna in the sense that given the cessation of human interference, these physiognomic types will revert to compound leaf woodland savanna or even woodland. Apart from purely edaphically conditioned tree and grass savannas, there appear to exist two main exceptions to this rule: level surfaces at relatively high altitudes and thus, perhaps, related to a different macroclimatic modality, may have a different potential vegetation; level surfaces on which human interference caused extreme deterioration of edaphic conditions may have to be related to a different time-scale in order to be assessed as having the same potential vegetation. It appears, in other words, that on such surfaces tree or grass savannas will revert to woodland savanna considerably later than on other anthropogenically conditioned level surfaces.

Assessment of potential vegetation on slopes with skeletal soils, is more difficult. The reasons for this are several. As indicated by the nature of the sub-formation, woody vegetation, in contrast with the grass layer, is floristically though not ecologically, much more variable than on level surfaces. The slope habitat may be interpreted as constituting a refuge to a great number of tolerant wood species which cannot compete with more stenotopic species in their optimal habitat on level surfaces. Furthermore, the extreme ecological circumstances on slopes make the effect of anthropogenic disturbance much more lasting and regeneration more difficult. It is, consequently, very seldom that a well-developed woody vegetation occurs on slopes, except under specific ecological conditions (gullies, outcrops etc.).

It is, however, mainly the vegetation of well-drained level surfaces that is relevant to the thesis of the present study since it is these surfaces which represent the different stages of geomorphic evolution. Vegetation of slopes and poorly drained valleys will be, therefore, discussed only briefly.

I. Acacia savanna communities

Well or moderately drained level surfaces are associated with two broad units of land surface: upland crests and lowland interfluves and pediments. Within each of these, the main ecological habitat factor appears to be soil moisture regime which in many cases transcends to the limits of broadly defined habitats to produce similarities and differences of vegetation. While this factor enables us to differentiate between relatively damp or moist and dry habitats within all major divisions of environment, it is associated with many other edaphic factors such as depth, reaction, texture and nutrient status. As observed, the distribution of a single species can, in many cases, be related to one or several of these factors, but it is the combinations of all the significant edaphic factors which produces the community in a natural or derived form. Consequently, the distribution of communities coincides with that of the soil series only very broadly depending only on certain of the soil properties which define series. Also, the significance of a soil property as an ecological factor may be different from its significance as a criterion in soil taxonomy. Communities may be similar on two different soil units if one of their properties such as reaction, is equivalent. They may differ on a single soil unit, if one of its properties such as moisture retention, is variable.

Nevertheless Acacia savannas in the study area are apparently associated with a broadly uniform edaphic environment whose differentiation affects them only on a relatively secondary level. Such a uniformity is reflected in the fact that in most communities of this subformation, the tree layer is actually or potentially dominated or characterized by the common presence of a single species of Acacia. Acacia gerrardii var. gerrardii usually grows in the area as a 3-12 m. high, white flowered, gregarious tree and occasionally, where young or weakly growing, as a large shrub. It has a variously shaped crown tending to be irregular in tree and grass savannas or where associated with other co-dominant or subdominant species, and to be umbrella shaped in wooded savannas and woodland where it is the only tree of dominant status. Very widespread in association with it is Acacia hockii, a small tree or shrub, never found within the area to exceed 3 m. in height and usually less than 2m. It is present in almost all communities actually or potentially dominated by A. gerrardii, and is very conspicuous with its yellow flower but is abundant and occasionally dominant only where other woody species have been removed. It is not confined however, to Acacia savanna communities and is found ubiquitously on all surfaces including slopes and poorly drained valleys.

Differentiation of communities within the Acacia savanna is consequently, defined by the variation of subdominant trees or shrubs which may be abundant or merely prominent. It can also be defined by the variation of associated grass communities which are, of course, the only criterion of differentiation in grass savannas. There are several communities in which A. gerrardii is absent altogether. These are usually associated with habitats with a ready moisture supply along drainage lines, or where an altitude-conditioned environment exists.

A. Acacia gerrardii communities of well-drained deep soils on level surfaces.

These communities are prevalent on mid-lowland interfluves, foothill pediments and some upland crests. On upland they occur on relatively narrow crests, on the periphery of broad flat crests or on broad convex crests whose soils are moderate in depth and are freely drained. Apart from topography they appear also to be limited by altitude, usually changing into transitional or modified forms above 5400-5500 feet.

The controlling edaphic factors appear to be depth of soil and moisture regime as reflected mainly in the measure of acidity and depending on topography and to some extent lithology and texture. A climatic factor seems to be involved too in conjunction with the edaphic one since acidity of the preweathered, mid-lowland soils of the Mawagola Catena is increased perceptibly in the northern part of the area where annual rainfall approaches 40". Within these limits of sufficiently deep soils with slight to very strong acidity and inadequate capacity for moisture retention or inadequate moisture supply in the dry seasons, the communities of this group are predominant. Since these ecological limits are prevalent on landforms forming the greater part of the area, the communities of this group are the most typical of it, and it is this group which imparts to the vegetation of the Acacia savanna its uniformity.

The woody communities within this group are distinguished here according to the co-dominant and sub-dominant tree species associated with A. gerrardii, which in certain ecological complexes may attain dominance. However, the group as a whole has a fairly definite floristic composition and variations involve only changes in relative abundance of components and the associated physiognomic change, either due to anthropogenic factors or to a catenary sequence of variants. Differentiation of communities is made difficult by the fact that grass and herb components are subject to a different magnitude of ecologic values than tree and shrub communities and, consequently, certain grass communities may be common to several variants or communities of trees and shrubs while a single woody layer may be associated with several types of grass layer. It is, however, significant that the uniformity of the tree layer reflected in the general dominance of one species and the presence of only very few co- or subdominants is paralleled by the uniformity of the grass layer, also reflected in the same way. Of course, the ecological and morphological nature of the life-form dictates a much greater variety on a local scale in the grass layer. This variety is expressed in a patchwork pattern of grass stands, where each patch has a different sequence of abundance involving many species and depending on both very local and relatively slight edaphic variations and incalculable factors of dispersal.

There are, consequently, grounds for regarding this group as one large variable community unified by a common dominant or abundant tree species in the greater part of its area and by the continuity of the major grass communities. It is differentiated by subdominance and local dominance of other tree species on the one hand and the absence of subdominant trees on the other. It is also differentiated physiognomically into several types which are related to one or another of the floristic variants.

According to these criteria of differentiation the group may be divided into three major units whose designation has no relevant significance within the present context; they may be regarded either as separate communities or as variants of one community. A fourth unit intimately associated with this vegetation complex has a fundamentally different floristic and physiognomic character. It is composed of deciduous and evergreen broad leaf tree and shrub species and compound leaf elements take almost no part in it. Physiognomically it belongs to the thicket formation. It is, however, a formation which is restricted to very special ecological conditions and consequently occupies a relatively small area in discontinuous restricted sites, widely dispersed and contained within the A. gerrardii and other community groups. Furthermore, most of its components and all those which are dominant and frequent in it, are also integrally associated with these groups without forming a well-defined community of their own.

The communities defined here are represented, therefore, by several physiognomic types which are assumed to be anthropogenically derived from them. Since grass layer associates are common to all the three communities they are treated separately. Tables and quadrates of sample stands from each community are presented in the Appendix (II) as is a definition of physiognomic types, as used in the present study.

1. Acacia gerrardii - A. hockii community

Woodland and anthropogenically derived wooded and tree savannas. Woodland usually forms stands of limited area and most of the area occupied by this community carries wooded, tree and grass savannas in intimate mosaic.

A. gerrardii is the only dominant tree in this community and in some woodlands forms almost pure stands. In wooded and tree savannas A. hockii is increasingly abundant in the small tree-shrub layer and is frequently the dominant woody species in open grassland clearings. Consistent associates of this community are broadleaf shrubs and small trees which tend to congregate in small groups on theedges of dense stands of shady trees. When occurring singly, in most cases in relatively diffuse shade of dense stands, they are often weakly developed. The commonest and most constant are Grewia trichocarpa, G. mollis, G. simils. Teclea trichocarpa and Allophylus africanus. In open spaces of woodland and tree savannas low to medium size broadleaf trees are often singly and widely scattered of which the most common are Maytenus senegalensis, Erythrina abyssinica and Euphorbia candelabrum.

On the upland crests the community is associated mainly with the deeper phases of the Isingiro clay-loams or sandy clay-loams but also with the well-drained phases of the Rugaga clay loams which dry out during the dry seasons. In the lowland it is associated with the foothill-pediment loams and sandy loams of the Mbarara Series, with some associates of the Mawogola Catena - mainly the loamy sands of the "Hillwash" Series and with the 'Brown' Series of the Koki Catena.

It appears from these edaphic associations that the limiting factors of the community are mainly depth of soil, base saturation and acidity. The community does not occur where soil depth is less than 2-3 feet, where base saturation is less than 30% and where pH is below 5.0*. The macroclimatic limit is less certain and is apparently modified by edaphic factors but in general it appears to coincide roughly with the 35" p.a. isohyet. Beyond this limit its distribution is dictated by local edaphic conditions. No doubt these ecologic limits are controlled by the ecological valence of the dominant species, although they certainly do not coincide with it. It would appear that within them A. gerrardii can exclude, by competition, all other tree species.

Within these limits the community comprises several variants, differentiated according to the relative proportions of subordinate woody species but these are doubtfully distinct and may be anthorpogenically derived. Several of these are enumerated here:

i. A wooded and tree savanna in which A. senegal is present in relatively small numbers but very prominently as large-sized, 10-15 m. high, trees. Appears to be associated with shallower soils over bedrock and is found, therefore, only on upland. It consequently may represent a transitional community.

Other variants are related to changes in the shrub or small tree layers.

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* A different set of limits is associated with heavier and less well drained soils, where a similar community exists. See below community 8.

ii. Woodland or tree savannas in which Dichrostachys cinerea replaces A. hockii as a dominant in open areas, or shares dominance with it. The edaphic associations of this variant are not clear. The impression is that it is either anthropogenically derived in overgrazed and heavily eroded areas or related to strongly acid (pH 5.0-5.5) soils produced by leaching or by a high-grade arenaceous parent material. In the first case Dichrostachys is dominant, in the second (Mawogola "Medium") it is co-dominant with A. hockii.

iii. Woodland in which the shrub understorey contains abundant Acacia brevispica. Associated with woodland floor in which shade is combined with proximity of seepage lines at the foot of upland slopes. Usually on gently sloping pediments of inter-upland lowland tracts.

iv. Woodland and wooded savanna in which the broadleaf shrub understorey is relatively dense and forms extensive stands. Appears to be associated with interfluve and pediment slopes on soils in which the subsoil is not compact enough to be impervious and not sandy enough to be excessively drained producing, therefore, an adequate retention of moisture derived from upslope.

v. Woodland and wooded savanna in which A. gerrardii is accompanied in the tree layer by A. sieberiana. This species, however, although quite prominent by its size is not abundant and does not attain a subdominant status. Occurs in situations transitional to those of the following community.

Apart from these variants of which undoubtedly several others exist, the community, as other communities of this group, is clearly differentiated into two types - one containing a thicket community and the other devoid of it. Both types occur on upland crests and in lowlands but the former is much more prevalent in lowlands. The discussion of the edaphic associations of the thicket community is deferred to a later stage.

2. Acacia gerrardii - A. sieberiana community

This community differs from the previous one only in having A. sieberiana as co-dominant and occasionally dominant tree species. The greater size that this species attains in relation to A. gerrardii, and the specific sites it tends to occupy, often enhance the impression of its dominant position despite low abundance.

Physiognomically the community is much less frequently disturbed than the previous one and consequently, does not often appear as a tree savanna. It never occurs on upland crests and is usually associated with the interfluve or pediment soils of the lowland. It is associated mainly with the heavier phases of the Mbarana Series soils, namely silty loams which are only moderately or slowly drained and are found either on broad, very level interfluves of arena-like lowlands or in upper parts of wide valleys, near the upland slope. In stands of lesser extent it is associated with lower parts of steep short pediments which terminate directly in a swamp or a lake.

From the pattern of its distribution in the area it appears that A. sieberiana has several ecological properties in which it differs from A. gerrardii. On the one hand it is not as limited by depth of soil cover, probably because of greater capacity of its roots to penetrate and draw sustenance from parent material. On the other hand, it has a narrow range of tolerance in relation to soil texture as reflected in moisture and pedoclimate regime, being more susceptible to both drying out of sandy soils and to permanent saturation of heavy clays. It should be emphasized that these limits are not absolute to the species but only relative to A. gerrardii, attaining a dominant or co-dominant status only where able to compete with it. This occurs either within the optimal limits of the texture-moisture complex, or where A. gerrardii is absent or weakened by shallow soil or strong acidity. Other limits for A. sieberiana obtain in regards to other woody species which are tolerant of even shallower soils and stronger acidity or are more vigorous within the limits of their own ecological optimum.

A. sieberiana, is, therefore, a rather stenotopic species and in consequence the distribution of the community in which it competes successfully with A. gerrardii is irregular and discontinuous. It is most extensive in arena-like lowlands with a relatively subdued relief, on mica-schists. Elsewhere it forms narrow belts on lower gentle slopes of lowland interfluves of the Mawogola Catena. It is much less extensively associated with a typical thicket community than is the previous community, but where A. sieberiana gains dominance, as in upper wide valleys, a specific variant of the community develops, in association with thicket species.

The variant is distinguished by a conspicuously reduced abundance of A. gerrardii and by a prominent increase of the thicket components both in numbers and in size. Usually they congregate in fairly large groups around the base of the large-size A. sieberiana trees, but often they form smaller groups also in the grassy spaces between them (2i).

3. Acacia gerrardii - Albizia spp.

Woodland and anthropogenetically derived wooded and tree savanna, also floristically similar to other communities of this group in most respects save the co-dominant or dominant status of Albizia spp. in the tree layer. The main species involved is Albizia coriaria, but A. zygia occurs also, and in lesser numbers - A. adianthifolia. They attain dominance in relation to Acacia gerrardii mainly on crests of interfluves.

The community occurs mainly on the upper associates of the Mawogola sandy and gritty loams but does not occupy the whole area of these soils. It disappears gradually in the northern part of the Ishura Lowland, and is replaced southwards by A. gerrardii and thicket communities. The only apparent cause for the presence of this community, is the increase of annual rainfall, above the 35" p.a. level, which when combined with the very strong acidity of the soils, reduces the competitive ability of A. gerrardii in relation to Albizia. Where not disturbed the community contains a large proportion of large size broad-leaf shrubs which, however, do not tend to congregate in well-defined thicket clumps as they do in the Acacia gerrardii - A. hockii community nor around the larger trees ar as in the A. gerrardii - A. sieberiana community, but are more dispersed or congregate in small groups.

The communities of the grass layer associated with the group of woody communities outlined above can be differentiated into two main types.

a. Themeda triandra-Cymbopogon afronardus - Hyparrhenia filipendula

A variable community predominating in most of the area occupied by the A. gerrardii group of tree communities and with most of the transitional communities of this group, forming extensive grasslands or an intimate mosaic of clearings and patches with stands of woody species in wooded or tree savannas. Its exclusive association with moderately deep and deep soils, freely or moderately drained, indicates the anthropogenic derivation through cutting, burning grazing and cultivation, of the more open physiognomic types.

As observed, the dominant status of certain species is reflected in the area of patches within any stand in which they dominate. All the three species after which this community was designated tend to dominate a larger area than any other species in all observed stands throughout the area. There are only few other grass species which tend to replace them over relatively small parts of the area. Due to the intricate patchwork pattern of the grass layer it is frequently difficult to assess the relative position of any one of the three dominants except by the direct quantitative method, but the general impression from many stands, gained by rough random countings, is that a certain pattern does exist.

All three dominants prefer exposed, open, sunny spaces and all avoid very shallow soils. Themeda triandra is the usual dominant species in the drier parts of the area, again roughly below the 35" p.a. isohyet. Beyond this limit it is apparently dominant only where soils dry out more excessively, though not in very sandy soils. Cymbopogon afronardus predominates in several situations: (1) in patches of heavier and deeper soils probably with better retention of moisture, within grassland dominated by other species, usually on flattened sites on slopes or broad saddles, relatively clayey sites on level crests and shallow small gully heads on crest-slopes; (2) in overgrazed areas where burning was reduced (Langdale-Brown, 1959b) (3) in areas of increased rainfall (approximately 40"). Hyparrhenia filipendula appears to be more ubiquitous than the others, but within the area only rarely attains dominance and then only locally, where both Themeda and Cymbopogon are reduced. It forms, however, a consistent subdominant to both of the other grasses.

The community is divided, therefore, into two main variants i) Themeda triandra with Hyparrhenia filipendula as subdominant and Cymbopogon afronardus as the next most abundant species attaining local dominance. (ii) Dominated by Cymbopogon afronardus with the same subdominant and with Themeda triandra in the third position. Within the study area both form a very intimate mosaic controlled by the variable nature of local disturbance and edaphic factors. In the drier parts of the area, on the Mbarara sandy loams and loams, on the southern Mawogola sandy loams and loamy sands and on the Rugaga and Isingiro sandy clay loams, the ai variant is predominant. To the east and north, aii gradually gains predominance on the heavier phases of soils, where a more clayey horizon is found at a relatively shallow depth, mostly on interfluve crests. In the Koki hills area it even dominates on the clayey shallow slope soils (see also Snowdon, 1953). A transitional variant in the north of the Ishura Lowland shows intermediate features with Themeda replacing Hyparrhenia filipendula as sub-dominant on interfluve crests.

As far as has been observed in the area there are two cases in which dominance in the grass layer is attained by other species than the three mentioned, over a more than a local scale and in consistent association with certain edaphic circumstances:

a1 On deep loams, well supplied with moisture, occurring usually on the middle slopes of foothill pediments or on gentle upland crest slopes, large tracts of grassland are dominated by Setaria sphacelata with many patches consisting of almost pure stands of this species but mostly with Themeda triandra and Hyparrhenia filipendula as sub-dominant.

A2 On sandy loams or loamy sands and sands which are also better supplied with moisture, such as found on exposed upper slopes of foothill pediments, on valley floors with a sandy overwash, or on very sandy mid-lowland interfluves in areas of higher rainfall (approaching 40"), very large areas of grassland are dominated by Hyparrhenia dissoluta, with Themeda, Hyparrhenia filipendula and Cymbopogon afronardus as common associates.

All forms of this community abound in subshrubs and herbs, many of them quite large in size, and many very prominent in the grass layer by the colour of their flowers. The pattern of their distribution was not studied very closely since in no case they were found to be dominant or sub-dominant. The general pattern appears to be mainly ecological, though undoubtedly a closer investigation would reveal also geographical patterns. It seems however, that floristic differences in the composition of herb and sub-shrub populations are inconspicuous within major habitats and the differences accruing from edaphic factors are reflected mainly in physiognomic features - density and relative abundance. Floristic differentiation is apparent mainly where human influence is prominent - in segetal and ruderal habitats.

b. Panicum maximum- Brachiaria decumbens - Setaria kagerensis

A grass community associated with the shady, relatively moist and probably relatively humus-rich sites. It is, consequently, found in relatively small and diffuse areas under the shade of trees in wooded and tree savannas and only under continuous tracts of wood or thicket it may extend over larger areas. It is a characteristic community of sites where edaphic factors do not, in general, favour retention of moisture and the relatively moist soil is due to the shade and perhaps, to some degree, also to greater content of organic matter.

Since it depends on factors controlling a rather limited area, the grass stands are usually very dense but tend to thin out the larger is the size of the tree and its crown, merging with other grass communities on the periphery of the shaded area. There appears to exist no regular pattern of distribution where the community covers larger areas, except perhaps that Brachiaria decumbens seems to be less dependent on the shade than the other two species.

Only few variants of this community may be discerned, since the controlling ecological factor is relatively homogeneous and associated with small areas. Of the three observed two are physiognomic and the third probably transitional.

i. The most prevalent variant is associated with isolated trees and tall shrubs or isolated groups of trees and shrubs.
   It is very dense where the tree or shrub have a non-spreading crown; thinner, where the shaded area is wide. The intensity of

shade also influences the density. In dark shade there is some concentricity of pattern possibly dependent on decreasing content of organic matter and the associated waterholding capacity, towards the periphery of the shaded area. Panicum maximum and Setaria kogerensis decrease in relative abundance and Brachiaria decumbens increases. In lighter shade, relative abundance of the former two species is decreased altogether and their distribution is more diffuse.

ii. In fact a combination of closely disposed stands of the previous variant, in tracts of woodland or thicket, where the ground is more or less completely shaded. Dense phases of this variant closely resemble the former one in siting, composition, and physiognomy. In more open spaces between trees and groups of trees, where shade is more diffuse the community includes subordinate elements of the open grassland such as Themeda, Setaria sphacelata, but mainly Hyperrhenia filipendula and Chloris gayana.

iii. The variant, possibly transitional to moist-type grass communities, is floristically differentiated by the addition of Beckeropsis uniseta to the dominants. It is particularly typical of pediment sites associated with depositional fans overlaying Mbarara sandy loams at mouths of small gullies, where density of A. gerrardii stands increases and a better moisture supply exists. It can be found also in other sites which have a ready supply of moisture coupled with less disturbed tree or shrub stands.

3. Transitional Communities

Apart from transitions within the group of A. gerrardii communities and from transitions, mainly physiognomic, imposed by anthropogenic factors which did not fundamentally modify edaphic conditions, there exist three types of communities transitional to other groups: transitional to slope communities - i.e. induced by shallower soils; transitional to moist communities, i.e. induced by better moisture retention and perhaps, base saturation; transitional to higher altitude communities i.e. also induced by greater efficiency of moisture supply. In all but the last type of these communities A. gerrardii is dominant or, at least, abundant indicating that environmental change is not profound enough to modify the fundamental aspect of the tree layer. It is, however, significant that all these types are more prevalent, i.e. - they occupy a greater proportion of the area of freely or moderately drained sites, on upland crests than on lowlands. This is obvious in relation to the first and third types, but is abnormal in relation to the type transitional to moist-site communities. Undoubtedly the appearance of such communities on crests of the driest part of the area whose drainage, however broad and level they are, would not be as slow as that in lowland except in very limited areas, poses a problem.

Transitions are never uniform and consequently the definition of transitional communities is concerned mainly with trends of change or averages and should be accepted as generalized.

4. Acacia gerrardii - A. hockii - Broad-leaf trees community

A wooded or tree savanna associated with shallower soils on slopes of broad crests and on narrow crests or on waste-mass junction with pediments at foot of upland slopes. Includes two main variants:

i. Occurs on upland crest-slopes. Similar to disturbed stands of A1 in dominance of A. gerrardii and abundance of A. hockii, but differs in association of a large number of broad-leaf trees such as Maytenus senegalensis Stereospermun kunthianum Ficus (ingens) Sapium elliptium, Lannea kerstingii, Maerua angolensis, and also Euphorbia candelabrum. These appear to be associated with the shallow phases of soil cover or more eroded facets of the crest slopes, where A. gerrardii cannot compete with them successfully. These are mainly sandy clays of the youngest phases of the Isingiro Series, which are differentiated from the skeletal slope soils of the Kateti Series mainly by a high base saturation, weak acidity and high capacity of moisture retention. Consequently, the shade of these trees, especially where soils form deep, moist pockets among rocky outcrops, constitute centres for groups of tall shrubs of the species usually associated with the Acacia savanna (Grewia, Teclea, Allophyllus, Harrisonia, etc.). Deep pockets of moist soils also support young A. sieberiana shrubs, and on a more even soil cover - Dichrostachys cinerea.

ii. Occurs at head of foothill pediments. Differs from the former in the composition of associated broadleaf and other elements. Of the broadleaf trees mentioned only Maytenus and Ficus are as prominent as in the previous variant. Instead, elements typical of the Mixed savanna take part, mainly - Combretum, Albizia and Bridelia species, and also some broadleaf elements characteristic of the pediments such as Dombeya dawei. The shrub associates are less abundant but very common.

It seems that the differentiation of this variant is related to the nature of the skeletal soils on lower slopes and the upper parts of the pediments, which are well-supplied with moisture but more acid and poor in bases than the crest slope soils.

The associated grass communities are very variable, being subject to control of slighter changes in edaphic factors. A pattern of communities appears in which the main trend is decrease in abundance of Themeda triandra and Cymbopogon afronardus and increase of Hyparrhenia filipendula, and other grasses. A definition of a community is, therefore, applied to a generalized approximation of a mosaic disposed in accordance to edaphic factors.

c. Hyparrhenia filipendula - Loudetia kagrensis community

The two grasses, while the most conspicuous in the whole transition belt, are not always the most abundant, and represent dominance at two extremes: the most well-developed of the shallow soils and the most skeletal. In between there are areas and patches in which other grasses, notably Brachiaria brizantha, Digitaria diagonalis, Cymbopogon excavatus and Sporobolus pyramidalis gain local dominance. In some places a variety of H. filipendula (var. pilosa) appears to be adapted to shallower soils than the usual variety. The distribution of the variants of this community is correlated with the distribution of A. gerrardii trees, where present. The variant dominated by Loudetia kagerensis is, as a rule, associated with very few trees; that dominated by H. filipendula is associated with scattered tree savanna or open wooded savanna. Gregariousness of A. gerrardii, even in small groups, is always associated with increased prominence of Themeda.

Similarly to the tree layer, the grass community is differentiated between crest-slope and foothill sites. Grasses like Digitaria diagaonalis and Cymbopogon excavatus do not occur on the foothill site and are replaced by Ctenium concinnum and Andropogon dummeri both usually sub-dominant to Loudetia kagerensis or locally dominant and like it - typical of slope grass communities on the Kateti Series soils. It would appear that the reasons are similar too, with the former grasses requiring less acid and more base-saturated soils while the latter are more tolerant of poor and acid slope soils.

d. Themeda triandra-Chloris gayana community

Where the transitional community (4) has been drastically reduced by human activity and where disturbance factors are currently active, extremes: the most well-developed of the shallow soils and the most skeletal. In between there are areas and patches in which other grasses, notably Brachiaria brizantha, Digitaria diagonalis, Cymbopogon excavatus and Sporobolus pyramidalis gain local dominance. In some places a variety of H. filipendula (var. pilosa) appears to be adapted to shallower soils than the usual variety. The distribution of the variants of this community is correlated with the distribution of A. gerrardii trees, where present. The variant dominated by Loudetia kagerensis is, as a rule, associated with very few trees; that dominated by H. filipendula is associated with scattered tree savanna or open wooded savanna. Gregariousness of A. gerrardii, even in small groups, is always associated with increased prominence of Themeda.

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d. Themeda triandra-Chloris gayana community

Where the transitional community (4) has been drastically reduced by human activity and where disturbance factors are currently active, the shallower phases of the Isingiro humose sandy clay loams, on level crests, support a grass savanna of few A. gerrardii and A. hockii trees or shrubs, and composed of numerous species of grasses.

It differs from the (a) communities mainly in Chloris gayana replacing Hyparrhenia filipendula as subdominant to Themeda triandra, in the scarcity of Cymbopogon afronardus and the relative abundance of Brachiaria decumbens and Setaria sphacelata.

The congregation of all these subordinate species appears to indicate a better retention of moisture consequent both upon a heavier texture of soils and a slower drainage.

5. Acacia gerrardii - Acacia vermoesenii community.

Woodland and wooded, tree and grass savannas derived from it. Occurs on clays and clay loams of the Rugaga Series, on broad upland crests. It is also found on deep depositional fans on foothill pediments at mouths of large gullies or small valleys and on raised parts of flat valley floors, where intermittent inundation is slight and soils only moderately heavy (sandy clays and clay loams). On upland crests, the community is usually represented by derived grass and tree savannas due to dense settlement and intensive cultivation, with only small areas of woodland and wooded savanna left intact.

In these tracts A. gerrardii is usually dominant as it is on lowland sites of this community. But it is closely subordinated by A. vermoesenii and it is difficult to judge, in the present state of disturbance, whether dominance of A. gerrardii is intrinsic or derived and conditioned by reduced competition of A. vermoesenii. Comparison with lowland sites in which stands are more intact, is not indicative since edaphic factors may not be the same. It is possible that under certain conditions A. vermoesenii may obtain dominance.

The community is distinguished by the size of the tree components which may attain maximal limits of the species (15m. high). It also includes many broadleaf tall shrubs in common with all the communities though, also attaining a larger size than usual. A prominent member of the tree layer, also of greater size than usual, is Entahda abyssinica.

The common edaphic factors of the different upland and lowland sites appear to be the relatively high moisture retention due to texture, and the relatively high-base saturation. Of the three main tree components only A. vermoesenii appears to be limited by a relatively restricted range of both these factors. Its ecological distribution within the area indicates a fairly high lower limit of base-saturation, at least 30%, and a narrow range of moisture supply; it is found along drainage and seepage lines but not where waterlogging is apt to be excessive or prolonged or where soil texture is very heavy and impervious. In addition it appears to be limited by soil depth which is possibly related to the other factors. A. gerrardii is much more ubiquitous as to moisture conditions and is able to flourish on shallower soils, but is similar to A. vermoesenii as to base saturation requirements. E. abyssinica is apparently able to tolerate a wider range of all factors in relation to both species, but is a non-gregarious species which is unable to compete with the others within the limits of their ecological tolerance. However, these ecological factors effect control in combination with each other and with other factors and it seems that A. vermoesenii, despite its stenotopy, has the advantage over the two other species in certain situations. It is not easy to define these situations since in no case does A. vermoesenii appear to assert dominance. But on certain sites it becomes subdominant to another species while A. gerrardii is reduced to a lower status or is absent altogether (see community 6). Edaphic conditions in these sites indicate a heavier texture than on the upland crest and depositional fan sites of the present community but better drainage than in its valley floor sites. Apparently under such conditions which are optimal to certain species, their competitive ability in relation to A. gerrardii is enhanced. It is possible therefore that where such conditions obtain in an upland site, e.g. - where the Rugaga clay loams include a sub-topsoil horizon of heavier texture - A. vermoesenii may be potentially dominant.

e. Beckeropsis uniseta - Hyparrhenia cymbaria community

A community of moist but sufficiently drained sites. It is usually associated with the A. gerrardii - A. vermoesenii tree layer but occurs also under dense woodland or thicket of the A. gerrardii group on depositional fans at gully mouths, on footslopes in upland valleys, or on lower pediments and along intermittent drainage lines. It is, thus, a community adapted to a more moist habitat than the shade community (b), depending not only on good retention of moisture but also on ready supply. It is, consequently, more characteristic of lowland sites of community 5 than of the upland ones, and is, therefore, subject to a somewhat different ecologic range with a greater emphasis on the ready moisture supply.

Of the two main components, B. uniseta appears to be more widespread outside this ecological range than H. cymbaria, especially in regards to moisture regime. It is found and can be abundant under both drier and wetter conditions and seems to be better adapted to heavier texture of soil. It is however, limited by altitude and is not observed to be dominant in any community higher than 5500 ft. a.s.l. H. cymbaria on the other hand, appears to be restricted to a narrow range of moisture regime, avoiding both dry and very wet soils, and occurring, consequently, on loams or clay loams or on sandy clays which are not waterlogged in the rainy season. It has, however, a much wider altitudinal range and competes successfully with B. uniseta at elevations higher than 5500 ft. a.s.l.

f. Cymbopogon excavatus - Melinis spp. - Beckeropsis uniseta

The community is characteristic of the upland crest sites associated with the tree community of A. gerrardii - A. vermoesenii although in most cases, it forms a grass savanna due to anthropogenic disturbance.

It is associated, therefore, with the heavier phases of the Rugaga clay loams.

The structure of the community is variable in the sense that each of the above species may dominate in certain situations. B. uniseta appears as dominant only at medium altitude sites, below 5000 ft. a.s.l., although it attains local dominance at elevations of up to 5500 ft. a.s.l. C. excavatus tends to dominate between ~~sands~~ 5000 and 5500 ft. a.s.l. allied closely with Melinis maitlandii which it, apparently, replaces as dominant in overgrazed areas. Melinis minutiflora is associated with M. maitlandii as sub- or co-dominant in areas of Rugaga soils approaching or exceeding 5500 ft. a.s.l. in elevation.

The common edaphic factor of this community appears to be the heavier texture of the clay loams in the subsoil. That this is the case is attested by the common association in the community of other grasses which seem to be adapted to heavy loams such as Digitaria diagonalis and more significantly Imperata cylindrica. The moist nature of the soils is attested by the prominence of such grasses as Brachiaria decumens, Hyparrhenia cymbaria, Chloris gayana and Setaria sphacelata, some of which also indicate the high base-content of the soils.

The community is therefore typical of moist sites or of transition to moist sites. It is at the same time typical of transition to high altitude, indicated mainly by the predominant position of Melinis spp. especially M. minutiflora and by the occasional but significant presence of Exotheca abyssinica, a typical grass of higher altitudes.

C. Moist-site communities

It is, of course, difficult to assess accurately the measure of moisture in different sites without numerous and detailed tests. That application of the combined edaphic-floristic indicator, usually adhered to in the present work, may be complicated by exceptions is evidenced by several examples of ubiquitous species occurring or dominating on both wet and dry sites and absent or subordinate in some intermediate conditions. A prominent example is that of A. gerardii which dominates, as observed, the vegetation of well-drained sites on clay-loams, loams and sandy loams or even lighter soils but also forms pure stands on clay-bound valley floors, though apparently not on such as are heavily inundated. At the same time it is absent or subordinate at some outlets of upland valleys on foothill pediments.

Clearly, then, of all the ecological factors affecting the distribution of species and formation of communities, the factor of moisture regime induces the most variable response and is, consequently, subject to the most detailed grading. The definition of moist, transitional and well-drained sites, is, consequently, largely arbitrary, and especially so since it is difficult to relate it to any consistent floristic criteria. Therefore, the definition adhered to in the present study is employed flexibly and the designation of moist-site communities as differentiated from communities on wetter sites and from those designated as transitional, is applied mainly on the basis of dominance and the gregariousness of Acacia polyacantha subsp. campylacantha. Communities in which this species dominates are associated within the area mainly with foothill pediments either of the Mbarara sandy loams and loams or the Koki silty or sandy clays, and rarely extend to valley floors. They appear to be differentiated into two or three units by annual rainfall and the nature of the soil, but the differentiation is weakly defined and involves many transitional grades to other communities, controlled by the combination of topographic, edaphic and anthropogenic factors.

6. Acacia polyacantha community

6.1 A woodland or derived wooded and tree savannas. Occurs in the drier parts of the area (< 35" p.a.) on foothill pediments and is associated only with heavy loams and alluvial clays deposited at wide valley-mouths or narrow belts on lower slopes of adjoining pediments. A common feature of these sites is the absence of any seasonal waterlogging so that although groundwater level may be relatively high and soil, due to texture, continuously damp, it is never inundated. On such sites A. polycantha tends to form pure stands with an understorey shrub layer of broadleaf shrubs and Acacia brevispica. It is associated usually with the dispersed variant of shade grass community (bii) but where the canopy of the tree layer is more patchy and topsoil dries somewhat, a Themeda triandra community is established. Variations of this type are associated with subtle changes of soil texture and large or small scale topography or else, with degree of anthropogenic disturbance. These are expressed mainly in the association of A. vermoesenii in the tree layer and that of Beckerepsis umiseta in the grass layer. This variation is consequently transitional both to community 5/d and to another moist-habitat community.

6.2. Wooded and tree savannas occurring in the more rainy parts of the area (> 35" p.a.) on sandy loams of the Mbarara foothill pediments. This combination of higher rainfall and relatively light soils produces a community in which A. polycantha is associated both with A. gerrardii and A. vermoesenii. The associated grass layer is also of a mixed type comprising the biii shade community with dominance of Beckeropsis uniseta and Panicum maximum and aii dominated by Cymbopogon afronardus and Hyparrhenia filipendula.

6.3. Wooded and tree savannas occurring in the more rainy part of the area (> 35" p.a.) on acid silty and sandy clays of the Koki Catena, on short steep pediments. A. polycantha is associated with Albizia coriaria and Albizia zygia as subdominants. Acacia gerrardii occurs conspicuously only on middle slopes of pediments. The associated grass layer is similar to the one in the previous, 6.2, community with a much greater abundance of Beckeropsis and with the abundant addition of Imperata cylindrica.

D. Edaphic grass communities on upland crests

Where upland crests are narrow and rounded as on many residuals or where level but formed on very resistant lithology such as high grade quartzite or massive ironstone and also where anthropogenic disturbance resulted in a very drastic deterioration or original soil cover, the present soils are often too shallow and skeletal to support dense woody vegetation, especially if human interference is continuing. These are mostly shallow phases of the Bugamba and Isingiro Series or soils of the Tolero and Sanga Series, mostly humose sandy or silty loams or clay loams.

g. Themeda triandra-Loudetia kagerensis community

The grass savanna community supported by these soils merges in intimate mosaic both with the transitional grass community (c) dominated by Hyparrhenia filipendula and the slope grass communities dominated by Loudetia kagerensis. It is allied with them in many common species characteristic of shallow, skeletal or very poor stony soils such as Ctenium concinnum, Andropogon dummeri, Loudetia simplex, Hyparrhenia dissoluta, Sehima nervosum, Microchloa kunthii and Sporobolus festivus.

It is, often difficult to separate the communities from each other, since each occurs in mosaic with the others, not only in transitional belts but also within the area dominated by one of them.

The present community, distinguished by the prominence of Themeda triandra, may occur on small flattenings of slope such as caused by subsidence of waste-mass or by small-scale lithological differentiation. It appears that this community is controlled by very slight variations grade quartzite or massive ironstone and also where anthropogenic disturbance resulted in a very drastic deterioration or original soil cover, the present soils are often too shallow and skeletal to support dense woody vegetation, especially if human interference is continuing. These are mostly shallow phases of the Bugamba and Isingiro Series or soils of the Tolero and Sanga Series, mostly humose sandy or silty loams or clay loams.

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The present community, distinguished by the prominence of Themeda triandra, may occur on small flattenings of slope such as caused by subsidence of waste-mass or by small-scale lithological differentiation. It appears that this community is controlled by very slight variations in soil depth but only in combination with some other edaphic factor, since soil depth alone does not appear to be decisive. There is a possibility that this community is simply a more disturbed variant, probably more regularly burned, of the c community, on shallower soils.

The community has a wide altitudinal range occurring at all elevations of upland crests in the area. In the higher altitudes ($>$ 5500 ft a.s.l.) several indicative species of the highland grass element are added, although never attaining great prominence, such as Exotheca abyssinica, Eragrostis blepharoglumis and Hyparrhenia pilgeriana.

E. High Altitude communities

As observed in the discussion of soils, the highest altitudes in the area, are apparently transitional in nature and do not enter fully into the montane or sub-montane belt. The transition is, however, gradual and is reflected in several altitudinal limits which are influenced also by edaphic factors and annual rainfall. Elements characteristic of montane flora appear already at an altitude of 4600 - 4700 ft. a.s.l. but only in azonal situations, such as skeletal soils on slopes. On more mature soils they appear at approximately 5000 ft. a.s.l. but attain dominant status in communities only above 5200 ft. a.s.l. The approximate level of 5500 ft. a.s.l. appears to contribute another altitudinal limit above which additional montane elements enter the composition of the communities. It appears however, that the nature of these communities depends on annual rainfall and the attendant edaphic factors. Where rainfall is relatively low (< 35") the main floristic features of deep soil communities still resemble those of lower communities occurring on such soils at 5000-5500 ft. a.s.l. Where it is higher, new communities arise. These are still transitional in the sense that they are dominated by tree and shrub species which are common or even dominant at lower elevations but in different ecological circumstances. The altitudinal differentiation is better defined in the grass layer but grass communities are still dominated by species typical of lower elevations. It appears that vegetation is affected by altitude not through direct macroclimatic influence but by the indirect effect of climate on soil - high content of organic matter, strong acidity and low base saturation. Such effects are less prominent on shallow and skeletal soils on which vegetation changes more gradually and merges into montane grass communities at higher elevations (> 5800 - 6000 ft. a.s.l.). Within the altitudinal limits present in the area the change is expressed by inclusion of montane elements which become more common but never subdominant (see above, community g).

7. <u>Acacia sieberiana - Albizia coriaria community</u>

Tree savanna occurring on broad or medium crests carrying Rwampara clays or sandy clays, mostly in areas of dense settlement and cultivation, so that no intact woodland or wooded savanna stands were observed.

The prominent features of this community are the absence or very subordinate position of A. gerrardii, the large size attained by isolated trees of A. sieberiana and the conspicuous presence of Albizia on upland crests which is very rare elsewhere. Associated with them are Entada abyssinica, Acacia hockii several broadleaf trees usually occurring in the area on slopes such as Combretum gueinzii, Bridelia (scleroneuroides) and Heeria reticulata and also others, notably - Maytenus senegalensis, Ficus spp. Erythrina abyssinica and Markhamia platycalyx (doubtfully indigenous in the community). Many large broadleaf shrubs are present also, usually of the same species as in lower level communities with a greater proportion of Rhus, Capparis and Carissa spp. and a lesser one of Grewia and Teclea. Occasionally, on slopes of valley heads, dense thickets of Acanthus arboreus occur, but these may be related to communities of upland valleys. It seems that the edaphic factors which control this community are the heavy texture of the soil with the consequent retention of moisture and the attendant strong acidity and low base-saturation. The latter properties probably act as deterrents to competitive species, mainly A. gerrardii, more than as incentives to the component species which are tolerant of low-base, acid soils but require moist sites. The influence of these factors is apparent also in the associated grass communities.

h. Hyparrhenia cymbaria - Hyparrhenia filipendula - Cymbopogon spp.

Occurs on crest summits, crest slopes and broad shallow saddles. Includes numerous species of which the above are the most abundant but perhaps only locally dominant. It is consequently a variable community whose variants are distributed in discontinuous patches of small areas, depending apparently on depth, nature of drainage and degree of leaching and also on the nature and measure of anthropogenic disturbance.

Several variants of this community can be distinguished.

i. On fire-free crest-slopes, where soils are deep but of a lighter sandy clay or clay loam texture and drainage is somewhat better. H. cymbaria forms dense high stands, with Beckeropsis uniseta, Panicum maximum and Brachiaria decumbens as common associates but never attaining the subdominant position of Hyparrhenia filipendula and Cymbopogon afronardus.

ii. Where soils are heavier Hyparrhenia filipendula becomes dominant with Cymbopogon excavatus and Beckeropsis uniseta in subdominant position. They are associated with Digitaria diagonalis and Melinis spp. while H. cymbaria is only occasionally present in the taller stands. The higher altitude element is more conspicuous than in the former variant represented, apart from Melinis minutiflora, by Exotheca abyssinica Hyparrhenia pilgeriana and Eragrostis blepharoglumis. Occasionally few individuals of the fern Pteridium aquilinum are present.

iii. On shallower clays and in more disturbed areas Cymbopogon excavatus is the predominant species but is closely followed by representatives of the montane element which are more conspicuous here than elsewhere, especially Exotheca abyssinica, Melinis spp. and

Hyparrhenia pilgeriana. Bracken is more abundant too, and representatives of shallow soils element such as Loudetia kagerensis are common.

It must be emphasized that the whole unit is defined tentatively for several reasons: most of the observed stands are situated within an area of cultivation and are very much disturbed; on relatively undisturbed sites there appears to exist no definable structure of floristic composition - so that no pattern of dominance and subordinate positions emerges; in all cases, stands of this community occupied small areas and were consistently associated with the Themeda triandra - Loudetia kagerensis community.

However, the edaphic, climatic and altitudinal factors enumerated above are well reflected in the general composition of the community, if not in any structural pattern.

F. Communities of Seasonally inundated flat valley floors

The vegetation of flat valley floors can be divided into several main community-groups according to the degree of inundation.

8. Where inundation or waterlogging are very brief or occasional (do not occur yearly), the predominant vegetation is Acacia savanna, almost invariably A. gerrardii - Themeda triandra community composed of almost pure stands of trees and a very uniform grass layer in which the dominant species forms very extensive tracts of exclusive presence.

9. i. In the more rainy areas or where aggraded valley floors finger into lower parts of upland valleys the community is richer in composition - the tree layer including A. polyacantha A. sieberiana, A. albida, broad leaf trees and shrubs, and the grass layer - abundant Hyparrhenia filipendula and species of the shade elements.

ii. On sites which are not inundated or waterlogged but are situated along a perennial drainage line, a special gallery woodland is formed, consisting of very tall or very large-size Acacias, mostly A. sieberiana, A. vermoesenii, A. polyacantha, and A. Albida, but also A. kirkii var. mildbraedii, Newtonia buchananii, several undetermined spp. of Albizia, and many small trees and shrubs of the thicket element.

10. Where waterlogging or inundation are seasonally prolonged, the predominant vegetation is usually a grass savanna in which Themeda triandra is gradually replaced by representatives of the hardy slope element, mainly Loudetia kagerensis and by species adapted to saturated heavy clays such as Imperata cylindrica, Digitaria Sporobolus Echinochloa spp. etc. Such sites merge gradually, in a belt pattern, with the aquatic vegetation of swamps or lakes.

II Mixed Savanna Communities

As stated the mixed savanna of the area is confined almost exclusively to slopes of upland features or to soils of the Kateti Series whose variety is great but all have the common properties of skeletal slope soils, being very leached, acid and of low base-content. It appears that it is these properties, especially acidity and rapid drying out, which condition the composition of the main community of slopes. It must be noted, however, that the slope habitat is variable and being characterised by marginal ecologic values, it is differentiated into distinct sites by relatively slight changes of the environment.

Mixed savanna communities are typical of the most extensive of these - that of intergully or spur-crest slopes and in the related shallow gully habitat. Other habitats are occupied by thicket communities.

11. Albizia coriaria - Combretum gueinzii - Bridelia scleroneuroides

Woodland, derived wooded or tree savanna. Occurs on exposed and shallow eroded slope soils. Associated with the dominants are many other tree and small-tree species of which the most frequent and abundant are *Acacia hockii*, *Heeria reticulata* and *Maytenus senegalensis*. A special variant of the community occurring in small valleys descending to the Orichinga and Kagera valleys involves a very considerable increase in size and pósition of Bridelia and also local dominance of *Albizia versicolor* which was not observed in any other place in the area.

Where the community has been disturbed or entirely denuded by cutting and burning, A. hockii dominates the pioneer woody community on the slope, forming almost pure stands. On the other hand, where new shallow gullies are being formed, the components of the community congregate in densely wooded ribbons. Throughout its extent the community is interspersed by shrub representatives of the thicket element, which form communities of their own in special habitats such as outcrops and narrow deep gullies. Where gullies widen with age representatives of the mixed savanna community encroach on the thicket and finally gain dominance.

The community is associated very uniformly with one grass community.

i) Loudetia kagerensis - Ctenium concinnum - Andropogon dummeri

Occurs on exposed rocky slopes and on narrow quartzite crests. Loudetia kagerensis much exceeds the two subdominants in abundance, except where flattenings of the slope enable accumulation of deeper soils. Where soil accumulates on outcropping, horizontal bedrock strata, mainly through erosion from upslope, it is very leached and sour and supports a slope community in which Andropogon dummeri is dominant. Where they form on mass waste, partially through weathering, they are richer in bases and support the (g) or even (c) communities, especially if a woody vegetation is established. Under well-preserved, mixed woodland the community includes representatives of the shade element (b) and a larger proportion of species typical of the transitional

(c) and crest (a) communities. These communities replace the slope community in shallow broad gullies which have been denuded of woody vegetation.

III Thicket communities

As observed, thicket communities are composed of species which are mostly associated singly or in groups with all savanna communities whether compound-leaf or mixed, and form in them a very conspicuous and characterizing element. It is often difficult to determine when or where groupings of these species within the savanna community deserve to be regarded as differentiated thicket communities, since both criteria of extent of occupied area and differential ecological complexes are not universally applicable and the thicket units are not always well-defined physiognomically. Consequently the definition of thicket communities in the present study is applied flexibly according to different criteria. It is possible, however, to distinguish several types of thicket, differentiated according to general habitat type. Only one of them is floristically well-differentiated from the others and even in this case, the differentiating components are subordinate. However, many thicket communities were very difficult to study in the circumstances of the present field work, due to their great density and floristic diversity. It would have necesitated more time, manpower and equipment than were available to study such a formation in a proper fashion. Consequently the impression gained from what was, in fact, only a superficial study, may have been deceptive.

12. Thicket-clump community

Within the area occupied by savanna communities there exists a very widespread and physiognomically well-differentiated thicket community which consists of clumps of thicket vegetation roughly round in shape and of limited area, sharply defined from the surrounding vegetation and regularly distributed within it. It occurs both on lowland and on upland crests, but while it is very widespread and apparently quite ubiquitous in lowland, its distribution on upland is limited both by altitude and by the edaphic pattern. It is entirely absent from slopes.

Its composition reflects that of the broadleaf element of the level, deep soil savanna communities that surround it, mainly that of the large-size shrub element but also of the broadleaf tree element, with the prominent addition of the Candelabra Tree. No species of those which were observed in it appeared to be specific and absent from the savanna communities and those species which dominate it or are common, such as the Grewia, Teclea, Rhus, Allophyllus, Harrisonia, Capparis and Carissa spp. were also the most abundant and frequent in the shrub element of the savanna communities. Physiognomically it is very distinctive, being dense and intertwined by climbers and spiny scandent shrubs (A. brevispica etc.), unless disturbed.

The community is found in two or three main site associations: on termite-mounds and their closest proximity; as regularly distributed clumps without apparent, direct association with any differentiated site; and in a less well-defined fashion - surrounding large size shady trees. This latter form appears to represent a more concentrated form of the usual groupings of shrubs in the savanna communities. It is parallel to other similar concentrations on sites which are relatively well-supplied by or retentive of moisture. Of the other, much better defined, forms, that associated with termite-mounds appears relatively simple to explain. Physical and chemical properties of mound soils (Hesse, 1955) indicate a much more favorable moisture regime than in surrounding soils, especially during the dry seasons. Consequently, representatives of the thicket element are better equipped to compete with the dominant tree species of the surrounding savanna and to withstand regular burning.* Moreover, once established the thicket is less subject to human interference in the form of grazing and cutting and subsequent cultivation. The distribution of the mounds themselves is a subject for a special study but appears, on general impression, to be primarily related to soil texture and depth (apart from elevation and macroclimate), being relatively rare on shallow and sandy soils. It also appears to be related to drainage being limited, according to texture, to sites in which waterlogging is interrupted for a sufficiently prolonged period during the dry seasons. It is only on mounds built in seasonally waterlogged valley floors that thicket is associated with Acacias (except for the undemanding and quickgrowing A. hockii which is widespread in association with mound thicket).

* These considerations apparently apply only to old, inactive mounds where cementing and build-up no longer continue. It is an unresolved question whether termite activity is as intensive under the present edaphic and climatic conditions of the area, as it formerly was and still appears to be in other parts of the region.

It is the thicket clumps which are not associated with termite-mounds that pose difficulties of interpretation. There is no apparent ecological reason for their sharp differentiation from the surrounding savanna. There are, however, several facts of circumstantial evidence which may point to the nature of these clumps. Where associated with the Acacia savanna, thicket-clumps are usually found where termite-mounds in various degrees of degradation, also exist; their spaced pattern and circular delineation parallels those of termite mounds but they are never found where termite mounds occur on seasonally waterlogged soils. They usually differ from the termite mound thickets in being of larger size, lesser density and poorer floristic composition. The examination of thickets on progressively degraded mounds indicates a gradual development of the same trends. It would appear, therefore, that thicket clumps represent a late stage in the degradation of termite mounds, maintaining itself either on the still existing remnants of the special edaphic habitat or through the creation of a specific moisture regime by the virtue of the physiognomic nature of the community. The tendency of representatives of the thicket element to congregate in groups suggests that a dense thicket community is developed in a progressive succession around an initial nucleus of a tree or some of its more hardy representatives. Degradation of the termite-mound site is correlated with a regressive succession of the thicket. The thicket clump stage is at times difficult to differentiate from the last stages of mound degradation and represents, possibly, the last stage at which human interference is still prevented by the density of the stand.

13. Thicket savanna community

This community is included within the thicket group mainly on floristic grounds, since physiognomically it resembles woodland or wooded savanna, and differs from the Acacia savanna mainly in having its tree layer composed of large-size representatives of the thicket element. It is associated with a well-developed shrub layer of the same element and of *A. hockii* and *Dichrostachys cinerea*. The tree and shrub layer tend to congregate in denser groups than in Acacia savanna but are much more dispersed than in the thicket clumps. As was observed, this community is associated with a grass layer representing a variant of the shade community (bii). No termite mounds are associated with it and several species characteristic of the previous community, notably the Candelabra Tree and *Harrisonia abyssinica* are either absent or very rare in it.

The community occurs on interfluve crests of mid-lowland dry areas (< 35" p.a.) mainly in the Ishura Lowland, and consequently, with the "crest" or "medium" series of the Mawogola sandy clay loams and clay loams which are strongly acid and of a low base saturation. As stated, similar sites and soils to the northwards are occupied by a compound leaf savanna in which Albizia takes a predominant part and the only apparent differentiating factor seems to be a higher rainfall, inducing an even stronger acidity.

14. Thicket community on perennially wet drainage lines

This is a lowland community which is little differentiated in floristic composition from the previous thicket communities except in the deletion of species adapted to drier conditions (Euphorbia candelabrum, Harrisonia abyssinica) the relative increase of some species (Capparis, Carissa spp) and the inclusion of certain new species (e.g. Flueggea, Syzygium, etc.) It is however, very pronounced physiognomically within the savanna landscape, attaining great density and relative height.

It is characteristic of stream and swamp banks which are not excessively inundated and its extent depends on the slope of the bank, so that on relatively flat banks raised above the incised stream it may form quite extensive belts.

15. Thicket community on slopes

This community is associated with two types of site: along rocky outcrops, and in deep narrow gullies. It is similar in essential composition to other thicket communities but contains a considerable proportion of tree and shrub species of slope and transitional elements (Albizia, Combretum, Heeria, Ficus, Maytenus, Bridelia, Stereospermum, Pappea etc.). Where outcrop and deep-gully sites are combined, composition is usually more varied and includes a greater proportion of uncommon species (Anona, Lannea etc.) A variant of this community occurs along incised gully extensions on pediment slopes where associated with the thicket are representatives of the Acacia savanna element.

16. Thicket community in upland valleys

The community combines features of slope and wet drainage line thickets with the addition of a specific element. Of this, the most prominent representatives are the Acanthus arboreus shrub which forms extensive dense thickets in a post-disturbance succession and Protea madiensis and Gardenia jovis-tonantis, which are especially abundant where the thicket has been disturbed on arenaceous slopes and the resultant soils are especially thin, acid and impoverished. Markhamia platycalyx is frequent in the deeper soils of the valley floors and may be a forest climax remnant, though in the more settled areas it may be planted since it is widely used in building - carpentry. A. brevispica which is absent from slope thickets is frequently present in valley floor thickets. There is no prominent change in composition of the thicket with altitude except perhaps in the addition of some species which are not as common at lower altitudes (Rhus vulgaris, Bersamna abyssinica etc.). In some areas (e.g. upper Muhurubuki Valley) the thicket is quite dense, continuous and well-developed, covering even part of the crests of flanking ridges and may represent a climax or a sub-climax stage.

The Pattern of Vegetation

The study of the vegetation pattern in relationship to the geomorphic features of the area, was confined to more or less level surfaces (angle of slope $< 10^{\circ}$) carrying deep ($>$ 2-3 ft.) soils with unimpeded drainage. It was considered that on slopes and in eroding or aggraded valleys specific conditions obtain which tend to obscure the effect of geomorphic differentiation. This view is reflected also in the treatment of the subject of the present study in the previous chapters.

The ecological nature of the study area

Very little is known directly of the ecology of the different plants which compose the vegetation of the area. Most of what is known is only in general terms concerning, mostly, the approximate climatic limits and the general nature of the most frequent habitats. Consequently, the ecological relationships of the vegetation had to be deduced from the distributional and phytosociological features of the various components. However, for such an ecological assessment to be accurate, detailed data of ecological factors are necessary. Such data are only partially available especially in regards to macromicroclimatic factors. More data are available concerning soil, but this is also only in regards to generalized soil types and units and selected edaphic factors. It was necessary, on the basis of this available material, to formulate some concept of the variable ecological nature of the area.

The formulation of such a concept necessarily involves an attempt at reduction of the intricate complex of factors into the smallest possible number of criteria which will have a general applicability within the investigated environmental frame. A reduction of this kind is based on the principle that many of the ecological factors are interdependent or produce combined effects and, consequently, several factors may be expressed by a single one.

The decisive role of moisture in the ecological relationships within the area can be easily recognized, and more pronouncedly so in its edaphic than in its macroclimatic aspects. This is understandable since the area was chosen and delimited to be climatically uniform as far as possible. Nevertheless, even with the paucity of available data on climatic differentiation within the area, at least one climatic limit appears to be reflected in the vegetation - the 35" p.a. isohyet. Of the other environmental factors which affect moisture, no quantitative data is available and only a general qualitative assessment can be made of some of them. It was reasoned that the ecological effect of the moisture regime is determined mainly by two values - the retention capacity of the soil and the extraneous supply. Of all the factors which affect the retentive capacity of soils, or the balance between supply and drainage, only rough estimates of soil texture and topography are available, while supply of moisture can be assessed only according to amount of rainfall and categories of lateral supply.

It was thought, therefore, that the closest approximation of moisture conditions that could be achieved is in the form of a graded relative scale.

Similar considerations were applied to what appeared to be a subordinate set of available factors - the chemical properties of the soils. Of these, as was deduced from the few sites from which quantitative values were available, the most important, both as ecological controls and as expressions of interdependence and effect of other factors, are soil reaction and base saturation. No doubt, in many ecological complexes these factors are interdependent among themselves and with the moisture factor. But as can be seen from the data of sample analyses, presented in the preceding chapter, the effect of moisture regime is modified by the intrinsic properties of the soil which also affect the dependence of soil reaction on base saturation.

However, while chemical factors are available in quantitative data, evaluation of moisture regime must be largely a matter of assessment. Since not even the simplest postulated ecological complex will be applicable without this factor, it is necessary to equate the moisture and the chemical factors by a common denominator of a graded relative scale.

The ecological evaluation of the various natural situations in the area is consequently constructed on the basis of these two factors: moisture regime and chemical properties of the soil as expressed by reaction and base saturation. It consists of a scale of relative grades of each of these factors, envisaged in combination with that of the other.

The grade-scale of the moisture factor is based on the following inductive formula:

$$\text{moisture factor (regime)} = \text{grade} \left(\frac{\text{texture}}{\text{slope}} + \text{moisture supply}\right)$$

The assessed relative grades of the members of the formula are as follows:

texture	A. grade	Slope ($< 10^o$)	B. grade
sands, loamy sands and gritty loams	1	$0 - 3^o$	1
sandy loams	2	$3 - 6^o$	2
loams	3	$6 - 9^o$	3
clay loams and clays	4		

$\frac{\text{A(texture)}}{\text{B(slope)}}$	A/B grade
< 1	1
1	2
1-2	3
> 2	4

Moisture Supply		C Grade	Moisture factor
$<$35" p.a.	$>$35"		Grade (A/B + C)
SOURCE OF SUPPLY			
rainfall		1	2-3
+ slope	rainfall	2	4
+ gully	+ slope	3	5
+ large gully or valley	+ gully	4	6 7
	+ large gully or valley	5	8-9

A similar procedure was applied to data on reaction and base saturation in order to equate them with the moisture factor.

Reaction (pH)	D. grade	base saturation %	E grade
4.5 - 5.0	1	$<$20	1
5.1 - 5.5	2	20-30	2
5.6 - 6.0	3	30-40	3
6.1 - 6.5	4	40-50	4
5.6 - 7.3	5	$>$50	5

The addition of the assigned grades of these two factors produces a similar scale as that of the moisture factor.

Chemical factor
grade (D + E)
2-3
4
5
6
7
8-10

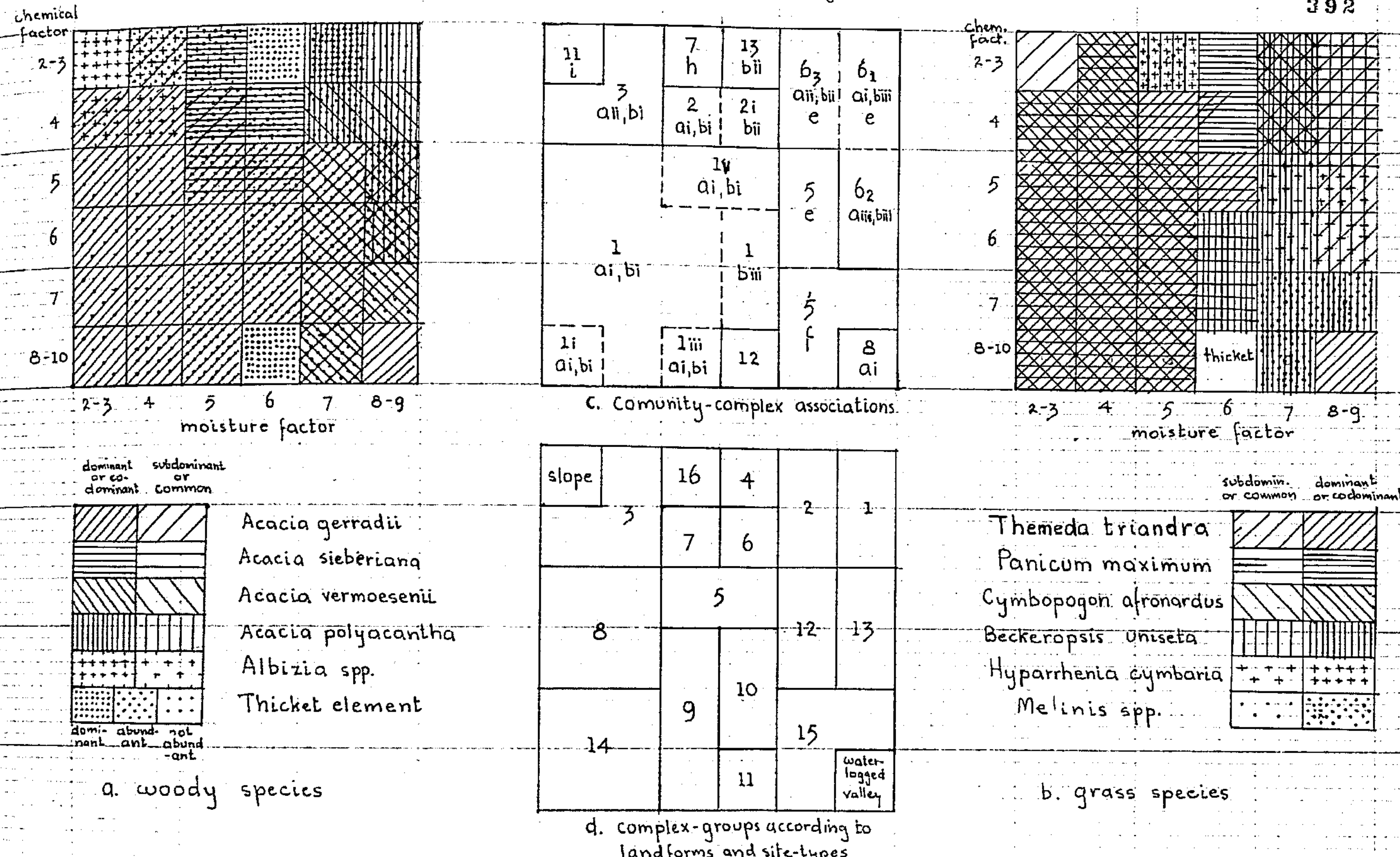
The combination of the two scales can be constructed as an ecological quadrate which must represent the possible ecological complexes of the area within the frame of the available data, since it comprises all the assessed values existing within the area (Fig. 40).

The ecological relationships of dominant species and elements

A pattern of vegetation as reflected in the distribution of distinct communities is produced basically by the ecological valence and differential efficiency of the dominant and subdominant species or elements, and can be generalized, in the absence of accurate ecological data, into a rational comprehensive outline, only if an assessment is made of these attributes in relation to each of these species or elements.

Such an assessment was attempted in the present study, by the means of the ecological quadrate described above. For the purpose, the level landforms of the area which carry deep soils with unimpeded drainage, were diagnosed according to the available pedological and climatic data and classified into the thirty-six ecological complexes depicted by the quadrate. Where no direct pedological evidence was available, the ecological nature of the landform was judged by comparison to similar landforms and according to general climatic and geomorphic features. In this way, these landforms were ecologically defined without reference to vegetation. It was found that two of the complexes do not fit into any ecologic situation on level surfaces with unimpeded drainage, but do so in relation to certain slope and aggraded valley sites. Five dominant or subdominant tree species and one woody element - (thicket) - were selected as the most prevalent and characteristic components of the vegetation, and the distribution of each, according to three categories of phytosociological

Fig. 40: Ecological complexes in relation to Vegetation



a. woody species

b. grass species

c. Comunity-complex associations

d. complex-groups according to landforms and site-types relationships, was checked against each of the ecological complexes.

The pattern that emerged (Fig.40a) shows a rational regularity of general structure although some of the details are difficult to explain, probably due to absence of sufficient data. It can be seen that A. gerrardii, the most widespread dominant species of the area, is limited in its distribution both by low values of the chemical factor and by high values of the moisture factor. At the same time it is evident that this limitation is relative, since the species is found to be exclusively dominant on waterlogged valley floors (complex 8-9/8-10) and to be subdominant or common where the chemical factor is at its lowest value (complex 4/2-3). It would seem, consequently, that its absence or infrequency are not due to transgression of absolute limits of the ecological valence, but rather to weakening of competitive capacity under these conditions. This is evidenced by the several grades of phytosociological status of the species changing from exclusive dominance in the tree layer where the combination of low moisture and high chemical factor occurs, to subdominance in the more moist, acid and base-poor complexes. This general tendency is complicated both by the interaction of factors and by the availability of competing species. Thus, A. gerrardii appears to be able to exert exclusive dominance (with no attendant subdominant trees) under fairly moist conditions (m.f. - 5-6) if the acidity is not too strong and base-saturation not too low (ch.f. > 5). On the other hand it is still exclusively dominant on a fairly acid and base-poor soil (ch. f.: < 5) if the site is too dry (m.f. < 5) to enable other species to compete with it. The chemical factor appears to be more limiting than the moisture factor since, as observed, the species is at least subdominant or common under the highest moisture values as long as the chemical factor exceeds the value of 4, and where this factor is of lower value it occurs, in any phytosociological status, only where the moisture factor is < 6.

A. sieberiana has a much narrower ecological range. It is restricted both by low (< 5) and high (> 6) moisture factor values, and appears also to be restricted by a high (> 5) value of the chemical factor. It is exclusively dominant in the tree layer only in one ecological complex (6/4) i.e., under conditions of medium moisture values and low chemical values. Apparently it is only under these conditions that the species competes successfully, to the exclusion of all other tree species. At lower moisture values it is either attended by a subdominant (A. gerrardii) or is only a co-dominant (with Albizia) while at higher chemical values it is reduced to subdominant status. It appears, consequently, that within these narrow limits, the moisture factor is more decisively limiting than the chemical one, since beyond the moisture limits of dominance (5-6) the species is absent altogether or is infrequent, while being still sub-dominant or common beyond the chemical limits of dominance (4).

A. vermoesenii is adapted to better moisture and higher chemical values than both of the previous species. It is present in a prominent phytosociological status only where the moisture factor is > 6 and where the chemical factor is > 3. It attains dominance, although never exclusive, where the moisture factor is > 7 and the chemical factor > 5. A. polyacantha clearly requires even better moisture conditions but can compete with A. vermoesenii and attain both exclusive and attended dominance where the chemical factor is < 5. It is limited, apparently, also by drainage and beyond a certain limit of impediment which is usually associated with higher base-saturation and lower acidity (> 6), it is either absent or infrequent. Albizia on the other hand, appears to represent an extraneous element on level surfaces. It attains a dominant or co-dominant status only on very acid, base-poor and rapidly drying soils and only where annual rainfall exceeds 35". Where rainfall is lower it is dominant or co-dominant only on slopes. It is, thus, possible that Albizia species mainly A. coriaria, are adapted better than any other of the five tree species to rapid utilization of moisture supply and can, consequently, withstand a low retention capacity of the soils. Where this capacity is higher it has to share its dominant status or be reduced to a sub-dominant one, either with A. sieberiana, where soils are acid and poor in bases (ch.f. < 4) or with A. gerrardii where it is less acid and richer in bases (ch. f. > 4).

The thicket element occupies a special position in this complex of relationships, since it usually forms the shrub layer and, therefore, has a lesser degree of competitive relationships with the tree species. Moreover, in many cases it appears to be dependent not only directly on the physiochemical aspect of the ecological complex, but also indirectly - on the biotic environment as conditioned by the tree layer. In the present case, its ecological relationships appear to be of significance mainly due to the fact that it is regarded as the dominant element of the potential climax-type in most of the level landforms in the area.

Thicket attains exclusive dominance in only two ecological complexes: one represents termite-mounds which are distinguished, chemically, by a very high base content and neutral reaction (Hesse, 1955), and the second - clay loams formed from pre-weathered material on interfluve crests in the < 35" p.a. rainfall area, and which are chemically distinguished by very strong acidity and poor base saturation. It is interesting to note that both complexes have the same measure of moisture factor (6) and represent extremes of the chemical factor. The abundance of the thicket element lessens gradually both with greater and smaller values of the moisture factor and are virtually absent on waterlogged sites and on shallow soils of dry slopes (except where specific moisture conditions obtain, as along outcrops and drainage lines). Generally it appears therefore, that the thicket element finds its ecologic optimum in a certain intermediate range of moisture and is relatively indifferent to the chemical status of the soil. The fact that it is not dominant in this moisture range except where chemical conditions are extreme, indicates its inability to compete with tree species where conditions for their growth become more favourable.

It appears to the writer, that these facts of ecological distribution of the thicket element have bearing on one of the fundamental problems of tropical vegetation, namely - the ability of lower life-forms to compete with higher ones and either attain an equilibrium with them and form a mixed climax or overcome them and produce a single life-form climax. The problem is closely associated with that of the nature of the savannas and appears to be one of the major reasons for doubts as to their genetic nature. The impression gained by the writer and the opinion deduced from the ecological distribution of plants in the area, is that comparison of the herbaceous and woody life-forms is deceptive. Grasses are subject to an entirely different scale and scope of ecological values and do not compete with woody vegetation. Their association in a savanna does not signify, therefore, a state of equilibrium with a higher life form but the exploitation of a distinct ecological niche. The savanna may represent, therefore, a climatic climax of more or less open woods with stands of grass between the trees, exploiting a different soil stratum in a different measure.

The relations between thicket shrubs and trees are presumably on a different level, both representing woody life-forms and at least partially competitive. It would appear that thicket shrubs, representing, in general, a lower life-form, would not be able to compete with trees where conditions are equally favourable to both, although they will be capable of forming a dense understorey. This is, as observed, indicated by the ecological pattern of thicket distribution in the area which shows that generally the thicket element representatives are unable to compete with dominant tree species except where their ecological optimum coincides with the relative pessimum of the tree species. This appears to put in doubt the concept of a thicket climax in the area. The evidence of ecological distribution and phytosociological structure under the environmental conditions of the area, suggests that thicket as composed within the area, is subordinate to a more euryvalent Acacia woodland or savanna climax type. Certainly, under different ecological circumstances such as a non-equatorial climate of the same rainfall range, a thicket element of similar composition may have a greater competitive potential, perhaps due to lesser dependence on even annual distribution of moisture supply (deeper root system?) and constitute the climax type. Wherever in Uganda a thicket formation is the dominant vegetation form at present, i.e. where it is not dispersed and physiognomically subordinate to savanna as it is in the study area, the associated ecological complex comprises a lower moisture factor than that which appears to limit the thicket in the area, either due to lower rainfall or to lighter texture of the soil. Furthermore, contrary to Langdale-Brown's definition of the thicket in the area as Deciduous, it appears to be, both floristically and ecologically, semi-evergreen and, thus, different from the thicket formation in the drier parts of Uganda.

Vegetation, soil units and surfaces

The pattern of dominant species or elements on the ecologic quadrate, lends itself to comparison with the pattern of communities as determined by the method described and as outlined above, and a pattern of ecological complex-community association can be outlined. This enables the grouping of the complexes according to site-types and landforms which can be further classified according to moisture habitat types, general rainfall regions and altitudinal levels (Fig.40d; Fig. 41)

The resulting diagram is, of course, a product of generalization in which certain details of vegetation and soil patterns may be obscured, but it does achieve a pattern of correlation between the elements of vegetation and those of soils, geomorphological features and surfaces. Several facts emerge from this pattern.

1. The communities of the area can be classified according to their surface relationships into four groups:

   a. Communities restricted to the Rwampara surface:

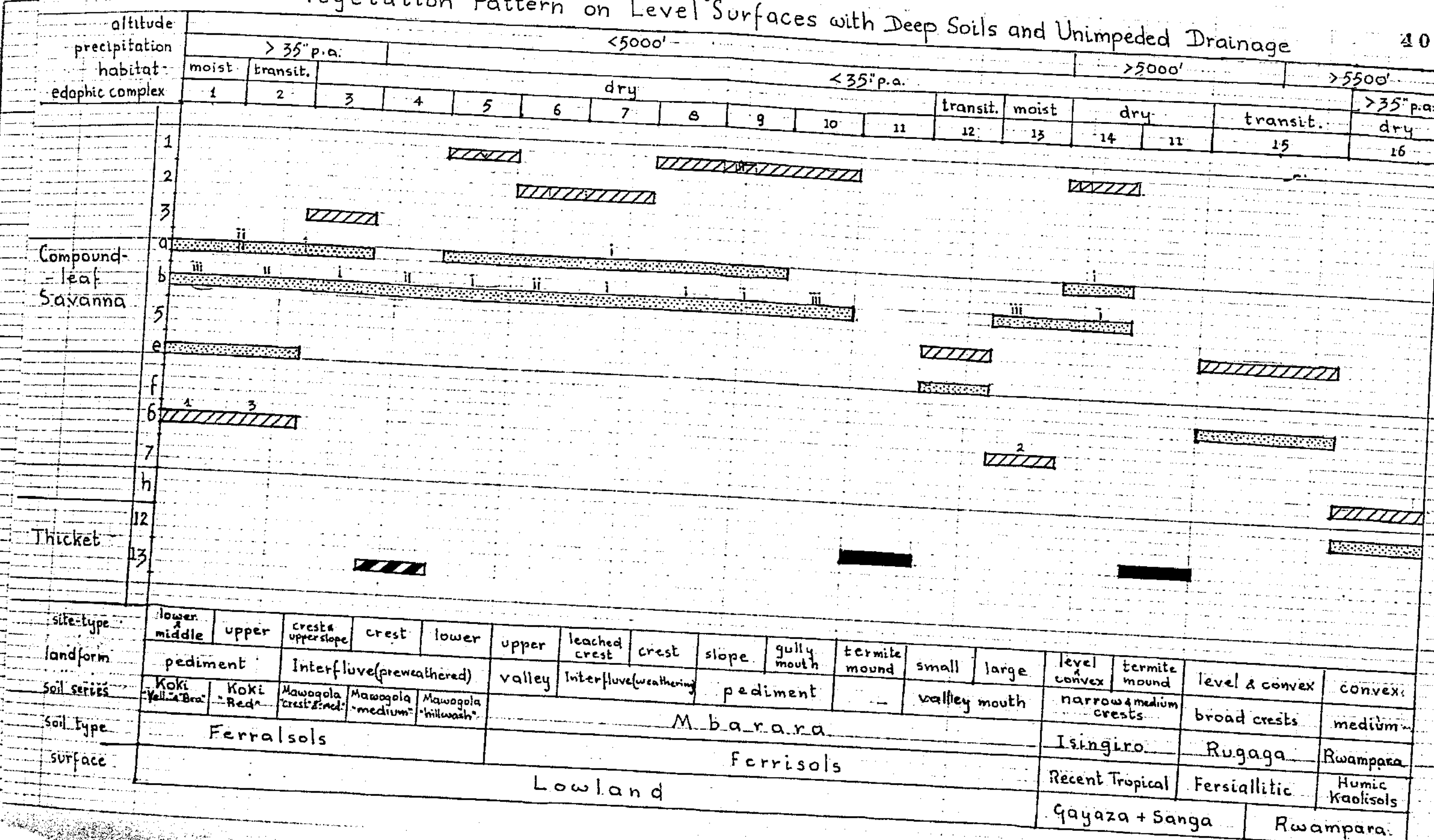
      1 tree and 1 grass community

   b. Communities restricted to the Gayaza + broad crests of the Sanga Surface: a grass community and variant of a tree community.

   c. Communities restricted to the Lowland Surface - 3 tree (or 3 variants), 1 grass community (or 2 variants) and 1 thicket community.

Fig. 41

Vegetation Pattern on Level Surfaces with Deep Soils and Unimpeded Drainage



d. Communities common to the Lowland and Gayaza + Sanga Surfaces: 2 tree and 2 grass communities (2 variants).

2. The grass communities restricted to upland surfaces are wholly or partially differentiated due to presence of species whose distribution is characterized either by a wide altitudinal range or by a montane or submontane range. Since grass communities, in contrast to tree communities, are subject to some degree of altitudinal control, their correlation with the historical aspect of geomorphic surfaces is of relatively small significance and it is mainly the tree communities that should be examined for a pattern of correlation. There is, however, only one well-defined tree community whose distribution is restricted to upland surfaces.

3. The <u>A. sieberiana - Albizia</u> tree community (no. 7) found on the deeper soils of the Rwampara surface is controlled, as can be seen from the ecological quadrate (Fig. 40c) by a moderate moisture factor and a very low chemical factor. The value of the moisture factor is produced by heavy texture and higher rainfall, modified by prevalence of relatively high angles of slope and the absence of considerable lateral supply (free drainage). The chemical factor is, no doubt, determined by the moisture regime which with other edaphic factors, mainly content and decomposition of organic matter, are at least

partially controlled by altitude. That effect of altitude on vegetation is not direct but realized indirectly through the soil, is evidence by the fact that the dominant species affiliate the community with lowland communities of similar ecological complexes. The nature of the community is, thus, controlled by soil that has been modified by altitudinal influences and, consequently, does not reflect significantly the geomorphic nature of the surface except in the sense that altitudinal influences could be exerted in a considerable measure only on the most uplifted surface, i.e. the oldest one.

4. Communities which are restricted to the Lowland surfaces (2,3,6,13) are all confined to several distinct landforms and site types. In the drier part of the area they are found only on interfluves, whether mid-lowland or periperhial. In the more humid part, they are found also on pediments. The common ecologic feature of these sites and landforms are the very low or low chemical factor values expressing both strong acidity and low base-saturation. Within these chemical limits the communities are differentiated according to the moisture factor. Only where value of the moisture factor are very high - in moist habitats, are these communities associated with moderate chemical values, and that only in the drier part of the area.

5. Except for the presence in a restricted area of upland crests, of a variant (1i) specific to the Gayaza Surface, which is of

doubtful correlative significance, the only woody communities occurring on this Surface are also found in lowlands. Consequently, the general impression gained in the area is that vegetation has a greater measure of correlation with individual landforms and site-types than with the surfaces as differentiated by geomorphic evolution. However, this impression is accurate only in general terms and mainly in the sense that the nature and distribution of vegetation are correlated with surfaces only indirectly, through the nature of the soils or the ecological complexes conditioned by the surface. It is also correct in the sense that vegetation is, on the whole, a product of contemporary environment, and is a much shorter-term natural phenomenon than soils. It cannot, therefore, be expected to correlate with the age of the surface unless the age is reflected in the nature of the present environment. That it is not reflected in the soil, which is the most conservative element of the ecological environment, was shown in the preceding chapter and is evidenced by the fact that communities are common to the younger and older surfaces.

Nevertheless, if correlation is sought not with the age of the surface but with the contemporary environment conditioned by it, several aspects of vegetation must be noted. Although there is no significant floristic or phytosociological differentiation between stands of the same communities on upland and lowland surfaces, there is a noticeable difference in their physiognomy. This is evident mainly in the least disturbed stands and is expressed in the consistence on the upland surfaces of greater density of vegetation within equivalent moisture habitat types and more vigorous growth within the different species. This is the first observational fact that is noted in the survey of the area's vegetation and it is only when floristic and phytosociologic features are examined, that the impression of uniformity is gained.

6. It is also evident from the diagram that of the two tree communities (1,5) that are common to the Gayaza and Lowland Surfaces, one - that dominated by A. gerrardii, is relatively widespread and eurytopic, associated with as many as five complex groups involving fifteen of the thirty six ecological complexes. The other, in which A. gerrardii is associated with A. vermoesenii, involves only two groups and five complexes. It is significant that all of these express high moisture and moderate to high chemical factors. This is to be expected in the lowland site-type with which this community is associated, i.e. - at mouths of small valleys where lateral supply of moisture and dissolved bases is relatively abundant. It is, however, an aberrant phenomenon on crests, even if broad, where the only moisture supply is through rainfall in the driest part of the area, and where average angles of slopes are certain to be higher and drainage more free. The high moisture factor is, consequently, mainly due to the heavy texture of the soil and the high chemical factor is mainly due to its intrinsically high base content. The extraordinary nature

of this phenomenon is brought into greater prominence if the relative areas of the surfaces occupied by this community are compared. On the Gayaza and part of the adjoining Sanga Surfaces this community is associated exclusively with Rugaga Series soils which occupy roughly 30-40% or more of the Gayaza (+ Rwampara residuals) Surface, on upland blocks. Samples of valley mouth sites occupied by this community form no more than 10-20% of the area of the adjoining pediments alone. There is no doubt, consequently, that this community of A. gerrardii - A. vermoesenii occurs on the Lowland surface only on topographically favoured sites and in a very restricted area. It is, on the other hand, widespread and characteristic of the Gayaza and part of the Sanga Surfaces not because of specially favoured topographic circumstances but due to intrinsic qualities of the associated soils. To this extent there is a clear correlation between this community and the nature of the surface.

7. The other tree community, which is common to both curfaces, is dominated exclusively by A. gerrardii, and, as observed, is relatively eurytopic. But a closer examination of its distributional pattern, shows that it also has definite limitations. On the upland surface it is associated with the deeper phases of the Isingiro soils which are much drier than the Rugaga soils (m.f. 2-4), being more sandy and shallow, but possess a high content of bases (ch. f. - 7-10) (Fig.4od; complex group 14).

f
r.
ons

On the lowland surface it is associated mainly with the Mbarara Series which represents soils developed on foothill pediments or on relatively young interfluves. They are still in a state of active pedogenesis and consequently endowed with a considerable amount of base nutrients, producing a moderate to high value of the chemical factor. Both this factor and the moisture factor depend on the nature of the site but in all cases they are never chemically poor (ch. f. > 4) or very moist (m.f. < 7). In one complext-group this community is found on soils of the Mawogola type, which are developed on deeply leached and weathered parent material, but there it is associated only with a certain site-type (lower slope) and a certain member of the catena ("Hillwash") in which a lateral supply of dissolved bases produces the suitable ecological circumstances. It can be seen, therefore, that the link between the surfaces that is provided by this relatively ubiquitous community is conditioned by a certain range of the ecological environment embracing ecological complexes occurring on both surfaces. In both cases these complexes are associated with the younger soils of the surface. On the upland surface where the soils are chemically favourable the community is limited, competitively, by lesser dessication during the dry season. In the lowland it is limited by low base saturation and strong acidity.

Conclusions as to the Nature and Distribution of Vegetation

Successional and Formational Considerations

1. An analysis of grass and tree savanna and grass communities distribution on deep soils with unimpeded drainage, reveals that in most cases grass communities which dominate the grass savanna are also found in association with wooded savanna or woodlands, in which certain tree communities dominate. It also reveals that the ecological complexes with which grass communities are associated on these soils always support also certain woody communities. There is, therefore, no reason to assume that grass and tree savannas are conditioned by climatic or edaphic circumstances and it is likely that they are derived formations, induced by direct or indirect human interference. There are grounds for believing that with cessation of interference, grass and tree savanna will revert gradually to wooded savanna or woodland. The situation is, of course, different where soils are shallow or waterlogged during the year, but where shallowness is due to denudation following human interference, reversion to wooded savanna or woodland may occur, although it will be much retarded in comparison to succession on undisturbed soils.

2. As observed, the evidence concerning the distribution and the ecological relationships of the thicket element does not support the suggestions of a thicket climax-type for the area. It is considered that components of this element are probably phytosociologically important in the structure of the area's potential vegetation, especially where it is a wooded savanna, but that under the range of moisture regime that obtains in the area, they may form a climax-type community only in certain ecological situations, where available tree species are excluded. It is also considered that the differentiation of thicket vegetation in the area does not attain a sub-formational level, as indicated by the major and most frequent components. While deciduous components are constantly associated with the thicket element, especially in the lowland, the most frequent ones are evergreen, so that even in the driest part of the area the thicket is better designated as semi-evergreen than deciduous.

3. Contemporary woody vegetation of deep soils at elevations exceeding 5500 - 5600 ft. a.s.l. is represented by two main physiognomic-floristic types. One is largely composed of thicket vegetation in which evergreen species are present in greater proportion than lower down, and is associated with Albizia tree spp.; the other - typical of the more disturbed vegetation - is a tree or grass savanna in which Albizia is associated with Acacia sieberiana and thicket is only subordinate in the woody layers. It appears, that on these sites, the immediately potential vegetation is largely evergreen thicket

associated with Albizia spp. and that A. sieberiana is a temporary seral element of the regenerating vegetation, since no stands of wooded savanna or woodland dominated by this species were observed at this elevation. However, even if the suggestion is correct, it is doubtful whether a semi-evergreen thicket represents the climax type of the high altitude sites. Inasmuch as all these sites are subject to higher annual rainfall, possibly even higher than implied by the rainfall map, thicket may represent only an advanced stage in the succession to medium altitude forest, possibly including Albizia spp. as one of its important components.

4. The climax type of all deep soils of the lowlands and of the lower and intermediate upland surfaces, appears to be a compound-leaf savanna dominated mainly by Acacia spp. but with a greater proportion of Albizia spp. in the more rainy parts. It is impossible to estimate to what time scale this postulation applies. Evidence derived from areas cleared of vegetation (see Appendix П) shows that a thirty year period is sufficient to restore the Acacia savanna to an aspect and structure similar to those of adjoining uncleared area. Evidence of some of the least populated and tse-tse infested parts of the lowland shows no significant floristic change from more disturbed areas. Predominance of thicket is, in most cases, referable either to local site-ecology or to human interference and in all such observed locations Acacia spp. or Acacia and Albizia spp. are either currently dominant or appear to be potentially so, in terms of physiognomic features (large isolated groups, a distribution pattern which cannot be accounted for

by any ecological differentiation, etc.). Consequently, if the basic assumption of the existence of a climatic compound-leaf savanna climax-type is accepted, and it appears to be accepted also by Langdale-Brown in regards to other areas (mostly under 25" - 40" p.a. rainfall and on sandy loams to clay loams) there seems to be no grounds to believe that the climatic climax type of the area should be other than a form of a compound-leaf wooded savanna. It is possible that the floristic composition of this climax type will be somewhat different: A. gerrardii appears to be specially prominent due to the advantage it has in being able to withstand a greater measure of seasonal dessication than other compound-leaf species; consequently, its role in the potential climax may be modified by the greater retention of moisture attending a denser vegetation; the climax type may, thus, be floristicly and phytosociologically more variable. It will be perhaps, a more moist type of vegetation but will still represent a form of compound-leaf savanna type.

Ecological relationships and distributional patterns

1. A principle stated previously - that vegetation, compared to other components of the landscape, is a relatively short-term phenomenon in that it expresses, actually or potentially, the existing environmental conditions, and retains relics of former environments only if and where their ecological complexes were preserved - appears to be basic in any attempt at correlation of vegetation with geomorphic features. As is well known, climate is the major

environmental control of vegetation, determining its nature on a formational level. If landforms or even their associated soils reflect their own mode of development, the vegetation will be adapted to these features only within the frame of climatic control. It is only where this control is modified very drastically by geomorphic and edaphic factors that vegetational response may transcend it. Such a modification never occurs prominently on deep, well-drained soils, but may be more noticeable where the limiting climatic factor, moisture in the present case, is modified to some degree by the nature of other environmental factors. Another fundamental principle in landform-vegetation correlations is that landform affects vegetation only indirectly, through the properties it imparts to its soil-mantle and soils, while more inert than vegetation, are less inert than the landform on which they rest. Consequently, the response of vegetation to the nature of the landform may be entirely unrelated to its evolutionary pattern.

2. The response of vegetation to edaphic factors within the existing climatic frame is quite well-defined in the area. Each of the several genetic soil units represented in the area, embraces a certain number of edaphic complexes controlled by climatic differentiation, site type and landform. These exert differential control on vegetation but only within the limits imposed by the properties common to all manifestations of the soil type. Since edaphic factors affect vegetation in combination and since

response of vegetation is limited in variation by the genetic range of its floristic components, similarities in ecological complexes and in response of vegetation may arise between different soil types. Consequently, an attempt to classify the vegetation of the area into comprehensive ecological elements would not result in complete correlation with genetic soil types. Thus, while the number of soil types represented in the area on level surfaces with unimpeded drainage is five, only four ecologic elements may be distinguished:

a. Vegetation of acid, low-base soils; associated mainly with ferralsols of the Mawogola and Koki Catenas, but also with those associates of the transitional ferrisols (Mbarara Series) that are more similar to ferralsols due to older age or to topographic and textural peculiarities causing increased leaching of bases and stronger acidity.

b. Vegetation of slightly acid and highly base-saturated soils of dry habitats. Associated mainly with the younger (pediment) or heavier textured but well-drained phases of the Mbarara ferrisols. However, since ferrisols are by definition transitional in properties, there are other soil-types or associate soil types, which under certain circumstances exert the same effect on vegetation. Thus, the lower slope associate of the Mawogola ferralsols approaches ferrisols in properties due to lateral supply of bases.

On the other hand they are approached by the Recent Tropical Soils of the Isingiro Series which are intrinsically richer in bases but are much shallower and subject to dessication which prevents the use of the nutrient content by the vegetation.

c. Vegetation of slightly acid to neutral and highly base-saturated soils in habitats transitional to moist. Associated predominantly with the fersiallitic Rugaga soils, but also with phases of the Mbarara ferrisols which have a compensating supply of moisture and bases (probably in a depositional overlay) on sites situated at mouths of large gullies or small valleys.

d. Vegetation of acid and low-base soils at high altitudes. Associated with the humic kaolisols of the Rwampara Series. Although actively pedogenetic, they have an altitudinally controlled edaphic regime and are very acid and leached. Consequently they have an affinity to preweathered ferralsols which is expressed to some degree in the vegetation.

3. Vegetation is, therefore, correlated with geomorphic features on two levels of differentiation. The lower level is associated with the relationships of vegetation with individual landforms and site-types. The measure of effect exerted by these features is not uniform and depends on both intrinsic and extraneous factors. Several main landforms can be distinguished:

a) Interfluves

Differentiated into old, mid-lowland interfluves which were developed on pre-weathered material, and on which pedogenesis is halted or retarded; and relatively young interfluves still actively weathering into soils. Pre-weathered interfluves are associated with marginal chemical factors and consequently vegetation is affected profoundly, on the community level, both by slight climatic changes and site-type differentiation. Thus, different communities are found below or over the 35" p.a. isohyet and on crests and lower slopes of the interfluves. Younger interfluves in the periphery of the lowland differ also in relative age, or in the conditioning of moisture regime by texture and topographic relationships. Vegetation is differentiated on the community level only where such intrinsic differences are profound and effect prominent modification of edaphic factors, mainly in degree of leaching (e.g. A. gerrardii - A. sieberiana community on leached interfluves of arena-like lowlands). Otherwise, site-types cause the differentiation of vegetation only on the variant or physiognomic level. Thus, on the lower interfluve slope vegetation may be differentiated from that of the crest by a larger proportion of the thicket element; the grass community may form a variant in which an associated species exerts conspicuous local dominance (e.g. Setaria sphacelata variant of the Themeda triandra community).

b) <u>Pediments</u>

Pediments are distinguished from other lowland landforms, in relation to vegetation, mainly by the additional supply of moisture and dissolved nutrients from the adjacent upland slope. Where gently sloping, the benefit of this supply is more pronounced than on short and steep pediments. If such pediments occur under higher rainfall and below low upland slopes, the effect of lateral supply may be entirely negated and the pediments soils will be strongly leached. Vegetation of pediments is differentiated on the community level, mainly due to the combination of these differences. Where one of these factors is mitigated, mainly the angle of pediment slope, the associated vegetation is differentiated only on a lower level - that of a variant (<u>A. vermoesenii</u> variant of the <u>A. polyacantha - Albizia</u> spp. community). Where several of the factors are mitigated the vegetation is differentiated only in a sub-variant level (e.g. <u>A. brevispica</u> understorey of the <u>A. gerrardii</u> community), or only in the grass community (e.g. <u>Beckeropsis uniseta</u> dominance under <u>A. gerrardii</u> at small gully mouths).

c) <u>Valley mouths</u>

Where pediments are interrupted by broadly incised drainage lines of upland valleys or larger gullies, special habitat conditions of moisture prevail, which cause a change in vegetation.

The measure of effect on vegetation depends mainly on the catchment basin at the back of the site and the nature of the slope, and on deposits on the valley-mouth bed, the latter being apparently more important than the former. The differentiation of the communities from those of the adjoining pediments is gradational: change of the subdominant on relatively well-drained sites (e.g. A. gerrardii - A. vermoesenii community); reduction of dominant to subdominant status on heavier deposits; exclusion of the pediment dominant and introduction of a new dominant on flatter, wetter beds (e.g. A. polyacantha communities).

d) Crests

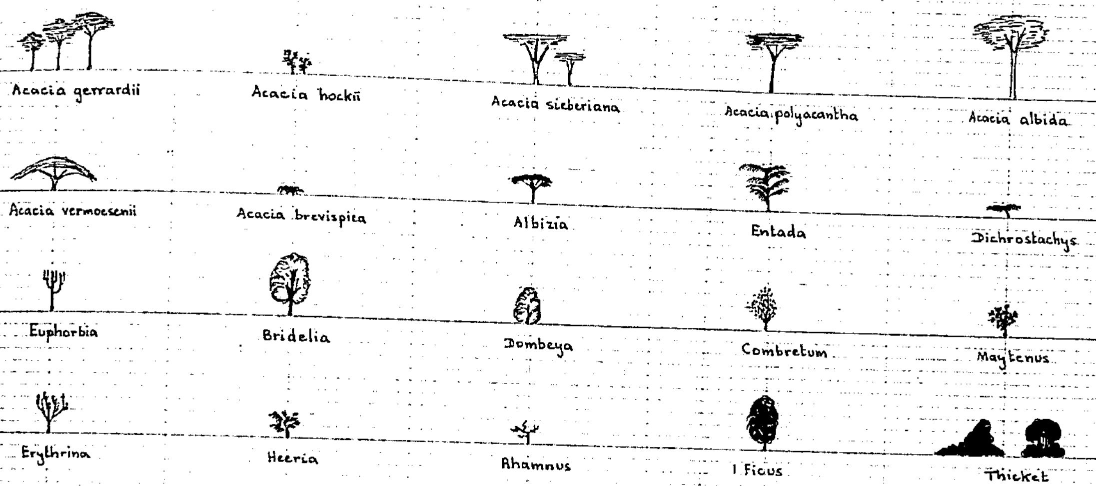
In relation to vegetation, crests are differentiated mainly according to width and form as reflected in the nature of the drainage. Soil texture, dependent both on lithology and drainage, increases the variety of possible combinations. These, however, may be generalized into narrow, medium and broad crests. Differentiation of vegetation on the community level occurs mainly where crests become broad and drainage more moderate, but other factors such as annual rainfall, altitude, topographic position or texture of soil may shift the limit of differentiation to medium crests or prevent differentiation on broad crests. On narrow crests - free drainage and consequent seasonal dessication may produce an ecological complex similar to that of well-drained pediments and, thus, cause similarity of vegetation. On medium or broad crests more moderate drainage combined with heavier soil texture and high base content may produce moisture conditions similar to those of the better drained valley-mouth sites and again cause similarity of vegetation.

4. The higher level of correlation between vegetation and geomorphic features occurs between differentiated ecologic elements of vegetation and genetic surfaces as associated with specific soil types. The controlling factors of differentiation on this level are mainly those associated with relative age of soils as reflected in measure of preweathering and leaching.

Consequently, the first order of correlation is twofold: 1. Between vegetation of preweathered, leached soils and surfaces with which such soils are associated. These occur in the older parts of the Lowland Surface, developed on incompetent lithology at a relatively early stage of the Lowland phase and are, therefore, deeply weathered and mature with geomorphic and pedogenetic processes decelerated or halted; 2. between vegetation of pedogenetically active, base-saturated soils and surfaces which are either relatively young - the peripherial parts of the Lowland Surface - or are being actively dissected - the older upland surfaces.

The second order of correlation is realized on the geomorphologically and pedogenetically active surfaces. It is controlled by moisture regime as reflected in the degree of seasonal dessication and produced by the balance of pedogenesis over erosion (expressing degree of dissection) and by soil texture (expressing lithology and topography).

Vegetation in seasonally dry habitats is correlated with lighter texture deep soils developed in the peripheral parts of the Lowland Surface or with heavier-textured, shallower recent soils developed on the more dissected parts of the upland surfaces; Vegetation of habitats transitional to moist is correlated mainly with the heavy textured deeper soils on well preserved remnants of upland surfaces but also with laterally supplied, mainly allochthonous, soils of special sites on foothill pediments. There is, therefore, an overlap in correlation, between upland and lowland surfaces where the properties of the more actively pedogenetic crest soils are degraded by the strong dissection, or where the properties of the less actively pedogenetic pediment soils are mitigated by lateral supply of moisture and nutrients.



Key to vegetation transects

Figs. 42-44

Mid-Lowland Vegetation-Soil-Landform Associations

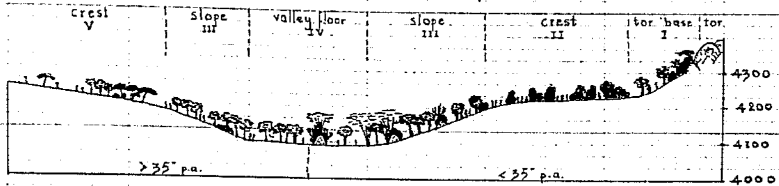
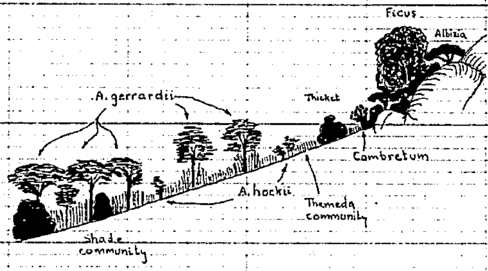
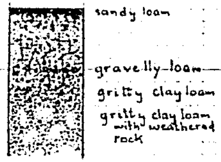


Fig. 42

Thicket Savanna



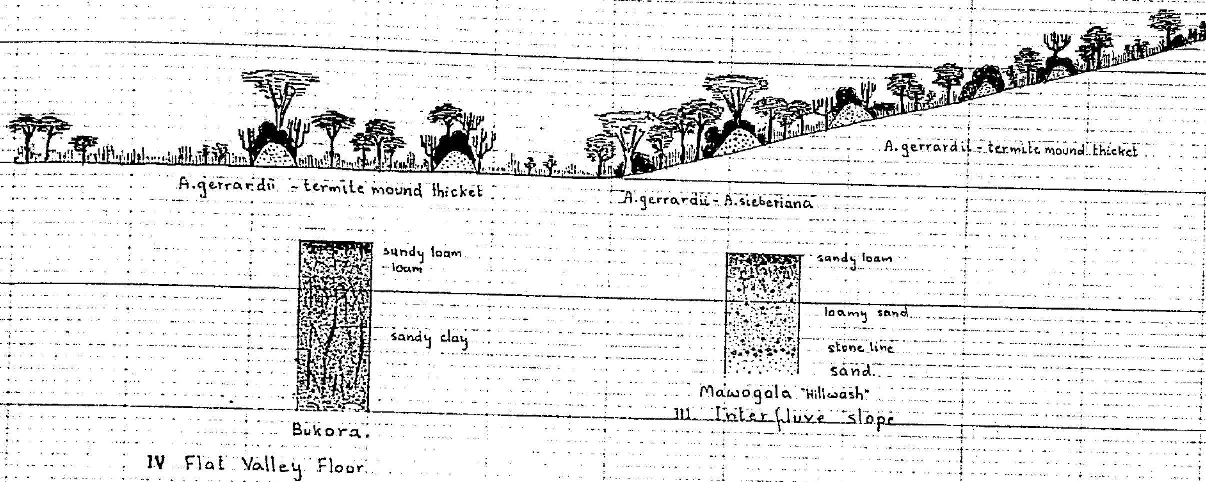


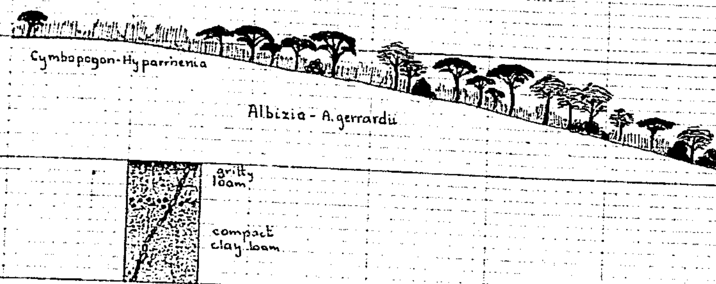
Mawogola "Medium"

Mawogola "tor-base"

I. tor-base

II Interfluve crest


A. gerrardii - termite mound thicket
A.gerrardii - termite mound thicket
A.gerrardii - A.sieberiana
sandy loam
loam
sandy clay
Bukora.
IV Flat Valley Floor
sandy loam
loamy sand
stone line
sand.
Mawogola "Hillwash"
III. Interfluve slope



Mawogola "crest"
(truncated "Medium"?)

V. Interfluve crest

Peripherial Lowland Vegetation-Soil-Landform Associations

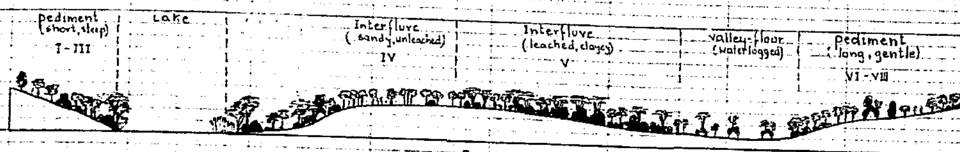
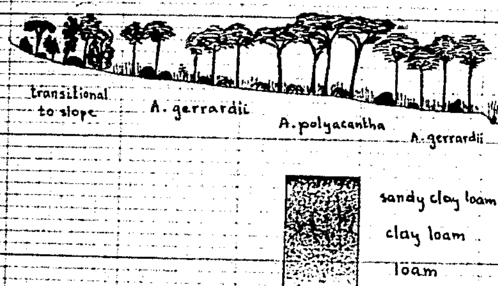
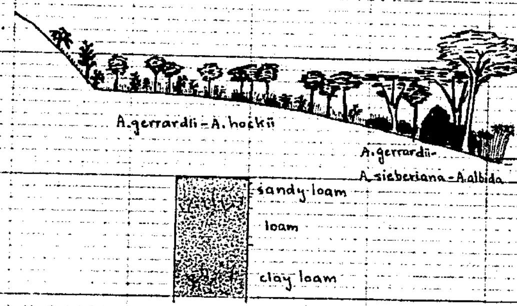


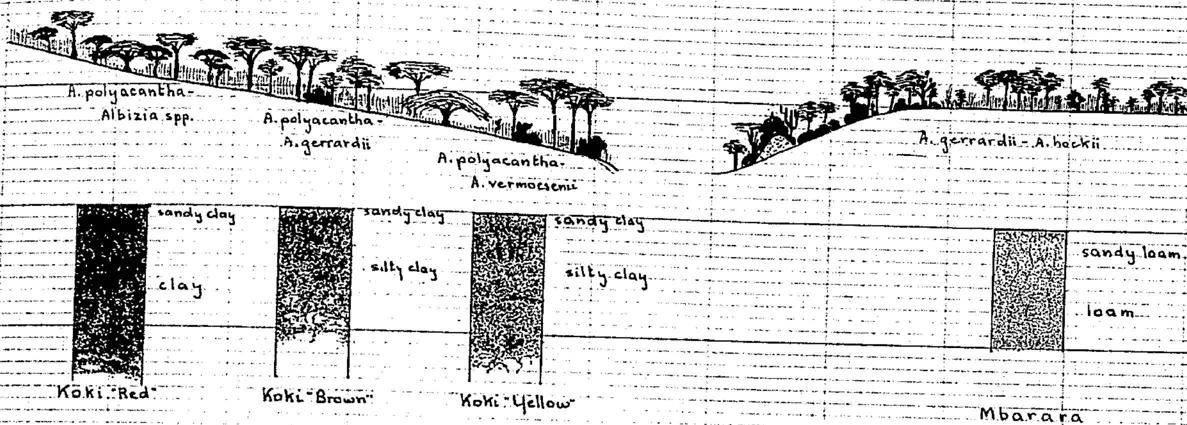
Fig. 43



I short-pediment concave slope

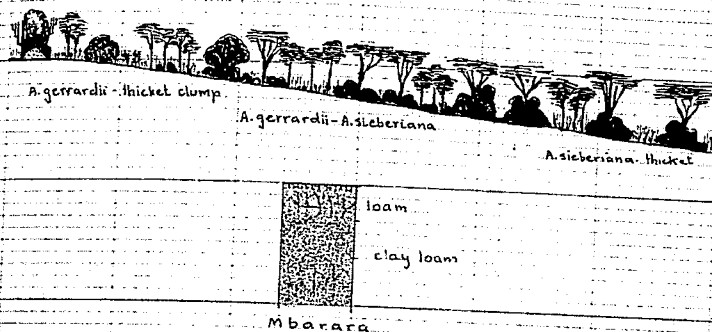


II Short pediment - convex slope

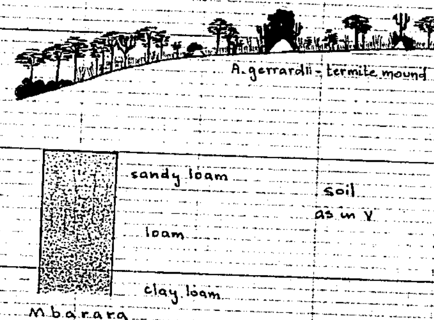


III Short pediment (≥35" p.a.)

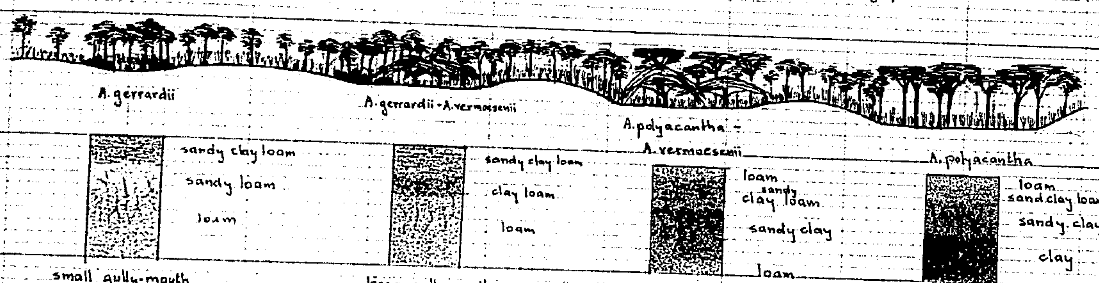
IV. Interfluve (sandy)



V. Interfuve (clay loam)



VI. Long pediment



VII. Inter-pediment valley mouths

Upland crests Vegetation-Soil-Landform Associations

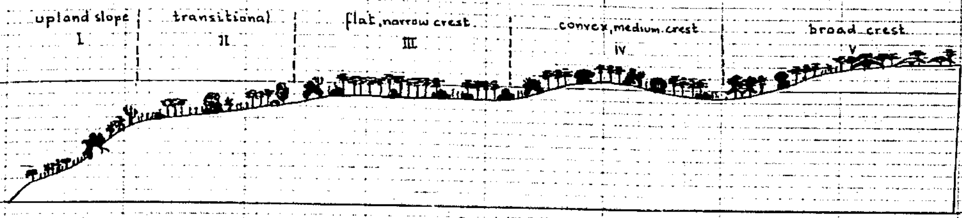
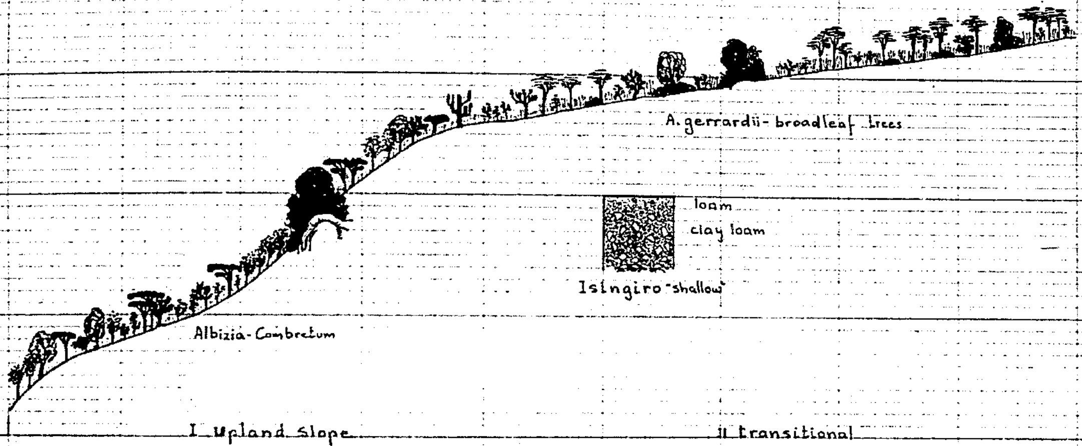


Fig. 44



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APPENDICES

Appendix I

Representative Profiles of Soils

The presentation of profile descriptions is based on their association with different geomorphic levels and situations and not according to their catenary disposition, although such an arrangement reflects conclusions reached after the fact. Parallel profiles described in the memoirs of the Research Division of the Department of Agriculture of Uganda (Series I: Soils) are presented for supplement and comparison.

I. Upland Soils

A. Rwampara crest surface profiles

1. Nahungyezi-Chewiro ridge, Eastern Rwampara, South of Kanywangani; ridge crest-slope (5^o); 5300' a.s.l.; 35-40" p.a.; under *Themeda triandra* - *Loudetia kagerensis* grass savanna.

0-5" Very dark-brown (10 YR 2/2) humose, sandy loam Many quartzite fragments. Weakly crumbly structure.

5-20" Dark brown (7.5 YR 4/2) sandy loam. Many quartzite fragments. Weakly compact. Structureless.

20"+ Pockets of dark-brown (7.5 YR 3/2) sandy loam in fragmented quartzite.

This is, obviously, a shallow A-C profile with a very humose A_1-horizon. It represents a very young, almost skeletal, soil in a state of active pedogenesis with a retarded decomposition of plant detritus, possibly due to the position on the crest slope and consequent free drainage. It is difficult to account for the shallowness and the youthfulness of the soil of the profile unless a recent exposure of the surface is stipulated. Erosional activity cannot be invoked since more mature profiles are to be found on steeper crest slopes. At the same time, the only laterite found in the vicinity is in the form of erratic blocks and there is no indication of currently disintegrating sheet of laterite exposing new bedrock surface to pedogenesis. It is possible that the soil represents new development following cessation of human activity which formerly accelerated erosional processes through burning and grazing. The dominance of Themeda triandra in the grass cover in relation to Loudetia kagerensis indicates the development of more favourable conditions and a stage preceding the disappearance of the latter species.

Harrop (1960) describes a similar profile from Bugamba (Central Rwampara) representing an upper component of the Bugamba Catena, with the attended difference of higher elevation (5,800') and rainfall (45-50") and phyllite as parent-rock.

Profile 28 (20237-39) (ibid. p.36)

0-7" Dark brown (7.5 YR 3/2) stony loam. Many fragments of phyllite Loose crumb structure. Many roots.

7-18" Compact but very friable, structureless. Much angular phyllite.

18"+ Mainly weathered phyllite _in situ_ with pockets of reddish-brown (2.5 YR, 4/4) loam.

Comparatively this is a less sandy and more leached profile and despite its somewhat lesser depth it represents, probably, more advanced weathering. These characteristics may be assigned to higher rainfall and somewhat less resistent parent-rock.

It is, however, of the same genetic nature and its general morphology is similar. It appears that as long as more data on the effects of climate and lithology are not available, the grouping of these profiles in the same series is justified.

2. Main ridge of Eastern Rwampara. NE crest-slope (8^{o}) of Mt Kagarama. 5,700' a.s.l.; 35-40" p.a.; under _Cymbopogen exåvatus_ - _Beckeropsis uniseta_ post-cultivation community.

0-11" Dark reddish-brown (5 YR 3/4) clay loam; humiferous; friable, weakly subangular-blocky structure.

11-35" Reddish-brown (5 YR 4/3) clay loam. Moderately subangular-blocky structure; more compact than the horizon above. Few ochre (5 YR 5/6)concretions and occasional laterite fragments.

35-43" Brown-red (2.5 YR 4/4) clay loam. Well-developed subangular blocky structure. Fairly compact. Concretions more numerous than in the horizon above; laterite fragments.

43"+ Phyllite rubble intermixed with clay-loam.

The profile represents a well-developed soil but appears to be still in a state of active pedogenesis. The B-horizon is quite distinct and has the attributes of a B-structural except that no clear clay-skins were found on the structural units. At the same time, there is a clear increase of clay and of ferruginization down the profile indicating a relatively intensive leaching. Yet, leaching is not intense enough to differentiate an eluvial A_2-horizon. It is, consequently, possible that clay illuviation is lateral (the crest is about 60 ft higher than the pit). The impression imparted by the profile is, therefore, of a mature crest soil developed in situ under a somewhat transitional climate, with sufficient rainfall to allow some degree of leaching, accumulation of clay, and differentiation of a structural-like B-horizon, but not sufficient to ensure the formation of distinct clay-skins.

3. Kasumba main ridge. Chanka Hill; a depression on the crest slope (5°); 5,300' a.s.l. (a modified remnant); 25-30" p.a.; *Cymbopogon excavatus* - *Themeda triandra* grass community (possibly post-cultivation), on edge of *Acacia vermoesenii* - *A. gerrardii* woodland.

0-5" Verydark greyish-brown (10 YR 3/2), heavily humose, sandy loam; friable; medium crumb structure

5-11" Dark greyish-brown (10 YR 4/2) sandy loam, stained with organic matter; friable, weak crumb structure. Laterite gravel

11-28" Grey-brown (5 YR 5/3) sandy loam; somewhat compact; weakly subangular; blocky structure; ochre (5 YR 4/6) patches and small dark concretions. Laterite gravel

28-36" Brown (10 YR 5/3) sandy loam; fine subangular - blocky structure; more compact than the horizon above; concretions more numerous; laterite gravel

36-55" Reddish-brown (5 YR 4/3) sandy clay loam; compact and structureless; many dark and reddish concretions; quartz fragments and laterite gravel

55"+ Quartz rubble in clay loam matrix.

The profile differs from the former in several significant respects. It reflects the arenaceous parent-rock in the lighter texture of all horizons. The B-structural horizon, although less distinct, is better differentiated from the C-horizon in being both less compact and less clayey. Leaching is apparently mostly lateral as indicated by site position. Site position, in a slight depression, and close to woodland, probably accounts also for the considerable amount of organic matter which appears to be quite well distributed in the upper horizons to a relatively great depth, so that the absence of a distinct eluvial A_2 horizon is very pronounced. It is, therefore, as in the former profile, a mature soil actively developing in situ, but for topographic and climatic reasons is less leached and possibly even illuviated to some degree.

B. Gayaza Crest-Surface profiles

1. Rugaga main ridge; Rugaga; level hill-crest (2^o); 5,100' a.s.l.; 25-30" p.a.; post-cultivation *Themeda triandra - Hyppharrenia filipendula* grass community.

0-8" Dark reddish-brown (5 YR 3/4) sandy clay loam; friable; weakly subangular blocky structure.

8-20" Reddish-brown (5 YR 4/3) sandy clay loam; fine subangular blocky structure. Laterite gravel.

20-35" Reddish-brown (2.5 YR 4/4) sandy clay loam; more compact than the horizon above, almost structureless. Laterite gravel.

35-46" Reddish-brown (2.5 YR 3/4) sandy clay loam; compact, structureless fine ochre (5 YR 5/6) concretions; laterite gravel.

46"+ Quartz, schistose phyllite?, laterite rubble.

In this profile the differentiation of a B-structural horizon is weaker than in the profiles of the higher surface, but it reveals a characteristic feature in being more clayey than the underlying C-horizon. Generally, the soil is heavier in texture than in the previous case, perhaps due to lesser metamorphic grade and greater contamination of the arenaceous parent-rock, or to intermixture of argillaceous parent-rock, but there is a definite impoverishment in clay in the C-horizon, which is, however, more compact*. This observation is probably related to site position, at the level top of the crest and, consequently, to prevalence

* Indicating that compactness is not necessarily correlated with clay content (see Kellogg & Davol, 1949).

of vertical illuviation over lateral, as is also indicated by the relatively meagre amount of concretionary material. However, as with the two preceding profiles, the effect of leaching is relatively small and the generally brown colour of the soil hints at a relatively high base content, which is to be expected under the stated low rainfall.

This profile is very similar to that described by Harrop (1960) from the same vicinity representing the Rugaga Series.

Profile 30 (20957-68) (ibid. p. 37)

3 miles east of Rugaga; level ridge crest. Altitude 5,200 ft (?) Rainfall 25-30" p.a., under <u>Imperata cylindrica, Beckeropsis uniseta Chloris gayana</u> and <u>Melinis minutiflora</u>

0-8" Dark reddish-brown (5 YR 3/4) sandy clay-loam. Friable with moderately firm subangular blocky structure. Many roots.

8-18" Reddish-brown (5 YR 4/3) sandy clay-loam, subangular blocky structure.

18-42" Reddish-brown (2.5 YR 4/4) sandy clay-loam with a weak subangular blocky structure but more compact than horizon above. Occasional laterite fragments.

42"+ Disintegrating laterite.

The most significant difference is, obviously, the presence of disintegrating laterite at the base of the profile, implying a continuous laterite sheet over the ridge-crest. The stated site of this profile, locates it at the foot of considerable 200 or 300 ft slope east of

Nyaruhuzi* (at what is regarded in the present work as the junction between the Gayaza and Sanga Surfaces). It is also, judging by the grass community especially the <u>Beckeropsis</u>, a more humid site. It is conceivable then, that both laterite and soil are derived from an upslope source and are not necessarily genetically related. It is also possible that laterite is not continuous over the whole crest and represents only a local, perhaps thin, accumulation. As can be seen horizons are even more weakly differentiated and there is no definite clayey C-horizon so that while undoubtedly the soil has had a long period of development it may have developed in transported material and is younger than the higher soil but more leached.

2. Gayaza ridge - Gayaza hillmass; 1.5 m. NE of Rest-House; a level crest (1^o), close to crest-edge quartzite scarp. 5,050' a.s.l.; 35-40" p.a.; <u>Themeda triandra</u> grass clearing in a dense <u>Acacia gerrardii</u> woodland.

0-8" Dark brown (7.5 YR 3/2) sandy loam; friable crumb structure quartz gravel.

8-15" Large quartzite boulders in dark brown (7.5 YR 4/2) sandy loam matrix; quartz gravel.

15-36" Reddish-brown (5 YR 4/3) sandy clay loam; moderately compact, structureless; laterite gravel.

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* It, consequently, cannot be that the stated altitude is correct. The highest summit of the Rugaga 'hillmass' is 5,114' a.s.l. and east of Nyaruhuzi crest altitude drops sharply to 4,800'.

36-45" Reddish-brown (2.5 Y 4/4) sandy loam; compact and structureless; quartz and laterite gravel.

45"+ Quartz rubble.

Except for the lighter texture due to high-grade quartzite parent-rock and the quartzite boulders in the lower horizon of the top-soil, apparently due to transport from adjacent, higher outcropt, the profile is fundamentally similar to the preceding one. It has the same pattern of increase in clay content in the intermediate horizon and decrease in the underlying C-horizon. Amount of clay, however, is not sufficient to cause a discernible structure in the B-horizon. No current precipitation and concretion of iron is discernible in the profile and drainage is excessive due to proximity of the open-jointed quartzite scarp and the crest-top position of the site. Laterite fragments found in the lower horizons, are as in other profiles, clearly unrelated to the present pedogenetic processes. It is significant in this connection that they are found only beneath the quartzite-boulder horizon, indicating their relatively early inclusion in the soil.

3. Kasya ridge, Kasumba hillmass; 1 m N of Chanka Hill; level crest (1°); 4,900' a.s.l.; 25-30" p.a.; under Acacia gerrardii - Themeda triandra tree savanna.

0-4" Dark-greyish-brown (10 YR 3/2) sandy loam; friable; weakly crumby structure

4-23" Yellowish brown (10 YR 5/4) sandy loam; compact, structureless; laterite gravel

23-36" Brown (7.5 YR 5/4) sandy clay loam; compact, structureless; laterite and angular quartz gravel.

36" Quartz rubble.

The nature of the soil represented in this profile appears to differ considerably from the above representation of the same surface. The lightly coloured horizon immediately underlying the top soil looks like a leached A_2-horizon, an aberrant phenomenon under such a low rainfall and relatively low elevation. Lack of any degree of laterization also argues against possible leaching. The most acceptable explanation appears to rest with the nature of the parent-rock and in the age of the soil. A comparable sequence of profile morphology appears, from examples in literature on African soils (Sys, 1960; Fauck, 1963), to be associated with sandstones, schistose sandstone and sandy deposits. It appears under various amounts of rainfall, both as ferruginous soils and as ferrisols. Under higher rainfall and with longer development the differentiation of horizons is more pronounced and may involve laterization. The Kazya profile appears consequently to represent a relatively young soil, developed on comparatively incompetent arenaceous, parent-material, and its profile morphology reflects lithological characteristics and not pedogenetic processes alone. It is conceivable that with longer development, profile morphology will approach that of the other soils.

If this assertion is correct then the soils represented by this profile may be regarded as a genetic link between Harrop's (1960) Isingiro Catena and the Rugaga Series. The Isingiro Catena, stated to occupy all the hills of that name except the highest crests, is defined as a lithosol and described as being shallow, dark humose sandy loam, distinguished by a high base content due to large amount of organic matter. They include, however, also deeper phases of which one is exemplified.

Profile 32 (20969-71) (ibid. p. 39)

(Kasumba 10° slope; altitude, 5,300 ft. Rainfall 25-30" p.a., under Themeda triandra with Cymbopogon excavatus becoming abundant after cultivation)*

0-9" Black (10 YR, 2/1) sandy loam, weak crumb structure and very friable. Numerous roots.

9-18" Very dark brown (10 YR, 2/2) rubbly loam containing small laterite fragments. Structureless.

18-28" Laterite gravel becoming dominant. Structureless. Dark brown (7.5 YR 3/2) loam matrix.

This profile seems to show incipient similarity to the Kazya profile and possibly represents an earlier stage of profile development on similar parent material. It may also represent a result of a steeper slope. On more resistant or more argillaceous parent material the stage parallel to that of the Kazya soil on gentler slopes will probably show a reddish-brown colour of sub-topsoil horizons and be already more similar to the Rugaga Series type of soil.

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* Site characteristics taken by Harrop from his Profile 31.

No soil pits were dug on the Sanga Surface crests where soils appeared to be of two general types: similar to those found on the Gayaza Surface or skeletal, very shallow lithosols developed over thick laterite sheets or on a partially ferruginized argillaceous bedrock.

C. Upland Slope Soils

1. Gayaza ridge; Gayaza hillmass; slope of shallow col (10°) on ridge crest, between two valley heads, breaching a massive quartzite bed; 4,980 ft. a.s.l.; 35-40" p.a.; Loudetia kagerensis - Andropogon dummeri; sparse grassland.

0-14" Black (10 YR 2/1) humose, sandy loam; friable, crumb structure. Much quartz and occasional laterite gravel.

14"+ Quartz gravel and occasional laterite gravel in very dark brown (10 YR 2/2) sandy clay loam matrix.

This is a very young and shallow lithosol and is very characteristic of all skeletal soils on quartzite slopes. The profile is identical with the type-profile of Harrop's Isingiro Catena (1960, p. 38).

2. Gayaza ridge; funnel-shaped gully-head on NW slope (35°); above quartzite outcrop; 4,850' a.s.l.; 35-40" p.a.; Acacia hockii - Albizia coriaria - Combretum gueinzii woodland.

0-6" Black (10 YR 2/1) humose loam; friable structureless matrix to numerous quartzite, phyllite and laterite fragments.

6-18" Very dark brown (10 YR 2/2) loam; friable structureless matrix to numerous quartzite, phyllite and laterite fragmerts.

18"+ Dark brown (7.5 YR 3/2) clay loam; moderately compact matrix to quartzite boulders.

The greater depth of soil is only partly assignable to downslope transport. While the upper horizons are only very faintly differentiated by amount of organic matter, the soil is apparently forming in situ in the underlying horizon which is partially preserved from erosion by the superficial material.

3. Gayaza ridge; flattened crest of gully interfluve (10°) on NW slope; 4,600' a.s.l.; 35-40" p.a.; Loudetia kagerensis - Andropogon dummeri grassland.

0-7" Dark brown (7.5 YR 3/2) clay loam, friable crumb structure; numerous small quartz, phyllite and laterite gravel.

7-24" Reddish-brown (6 YR 4/3) clay loam; weakly compact structureless; large (2-3") rounded fragments of rock and laterite.

24-32" Brown-red (2.5 YR 4/4) clay loam, compact and structureless, mottled with yellow (5 YR 8/4) and red (2.5 YR 5/6) friable patches and streaks; angular phyllite and laterite gravel mostly in lower part.

32"+ Phyllite rubble.

Leaching, most likely lateral, caused the differentiation of an illuvial, iron-rich B-C-horizon. The soil appears to have developed primarily on transported fine material since most fragments, to the depth of 28-30", show evidence of surface wash and translocation (quartzite from outcrop high, upslope).

II. Lowland Soils

A. Foothill pediment soils

1. Orichinga Valley; foot of Kyabirikwa ridge, NW part of the Valley; slope - 10°; 4,200' a.s.l.; 30-35" p.a.; under *Acacia gerrardii* - *Themeda triandra* woodland savanna.

0-8" Dark greyish-brown (10 YR 4/2) sandy clay loam; friable weak crumb structure.

8-16" Grey-yellowish brown (10 YR 4/3) clay-loam; moderately compact, weak subangular blocky structure.

16-19" Yellowish brown (10 YR 5/4) clay loam mottled with yellow (5 YR 7/6) and red (5 YR 5/5); compact, moderately developed subangular block structure.

19-24" As above with ferruginized (7.5 YR 5/6; 2.5 YR 5/8) phyllite and quartzite gravel

24"+ Phyllite rubble in yellow (7.5 YR 5/6) and red (2.5 YR 5/6) clay loam matrix.

This is apparently a seepage-line profile. Lighter colours of brown and yellow are not related to parent rock but to hydration and reddish mottling indicates precipitation of laterally transported iron in an upper pediment slope illuvial horizon, possible at the head of a current laterization transect. It is also possible that the A-B horizons represent pedogenetic development in a footslope accumulation of fine waste, although the profile appears relatively well-developed as an integrated unit despite its shallowness. This is, no doubt, due to the constant seepage under a protective cover of woodland.

2. Masha arena; ~~ibid.~~ pediment slope (6°) at SE margin; 4,300' a.s.l.; 35-40" p.a.; Acacia gerrardii - Themeda triandra tree savanna with termite-mound thickets.

0-8" Very dark grey-brown (10 YR 3/2) sandy loam; structureless (granular) few small ferruginized quartzite gravel.

8-18" Reddish brown (5 YR 4/3) loam; weak subangular blocky structure.

18-40" Yellowish-red (5 YR 4/6) clay loam; compact, subangular blocky structure.

40-60" Yellowish-red (5 YR 5/8) clay loam; with slightly yellow and red (2.5 Yr 8/6, 2.5 YR 5/8) mottling; compact and structureless.

60-80" Yellowish-red (5 YR 5/8) clay-loam; slightly mottled as above; compact and structureless; fragments of partially weathered ferruginized argillites (?) increasing in number downwards.

The bottom of the profile has not been reached at 80" but increasing amount of rock fragments (mica-schist ?) indicates the proximity of the weathered bedrock. B-structural horizon without clay skins is quite well differentiated with, perhaps, an overlying transitional horizon. A certain amount of iron precipitation occurs in the subsoil, probably inhibited by compactness and texture and appears to be only incipient. The considerable depth of the subsoil indicates a relatively active pedogenesis of sedentary soils on comparatively incompetent lithology without marked interference by erosion.

The profile appears similar to the type-profile of Harrop's (1960) Mbarara Catena and also to the "Red" component of Radwanski's (1960) Koki Catena. It differs from the former in being more leached and ferruginized and from the latter in being of lighter texture, less steep (probably less competent and more metamorphosed parent material) but less leached (probably lower rainfall and lower position on pediment).

Profile 46 (10363-68) (Harrop, 1960, p.50)

4 miles N of Birembo (Chezo Valley), Ankole; 6° pediment slope. Altitude 4,600 ft. Rainfall 35 in. p.a., under Themeda triandra.

0-6" Very dark brown (10 YR 2/2) loam, small subangular blocky to granular structure. Numerous roots.

6-15" Very dark grey-brown (10 YR 3/2) loam. Moderately firm subangular blocky structure.

15-25" Dark brown (7.5 YR 4/4) loam.

25-48" Yellowish-red (5 YR 4/6) loam, weak subangular blocky structure.

Profile 2 (14560-5): Koki "Red" (Radwanski, 1960, p. 34)

$1\frac{1}{2}$ mile from Lulagala to Bugoma (N. Koki); upper pediment; altitude 4,400 ft; rainfall 35 in. p.a., under savanna with herbs.

0-3" Dark brown (7.5 YR 4/4) stained with humus, sandy clay. Crumbly and firm. Frequent grass roots. A_1.

3-8" Yellow-red (5 YR 5/6) slightly stained with humus, clay. Weak crumbs. Slightly compact. A_3.

8-18" Yellow-red (5 YR 5/8) very slightly stained with humus, clay. Subangular blocks. Slightly compact. Transition to B.

18-36" Yellow-red (5 YR 5/8) clay. Subangular blocks of varying size and stability. Compact B.

36-60" Yellow-red (5 YR 5/8) clay. Structureless and compact. C.

60-72" Yellow-red (5 YR 5/8) clay with abundant fragments of weathered multicoloured phyllite (?). Weathered rock.

3. Masha arena; depositional fan at small gully-mouth, on marginal SE pediment (6^{o}); at foot of Gayaza ridge; 4,400 ft. a.s.l.; 35-40" p.a. Acacia gerrardii - Themeda triandra woodland savanna.

0-3" Dark grey-brown (10 YR 4/2) loam; weakly crumb structure; numerous small rounded gravel (mostly quartzite).

3-16" Brown (10 YR 4/3) friable distinctly laminar loam; numerous rounded quartz gravel

16-40" Reddish brown (5 YR 4/3) blay loam, compact and structureless.

This type of soil is characteristic of small gully-mouths on foothill pediments, where the volume of drainage is as yet insufficient to incise a drainage line and the discharge is spread in a fan over the pediment surface. The upper horizon is clearly depositional over the lower one which is part of the pediment and perhaps related to the sub topsoil horizon of a former profile.

4. Orichinga Valley (Ntogota); alluvial fan (3^o) at large gully mouth, incised in pediment on the footslope of Isozi ridge; 4,150' a.s.l.; 35" p.a.; under <u>Acacia polyacantha</u> woodland.

0-13" Black (10 YR 2/1) sandy clay, loam friable, weak crumb structure.

13-32" Grey-brown (10 YR 5/2) clay loam; firm weakly subangular blocky structure.

32-54" Brown (10 YR 4/3) clay loam; structureless, compact.

54"+ Brown (7.5 YR 5/4) clay loam; structureless, compact.

There is no sharp transition as between the depositional material and the pediment soil in the previous profile. The profile represents a genetic unit separate from the flanking pediments. It is probably comparable to soils developed on aggraded valley floors though it differs from them significantly in standing perennially above the water-table. Hydromorphic characteristics appear to be less pronounced in the lower horizons and it is possible that intermittent saturation is diminished with depth indicating the dominance of lateral moisture supply. Drainage consequently is never impeded but the profile is also never dried out for long periods.

B. <u>Mid-lowland pediment soils</u>

1. Nakivali lowland; pediment slope (5^o) north of Mukistenyi; 4,250' a.s.l., 25-30" p.a.; under <u>Themeda triandra</u> - <u>Cymbopogon afronardus</u> grassland with <u>Grewia</u> - <u>Teclea</u> thicket on old termite mounds.

0-6" Dark reddish brown (5 YR 3/4) sandy loam, loose weakly granular to structureless.

6-38" Reddish brown (5 YR 4/4) sandy loam, structureless and firm.

38-60" Reddish brown (5 YR 4/3) loam; structureless and moderately firm.

60"+ Red (2.5 YR 4/8) loam; structureless and friable.

Although bedrock has not been reached it appears that the C-horizon is represented in the lower part of the profile, probably below 38" depth. It is, consequently, an A-C profile which is typical of the lowland landscape pediments of the drier areas such as Radwanski's Buruli Catena* (1960). It appears to differ from this soil in being of somewhat heavier texture and less gritty, probably due to lesser amount of quartz veins in the parent material, and apparently also in greater amount of organic matter and lesser leaching. The Buruli Catena of Northern Mengo also has a well defined, lateritic horizon which was not identified in the present profile, although it is possible that it has not been reached or that a lower site would have shown it at shallower depth. This is indicated by another pit situated lower down the pediment slope which reveals a yellowish-red horizon with occasional semi-hard concretions at a depth of 40". A higher pit appears to have a shallower profile (C-horizon at 25") and a lighter texture throughout the profile. The redder colour of the sub topsoil A-horizon also points to greater leaching.

* Defined originally by Langdale-Brown (1957).

2. Nakaiita (Eastern Nyabushozi); crest of long gentle pediment (5^{o}) below rounded hill crest; 4,400' a.s.l.; 35-40" p.a.; degraded <u>Themeda triandra</u> <u>Cymbopogon afronardus</u> grassland.

0-12" Very dark to dark brown (10 YR 2/2 to 7.5 YR 4/2) sandy loam weakly granular moderately firm structure. Frequent fine quartz gravel and occasional quartz stones.

12-24" Reddish-brown (5 YR 4/4) gravelly loam; structureless and firm

24-40" Yellowish-red (5 YR 4/6) gritty clay loam, structureless and compact. Stone line.

40"+ Yellow (2.5 Y 8/6) loamy sand; friable with traces of weathered rock. A quartz vein transects the profile.

The granitoid nature of the parent material is apparent in the large proportion of coarse sand and quartz grit. The profile is well-differentiated into A-C and deeply weathered D horizon. C-horizon lies probably below the 12" depth level and is conspicuously more clayey than both upper and lower horizon. A parent-material poor in iron and an efficient internal drainage due to lighter gravelly texture probably prevents any noticeable laterization in this profile. In lower slope profiles, however, a mottled horizon may appear. Another type of profile from mid-lowland areas is characteristic of sites adjacent to granite tors. It is much darker in colour and less gravelly and light in texture, it is also shallower and more compact.

This type of soil is almost identical with Harrop's (1960) and Radwanski's (1960) Mawogola Catena described in the same area.

Together they recognize 3 members of this catena: the "tor" associate, the "Medium" from mid-slope, and the "Hillwash" from downslope. It also closely resembles the pediment soils of the Nyabushozi Catena which are presumably differentiated from the Mawogola Catena not only in having a crest laterite member, but also in being less sandy.

C. Valley flat-floor soils

1. Masha arena; flat valley floor of a Rugyeye tributary in the SE part of the arena; 4,250' a.s.l.; 35-40" p.a.; under Themeda triandra - Hyparrhenia spp. grassland with scattered termite mound thickets.

0-4" Dark grey (5 Y 4/1) loam, firm; weakly crumby to weakly subangular blocky structure.

4-20" Grey (5 Y 6/1) sandy clay; firm, weakly subangular blocky structure.

20-40" Yellowish grey (5 Y 6/3) sandy clay; compact and structureless cracked.

40"+ Yellowish brown (7.5 YR 5/8) sandy clay, as above but with quartz gravel and weathered rock (schist?).

The profile is typical of the flat valley floors and closely resembles the description by Harrop (1960, p. 74) from Nyabushozi of the Bukora Series defined in Koki by Radwanski (1960, p.76). Differences in texture and differentiation of horizons between the two areas are related to the origin of the alluvium in which these soils develop. Where they are derived from low grade argillites such as the Koki Shales and mudstones, the soils contain much silt and horizons are well differentiated; when parent-rock is acid plutonic or highly metamorphic such as the granitoids of the Nyabushozi and the schists and phyllites of the Rwampara area, the soils are sandy and the profile is weakly differentiated. Other differences are associated with the degree to which drainage is impeded and the measure of aggradation. Where drainage is constantly impeded and groundwater is perennially sub-surface, a gley horizon may develop. But in most cases the profile is only seasonally inundated to different degrees depending on the grade of the valley floor (on which also depends the measure of aggradation), and the sequence of horizons as to relative thickness, colour and texture depends on the length and depth of inundation. The example presented above shows a shallow profile, probably developed in a relatively slightly aggraded alluvium. Proximity of the upland, however, causes a perennial saturation of the soil even if groundwater rises above the surface for only relatively short periods. The grassland community indicates that the profile is drained, if not dried out, to moderate depth.

Appendix II

Vegetation quadrates

The following tables present three types of data:

1. Frequency of species or elements: presence of the species or element in numbers of stands expressed in percentage of total number of observed stands of the community in which species lists were prepared.

2. Quadrates: in selected stands of the community - number of individual plants; percentage cover of the ground area; percentage of the layer calculated by covered area. Quadrates of woody communities: 30 x 30m; of grass communites: 10 x 10m, in which the general patch pattern with sequence of the three most abundant species in each patch; 1 x 1m - in which individual plants are represented. Ground cover in grass communities is calculated by measurement of tussock diameter at the height of 2-3 to 4-5 inches above ground level (according to the size of the plant). Herbs are not calculated in the table. In woody communities - shrubs or trees growing under the cover of higher trees are not calculated.

3. Several of the quadrates { } (+) are represented in plans mapped by the grid method.

* Cover-area included in mound thicket.

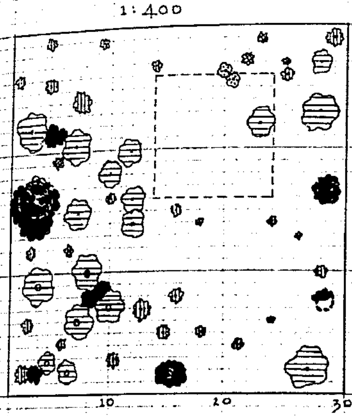
Physiognomical Categories

Physiognomic types of savanna are differentiated according to percentage cover of the woody layers:

grass savanna:	< 5%
tree savanna:	5-15%
open wooded savanna:	15-25%
wooded savanna	25-40%
densely wood savanna:	40-50%
woodland:	> 50%

1. Acacia gerradii – A. hockii	freq. % 14	+ q. no. 1 no.	% cover	% woody layer	q. no. 2 no.	% cover	% woody layer	q. no. 3 no.	% cover	% woody layer	q. no. 4 no.	% cover	% woody layer	q. no. 5 no.	% cover	% woody layer
Acacia gerrardii	100	17	9	61	22	17	65	28	19	73	35	30	91	60	53	96
A. hockii	100	25	2	13	47	4	15	31	3	12	25	2	6	12		2
A. sieberiana	35										7			5		
Dichrostachys cinerea	43				14	2	8									
Entada abyssinica	22									3						
Erythrina abyssinica	35			2		2										
Euphorbia candelabrum	57	4*														
Ficus sp.	28															
Maerua angolensis	35	2	3													
Maytenus senegalensis	78	3			3		2	2		3	3			3		
Ziziphus abyssinica	28															
Thicket components	100			3		2	8		2	9						
Thicket clumps	43		3	20												
			15			26			26			35			55	

1:400



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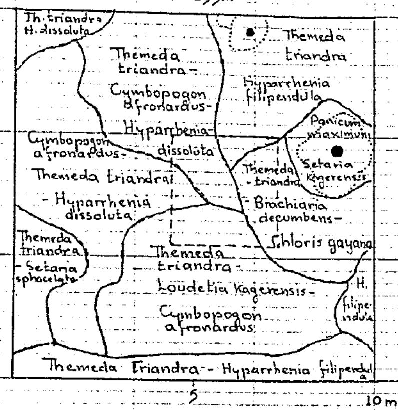

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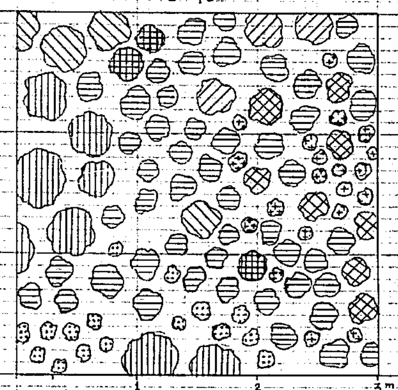


- Acacia gerrardii
- Acacia hockii
- Maerua angolensis
- Maytenus senegalensis
- Euphorbia candelabrum
- Thicket components:
  - Grewia trichocarpa
  - Harrisonia abyssinica
  - Vernonia amygdalina
  - Allophyllus africanus
- termite-mounds

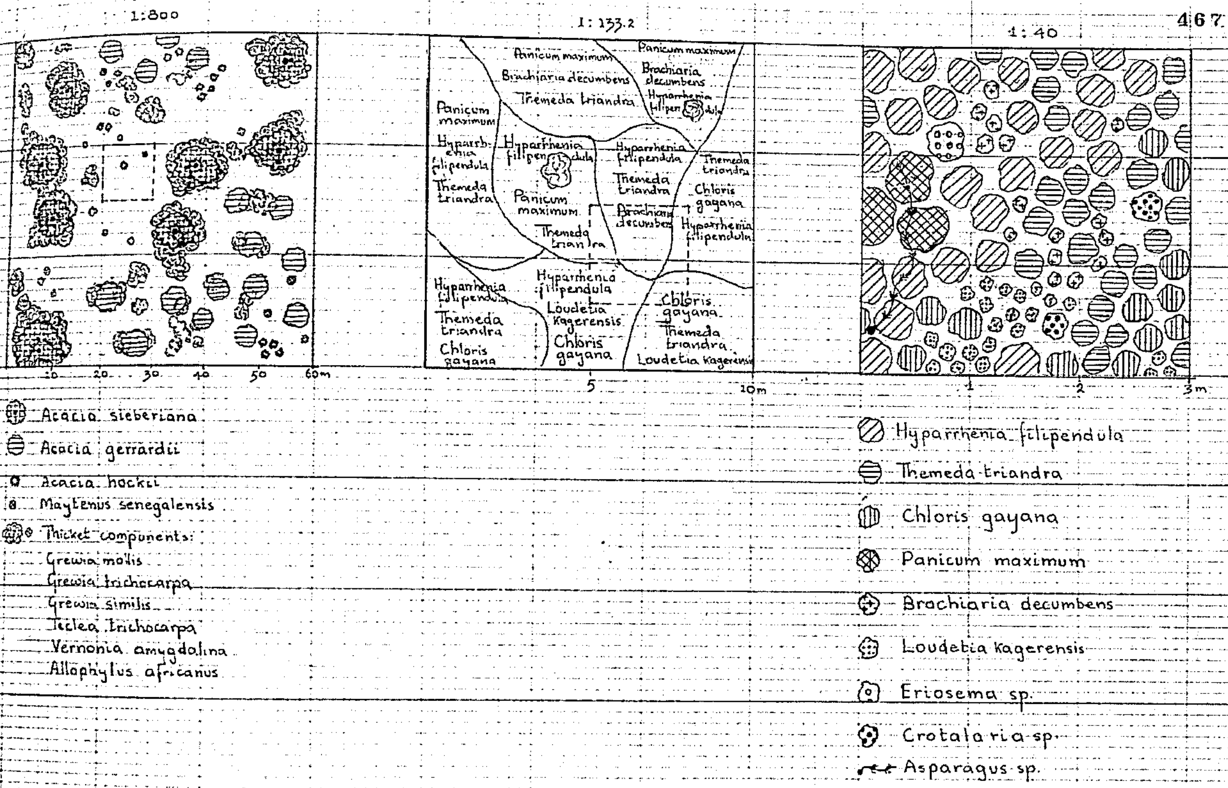
- Themeda triandra
- Cymbopogon afronardus
- Hyparrhenia filipendula
- Hyparrhenia dissoluta
- Chloris gayana
- Digitaria diagonalis
- Brachiaria decumbens
- Loudetia kagerensis

Variants of I. A. gerrardii – A. hockii	I.i A. senegal			I.iii A. brevispica							I.iv thicket										I.v A. sieberiana									
	q. no. 1			freq. %	q. no. 1			q. no. 2			freq. %	q. no. 1			q. no. 2			q. no. 3			freq. %	q. no. 1			q. no. 2			q. no. 3		
	no.	% cover	% woody layer	5	no.	% cover	% woody layer	no.	% cover	% woody layer	10	no.	% cover	% woody layer	no.	% cover	% woody layer	no.	% cover	% woody layer		no.	% cover	% woody layer	no.	% cover	% woody layer	no.	% cover	% woody layer
Acacia brevispica				100	10	2	4	16	3	6											-	-	-	-	-	-	-	-	-	-
A. gerrardii	18	14	50	100	32	43	93	36	48	94	100	24	27	63	28	31	63	17	23	49	100	26	25	60	21	23	51	18	20	43
A. hockii	34	3	11	100	18	2	4	12	1	2	100	37	3	7	30	3	6	32	3	6	100	45	4	10	43	4	9	47	4	9
A. senegal	3	4	14	-	-	-	-	-		-	-	-	-	-	-	-		-	-	-	-	-	-	-	-	-	-	-	-	-
A. sieberiana				40	-	-	-	5			60	8			2			12		2	100		4	16	2	9	20	2	9	20
Bridelia scleroneuroides	2		4	20				-			-	-		-	-	-		-	-	-	-	-	-	-	-	-	-	-	-	-
Dichrostachys cinerea				-	-	-		-			-	-			-	-		-	-	-	90	17	2	5	12		2	21	2	4
Dombeya dawei				60	3			2			-	-			-	-		-	-	-	-	-	-	-	-	-	-	-	-	-
Entada abyssinica				-			3	-		4	20	-		5			6	2		2	30	-	-	-	-	-	-			2
Erythrina abyssinica				-				-			50	3			2			5		2	40	3		2	2					
Euphorbia candelabrum	2		10	-				-			80	4			2			3			70	8*	-	-	9*	-	-	7*	-	-
Harrisonia abyssinica	4			-				-			40	-	-		3			6		4	-	-	-	-	-	-	-	-	-	-
Maytenus senegalensis	5			80	2			3			80	6			3			8			30	-	-	-	-	-	-	-	-	-
Thicket components		3		100		2	4		4	8	100		8	19		8	17		12	25	100		2	3		2	4		3	7
Thicket clumps	-	-	-	-	-	-	-	-	-	-	80		5			8	8		8	10	100		5	10		6	13		7	15
		28				48			51				43			49			47				42			45			46	

	2. A. gerrardii – A. sieberiana							2.i A. sieberiana – thicket							3. A. gerrardii – Albizia spp.						
	freq.	q. no. 1			q. no. 2			freq.	+ q. no. 1			q. no. 2			freq.	+ q. no. 1			q. no. 2		
	% 5	no.	% cover	% grass layer	no.	% cover	% tree layer	% 5	no.	% cover	% tree layer	no.	% cover	% tree layer	% 5	no.	% cover	% tree layer	no.	% cover	% tree layer
Acacia gerrardii	100	9	16	37	8	14	35	180	4	6	17	6	10	24	100	11	8	28	20	16	44
A. Hockii	100	36	4	9	18	2	5	100	13	1	2	18	2	5	100	18	2	7	15	2	6
A. sieberiana	100	7	15	35	7	16	40	100	2	9	25	4	16	38	–	–	–	–	–	–	–
Albizia spp.															100	13	18	62	11	15	42
Dichrostachys cinerea	40	–	–	–	6	1	3	–	–	–	–	–	–	–	40	–	–	–	–	–	–
Entada abysinnica	–	–	–	–	–	–	–	20	–	–	–	–	–	–	–	–	–	–	–	–	–
Erythrina abysinnica	60	4	1	2	–	–	–	30	–	–	–	–	–	–	60	–	–	–	–	–	–
Euphorbia candelabrum	80	–	–	–	4	2	5	–	–	–	–	–	–	–	40	–	–	–	–	–	–
Ficus sp.	–	–	–	–	–	–	–	20	–	–	–	–	–	–	–	–	–	–	–	–	–
Maytenus senegalensis	80	6	2	4	3	1	3	80	4	1	1	–	–	–	80	1	1		–	–	–
Thicket components	100		5	13		4	10	100		20	55		14	33	100		1	3		3	8
			43			40				36			42				29			36	

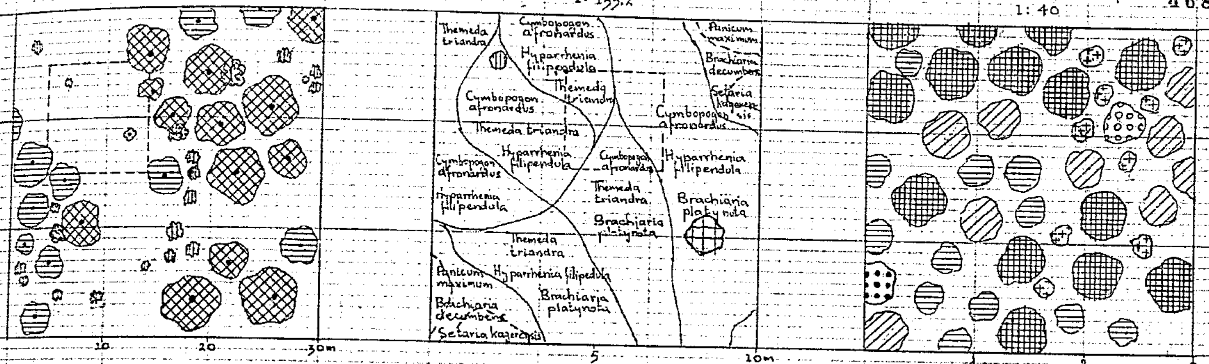
a. Themeda triandra grass community group	ai. Themeda triandra – Cymbopogon afronardus – Hyparrhenia filipendula													aii. Cymbopogon afronardus – Hyparrhenia filipendula – Themeda triandra									
	freq. %	+ q. no. 1			q. no. 2			q. no. 3			q. no. 4			freq. %	+ q. no. 1			q. no. 2			q. no. 3.		
	15	no.	% cover	% grass layer	no.	% cover	% grass layer	no.	% cover	% grass layer	no.	% cover	% grass layer	8	no.	% cover	% grass layer	no.	% cover	% grass layer	no.	% cover	% grass layer
Andropogon dummeri	30	–	–	–	–	–	–	18	2	5	–	•		10	–	–	–	–	–	–	–	–	–
Bothriochloa sp.	30	–	–	–	–	–	–	9	1	8	–			20	–	–	–	–	–	–	–	–	–
Brachiaria brizantha	40	–	–	–	–	–	–	–	–	–	38	4	6	50	–	–	–	–	–	–	9	2	6
B. decumbens	70	20	3	6	5			–	–	–	18	2	3	75	–	–	–	9		2	9		3
B. platynota	50	–	–	–	14	2	5	–	–	–				100	9	3	7	3	3	5	6	2	6
Chloris gayana	70	8	4	8	10	4	10	–	–	–	9	4	6	75	–	–	–	18	8	14	4	2	6
Cymbopogon afronardus	90	8	9	21	12	13	28	–	–	–		12	20	100	14	21	51	10	16	28	8	12	35
Digitaria diagonalis	60	3	2	3	3		2	–	–	–	4	2	3	60	–	–	–	13	6	11	2		3
Eragrostis racemosa	30	–	–	–	–	–	–	4		3	–	–	–	10	–	–	–	–	–	–	–	–	–
Hyparrhenia dissoluta	50	4	4	9	–	–	–	4	3	8	–	–	–	70	–	–	–	–	–	–	2	2	6
H. filipendula	100	3	2	5	7	5	12	13	10	28	6	5	8	100	9	10	24	8	8	14	5	5	15
Loudetia kagerensis	50	16	2	6	–	–	–	24	4		–	–	–	30	–	–	–	–	–	–	27	3	8
Setaria sphacelata	40	–	–	–	3		2	–	–	–	33		18	30	–			12	4	7	–	–	–
Sporobolus pyramidalis	30	–	–	–	–	–	–	8		3	–	–	–	10	–			–	–	–	–	–	–
Themeda triandra	100	43	19	43	38	17	41	32	14	39	50	22	36	100	12	7	18	17	11	19	6	4	12
		45			42			36			62				41			57			34		

b. Shade communities	bi tree shade				bii thicket savanna							biii gully mouth			
	freq.	q. no. 1			freq.	q. no. 1.			q. no. 2.			freq.	q. no. 1.		
	% 10	no.	% cover	% grass layer	% 5	no.	% cover	% grass layer	no.	% cover	% grass layer	% 5	no.	% cover	% grass layer
Beckeropsis uniseta	20	–	–	–	40	–	–	–	–	–	–	100	20	27	37
Brachiaria brizantha	30	28	3	4	60	–	–	–	–	–	–	20	–	–	–
B. decumbens	100	60	10	15	100	62	10	18	15	2	4	80	47	8	11
B. platynota	20	–	–	–	80	10	2	4	–	–	–	–	–	–	–
Chloris gayana	80	7	4	6	100	18	8	15	11	6	11	60	–	–	–
Cymbopogon afronardus	70	–	–	–	40	–	–	–	–	–	–	40	–	–	–
Hyparrhenia cymbaria	–	–	–	–	–	–	–	–	–	–	–	80	3	6	8
H. filipendula	60	–	–	–	80	3	3	6	26	27	48	60	2	2	8
Panicum maximum	100	20	26	39	100	11	14	26	3	5	10	100	14	18	25
Setaria kagerensis	100	90	20	30	100	36	8	15	22	3	5	100	54	12	16
S. sphacelata	60	–	–	–	100	15	5	9	–	–	–	40	–	–	–
Themeda triandra	70	9	4	6	80	9	4	7	28	11	20	40	–	–	–
		67				54			56				73		



1:800
1:133.2
1:40
Panicum maximum
Brachiaria decumbens
Themeda triandra
Hyparrhenia filipendula
Chloris gayana
Loudetia kagerensis
10 20 30 40 50 60m
5 10m
1 2 3m
Acacia sieberiana
Acacia gerrardii
Acacia hockii
Maytenus senegalensis
Thicket components:
Grewia mollis
Grewia trichocarpa
Grewia similis
Teclea trichocarpa
Vernonia amygdalina
Allophylus africanus
Hyparrhenia filipendula
Themeda triandra
Chloris gayana
Panicum maximum
Brachiaria decumbens
Loudetia kagerensis
Eriosema sp.
Crotalaria sp.
Asparagus sp.

1:400 1:133.2 1:40



Albizia spp

Acacia gerrardii

Acacia hockii

Maytenus senegalensis

Thicket component:

- Grewia mollis
- Allophylus africanus
- Harrisonia abyssinica
- Pavonia sp.

Cymbopogon afronardus

Hyparrhenia filipendula

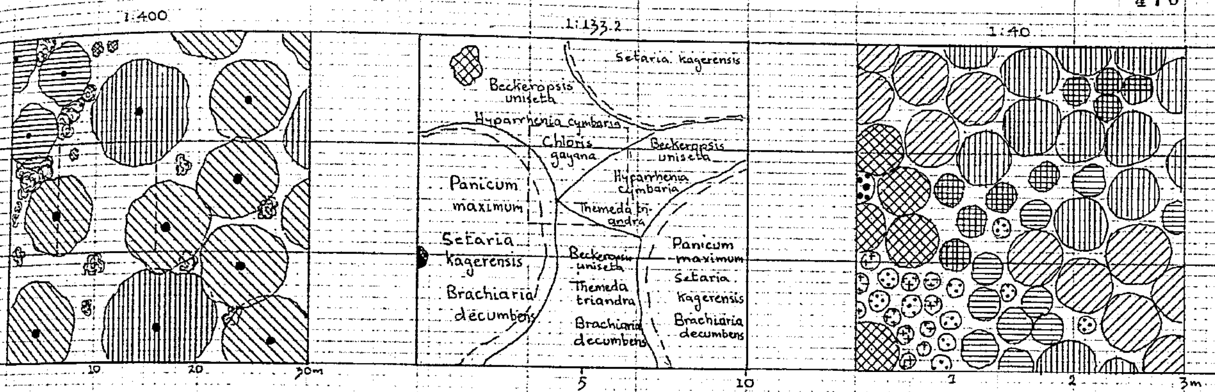
Themeda triandra

Brachiaria platynota

Pseudoarthia hookeri

Aspilia sp.

	e. Beckeropsis uniseta – Hyparrhenia cymbaria										f. Cymbopogon excavatus – Melinis spp.									
	freq. %	+ q. no. 1			q. no. 2			q. no. 3			freq. %	+ q. no. 1			q. no. 2			q. no. 3		
	10	no.	% cover	% grass layer	no.	% cover	% grass layer	no.	% cover	% grass layer	7	no.	% cover	% grass layer	no.	% cover	% grass layer	no.	% cover	% grass layer
Beckeropsis uniseta	100	14	20	30	16	23	32	11	16	24	100	7	11	19	22	32	43	5	8	11
Brachiaria decumbens	100	20	5	5	14	3	4	18	4	6	70	–	–	–	18	2	3	9	1	1
Chloris gayana	80	6	5	8	8	7	10	6	5	7	40	7	4	7	–	–	–	–	–	–
Cymbopogon afronardus	30	–	–	–	–	–	–	3	4	6	40	–	–	–	–	–	–	–	–	–
C. excavatus	–	–	–	–	–	–	–	–	–	–	60	29	22	38	23	18	24	18	12	17
Digitaria diagonalis	30	–	–	–	–	–	–	–	–	–	60	6	4	7	–	–	–	9	6	8
Erotheca abyssinica	–	–	–	–	–	–	–	–	–	–	40	–	–	–	–	–	–	3	2	3
Hyparrhenia cymbaria	100	11	21	30	19	18	25	8	16	24	30	–	–	–	–	–	–	4	8	11
H. diplandra	–	–	–	–	–	–	–	–	–	–	40	–	–	–	3	5	6	–	–	–
H. filipendula	60	–	–	–	2	2	3	3	3	5	100	2	3	5	6	8	10	5	7	10
Imperata cylindrica	–	–	–	–	–	–	–	–	–	–	40	–	–	–	18	4	5	–	–	–
Melinis spp.	–	–	–	–	–	–	–	–	–	–	100	44	4	7	42	4	5	50	44	20
Panicum maximum	80	5	9	13	4	6	8	2	2	3	60	–	–	–	4	4	5	8	8	11
Setaria kagerensis	80	7	2	3	11	3	4	18	5	7	–	–	–	–	–	–	–	–	–	–
Setaria sphacelata	40	–	–	–	–	–	–	–	–	–	40	2	1	2	9	2	3	27	6	8
Themeda triandra	50	10	7	11	15	10	14	18	12	18	40	–	–	–	9	5	6	–	–	–
		67			73			67				58			74			72		



- Acacia polyacantha
- Acacia vermoesenii
- Acacia gerrardii
- Acacia hockii
- Thicket components:
  - Grewia mollis
  - Grewia trichocarpa
  - Grewia similis
  - Teclea trichocarpa
  - Rhus natalensis
  - Carissa edulis

- Beckeropsis uniseta
- Hyparrhenia cymbaria
- Panicum maximum
- Themeda triandra
- Chloris gayana
- Brachiaria decumbens
- Setaria kagerensis
- Geniosporum paludosum

	5. Acacia gerrardii – Acacia vermoesenii																61 A. polyacantha				62 A.polyacantha – A.vermoesenii				63 A.polyacantha – Albizia spp.			
	freq.	q. no. 1			q. no. 2			q. no. 3			q. no. 4			q. no. 5			freq.	q. no. 1			freq.	+q. no. 1			freq.	q. no. 1		
	% 10	no.	% cover	% woody layer	no.	% cover	% woody layer	no.	% cover	% woody layer	no.	% cover	% woody layer	no.	% cover	% woody layer	% 5	no.	% cover	% woody layer	% 7	no.	% cover	% woody layer	% 5	no.	% cover	% woody layer
Acacia brevispica	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	80	15	-	-	-				-	-	-	-
A. gerrardii	100	5	10	72	14	28	58	10	21	31	14	28	37	9	6	33	70	-	-	-	100	3	7		60	8	10	22
A. hockii	100	14	2	8	10	1	2	8		2	18	2	3	15	2		40	-	-	-	100	3		-	80	8		2
A. polyacantha	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	100	16	53	81	100	10	38	59	100	5	16	35
A. sieberiana	40	-	-	-	-	-	-	-	-	-	-	-	-	2	2	-	20	-	-	-	50	-	-	-	50	-	-	-
A. vermoesenii	100	2	8	33	2	13	27	4	27	40	5	30	40	2	8	44	80		12	19	100	3	15	24	100		6	12
Albizia spp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-				100	5		25
Dichrostachys	30	-	-	-	-	-	-	-	-	-	-	-	-			-	-	-	-	-	-				-	-	-	-
Entada abyssinica	60	-	-	-	-	-	-	3	4	6	5	6	8	-	-	-	-	-	-	-	-				-	-	-	-
Ficus sp.	-	-	-	-				-	-	-				-	-	-	-	-	-	-	-				-	-	-	-
Thicket components	100	-	4	17		6	13		17	21		9	12					9			100		4	6	100		2	4
			24			48			67			75			18		60		65				64				46	

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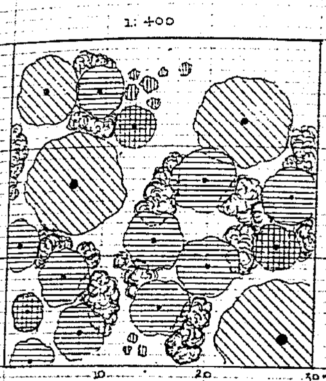

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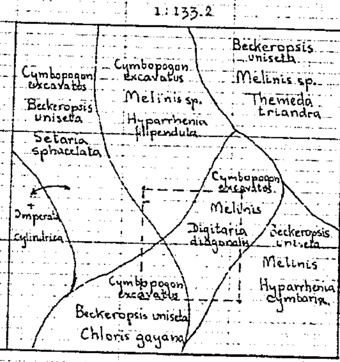

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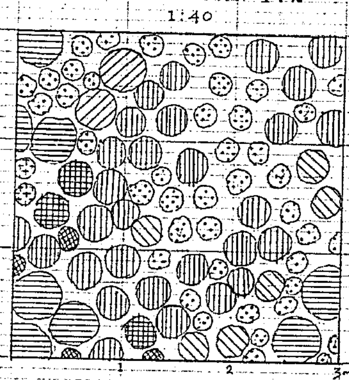


- Acacia vermoesenii
- Acacia gerrardii
- Entada abyssinica
- Acacia hockii
- Thicket component

- Beckeropsis uniseta
- Cymbopogon excavatus
- Hyparrhenia filipendula
- Digitaria diagonalis
- Melinis sp.
- Setaria sphacelata
- Brachiaria decumbens

aiii/1 N Ishura lowland (TQ 860488); 4300 ft.a.s.l.; interfluve crest; wooded savanna

aii/2 W Koki Hills (TQ 961453); 4100 ft.a.s.l.; foothill pediment; grass savanna.

aii/3 E Nyabushozi lowland (TQ 723561); 4350 ft.a.s.l.; interfluve slope; tree savanna.

bi/1 as in 1/1

bii/1 Ishura lowland (TQ 892405); 4250 ft.a.s.l.; interfluve crest; dense thicket savanna.

bii/2 as in 1v/3

biii/1 W Nakivali lowland (TQ 620054); 4350 ft. a.s.l.; upper lowland valley; wooded savanna.

2/1 Mburo lowland (TQ 696330); 4080 ft.a.s.l.; interfluve crest; densley wooded savanna (cleared in 1933)

2/2 Mburo lowland (TQ 695304); 4150 ft.a.s.l.; interfluve crest; densely wooded savanna.

2i/1 as in biii/1

2i/2 W Nakivali lowland (TQ 667066); 4350 ft.a.s.l.; upper lowland valley; densely wooded savanna.

3/1 as in aii/1

3/2 E Nyabushozi lowland (TQ 882569); 4300 ft.a.s.l.; interfluve crest; wooded savanna

e/1 Lower Kabingo valley (TQ 556136); 4400 ft. a.s.l.; gully mouth; woodland.

e/2 Orichinga valley (TP 516962); 4250 ft.a.s.l.; small valley mouth; wooded savanna.

e/3 W Nakivali lowland (TQ 594100); 4150 ft.a.s.l.; small valley mouth; wooded savanna

f/1 Kasumba hillmass (TQ 724045); 5300 ft.a.s.l.; upland crest; woodland.

f/2 E Rugaga hillmass (TQ 852074); 4850 ft.a.s.l.; upland crest, tree savanna

f/3 Ngarama hillmass (TP 602994); 5550 ft.a.s.l.; upland crest; open wooded savanna

5/1 as in e/2

5/2 Bigasha lowland (TP 597932); 4200 ft.a.s.l.; valley mouth, densely wooded savanna.

5/3 as in f/1

5/4 Kasumba hillmass (TP 693920); 5200 ft.a.s.l.; upland crest; woodland.

5/5 as in f/3

6_1/1 Orichinga valley (TQ 537078); 4150 ft.a.a.l.; small valley mouth; woodland.

6_2/1 as in e/1

6_3/1 N.Koki Hills (TQ 962431); 4150 ft.a.s.l.; mid-pediment slope; densely wooded savanna.

Map 4 : Physiography of Southwest Uganda

Regions and Subregions

A. Lakeside Region

1. Coastal plain (X a, b)
2. Hill belt (VIa, d, e)

B. Katonga Plateau

3. Wamala basin (VIb; VIIId; Xc)
4. Mawogola rolling plains (VIc; VIIIe)
5. Nyabushozi tor landscape (VIIa, b; VIII f, h)

C. Ankolean Upland Region

6. Northern downlands and outliers (IIIa; IVa, b; V; VIIa, c; VIIIc)
7. Koki Hills (IIIc, d, e)
8. Koki foothills (IIIe)
9. Isingiro Hills (II; IIIb)
10. Rwampara Mountains (Ia, c, d)
11. Southern downlands and outliers (IVb, c; VIIa, c; VIIIc)
12. Kigezi Mountains (Ib, c, d, e)
13. Bushenyi plateau (VIII f, g)
14. Buhwezu Highland (Ia, b, c, e)
15. Rift Slope (VIIIb, g, h)

D. Toro-Mubende Upland Region

16. Toro rolling plains (VIa, f; VIIIb)
17. Mubende tor landscape (VIIa; VIIIf)
18. Rift slope (VIIIb)

E. <u>Singo Hills Region</u>

19. Singo Hills (V)

F. <u>Northern Mengo Region</u>

20. Northern Mengo (VIIIa)

H. <u>Western Rift Valley Region</u>

21. Lake Edward plains (IXa, b)

22. Ruwenzori (IXc)

23. Lake Albert plains (IXa)

Map 4 : Physiography of Southwest Uganda

Geomorphic characteristics

I Upland blocks with predominance of Ankole Surface (Jurassic) remnants

a. Continuous upland blocks - well-preserved Ankole Surface remnants

Crest altitude: 5,000-6,300 ft a.s.l.

bevelled-convex crests; steep slopes

narrowly v-shaped, ungraded, valleys

b. Continuous upland blocks - well-preserved Ankole Surface remnants

Crest altitude 5,500-8,300 ft a.s.l.

bevelled-convex crests; steep slopes

narrowly u-shaped, aggraded to drowned valleys

c. Continuous upland blocks - well-preserved Ankole Surface remnants

Crest altitude: 5,500-8,300 ft a.s.l.

bevelled-convex crests; steep slopes

broadly u-shaped, drowned (lacustrine) valleys

d. Discontinuous upland blocks - occasional Ankole Surface remnants

Crest altitude: 6,000-7,500 ft a.s.l.

bevelled-convex to convex crests; steep to moderate slopes

narrowly u-shaped, short pedimented, aggraded to non pedimented ungraded valleys

e. Continuous upland blocks - degraded remnants of Ankole Surface

Crest altitude: 5,000-7,000 ft a.s.l.

Convex crests; steep to moderate slopes

narrowly v-shaped, rejuvenated valleys

II <u>Upland blocks with both Ankole and Koki (Cretaceous) Surface remnants</u>

Crest altitude: 4,900-5,650 ft a.s.l.

bevelled-convex crests; steep to moderate slopes

narrowly to broadly v-shaped, ungraded valleys

III <u>Upland blocks with both Koki and Buganda (early-Tertiary) Surface remnants</u>

a. Continuous upland blocks with Koki Surface remnants and modified residuals of Ankole Surface

Crest altitude: 4,900-5,650 ft a.s.l.

bevelled-convex crests; steep slopes

narrowly v-shaped ungraded valleys

b. Continuous upland blocks with well-preserved remnants of Koki and Buganda Surfaces

Crest altitude: 4,500-5,150 ft a.s.l.

bevelled-convex crests; moderate slopes

narrowly to broadly v-shaped, ungraded valleys

c. Continuous upland blocks with well-preserved Buganda Surface (lithologically controlled) and occasional Koki Surface remnants

Crest altitude: 4,500-5,100 ft a.s.l.

bevelled crests; steep to moderate slopes

narrowly to broadly v-shaped, ungraded valleys

d. Discontinuous upland blocks with well-preserved Buganda Surface remnants (lithologically controlled)

Crest altitude: 4,500-4,800 ft a.s.l.

bevelled crests; steep to moderate slopes

narrowly to broadly u-shaped, partially aggraded valleys

e. Discontinuous upland blocks with modified Buganda Surface remnants (lithologically controlled)

Crest altitude: 4,300-4,500 ft a.s.l.

bevelled crests; moderate slopes

lowland, aggraded or drowned valleys with distinct pediments

IV <u>Residual upland with remnants of Ankole (lithologically controlled) or Koki Surfaces</u>

a. Numerous upland residuals with well-preserved surface remnants

Crest altitude: 4,900-5,200 ft a.s.l.

bevelled-convex crests; steep slopes

broadly u-shaped and lowland, aggraded valleys; distinct pediments

b. Occasional upland residuals with well-preserved surface remnants

Crest altitude: 4,900-7,200 ft a.s.l.

bevelled-convex crests; steep to moderate slopes

lowland valleys, aggraded with distinct pediments

c. Occasional upland residuals with modified surface remnants

Crest altitude: 4,900-6,000 ft a.s.l.

convex crests; moderate slopes

broadly v-shaped, ungraded to lowland of rolling interfluves and broad drowned valleys

V <u>Residual upland with modified Ankole and well-preserved Koki/Buganda Surface pattern</u>

Crest altitude: 4,500-5,450 ft a.s.l.

bevelled-convex crests; steep to moderate slopes

narrowly u-shaped, aggraded and drowned valleys

VI Residual upland with Buganda Surface remnants in Tanganyika Surface Landscape

a. Well-preserved remnants of the Buganda Surface

Crest altitude: 4,200-4,400 or 5,300-5,500 ft a.s.l.

Flat crests; moderate to gentle slopes

Lowland; distinct pediments;

incised ungraded or flat floored aggraded valleys

b. Occasional well-preserved remnants of Buganda Surface

Crest altitude: 4,600-4,800 ft; interfluve altitude: 4,000-4,200 ft a.s.l.

flat crests; gentle slopes or rolling interfluves with distinct pediments

great proportion of flat floored, aggraded and drowned valleys

c. As in VIb except !

few flat floored aggraded valleys; mostly incised ungraded

d. Few well-preserved remnants of Buganda Surface

Crest altitude: 4,200-4,400 ft; interfluve altitude: 4,000-4,200 ft a.s.l.

flat crests; gentle slopes or gently rolling interfluves with long pediments

great proportion of flat floored, aggraded and drowned valleys

e. Occasional modified remnants of Buganda Surface

Crest altitude: 4,200-4,300 ft; interfluve altitude: 4,000-4,200 ft a.s.l.

convex crests; gentle slopes or gently rolling interfluves with long pediments

great proportion of flat floored, aggraded and drowned valleys

f. Few modified remnants of Buganda Surface

Crest altitude: 4,600-5,100 ft; interfluve altitude: 4,000-4,600 ft a.s.l.

convex crests; moderate slopes; rolling interfluves with distinct pediments

very small proportion of aggraded valleys; mostly incised and ungraded

VII <u>Geologically controlled erosion surfaces</u>

a. Tor landscape and prominent quartzite ridges, partly above Buganda Surface

Crest altitude: 4,500-4,850 ft; interfluve altitude: 4,200-4,500 ft a.s.l.

narrow crests; steep slopes; rolling interfluves with distinct pediments

variable valleys

b. Tor and quartzite ridge landscape with well-preserved remnants of Buganda Surface

Crest altitude: 4,600-4,800 ft; interfluve altitude: 4,200-4,600 ft a.s.l.

flat crests; moderate slopes; rolling interfluves with distinct pediments

flat floored aggraded and drowned valleys

c. lithologically controlled lowland of the Tanganyika Surface with few quartzite ridges

Crest altitude: 4,400-4,500 ft or 5,000-5,100 ft; interfluve altitude: 4,200-4,300 ft or 4,600-5,000 ft a.s.l.

Undulating interfluves

Wide flat floored aggraded and drowned valleys

VIII <u>Lowland landscape of the Tanganyika and Acholi (End Tertiary and Pleistocene) Surfaces</u>

a. Tanganyika and Acholi Surfaces in similar proportions; outliers-modified Buganda Surface

interfluve altitude: 3,500-3,800 ft; outlier crest altitude: 3,800-4,100 ft

Gently rolling interfluves with long gentle pediments

Wide, flat floored, aggraded and drowned valleys

b. Degraded Tanganyika Surface on Rift shoulder with unmodified surface remnants and older surface residuals interfluve altitude: 4,200-4,400 ft a.s.l.; crest altitude: 4,800-6,000 ft a.s.l.

bevelled crests with steep slopes; rolling interfluves with distinct pediments

incised, rejuvenated valleys

c. Tanganyika Surface with small proportion of Acholi Surface

interfluve altitude 4,000-4,400 ft a.s.l.

Gently rolling interfluves; long and gentle pediments

flat floored slightly aggraded and drowned; or incised ungraded valleys

d. Tanganyika Surface and exhumed sub-Singo surface with large proportion of Acholi Surface

interfluve altitude: 4,000-4,400 ft a.s.l.

Gently rolling interfluves; long and gentle pediments

flat floored aggraded and drowned valleys

e. Degraded Tanganyika Surface on Rift shoulder

Interfluve altitude: 4,000-6,000 ft a.s.l.

Sloping ridges; steep slopes or rolling interfluves with moderate slopes

incised, ungraded rejuvenated valleys

f. Etched Tanganyika Surface - tor and/or quartzite ridge landscape

crest altitude: 4,600-4,800 ft or 5,400-5,700 ft a.s.l.; interfluve altitude: 4,200-4,500 ft or 5,000-5,400 ft a.s.l.

Gently rolling interfluves; long and gentle pediments

flat floored, slightly aggraded and drowned, or incised ungraded valleys

g. Modified Tanganyika Surface with modified residuals of older surfaces

Crest altitude: 6,000-6,400 ft; interfluve altitude 5,200-5,600 ft a.s.l.

Gently rolling interfluves with distinct pediments; bevelled-convex crests moderate slopes

incised ungraded or slightly aggraded and drowned valleys

h. Modified Tanganyika Surface

interfluve altitude: 4,400-4,700 ft a.s.l.

rolling interfluves with distinct pediments

incised streambeds below aggraded valley floors

IX <u>Rift Valley Surfaces</u>

a. Rift floor plains on old lacustrine sediments

interfluve altitude: 3,000-3,700 ft a.s.l.

Gently undulating interfluves

incised valleys or lake shore flats

b. Rift floor plains on late volcanics

plain and hummock altitude 3,000-4,500 ft a.s.l.

hummocky volcanics or almost flat plains

shallowly incised valleys

c. Tectonically elevated Rift structure - probably multi-level

X. <u>Lacustrine Surfaces</u>

a. Lacustrine plain with isolated remnants of older surfaces

crest altitude: 4,200-4,500 ft a.s.l.; plain altitude: 3,800-4,000 ft a.s.l

convex crests with steep slopes; gently undulating interfluves

flat floored aggraded shallow valleys and extensive flats

b. Lacustrine plain emergent or seasonally inundated

altitude: 3,700-3,800 ft a.s.l.

flats

c. Lacustrine plain – flooded

altitude: 3,700-3,800 ft a.s.l.

Map 4a. Physiographic Units

I. South Ankolean Highland Subregion

A. South Ankolean Highlands

1. Rwampara Mountains (I)
   - 1a. Central
   - 1b. Eastern
2. Western Isingiro (II)
   - 2a. Ngarama hillmass
   - 2b. Kasumba (Bukanga) hillmass
   - 2c. Kagango (Upper Bigasha) Valley (Vc)
3. Eastern Isingiro (Rugaga hillmass) (IIIb)

B. Koki Hills

4. Western Koki (IIIc)
5. Karunga Valley (IVa)
6. Northern Koki (IIIe)

C. Northern downlands and outliers

7. Rwampara's northern fringe
   - 7a. Foothill spurs (IIIe)
   - 7b. Gayaza hillmass (IIIa)
8. Bihunya-Kabulangire range
   - 8a. Rukoma-Bihunya hills (IIIe)
   - 8b. Kabulangire-Kishasha hills (IIId)
9. Nshara Upland
   - 9a. Nyamitsindo-Ihunga Hills (IIId)
   - 9b. Ntarwete-Kakumyu ridge (IIId)

9c. Lower Ruizi basin (IVd)

9d. Kakunyu Spurs and benches (IVb)

9e. Sanga Hills (IVd)

10. Bugarama Hills

10a. Mpororo spurs (IVd)

10b. Bugarama ridge (IVb)

11. Nakivali-Mburo lowland

11a. Eastern (Va)

11b. Western (Vc)

12. Masha arena

12a. Eastern (Vb)

12b. Western (Ve)

13. Mbarara arena

13a. Northeastern (Ve)

13b. Southern (Vb)

D. <u>Inter-upland valleys</u>

14. Orichinga-Muko Valley (VIa)

15. Nyabubare Valley (VIa)

E. <u>Southern downlands</u>

16. Ikariro lowland (Vb)

17. Bwarkasani lowland (Vd)

18. Bigasha lowland (VIb)

19. Kagera Valley (VIc)

19a. Nsongezi gorge

19b. Kagera valley

II <u>Nyabushozi subregion (Katonga Plateau Region)</u>

20. Mazinga lowland (VIIb)

21. Ishura (Kateti) lowland (VIIb)

22. East Nyabushozi lowland (VIIc)

23. Central Nyabushozi (VIIa)

24. Mbuga-Bubale lowland (VIId)

25. Mawogola Subregion (VIIc)

Map4a Geomorphic Features (based on McConnell's postulated erosion surfaces)

I Predominance of the Ankole Surface

Major, simple folds; an alternate, high-grade, phyllite-quartzite succession

Rectilinear orographic pattern; topographic continuity along ridge-lines.

Crest altitude: 5,000-5,900 ft a.s.l.

Crests: bevelled-convex; slopes - high (over 500 ft) and steep (over 20^{o})

Valleys: narrowly v-shaped; ungraded

II Ankole/Koki Surface mosaic

Complex, broad, synclinal structure; heterogeneous arenaceous succession

Radial and rectilinear orographic pattern; topographic continuity along ridge-lines

Crest altitude: 4,800-5,600 ft a.s.l.

Crests: bevelled-convex; slopes - high and moderate to steep (over 15^{o})

Valleys: broadly v-shaped; ungraded

III Koki/Buganda surface patterns

IIIa Predominance of Koki Surface remnants

Major, simple synclinal structure; an alternate (high grade) phyllite-quartzite succession

Rectilinear orographic pattern; topographic continuity along ridge-lines

Crest altitude: 4,900-5,250 ft a.s.l.

Crests: bevelled-convex; slopes high and steep.

Valleys: narrowly v-shaped; ungraded.

IIIb Koki Surface remnants in at least half crest-area

Complex, broad, synclinal structure; consecutive arenaceous-argillaceous (low-grade phyllite) succession

Dendritic orographic pattern; topographic continuity along ridge-lines

Crest altitude: 4,500-5,150 ft a.s.l.

Crests: bevelled-convex; slopes medium to low (below 500 ft), moderate (10^{o}-20^{o})

Valleys: shallow and u-shaped to narrowly v-shaped; ungraded

IIIc Few remnants of Koki Surface

Complex structure of minor folds; predominantly argillaceous succession grading from phyllites to shales.

Dendritic to rectilinear orographic pattern; topographic discontinuity along ridge-lines

Crest altitude: 4,500-5,100 ft a.s.l.

Crests: bevelled (convex crest-slopes); slopes medium to low; moderate to steep

Valleys: broadly v-shaped; partly graded

IIId Koki Surface on outliers (with modified Ankole Surface residuals)

Simple, mostly synclinal, fold structure; alternate high-grade succession with at least one massive quartzite band

X Orographic pattern variable; topography continuous to discontinuous

x Crest altitude: 4,900-5,600 ft a.s.l.

Crests: bevelled-convex; slopes high and steep

Valleys: -

IIIe Few isolated and modified remnants of Koki Surface

Structure - variable; lithology - variable

Orographic pattern - variable; topographic discontinuity along ridge-lines

Crest altitude; 4,900-5,300 ft a.s.l. or 4,500-4,800 ft a.s.l.

Crests: bevelled-convex or bevelled; slopes medium to low - moderate (10^{o}-20^{o})

Valleys: u-shaped, broad to narrow; narrow pediments; mostly graded and partially aggraded.

IV Predominance of the Buganda Surface

IVa Erosionally lowered parts of the Buganda Surface

Benches on valley sides at 4,300-4,500 ft a.s.l.

Valleys: mostly drowned or seasonally inundated

IVb Continuous remnants of the Buganda Surface

Minor, sub-parallel, fold structure (mainly synclinal); high grade phyllite with minor quartzite bands.

Rectilinear pattern; topographical continuity

Crest altitude: 4,600-4,800 ft a.s.l.

Crests: bevelled (convex crest slopes); slopes medium and moderate

Valleys: -

IVc Strucuurally elevated Buganda Surface

Structure - undetermined; alternate quartzite-argillite succession

Rectilinear orographic pattern; topographic continuity along ridge-lines

Crest altitude: 4,600-5,000 ft a.s.l.

Crests: bevelled-convex; slopes: medium, moderate to steep

Valleys: narrowly u-shaped; narrow pediments; partially graded and aggraded.

IVd Discontinuous remnants of Buganda Surface

Structure - undetermined; phyllites variously graded

Dendritic orographic pattern; topographic discontinuity

Crest altitude - 4,600-4,800 ft a.s.l.

Crests: bevelled, scarpped; slopes low, moderate

Valleys: narrowly u-shaped with short pediments, mostly ungraded.

V-VII Predominance of Tanganyika Surface

V Arenas and arena-like lowlands

Va Large proportion of Acholi Surface

Limb of a broad synclinal structure; mica-schists interbedded with quartzites

Rectilinear pattern; prominent quartzite ridges

Interfluve altitude: 4,200-4,300 ft a.s.l.; quartzite ridge altitude: 4,300-4,500 ft a.s.l.

Interfluve crests: broad, bevelled; quartzite ridge crests: narrow, convex; slopes: short, gentle to moderate

Valleys: Mostly drowned, aggraded and intermittently flooded, shallow and wide, flat floored

Vb Large proportion of Acholi Surface (Flat-floored Valley Surface)

Limb of a broad synclinal structure or metamorphic aureole; mica schists interbedded with metasedimentary quartzite or penetrated by tectonic quartzite

Dendritic pattern; topographical discontinuity along ridge-lines

Interfluve altitude: 4,200-4,500 ft a.s.l.; quartzite ridge crests: 4,400-4,700 ft a.s.l.

Interfluve crests: broad, undulating; quartzite crests: narrow, convex; slopes - as in Va.

Valleys: wide, flat-floored, mostly aggraded and intermittently flooded but not drowned; some shallowly incised.

Vc Large proportion of Acholi Surface

Limb of broad synclinal structure; mica schists - no quartzite

Rectilinear pattern; topographic continuity

Interfluve altitude: 4,200-4,300 ft a.s.l.

Interfluve crests: as in Va

Valleys: as in Va.

Vd Large proportion of Acholi Surface

Structure undetermined; quartz schists (Toro)

Rectilinear-dendritic pattern; topographic continuity

Interfluve altitude: 4,300-4,450 ft a.s.l.

Interfluve crests: very broad and bevelled; laterite capped; slopes long, gentle to moderate

Valleys: as in Vb.

Ve Small proportion of Acholi Surface

Core of dome-like intrusion; granites

Dendritic orographic pattern; topographical continuity

Interfluve altitude: 4,400-4,600 ft a.s.l.

Interfluve crests: convex; slopes - long and gentle

Valleys: wide to narrow; flat floored but mostly incised; partially and slightly aggraded

VI Inter-upland valleys and lowlands; structurally controlled; phyllitic(?)

VIa Short to medium moderate to gentle pediments; narrow, incised or narrow flooded or drowned stream beds 4,100-4,300 ft a.s.l.

VIb Long, gentle to moderate pediments; narrow incised and ungraded 4,000-4,200 ft a.s.l.

VIc Short, moderate pediments, ungraded valleys. 4,200-4,400 ft a.s.l.

VII Undulating plains of granitoid rocks

VIIa Frequent laterite-capped remnants of Buganda Surface

Dendritic orographic pattern; topographic discontinuity along ridge line

Interfluve altitude: 4,400-4,600 ft a.s.l.; laterite caps: 4,600-4,800 ft.

Interfluve crests: smoothly rounded and undulating to flat and scarpped; slopes long and gentle to moderate

Valleys: wide, flat-floored; shallow; thinly aggraded and seasonally flooded tributaries: narrow, incised.

VIIb Few remnants of Buganda Surface; 'tor' landscape and tectonic quartzite ridges

Orographic pattern and topography - as in VIIa

Interfluve altitude: 4,300-4,500; quartzite ridges and remnants: 4,500-5,000 ft a.s.l.

Interfluve crests as in VIIa; quartzite ridges - convex, steep slopes

Valleys: as in VIIa; more heavily aggraded and inundated.

VIIc No remnants of Buganda Surface; 'tor' landscape and tectonic quartzite ridges

Larger proportion of Flat-floored Valley Surface

Interfluve altitude: 4,200-4,400 ft a.s.l.; quartzite ridges and tors: 4,400-4,500 a.s.l.

Valleys: as in VIIa; but heavily aggraded and at times drowned.

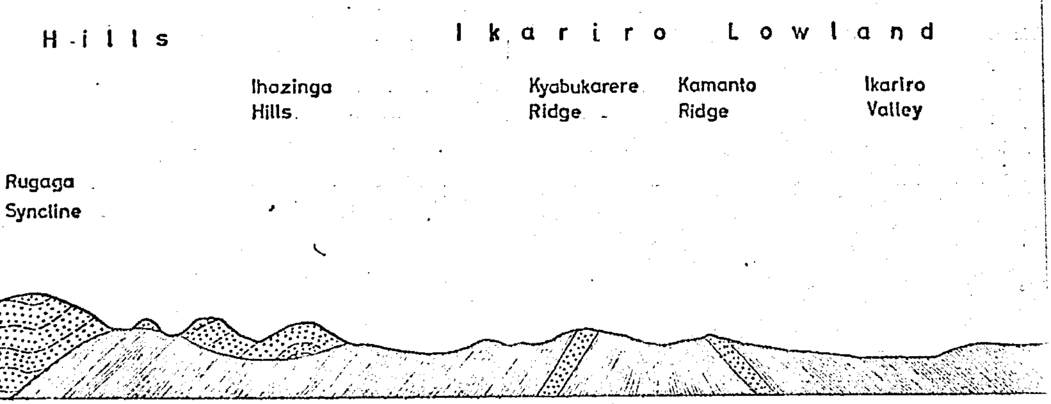
VIId Few tors and quartzite ridges; Acholi Surface dissected

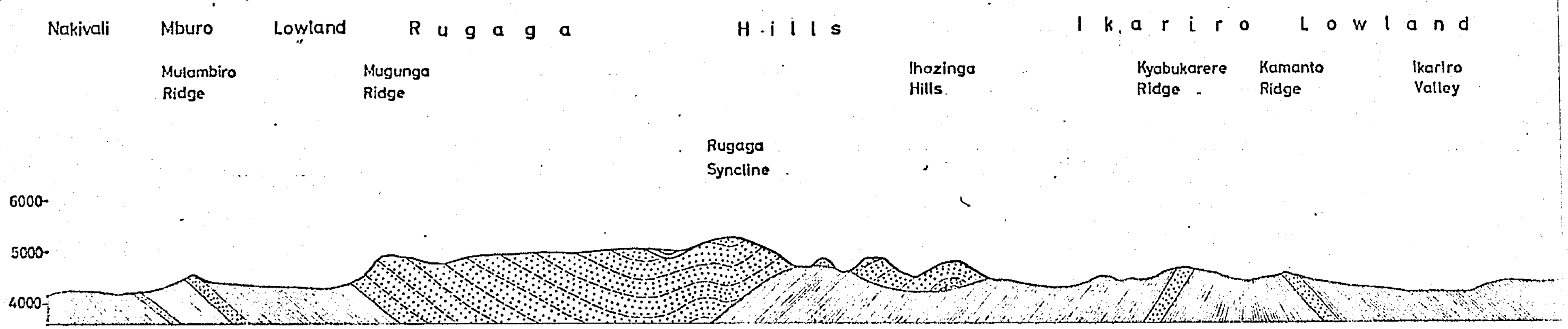
Interfluve altitude: 4,600-4,850 ft a.s.l.

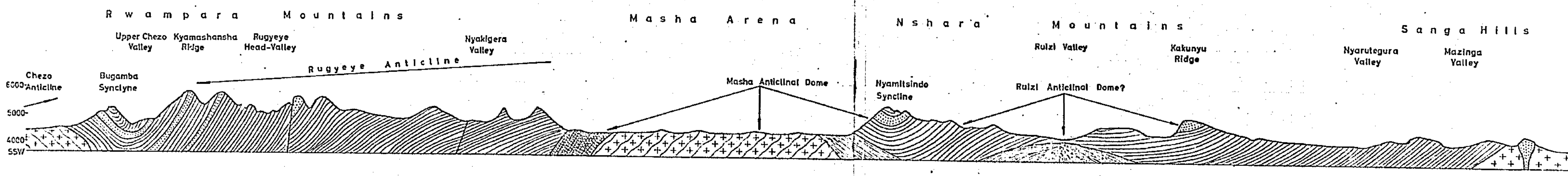
Valleys: narrow floored, unaggraded and uninundated.

KEY

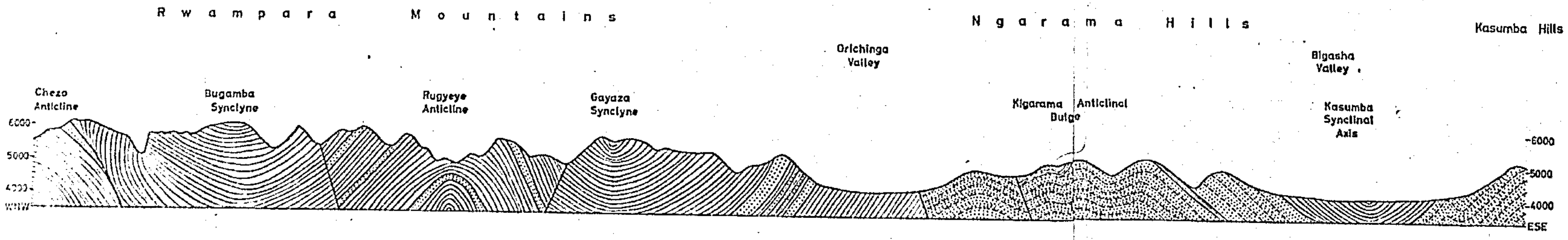
Shales and Mudstones	Karagwe Ankolean System
Phyllite	Karagwe Ankolean System
Quartzite	Karagwe Ankolean System
Schists	Karagwe Ankolean System
Schists	Toro Systems
Intrusive Granite	
Tectonic Quartz	
Gneissose Granite	Basement Complex
Porphyritic Granite	Basement Complex
Granodiorite	Basement Complex
Granulites	Basement Complex


H i l l s
I k a r i r o   L o w l a n d
Ihazinga Hills
Kyabukarere Ridge
Kamanto Ridge
Ikariro Valley
Rugaga Syncline

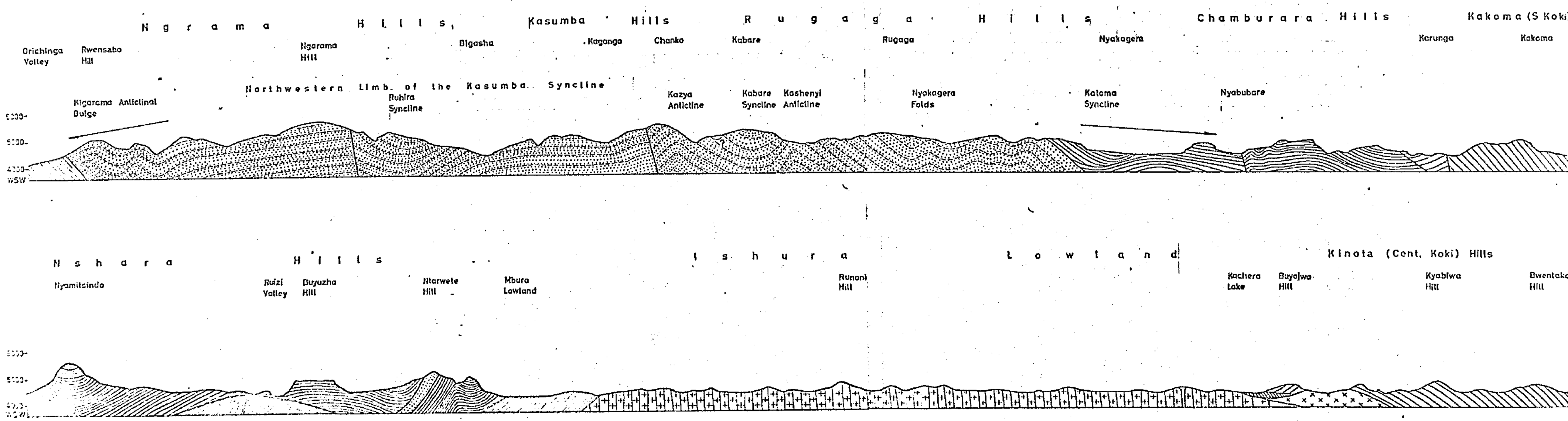

Nakivali
Mburo
Lowland
R u g a g a
H i l l s
I k a r i r o
L o w l a n d
Mulambiro Ridge
Mugunga Ridge
Rugaga Syncline
Ihazinga Hills
Kyabukarere Ridge
Kamanto Ridge
Ikariro Valley
6000
5000
4000



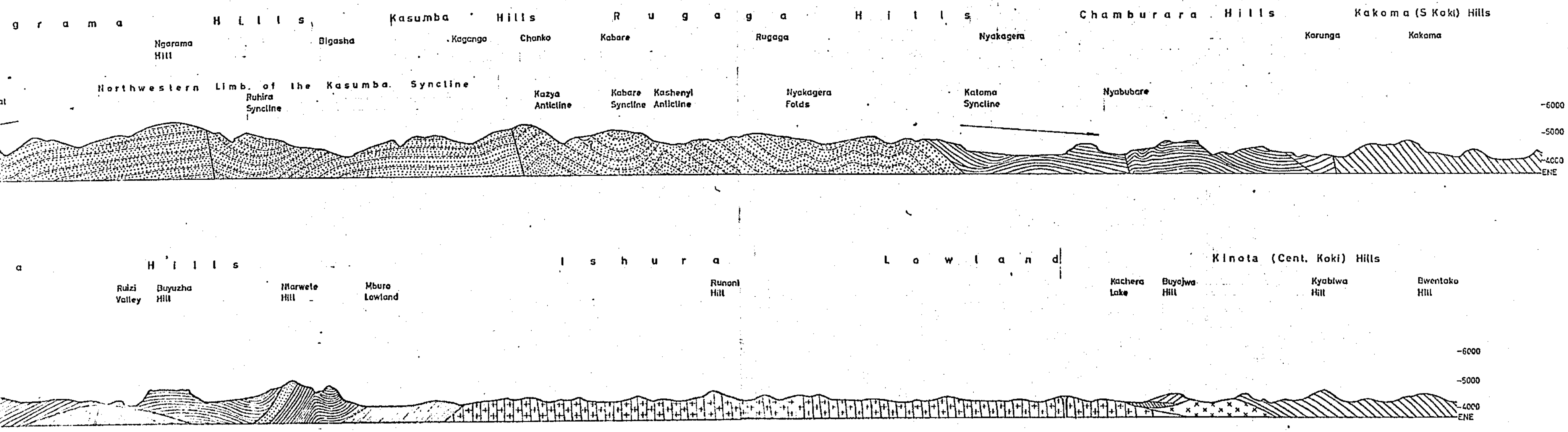
Rwampara Mountains
Masha Arena
Nshara Mountains
Sanga Hills
Upper Chezo Valley
Kyamashansha Ridge
Rugyeye Head-Valley
Nyakigera Valley
Rulzi Valley
Kakunyu Ridge
Nyarutegura Valley
Mazinga Valley
Rugyeye Anticline
Chezo Anticline
Bugamba Synclyne
Masha Anticlinal Dome
Nyamitsindo Syncline
Rulzi Anticlinal Dome?
6000
5000
4000
SSW

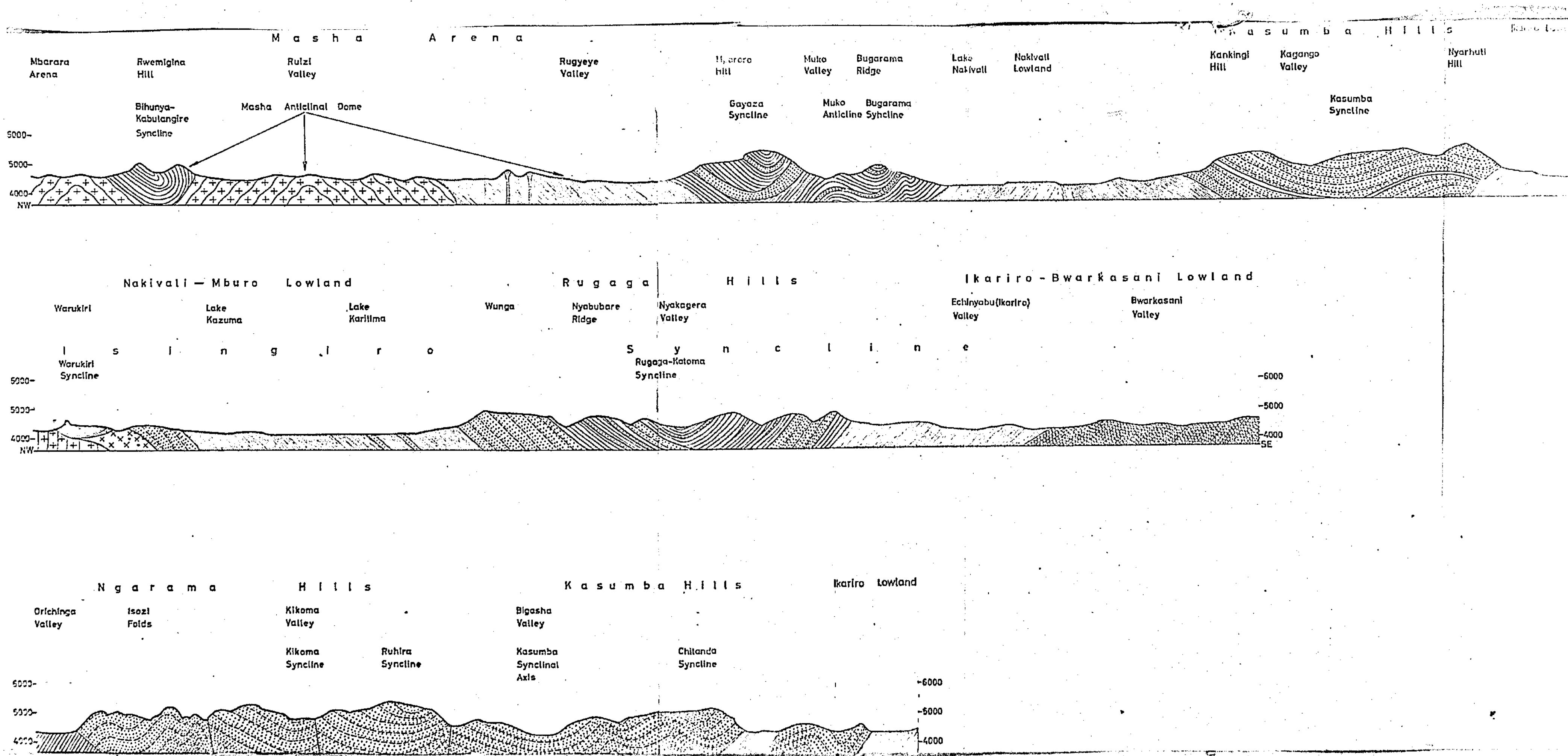


Rwampara Mountains
Ngarama Hills
Kasumba Hills
Orichinga Valley
Bigasha Valley
Chezo Anticline
Bugamba Synclyne
Rugyeye Anticline
Gayaza Synclyne
Kigarama Anticlinal Bulge
Kasumba Synclinal Axis
6000
5000
4000
WNW
ESE

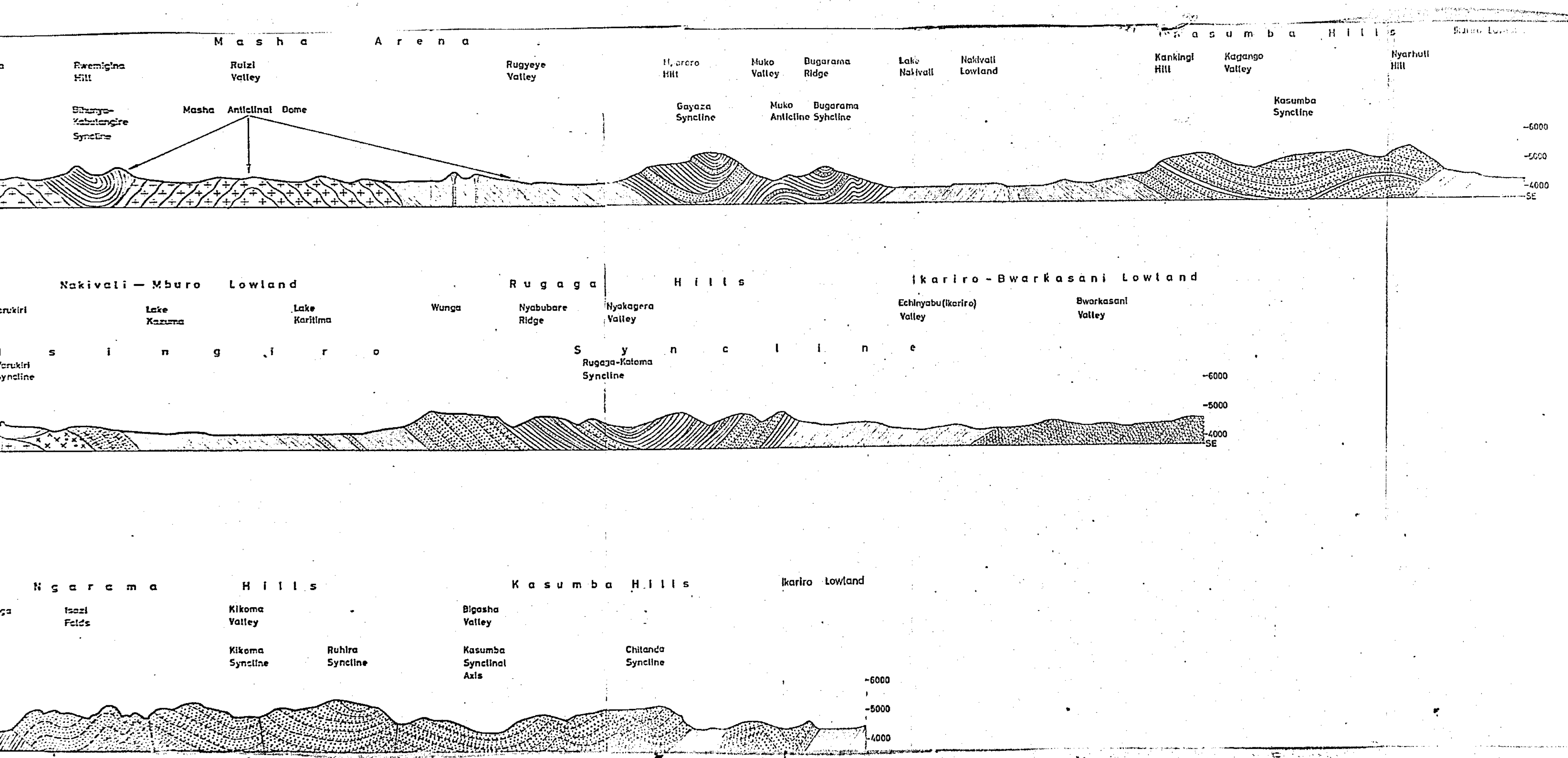


N g r a m a H i l l s
Kasumba Hills
R u g a g a H i l l s
Chamburara Hills
Kakoma (S Koki)
Orichinga Valley
Rwensabo Hill
Ngarama Hill
Bigasha
Kaganga
Chanko
Kabare
Rugaga
Nyakagera
Karunga
Kakoma
Northwestern Limb of the Kasumba Syncline
Kigarama Anticlinal Bulge
Ruhira Syncline
Kazya Anticline
Kabare Syncline
Kashenyi Anticline
Nyakagera Folds
Katoma Syncline
Nyabubare
WSW
N s h a r a H i l l s
I s h u r a L o w l a n d
Kinota (Cent. Koki) Hills
Nyamitsindo
Ruizi Valley
Buyuzha Hill
Ntarwete Hill
Mbura Lowland
Runoni Hill
Kachera Lake
Buyojwa Hill
Kyabiwa Hill
Bwentako Hill


g r a m a H i l l s
Kasumba Hills
R u g a g a H i l l s
Chamburara Hills
Kakoma (S Koki) Hills
Ngarama Hill
Bigasha
Kagango
Chanko
Kabare
Rugaga
Nyakagera
Karunga
Kakoma
Northwestern Limb of the Kasumba Syncline
Ruhira Syncline
Kazya Anticline
Kabare Syncline
Kashenyi Anticline
Nyakagera Folds
Katoma Syncline
Nyabubare
6000
5000
4000
ENE
a H i l l s
I s h u r a L o w l a n d
Kinota (Cent. Koki) Hills
Ruizi Valley
Buyuzha Hill
Marwete Hill
Mburo Lowland
Runoni Hill
Kachera Lake
Buyojwa Hill
Kyabiwa Hill
Bwentoko Hill
6000
5000
4000
ENE

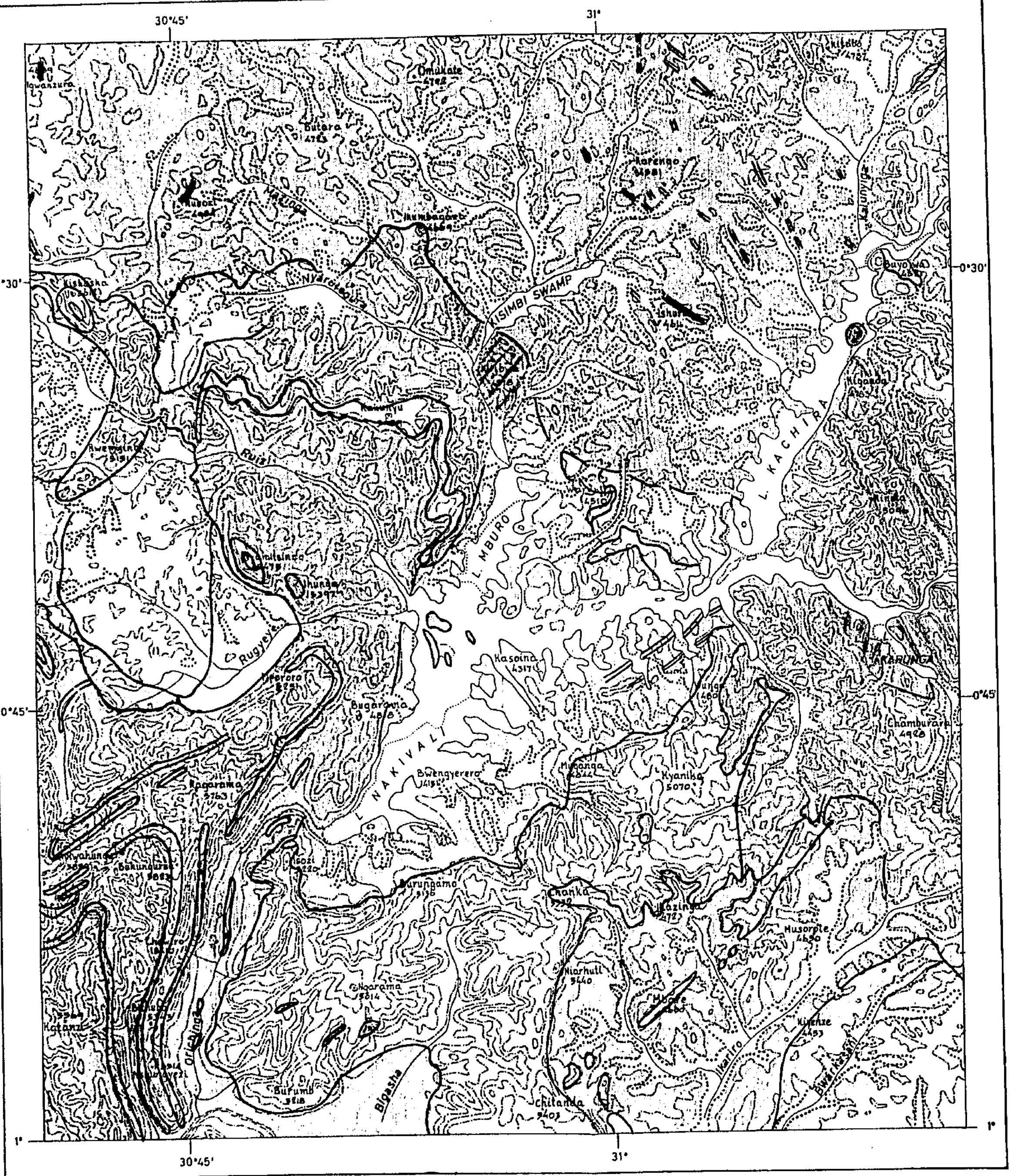


Masha Arena
Kasumba Hills
Mbarara Arena
Rwemigina Hill
Ruizi Valley
Rugyeye Valley
Muko Valley
Bugarama Ridge
Lake Nakivali
Nakivali Lowland
Kankingi Hill
Kagango Valley
Nyarhuti Hill
Bihunya-Kabulangire Syncline
Masha Anticlinal Dome
Gayaza Syncline
Muko Anticline
Bugarama Syncline
Kasumba Syncline
5000
4000
NW
Nakivali — Mburo Lowland
Rugaga Hills
Ikariro - Bwarkasani Lowland
Warukiri
Lake Kazuma
Lake Kariima
Wunga
Nyabubare Ridge
Nyakagera Valley
Echinyabu (Ikariro) Valley
Bwarkasani Valley
Isingiro Syncline
Warukiri Syncline
Rugaga-Katoma Syncline
6000
5000
4000
SE
Ngarama Hills
Kasumba Hills
Ikariro Lowland
Orichinga Valley
Isozi Folds
Kikoma Valley
Bigasha Valley
Kikoma Syncline
Ruhira Syncline
Kasumba Synclinal Axis
Chitanda Syncline
6000
5000
4000



Masha Arena
Kasumba Hills
Rwemigina Hill
Ruizi Valley
Rugyeye Valley
Muko Valley
Bugarama Ridge
Lake Nakivali
Nakivali Lowland
Kankingi Hill
Kagango Valley
Nyarhuli Hill
Masha Anticlinal Dome
Syncline
Gayaza Syncline
Muko Anticline
Bugarama Syncline
Kasumba Syncline
6000
5000
4000
SE
Nakivali — Mburo Lowland
Rugaga Hills
Ikariro - Bwarkasani Lowland
Lake Kazuma
Lake Karitima
Wunga
Nyabubare Ridge
Nyakagera Valley
Echinyabu (Ikariro) Valley
Bwarkasani Valley
Syncline
Rugaga-Katoma Syncline
6000
5000
4000
SE
Ngarama Hills
Kasumba Hills
Ikariro Lowland
Isazi Folds
Kikoma Valley
Bigasha Valley
Kikoma Syncline
Ruhira Syncline
Kasumba Synclinal Axis
Chitanda Syncline
6000
5000
4000

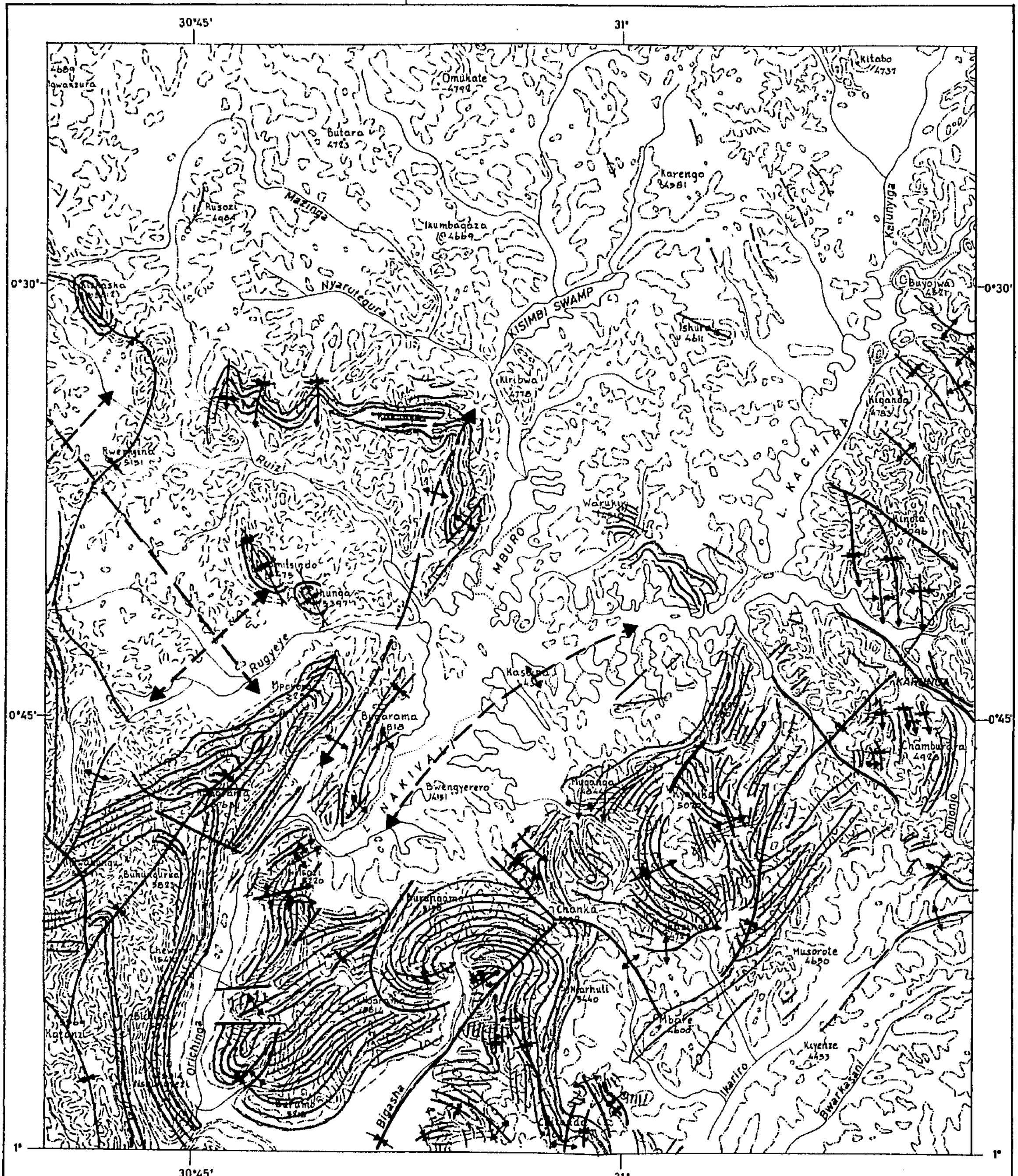
Map 1. Geology of the Study-Area



1 : 250 000

0 1 2 3 4 5 10 Km

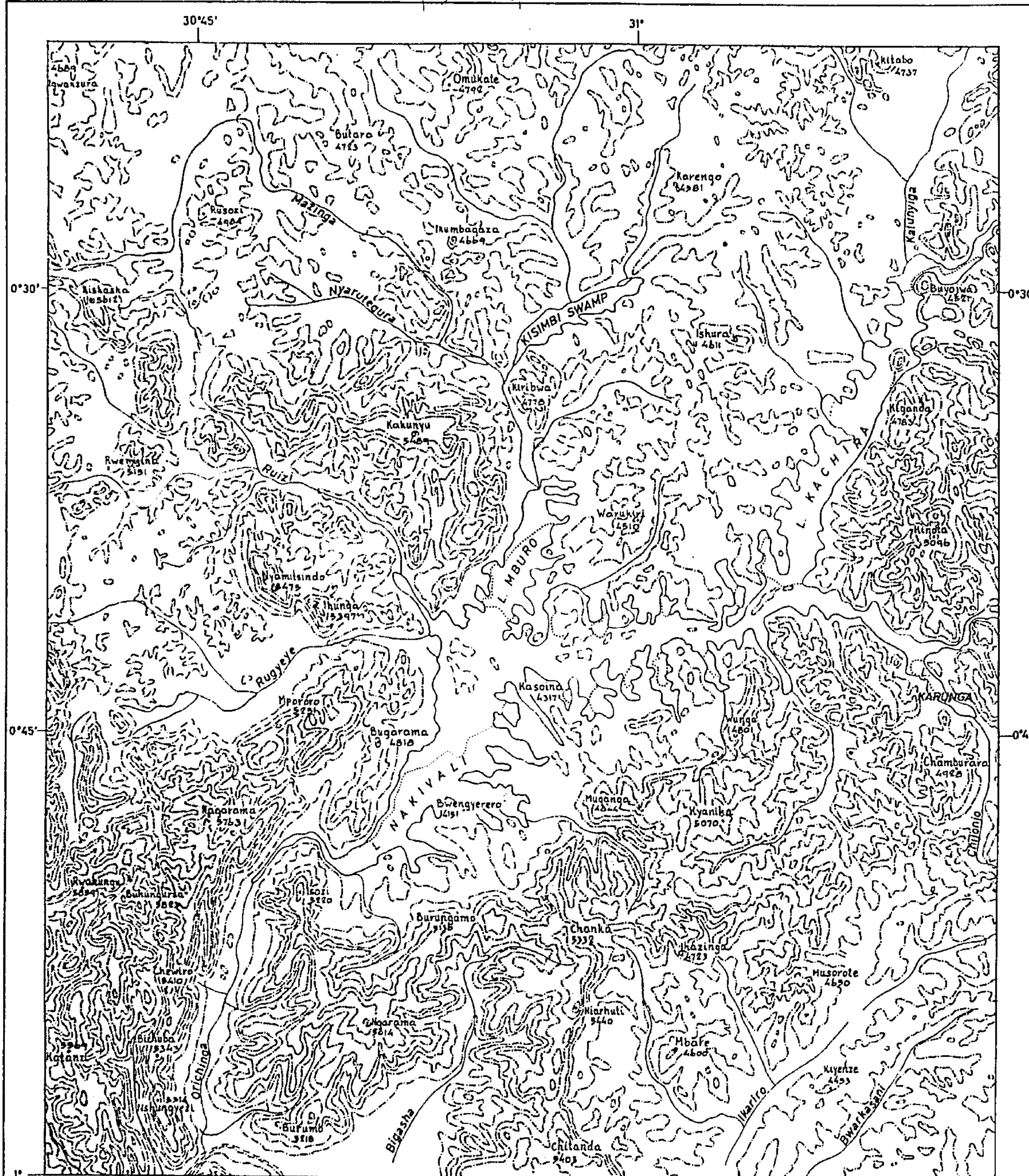
Map 2: Structure



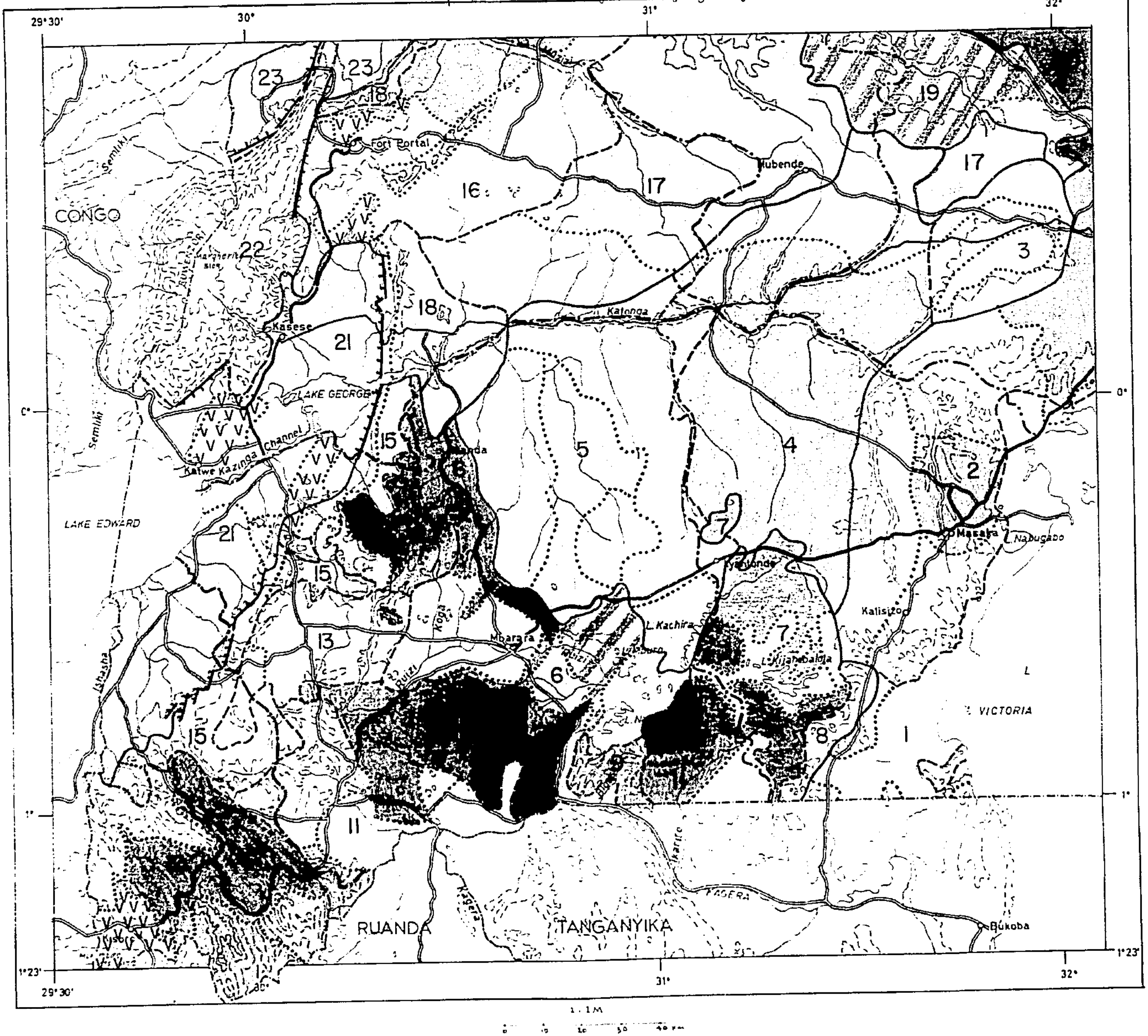
1: 250 000

0 1 2 3 4 5 10 km

Map 3: Relief

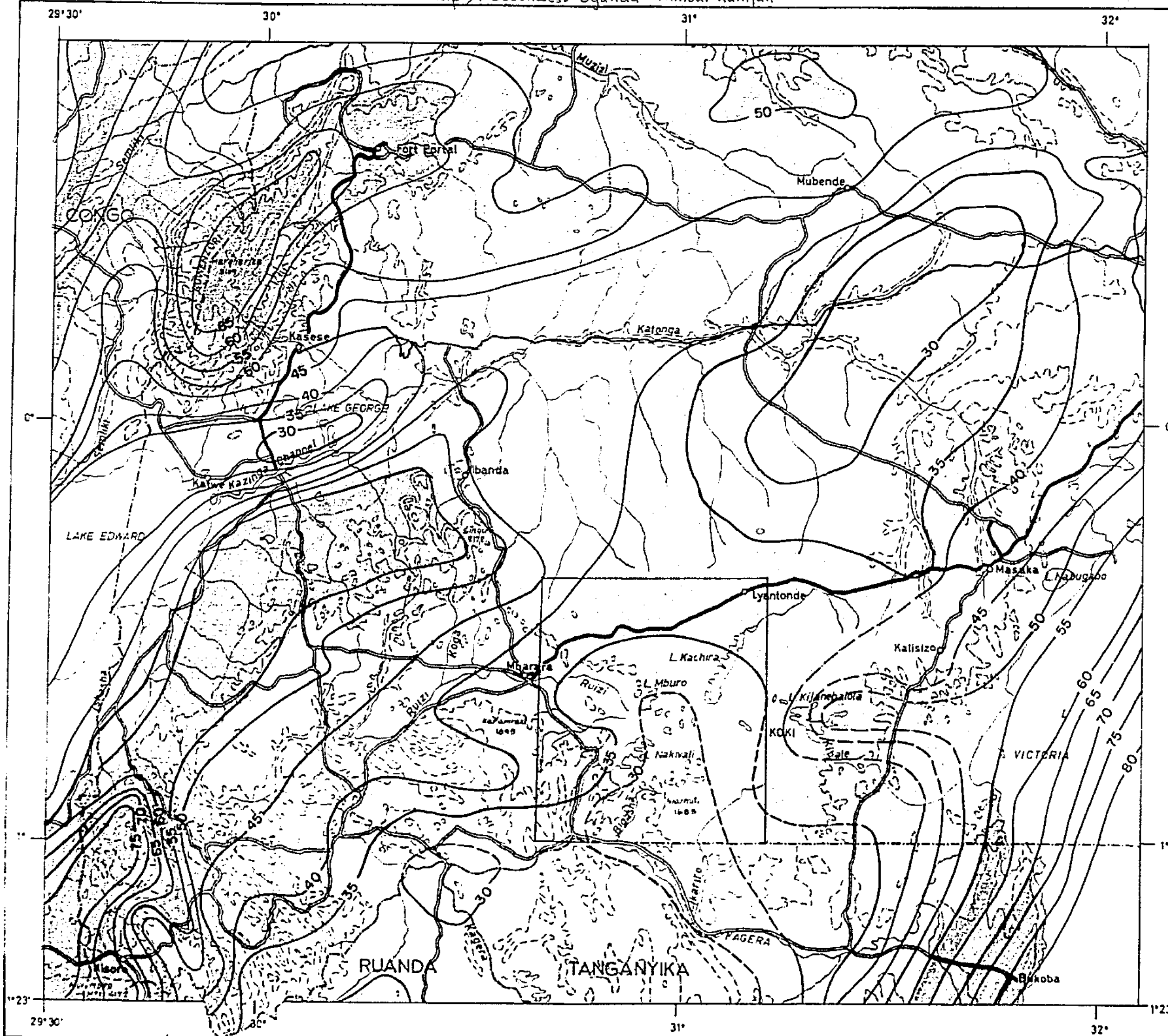

30°45'
31°
0°30'
0°45'
1°
Omukate
4792
Kitabo
4737
Butaro
4783
Karengo
4381
Mazinga
Rusozi
4984
Ikumbagaza
4664
Kalunyiga
Buyojwa
4827
Kishasha
Nyarutegura
KISIMBI SWAMP
Ishura
4611
Kiribwa
4778
Kiganda
Kakunyu
Rwemgini
5191
Ruizi
Waruku
4510
L. MBURO
L. KACHIRA
Ringta
5046
Nyamitsindo
6475
Ihunga
Rugyeye
Kasaina
4317
KARUNGA
Mpororo
Bugarama
4818
Wunga
4801
Chamburara
4928
L. NAKIVALI
Bwengyerero
4151
Muganga
Kyanika
5070
Chitonio
Rugarama
Ryakungu
Buhungura
Sozi
5220
Burungamo
Chanka
5332
Ihazinga
Husorote
4650
Chewiro
Niarhuti
5440
Bichuba
Rugarama
5814
Mbare
4600
Katanzi
Orichinga
Kishungye
Kiyenze
Ikariro
Bwarkasani
Bigasha
Burumo
5818
Chitanda
9403

Map 4: Southwest Uganda - Physiography



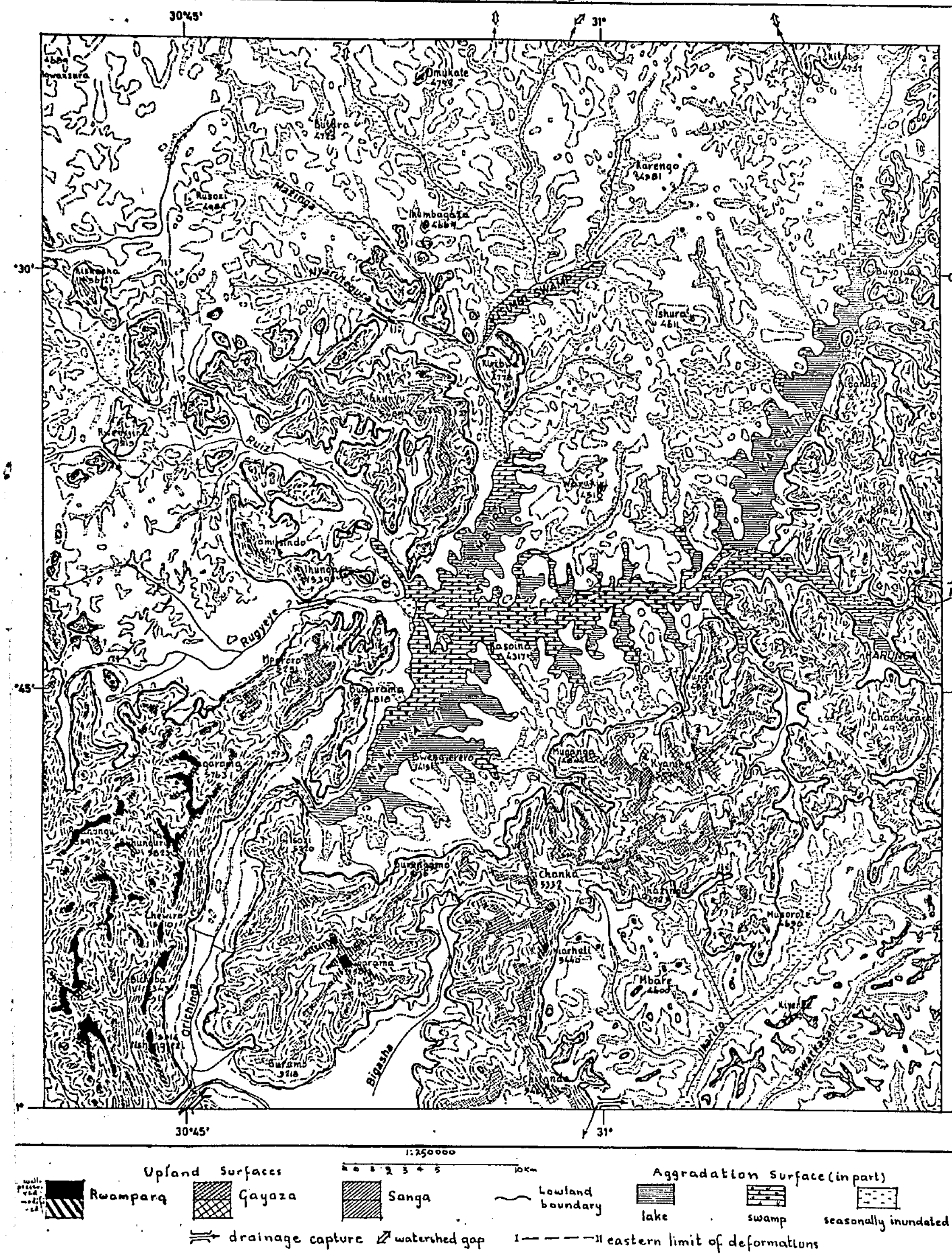
1 : 1M

Map 5: Southwest Uganda - Annual Rainfall

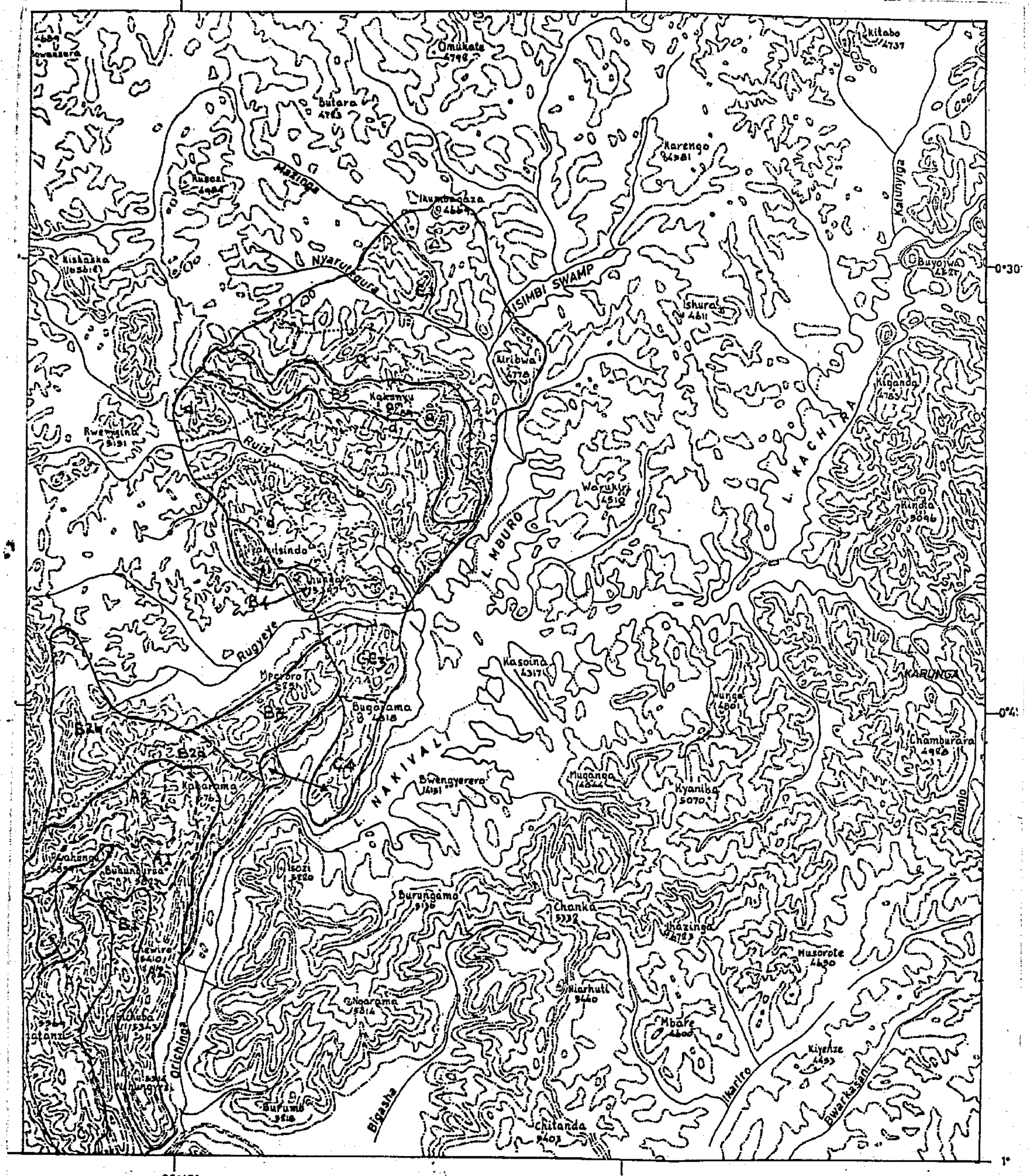


1 : 1 M.

Geomorphology



Map 6



Map 7

A. Rwampara Surface Units

1. Watershed ridge
2. Southern ridges
3. Northern ridges

1:250 000

0 1 2 3 4 5 10 Km

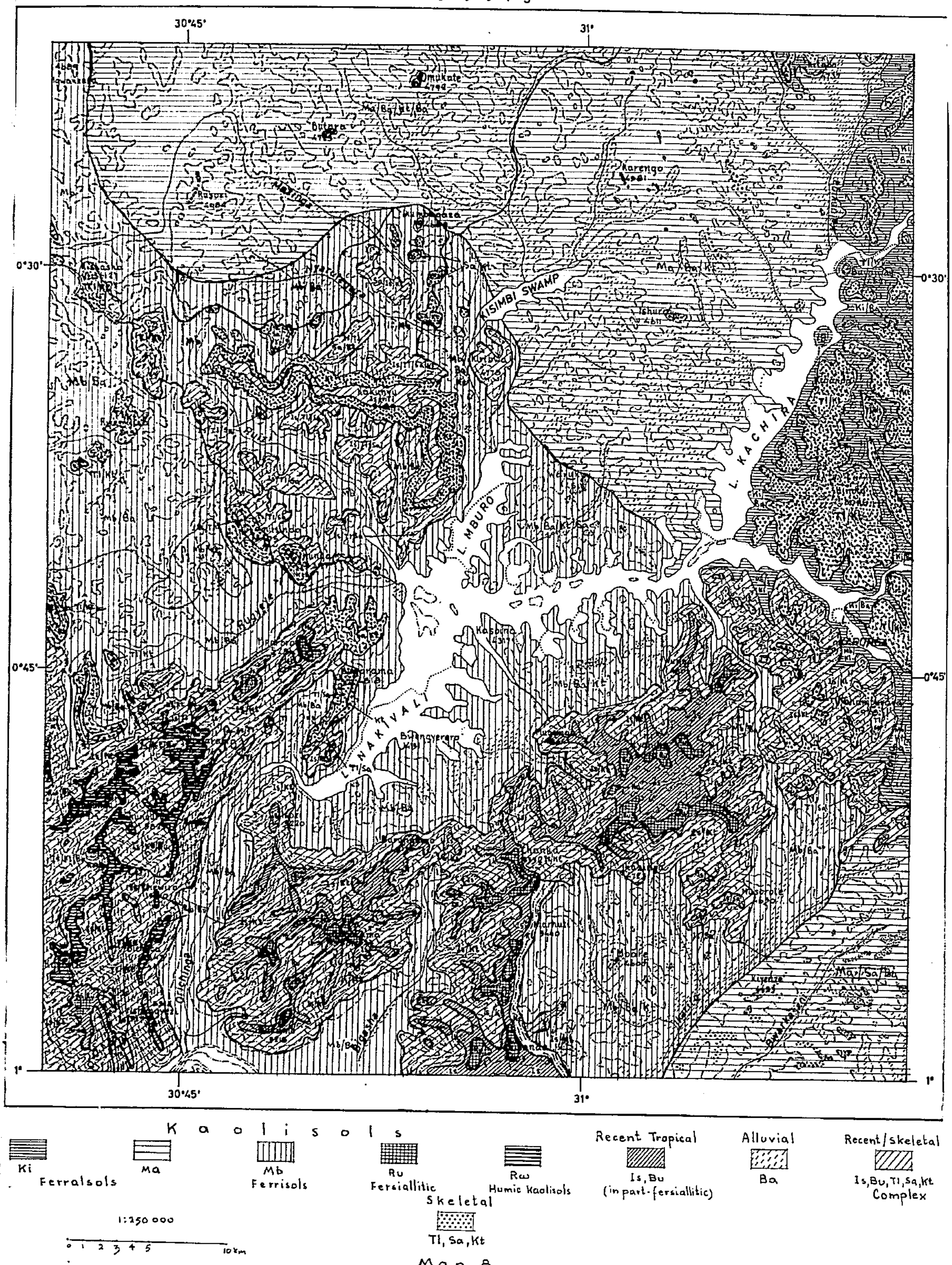
B. Gayaza Surface Units

1. Rwampara valley-side benches
2. Rwampara northern spurs
   a. Gayaza Surface rise to A
   b. Foothills
3. Gayaza hillmass
4. Nyamitsindo-Ihunga Hills (A-residuals)
5. Ntarwete-Kakunyu ridge
   a. A-residuals.

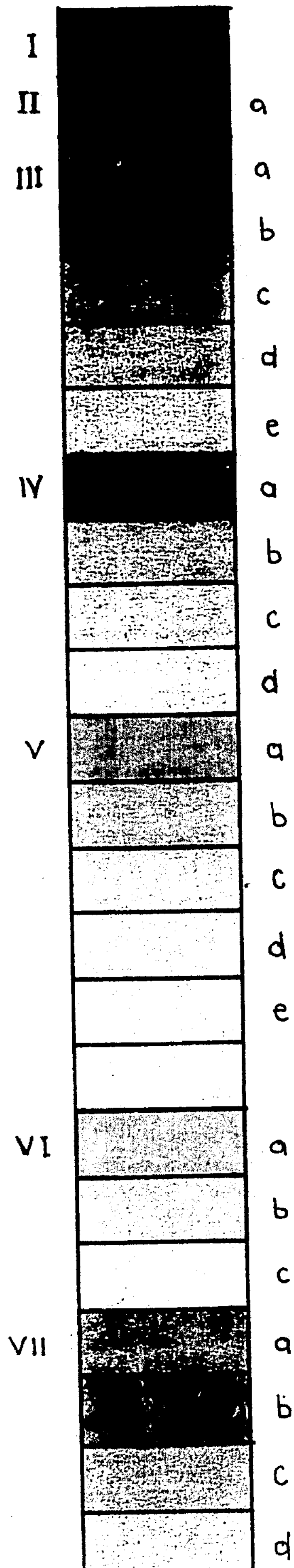
C. Sanga Surface Units

1. Sanga Hills
   a. rise to B
2. Lower Ruizi basin; altitudinal belts:
   a. 4500-4600 ft
   b. 4600-4700 ft
   c. 4700-4800 ft
   d. 4800-4900 ft
3. Mpororo spurs
4. Bugarama ridge

Soils


30°45'
31°
0°30'
0°45'
1°
KISIMBI SWAMP
L. KACHIRA
L. MBURO
L. NAKIVALI
Karengo
Kabuno
Mbale
Kaolisols
Ki
Ferralsols
Ma
Mb
Ferrisols
Ru
Fersiallitic
Rw
Humic Kaolisols
Recent Tropical
Is, Bu
(in part - fersiallitic)
Alluvial
Ba
Recent/skeletal
Is, Bu, Tl, Sa, Kt
Complex
Skeletal
Tl, Sa, Kt
1:250 000
0 1 2 3 4 5
10 km

Map 8


I
II a
III a
b
c
d
e
IV a
b
c
d
V a
b
c
d
e
VI a
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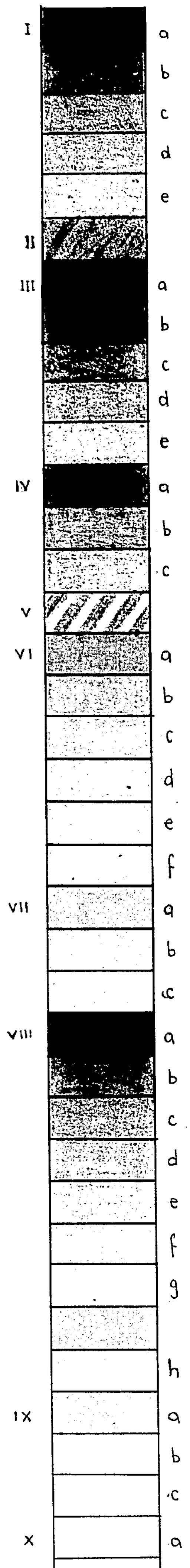
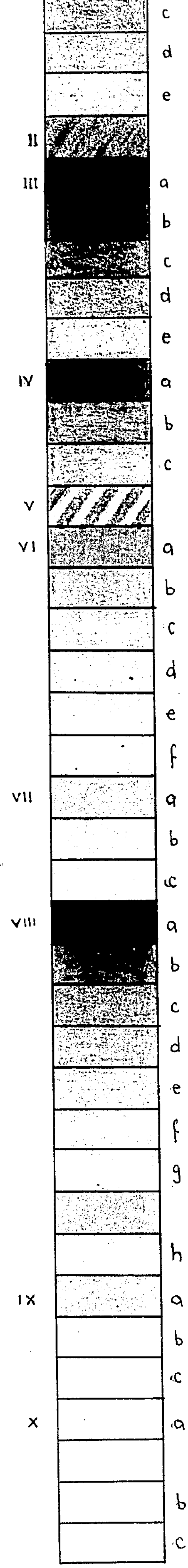
c
VII a
b
c
d


I a
b
c
d
e
II
III a
b
c
d
e
IV a
b
c
V
VI a
b
c
d
e
f
VII a
b
c
VIII a
b
c
d
e
f
g
h
IX a
b
c
X a


c
d
e
II
III a
b
c
d
e
IV a
b
c
V
VI a
b
c
d
e
f
VII a
b
c
VIII a
b
c
d
e
f
g
h
IX a
b
c
X a
b
c