AMANI MEMOIRS

A SOIL RECONNAISSANCE JOURNEY THROUGH PARTS OF TANGANYIKA TERRITORY DECEMBER 1935 TO FEBRUARY 1936

BY

G. MILNE

CONTRIBUTION FROM
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A SOIL RECONNAISSANCE JOURNEY THROUGH PARTS OF TANGANYIKA TERRITORY DECEMBER 1935 TO FEBRUARY 1936

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(*With Plates* 1–5, *containing Photographs* 1–10, *one Map and four Figures in the Text*)

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EDITOR'S PREFACE

When Geoffrey Milne's grand and stimulating Reconnaissance Report was first circulated in typescript to various Technical Departments and interested individuals towards the end of 1936, the desire was keenly felt to have this masterful exposition of many 'burning' problems brought to the notice of a wider scientific circle. And when, at about the same time, Prof. A. G. Tansley, of Oxford, in a letter to Milne regarding the Itigi thicket controversy, expressed his conviction that 'the soil-vegetation complex is in many ways so intimately one thing that it should be dealt with as a whole', and 'that it is all to the good that plant ecologists should have their attention firmly directed to pedology', the possibility of covering Milne's ground in a joint paper with B. D. Burtt was ventilated. But fate willed otherwise. Leave movements of Burtt in 1937 and of Milne in 1938 first delayed, and then Burtt's deplorable death in 1938 put a sad stop to further progress in this direction. On his return from Central and North America late in 1938, Milne was preoccupied with more pressing work, and then the war demanded his brain and energy to work on problems very different from those of long-range research. Thus, when early in 1942 we had to adjust ourselves to the irretrievable loss caused by his premature death, this Reconnaissance Report, in many ways perhaps the finest deposit from his deeply penetrating and highly synthetical mind, still lay unpublished: 'his clear and comprehensive outlook, his wide and thorough attainments'—to quote Prof. F. Hardy of Trinidad —were still withheld from the many whom his all too short work of the past had constantly inspired, not only in the British Tropics but throughout the world.

After further unavoidable delays the pleasant task of editing this work was at long last entrusted to one who, though a mere dabbler in both pedology and ecology, is well fitted through his own geographical studies in East Africa and through his long co-operation, on many problems, with his young friend, to appreciate fully the great synthesis of rock and soil, of vegetation and Man, that Milne has sketched so vividly for us.

A firm conviction that Milne's probings into the urgent questions of proper land use are of the utmost importance to the administrator of the present clearly marked the editor's road: to cut as little as possible even where—or just where—the author's courageous emphasis on the use and misuse of the land might by some be considered as trespassing from his legitimate realm on to the borderland of other departments. That Milne's fluent and expressive style requires no editing, further simplified matters. Another point to decide, however, was whether or not to indicate in the course of editing—with the aid of footnotes, for instance—where fresh knowledge gained in the interval between writing and publishing might conceivably have led the author to alter some of his views. Those on *Brachystegia* woodland soils, on the still controversial Itigi thicket problem, on hard-pan soils, on the lateral resorting theory of the *lusanga* soils, and several geomorphological statements are examples. But here also the choice was easy: not to spoil this Memorial to a great mind by controversy, but loyally to let stand what, at the time of writing, he saw good reason to accept as the most likely theories.

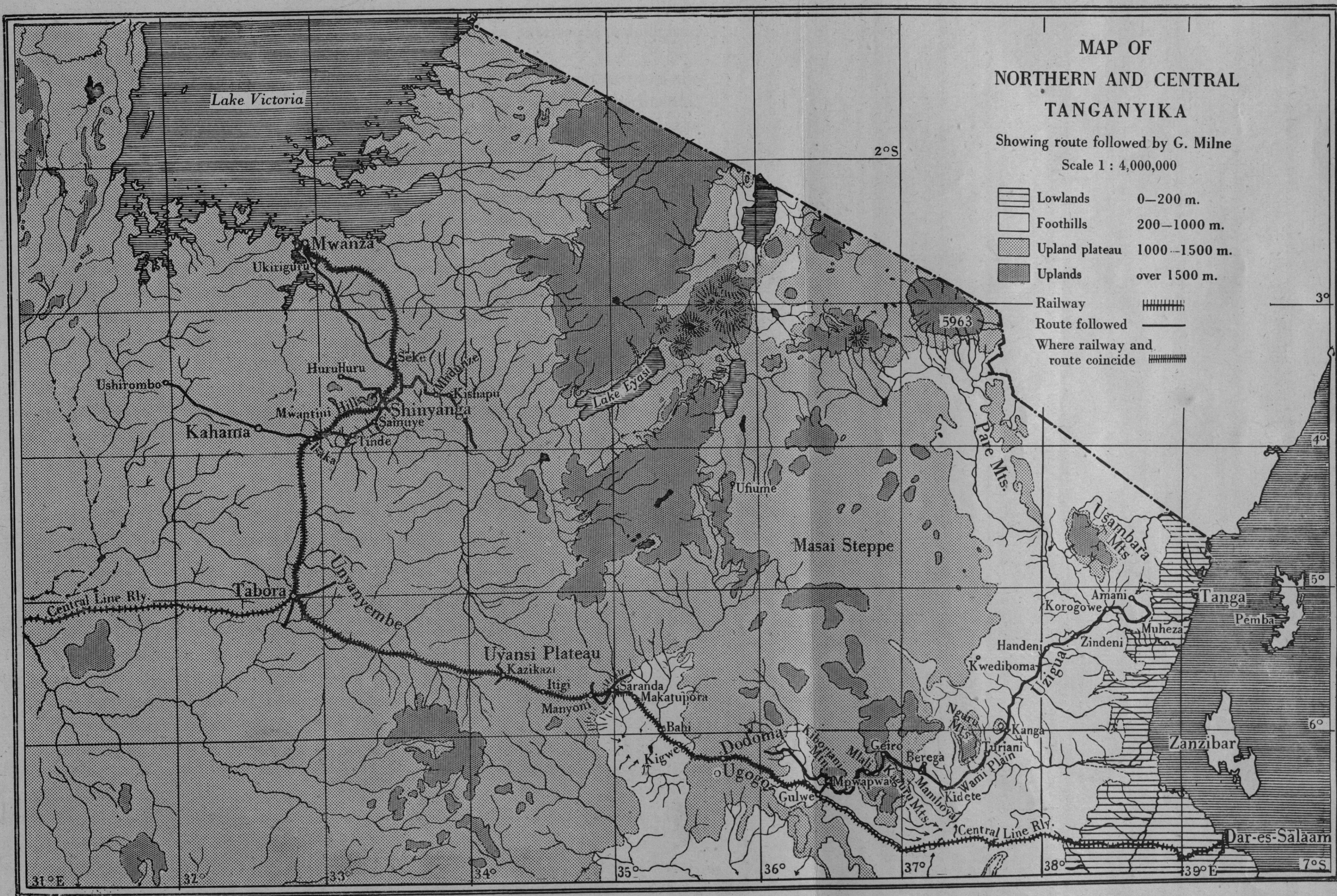
To adopt the form of a Memorial and thereby to create a companion to the Burtt Memorial Supplement of the *Journal of Ecology* of 1942, seemed an obvious solution; and although the publication comes somewhat late in the day the present moment may, after all, prove a most opportune one: for are our hopes not set on a forthcoming phase of planning *real* African development based on embracing ecological research rather than on the haphazard 'methods' of the past?

C. Gillman

Dar-es-Salaam
March 1944

INTRODUCTION

This soil reconnaissance journey was made between 7 December 1935 and 4 February 1936 to certain parts of the Central, Western and Lake Provinces of Tanganyika Territory, passing *en route* through parts of the Tanga and Eastern Provinces. For some portions of the ground covered other information was already to hand and in making the commentary this earlier material has been incorporated. Previous laboratory acquaintance had also been made with some of the soils from the admirably documented collections made by B. D. Burtt in 1933–4. The present report is thus a connected generalized account of soil conditions along the route so far as they are understood to date. The objects of the journey were to look for the relationships of the principal soil types to each other and to the various natural factors concerned in soil formation, taking particular account of vegetation. It was found that here, in semiarid Tanganyika, the soil and vegetation zones



Topographic map of Tanganyika Territory showing Soil Reconnaissance Route 1935–6 are so linked that neither set of observations can be fairly discussed without the other. Much of the country travelled through is not in agricultural occupation, but wherever possible discussions of questions concerning agriculture and land utilization have been included, and it is believed that these discussions will be of general interest to pedologists, geographers and ecologists.

In the Central, Western and Lake Provinces the opportunity was taken to meet the agricultural and administrative officers and in their company to visit the experimental farms and typical areas in native cultivation. The Central Province was seen under the authoritative guidance of Mr C. Gillman as to geology and geomorphology, and that of Mr B. D. Burtt as to vegetation. During the visit to the Veterinary Department's headquarters at Mpwapwa a day was spent on Kiboriani mountain which overlooks the Veterinary Station from the north and a general view was obtained over the adjacent parts of Ugogo. In the company of the Veterinary Department's staff, a circuit was made of the experimental work on the protection and development of grazing, anti-erosion measures, manure-conservation and the relation of riverine vegetation to stream permanence. At Shinyanga visits were made to the Tsetse Department's headquarters and to the Agricultural Department's district headquarters and excursions were made in the company of members of both departments to the relief grazing grounds of Huru Huru. At Tinde the Sleeping Sickness Research Station was visited and the opportunity was taken, at the Native Authority School and Demonstration Farm, to observe protective methods on erodible soils.

PART I. EASTERN PLAINS AND FOOTHILLS

1. Usambara Foothills (Amani-Muheza-Korogowe-Kwa Msala)

The soil catena of the Muheza region

The complex of soils most generally found in the southern foothills of East Usambara, between the foot of the main range and the Pangani river, is a catena or situational succession determined by the topography. Except for a few outlying major hills the country consists of an intricate switchback of alternate ridges and hollows. Red earths of fairly heavy though sometimes gritty texture occupy most of the ridges and their slopes and are by far the most extensive type. Dark grey to black clays lie in the hollows, which are flat-bottomed and tend to be swampy. Often the flank of a ridge descends so abruptly to the adjacent bottom-land that there is hardly any footslope, and the transitional soils are a belt of negligible width; but where the change of slope is more gradual, the intermediate situation between the swamp level and the red earths is occupied by dull brown to yellow-brown soils which are sandy at the surface but heavier below, and which have a horizon of 'gley'* mottling or (more rarely) of limonitic concretions midway in the subsoil. This succession of soil types from ridge to hollow, characterized by different degrees of free or impeded drainage according to position in relation to the relief, may be regarded as normal to the district and its particular climate and topography.

* A 'gley' soil is one with a fluctuating high water-table showing rusty coloured bluish grey mottling in the zone of intermittent waterlogging. The rusty colour is produced by iron compounds near cracks and root channels where the air has been able to enter and effect oxidation. A gley mottled soil may be a stage in murram development or, at least, a cognate phenomenon.

Anomalous grey soils

Along the Muheza-Korogowe road there are several stretches where the normal succession as above described is interrupted by the occurrence of grey soils in relatively high-lying situations, where more typically the soil should be red. At times the whole surface of a long ridge, including its approach slopes, consists of the anomalous grey soil, at others the steepest approach slope is red and the ridge top is grey, sometimes the colour changes arbitrarily on uniform topography. Just as the range of colour in the 'red' soils is considerable, including a variety of dull or bright red-browns and orange-browns, so the 'grey' soils here spoken of go from nearly black, with the properties of a sandy clay, to a yellowish grey or pale grey-brown, with a lighter texture as of a very firmly packed cohering sand. There are few exposures of the profile to be seen, but appearances suggest that, like the grey soils of the hollows, these high-lying grey soils are of impeded drainage. Such of the natural vegetation as is left upon them is of savannah rather than forest type. Two alternatives offer themselves in explanation of the anomaly of poorly drained grey soils situated well above the normal drainage lines. They may represent the remains of a former land surface of mature form and sluggish drainage, now dissected into ridge-and-hollow but not yet fully adjusted to the present conditions. Against this is the non-occurrence of outcropping beds of murram (concretionary ironstone), which might be looked for under soils with such a history. The more likely alternative is that a parent-rock factor is involved in their formation, producing effects which the climatic and topographic factors have been unable to subdue to bring about development of the standard red earth. Such rare outcrops of rock as are seen along the road in the grey soil areas are, it is true, of a gneiss apparently not very different from that common to the whole region. It is, however, quite possible that petrographic examination may reveal a mineral composition that would direct the course of weathering towards the production of a water-retentive 'fat' clay higher in silica and lower in free oxide of iron than is the readily permeable sesquioxidic clay of the red earths. In this connexion it may be noted that seams of quartz rubble are sometimes a feature of the yellowish-grey soils. The dip of the gneiss also needs study, for it will govern the outcrops of particular beds on the undulating ground surface and will also affect the outfall of seepages.

The anomalous grey soils are thus of considerable interest pedologically and they also deserve study from the agricultural viewpoint, for their properties in cultivation are obviously different from those of the red earths. They were avoided by the planters of Ceara rubber, but on the alienated lands sisal seems now to be planted on them indifferently. In view of the pressure upon land for native occupation in this densely settled region, each soil type should, in an ideal economy, carry mainly the crop for which it is most suited. It seems desirable to know more about the fertility of the grey soils under the various local crops as compared with the red soils in corresponding situations, in order that in time some degree of specialization may be achieved in the directions in which advantage is shown to lie.

Proceeding towards Korogowe, grey soils continue at intervals until after the Sagama promontory (the southernmost point of the East Usambara highland) has been rounded. The dark-coloured soils seen after passing Mnyusi village, in going north-west through Magunga towards the Luengera flats are, however, not of the anomalous type just discussed but are mainly straightforward situational types on transported material. The black-brown surface colour is that of a relatively shallow top soil over a dull reddish brown subsoil. In slightly higher situations this becomes typical red earth, and on lower ground passes into a hard-surfaced grey-black sandy clay with seasonally high water-table. These soils are mostly in agricultural use, growing native crops at Mnyusi and sisal at Magunga, where planting is continued westwards until increasing liability to waterlogging on the Luengera flood-plain sets a limit to it. On sloping ground at the foot of the promontory a stand of *Acacia usambarensis* Taub. and associated trees in orchard formation seems to indicate a strip of soil of a heavy 'mbuga'* type akin to the grey soils discussed as 'anomalous' above. Here, however, an additional factor, seepage from the face of the escarpment, aggravates the other causes of poor drainage. There is also a climatic change from humid towards seasonally arid on rounding the promontory, for on its eastern side on similar ground the vegetation is evergreen.

Alluvial soils

The crossing of the Luengera valley farther west affords an example of the distinction to be drawn between the geological term *alluvium* and the pedological and agricultural term *alluvial soil*. The river lies very near the western edge of its flood-plain and from the limit of the Magunga sisal to the river-crossing, a distance of 2½ miles, there is no agricultural occupation of the land. The soil no longer possesses the fertility it presumably once had as a newly formed river alluvium, but by development in response to the conditions of the site (viz. wet-season waterlogging and dry-season aridity) after the deposition of fresh silt had ceased, it has acquired the unpleasant physical properties of a true *mbuga* soil. It may be noted in passing that it is a *black* soil in the top foot or so only: the subsoil mostly has yellowish or greyish tints of light brown. Though the under-drainage is sluggish it is evidently not *nil*, and the land might respond to ameliorative works if such were ever to be considered economic. Across the river, however, in small embayments of more recent or 'living' alluvium on the western bank, there are rice cultivations. The soil here, being still under the influence of the alluvial process, has the fertility familiarly associated with the true alluvial soil.

Various intermediate stages between the two types would no doubt be encountered in a detailed survey of the flood-plain, as well as textural variations due to differential transport of clay, silt and sand. These local soil differences and the minor topographic irregularities are reflected in the vegetation, which is mainly a very open tree-steppe with short grass, but has occasional stands of tall grass (*Hyparrhenia rufa* Stapf), groups of branched *Hyphaene* palm, patches of thicket and riverine forest.

Brachylaena *evergreen forest and Muheza soils*

Beyond the Luengera river, catenary foothill country with soils approximately of the Muheza types is re-entered and continues past Korogowe along the Handeni road to about mile 8. At Kwa Msala there is a considerable stand of forest, which deserves notice as probably being the original vegetation type on the red loams in the outer, less humid zone of the Usambara foothills. In character it is drier than true rain forest, but is without

* *Mbuga*. A flat grassy plain, seasonally waterlogged, sometimes with very scattered small trees (usually *Acacia* spp.). It is, or at the time of its formation was, low-lying ground in relation to the surrounding country and the soil represents the finest clay products of disintegration of the surrounding rocks. The dead roots of the grasses have an important effect on soil structure.

the long-dry-season adaptations of savannah wooding or xerophytic thicket. It is evergreen and there are lianes, orchids and beard-lichens, but no ferns. The dominant tree is *Brachylaena hutchinsii* Hutch.; others are *Cynometra* and *Mimusops* spp. *Mundulea sericea* A. Chev. is present as an undershrub. The shade cast is not dense, but there is no grass amongst the undershrubs except in artificial open spaces and along paths which are floored with a procumbent *Panicum*. The soil is well covered with forest litter, below which it appears as a bright red sandy loam which seems identical with that of the new sisal experiment station at Mlingano, and is akin to the red loams at Lewa, south of Muheza, and Kwamkembe, between Pongwe and Tangata in the coast belt. In both the latter localities there is still forest of similar general aspect. The rainfall supporting this type of forest seems to lie between 1400 and 1000 mm. with the usual two maxima and a somewhat irregular distribution in between, but with a completely dry month a comparative rarity. Soil temperatures noted at two of the localities named lie within the range 23–26° C. The soils are deep, with no visible differentiation of the profile into horizons, and tend to be acid below the top 30 cm. In cultivation their physical properties are almost ideal, but from the viewpoint of intrinsic chemical fertility they are poor and cannot maintain high yields under continuous cropping.

The piece of forest in question, at Kwa Msala, was being logged, by extraction of mature trees of *Brachylaena*, apparently without much general disturbance of the rest. On these terms it may long continue to exist as a representative of its elsewhere largely vanished type. It is greatly to be hoped that it will be preserved from any destructive form of exploitation.

2. Uzigua (Kwa Msala-Zindeni-Handeni-Turiani)

Kwa Msala to Zindeni

A stretch of semiarid country of low relief is entered beyond Kwa Msala, and from there to the Zindeni water-holes at mile 21 from Korogowe the road skirts, and occasionally crosses, a long series of *mbugas*. True red earths classifiable with those discussed at the end of the previous section are rare, and though there is still a catenary succession of types dependent on topographical situation, the highest lying member corresponds only to one of the lower intermediate links in the Muheza catena (a dull orange-brown sandy loam). The horizontal scale in the succession is much extended. The long gentle slopes of which most of this country consists are covered either with thickets containing species of *Euphorbia*, *Commiphora* and *Acacia*, with *Albizzia maranguensis* Taub. and succulent climbers, or with an open orchard-bush formation containing numerous kinds of low trees standing singly at uniform spacing and having a general resemblance in habit. In its detail of associated species this formation varies perpetually. There is much minor variation in soil type, reflected in the occurrence of the tree species and of grasses and herbs in various combinations. For the first time also on this journey a major and distinctive soil type known as the 'hard-pan' soils was encountered here in considerable total extent on nearly level ground adjoining the *mbugas*. 'Hard-pan' in this connexion is not to be confused with murram or lateritic concretionary pan, of which there is none, or at any rate none exposed, along this part of the route.

Skeletal soils derived from gneiss

Near Zindeni the long slopes culminate in projecting bosses of bare gneiss, to which cling thickets of *Euphorbia* spp., *Sansevieria* spp., *Fagara*, *Pterocarpus zimmermannii* Harms. (a tall tree) and various succulent herbs including an aromatic Labiate. The rudimentary soil of these excessively spiny thickets, a shallow, nearly black, gritty humic loam, represents the earliest product of primary soil formation from the gneiss rock under the prevailing semiarid climate. At the foot of the rock masses is a narrow belt of deeper soil, somewhat redder in colour, which has developed on the accumulated material that has undergone the first stage of colluvial transport downhill. Here some of the infrequent cultivations of this district are sited, clearly with a view to utilizing the newly unlocked fertility of these young soils. The agricultural effectiveness of light rains must be materially increased on such sites by the action of the exposed rock surfaces above in shedding water into the subsoil. The danger is that clearing for cultivation may creep too far up the rock slopes. If the tangled spiny thicket is done away with, soil demolition will succeed soil manufacture, and the fertility of the girdle of fresh earth below will be short-lived.

Dark-coloured shallow primary soils as just described were seen generally elsewhere during this journey in corresponding situations, e.g. occupying the steep northern face of Geiro hill on the Masai steppe, on parts of Kiboriani mountain above Mpwapwa, on the kopje at Manyoni, and generally on the granite kopjes of Unyanyembe and Usukuma including the rocky Lake coast near Mwanza. They are evidently the 'skeletal grey earths of the heights' mentioned by P. Vageler (1912*a*) and there is an analogous type in humid Usambara, lying amongst rocks on steep escarpment faces or at the foot of sheer cliffs. Here, too, the type is sought after by native cultivators and, under the better rainfall, crops such as sugar-cane and bananas, and even maize, do well upon it even in very rocky situations.

These primary dark grey soils were not given representation on the East African Soil Map, for they have only a small total extent in any one locality, and at the time of drafting the map their significance had not been realized. They are, however, by no means to be overlooked as members of the regional soil complex, whether as a first source of manufactured soil substance (from the point of view of soil genetics), or in regard to their position in local native agriculture. They are, in fact, the uppermost soil type of the complete 'catena'.

From Zindeni to Handeni (18 miles) the first 6 miles is mainly bright red loam and the road pursues a straight course up and down long slopes, the *mbugas* at the bottom being very narrow. The ditches alongside tend to erode, which indicates a non-laterized type of red earth, probably quite fertile if there were domestic water for inhabitants—Gillman's 'limiting factor for population'—in operation.* The vegetation is still a low-tree savannah, but without indicators of an impervious subsoil.

Handeni soil complex

The last 12 miles into Handeni is very puzzling country. The circuitous approach to Handeni township around the north-west flank of Handeni hill goes across broken ground with intricate though nowhere very steep slopes. The soils are mainly grey-brown to yellow-brown, some even black; red is a rare colour on the road surface except for short stretches

* For a discussion of red earths occurring in dry districts see sections 4 (Kaguru foothills) and 5 (Southern Masai steppe).

on the steeper ascents. Everywhere the soil is coarsely sandy, and weathered rock outcrops always contain a heavy proportion of quartz rubble, some of which when found in the soil has been water-smoothed. Variation in soil profile from point to point is very rapid. The vegetation now includes some *Brachystegia* woodland ('miombo'),* but this changes back again frequently to *Euphorbia* thicket, or to *Combretum* or *Acacia* orchard bush. The latter occasionally includes the characteristic red-stemmed thorn of *mbugas*, *Acacia seyal* Del., on slopes of considerable gradient. It is evident that we have here an intricate complex of parent materials (some sedentary, some transported) and of varying drainage conditions, and that some factor, whether lithological or physiographic, has entered to disturb the usual relationship of soil types to topography. Some of the soils seem to be the semiarid analogue of the anomalous dark-coloured soils of the Muheza-Korogowe road, discussed previously.

Just south of Handeni there is another outpost forest of the semihumid type dominated by *Brachylaena hutchinsii*, again with its characteristic bright red friable loam. It is succeeded by a long stretch of erodible brown to dull red-brown shallow loams occupying moderate slopes, at the foot of which are narrow but evidently fertile black-soil hollows, containing riverine forest and cultivations. The main vegetation type above the hollows is *Combretum* savannah with *Acacia nigrescens* Oliv. (an indicator of indifferent drainage), passing sometimes into *Euphorbia* thicket containing tall *Aloe* spp. There is much quartz rubble lying about and the ridge tops are rocky with outcrops of a very quartzose gneiss. In places there is more of the grey-brown to yellow-grey sandy clay, of the anomalous type already mentioned.

Handeni to Turiani; evergreen forest to deciduous 'miombo'

At mile 15, south of Handeni, *Brachystegia* woodland is entered, and continues thence for 50 miles, almost to Turiani, broken only by short intervals of *Combretum-Acacia-Commiphora* open savannah on low-lying ground, or by riverine forest with cultivations near watercourses. Throughout the whole of this distance exposures of the soil profile are rare as, although it is a well-maintained and well-graded main road, the road authority seems to have had little occasion for either borrow-pits or cuttings, which is significant evidence in itself of the nature of both soil and topography. Notes made on soils are therefore on surface appearance only. They include mention of the following types, succeeding each other with little apparent change in the type of woodland they carry:

Reddish brown, not distinguishable at the surface from a true red earth, eroding a little in roadside drains but not at all amongst the trees.

Grey-yellow, gritty, hard non-cracking surface.

Grey-black, with a wash of pink-stained sand at the surface.

Black or nearly so, sandy clay tending to crack slightly at the surface.

As these various soils all lie under *Brachystegia* woodland of approximately uniform general character, this 50-mile traverse gives little encouragement to the belief that 'miombo', as a vegetation type, can be correlated definitely with a narrowly defined set of soil conditions. Reference to this important question will be made later, after discussing observations in other *Brachystegia* areas. In the meantime it will suffice to remark that monotonous and 'generally uniform' though such an area may seem in travelling rapidly through

* *Miombo.* Open to closed woodland composed of species of *Brachystegia* or *Isoberlinia* trees as dominants or with admixtures of both genera. Other tree genera can also be present but never as dominant components.

it, in detail it varies constantly. Four species of *Brachystegia* and associated species of *Isoberlinia*, *Pterocarpus*, *Combretum*, etc. were dominant or prominent trees seen along the route and no doubt the grass and herb flora varies similarly from point to point. Whether such floristic detail is really correlated with the observed soil differences is a question that could only be settled by close survey. But the above notes seem to suggest that if we are looking for general correlations between vegetation types and soils, the term 'miombo', not further particularized, is too comprehensive. It may indicate well enough a major regional condition such as rainfall distribution, but under the regime so defined there may be considerable differences in soil type and subsoil conditions, to which within certain limits the deciduous *Brachystegia* forest as a broad type is tolerant. Correlation with the type as a whole must then be confined to stating the limits. Until a large 'miombo' area such as this of Uzigua has been examined fairly thoroughly it would be rash to attempt to do so, but it is thought that the tolerance never extends to calcareous soils, and it obviously does not to the 'hard-pan' soils, nor to the heavier types of cracking clay.

There is a somewhat open and tussocky stand of grasses under the trees throughout this *Brachystegia* country. As the neighbourhood of Kange mountain is approached the grass becomes almost pure *Panicum maximum* Jacq. and at this time, after fire probably in August and rain in November, it presented a very lush green appearance. As there is tsetse fly and no permanent water, this potential grazing land goes unutilized. The Lukigura river (pools only, 8 December) is crossed at mile 37 from Handeni, and though from this point onwards there are many watercourses, none contained flowing water until the Luala-Liwale river at Turiani.

3. Nguru Foothills and Scarp-Foot (Turiani-Wami Plain-Kidete)

Eastern foothills and forest transitions

Approaching the outer (eastern) foothills of the Nguru mountains, the *Brachystegia* is interrupted from time to time by patches of lowland evergreen forest and cultivations which recall those of Kisiwani in the upper Mkomazi valley between South and Middle Pare. The road winds through them on the level over heavy grey-black semi-swamp soils; there is much tall grass, some closed stands of *Acacia campylacantha* Hochst. and scattered single large trees of *Chlorophora*, *Sterculia*, *Vitex*, and then one emerges again into *Brachystegia* on gently undulating ground until the next watercourse is reached. (The involuntary use of the word 'emerge' here is significant. The *Brachystegia* is a forest, whereas the interludes on the whole are open ground, being largely occupied by cultivations; and one does not usually emerge *into* a forest. The effect is due to the sense of being closed in by the rank growth of roadside grasses and secondary vegetation of humid types, near the watercourses, by contrast with the long views obtained between the trees in the *Brachystegia*.)

South of Turiani the road for some 20 miles hugs the foot of the main range and the contrasts just mentioned become very marked, though the relative proportion of the two types is reversed. The edge of the fertile scarp-foot plain is travelled over for long distances, over grey-brown to dark grey heavy loams and sandy clays, the products of soil development under varying conditions of subsoil drainage on the sheet of stratified alluvium which laps the base of the range. These soils are densely occupied with cultivations, including cotton, and there is one prosperous looking citronella-grass estate with distillery. Temporarily unoccupied ground is thickly covered with elephant grass, *Pennisetum purpureum*

Schum. Then from time to time there is a short climb over a *Brachystegia*-clad rocky spur, where the road cuttings show a very shallow and immature development of a grey soil, which has a reddish tinge in its brashy subsoil and appears to be a semiarid representative of the 'red-earth' group. It is difficult to believe that the 'bays' along this hill-foot 'coastline' get more rain than the 'promontories', or get it more regularly. Yet there is a contrast between them not far short of that between Uganda and Ugogo. It seems that the 'promontories', having formerly lost their soil by denudation to the plain below, now lose their water also, and that that which they part with too readily by run-off and excessively free drainage appears in the subsoil at the fringe of the alluvial plain, conferring upon the cultivations and natural vegetation there a humid aspect which is not a true reflexion of the overhead conditions of climate.

Soils and vegetation of the Wami plain

A little farther south, a mile or two short of the turning for Morogoro, the road diverges from the foot of the hills on to the Wami plain proper, and the truly semiarid character of the regime is seen as soon as the narrow belt of favoured country, watered by this natural subirrigation, is left behind. Elephant grass gives place to a short tufted *Hyparrhenia* and much of the dark grey-brown soil surface is left visible. There are long level views through a continuous open stand of *Acacia usambarensis*. Variations in topography are very slight, but lower ground is marked by a change of soil colour towards black, of soil texture towards soapy clay and of the *Acacia* to *A. nigrescens*. No exposures of the soil profile were to be seen by the roadside and the true character of the ruling grey-brown soil on this plain is not known. It is not calcareous near the surface. The presence of an unbranched species of *Hyphaene* palm in scattered groups seems to indicate a water-table at shallow depth, but it is probably seasonal and may be brackish. The few shallow watercourses are quite dry. There are clearings for cotton, but they have the appearance of occasional cash-crop cultivations only, not resided upon by their owners. Except for these clearings at long intervals, the acacia woodland is continuous all along the Kilosa road to Kidete, where there are more extensive clearings, all apparently on the same dark grey-brown loam, a settlement and a ginnery. Here, at mile 33 from Turiani, the Mpwapwa road goes north-west to Mamboya.

Note on the 'dark grey-brown loam'

A soil sent to the Amani collection in 1934, from Masanze village just east of Kilosa township, may represent the scarp-foot variant of this type. This soil has the same dark grey-brown colour in the top half metre and the same texture also to that depth. Below half a metre it is an unchanged alluvium of stratified coarse sands and grits, with an occasional horizon of micaceous loamy silt. It has no horizon of accumulation of calcium carbonate, but is neutral in reaction near the surface and very slightly leached below, possibly by the lateral movement of seepage water towards a drainage line rather than by the downward percolation of rain water. At the time of sampling (April) the water-table in this soil lay at 3·5 m. depth. Non-acid sandy soils with a loamy surface horizon and having a moving water-table within reach of crop roots by a short capillary ascent, such as this grey-brown loam seems to be, are a very fertile type, less than usually dependent upon the accidents of rainfall distribution. They seem to be of general occurrence along the western margin of the Wami plain, wherever it abuts abruptly against the mountains. (Gillman's Railway Reconnaissance Notes indicate that the same soil type occurs in the neighbourhood of Ifakara and in other—somewhat restricted—localities, similarly situated with respect to a scarp-foot, on the margin of the Ulanga plain.)

4. KAGURU FOOTHILLS (KIDETE-MAMBOYA)

Vegetation of Mamboya region

After 2 or 3 miles through the acacia woodland of the plain, the Mpwapwa road begins a 20-mile climb of 365 m. into the hills that lie between the major plateau masses of Nguru to the north and Kaguru to the south-west. At first the country is broken and often rocky, and the road takes an intricate route along ascending ridges, with dry V-sectioned ravines falling away right and left. The soils are of the shallow, skeletal, grey to reddish type seen previously on the dry 'promontories' of the Nguru mountain-foot. The later parts of the climb are on less rocky ground and the soil is a mature red earth, which alternates with short stretches of a yellow-brown gritty clay associated with outcrops of a very quartzose gneiss. The vegetation throughout is *Brachystegia* woodland, varying very little in general habit in spite of differences in soil type and situation. On the deeper red earths (a bright reddish orange-brown in colour, gritty clay-loam in texture) there are occasional cultivated clearings, but they are isolated and infrequent and there appears to be no resident population until near Mamboya.

Mamboya village, and the Mission station at Berega a few miles to the north-east of it, are in a region of broad low ridges, wide shallow valleys, and scattered inselbergs large and small, some of them very spectacular, with a 'breaking wave' outline and immense rock faces on the concave slopes. On the larger inselbergs there are remnants of evergreen forest, but the prevailing vegetation type is *Brachystegia*. Sometimes intermingled with *Brachystegia* and sometimes replacing it altogether are representatives of a more xerophytic type of scrub, *Commiphora fischeri* Engl. and other *Commiphora*, *Gardenia*, *Cissus*, *Grewia*, baobab. There is some *Lannea humilis* Engl. indicating localized 'hard-pan' conditions. Low bosses of bare gneiss are fringed with red-leaved aloes and a shrubby *Vellozia* (Phot. 1). The valley slopes are dotted with large *Acacia spirocarpa* Hochst. and in the valley bottoms are *Kigelia* and occasional *Acacia albida* Del. as relicts of former riverine forest. The sandy river beds, though dry at the surface through most of the year, have a water-table high enough to support reeds, *Phragmites*, and yield permanent, if somewhat precarious, supplies of water for a considerable population.

Mamboya red loam and its origin

In places the ridges have rocky surfaces, strewn with quartz rubble and coarse garnetiferous gneiss, and the soils are merely skeletal. Mostly, however, there is a deep mantle of red earth, derived from gneiss and, as clay analyses have shown, of essentially the same type as the red earths of the Usambara foothills. This is the soil principally selected for cultivation and most of it around Mamboya itself is so occupied, though *Brachystegia* woodland of rather poor type persists upon it undisturbed in parts and regenerates on abandoned sites. The development of a red earth with a mature profile 2 m. deep required prolonged decomposition of the parent rock, accompanied by leaching, under a climate at least semihumid and a vegetative cover close enough to ensure that erosion losses at the surface are slower than the progress of soil formation at depth. Having regard to the rare opportunities for saturating and leaching it that the present-day climate at Mamboya affords and the incomplete protection given by the existing deciduous woodland, one cannot regard this particular red earth as a contemporary and 'living' formation.

It is of interest to look into this last conclusion a little more closely. By 'leaching' is meant the removal of soluble products of weathering in the drainage water. In any soil situated well above a permanent water-table, drainage ceases when the moisture content has been reduced to that held at the 'field capacity', a condition that can be reproduced approximately in the laboratory and which corresponds to the equilibrium reached when a suction force of about one atmosphere is applied to the saturated soil. Measurements of the moisture content in this state are available for the various horizons down to 2 m. depth of a typical Mamboya red earth sampled in 1934. The mean for the whole profile is just over 20% of the dry weight of the soil and we may take this figure as the minimum moisture content that must be exceeded before drainage can occur. At the end of the dry season trees and shrubs are leafless, grass has withered and herbs have died down, and it is evident that the moisture content of the soil down to the depth of root penetration has been reduced below the point at which green leafage can be maintained, which in this soil is probably about 10% averaged over the top 2 m. There is thus a moisture deficit of 10% of the dry weight of the soil, which must be made up before the condition can be reached when further additions of water, if not consumed by evaporation or transpiration, pass away from the site as drainage. Calculated on a density of the soil *in situ* = 1·25, this represents a precipitation of 250 mm. Rainfall records are kept at Berega Mission and the daily figures for the years 1932–5 are published by the B.E.A. Meteorological Service. The annual totals for these 4 years are 764, 724, 691 and 612 mm., falling mainly in the months of December to May with showers in June and November.

In considering the effectiveness of this rainfall in the present context, we must discount the light showers falling in otherwise dry periods, for they are quickly evaporated and contribute nothing to the reserves of soil moisture. Similarly, the torrential downpours cannot be given full weight for a proportion of them is lost in run-off. The main consideration, however, is that the period of the most effective rains is precisely the period of maximum use of the soil moisture by the deciduous vegetation, which at this time puts out a luxuriant spread of transpiring young leaves. Thus Staples (1934, p. 120) found that moisture contents to 1 m. depth in a red sandy loam at Mpwapwa under deciduous scrub had been reduced below 10% only 2 weeks after some 200 mm. of rain had fallen, and he concludes that the moisture that had penetrated the soil was being used up 'astonishingly quickly' by the vegetation. A scrutiny of the rainfall figures for Berega shows no time of the year when as much as one-third of the annual gross total (250 mm. out of from 600 to 800 mm.) is likely to have been added to the soil reserves after transpiration requirements have been met and evaporation and run-off losses allowed for. The conclusion is then, as above stated, that under the present climate and type of vegetation the Mamboya red loam is rarely moistened to its 'field capacity' and therefore rarely nowadays undergoes the leaching process.

The present trend of its development is as a pedocal. Partial leaching during rain is arrested midway down the profile, dissolved matter is accumulated there, the moisture is subsequently recalled to the surface and nothing escapes into subsoil drainage. The result is a tendency to the formation of a horizon of least acidity though not as a rule to the actual presence of calcareous concretions, for the lime status of the soil is low owing to its previous history of leaching. Agriculturally the condition described is a favourable one and the soil is in fact a fertile type, suffering however in cultivation from its liability to sheet erosion and even gullying, which can be seen beginning here and there, not least at the very doors of the Mission.

The presence of permanent water below the sandy river-bed floors calls for explanation if it be accepted that there is no seepage from the red-earth ridges. Gillman (1931) notes that certain of the streams are fed by springs at the foot of the higher island mounts, showing the dependence of this water on the yield from the relatively small area of humid mountain land. The soil type of one of these forested upland areas is known and is a very acid yellow-to-orange-brown deep friable loam, belonging to the 'laterized red earth' group, with considerable accumulation of organic residues in the top 30 cm. It can be matched closely by examples from the Usambara rain forest at similar altitudes and has similar vegetation—evergreen forest with tree ferns, and with bracken in clearings. Though it is spoken of as a 'rich' soil, there is little doubt that this is an illusion based on its obviously high humus-content. Under cultivation, rain-forest soils of this type are disappointing and unresponsive after a season or two, and the proper destiny of this mountain land is *not* to be exploited for the uneconomic support of a few hill dwellers (whether black or white) but to be managed responsibly as a catchment area under a regional plan, for the maintenance of a supply of water and of forest produce to cultivators settled upon the intrinsically more fertile red loams of the lower ground.

Associated with the red loams are yellowish sandier types on the lower slopes of the *Acacia spirocarpa*-covered valleys, and in the valley bottoms there are limited strips of sandy alluvium which here and there have developed into brown columnar-structured sandy clays. In a valley to the north of the Mission is an exposure of massive murram or vesicular ironstone, which seems to represent the eroded remnant of a continuous sheet whose formation, as a subsoil horizon in an area of sluggish drainage and seasonally fluctuating water-table, may have been contemporaneous with the original development of the red earths. Hereabouts also is a great deal of sloping rocky ground from which soils of earlier days have been stripped—a warning of what will befall the remainder if man continues to behave as an agent of geological denudation, a mere earth-scuffling animal, instead of pitting himself intelligently against the natural tendency of soil to travel downhill with the storm water. Locally, near Berega, there are small areas of a chocolate brown clay loam of typical 'Kilimanjaro' colour. This is formed by decomposition of a moderately coarse-grained blue-grey basic rock (diorite, gabbro ?) which occurs in narrow dykes and weathers by the scaling off of successive ellipsoidal shells.

5. Southern Masai steppe (Mamboya-Geiro-Mlali-Mpwapwa)

Soils of the savannah woodland bordering the steppe

Going north-west from Mamboya the road, still climbing and making detours around projecting rocky bosses of gneiss, gradually leaves the *Brachystegia-Isoberlinia* country and enters open savannah woodland (Phot. 2), consisting mainly of fairly tall species of *Combretum* and *Commiphora* at regular spacing, with long views across a scanty-short-grass floor between them. For lack of exposures of the profile, it is not possible to determine whether the savannah soils here are to be classified as 'red earths and plateau soils' or as 'plains soils'; that is, speaking broadly, whether they are leached or not. So far as can be judged by the material exposed in ant-bear diggings they have no calcium carbonate horizon. At the surface they are reddish brown, yellow-brown, to yellow-grey. They are firm and hard-packed, without cracking. They probably have a similar history, as regards survival from a more humid period of soil formation, to the Mamboya red earths. Their parent material has evidently undergone local transport to its present position from the site of its original weathering on the flanks of the nearby residual gneissic masses. It is not however by any means yet at the 'end-product' stage of soil formation as compared, for instance, with the footslope soils of the residual granitic hills of Unyanyembe. The topography is still immature, for there are no extensive bottom-lands and the slopes intersect in watercourses which are too steeply graded to have water-bearing sand in their beds as at Mamboya. There has not yet been much sorting out and differential travel of sand and clay particles. There are signs, however, that surface wash is severe and, with the slight protection afforded by an incomplete grass cover (almost disappearing towards the end of the dry weather), the present-day rate of progress towards peneplanation must be fairly rapid. It seems unlikely that the inherent fertility of these stretches of moderately sloping and relatively 'young' land, which are in many ways attractive, can ever be given expression in the form of agricultural or even pastoral production. The rainfall itself may be sufficient in amount for the growth of crops selected to suit its distribution, but supplies of domestic water are distant and there is the further consideration that disturbance of the ground by unimproved native methods of cultivation would undoubtedly hasten denudation.

This belt of tree savannah punctuated by abruptly rearing 'inselbergs' is the borderland of the Masai steppe. The total extent of it in northern Ukaguru must be considerable and resembles landscape of similar type on the Handeni-Kibaya road west of Kwediboma near the northern end of the same piece of country. It is not clear why it does not carry *Brachystegia* woodland. Either the rainfall is below the lower limit of tolerance of *Brachystegia*, or the soils are prevailingly a neutral or alkaline type and the *Brachystegia* prefers (it is thought) acid soils. A little time spent in this area with leisure and labour to dig pits followed up by laboratory examination of the material collected, should provide data of great interest. On this occasion, as formerly farther north, it was seen in transit only.

Red soils of the subarid steppe

As the Masai steppe proper is entered, *Brachystegia* disappears altogether and the vegetation consists of ragged semi-thickets of several species of *Commiphora*, denser thickets of *Acacia pennata* Willd., conspicuous scattered individuals or small stands of *Acacia spirocarpa*, frequent candelabra Euphorbias (*E. bilocularis* N. E. Br.), occasional *Erythrina burttii* Bak. f.; stands of *Acacia seyal* on the lowest-lying ground though not very commonly; short-grass open *mbugas*, devoid of tree growth, seen distantly; grasses otherwise not much in evidence, and the bare soil surface mostly exposed without covering. A good deal of the ground is rocky and has skeletal soils only. From time to time washes of loose grey or pinkish sand are crossed, apparently occupying the course taken by sheet floods of rapidly moving water. The most well-defined soil, however, travelled over for long stretches, is a firm red-brown sandy loam, probably classifiable with that of Mamboya as a true red earth in origin but now become a 'plains soil' and rarely experiencing the leaching process.

A decision on the true character of this red steppe soil would have an unusual interest, for it is one of the very few soil types of semiarid Africa that receive specific mention in the writings of the early travellers on foot, and indeed in most geographical descriptions to the present day. The references, it is true, are only to its brick-red colour and hard-baked bare surface; but when aided by descriptions of the aridity, the xerophytic vegetation and the topography, which are given by the more explicit of these writers, they enable the type to be identified and give an idea of its distribution. Thus O. Baumann (1894, pp. 124–5) speaks of it in the Masai steppe on his return route in 1893, when he crossed from Ufiume to Mgera. It gave 'red Ugogo' its reputation along the caravan route from Bagamoyo to Tabora, though as Vageler (1912*a*) points out the appellation is fair only for the part of Central Ugogo that the caravans chose for their crossing, grey types being on the whole more prevalent to the north and south of this line. It is the soil of large parts of the 'nyika' that had to be crossed in waterless forced marches on the Uganda route, between the edge of the Archaic plateau above Mombasa and the foot of the Teita hills. Gregory speaks of it as extending north into Somaliland, and it occurs in the Umba steppe. The Tanga-Moshi railway runs over long stretches of it (alternating with other types) in the most waterless part of its route, at the western foot of the Pare range. It might well seem that it is a soil type characteristic of subarid regions. Such a relationship might be held to follow, for example, from the geologist's assignment of the red sandstones and marls of Permian and Triassic times to a period of semidesert conditions. The proofs depended on there, however, lie not so much with the nature and mode of original formation of the red-coloured materials, as with the manner of their erosion and redeposition, and with the contemporary occurrence of evaporating dischargeless pans of brackish water. Aridity can undoubtedly enhance a red colour, by dehydrating pre-existing ferric hydroxide, and bring it into prominence in a landscape by preventing the maintenance of a humic top soil and grass cover. But it cannot be admitted that weathering under arid conditions, alternating with short-period and often torrential rain, and with minimal production of vegetable residues, can bring about the deeply penetrating hydrolytic decomposition of rock masses, with accumulation of the less soluble products in place, that is required for the formation of a thick mantle of red earth.

Sedimentary and resorted soils

We should rather refer the actual manufacture of all this red-earth material to a phase of climate now superseded, which was more humid and permitted a greater luxuriance of vegetation. We can then recognize (*a*) a subtype that has remained in place or has been subjected only to gradual colluvial shift, so that its texture and proximate composition have not been much changed, e.g. the Mamboya *Brachystegia* soils and perhaps much of the Masai steppe red earth lying on old plateau surfaces well away from eroded hill slopes; and (*b*) a second subtype in which the original material has been transported to lower ground by violent denudation, so that it shows irregular stratification, is sandier and has lost part of its substance by elutriation to the flood waters of the past and the *mbuga* lands of the present.

In their new climatic and (for type (*b*)) topographical situation, the ex-red earths have begun a readjustment, the effects of which depend largely on the degree of change of the governing conditions of rainfall, temperature, etc., but also on the stage to which irreversible chemical weathering, with its concomitant losses, had proceeded under the earlier regime. Thus a material that is texturally sandy and pervious but still contains easily decomposable lime silicates will in time develop a horizon of nodular calcium carbonate in the middle subsoil. There is no actual record of this in a red soil from the Masai steppe, but it was seen at Voi in Kenya. It has also been seen in the Vudei valley in the Southern Pares. In more exhaustively weathered material the pedocal morphology will be too rudimentary to be recognizable as a visible feature in the field and will be traceable only in the laboratory as a horizon of least acidity. In any situation where run-off water from higher ground accumulates in the wet season, the red colour will disappear owing to reduction and hydration of the iron oxide; and with other associated changes the result will be the familiar development, in depressions, of heavy dark-coloured clays.

The red soils traversed on the Mamboya-Mpwapwa route exemplify both of the subtypes referred to as (*a*) and (*b*) above. At first the soils crossed are mainly of subtype (*a*), sedentary or colluvial, as when the road climbs and turns south-west over the shoulder of Geiro hill, and also on a good deal of the more gently undulating ground of the steppe proper. The southern limit of the Masai steppe is reached at Mlali, at the foot of a mountain range forming part of the northern Usagaras and, going westwards here, skirting the lowest slopes, the road runs over orange-red sandy loams of subtype (*b*). These seem to be identical in character with the similarly situated mountain-foot fan-slope soils of the Gulwe-Mpwapwa district and are similarly occupied by Gogo cultivations and grazings. Here, for the first time since Mamboya, there is permanent water.

Brown mbuga *soils near Mlali*

Near Mlali there are some short-grass open *mbugas* that deserve comment. Their soil differs from the usual black or grey clays found in such situations, most obviously in its colour, which is a rich dark *brown*, but also in its structure as shown by the nature of the shrinkage cracks. The soil profile was exposed in roadside gullies to a depth of nearly 2 m. and, though showing no visible differentiation into horizons to this depth, was found (by use of the acid bottle) to be slightly calcareous from about 120 cm. down. The structure is revealed by a relatively fine-meshed system of cracks that breaks the whole soil mass into innumerable loosely packed angular fragments, contrasting strongly with the large heavy irregular prisms or clods, separated by wide major vertical fissures, that are familiar in the ordinary black *mbuga*-clay as seen in section in dry weather. Instead of the usual vertical-walled sandy-bottomed gully, the structure described results in smoothly rounded erosion forms, with swelling 'mammae' left between incipient feeder-gullies at the edge of the main channel. Similar erosion forms exist at mile 27, south of the Chimala river on the main road between Malangali and Mbeya in Iringa Province. There, a similarly structured red-brown clay, formed under better drainage conditions and non-calcareous, and carrying *Brachystegia* woodland, was seen to be derived from a basic rock which was exposed in highly weathered form below. If the analogy is a true one it seems that in the Mlali neighbourhood we have local accumulations of the weathering products of basic members of the Lower Basement Complex rocks—similar material to that noted in course of formation on a very small scale near Berega Mission, but transported to the depressions without admixture with other more sandy detritus, and there developing as a *mbuga*-clay whilst retaining certain characteristic properties expressed in colour and structure.

It is however possible, as an alternative, that we have here the residues left after solution of a large bulk of a crystalline limestone such as that which occurs amongst the Lower Basement Complex rocks west of Handeni, in the Uluguru mountains, at Mehenge and elsewhere. It is true that no occurrence of this limestone *in situ* is on record for northern Usagara, but at the entrance to the Mlali gap, by which the Mpwapwa road leaves the Masai steppe and descends through the mountains into Ugogo, there is a considerable sheet of fossiliferous limestone and associated travertine, lying at a slightly lower level than the brown-clay *mbugas* just mentioned. This is presumably a lake-floor

Photograph of Geoffrey Milne taken at Amani, 1937 formation of geologically recent date and the waters of the lake must have received a large quantity of calcium bicarbonate from an older limestone or lime-silicate rock exposed in their catchment area in the mountains above Mlali.

Brown *mbuga* clays of a similar type were seen again, also not far from occurrences of secondary limestone, 2 days later on the Mpwapwa-Dodoma road. None of them, either there or at Mlali, seems to be in agricultural use, no doubt owing to the alternation between extreme dryness and extreme stickiness that they undergo seasonally. Yet the reserve of chemical fertility that they contain would seem to be high in comparison with the sandy red earths that are in practice the only cultivated type in these steppe borderlands, and their physical properties should not be so intractable under management as are those of the ordinary *mbuga* clays. The small size of the structural units into which the brown soils fall on drying should give a distinct advantage in obtaining a tilth, and in preventing the formation of deep open cracks with resultant premature drying-out of the subsoil. These brown clays are at any rate a soil type that offers more hope of successful handling as arable land, under intelligently adapted cultural methods, than the common black clays. They are of course very erodible if flood water is allowed to gather way upon their surface.

6. MPWAPWA

Skeletal soils and conservation measures

At the Veterinary Station the brownish red deep sandy loam, termed for convenience the 'Kikombo red' type lies on moderate slopes at the hill foot on both sides of the Kikombo valley, under *Commiphora* thicket—whose botanical detail is now on record, from a census by Mrs Hornby (1934). On the hillside itself, going up Kiboriani mountain, the thicket of the main valley is left and *Brachystegia* woodland is entered. Until the upper ridges are reached the ground is steep and rocky, and such soil as there is belongs to the group of primary dark-grey loams, which have already been discussed for localities in Uzigua and Usambara and which were mentioned also as occurring on the northern face of Geiro hill. The visible rock here is mostly quartz, which crumbles into a granular rubble looking like coarse sugar, but the major contributions of soil-forming material are doubtless made by the easily weathered amphibolite schists which, according to Gillman's (1933) account of the geology of Kiboriani, alternate with the bands of quartz rock. As in the examples previously noted, this dark grey-brown humic loam, skeletal and discontinuous though it is, and (as here) not directly utilizable by reason of its shallowness and the steepness of the ground, is by no means to be overlooked as a soil type of importance to the area. We are to look upon it as a first product of the processes that transform weathered rock and organic residues into soil. The hillside that carries it is, as it were, a factory maintaining a steady output of fresh soil substance, which by natural slow erosion is transferred cumulatively to lower ground. Provided the vegetation that finds a lodgement is not disturbed, even the rockiest slopes thus have a function which has an ultimate influence on the economy of the countryside.

In framing policies of forest conservation, grazing and fire-control, etc. this particular aspect of the general subject should not be lost sight of. It may be thought to be an extreme case of taking the long view but, just as soil destruction may in the tropics proceed at times with disconcerting rapidity, so soil manufacture under our prevailing high temperatures is not by any means an imperceptibly slow process when favourable moisture conditions are maintained in the accumulating residues. There may very well be circumstances in which the effects of deliberately fostering the synthetic process would be perceptible in a generation.

Contrasting soil profiles and their vegetation

At altitudes between about 1500 and 1800 m. above the precipitous slopes just described there is an upland area of ridges and saddles a large part of whose surface is more moderately inclined. Here there are deeper and more mature soils, of which the following two types were noted and sampled:

(*a*) On the top and gentle northern slope of a ridge, under *Brachystegia* woodland of an open type including *B. spiciformis* Benth. with *Protea* and *Faurea* and occasional *Uapaca*; tufted grasses, liliaceous plants and herbs including *Helichrysum*; subject to fires in the dry season. Soil a dark grey-brown loam; chocolate brown subsoil of gritty but fairly heavy texture, quartz gravel frequent at 40 cm. but total depth to underlying rock not seen.

(*b*) On a steep but not rocky slope forming the southern side of the same ridge, under light evergreen forest including *Olea* and *Randia* spp., *Calodendrum capense* Thunb. and a *Coffea* sp. The forest has a sharp upper limit, determined by fire, at the ridge line, beyond which is the *Brachystegia* of (*a*). The distance of the sampling point from that in (*a*) was not more than 200 m. but the soil differs remarkably. The surface was covered by leaf litter; grey loose gritty loam below with a high content of organic debris and roots; subsoil pale grey, very friable and open textured, with a horizon at 22–30 cm. paler in colour and more acid in reaction than the horizons above and below. Total depth and lower horizons of soil were not seen.

These two soils differ so strikingly that at first a correlation with the differences in vegetation, slope and exposure was rejected and it was supposed that they were soils of immature development on different parent rocks. In the laboratory, however, comparison with other profiles in the Amani collection shows that the soils agree in their morphology with somewhat similarly situated soils from Ubena (Iringa Province). Type (*a*) corresponds to a reddish brown soil of Lupembe on the Ubena plateau proper but near its eastern edge; type (*b*) corresponds to the pale-coloured soil of the steep forested slopes of Igololo, on the plateau rim a little farther east. The Kiboriani soils are less acid and they are shallower and less mature, but these effects are in accord with expectation on climatic grounds, for the Ubena localities are a good deal wetter. Otherwise the resemblances are close, and the soils were regarded at first not as purely local types but as examples of a general relationship to vegetation and situation. Further analysis, however, inclines one to attribute to the parent rock a greater share in controlling the development of these soils and their vegetation. Given this lithological control, the overhead climatic control and the interaction of the two in defining 'soil climate', soil profile and vegetation develop together in characteristic association.

7. Ugogo (Mpwapwa-Gulwe-Kikombo-Dodoma-Saranda)

Productive red fan-slope soils at Mpwapwa

The bright red deep sandy soil on which Mpwapwa township is situated and which, with variations in colour and texture, occupies most of the ground between it and Gulwe railway station, was described with analytical details in the author's 1934 Notes,* from

* 'A Note on Three Soil Profiles at Mpwapwa, North-Eastern Ugogo, Tanganyika', with analytical data, G. Milne, May 1934. An unpublished manuscript.

exposures on the Veterinary Department's lower farm. In its mode of origin and general character it is subtype (*b*) of the S. Masai steppe, already described, and in these aspects it need not here be discussed further. Gogo cultivations and grazings are almost continuous on it for some miles east and to about mile 10 west of Mpwapwa along the southern foot of the forehills that lie below the main Kiboriani range. At farther distances from the hills, i.e. from permanent water, it remains under *Commiphora-Acacia*-baobab semi-thicket. In broad flat depressions the same red transported material has become a dark brownish grey sandy clay, cracking into large irregular-columnar clods and showing a horizon of flecks and patches of calcium carbonate at about 125 cm. from the surface. Below this horizon, when the profile is exposed in a sufficiently deep gully, the unchanged red-coloured detritus can be seen as a C-horizon (Phot. 3); and from such exposures it is clear that the dark-coloured sandy cracking clay has not been deposited *on top of* the red material, from a different source, but has developed *from it* during a long-continued alternation of flooding and desiccation. On the lower slopes of long-established shallow V-shaped drainage lines which are crossed on the road leading east from Mpwapwa to the Matamondo valley, the red soil, while retaining most of its bright colour because of the absence of waterlogging, has acquired a thick subsoil horizon of nodular or vesicular-massive calcium carbonate, deposited from run-off and subsurface seepage waters which have brought it in solution from higher ground.

From the agricultural viewpoint a notable feature of the red sandy soils is their continued productivity on severely sheet-eroded surfaces, admittedly at a low level of yield but still far short of a state of infertility. It is evident that the tilled 'top soil' is removed by run-off waters after a very short agricultural life, for minor channels running towards the feeders of the Kinyasungwe river are multiplying across the contiguous cleared fields out of all proportion to the reasonable requirements of the ground for disposal of storm-water. The channels themselves represent of course so much land permanently lost to the cultivator. Yet the remaining land surface between, having already lost last season's top soil in part or in whole and probably other top soils before that, if not too deeply scored is again hoed and sown and yields a harvest.

This very convenient persistence of fertility in depth would not be shown by most true red earths of sedentary formation in which the 'top soil' and 'subsoil' are distinct pedological horizons; if the one is lost the other cannot immediately take its place, for its reactive mechanisms are still undeveloped. The red soil of the Gogo cultivations differs however from the sedentary red earths in having been built up by geological deposition, in the manner suggested for some of the Masai steppe red soils (subtype (*b*)). The material of each stratum was stripped by denudation from the hillside above, where originally it lay as a top soil. No doubt it lost much in the process of removal, and suffered admixture with less valuable stuff. But at every depth in the resulting pile of irregularly stratified detritus there is material that once had this experience of being top soil and may still retain properties it then acquired. Furthermore, each stratum lay for a while exposed on the surface of the fan-slope before being covered by the next deposit, and was at that stage, temporarily, again a top soil. Thus the cultivator of the present day, who is now reversing the accumulative process and stripping the deposit down again, is given another chance after each season's debauch of sins of omission in the care of his land; for what he finds exposed for the next season's operations is not an infertile raw subsoil but a fossil topsoil. Truly this is a form of mining, not of agriculture.

The paring-down process works steadily towards the limit when the deposits shall have been stripped to the bottom. The point of this discussion is not, however, merely to declaim against this destruction, but to offer the opinion on technical grounds that the soil type in question is an exceptionally favourable one for yielding an immediate return for effort expended on measures of conservation. Provided that further losses are checked while yet a reasonable depth remains, the stabilized land surface should be easily capable of being brought into good heart without having to wait for slow weathering and mellowing of raw subsoil.

Calcareous grey sandy clays near Dodoma

A distinctive soil of grey colour and quite different character from that just discussed is encountered in going west from Mpwapwa towards Dodoma, after the road has left the foot of the Mpwapwa hills and is making for the crossing of the Kinyasungwe river. Below the fan-slope cultivations the plain for some distance continues to carry the red soil type, in its extreme sandy form. At about mile 18 from Mpwapwa, there is a short stretch of brown cracking clay of the type remarked upon near Mlali, and this is succeeded by a hard-surfaced whitish grey sandy clay which has an unusually regular level surface without cracks or erosion gullies and which continues without a break for a distance of about 2 miles under a very characteristic vegetation (Phot. 4). Beyond the Kinyasungwe there is an unbroken stretch of about 5 miles of the same soil. It was seen again from the railway, identifiable quite clearly from surface appearances and vegetation, at several places beyond Dodoma between Singe and Bahi stations, especially in the neighbourhood of Kigwe. The same type is recognizable in one of Vageler's (1912*a*, p. 59) illustrations to his account of Ugogo, but he gives no description of it beyond allocating it to his rather miscellaneous group of 'alluvial grey earths', which is comprehensive enough to include also the black *mbuga* clays of quite different character.

No exposures were seen of the profile of this grey soil deeper than about 20 cm., for it rarely erodes into gullies and in the dry state is difficult to dig into when only a few minutes are available. At the surface there is a wash of nearly white or slightly stained quartz sand and below it a hard, gritty, light grey sandy clay, not effervescing with acid to the depth seen. The ground is dead level and has few irregularities of any sort, except that at long intervals there are small roughly circular saucer-like depressions that contain water and around which are small Gogo settlements, apparently of cattle-tenders rather than cultivators. Near Kigwe, however, the grey soil is cultivated so closely in parts as to approach 'cultivation-steppe' in character. Near the pools the vegetation is of fringing-bush type. Elsewhere it is a thorny semi-thicket of 3–4 m. high, dominated by *Acacia mellifera* Benth. with frequent *A. kirkii* Oliv. and occasional *A. spirocarpa*, scattered dense clumps of *Commiphora stolonifera* B. D. Burtt and a few individuals of other species of *Commiphora*, *Salvadora persica* Garcin, etc. There is a variable proportion of open space amongst the thicket clumps and individuals, and this is scantily covered with short tufted grasses, leaving much of the grey-white soil surface visible.

Without notes of the nature of the subsoil horizons this soil cannot be classified definitely and its topographic situation needs study in relation to the drainage and to the low hills that interrupt the plain on which it lies; but in its surface appearances and vegetation it comes very close to a grey soil seen later on in the eastern part of Shinyanga district, between the Tungu and Mango rivers in the basin of the Manyonga. If we accept the correlation, the soil is to be regarded as a member of the 'hard-pan' group developed on a sandy and moderately calcareous clay probably of lake-floor origin. This accords with Vageler's reconstruction of the Ugogo 'diluvial times' as containing a number of lake basins, and also with his mention of a stratified formation of alternating clayey sands and marls in association with this vegetation type. A calcareous subsoil was in fact seen exposed on eroded ground near a Gogo village at the edge of one of the grey soil areas where it abutted on to rising ground carrying red earth, but as the site was near a major drainage line the exposure could not be fairly regarded as evidence that a calcium carbonate horizon is a general feature of the profile. Having regard to the conditions, however, there is little doubt that the formative process is pedocalic, and the likelihood that calcium carbonate is present in the parent material is increased by the occurrence of limestone on higher ground nearby. This was seen at several places in the neighbourhood, in two forms. One is a hard travertine cropping out as bouldery masses on the lower slopes and terraces of rocky hillocks, where it is evidently a redeposited solution-product from the weathering of a dark blue hornblende-gneiss. The other form shows small carbonate nodules embedded in grey marly earth forming mounds and ridges a metre or so high at the edges of black or brown clay *mbugas*. The travertine may be looked upon as a pointer to the original source from which the waters of the former lake derived their lime carbonate, and nodular mounds may be relics of a part of the lake floor exposed at a middle period of its drying-up and since mostly removed by denudation.

At first sight there seems little to say from the agricultural viewpoint about this grey soil. It must be extremely poor in organic matter though probably richer than the red types in phosphate and other mineral nutrients. It may be for this latter reason that the Gogo herds find it worth while to graze upon it, scanty though the herbage is and difficult of access amongst the thorny semi-thicket. In the dry season the gritty hardness of the soil surface and the presence of a dense alluvial clay pan at a few centimetres depth make cultivation with the hoe impracticable, or at least very hard work; the rain supersaturates the top spit without moistening the subsoil. However, these unattractive physical properties may not be a complete disqualification of the type as an agricultural soil. It is possible that additionally there is salinity to be reckoned with, for *Salvadora persica*, which occurs in the vegetation, is regarded as a halophyte. Apart from this—and there are no other evident signs of excess soluble salts—there seems no reason why suitably chosen grain and pulse crops, or even cotton, should not be grown on the rainfall (which may be about 500 mm.), given power cultivation in the first place to break up the hard-pan and, later, tie-ridging or some such device for retaining rain and minimizing sheet wash. A soil of this calcareous type, whose parent material is an *accumulation* of the products of weathering of primary rock, is more likely to maintain fertility from its own reserves (under a rotation of crops and proper management) than is the red earth (of the same locality) which is the complementary *residuum* of the same earlier weathering. As to water for domestic use, the occasional natural pools have already been noticed and their presence seems to indicate that subsoil water could be tapped at intermediate points by wells of no great depth. It is suggested then that though the areas of this grey soil along the Mpwapwa-Dodoma road are at present waste lands, the soil is not fundamentally a desert type, but with enterprise and a sufficient economic inducement it could be brought into agricultural use. The railway is at hand and passes through the district without deriving profit, so that one element of inducement already exists.

'Lacustrine grey' soils and Dodoma 'grey-cement'

The soils just discussed may provisionally be referred to as the 'lacustrine grey' type. The question immediately arises of their relationship to the higher-lying sandy grey soils that are so characteristic of the surroundings of Dodoma township, and which are an extensively occurring type in the part of the Ugogo peneplain that lies between the Kinyasungwe and Bubu rivers, north of the railway. The question can be answered only very tentatively until there is more knowledge of the profiles of both types, but it is believed that there are fundamental differences between these two grey soils corresponding to differences in the conditions of formation of their parent materials which the processes of soil formation under a semiarid climate have not eliminated. The Dodoma grey soil has as its parent rock the sedimentary formation of pre-Rift age known to the Tanganyika geologists as 'the grey cement'. This formation is found extensively as a covering over the granite not only in this part of Ugogo but also on the terraces of the stepped escarpment of the Rift wall and on the plateau surfaces of Usandawi, Uyansi and Turu. In its bearing on present-day soil characters the 'grey cement' will be discussed more fully in the next section. Here it is only necessary to note that though sometimes it is calcareous it is likely to be so only when rocks more basic than granite were major contributors to the material of which it is composed. Around Dodoma the older rocks are for the most part granites and the 'grey cement' consists mainly of quartz sand, bound together by silica or secondary aluminosilicates which appear in the derived soil in the form of unsaturated clay. By reason of its origins therefore the Dodoma grey soil is fundamentally an acid type and being sandy, pervious and of low field moisture capacity it may still be undergoing intermittent leaching during spells of wet weather. Agriculturally it is judged to be very much poorer than the lacustrine type as regards mineral sources of fertility, though it is more easily cultivated. It passes sometimes into redder types, also with the 'grey cement' as their parent material; as seen in section along the railway these seem to lie usually on slopes. There are also variants of it transitional towards the *mbuga* clays. Termite heaps are a prominent feature of the Dodoma grey soil areas and the relationship of termite activities to the genetics of this soil type, and to agricultural conditions upon it, needs investigation.

Poorly drained floor of the Rift valley

Between Kigwe and Makutupora stations the railway crosses for some 30 km. the low-lying ground of the Rift valley floor, which just south of this becomes an open saline swampy plain containing the terminal sump of the Bubu and Mitwe rivers. The soils as seen from the railway vary from light brownish-grey loamy sands to grey-black sandy clays strewn with whitish sand at the surface. They are obviously of poor drainage in various degrees, though whether calcareous or not, or at this part of the depression saline as they are lower down, cannot of course be said without study on the ground itself. Vageler's data on the samples he collected in this area give little help. As far as the crossing of the Bubu river at Bahi there are cultivations, mainly on the lighter soils. Granite crops out locally in the form of low flat domes a few metres in diameter, and in cuttings one can see a horizon of concretionary ironstone lying directly on the granite surface under about a metre of brownish grey soil. The 'grey cement' was not seen here. The vegetation type from which these cultivated clearings have been cut is a semi-thicket woodland of *Combretum* and *Terminalia* spp. with scattered palms (*Hyphaene coriacea* Gaertn.) From Bahi to Kintinka the grey-black clays become predominant and are evidently uncultivable, for the native vegetation, much of which is secondary, is unbroken for long stretches. Palms are more frequent and the *Combretum-Terminalia* bush is replaced by pure stands of *Acacia kirkii* or this species mixed with *A. stuhlmannii* Taub. and *A. spirocarpa*. A great deal of flood water was lying about on the surface after heavy rain the previous day.

The very sketchy and speculative discussion of a few of the soil types of Ugogo that has occupied this section will illustrate the varied interest of the area. Little has been done in the study of its known or suspected soil types since Vageler's work of 1912, which gave an imperfect picture because of the lack of good descriptions of soil profiles and the disproportionate emphasis placed on the results of certain chemical and physical analyses which were supposed, by the doctrines of that day, to give direct guidance on agricultural possibilities. Whatever the *ad hoc* advisory value of the mass of tabulated analyses that Vageler published, they do not throw much light on essential points in soil morphology and are thus of little help in classification. Also the localities and sampling sites are not described sufficiently to assist much in plotting distribution. The real value of his papers lies not in their detail about soil characters, but in the attempt to sketch the general physiographic relationships of the soils as verbally defined in a few broad groups. From this work of Vageler's it is clear, and slight acquaintance with the ground confirms, that Ugogo offers an exceptional field for a kind of investigation that is much needed, namely, an experimental semi-intensive soil and vegetation survey of a sample subarid area. The purpose of such a project would be not so much to establish the extent and whereabouts of each or any particular soil type (though that in itself would no doubt be a useful result locally) as to build up an understanding of the processes and material factors that decide soil type and distribution in tropical dry country. At present, attempts to discuss soil conditions in general terms in a subarid area of any complexity are soon involved in speculation. The common regional factor of climate has not the same smoothing-out effect on local influences that it has under higher rainfalls. Lithology of parent materials and the accidents of local denudation become factors of deciding importance, yet exactly *how* a given set of parent rocks and of past and present denudation conditions expresses itself in the soil pattern has never yet been worked out in detail in a representative area.

To undertake such a piece of work would require the provision of staff and funds, and the co-operation of the Survey Department in producing the necessary base maps on suitable scales. Without resources beyond those at present at the disposal of the Amani Research Institute sample surveys of the kind suggested cannot be embarked upon, but sooner or later they will be found to be essential to further progress and will have to be undertaken in selected parts of East Africa representing particular ranges of soil conditions. Within a 50-mile radius of Dodoma there are several areas of reasonable size for sample survey work, offering suitable combinations of natural factors. They contain a sufficient variety of rock types and surface forms, and also (vide Gillman, 1935) a considerable range of population density and types of settlement, which introduces the important factor of human influence. Except for the effect of altitude on temperature, the overhead climatic factors can probably be regarded as uniform over all localities in this area, though due account will have to be taken of the notorious irregularity of the incidence of weather in Ugogo as to time, place and intensity from year to year and in any one year. There is ample material for studying the indicator value, if any, of bush types or individual plant species in relation to soil types and agricultural possibilities. Finally, access to the selected areas should not be difficult from the railway and main and district roads that intersect this part of the Central Province, and Dodoma with geological advice at hand would be a good base of operations.

PART II. THE RIFT WALL AND THE UYANSI PLATEAU

8. SARANDA, MANYONI, KAZI-KAZI

This section is an attempt to summarize soil conditions on the Rift escarpment and the Turu-Ukimbu plateau beyond, as seen along the route of the Central railway or at short distances from it.

Topographic features of the Uyansi plateau

The essential features of the topography will be understood from the attached diagram (Fig. 1), in which is plotted from Obst's 1:300,000 map (1915, 1923) a straight-line section 140 km. long from Chaya station on the Central railway, in the west, to the railway-crossing over the Mitwe river and thence to the Bubu river at the further edge of the

Mitwe-Bubu depression, in the east. This line runs about 12° south of east. From Chaya to Manyoni it coincides roughly with the railway, but from Manyoni eastwards it represents the profile of the Rift wall in a direct descent, from which the railway of course deviates considerably in obtaining its grades. The scale of heights in the diagram is exaggerated twenty-five times in proportion to distances. It will be convenient in considering this piece of the country and its soils to work from west to east on the diagram, thus departing for the time being from the east-west sequence so far followed. (The soils last discussed in detail were those occurring along that part of the railway route whose projection on Fig. 1 is the portion *JH*.)

The portion *AB* of the diagram represents the central part of the great Turu-Ukimbu elevated peneplain, which bears the name Uyansi. The almost featureless landscape can best be described by the impression one has of it from the railway station platform at Kazi-Kazi: on all sides there are level, low, straight-edge skylines as if one were standing inside a polygon of intersecting railway embankments. The flat skylines are the upper surface of the deciduous bush, the so-called Itigi thicket, which occupies all the slightly

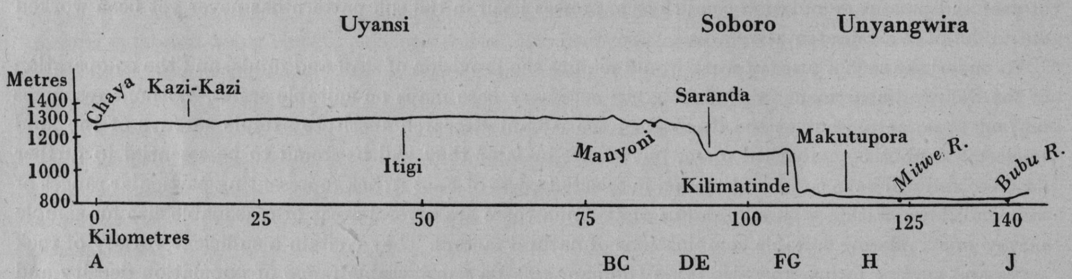


Fig. 1. Section from Chaya through Manyoni kopjes to the Bubu river, on line 12° S. of E. Plotted from Obst's 1:300,000 map, 1915. Scale of heights 25 × scale of distances. *Note*: Kazi-Kazi, Saranda and Makutupora lie a little to the north, Itigi and Kilimatinde a little to the south, of the line of section. Their topographic situations, not their exact projected positions, are shown.

swelling higher ground. Between the observer and these horizons there are gentle slopes, hollows and flats, but the differences of level are not great. The low ground consists of an interconnected system of open *mbugas* of very various shape and extent. Some of these have no watercourses, others form part of more definite drainage lines which trend deviously north-west to the Wembere steppe, or south-east to the Kisigo-Ruaha and so to the Indian Ocean, or down the Rift escarpment to the Mitwe-Bubu sump. There is flow of water only after rainstorms; at other times water is obtainable only in a few widely scattered water-holes in the middle of some of the *mbugas*. The rising ground culminates in broad level or nearly level surfaces devoid of any outcrop of rock. Residual inselbergs, hillocks or piles of rocks, so conspicuous a feature of some other peneplain landscapes as those in sections *CD* and *EG* of the diagram, or as in Turu proper farther north, are here absent. Rock outcrops are, however, seen occasionally at the *mbuga*-edges or other intermediately low points, in the form of granite bosses projecting only slightly above ground level. Above the granite lies a variable thickness of 'grey cement' under about 2 m. of soil. The railway cuttings, rarely deep enough to expose the granite, frequently expose the 'cement'. A close counterpart of the 'cement' exists also under the *mbuga* floors and is exposed in the beds of the shallow seasonal watercourses.

Parent materials of plateau soils

The denuded surface of the granite is covered by 'cement' not only on the plateau proper (*AB* on the diagram), but also on the successive shelves *CD* (Manyoni), *EF* (Saranda-Kilimatinde) and *GH* (Makutupora) by which the precipitous descent of the Rift wall is interrupted. Similarly, after one has climbed out of the Rift valley again going east, 'cement' covers the granite surfaces of the Ugogo peneplain. The accepted geological conclusion from this distribution of the 'cement' is that it was formerly continuous (except for the projecting inselbergs) over the whole area, being older, as a formation, than the tectonic movements that caused the Rift. It must have undergone denudation since those movements, in the course of the renewed erosion that they initiated. Thus an unknown thickness of the 'cement' has been pared off from the plateau surface by the waters flowing to the three drainage systems mentioned above. The spoil has been redistributed on the lower slopes and along the floors of the feeder valleys, and soil formation has gone on simultaneously. We must therefore expect to find the following as soil parent materials:

(1) The 'cement' itself, *in situ*, developing into a sedentary soil.

(2) The accumulated, but sorted, erosion products of the 'cement', less what has been carried right away out of the region.

(3) The granite: (*a*) in places where the covering of 'cement' was originally incomplete on residual projecting hills; and (*b*) in places where the 'cement' covering has been cut through by post-Rift erosion.

(4) Granitic erosion products, redistributed on lower ground and not very different in character from (2) except that they contribute bases derived from primary silicates, of which the 'cement' possesses practically none, and may give rise on weathering to a different type of clay substance.

As has already been mentioned, sites corresponding to (3*a*) in this scheme appear to be few or none in Uyansi though they occur farther east and north. Sites corresponding to (3*b*) seem to be confined to very limited spots near the margins of *mbugas* or to minor declivities descending into the better defined valleys; erosion does not yet seem to have exposed granite on the ridge tops, which are thickly mantled with soil apparently derived from 'cement'.

The lithological character of the 'cement' requires brief description. The many hand-specimens of it collected by Obst were classified by his collaborating petrologist (Herzenberg, in Obst, 1915, pp. 150 *seq.*), in two general groups: *Konglomerat*, consisting of coarse quartz rubble bound in a cementing matrix which is at once ferruginous and siliceous, and *Opalsandstein*, consisting of quartz grains somewhat loosely bound in a matrix of amorphous opaline or partly chalcedonized silica. Teale (1931, p. 13) refers to the binding material in Ugogo as being principally a very fine white to grey clay which, curiously, is not mentioned anywhere by Obst's petrologist. (In this connexion see the discussion later of the nature of the clay fraction of the derived soils.) The quartz grains may be smoothed, subangular or sharp. Bits of silicified wood are recorded. Primary minerals other than the most resistant (e.g. zircon and quartz) are not commonly found. There is usually a slight rusty mottling in the grey matrix. In a peculiarly smooth-textured variety free from quartz grains and resembling a weathered lava, found locally in the Manyoni-Saranda area (e.g. at km. 588, 577·5 and 556/7 on the railway), irregular cylindrical vesicles are preserved which may be root traces.

Deposits with these general characters could have been formed in the extensive swampy flats of a humid region of nearly mature topography. The sandy detritus (or locally, sand-free clay beds) accumulating under swamp vegetation on the flats would have undergone exhaustive hydrolytic weathering of a lateritic type on the slopes before being shifted by erosion. The seepage waters feeding the swamps would contain silica in solution as a soluble product of the same weathering, and so would bring about synthesis of secondary clay-substance by combination of silica with alumina and iron oxides, accompanied by deposition of silicic acid gels. In the permanently wet condition of the swamps oxidation of iron would be at a minimum and the predominant colour, below the horizon of vegetable residues, would be grey. As long as an outflow of drainage was maintained, and if granite were the principal contributory rock, the swamp-floor deposits would be acid but, in sumps without outlet or in presence of fresh silicate minerals from basic rocks, there would be some local accumulation of carbonates. Underneath the swamp floor there would be some decomposition of the granite bedrock by percolating waters. Finally, after large areas had been reduced to swamp level, the elevation and tilting of the region at the time of the Rift movements brought new drainage lines into action, whereby the swamp floor was left high and dry and its accumulations, after first hardening, began a fresh career of slow erosion and soil genesis.

We need not suppose that the conditions under which such processes could occur were peculiar to pre-Rift times. The deeper horizons in the Kazi-Kazi *mbugas*, below 1–2 m. of black clay, consist of a grey gritty aggregate essentially as described for the 'cement' though composed, in part, also of sesquioxidic concretionary material. The deposit as now found differs from the standard 'cement' in containing traces of calcium carbonate distributed irregularly through the matrix; this seems not to be an original property, but rather a later modification due to the deposition of calcareous semiarid weathering products above it. As the *mbuga* floors at Kazi-Kazi lie lower than the granite outcrops from which the pre-Rift 'cement' has been stripped, they are almost certainly much later in date than the original 'cement' and may belong to a period of pause in the erosive modelling of the present topography, when the climate was still humid. Somewhat similar 'cement'-like material was seen in the spoil heaps from the recently excavated ponds in the Huru Huru *mbuga* near Old Shinyanga. The extensive swamp areas that occur in the valleys of the Malagarasi, Ugala-Zinde and Kagera may at the present day be the scene of deposition of analogous formations. Something approaching the conditions described is certainly found in the swampy reaches of plateau valleys between 900 and 1500 m. altitude in Usambara; material dug during the drainage of one such site near Amani in 1932 resembled an unconsolidated 'cement', the detritus here being of course not from granite but from the local gneiss. Here decomposition had also penetrated deeply into the gneiss rock in the floor of the swamp, resulting in a 'cement'-like material with the original banded structure still preserved.

Main vegetation types

Returning to soil conditions on the Uyansi plateau, we have then a relief that is but slightly accentuated but in which quite small differences of level are important in deciding the nature of the site factors *drainage* and *parent material*. Soils and vegetation may therefore be expected to be zoned by topographic position. In the Kazi-Kazi area, Burtt has distinguished six main vegetation types. His account of their distribution is generalized diagrammatically in Fig. 2, which represents a section through a low ridge and across the adjacent *mbuga*. As traversed on going from high ground to low, the sequence is as follows:

ab, crests of ridges. Thicket I. Deciduous thicket as II but with additional species (*Bussea massaiensis* Harms. and Rubiaceous shrubs).

bc, upper and middle slopes. Thicket II. Deciduous thicket of shrubs of coppice-like growth, chiefly species of *Baphia*, *Craibia*, *Combretum* and *Grewia* peculiar to this formation.

cd, lower slopes and occasional minor declivities bordering the valleys. Open woodland composed of *Brachystegia* and *Isoberlinia*, large trees widely spaced, poor grass growth.

de, lowest gradual slopes. Transition woodland. Open woodland of *Terminalia* and *Combretum*; smaller trees of more variable habit, grasses more luxuriant.

ef, marginal parts of *mbuga* floor. Hard-pan vegetation. Open low bush of *Lannea* *humilis* and *Commiphora* spp.; loose clumps or widely spaced individuals, very short-tufted grasses, bulbous herbs.

fg, central parts of *mbuga* floor. *Mbuga.* Grassland with scattered gall-acacias; grasses luxuriant, many herbs; seasonally swampy.

With the botanical detail of these vegetation types we are not concerned, but some description of the general conditions found within each will be necessary in proceeding to discuss correlations with soils. The first two, the thicket types, occur mostly in continuous blocks of large acreage, unmixed with the rest. The boundary at *c* on the diagram, between thicket and *Brachystegia-Isoberlinia* open woodland, is always very well defined, a transit of half a dozen paces being sufficient for emergence from typical closed thicket into open woodland. The remaining types are met with more irregularly, and may be in small local patches or in continuous belts. They succeed one another on the lower ground according to the topography, perhaps with one or other locally suppressed, until the next main ridge ascends again into thicket.

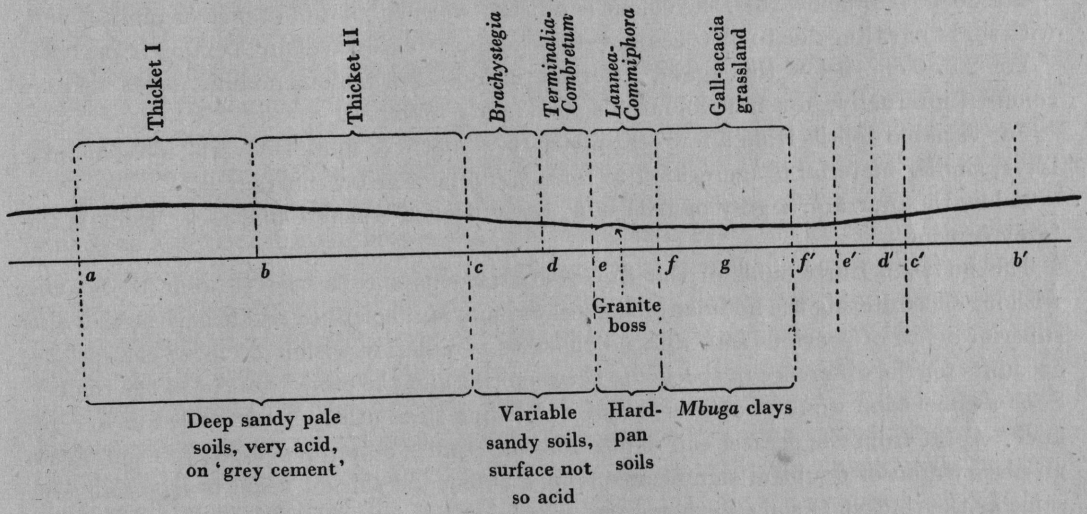


Fig. 2. Vegetation zones at Kazi-Kazi, after Burtt

In the thicket the two subtypes distinguished by Burtt are not very different in general character and, to the layman, passage from one to the other is not readily noticed. Seen for many miles along the lane, cut and maintained through it for the railway, the thicket presents an unbroken dense wall of uniform height, with single somewhat taller trees occurring infrequently. From inside, the coppice-like growth gives an effect of low vaulting. The soil surface is covered a few centimetres deep with small fallen leaves so that grasses and herbs, though not quite excluded, are scanty. The thicket has been regarded as a savannah type of vegetation; it is better described as a dwarf forest, and conditions at the ground surface are in some essentials those of forest soils.*

The thicket floor is somewhat hummocky owing to the numbers of termite mounds, which are of three kinds: (1) 'church hassock' type, small, hard-surfaced and vesicular, as

* EDITOR'S NOTE: It is of considerable historical interest that the first to describe this much discussed Itigi thicket was Burton (1860, **1**, 282). He states: 'The general aspect is a dull uniform bush, emerald coloured during the rains, and in the heats a network of dry and broom-like twigs.... The trackless waste of scrub... is found in places alternating with thin gum-forest; the change may be accounted for by the different depth of water below the level of the ground.'

seen in millions in the *Brachystegia-Isoberlinia* of the Iringa highlands or the Njombe grasslands; (2) low-pinnacle type, consisting mainly of an open vertical shaft with raised rim up to 30 cm. high; (3) less frequent, a broad, low, rounded type. These mounds do not seem to be calcareous and carry no distinctive vegetation; being clear of fallen leaves they exhibit the colour of the subsoil, usually a dull greyish yellow. The soil surface exposed along paths is strewn with a wash of purplish or pinkish coarse sand—the colour being an iron-oxide stain on clear quartz particles.

Soils of Itigi thicket

The soil profile under thicket vegetation in the Kazi-Kazi area is as follows:

0–15 cm. Brownish grey to light greyish brown loamy coarse sand.

15–30 cm. Drab-coloured loosely cohering sand.

30–100 cm., or may extend unchanged to 2 m. depth. Pink-stained quartz sand in a floury matrix of a yellowish buff colour, the whole being almost without cohesion.

For 20–50 cm. below this, the colour is a little 'warmer', a dull orange or pinkish buff, with slight mottling due to blotches and stains of a maroon-red colour. Texture is as above.

For 20–30 cm. below this again, a horizon of loose ferruginous nodules, rusty maroon coloured internally, in a buff-coloured coarse sandy matrix.

For variable depths from a few centimetres to a metre or more below the loose nodular layer, similar material is aggregated to form a compact gritty murram.

Below the murram, a grey or pale buff, rusty flecked concrete-like rock, which is the 'grey cement'.

The pit that Burtt sunk in the *Bussea*-Rubiaceous shrubs thicket went to 240 cm. without encountering the nodular or aggregated murram horizons, and it may be that this superior depth of pervious soil, with no check to percolation within 2·5 m. of the surface, accounts for the difference in species as between this and the other subtype of the thicket. Such a conclusion would, however, require checking from other exposures before acceptance. Apart from the greater soil depth, and a possibly better-developed top soil (again an observation of doubtful significance as it stands), the thicket I soil is essentially the same as the thicket II soil. Both are acid to all depths, with *p*H about 5·0 in the top few centimetres, going to 4·0 or even below that in the subsoil horizons. These figures represent a high degree of acidity and a very low lime status indeed. As to texture, the floury matrix in which the sand grains lie is represented in a mechanical analysis by an item for 'clay' amounting to from 25 to 40% of the whole. In the field, however, the soil at all depths above the concretionary horizons behaves as if it were a pure sand of mixed particle-size but of single-grain structure. That is, the 'clay' lies between the larger grains but exercises no binding function. It is evidently a non-plastic material of the china-clay type, with low values for the physical properties of swelling, imbibition and cohesion that are usually exhibited by soil clays of the halloysite-nontronite group. Its ultimate composition is near that of kaolin, as it has a silica-sesquioxide ratio of about 2·0 and a wide alumina-ferric oxide ratio of about 9 (both molecular). These figures could accord also, however, with the composition of an uncombined mixture of bauxitic products of the original primary weathering with deposited amorphous silica or very finely divided secondary crystalline silica. The clay fraction of the thicket soils is presumably the chief seat of the high acidity that has already been mentioned, and the clay substance must therefore be supposed to have the chemical reactions of a colloidal electrolyte. There is clearly a field here for further investigation which will be necessary before the nature of the clay in these unusual soils can be fully specified.

Corresponding to their textural 'lightness' the thicket soils have a lower water-retaining capacity than would be anticipated from a clay-content of 25–40%. Under a suction of one atmosphere, the heaviest horizon-sample encountered in a detailed study of several different profiles drains to a final water-content of not more than 11%; the usual range seems to be between 5 and 10%, calculated on the dry soil. If now a rough calculation is made on a similar basis to that made for the Mamboya red earth, assuming the dry-season water content to reach the minimum level of about half the above figures, the moisture deficit to be made up at the onset of the rains, before drainage can begin, is found to be of the order of 75–125 mm. of rainfall. The total annual rainfall on the Uyansi plateau can be estimated from records for Manyoni to the east which has about 500 mm. confined to the 5 months December to April, and for Tabora to the west which has about 800 mm. in the 6 months November to April. If we take a middle figure of about 650 mm., the deficit of 75–125 mm. represents not more than one-fifth of the annual total, perhaps less than one-eighth in the sandier varieties of soil.

In the discussion of the Mamboya soil, the conclusion was reached that as much as one-third of the annual precipitation was unlikely to be available for storage in the soil to make up the dry season deficit, after losses by run-off, surface evaporation and water consumption by the natural vegetation had been allowed for. That was under *Brachystegia* woodland or *Commiphora* bush, which casts no shade. In the present soil, the closed canopy of the thicket gives protection from direct rain beat, the carpet of fallen leaves obstructs run-off and the soil surface is kept cool by shade; the upper horizons of the soil are freely pervious to water at all degrees of moistness. Losses due to non-penetration of rain in storms, and to direct drying of the top soil by sun and wind, are thus likely to be small. On the other hand, light showers will not reach the soil surface at all, and the deciduous shrubs that constitute the thicket may be supposed to be fully efficient in making quick use of soil moisture in the early part of the rainy season. It is of course impossible to make up the balance sheet quantitatively without a numerical estimate of the last all-important item, transpiration, and for this there are no data; but one may regard the occurrence of regular seasonal leaching in these soils as very much more probable than in the heavier Mamboya soil with its higher surface temperatures and greater exposure. Soil acidity is thus probably being maintained or increased by current processes. In no sense are these soils pedocalic; under a narrowly conceived theory of climatic determination of soil type they would be misfits, for by ordinary standards the overhead climate is a semiarid one of a fairly severe type, with no rain whatever during half the year. From the point of view of the soil's own experiences, however, that is to say by the standards of *soil climate*, the conditions are better described as semihumid.

The excess moisture that penetrates the upper horizons of the thicket soils, and is not evaporated or used by the vegetation, may in part percolate deeply to a subterranean water-table, but the 'grey cement' in its most usual form is not a jointed rock and percolation will for the most part be checked at its upper surface, 2 or 3 m. below ground-level. At this horizon, after heavy rain, some of the surplus water will accumulate for, as the drainage gradients are very slight, there will be delay in disposing of the excess by lateral seepage. We thus have a temporary suspended water-table, a horizon of intermittent saturation, from which after a time excess water is withdrawn, partly by lateral drainage, partly by root transpiration and (if not more than about 2 m. below ground) by capillary rise in response to surface drying. In diminution of the last-named effect the leaf litter of the thicket floor will act as an efficient mulch.

To this liability to seasonable subsoil saturation must be attributed the formation of the concretionary bed of murram (see profile description). We may suppose it to have begun as a mere localized rusty staining or mottling akin to the gley mottling of swamp subsoils, which is due to the reduction, movement, reoxidation and precipitation of iron (and to some extent manganese) salts brought into solution by acid leaching water. Further deposition proceeds around the first nuclei, whereby pisoliths and tuberous pieces of concretionary gravel are formed; gradually these coalesce to form the murram proper, which is built up in thickness by long repetition of the same periodic process, the essential features of which may be enumerated thus:

(1) Accessions of iron, aluminium and manganese in solution.

(2) Waterlogging with exclusion of air.

(3) Formation of ferrous bicarbonate and reduced manganese compounds under the influence of root-respiration.

(4) Partial reoxidation and deposition of oxides as the water content drops and air is readmitted.

(5) Dry season desiccation, with irreversible precipitation of colloids and hardening of the gels.

The resulting mass is not impervious to water, for it tends to have a cellular or vesicular structure, a property due partly no doubt to the share that roots have in its formation, partly to volume-changes during the dehydration of gelatinous hydroxides. It is doubtful, however, whether true soil formation can proceed farther in depth into the parent 'cement' once the concretionary layer has become continuous. On slopes below the ridge line it will go on thickening at the expense of the soil immediately overlying it, being fed by dissolved or colloidal suspended matter brought in seepage from the higher ground. The top soil is at the same time being thinned off by slow erosion and the final stage will be the emergence of the murram, or the pisolithic horizon just above it, at the ground surface.

An approach towards truncation of the soil profile as just described was observed in one of the Kazi-Kazi pits, just outside the thicket edge. Here the pisolith horizon was only 90 cm. from the surface. At this place Burtt speaks of a narrow 'lane' of scanty vegetation running along outside the thicket margin; in it the herbs of the adjacent *Brachystegia-Isoberlinia* woodland are stunted in form and poorly represented, and across it there is a definite downward slope from thicket to woodland, with signs of severe surface wash. On the diagram (Fig. 2) this is at the point *c*. Along this contour there is certainly a sharp discontinuity in vegetation, which, whether it be an effect of man's occupation or not, can probably be taken as good indirect evidence of a limit in some significant soil condition.

The existence of a soil boundary along some contour of the lower middle slopes is to be expected for reasons such as the following: On the Rift escarpment there are pronounced steps or shelves (see Fig. 1, east end) that may correspond to interruptions in the differential tectonic shift that brought about the present-day elevation of the plateau. From this it may be inferred that the shallow valleys of Uyansi are to some extent polycyclic. That is to say, there were halts in the process of their excavation, and at each halt the valley sides attained mature forms and the soil profiles likewise developed at leisure towards maturity. Then with renewed dissection, caused by the working back of the main drainage lines from a lowered base-level, the infillings of the temporarily 'mature' valleys were swept out again and a steeper angle was imposed on the lower valley slopes, with exposure of fresh materials as the basis of soil development. The fresh materials would include the 'cement' at its lower levels; sooner or later the underlying granite would be exposed, and at all stages there would be intermixture with erosion-spoil from the thinning down of the older soils of the upper slopes. Independently of present-day drainage conditions, therefore, we should look for soil differences on the lower slopes, due to parent materials and degree of maturity. But we are witnessing at the present day the effects of a period of sluggish drainage, a 'halt' stage during which the valleys have been filled in (at a lower level than before) by flat clay floors. Possibly there is already some response to a renewed cutting-back initiated by the latest of the differential movements at the distant Rifts, but for the most part seepage is arrested in the *mbugas*, there to await evaporation in the next dry season. As the cross-section of the valleys is very flat, the effect of this is felt far out on the lower slopes, whose soils must have, seasonally, a fairly high ground-water table.

Soils of Brachystegia-Isoberlinia *woodland*

Whether these general considerations can be made the basis of a purely edaphic explanation of the sharp boundary between thicket and woodland in the Kazi-Kazi area is another matter. In the exposures seen, the woodland soils do not differ very remarkably from the nearby thicket soils. Like them they are porous acid soils ranging in texture from sandy loams to lightly cohering sands, and in depth from but little more than 1 m. to over 2·5 m. In the Kazi-Kazi woodland pits and borings no granite was encountered in recognizable form. In deepening Burtt's 1933 pit a horizon of coarse quartz grit or rubble was entered, containing irregularly subangular pieces up to 2 cm. diameter which might possibly represent a much-weathered quartz vein *in situ*. In other exposures there were murram horizons very similar to those in the thicket soils and, below, a gritty rusty grey material indistinguishable from 'grey cement'. On the whole, the woodland subsoils are somewhat the redder (at most a dull pinkish brown) while the thicket soils are greyish yellow to yellow-brown; but the colour ranges overlap and any significance is discounted by observations farther east. Near Saranda a much redder soil than any at Kazi-Kazi occurs under typical thicket. In the single pair of comparative analyses on clay composition that is available to date, the woodland soil clay has proportionately more silica and iron and less alumina:

Molecular ratios

	$\frac{SiO_2}{Al_2O_3}$	$\frac{SiO_2}{Al_2O_3 \text{ and } Fe_2O_3}$	$\frac{Al_2O_3}{Fe_2O_3}$
Thicket soil	2·14	1·93	9·15
Woodland soil	2·70	2·38	7·53

This accords with the lower position of the woodland soil on the topography and on a normal interpretation would indicate that it had a 'heavier' effective texture for a given clay content. Data on water-retaining capacity under standard suction possibly support a similar conclusion, but both soils are 'light' and on textural and physical properties generally they are more readily grouped together than separated.

From Burtt's 1933 samples there was some indication that although under both vegetation types the subsoil acidity is high and of the same order (pH 4–4·5), the surface soil of the woodland areas is the less acid, being of the order of pH 5·5–6 as against 4·5–5 under thicket. With this point in view a number of further samples of surface soil were collected which on measurement of pH in water suspension by the hydrogen electrode method have given the following results:

The mean of all thicket samples is 4·4 , and that of all woodland samples except the one from Manyoni kopje is 4·9. The difference is in the same direction as appeared from Burtt's samples, and it is thought that the values themselves give a fairer picture of the soil acidity than did Burtt's 'surface scrapes', which sometimes consisted mainly of loose superficial sand-wash mixed with vegetable debris. It seems then that the Kazi-Kazi woodland soils are a little less acid at the surface than are thicket soils in general, but are very much more acid than, and in fact do not correspond at all to, the skeletal soil under woodland on a granite kopje. On the plateau surface just below the kopje, wash from the slightly alkaline soil above has influenced the top soil and a mixture of woodland and thicket species is the result.

Agricultural considerations

Whatever significance may be attached to this factor of surface soil acidity in directly determining the distribution of the two vegetation types—and since it is merely a top soil difference and not a difference in properties between the soil profiles as a whole, it may easily be a *result* of the vegetation distribution rather than a cause of it—it may be that the agricultural conditions are a little more favourable on a freshly cleared woodland site than on a similar thicket site. With a crop not very tolerant of soil acidity, such as maize, growing under otherwise somewhat marginal conditions of fertility, the difference may amount to that between tolerable success and complete failure. As surface erosion proceeds on the cleared site, the advantage will be lost, but *Brachystegia* or *Isoberlinia* regenerates readily from stumps and roots, and there is some evidence that in due time the advantage is recovered. Thus at the site of a pit in woodland at 3 km. west of Kazi-Kazi, the *Brachystegia* and associated trees, though fully adult large specimens at normal spacing, were all ratoons, and from inspection of trunk bases it appeared that there had been a loss of from 15 to 20 cm. of soil since the first growth of the trees. Charcoal was found at 40 cm., corroboration that the site had probably been cultivated.

There is, then, inducement for a small population to confine its shifting agriculture to a circuit lying within the *Brachystegia-Isoberlinia* zone (or this and the *Combretum-Terminalia* zone, to which much of this discussion applies equally) without encroaching further upon the thicket blocks. It is here that evidence is needed from the plant physiologist and experimental ecologist. For it would only be necessary to postulate that thicket species cannot regenerate on land once cultivated, for the sharp boundary of thicket against woodland to be explainable as man-made, man having limited his clearings in an up-slope direction according to his experience of the fertility gradient, the response of his crop to seasonal moisture changes and his own distance from water in the valley bottoms; all of which would tend to a limit running roughly along a contour. On this view the woodland belts and patches could be regarded as immigrant, following cultivation, into an area that was originally simply thicket and *mbuga*.

As to whether thicket of this type can or cannot regenerate on abandoned cultivated land requires further ecological studies. Thicket individuals having the typical coppicing growth habit can at least *persist* in woodland areas. But whether such individuals are surviving aboriginals, or colonists, could be settled by some method of determining their relative ages as compared with neighbouring *Brachystegia* individuals and should be decisive on the question at issue. Apart from these secondary changes in the surface soil, one cannot be satisfied that any consistent differences have yet been established in the Kazi-Kazi area between the soils of the zones occupied by *Brachystegia-Isoberlinia* or

Phot. 1. Bare gneiss outcrop with red-leaved aloes and *Vellozia*; *Brachystegia-Isoberlinia* woodland beyond. Between Mamboya village and Berega Mission (p. 203)

Phot. 2. *Isoberlinia globiflora-Brachystegia* woodland on sheet-washed gentle slope of reddish orange-brown non-calcareous sandy loam with gneiss inselberg behind. About 10 miles north-west of Mamboya on Mpwapwa road (p. 205).

1
2
3
4

Phot. 3. Profile of dark brown cracking sandy clay. (1) Top soil, (2) with calcium carbonate horizon, developed along sluggish-drainage line on transported-red-earth fan-slope which is seen unchanged at (3), and (4) dissected by storm gully. On Mpwapwa-Dodoma road, 5 miles from Mpwapwa (p. 211).

Phot. 4. Thorn-bush on hard-surfaced whitish grey sandy calcareous plains soil. *Commiphora stolonifera* left, *Acacia mellifera* right front with *A. kirkii* above (p. 212).

Combretum-Terminalia and the soils of the thicket blocks, that would be sufficient to explain the exclusion of thicket. At Kazi-Kazi, it is true, no example is known of thicket extending down to the *mbuga* edge without the occurrence of the intervening vegetation zones; but there are certainly such examples in the Manyoni area. Thus at km. 588, 2 km. west of Manyoni station, thicket is continuous from ridge-top nearly to *mbuga* level, and the open woodland zones are quite absent. Here the parent rock is a peculiar very smooth-textured variety of the 'cement' and the soil at all depths is highly acid. The point is, however, that proximity to the wet season flood-level is not of itself an excluding condition for thicket.

A generalization has been made by several observers, notably by Gillman (see, for example, his note on Kilimatinde Shelf and Scarp, 1930),* and by Teale (1931, p. 13) on the occurrences of thicket of the Itigi type and *Brachystegia-Isoberlinia* woodland respectively, in relation to surface geology. Briefly, this view is that under conditions of climate and drainage that either formation could tolerate, the occurrence of thicket or of woodland is determined by whether the soil is an immediate derivative of 'cement' or of granite. There seems no doubt that in the broken country of the Rift escarpment, and elsewhere where residual granite hills project above the old peneplain, the generalization goes far to express the facts. The granite is exposed on steep declivities and its soils are either the primary dark grey loams described earlier or are young, shallow or even skeletal members of the red-earth group. The 'cement' is on level or gently tilted ground and its soils are deep, of grey, yellow, buff and pinkish brown colours, very acid, with murram horizons, and otherwise distinctive. *Brachystegia-Isoberlinia* woodland and thicket species may sometimes intermingle to form a mixed vegetation type, as has already been instanced on the foot-slope of Manyoni kopje between the foot of the rocks and the edge of the township, and as quoted by Burtt 'on the summit of the Rift wall between Kilimatinde and Saranda'; but there would seem no reason to deny such a transitional type its due place in the scheme on sites where fresh granitic debris overlies, or has mixed with, a 'cement'-derived soil. Between such situations half a dozen major differences in soil conditions can be adduced—in depth, moisture relationships, soil reaction, organic matter content, supply of plant nutrients from primary minerals, type of clay substance; and there is no difficulty in accepting these differences as sufficient cause for the observed great contrast in the vegetation types. The question then naturally arises, is the zoning of vegetation farther west to be interpreted (as regards the thicket and woodland) simply as another manifestation of the same linkage between these formations and the geology? May we argue from the known conditions on the Rift wall, and resolve the 'riddle of the sands' on the Kazi-Kazi area by saying, although we mostly do not find evidence for it in the soil itself, that the *Brachystegia-Isoberlinia* woodland soil is directly granite-derived and this explains why it carries woodland and not thicket?

We know that the cement capping of Uyansi has been cut through by the newer drainages, exposing the granite, and the hypothesis is a tempting one. But we must go more cautiously. Accepting the above-mentioned correlation as established for the steep declivities of the Rift escarpment and the projecting hills that stud the surface of its shelves, one may doubt if it has the same value on the very gentle topography of the main plateau at Kazi-Kazi, or on those parts of the Rift shelf surfaces on which a similarly low relief has been modelled by erosion from unfractured portions of the old 'cement'-covered peneplain. In the first place, the Rift wall *Brachystegia-Isoberlinia* woodland is of course not bound to the granite as such, but to factors of soil and site that it finds on the scarp slopes and hill-sides and not as a rule on the old 'cement' surfaces. In the absence of any plant-physiological data we do not know which amongst these factors are really directive and which could be tolerated indifferently by either formation. In the discussion of the Handeni area it was suggested that we can infer little from the occurrence of *Brachystegia* or *Isoberlinia* unless further particulars are given, because the occupation of a given site by woodland of this general type may mean nothing more than that certain climatic conditions are fulfilled and that the soil falls within certain fairly wide limits. On the straightforward 'cement'-derived soils some soil factor (possibly surface soil acidity, but it may be something more complex than this) evidently lies beyond the limit and the woodland is replaced by thicket, which presumably has the

* His views were published in a letter to *J. Ecol.* August 1936 and a reply by Milne in February 1937. (Editor.)

necessary adaptations. All we can safely say about the woodland zones farther west is that the defaulting soil factor has there been restored within the limits of tolerance and the normal vegetation type can again take possession. In the second place, the possibility has been mentioned in discussing the Handeni area that floristic differences within *Brachystegia* woodland as a broad type may be the key to closer soil correlations, and we seem to have an instance of it here. We are not secure in extending the Rift wall correlation to the plateau, because the *Brachystegia* woodland of the plateau is different. It differs from the usual type in the poverty of its grass growth, in the absence of fire as a seasonal occurrence, in the prominence of *Commiphora ugogensis* Engl. amongst the larger trees and in its herbs, many of which Burtt speaks of as peculiar to that area. Finally, the few granite outcrops that were seen in the Kazi-Kazi area appeared to lie in the 'hard-pan' or *mbuga*-edge zone rather than in the woodland, and the railway cuttings showed undoubted examples of 'cement' *in situ* below woodlands of the *Brachystegia-Isoberlinia* or *Combretum-Terminalia* types. While therefore the same conditions of site and soil as on the Rift wall declivities may perhaps be found locally on the plateau where the erosive back-cutting has exposed a definite rocky slope, in general it seems that the thicket-woodland distribution at Kazi-Kazi is not to be explained simply in terms of subsurface lithology and 'soil parentage'.

Soils of Combretum-Terminalia *woodland*

The *Combretum-Terminalia* open woodland that lies in Burtt's scheme of vegetation zones next below the *Brachystegia-Isoberlinia* woodland, but still on 'well-defined slopes', is stated by him to carry a rich grassy herbage, which is burnt annually, and to be the type most often cleared for agricultural use. So far as can be judged, its soil profile characters and subsoil conditions vary over a wide range, from deep colluvial sands to shallow clay loams showing the mottling characteristic of impeded drainage and having a gravelly murram horizon at 40 cm. from the surface. The gravel includes some well-smoothed forms but is mostly subangular or sharp. The samples had a subsoil acidity of the same high order as that of the thicket and *Brachystegia-Isoberlinia* woodland subsoils. The top soil, however, was slightly alkaline; this needs verification on other sites, but if it is a typical feature, due perhaps to ash from the annual burn, it would in part account for the preference shown by native cultivators. In general, one can assign to this vegetation type a tolerance for somewhat restricted root-range and seasonally high water-table, though not for actual surface flooding.

Soils and vegetation of mbuga *margins*

The marginal parts of the *mbuga* floors are characterized by a low scattered bush of *Lannea humilis*, *Dalbergia melanoxylon* Guill. & Perr. and one or two *Commiphora* species with a patchy ground cover of short tufted grass, *Microchloa indica* P. Beauv., only 2–5 cm. high. This is the 'hard-pan' vegetation of the Tsetse Dept. ecologists, being so called because of the very distinctive soil type to which it is a pointer, and which has a dense, tough and almost impervious gritty clay horizon, the hard-pan, beginning at a few centimetres depth below the ground surface. This soil was seen at Kazi-Kazi only in dry weather conditions when its properties cannot be fully studied; but it is believed to be essentially the same type as was seen a few days later at Shinyanga after heavy rain. At Kazi-Kazi the profile is as follows:

Much of the soil surface is exposed, without vegetation or leaf litter. On it there is a thin strewing of rusty stained quartz sand.

The top few centimetres are sandy, but the rusty coloured sand grains are bound in a neutral-grey structureless matrix of fine material, the whole forming when dry a moderately hard level surface which offers much resistance to digging tools; it is not tough, but rather brittle and friable when broken.

From 10 cm. or less below the surface to about 50 cm. is a tough gritty clay, mottled in grey, dark grey and dark brown and speckled with rusty stained coarse sand and grit. This is very hard to dig and seems to have no structure, the quantity of grit and sand probably preventing the formation of structural units by shrinkage. In the dry state, loose lumps show visible pores and shrinkage vesicles, and the lumps disintegrate immediately on wetting; but when wetted *in situ*, expansion closes the pores tight and the mass offers great resistance to the passage of water. Newly cut surfaces on the side of the pit show occasional pin-head flecks (and smears from them) of a friable creamy white material, not calcium carbonate.

To 50 cm. depth, carbonates are detectable only in traces though the reaction becomes more alkaline from the surface downwards (pH$=6{\cdot}6$ near surface, 8·8 at 50 cm.).

Below 50 cm. a gritty clay continues, similar to that above but lighter grey in general colour, less hard to dig and containing carbonates generally distributed.

At 120 cm. (thickness unknown), there is a hard concrete-like mass consisting of grey, buff, blue-black and maroon-red concretionary non-calcareous nodules, aggregated together by the interstitial cement which is grey-white in colour and contains carbonates locally; the reaction of the whole is about pH 9.

Some of the infrequent low rounded granite outcrops occur in the zone of these soils, but it is not known whether there is any genetic connexion except that the carbonates found in the middle horizon of the soil profile are probably derived from the primary silicates of the granite.

No agriculture is attempted on these sites. In so far as any discussion of the 'hard-pan' soils as a group is possible in advance of the laboratory data, it will be given later when the Shinyanga representatives of the group are described.

Mbuga *soils and vegetation*

Finally there are the *mbuga* soils. At Kazi-Kazi these are tough blue-black clays that crack and fissure deeply in dry weather. Notes on a freshly dug pit in the middle of one of the smaller *mbugas* having no defined drainage-channel are as follows:

Vegetation, *Acacia formicarum* Harms. and short grass.

Profile: 0–20 cm., moderately friable heavy clay, cracking into irregular fragments hazel-nut to walnut size; in colour black with a whitish cast on cut surfaces.

20–75 cm., very stiff soapy clay, dark grey-black with whitish flecks and visible quartz grit, some clear or milky, some rusty stained. There are also minute rusty stains locally along the tracks of decayed grass roots. The clay mass divides by fissures into very large units which are irregular cones and prisms, not recognizably columnar though the partings run more or less vertically. Interstices between clods may be wide enough to insert the fingers.

Below 75 cm. only the larger cracks persist, and these are closed. The soil becomes solid black clay having a 'conchoidal' fracture. There are white flecks throughout. The same continues to 140 cm., the last 10 cm. at the bottom of the pit being rather more gritty.

To 40 cm. depth carbonates were only very doubtfully detectable with acid. From 40 to 130 cm. effervescence with acid is confined to the white flecks. Below 130 cm. there is general effervescence, the 'gritty' material being an earthy carbonate.

Burtt's pit of 1934 reached, at 120 cm., a hard cemented greyish buff coloured mass, gritty and partly concretionary, mottled with rusty stains and containing carbonates only in local traces; this continued to 2 m. A similar material is to be seen exposed in the drainage channels of those *mbugas* that have definite drainage, and in some places it resembles the 'grey cement', but more generally seems to be a partly concretionary murram incorporating the upper layers of a bed of 'grey-cement'. It is unlikely that this consists of fresh granitic detritus of the current erosion-cycle, for under the present climatic and drainage conditions it would almost certainly contain carbonate throughout its mass. The material impressed one as being a deposit of the 'grey-cement' type, of granitic detritus exhausted by leaching under acid swamp-waters, and since then infiltrated by water containing bicarbonates. This water has soaked through the overlying calcareous clay which is of later, and current, deposition.

Though the *mbuga* soils contain great reserves of the mineral elements of fertility, their physical properties and liability to extremes of drought and flood make them incapable of utilization by primitive methods. That is not to say that they need always remain beyond the discipline of more sophisticated agricultural methods if inducement for their reclamation, and for the control of the water that reaches them annually from higher ground, should ever become sufficient. Their physical properties probably do not reach the extreme of intractability of the Sudan 'badob' soil, which by appropriate means has been bullied into producing cotton and food. In Uyansi there is no irrigation water but there is a much higher rainfall; the problem of *mbuga*-utilization need not be insoluble.

The following soil temperatures in three of the Kazi-Kazi vegetation types are of some interest. All were taken on 21 December, i.e. at midsummer, by insertion of thermometers 15 cm. into the side wall of a newly dug pit at the depths stated. The thicket and woodland pits had been finished the evening before and the side of the pit used was that on which the sun had not yet shone. The *mbuga* pit was dug the same morning; though the time of observation was just after noon, the sky had been fully overcast and no direct sunshine had reached the wall of the pit.

Depth (cm.)	Thicket (under typical closed canopy in leaf) 9.30 a.m. sun time (° C.)	Woodland (under large *Brachystegia* in leaf) 8.0 a.m. sun time (° C.)	*Mbuga* (in open grassland) 12.30 p.m. sun time (° C.)
10	21·2	21·0	31·5
30	21·2	22·2	—
60	22·5	23·5	—
90	22·5	24·1	28·0
120	22·7	24·0	—

Although the thicket data refer to 9.30 a.m. as against 8 a.m. for the woodland, and the air temperature in the pit was by that amount further advanced in its daily rise from night temperatures, the thicket soil at depths below 50 cm. was from 1 to 1·5° C. the cooler. We have here a reflexion of the forest-like conditions in *Brachystegia*. The temperatures of the unshaded and heat-absorptive black *mbuga* soil are of course much higher.

The soil complex of the Rift wall

Some of the soil conditions on the stepped escarpment between Manyoni and Makutupora have already been touched upon incidentally in the foregoing discussions on the Kazi-Kazi area. Manyoni itself lies on the uppermost of the escarpment shelves. This is a strip of the old peneplain, carrying its cover of 'cement' except where that rock has been cut through along later drainage lines with exposure of the underlying grey granite. The resulting granite outcrops occur at the margins of broad *mbugas*, which are filled with the usual heavy, slightly calcareous black clay and carry scattered gall-acacias or, more centrally, denser groves of tall *Acacia seyal*. The 'cement' in places is an exceptionally smooth-textured variety, which in massive form as exposed in railway cuttings is a hard, jointed, fine-grained, yellowish grey rock containing irregular vesicles like portions of ancient root-channels. In an intermediate stage towards soil formation this is to be seen, exposed by erosion at km. 588 on the railway, as a grey-white, leathery material with a floury fracture and a consistence not unlike Army biscuit; in this state, though very fine-textured, it has few of the usual properties of a clay. The derived soil itself, close by under virgin thicket, is in the same way close-textured, with from two to four times the water-retaining capacity of the neighbouring sandy 'cement' soils; but it would not be regarded as correspondingly 'heavy' in the usual sense, for its shrinkage and stickiness appear to be small. It is, like the sandy soils under thicket, very acid. The old plateau surface here differs from that farther west in being broken by residual granite hills of which that overlooking Manyoni township was visited. The primary skeletal dark-grey loam amongst its rocks under *Brachystegia-Isoberlinia* woodland, and the mingling of this and thicket at its foot on a 'cement' soil modified by the proximity of fresh granite, have already been mentioned. A number of minor granite masses break the plateau surface as one goes east, until at the escarpment edge the 'cement' in place becomes occasional only. Here also there are exposures of a narrow dyke of dolerite, but no effects of this rock in the adjacent soils could be traced. The vegetation along the scarp edge includes not only woodland and thicket in distinctive patches or in mixture but also a variety of other more xerophytic types including *Commiphora* and *Acacia* thornbush as seen in Ugogo. Along the line of descent of the railway there are examples, on granite declivities, of what are taken to be rudimentary red earths—a development of the primary dark grey loam to a depth sufficient for the top soil (a grey, gritty loam 10–20 cm. thick) to be distinguishable from the subsoil, which is pinkish brown, very gravelly and of variable depth less than a metre. In their very freely drained situation, these soils must undergo some degree of leaching during the rains, and they are an interesting example of the formation of red earth (which ordinarily reflects at least semihumid conditions) from crystalline rock under a semiarid climate. The vegetation here is *Brachystegia* woodland.

The much broader lower shelf (named Soboro on Obst's map, see diagram, Fig. 1), on which Saranda lies, again has broad expanses of thicket of the Itigi type on typical yellow to pinkish, sandy, very acid soils having murram horizons at 1–2 m. depth and being derived from coarse gritty 'cement' which lies in place underneath. For a few kilometres along the railway route going east from Saranda station the colour of these soils is a bright orange-red (Phot. 5) and examination of samples has shown that they are here somewhat more loamy in texture, though still very 'light' and as usual very acid. The flats near Saranda have a grey coarse-sandy floor with none of the usual *mbuga*-clay characteristics and, as tested at points by the railwayside, the profile is non-calcareous to the full depth of the gullies into which it is eroding. The vegetation is *Acacia spirocarpa* and *A. rovumae* Oliv. Typical inky black *mbuga*-clay, is, however, crossed at about the same level farther south along the road route to Dodoma. North of Saranda along a line just west of the Kondoa-Irangi road the boundary between thicket on grey-yellow soil on the plateau shelf, and *Isoberlinia-Brachystegia* woodland on shallow granite soils on the rising escarpment slope, is well defined. In the deep gorge by which the Ruira river (the Luwila of Obst's map) descends this escarpment from the upper (Turu) plateau, there is an outcrop of a smooth-textured grey slate having nearly vertical schistosity and splitting into large slabs. This, presumably, is a Basement Complex rock. It has probably contributed something, as parent material, to the soil of the wide belt of riverain forest that accompanies the river across the Soboro shelf below the gorge. At several points along the railway route on the last part of the descent of the Saranda-Makutupora scarp, the cuttings expose a dark-blue basic rock which may be dolerite or diorite or even gabbro (Phot. 6). There seemed to be some evidence at such points that the very smooth-textured variety of 'grey-cement', already mentioned as occurring on the old peneplain, is associated in origin with these quartz-free 'strangers' in the prevailing granite.

PART III. PLATEAU SOILS AND VEGETATION

9. Unyanyembe (Tabora and surrounding district)

Topographic features

Three days spent at Tabora gave opportunity for short reconnaissances to the north-east along the Nzega road and to the south along the Lupa road. In both directions substantially the same impression was gained of soil conditions which are very closely related to the denudation forms. The relationship is generalized in the diagram below, Fig. 3.

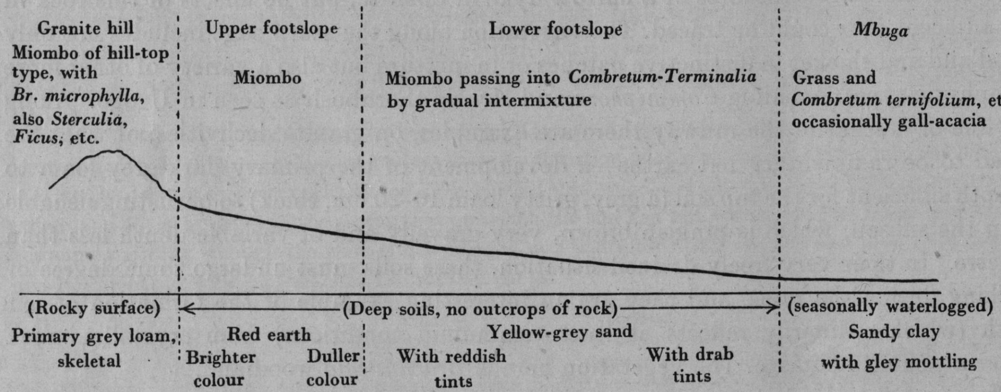


Fig. 3. Soil catena of Unyanyembe

Unyanyembe proper is a not very extensive piece of country forming the low watershed between the Gombe and the Wala-Ugala river systems, which drain respectively north-west and south-west, both ultimately joining the Malagarasi to flow into Lake Tanganyika. Its relief is much more accentuated than that of the main plateau just discussed. The general altitude of the plateau is about 1300 m. and this height is equalled only by the hilltops of Unyanyembe which may be regarded as a broken-down western extremity of the plateau. The skylines are nowhere level as at Kazi-Kazi, but are interrupted by granite hills, some of which are minor isolated hummocks and some are bulky and of hogback outline. They are approached by long gentle slopes that end abruptly at the foot of the rocks and are separated by broad bottom-lands of sluggish drainage. The diagram shows a section (not to scale) across such a hill-foot slope.

Tabora catena—skeletal soils and reddish loam

The soils form a good example of a catena or situational succession of types. The primary skeletal loam of the rocky hillsides is a dark grey-brown (when wet, nearly black) mixture of granitic brash, leaf-mould and roots, with a variable proportion of true earthy matter but no developed profile; it is neutral or very slightly acid (*p*H 7·05–6·4). Here the greater proportion of the ground is occupied by lichen-covered slabs and boulders. On uncleared sites the vegetation, extending right over the crestline except for occasional tors, is a tall growth of *Brachystegia* forest of which the principal tree is the hill-top species *B. microphylla* Harms.; *B. boehmii* Taub. was also noted, and there is a variety of other major trees including a tall *Commiphora* with grey non-peeling bark and cylindrical bole, a tall *Combretum*, an *Albizzia*, a large *Ficus*, *Sterculia quinqueloba* K. Schum., *Ostryoderris stuhlmanni* Dunn, *Afrormosia angolensis* Harms. and a tall unidentified pinnate-leaved tree with papery bark peeling off in large sheets from the upper branches.

Immediately at the foot of the rocks begins a zone of reddish chocolate loam with a bright red-brown to reddish orange-brown subsoil. No exposures were deep enough to show the complete soil profile, but judging by the absence of murram outcrops at this level at any of the sites visited, we may have here a straight red earth, whose under-drainage is free enough to prevent any hold-up of seepage in the subsoil in the wet season. (Compare the corresponding zone in the catena studied a few miles west of Kahama described in section 10 below and contrast the *kikungo* or *itongo* zones at Shinyanga and Ukiriguru described later in sections 11 and 12.) The reaction of the surface soil is *p*H 5·7. This zone does not seem anywhere to exceed a few hundred metres in breadth, and around the minor hummocks that are passed near the road on the outskirts of Tabora going south or west, it extends to no more than 20 m. or so from the rocks. It is therefore a minority soil in this district. Its vegetation is *Brachystegia* woodland without the characteristic hill-top species (*B. microphylla*, the *Sterculia*, etc.) but otherwise not very different from that of the zone next to be described.

Tabora sand or lusanga

In the lower parts of the red-earth zone the top soil has a duller colour and sandier texture and the subsoil begins to exhibit signs of imperfect drainage. This marks the transition to the next zone, that of the pale-coloured loamy sand, which seems to be the prevalent and most characteristic soil of the Tabora district and occupies by far the largest total area. Locally it is called *lusanga*; it corresponds to the *lusenye* of Shinyanga and Ukiriguru, and occurs again, similarly situated, in the localities visited to the west of Kahama and in Usinza. It is understood to be the same type that is reported as being widespread in the region between the Central railway and the Rungwa river (Lake Rukwa drainage) and also in Usure and possibly in Iramba. In general character it is not far removed from some varieties of the sandy coastal soils. Geographical descriptions of the Lindi hinterland seem to indicate a great extent of similar pale-coloured sandy soils along the route from the coast to Songea. This 'Tabora sand' represents, therefore, one of the most widely distributed soil types of the Territory. As noted here in Unyanyembe, its top soil colour varies from grey-brown to dull yellow-grey; below, the colour is sometimes pinkish brown or orange-brown, more usually a dull yellow to yellow-grey, becoming progressively paler at depth and showing slight rusty flecks and mottlings, this being an indication of nearness to the wet-season water-table. Deep drains or gullies seen at the Kazima (prison) farm north-east of Tabora exposed a pisolithic or aggregated dull brown murram at 2 m. depth or thereabouts, lying directly upon granite rock. The top soil has a reaction about *p*H 5·5–5·75. For subsoil acidity there is no data yet, but it is probably not very severe; on the other hand, there is no sign of calcium carbonate accumulation.

On uncleared sites the vegetation is *Brachystegia-Isoberlinia* woodland, including the following species: *Brachystegia spiciformis*, *B. boehmii*, *Isoberlinia globiflora* Hutch. ex Greenway, *Pterocarpus bussei* Harms., *Lonchocarpus* sp., a tall *Combretum* and a shrubby *Strophanthus*. In the lower lying sites, still occupied by *Brachystegia* woodland though nearer *mbuga* level, additionally there are *Terminalia* spp., *Combretum gueinzii* Sond. subsp. *splendens* Exell., *C. zeyheri* Sond., *Strychnos pungens* Solered., a *Dombeya* and occasional *Albizzia amara* Boiv. and other trees not identified. The gradual change of this soil type towards that of the red-earth zone as higher ground is approached on passing the flank of one of the granite hills, is well shown by the colour and quality of the road surface, which becomes perceptibly redder and firmer (less sandy) on an up-grade; but the motor routes are alined to avoid unnecessary gradients and in uncleared country it is possible by road travel alone to receive a false impression that true red earths are non-existent. A traverse through the woodland at right angles to the motor road towards one of the hills reveals the narrow red-earth zone in its due place.

Lusanga *to* mbuga

The transition from *lusanga* to the soils of the level bottom-lands is marked by a stiffer texture in the subsoil and a paler subsoil colour with more pronounced mottling, though the surface remains loose and sandy. Here the soils of the actual *mbuga* floor are not, however, the blue-black, stiff, calcareous, fissuring clays of Kazi-Kazi. They are never more than dark grey in colour, frequently light grey or whitish. They show no cracking when dry, and though of a stiff sandy clay texture below the top few centimetres, they have not the high shrinkage and prismatic-cloddy structure of the typical semiarid *mbuga* soil. They are acid in reaction near the surface (*p*H about 5·7) and there is no indication of the occurrence of a horizon of carbonate accumulation at depth. On the contrary, they show well-marked gley mottling, and the spoil dug from water-holes was observed to contain numerous hard, rough-surfaced, rusty brown ferruginous concretions. They thus seem to reflect semihumid rather than semiarid conditions. The *mbuga* floor vegetation sometimes includes gall-acacias, but the dominant shrub is *Combretum ternifolium* Engl. & Diels., this being apparently replaced by the scandent *C. obovatum* F. Hoffm. on soils of paler colour and lighter texture. The *mbuga* here is not so characteristically a grassland. There are open grassy glades, but also a considerable development of mixed shrub growth (e.g. *Randia* sp., and many others not identified) at fairly close spacing. If there is a local soil type corresponding to the 'hard-pan' soils of Kazi-Kazi and Shinyanga it was not met; possibly the pointer vegetation is different, for neither *Lannea humilis* nor the grass *Microchloa indica* were seen in this area. On ground transitional between *mbuga* and *Brachystegia-Isoberlinia-Terminalia* woodland, *Phyllanthus engleri* Pax is a common shrub and *Vitex mombassae* Vatke a common small tree.

Interrelations of catena soils

This topographic succession of soil types as we now find it may be supposed to have been formed by a combination of soil profile development in place and lateral transport of slowly eroded material. The topography is in an advanced middle stage of maturity—not yet a peneplain, but with the drainage gradients already flattened out except at the immediate bases of the remaining rocky hills. There are true red earths only in relatively narrow zones of free drainage and they are still, no doubt, contracting gradually upon the high points as these are worn further down by denudation. Increasing expanses of sandy wash lie below them; for whereas the red earths contain the complete range of particle sizes (from quartz sand to felspar-derived clay) that the granite is capable of yielding as it weathers, their material undergoes a sorting process as it is pared off by slow erosion and redeposited lower down; the clay is lost in the flood waters or left in the *mbugas*, and the sand remains. All this takes place under undisturbed woodland and with imperceptible slowness by the time-scale of our experience, so that the soil zones appear to be stable. The whole complex is nevertheless evolving towards the elimination of its two 'youngest' members, viz. the mature red earth and the primary dark-grey loam of the rocks above it. Farther south in the Ugala basin the process has reached a more advanced stage than in Unyanyembe and the red earth is extinct. In Unyanyembe itself, where considerable areas are in agricultural occupation, the slow natural course of these events is nowadays expedited by clearing and tillage.

Accumulation of calcium carbonate in termite mounds

No account of the soils of Unyanyembe would be complete without mention of the large termite mounds, of the shape of the crown of a cocked hat and of diameter up to 10 m. at the base, that are dotted about everywhere (except on rocky ground or on seasonally inundated flats) at the rate of about five to the hectare. In a region of non-calcareous soils, they are remarkable for their large content of calcium carbonate. A test with the acid bottle gives effervescence at the surface of the heap. In section, as exposed when the road happens to cut through the middle of one, the earth composing the mound becomes more calcareous towards the centre, with visible carbonate nodules. The core and base of the heap below ground-level consists of a hard concretionary mass of impure limestone. Samples taken include a composite of surface earth to 15 cm. depth from a mound at Kazima, and two other samples, taken from a different mound on the Nzega road, representing respectively the calcareous earth with small concretions from the middle bulk of the heap, and the massive lime carbonate at its base. The hard limestone of this latter mound was being taken for road metal. Analyses are as follows:

Termite mounds, Tabora district

	Carbonate as $CaCo_3$	Total nitrogen	Nitrate nitrogen
Surface earth (Kazima)	3·75	0·050	0·0016
Middle earth (Nzega road)	6·8	0·098	0·0108
Limestone core and base (Nzega road)	53·0	N.d.	N.d.

Taking the earthy material to have a mean content of calcium carbonate of about 7%, as represented by the 'middle earth' sample, and assuming that heaps of hemispherical shape averaging 5 m. diameter and of mean apparent density $=I$ (i.e. weighing 1 metric ton per cubic metre bulk) occur at five to the hectare, then we have somewhere about 11 tons of calcium carbonate per hectare in this form, which is equivalent to a heavy agricultural dressing. To this must be added the unknown but presumably much larger amount present in the base of the heaps as hard limestone. It is a puzzling problem to account for the large quantity of calcium carbonate thus concentrated in the termite mounds. Ultimately it must have been derived from the primary silicates of the granite. To have become concentrated in this manner it must either have been drawn from the ground-waters as bicarbonate, by a purely physical capillary mechanism due to the structure of the heap, or have been gathered by the termite itself over a wide area from the soil in which it feeds. In a region of alkaline ground-waters and of soils in which a horizon of carbonate accumulation occurred as a standard morphological feature, it would be reasonable to accept the purely physical explanation, that the presence of greater evaporating surface offered by the numerous tunnels facilitate gaseous exchange and the release of carbon dioxide from bicarbonate-containing waters.* In Unyanyembe, however, the acid nature of the *mbuga* soils seems to indicate that the ground-waters are not alkaline and could not provide the necessary supply of bicarbonates. So far as the admittedly limited observations go at present, the regional soil character is not pedocalic and lime-carbonate accumulation in the termite mounds is not a local exaggeration of a regional soil horizon. It is an effect altogether peculiar to the mound sites.

Whilst bearing in mind the purely physical explanation as a possibility to be re-examined when the conditions of soil formation as a whole in the area are better known, it is worth looking at the alternative biological explanation, which may or may not be admissible on the known facts of termite habits and metabolism; the literature available gives little help. It would require that this species of termite, whatever it is, builds up the lime-carbonate accumulations not from free calcium carbonate present in the soil, for of that there is none, but from lime present (*a*) as a mineral ingredient of plant remains, or (*b*) as a part of the soil substance itself, the exchangeable lime of the clay-humus complex. A possible but not very probable source is that lime ingested incidentally with the insect's food is excreted mainly in the heap. A second possibility is that the breeding stages, conducted within the heap, require an alkaline environment (perhaps for the propagation of a necessary fungus), when the gathering of lime would not be incidental but purposeful. A third and simpler possibility is that organic residues are carried from a considerable distance around into the interior of the heap for nursery purposes, their energy and nitrogen content being there utilized and the mineral residues left to accumulate over long periods of time.† The fact that even the outside of the heap is calcareous suggests also that the earth composing the heap has been cemented together for structural strength by a calcareous secretion, the necessary lime for this 'mortar' having been derived from the mineral constituents of soil humus or plant tissue consumed as food. The concretionary habit of the accumulations in the middle of old heaps is probably an effect of repeated wet season-dry season moisture changes and local capillary movements.

If the biological explanation of the carbonate content of these termite heaps is in a general way the true one, as against a merely physical process of withdrawal of bicarbonates from alkaline ground-waters, then, whatever the precise mechanism, there is clearly a bearing on soil genetics, for the carbonate accumulations will represent material that in the absence of this form of termite activity would have remained generally distributed in the soil mass, instead of in two or three termite heaps. At a given stage in soil development towards equilibrium under the prevailing climate, we shall have a more acid, minerally poorer soil that would be found otherwise. This in turn will adversely affect the

* Editor's Note. The painstaking observations in the Northern Transvaal by F. N. Marrais (1938, pp. 65, 94, and Chap. xiii) on the connexions between termitaries and ground-water, and more particularly on shafts 'at least 65 ft. deep', up which the termite workers actually carry water, should not be overlooked.

† If the lime carbonate accumulations are mineralized organic residues, there should be a proportionate content of other mineral constituents commonly present in the 'ash' of plants, in particular potash and silica; on this point further analyses on representative material, not yet to hand, should throw light.

soil's equilibrium content of humus, independently of the direct consumption of humus or potential humus (dead plant tissue) by the termites in the ordinary way of food.*

A compensating feature is that the reserves withdrawn in this way from the soil are not lost but only concentrated. If no unforeseen effect on biological balances were to result from disturbance of inhabited mounds (and many of these mounds are possibly *not* now inhabited) there seems no reason why the lime concentrates thus conveniently dotted about the fields should not be redistributed as fertilizer when inducement arises towards higher crop production. Almost every acre of ground has the equivalent of heavy dressings of lime available in accessible form upon it. To employ the friable marly earth that forms the bulk of the above-ground part of the mound, nothing more is required than digging, and transport to a maximum distance of half-way to the next heap. The hard concretionary mass in the base of the mound, though it is the richer reserve of lime carbonate, is not so easy to utilize, but it might be converted to a distributable form by burning. There is agricultural evidence on the spot that termite-mound earth is more productive than the non-calcareous sandy soil around it. The mounds are often cultivated right over the top and the state of crops upon them, e.g. maize, which was markedly greener and taller on mounds than alongside them, serves as a demonstration. It would seem well worth while to carry out some experiments on the fertilization of small areas in the manner proposed —not by merely levelling out the mounds, but by excavating them systematically and distributing the spoil, or such proportion of it as represented a reasonable dressing per acre, as uniformly as possible.

It is not yet known how general is this calcareous character of termite heaps, nor whether more than one species are concerned. Just west of Kazi-Kazi station a large mound of the Tabora type was noted that had been cut through by the railway and showed a limestone core. Similar cases were noted from the train at several points between Soga and Dar-es-Salaam. Numerous mounds of this shape and type are to be seen between Kilosa and the edge of the Mkata plain but no observations on them are available. Mounds of various shapes and sizes, usually smaller than the Tabora type, have been noted as calcareous in the Old Shinyanga area. One or two instances of very large calcareous heaps are known along the Tanga-Ngomeni road. Further observations from any part of the Territory would be very welcome.†

Agricultural considerations concerning Tabora soil types

Dealing with the question of the general fertility of the prevailing soil types in the Tabora area, especially with regard to their status as potential cotton-growing soils, one can only give, with reserve, a general impression of these soils aided by what was seen of related soil types elsewhere. It has already been suggested that soil evolution in Unyanyembe has progressed far towards eliminating the 'climax' soil type of the region, namely the red earth, which is being driven in upon the remaining high points of the country by slow denudation. At best a red earth derived from granite is a comparatively poor soil,

* The figures for nitrogen content in the earth of the mounds are of the same order of magnitude as might be expected for ordinary top soil in this area. Some accumulation of nitrate in the middle zone of the heap could reasonably have been looked for, and may perhaps occur in similar heaps in regions of drier climate, e.g. in Ugogo; but in Unyanyembe the prevailing conditions are evidently too wet for salts so soluble as nitrates to remain unleached.

† EDITOR'S NOTE. In Central Ufipa the substantial churches and mission buildings are all constructed with lime mortar derived from the lower core of gigantic mounds.

but as regards texture, structure, properties of the clay-humus complex and reserves of plant nutrients, it probably represents the optimum stage of soil development for this parent rock and the given climatic conditions. The soil types that at present prevail in the area, namely the *lusanga* and the clayey sands of the *mbugas*, have been derived at second hand by the slow erosive process that has pulled the red earths to pieces and redistributed their fragments. The *lusanga* has lost body, crumb-structure and mineral reserves in proportion to the degree of transport and sorting out that its material has undergone. It is therefore a poorer soil in these respects than its parent red earth and the deterioration will be the more marked the more mature the topography on which it is found. Thus in those parts of the district where granite hills and their girdles of red earth still survive in bulk (e.g. to the north-east of Tabora), the soils of the lower slopes will be 'younger', i.e. less exhausted by erosive reworking, than in areas of more advanced peneplanation such as are entered a few miles south from Tabora, where the sandy soils are almost an end-product of the redistribution process. There is, however, one count on which the *lusanga* has an advantage over the red earth: its dry season moisture supply has improved, by the fact that it lies on sites not so far above water-table and is fed by seepage from higher ground. A deep-rooted annual crop is less likely to suffer from drought on the low-lying compact sands than on the more open-structured, though heavier, red earths in their higher topographic position.

The *lusanga*, then, except in its most advanced forms, can be a fair medium for the growth of crops, but it has in it nothing that can be exploited. The *mbuga* soils in an unimproved state are limited by bad drainage to their present crops, principally rice. By the present non-intensive methods of the peasant cultivator, food enough is produced and there is some saleable surplus. The question is, can these soils produce *additionally* the desired yields of cotton? Experience in cotton-producing areas elsewhere in East Africa has shown that cotton represents an *addition* to the total acreage under crops; less ground is left at any one time under bush fallow and the rotation is thus shortened. Even in the naturally high-yielding cotton districts of Uganda, there is now a clear need for manuring or at least for the deliberate establishment of the best type of regenerative cover on fallowed land. The initial period of soil exploitation is there drawing to a close and soil-mining practices are having to be substituted by sound farming. The same initial period is in full swing in the cotton-growing areas of the Lake Province of Tanganyika on soil types such as the *mwibushi*, which are easy to handle and possess reserves of fertility. There also it will probably not out-last a generation, but in the meantime its profits, of doubtful honesty, are available for promoting the general advancement of civilization in the area, including (one hopes) education in the proper use of land. The difference between the development of these areas and that of the *lusanga* areas of the Western Province, is that the latter soils cannot support a more intensive cropping than is normally required of them for food production, unless methods of 'high-farming' are adopted upon them not only from the very start with the new crop, but for some years in advance of it. There can be no introductory period of profitable sin against the land; the soil conditions are too austere to permit it. Yet they are not so forbidding that cotton, *properly manured on land maintained in good heart*, should not in due course take its place here, in the local agricultural system, as it has on similarly unpromising soils elsewhere in the world once the grower has put out of his mind the idea of getting something for nothing.

There is here a much greater problem than the establishment of a new crop. It is the problem of working up the agricultural standards of the area from subsistence level to producing level, in advance of the introduction of the crop and therefore in advance of the cash inducement to the individual which that crop will ultimately provide. Whether it is a soluble problem will depend on how seriously it is taken; a very great deal of detailed educative effort will be required, on selected ground and with selected peasants, and this cannot be done without *ad hoc* staff and expense and will take a long time. But one cannot perceive how else the advancement of a native people inhabiting a poor-soil area can be embarked upon otherwise than by improving their agricultural methods to the point where care and foresight begin to compensate for low natural productivity.

There is one further point relevant to this question of export production on poor soils—or indeed in the long run on any soils however fat they are to begin with. The gross proceeds from sale of cotton, groundnuts or whatever the cash crop may be, or of food-stuffs if it is a food-producing area as Unyanyembe is to some extent, must not be regarded as income to be spent entirely off the land. A due part of it must in fairness go for the purchase of the elements of fertility, in compensation for those exported in the crop. Every European farmer regards his fertilizer and cake bills as part of his normal year's expenses and does not reckon his income until they have been met. This elementary principle of sound farming has had singularly little adherence in East Africa where native production is concerned. It may be that the working out of the best forms that purchased fertility should take yet remains to be undertaken, but to say that the export-producing native cannot afford to buy lime or feeding stuffs or spend money on compost-making is unacceptable; rather, since he must incur expenses on these things, if his production is to be a permanent thing, he cannot in the early years afford trousers, or a bicycle, or the pleasure of enabling his District Officer to make a gratifying tax-yield return. One must insist upon this principle as being indispensably a part of any code of sound soil management, yet one that has received too little attention from those who should be guiding the native in the spending of his cash-crop earnings.

10. Kahama district (Tinde, Kahama, Ushirombo)

Tinde to crossing of Manyonga river—red soils with murram horizon

Going west, the road crosses a cultivation-steppe plateau that lies at the foot of a low range of granite hills to the north and which near Tinde itself is studded with outcropping granite blocks and small curiously piled kopjes. The soils are prevailingly of a red-brown colour, but are not true red earths, for a continuous sheet of murram appears to underlie the area. It is mostly under a fair depth of soil on the level or gently inclined surface of the plateau, but is always exposed on the steeper slopes by which the road drops to cross the drainage lines. These are wet-season watercourses flowing south or south-west to the Manyonga river; they are bordered by marshy flats of irregular width, carrying a vegetation of reeds, and are apparently saline in places, for women were seen gathering the earth. There appear to be two distinct formations of the murram, the upper being a fringe around the granite kopjes or along the base of the range of hills, the lower being a sheet underlying the flat expanse of cultivated land. They must indicate two successive stages of denudation during each of which a horizon of subsoil ironstone had time to form before the base-level of erosion was again lowered. Provided the depth of super-incumbent soil is sufficient, their present effect on agricultural utilization of the land is probably beneficial. There is presumably a check to downward percolation at the base of the murram horizon, which thus, depending on its thickness, functions as a water reservoir. As the horizon is not itself impervious to water movements and has been cut through at intervals by the stream courses of the present erosion cycle, excess water can escape laterally; the drainage is not nowadays stagnant, only regulated, and the result is a moderation of the drought experienced by the crops, if they are sufficiently deep-rooted, at the beginning of the dry season.

The only woody vegetation visible over a wide horizon consists of scattered baobabs, occasional large *Ficus* and other trees, a few planted *Cassia siamea* Lam. along the road or near villages, and a thin growth of low shrubs on temporarily untilled land. The general aspect was green, following some weeks of rain; and perhaps for that reason one failed to get the impression, for which one had been prepared from accounts of overstocking in Usukuma, that the land was being cut to pieces by its cattle population. The numerous squads of people working in line, wielding the hoe in workmanlike fashion in preparation for planting, gave the contrary impression of a prosperous agricultural countryside. In the dry season, however, the aspect is very different—a bare red-brown wilderness. It is then, no doubt, that the real damage caused by uncontrolled grazing, and by perpetual crop-taking without equivalent return to the land, becomes apparent. Except that a better rainfall and more accessible ground-water permits here a denser population, the conditions recall those of the red fan-slope soils of Mpwapwa, in that sheet-eroded surfaces, having lost their original top soil, readily come into some degree of productivity on renewed cultivation. Possibly the manner of formation of the Tinde soil, similarly situated with respect to a range of bare hills, was the same as that described for the Mpwapwa soil. At any rate there seems to be a difference here from the conditions of degenerative soil evolution that have operated in Unyanyembe, or rather, a difference in the stage that has been reached; for the red soils, here also, are undoubtedly being reduced by surface erosion, and the end will be an exposed pavement of uncultivable murram. Under proper leadership of the population, the process can be checked. (For an example on somewhat similar ground at Ibadakuli, see the section on Shinyanga.)

Manyonga river-Isaka-Kahama—gravelly loams and Brachystegia *woodland*

At the crossing of the Manyonga river, which here comes down on a southerly course from its sources to the north, there is an exposure of a considerable thickness of a stratified rock which is clearly a form of the 'grey cement'. Across the river it is much tilted and contorted. Capping it, is a bed of several feet of slag-like murram and, over that, a red-brown soil, thinned down by erosion. The Tinde cultivation-steppe had been left behind 6 miles before reaching the river and since then no granite outcrops had been seen. As in Uyansi, it seems that the 'cement'-derived soil is too unproductive to attract settlement.

The Tabora-Mwanza railway is crossed near Isaka station some 4 miles west of the Manyonga and for another 4 miles there is a level stretch of *Brachystegia-Isoberlinia* woodland, except for a short interval of *Acacia formicarum mbuga*. Burtt's identifications here include *Brachystegia spiciformis* and *Isoberlinia globiflora* as codominants, *Commiphora fischeri* and *Commiphora pilosa* Engl., *Combretum gueinzii* subsp. *splendens* and *Commiphora zeyheri* as common lesser trees, *Ostryoderris* frequent, *Sterculia quinqueloba* and *Diplorhynchus mossambicensis* Benth. also noted. This is a somewhat similar assemblage to that described on the deep pale-coloured sands near Tabora, at any rate as regards the tree flora; but the soil here is very different. It is a fairly heavy but gravelly and shallow loam of chocolate colour, the gravel being mainly subangular ferruginous concretions; below, the subsoil colour is dull reddish brown and there are increasing quantities of gravel of the concretionary kind and also of broken quartz-vein rock or sugar-grained quartzite until, at 40 cm., a sample consists almost entirely of gravel. In many borrow-pits by the roadside a heavy, slag-like, non-gritty murram is exposed. The 1936 Geological Map shows the areas as granite. No granite outcrops are to be seen along the road, however, between mile 6 east of the Manyonga river and Kahama township, a distance of 34 miles. It may be suggested that the small area of Upper Basement Complex rocks shown just south of Isaka should be extended farther north on the map to include this area of woodland. The heavy nature of the soil and the occurrence of quartzite gravel would be readily accounted for if the parent material is supposed to be Upper Basement Complex (or even Muva-Ankolean), but they remain anomalous in a granite area. It may be that we are dealing here with transported material of Upper Basement Complex origin with granite as the country rock below.

Composite samples of the shallow surface soil, to 12–15 cm. depth, were taken in the *Brachystegia-Isoberlinia* woodland. They show relatively slight acidity of *p*H between 6 and 7. Occupation of this site for agricultural purposes is probably excluded by the shallowness and gravelly nature of the soil rather than by any intrinsic infertility of what true soil there is. We have here a picture of the probable end-state of such cultivation-steppe as that of Tinde, when the depth of tillable soil above the underlying murram shall have been reduced to a few centimetres by long-continued sheet-erosion. This may even be the actual history of the site, now long abandoned to *Brachystegia-Isoberlinia* woodland.

Mbuga *soils near Kahama*

The *mbugas* in this area are of stiff black clay. They do not contain calcium carbonate in the top few centimetres but are probably calcareous at depth. Their vegetation is tufted grasses and a fairly dense stand of gall-acacias, *Acacia formicarum*. Nearer Kahama and to the west of it, for about 6 miles, there are extensive flat areas not carrying a distinctive *mbuga* vegetation yet lying very wet and crossed by the road on low embankments. The soils appear to be grey sandy clays; they were seen only from the car in transit. Between the flat areas, on slightly higher ground, the greater part of the route lay across grey-white hard-packed clayey sands, which show gley mottling at shallow depth and recall in some respects the soils of certain coastal savannah belts on Jurassic calcareous clays. The vegetation consists largely of scattered clumps and single scandent bushes of *Combretum purpureiflorum* Engl. with a good many Borassus palms visible; cultivations are mainly cassava. There are no rock outcrops and no woodland until Kahama township, which lies at the foot of a *Brachystegia-Isoberlinia*-clad granite ridge or low hill.

Recurrence of catena of Tabora type—Kahama-Ushirombo

From Kahama township to the farthest westward point reached, mile 18 along the Ushirombo road, the conditions of topography and soil have much in common with those of Unyanyembe. The catenary succession from high ground to low is much the same. As studied in some detail at mile 18, it runs as follows:

(1) Top and flanks of rocky hill (granite): dark grey-brown friable gritty loam, containing much plant-debris. Soil is slightly acid (*p*H 6·65). Vegetation includes large trees of

Brachystegia microphylla and a variety of other usual associates, e.g. *B. spiciformis*, *Isoberlinia globiflora*, *Combretum* spp., *Pterocarpus bussei*.

(2) Immediate foot of rocks, on moderate slope: A narrow zone of red earth, going to irregular depths of 2 m. or more amongst granite boulders, with free drainage and no development of a murram horizon at rock surfaces. The zone is a mere transition between (1) above and (3) below.

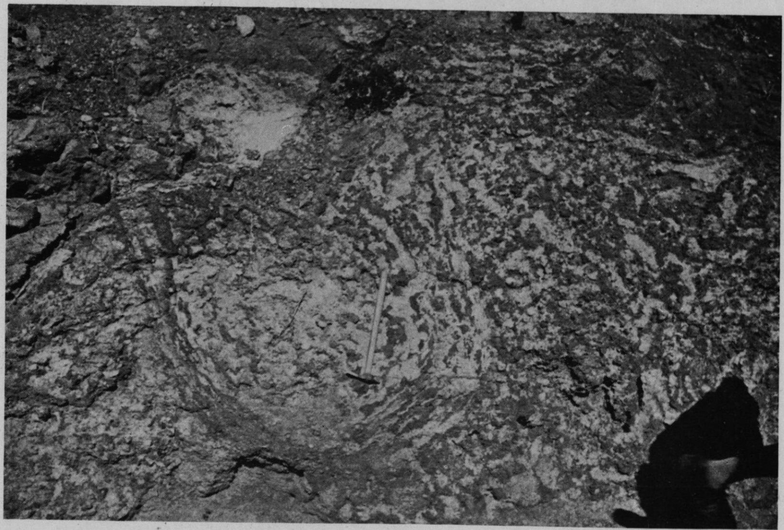
(3) Long gradual slope towards the *mbuga*: Surface soil is a dark slightly brownish grey to 12 cm., thence goes to at least 2 m. depth with a gradual colour change through dull greyish pale orange-brown to a creamy fawn; the texture is very sandy, with almost no coherence when freshly dug and falling to loose sand on drying. There is slight gley mottling at 45–70 cm. but no signs of murram formation to the depth reached, 200 cm. The top soil varies locally from nearly neutral (pH 6·7) to moderately acid (pH 5·4); for subsoil conditions there are no measurements yet but they seem to be slightly acid. The sandy nature of this soil is shown by the very low figures for moisture retention under suction of one atmosphere: 7·0–4·0% in the top soil, 5·0–4·0% at various depths to 2 m. in the subsoil. The vegetation is woodland of a well-grown type, including *Brachystegia spiciformis*, *Pterocarpus bussei*, *Commiphora pilosa*, *Diplorhynchus mossambicensis*, *Monotes*, *Markhamia*, *Strophanthus*, *Bridelia* and a scilla-like herb with a rosette of spotted leaves which was very common.

(4) At the foot of the slope, where it flattens out to *mbuga* level: A narrow zone of 'hard-pan' soil. The morphology of this soil appears to have been modified by an overlay of sand, so that the 'hard-pan' horizon is not encountered till 60 cm. This is a hard-set sandy clay with sintery appearance and vesicular pores (old root traces); of brownish grey colour and with rusty mottling. It could not be penetrated far with the pick end of an entrenching tool in the time available, and the underlying horizons were therefore not seen. Above it lies 15 cm. of an almost white sand with slight rusty mottling, and thence to the surface lies 45 cm. of more loamy grey sand, hard-packed but with little cohesion. All horizons sampled, including the hard-pan, are devoid of calcium carbonate and are acid. The vegetation is scattered *Lannea humilis* and very short grass.

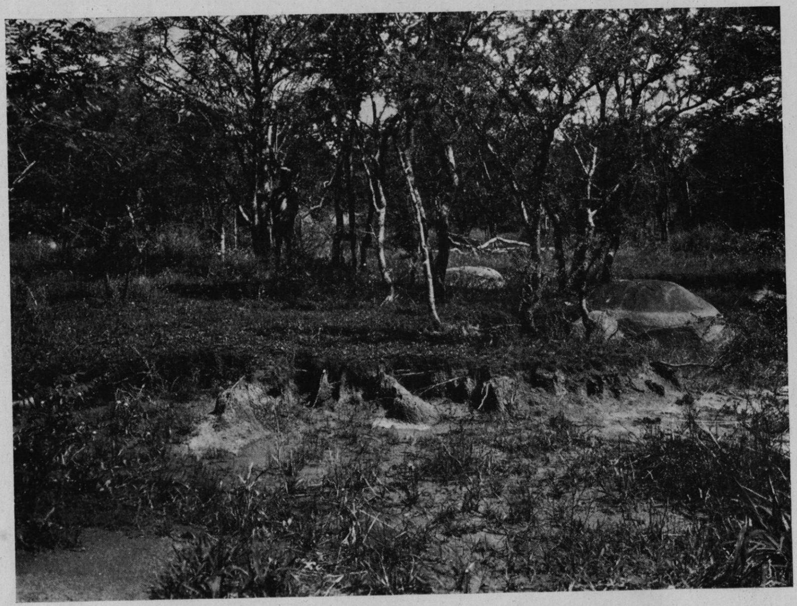
(5) The *mbuga* floor: A heavy clay, appearing black at the surface but actually of a light grey colour from about 3 cm. down, with pronounced gley mottling in yellow, greenish yellow and blue-grey. In local patches there are calcium carbonate nodules at the surface and the soil mass is calcareous, but in general the upper horizons at least are slightly acid. Below 30 cm. there are wide fissures, which were closed at the surface owing to recent rain; though heavy, this had evidently not penetrated far into the subsoil. The vegetation is mainly grasses, *Hyparrhenia dissoluta* Steud. and *Setaria holstii* Herrm. with frequent shrubby *Combretum ternifolium* and occasional *Bauhinia thonningii* Schumach. There are scattered gall acacias, *Acacia formicarum* and *A. burtii* Bak. f. and a large *A. rovumae* here and there near the *mbuga* edge.

Continuous with the woodland of zone (3) and on slightly lower ground but above *mbuga* level, a considerable area of another soil type is passed through along the motor road. This is a grey-black sandy soil with yellow-grey subsoil to 40 cm. Below this level there is much loose nodular ferruginous concretionary material passing at 1 m. depth into a compact murram horizon in variegated colours of vermilion, orange, yellow and black, and of thickness at least $\frac{1}{2}$ m.; exposures to the underlying rock were not available. This soil carries woodland of the same general habit as that of zone (3) above, but has

Phot. 5. Red-soil profile showing pisolith murram between soil and 'cement', between Saranda and Makutupora (p. 229). Phot. by B. D. Burtt.



Phot. 6. Concentric weathering in a diorite boulder, near Makutupora (p. 230). Phot. by B. D. Burtt.



Phot. 7. 'Hard-pan', exposed by erosion and weathering along drainage-line, and granite outcrops. Mwantine hills, Shinyanga, *Commiphora schimperi* and *Lannea humilis* (p. 248).

Phot. 8. Communal grazing land and cultivation steppe, Uduhe, on hard, grey, gritty clay ('hard-pan' type) with calcareous subsoil. Grass is *Microchloa indica*. Scattered *Anisotes dumosus* and baobab (p. 249).

Brachystegia boehmii, a characteristically dark-green-leaved tree, as the dominant. This is a further illustration of the variety of soil conditions that can be tolerated by *Brachystegia-Isoberlinia* woodland as a broad type, with local adaptations in its constituent species. This particular area was the most ill-drained site occupied by it that was seen on this journey, except possibly for some dark-soil areas seen in transit along the Handeni-Turiani road.

About Usoka, some 7–10 miles west of Kahama, the catena of soil types just described may be seen under cleared conditions, except that zone (1), the rocky hill top, mostly still has its wooded covering. The red-earth zone here seemed to be rather wider and showed up distinctively by colour in the general view, with its transition through the yellow-grey of zone (3) to the grey-black of the *mbuga*. Each of these soil belts no doubt has its place in the general scheme of communal land utilization, a subject that would repay closer study. In view of the extremely sandy character of the zone (3) soils, the possibilities of intensive production seem to be confined to the *mbuga* lands under conditions of improved drainage; at least until it becomes practicable to work up the fertility of the sandy soils, by lavish use of compost, on 'market-gardening' lines.

11. Shinyanga district (Shinyanga, Usanda, Ibadakuli, Uduhe, Lubaga, Samuye, Huru Huru)

The Shinyanga administrative district includes some five or six distinct types of country, each with its own set of soil conditions. The present attempt to sketch these soils and their relationships in the different natural divisions of the district no doubt omits consideration of many points of importance and is intended as a series of suggestions rather than as a formal description.

Sukuma soil nomenclature

In the Sukuma language there are names for a number of the more distinctive soils that occur in the tribal area, which includes Shinyanga district and also Maswa, Kwimba and Mwanza. With the help of the agricultural officers and their native instructors it was possible to identify most of these soil types in the field under their Sukuma names. J. G. M. King and B. D. Burtt have since supplied a glossary of soil names, which is reproduced here in annotated form before proceeding further. It will serve as a generalized account of soil conditions and the use of the native terms where necessary will save repetition in the subsequent discussion of the different areas. The list is amended from an original one compiled by B. J. Hartley when he was Agricultural Officer at Maswa; Burtt has added vegetation notes and the author has put the soil descriptions into his own terms and included some correlations with similar types seen at Ukiriguru or at Tabora. The list is rearranged so that as far as possible the soils are mentioned in the order in which they are met with in going from high ground to low.

The shallow dark grey loam commonly found high up amongst the rocks of a granite kopje or hillside does not appear to have a special name, nor does the granite itself as rock type, for the words *iruguru* or *luguru*, a large hill or rock mass, and *karaguru*, a minor kopje, appear to have the same root as occurs in the names of the Uluguru and Nguru mountains which are not granite, and Gurui (another name for Hanang) which is a volcano. *Inghanghe* is the banded ironstone of the Upper Basement Complex. *Magongho meupe* are quartzite hills with scanty soil often clothed with gall-acacia, *Acacia* *drepanolobium* Harms., and scattered *A. spirocarpa*. Dolerite is spoken of merely as *mawe* (i.e. stone).

Itongo is the reddish or brown sandy loam found as a zone around the base of the rocky hill-top. The word may merely be a variant of

Kikungo, which is the red-brown to bright red loam occurring extensively on broad ridges and slopes and well-drained plateau surfaces, as at Ibadakuli and Tinde. Both words seem to be related to the Swahili root *ekundu*=red, and may imply no more than the colour of the soil; but there is another word, *nduha* or *mduha*, used for a heavier bright red clay-loam formed on schist or on banded ironstone. Vegetation of the Shinyanga *kikungo* is *Combretum zeyheri*, *Ostryoderris stuhlmannii*, *Commiphora fischeri* and *C. pilosa*, *Terminalia sericea* Burch., *Lonchocarpus eriocalyx* Harms., *Schrebera koiloneura* Gilg. and *Markhamia obtusifolia* Sprague. It is possible that this soil can also carry, and on many sites may have originally carried, *Brachystegia* woodland. In the tsetse-free areas *kikungo* is generally so fully occupied by agriculturists that it is reduced to the condition of 'cultivation steppe'; the original bush has vanished. Baobabs are then an outstanding feature. The depth of red earth, if not reduced by sheet-erosion, may be as much as 2 m. A bed of murram underlies it and on eroded slopes this may be exposed. *Kikungo* in the Shinyanga area has been built up partly by transport, and possibly under conditions of higher rainfall but less free drainage than now obtain. Genetically it is not a straightforward red earth, but is now probably classifiable as such if of depth enough and not truncated. Besides granite, the Upper Basement Complex schists are involved as parent material in some localities. There are no exact data yet for soil acidity but preliminary tests show it to be slight to moderate, not high. There is leaching in wet seasons when under cultivation, doubtfully so under natural bush. On grazed but uncultivated fallow land the proportion of run-off is high. The discussions on the Mpwapwa red soils apply to this soil in some degree.

Mashishewe and *mashaloro* are the words given for murram, or concretionary subsoil ironstone, in King and Burtt's list. The word used at Ukiriguru was *isegenghe*.

Isanga is the fine sandy wash, usually a red type, of a fan-slope below an *itongo* or *kikungo* zone.

Lusenye is the name for a granitic wash of coarser type similarly situated or it may be a more general term including *isanga*. The equivalent at Tabora is *lusanga*. (The root of these words seems to be that of the Swahili *mchanga*=sand.) Vegetation consists of odd trees of tamarind, baobab, *Afzelia quanzensis* Welw., *Thespesia garckeana* F. Hoffm., *Acacia spirocarpa* and *A. benthami* Rochebr. (To this list of Burtt's might be added woodland of the *Combretum-Terminalia* and *Brachystegia* types under natural conditions.) The soil colour is light brownish grey at the surface, fawn to yellow-grey below; the texture is sandy, sometimes to an extreme; consistence is close-packed and without crumb-structure but loose to dig; reaction is acid, sometimes neutral at depth, but calcium carbonate is absent; it may have murram irregularly in the subsoil at about 2 m. depth; it is a soil of poor 'body' and low reserves but is favourably situated as to water-table, being neither overdrained nor waterlogged. It is almost always ridged in cultivation, the main crops being cassava, bulrush millet, sorghums, groundnuts, maize and sweet potatoes.

Ikurusi. Hartley speaks of this as a red loam, as at Ibadakuli. Notes taken during conversation with King at Lubaga say that it is synonymous with *mbambasi*, the hard-pan soils. The revised list of King and Burtt places it in the group with *kikungo* and *lusenye*, i.e. the pervious non-clayey soils, and refers to it in 'the banded ironstone areas as at Samuye', where presumably it has a red or reddish colour. Burtt's vegetation list is *Acacia spirocarpa*, very common; *Delonix elata* Gamble, *Commiphora schimperi* Engl., very common, forming thickets with *Grewia platyclada* K. Schum., *Markhamia acuminata* K. Schum. and *Anisotes* sp.; *Fagara chalybea* Engl. 'Good for crops'. This general vegetation places it on flat alluvial lands near the crossing of the Manyonga on the Tinde-Tabora road, subject to flooding, a hard grey soil locally calcareous, i.e. akin to *mbambasi* and far removed from the red types. It is clear therefore that it requires further notes and samples from various occurrences.

Mwibushi or *ibushi*. A dark-coloured but not ill-drained soil overlying, and directly derived from, beds of detrital material sufficiently rich in lime to yield travertine limestone on weathering. It is mainly found in depressions between higher-lying blocks of the plateau, but the depressions are not *mbugas* though they may include *mbuga* areas; they are dissected and drained by rivers of moderate grade and the *ibushi* occupies the interfluves. Its relation to geology and the origin of the limestone is discussed later. The colour of the top spit is 'greyish and black' (Hartley), 'grey, but brown when wet, not as black as *mbuga*' (King). The subsoil colour above the limestone horizon is a dull greyish chocolate, quite different from any shade seen in a *mbuga* soil and tempting one to use the adjective 'reddish' by comparison; free from mottling and friable though not sandy. It is suggested that this soil is, genetically, a pedocal lying somewhere intermediate between 'chernozem' and 'chestnut-coloured earth'. Morphologically it is marked by a pronounced horizon of calcium carbonate redeposition at the present limit of true soil development, which is at 60 cm. or less from the surface at Lubaga, and up to 1 m. on non-eroded sites. The content of calcium carbonate in the upper horizons varies from nil to high, but there is no acidity. The vegetation is *Acacia spirocarpa* and *A. usambarensis*. Agriculturally *ibushi* is very fertile but probably feels drought earlier than the sandy types and its physical properties require care to preserve crumb-structure and avoid wet-weather poaching and dry-weather pulverization.

Mbambasi or *ibambasi*. The 'hard-pan' soils, of variable morphology in detail, but always characterized in dry weather by a scantily covered hard grey surface with many bare patches and slight sand-wash. The top few centimetres are close-packed but medium textured and moderately friable; below, there is a well-marked horizon of hard clay (the hard-pan) mottled in dark grey, black and dark brown, difficult to penetrate and showing tiny white streaks where cut by the sampling tool. It is usually more or less calcareous below the hard-pan, but some examples overlie murram; here the murram is probably an 'accident', a mere floor on which the soil rests. In wet weather the top spit is supersaturated and the clay layer remains bone-dry below. *Ibambasi* as a general term carries with it a variable agricultural reputation according to its subtypes of which Burtt lists five. In situation, and extent also, the *ibambasi* soils vary; they may be flat or gently inclined, near *mbuga* level or on windy ridges (as in Madui), mere patches or extensive belts of country (e.g. the *Commiphora campestris* Engl.-*Acacia mellifera* belt in Uduhe). In regard to their hard-pan character they form a natural group. The processes by which the hard-pan horizon may have been formed are discussed later; they probably differ somewhat amongst the subtypes.

Mitogoro or *itogoro* is a general name for heavy soils of moderately free-working consistence, clay loams to sandy clays or clayey sands. They may lie between *lusenye* and *mbuga*, *ibambasi* and *mbuga*, *mwibushi* and *mbuga*, etc., in regard both to texture and drainage and also to topographic position. Their colour may be dark brownish grey to black. They may be either acid or calcareous; if acid there is gley mottling in the subsoil. They do not crack when dry and are not impervious when wet, so that they are not so difficult as true *mbuga* clay in cultivation. They are used, put up into wide ridges, for groundnuts. Their natural vegetation appears to be a grass growth less dense than on *mbuga* and without gall-acacias. Their silt-fraction may prove to be high. Possibly the majority of the soils of *mbuga* situations in the Tabora area would be described under the name *itogoro*.

Mwilago is river-side alluvium. Burtt and King confine the term by itself to permanently wet soils along rivers or where water comes to the surface at springs; vegetation is reeds, *Phragmites mauritianus* Kunth, or elephant grass, *Pennisetum purpureum*. In the form of *mbuga ya mwilago* it covers riverine alluvial land more generally; the soils are non-cracking brown to grey loams of fine sandy texture and soft consistence; they may be calcareous, are well drained, but are not far above river-bed water-table and so are subirrigated. Vegetation is fringing forest of *Acacia campylacantha*, *Ficus sycamorus* L. and *Piptadenia* with undergrowth of *Grewia* spp. Such land is very fertile and carries intensive cultivation of a gardening type. In one riverside garden at Mamagembe, Uduhe, sixteen different crops were noted, viz. sugar-cane, banana, maize, cassava, pigeon-pea, tomato, sweet potato, pumpkin, onion, red pepper, aniseed, turmeric, pawpaw, mango, soursop, date-palm.

Mbuga. In Usukuma this word seems to imply a definite soil type rather than merely a grassy and seasonally wet lowland without human habitation, as is often general usage elsewhere. It is a heavy black fissuring clay, usually calcareous at depth, often so to the surface. It may be strewn with hard lime-carbonate concretions or have a horizon of these below the limit of dry-season cracking. The colour is usually blue-black but may be whitish grey when there is a very high content of calcium carbonate (as in the Wembere), or black only at the surface and gley mottled below when the subsoil is acid (as in the Huru Huru). The *mbuga* receives a great deal of excess water from surrounding higher lands during rain, and parts with it with difficulty, largely by evaporation. *Mbuga ya Malala*, i.e. real seasonal swamp as in the central Wembere, flooded for months in the rains and clothed with sedges (Cyperaceae) long into the dry season, is good for red millet when drying up. In ordinary circumstances the only crop seen on *mbuga* is sorghum. When dams are made, good rice is grown. Cultivation is difficult once the soil is wet and the usual practice therefore is dry sowing.

Most of the above soil names can be used to qualify each other, e.g. *itogoro-ibambasi*, *itogoro-mbuga*. By this means a pretty complete and exact soil vocabulary can be built up, such as appears to have no parallel in any other East African language (Uganda and Kenya produce nothing similar or approaching it).* One or two further terms are mentioned in Burtt and King's list, not strictly soil names but of related interest: *itaba*, a seasonal shallow rice pond on impervious soil; *kiguru*, the earth of termite mounds (or the mound itself). The root is again the same as in the word for hills—*guru*; *misengelerwa*, river sand as found in the bed of seasonal rivers.

* Northern Rhodesian tribes probably have soil names. They certainly have names for grasses that indicate particular soil types.

Distribution of main topographic types

In the above discussion of the Sukuma soil nomenclature, most of the various soil types seen in the Shinyanga area have been mentioned in general terms. In proceeding to discuss their occurrences in the different parts of the district it will be convenient to consider in turn the following types of country:

Granite hills, their footslopes and adjacent plateau surfaces. (Usanda, Mwantine hills, Old Shinyanga area generally, Kisumbi, Tinde.)

Plateau surfaces with minor granite outcrops only. (Ibadakuli, Madui, Uduhe.)

Valleys and plateau depressions floored by calcareous detrital deposits and lake marls, probably overlying Upper Basement Complex schists. (Lower Ningwa river, Lubaga, Mhumbo river valley.)

Banded ironstone hills (Samuye hills).

The Manyonga-Wembere steppe.

The Huru Huru flats.

Factors affecting the distribution of Brachystegia *woodland*

Of the granite hill-plateau country, detail was seen mainly at scattered points around Old Shinyanga and from there to the Mwantine foothills. This area is divided into large surveyed blocks that are under experimental control by the Tsetse Research Department. The impression of the vegetation received by a visitor new to the conditions is at first somewhat confused by the treatments, e.g. fire exclusion, clearing and subsequent annual firing, selective tree-felling, etc. There is the further complication that on much of the area, which was formerly inhabited and later abandoned to fly, the vegetation is secondary and may not have again reached equilibrium. It appears, however, that as regards hills and hill-foot sites, *Brachystegia-Isoberlinia* is not the natural vegetation except in a few restricted localities and it does not occur at all on the main plateau surface. Instead of *Brachystegia-Isoberlinia* woodland there is either a woodland of similar habit but lacking *Isoberlinia* and *Brachystegia*, the dominants being such trees as *Pterocarpus*, *Ostryderris*, *Afzelia*, *Albizzia amara* and *A. harveyi* Fourn., or a more open savannah with taller grasses, *Hyparrhenia* instead of *Panicum* or *Pogonarthria*, and more widely spaced trees, *Terminalia sericea*, *Combretum zeyheri*, *Ostryoderris*, *Commiphora pilosa* and *C. fischeri*, *Randia taylorii* S. Moore, *Schrebera koiloneura*, *Dalbergia stuhlmanii* Taub. Similarly, on the scree-slopes of isolated rock masses such as Igaramhuri, Chibe and Shinyanga kopje, situations in which 'hill woodland' characterized by *Brachystegia microphylla* might be looked for, there is instead a semi-forest dominated by the stately beech-like *Commiphora eminii* Engl. with *Ficus* spp., *Combretum* spp., and aroid herbs (no succulents), or else a miscellaneous mixed scrub including young baobabs, obviously secondary.

The question arises, can this 'minority distribution' of *Brachystegia* woodland and its replacement by other woodland and savannah associations be explained by soil conditions? So far as an answer can be given at present, it is mainly negative. The material available includes profiles from two sites in the Mwantine foothills carefully selected and sampled by Burtt with this particular problem in mind, and brought by him to Amani in November 1935. Both these soils belong to the *itongo* type, being reddish brown sandy loams less than 1 m. deep and overlying, at that depth, a concretionary murram bed apparently resting on granite. Except that the *Terminalia-Combretum* soil of this pair is rather deeper in development than the *Brachystegia* soil (or has suffered less truncation by slow surface erosion), the two profiles are identical. It is true that further analytical work in the laboratory might reveal differences, but the soils are the same in morphology, parent material, colour, structure, texture and acidity. Any quantitative chemical differences would have to be checked by data from other pairs of sites in the field before they could be accepted as correlated with the differences in vegetation. Similarly, pairs of composite samples taken on a low ridge in the eastern Mwantine hills on soils of the shallow primary loam type under closed woodland, respectively with and without *Brachystegia* trees, are substantially identical in character; the acidity data for duplicate field samplings prove to be: *Brachystegia* 6·45, 6·45; non-*Brachystegia* 6·65, 6·75. Having regard to errors of sampling and measurement, the difference is not significant. From these two sites rock specimens were also taken from granite outcrops; they have not yet been petrographically examined in thin section, but are very much alike to the eye. Finally, samples of shallow organic loam, taken from the scree-slope crevices of Igaramhuri, under *Commiphora eminii*, do not differ in any immediately discernible way from corresponding samples under *Brachystegia microphylla* taken at Kahama, Tabora or Manyoni. This problem cannot thus be helped forward on present data from the soil side. One must suppose either that soil differences exist but are of a kind not to be picked out without thorough investigation, or that 'successional' or 'distributional' causes are involved that are not edaphic.

On the plateau sites between the granite kopjes a factor of parent material enters (how generally is not known) which probably influences soil characters, and therefore vegetation, considerably. The area of dark-coloured soils (*ibushi* and *ibambasi*) between Old and New Shinyanga is stated by Teale to be probably underlain by schists of the Upper Basement Complex system. In several roadside pits in that area a foliated rock was seen which is probably this schist in highly decomposed and carbonated form, but which may only be a calcareous 'cement' or other sedimentary rock. Its relation to the *ibushi* soil at Lubaga is discussed later. The same rock was found however at 2 m. depth below an apparently *granitic* red loam in one pit on the plateau about 1 mile west of Old Shinyanga. It therefore seems that the Old Shinyanga plateau, on which the only obvious outcrops are granite, carries also this other rock, at any rate locally. Possibly blocks of it have been let down by faulting and so have escaped complete denudation or, if it is really the Upper Basement Complex schist, they are the remains of the lowest beds of the formation, into which the granite (which is a younger rock) was intruded. As seen in this pit also, it was rich in carbonates. Under the existing climatic conditions any soil influenced by a masked outcrop of this rock is thus likely to be calcareous, or at least less acid at depth than the purely granitic soils. It was previously suggested that *Brachystegia-Isoberlinia* woodland seems to avoid calcareous soils, and in so far as the carbonated rock may be the contributory parent material of the plateau soils around Old Shinyanga, or even if truly granitic red loams overlie it at depths not beyond root penetration, we may have here a clue to the absence or restricted occurrence of *Brachystegia* as an element in the vegetation.

As a possible example of this effect from another area, may be quoted a red-earth (*nduha*) profile collected from near the Simiyu river in the Shanwa district. This similarly overlies a more or less carbonated schist (here undoubtedly a metamorphic rock), though its parent material is, at least in part, transported granitic detritus. From just below the surface to about 1 m. depth the reaction is moderately acid, but becomes alkaline below that owing to the presence of calcium carbonate. The vegetation is a savannah of star-grass, *Cynodon plectostachyum* Pilger, with scattered *Acacia usambarensis* and *Commiphora schimperi*. From such a site, *Brachystegia-Isoberlinia* woodland may well be excluded by the subsoil alkalinity. There are, however, as has been noted above, at least some sites in the Old Shinyanga area where no such explanation is tenable; and it should be kept in mind that *Brachystegia* or *Isoberlinia* is by no means necessarily tied to soils having granite as a parent rock, but may equally occur on any other geological formation provided that the soil conditions fall within its limits of tolerance. The suggestion is that where a carbonate-rich rock, such as that here called the schist (possibly wrongly so in the Old Shinyanga area) occurs near enough to the surface to influence soil reaction, it brings with it an excluding condition for *Brachystegia-Isoberlinia* woodland.

Plateau soils

A feature of the *itongo* or *kikungo* soils of the plateau is their murram or concretionary ironstone horizon. This is in the main to be regarded as belonging to a past stage in the drainage conditions of the area, though it is being modified at the present day and may even still be added to during times of temporary subsoil saturation. It probably dates from a period of mature topography before denudation was renewed by the warping that accompanied the creation of the Lake Victoria and Manyonga-Wembere-Eyasi basins. It was no doubt formed by processes essentially the same as those already suggested for the murram horizons of the Kazi-Kazi area. Since then new drainage lines have been cut into it, the periods of subsoil saturation are rarer and shorter, and the murram and the soil above it are more fully oxidized and their sesquioxides less hydrated. On most sites the depth of soil has been lessened by erosion and, on some, it has been brought down to the point where the murram is exposed at the surface or nearly so. Where the remaining depth of soil is sufficient, say a metre or more, the *itongo* forms good agricultural land which will respond to fair treatment though it will not stand exploitation. Murram is not an invariable feature of the profile; thus, pits near the building at Old Shinyanga Boma show the red-brown gritty loam passing directly into bouldery granite, and there is the example already noted of a deep red loam overlying highly carbonated schist or calcareous 'cement'. The red soils influenced by this rock should be regarded as definitely more favourable agriculturally than those of purely granitic origin.

The whole of the *kikungo* area to the north and east of the Mhumbo river near New Shinyanga, represented by the Department of Agriculture Farm and the school grounds at Ibadakuli and extending as far along the Mwanza road as Kolandoto Hospital, seems to come into this last category. In so far as granite has contributed to the formation of the Ibadakuli red loam, it has been transported and mixed with other material, probably of more basic character. One is reminded of descriptions of the 'contact soils' of Southern Rhodesia which are there highly valued for bright-tobacco growing. At Ibadakuli the red loam continues to give good yields of sorghums and groundnuts and fair yields of cotton even after undergoing considerable sheet-erosion. It responds markedly to kraal-manure, as is demonstrated on the school gardens. It is not regarded as a product of the soil-forming forces of the present day, but rather as a relic, unstable unless conserved *against* the natural tendencies. Although much loss of this valuable soil has already been incurred under closely settled 'cultivation-steppe' conditions, with neglect and overgrazing of fallow lands, there is every prospect of future losses being minimized. Under pressure from the Agricultural Officer and as much supervision as he can afford, erosion control by contour hedges, windbreaks and drained contour-ridging is now insisted upon by the native authority as a condition of land tenancy.

Hard-pan soils

The *ibambasi* or hard-pan soils are encountered frequently in positions corresponding to those of the same soils at Kazi-Kazi, i.e. as a belt of varying width on very gentle lower slopes dropping towards drainage lines and bottom-lands, or alternatively in local patches around low rounded outcrops of granite when these occur towards the foot of the main slopes (Phot. 7). They were seen in wet condition when the state of super-saturation of the top soil was very marked in contrast to the dry hard clay below. None was seen in deep section. A sample of the hard-pan taken in Block 10 A, Old Shinyanga, has been examined analytically in a preliminary way.

It has an alkaline reaction and a measurable, though small, content of soluble salts (sulphates 0·009% expressed as the sodium salt, chlorides 0·011%, alkali carbonates 0·051%). The exchangeable bases total a little over 7 mg.equiv.%, with calcium, magnesium and alkalis represented in the proportions of about 5:1:2. The clay fraction is in a deflocculated condition which in the laboratory manifests itself by extremely slow filtering on the Buchner funnel after shaking with water and difficulty in getting a clear filtrate.

The hard-pan horizon may be explainable as a horizon of illuvial concentration of clay, held in a deflocculated state by a rather high proportion of magnesium and sodium amongst the exchangeable cations. The occurrence of black and dark brown amongst the mottlings suggests the deposition of manganese oxides, but so far the analyses have not supported this; the dark colours may only be due to local redistribution and precipitation of humus sols. Scattered over the hard-pan areas are termite mounds of irregular conical shape usually surmounted by clumps of bush of species not occurring on the flat. These mounds usually react for carbonates when tested with the acid bottle; the rain-water shed from them must contain bicarbonates in solution and this is probably an important factor in the genetics of the hard-pan soils around them.

Ibambasi soils are extensive also on the plateau areas that are without prominent granite hills or kopjes and that show the underlying granite only as low, slightly projecting masses or as bouldery patches. Thus in Madui, through which the Mwanza road goes after passing Kolandoto (some 10 miles north-east from New Shinyanga), red earths are hardly seen; the wind-swept plateau top, and the long slopes by which it drops towards the Mhumbo river and other feeders of the Manyonga, are mainly covered by 'hard-pan' or kindred soils. The vegetation is scattered shrubs of *Anisotes* sp. and *Royena fischeri* Guerke & Mildbr., with short grasses of tufted habit (*Sporobolus* sp., *Alloteropis cimicina* Stapf and a *Panicum* sp.) and with an *Indigofera* as a frequent herb. Seen in wet condition, the profile was a soft and saturated sandy loam to 15–20 cm., with a dry, hard gritty clay below, mottled in black and grey with occasional white streaks and much reddish stained grit. Roadside pits nearby showed a horizon of angular quartz pebbles below the hard pan and, below that, granitic debris containing calcium carbonate interstitially. Termite mounds are calcareous except at their immediate outer surface. There is sufficient agricultural occupation of these soils to have brought the appearance of the plateau to that of cultivation-steppe, and the woody vegetation as now seen is a vestige only of what must have been carried originally. There is some ploughing with oxen, and rice-ponds are made on slopes by building low dams that intercept run-off water and hold it, by reason of the imperviousness of the hard-pan horizon, until it evaporates. There are also deeper ponds of circular shape, whose margins are used for rice planting. These circular ponds recall those of the *Acacia mellifera-A. kirkii* country described in the section on Ugogo and there seems no doubt that in essentials we have here in Madui, and also farther east of Uduhe, a similar soil type and somewhat similar hydrographic conditions.

Uduhe lies east of the Tungu river, one of the main feeders of the Manyonga, from the north, and is reached along the main east road from Shinyanga, namely that which crosses the Wembere steppe for Sekenke, Mkalama and Singida. This road leaves the Mwanza road at Kolandoto, and for 10 miles passes through country continuous with that described for Madui but considerably eroded, the prevailing 'hard-pan' soils having been stripped in many places, leaving uncultivable rubbly ground. For another 10 miles there are frequent granite outcrops and the soils are shallow, often skeletal, being sometimes a blackish gravelly loam 20–30 cm. deep, more usually a chocolate to dull red-brown gritty loam of a rudimentary red-earth character. Dolerite dykes are crossed at intervals. Debris fans from these, and the weathered rock itself when not actually exposed at the surface, contain carbonates in quantity. For a mile or so before the crossing of the Tungu river and for some 5 or 6 miles beyond it, outcrops of rock are rare and the soils are mainly of dark colours and belong to one or other of the groups *ibushi*, *itogoro-ibushi*, *itogoro-mbuga*, *ibambasi*. This 25 miles of country was seen from the car only, except at roadside halts and in the immediate neighbourhood of the rest-camp at Kishapu, and the material available is thus insufficient for a full discussion of the relationships of the soils. It seems clear that the general soil-forming processes are pedocalic; that is, they tend towards the accumulation of basic weathering products. Only in the more broken country of the rocky outcrops, between mile 10 and about mile 19, does wet-season drainage get away below sufficiently to allow leached soils (shallow red earths) to develop. On more gentle topography the most calcareous of the parent materials (to which, besides the granite, the dolerite dykes have been contributors, and perhaps also schists of the Upper Basement Complex) give rise to *ibushi*, passing into an *itogoro-ibushi*, which is heavier and greyer-coloured, towards the foot of the valley slopes and on flat lands of indeterminate drainage. Except for the 'skeletal soil' country, there is settlement to 'cultivation steppe' density throughout, and the trees are mainly baobab. Originally there must have been much *Acacia spirocarpa*, somewhat as seen farther east on the margin of the Wembere steppe, for its regenerating growth is a usual feature of temporarily abandoned *ibushi* land. Dense patches of *Acacia fischeri* Harms. occupy some of the hard-pan land.

Kishapu district—vegetation of soils derived from lake marls

To the east of Kishapu there is a broad belt of bushed country, some 8 miles across, going west to east and extending nearly to the Mango river. This gives the key to what must have been the natural conditions of vegetation and soil over large parts of Uduhe (e.g. to the south of Kishapu) that are now bare of woody growth, or indeed of any growth but the scantiest grass and scattered shrubs (Phot. 8). The type of bush is best described as a semi-thicket in clumps with open glades between. It is comparable with Phot. 4, taken on the Mpwapwa-Dodoma road in Ugogo. The vegetation is the same as regards the dominant acacias, *A. mellifera* and *A. kirkii* (the latter particularly around small heavy-soil depressions, some of which contain permanent ponds), with scattered *A. spirocarpa*. In parts the acacias are accompanied by the large-spreading blue-barked *Commiphora campestris* and also by *C. subsessilifolia* Engl. and *C. schimperi*. Shrubs include *Anisotes* sp., *Salvadora persica*, *Maerua johannis* Volk. & Gilg. and *M. trichophylla* Gilg. in occasional thickets, *Euphorbia matabelensis* Pax. and *Cissus quadrangularis* L. as a climber. Grasses are low and of tufted habit with much bare earth showing between. They are usually *Microchloa indica* and *Eragrostis patens* Oliv. except on wet clays amongst *Acacia kirkii*, where they are replaced by a low growth of *Panicum maximum*. Occasional patches of open *mbuga* have a gall-acacia, *Acacia malacocephala* Harms. and the grass *Echinochloa haploclada* Stapf. The area forms a plain with barely perceptible slope towards the Mango river and the soil surface is so smooth and uniform (except for slight depressions that form the *Acacia kirkii* sumps) that a car can be driven anywhere through the open glades. In general there are no rock outcrops but granite is exposed near shallow watercourses. The immediate parent material of the soils is a grey friable loamy sand with variable amounts of granitic grit and containing (below the uppermost 10–30 cm.) calcium carbonate in mostly non-concretionary, i.e. marly or chalky, form especially at depths approaching 2 m. where it is best described as a gritty and clayey soft limestone. The whole area is presumably a former lake floor, upon which the deposits were less rich in carbonates and consisted largely of fresh granitic detritus. The soil is of the *ibambasi* group, with a shallow, gritty clay hard-pan beginning abruptly about 5 cm. from the surface and passing gradually below into the friable gritty marl. The clay depressions are of *mbuga* or *itogoro* character, with a tendency to crack, with no definite hard-pan and an irregular distribution of gley mottling and carbonate nodules at depths below 50 cm. Following rain a few days earlier, the clay depressions were wet but the plain itself had dried up completely, the rain having penetrated only the uppermost few centimetres.

Grazing and agriculture on ibambasi *soils*

Phot. 8 shows the aspect of originally the same type of country to the south and south-east of Kishapu, where all woody vegetation has been cleared, much of the ground has at one time or another been cultivated and the whole is now common grazing. Bare as it is, and to some extent eroded, for the watercourses have numerous feeder-channels that are cutting into the surface, it is not thought that this land has been damaged by its inhabitants and its cattle to the extent that one might expect from some accounts of these 'over-grazed' common lands in the Shinyanga district. Judged by comparison with the belt of untouched bush land described above, the soil over most of the cleared area is seen to be intact. The scanty growth of *Microchloa* is much as it must have been before clearing, as the numerous bare patches are equally a feature of the original. The stock-carrying capacity of such land, as unimproved grazing, is obviously very low even before clearing, and with the elimination of all woody growth, browse has been done away with without any compensating advantage to the herbage. Almost any grazing, therefore, is *over*grazing; but the hard level surface of this *ibambasi* soil has resisted to a remarkable degree such trampling as it gets, and also wash and wind erosion. Cattle that feed here must obviously scatter widely in order to get a living at all and are not likely of themselves to cause further damage to the land, for the soil type naturally has a bare or but thinly grassed surface yet it resists erosion if undisturbed. The real risk is intensified *agriculture*, stimulated by the 'plant more crops' campaign in advance of the necessary improvements of method. These Uduhe hard-pan soils may be regarded as potentially valuable types and, though overgrazed, if not overcultivated by crude methods they should in due time come into their own as productive land when the necessary advances have been made in agricultural and stock-owning practice. In the meantime they should be left strictly in abeyance, and any encouragement of their population to higher crop production should be carefully proportioned to the results that can be achieved in the field of agricultural education following investigations into the problems of management of *ibambasi* soils. The foregoing refers to this particular grey soil type and must not be taken as a *general* observation on overgrazed lands.

Pedo-genetic significance of hard-pan soils

A considerable area of similar hard-pan soils under the same *Acacia mellifera-Commiphora campestris* bush exists to the south-east of Kisumbi and another belt is passed through by the railway route between Seke and Malampaka. Madui and the eroded area to the east of it are mainly hard-pan areas with *Anisotes* as a relic of a similar vegetation. If we add the *Acacia fischeri* areas, the hard-pan soils that carry gall-acacias at the Shinyanga aerodrome and the many occurrences of *Lannea humilis-Dalbergia melanoxylon* hard-pan on the Old Shinyanga plateau, we are compelled to admit this whole group of soils as one of the most important in total areal extent in the Shinyanga district, and in fact in Usukuma generally. They have come under notice also at Kahama, at Kazi-Kazi, in Ugogo and in Uzigua. If we now examine again the occurrence in Madui, the reason for this widespread distribution can probably be found. In Madui, the topography and the frequent appearance of bouldery patches of granite make it difficult to suppose that the parent material of the *ibambasi* soils is there a transported deposit as it apparently is in Uduhe and many of the other occurrences. The parent material of the Madui soils can be little else than the granite itself as broken down under the present-day conditions of 'pedocalic' weathering and soil formation. Further, the Madui soil is not a mere zone at a particular contour of the topography, but occupies level ridge-top and sloping valley-side alike. We are thus led to recognize in the Madui *ibambasi* the characteristic response of a parent material, that consists of the whole produce of the decomposition of granite, to the action of a semiarid climate and a vegetation of open xerophytic bush taking place on a topography that excludes the extremes of steep hillside or sump-like bottom-land with their specialized conditions. There is here no legacy from the past in the form of a sheet of murram; there is no mantle of washed sand such as constitutes the *lusenye* soils elsewhere; the other chemical extreme, of high calcium content as on *ibushi* soil sites, is also avoided. *In so far as it is ever possible to demonstrate a 'zonal climatic type' in the classical Russian sense, here we appear to have it for this region.*

It will be noted that the example is governed (as an orthodox Glinka climatic type should not be) by a factor of parent material, of equal rank with those of climate and topography. By reference to examples of *ibambasi* elsewhere, we find that the factor of parent material is not really defined by 'granite', but by 'avoidance of textural and chemical extremes'. This is a condition that granite (or gneiss) happens to fulfil when its decomposition products have not been segregated by previous processes of leaching, erosion and transport, and which may be fulfilled also by other possible parent materials including certain kinds of transported deposits. Lake-floor deposits that are sufficiently sandy and not too calcareous evidently fall within the right range, as in Uduhe and Ugogo.

The position of the hard-pan soil as a link situated low down in, but not at the bottom of, a catena, as at Kazi-Kazi and Kahama, receives explanation as a result of differential lateral transport downhill of sand, silt and clay, and of the travel of dissolved matter in subsurface seepages, whereby the necessary mechanical and chemical ingredients 'for the avoidance of extremes' are brought together just at that contour and not above it or below it. On any such parent material then, under the semiarid-semihumid climate of much of central Tanganyika, a soil of the hard-pan group will develop if the course of soil formation is not interfered with, and if the topographic lie of the site does not cause drainage to go to either extreme. Such at least is the hypothesis to which one is tentatively led by consideration of these hard-pan soils of Usukuma.

On the mechanism that brings about the characteristic profile, including the hard-pan itself, one cannot say much until detailed chemical data are available. It involves some downward travel of clay particles from the surface during rain and their coagulation by intense drying, and also a redistribution of the exchangeable bases in the upper horizons whereby the clay is brought into a deflocculated state and has a high coefficient of swelling on wetting. The humus fraction of the uppermost few centimetres, low in absolute amount though it is, must also be brought into the picture. There is no point in pursuing speculation further than this on present data.

Agriculturally, the hard-pan soils should not be infertile once the initial difficulty of deep cultivation has been overcome, a difficulty which to the native with hoe alone is probably a complete deterrent on mature soils of this type. (The *ibambasi* of Uduhe is immature, and hence is much cultivated; its hard-pan horizon is only a few centimetres thick. Contrast some of the *Lannea humilis* hard-pans which are more formidable.) Unless, however, the factors that are responsible for the formation of hard-pan are permanently modified or continually corrected, the soil in cultivation will always tend to revert, developing again in time a compacted and impervious subsurface horizon. At present, as stated, we do not understand the mechanisms involved, but if field experimental work were undertaken (as it certainly should be) towards the reclamation of *ibambasi* where it is an extensive and potentially important type, one would like to see the following treatments included: trench draining to encourage leaching, gypsum dressings, high ridging for all crops and heavy composting; with, of course, deep subsoiling to begin with and the necessary anti-erosion lay-out of the site. The *ibambasi* soils are not alkali soils in the ordinary sense, but their successful handling will probably have something in common with the methods that have been worked out for reclaiming alkali soils. A reasonable procedure would seem to be a period of experimental work followed by a period of observation on supervised (and, if necessary at first, subsidized) 'ideal native holdings'.

As has been remarked already in regard to heavy *mbuga* clays the bringing of these neglected, because somewhat intractable, hard-pan soils into the agricultural picture may perhaps be a policy of the future rather than of the immediate present. The progressive exhaustion and bodily loss of the more attractive lighter soils will, however, lead us to it inevitably, and not very distantly. The problems involved, because they may take a long time to bring to effective solution, are best regarded *not* as problems of the future, but of the actual present.

Limestone soils (ibushi)

Ibushi soils (dark grey-brown to black friable loams over concretionary limestone) are not a principal feature of the granite plateau areas, but are found in greatest extent in the broader river valleys. That they do occur however on the plateau was seen at a group of pits near Igaramhuri where red *itongo* overlying murram gives place abruptly to *ibushi* overlying nodular limestone, at a few paces distance and without change of level. A similar occurrence of the red and black types in unexpectedly close juxtaposition and without any apparent relation to the surface topography is to be seen in the Kisumbi area along the Tabora road, where borrow-pits give exposures for study. The two soil types may even confront each other from opposite faces of the same pit. The correlation of red or reddish soil with leached granitic detritus and of black to chocolate-brown soil with lime-rich materials is quite clear; the points of interest are the origin of the 'lime-rich materials' and the true nature of the dark-coloured soil upon them. In the *ibushi* profiles the soil proper is bounded sharply at from 50 to 100 cm. depth by an irregular but more or less continuous sheet of dirty reddish cream-coloured secondary calcium carbonate having a cauliflower-like form. This is to be regarded as a pedological horizon (the *B*-horizon of the profile) rather than as parent material. The parent material lies below; it is a somewhat variable and miscellaneous-seeming rubble consisting of a matrix of marly earth containing more or less quartz grit and packed with small irregular granulated nodules of softish cream-coloured calcium carbonate, but also containing larger, rounded (almost spherical) masses which are chalky externally but have hard, dense, dark grey, flint-like cores. At first these dark-centred lumps were taken for weathered and carbonated dolerite pebbles, to be seen amongst the dolerite scree on Kisumbi hill nearby; but they are the travertine nodules described by F. Oates (1933, p. 68) from F. B. Wade's samples, and according to his analyses they are fairly pure calcium carbonate with only 10% of silicates and iron oxide. Oates ascribes the dark colour to manganese and this has been verified on samples taken on this occasion.

In the Bulletin quoted, the source of the calcium carbonate in these various secondary concentrates is regarded as simply the lacustrine marl in which they are embedded or on which they form a capping. For our purposes, however, an explanation going no further than this is hardly sufficient, for we have seen that in Uduhe a presumably lacustrine deposit has given rise not to *ibushi* but to *ibambasi*. It is evidently necessary to distinguish lithologically between the one marl and the other. Thus in the neighbourhood of Lubaga there are extensive areas of *ibushi* and *ibambasi* (the soils of the Department of Agriculture farm and of the aerodrome, respectively), which are contiguous and at almost the same level. To speak of both as part of a common 'lake floor' area leaves much to be explained. Also the lake-marl explanation does not seem to apply very well to the patchy occurrences of *ibushi* in the Kisumbi and Igaramhuri areas. It is suggested as an alternative or accessory explanation, that the richly calcareous deposits upon which *ibushi* develops are, in this area at least, debris fans of basic rock material such as the Kisumbi dolerite or the greenstone schists that are known in the neighbourhood, mixed with more or less granitic detritus; or they may even be the schist itself, in carbonated form, in place. In any event the ultimate source of the lime must be referred back to an original country rock, whether or not the carbonates have undergone in the meantime a phase of deposition from lake waters; and we can expect to find the necessary amounts of lime only in the neighbourhood of rock masses (now existing in place or reduced to debris and secondary chemical deposits) richer in lime silicates than is the granite itself. The *ibushi* is thus tied, directly or indirectly, to basic rocks. On these terms it takes its place with the *ibambasi* as a zonal climatic type in the Russian sense, the factor of parent material having moved over in this instance to one of the chemical extremes. It is probably a near relative of the south-European chernozem, nearer certainly than are the calcareous *mbuga* soils that are sometimes mistakenly spoken of as of that group. The dull chocolate-brown colour of the *ibushi* subsurface horizon recalls the 'chestnut-colour' by which the soil of the next drier and warmer climatic zone is named in the Russian system.

The only necessary remark on the agricultural utilization of *ibushi* wherever it occurs is to counsel a most careful conservation of this soil as an excellent medium for 'high farming'. Unfortunately it *will* stand exploitation, probably for a number of years if it is not by then lost bodily by erosion; but it deserves a better fate than to be brought down to the common level of other worn-out soils. Every possible effort should be made to encourage the use of sound methods upon this soil even though it continues to give yields without them. One was impressed by the thoroughness of the methods of conservation and improvement now being applied on the *ibushi* area at Lubaga, following an earlier period of destructive exploitation. It is to be hoped that the greatly increased crop production of recent years in Usukuma, which must have been won mostly by soil-exploiting methods, has not already resulted in too serious damage to this valuable soil type in the native areas, where it will not be repaired so expertly.

Reddish skeletal soils on Samuye hills

The rounded hills of banded ironstone or itabirite-schist, that lie to the south-east of Kisumbi in the locality known as Samuye and overlook the Manyonga steppe to the south and east, have few points in common, as regards soil conditions, with the granite hills of the district; for although their fundamental experiences of climate and denudation have no doubt run parallel, the factor of parent material has imposed differences. On the hill slopes proper, such soil as there is is a very shallow, gravelly, dark reddish chocolate heavy loam, neutral in reaction but not calcareous. This is probably the analogue of the 'dark grey primary humic loam' that has been frequently referred to in corresponding situations on granite hillsides. Here, however, it seems to be the present-day successor to a much deeper red loam that was stripped from these hills by erosion and deposited in Lake Manyonga on the one side, and on the Kisumbi-Usanda plateau on the other, before the present drainages of the area were established. The surface on which the shallow skeletal soil lies seldom consists of massive rock in place; the only true outcrops seen were not the itabirite, but a finely laminated slate-like schist or shale resembling the Muva-Ankolean shales seen west of Bukoba. The parent rock of the present soil seems to be mainly a broken-up '*C*-horizon' brash, of loose fragments and boulders, which has accumulated as leavings after erosion of the rest of the original profile. No example of a deeper soil was seen anywhere on the hillsides, even under dense bush. There are some valley bottoms of small extent covered with a mostly reddish transported soil which were not seen in profile.

Red loams on Samuye hills

At the foot of the outer slopes on the north-west side, i.e. as approached from the Shinyanga-Tinde road across a south-flowing tributary of the Manyonga, there are remarkable bouldery masses of murram which consist of fragments of the banded ironstone, bound firmly in a ferruginous cement to form a conglomerate (Phot. 9). These evidently represent a zone of seepage outfall to a former level of sluggish drainage which has since been cut down by the feeder-streams of the Manyonga basin. The plateau across which the Kisumbi-Tinde road runs, and which has a general slope from the granite Usanda hills on the west to the foot of the Samuye hills to the south-east, is capped by a sheet of murram that is obviously part of the same formation, though the banded ironstone fragments cemented into it are smaller and less frequent as the distance increases from their place of origin. On the plateau, overlying the murram, there is a variable depth of bright red loam (the *nduha* of the Sukuma terminology) to which, at second hand, both banded ironstone and granite have contributed. Here there is fairly dense settlement and the tree vegetation consists mainly of baobab, tamarind, figs and other large scattered individuals. In many places, however, the soil has been thinned to the point of exposure of the murram, which can be traced irregularly along a contour like a cliff 30 cm. or so high. The murram sheet itself appears to have been much eroded, for some of the loose ferruginous gravel seen in shallow pits is clearly detrital. On patches of more or less carbonated debris of the schists and the granite, occupying breaches (or original discontinuities) in the murram sheet, there are the soils of the present regime, *ibushi* and *ibambasi*. The streams running to the Manyonga or its feeders have cut below the murram and run in shallow V-sectioned valleys, whose lower slopes have hard-pan soils but which are not yet mature enough to have *mbuga* floors.

Wembere steppe—ibushi *and* ibambasi *soils*

On the outer south-eastern slope of the banded ironstone hills the descent is a direct sweep to the floor of the main Manyonga valley which is the western extremity of the Wembere steppe. A bright red fan-slope soil persists down the slope very nearly to flood-level, where, within a few yards, it passes into the grey calcareous clay of the steppe. Vageler's (1912*b*, pp. 373–82) account of the soils and vegetation of the Wembere steppe, with its coloured schematic map, enables the conditions to be grasped very well in general terms, though it leaves much to be desired from the point of view of exact description and classification, and as usual his analyses (of top soils only) do little to supplement the text. Not very much can be added to his material, as the Wembere steppe was reached at only two places on its north-western margin. The first of these, as above noted, was at the foot of the red fan-slope of the Samuye hills. Proceeding out on to the plain from the edge of the red earth, there is at first a belt of fairly dense gall-acacia, *Acacia drepanolobium*, with some *A. mellifera*, other thorny shrubs and scattered tall Albizzias of two species, *Albizzia harveyi* and *A. amara*. Farther out this becomes more open, a gall-acacia grassland; and again farther out the *Acacia* disappears except in local clumps and there is a waist-high stand of grasses and sedges. The soil is a heavy clay throughout, dark grey in its own colour but whitish by reason of numerous flecks and small nodules of carbonate. In dry condition the soil of the hill-foot belt probably has more difficult physical properties than that farther out on the plain, for it contains a good deal of quartz grit and sets like cement, whereas the soil of the open grassland has a higher carbonate content (30% as against 11% in the *Acacia* belt) and less sand, so that it dries into smaller structural units. Another distinguishing feature is the presence of hard black carbonate concretions, as well as white chalky ones, in the grassland soil.

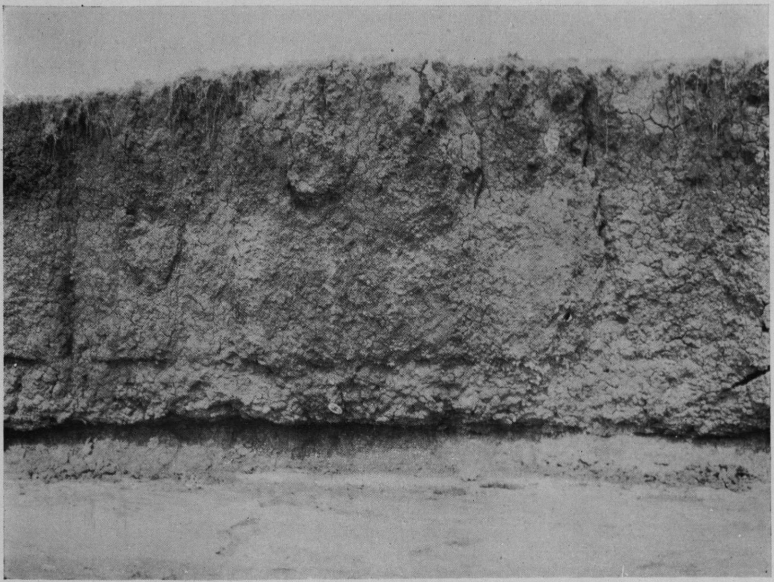
Pending further analyses and some knowledge of the nature of the subsoil horizons, description of these soils cannot be carried further. They are undoubtedly rich in mineral nutrients though not in organic matter and nitrogen. The problem of manipulating their moisture supply to suit crops such as rice or cotton remains where it was left by the German engineers who, in Vageler's day, proposed to water this clay steppe from Lake Victoria. If engineering works were ever to be undertaken here for irrigation purposes, some less heroic measure would seem to be called for, considering the amount of water that runs to waste in annual spates from the upper Manyonga catchment.

Further downstream, where it has broadened out as the western limb of the Wembere depression, the Manyonga valley has a flanking terrace both on the north and south sides, scalloped by tributary valleys into a series of low projecting promontories, across which the old lake floor can be reconstructed in imagination. The inner and lower broad shallow valley is of varying width, constricted between the promontories and expanded across the bays; it is gently inclined towards the Manyonga-Wembere confluence and Lake Eyasi, and is the present-day inundation plain of the main river and of the lower reaches of its feeders. The Shinyanga-Sekenke road, going east from Uduhe towards Kitalala after crossing the Mango river, gradually descends on the northern side from the upper of these two levels to the lower, and in so doing crosses at one point the foot of one of the projecting promontories. The section here revealed gives the key to the parent materials of the soils of both the higher and lower levels. For most of the short ascent by path from the road to the top of the promontory, a fawn-coloured laminated clay is exposed, which itself is mainly non-calcareous but is seamed and penetrated by white limy deposits. Near the top, closely underlying the grassland soil of the upper plain, is a stratum containing packed masses of bivalve shells. The upper part of this has weathered into limestone nodules; over this in turn is a highly calcareous whitish-grey clay and, finally, there is the somewhat turfy top soil. The profile may be classified as that of a young and immature *ibushi*.

If this geological section can be taken as general for the old lake floor in the northern part of the Wembere, we may expect *ibushi* soils on parts of the upper plain where the shell bed or some equivalent lime-rich deposit is effectively the parent material, and *ibambasi* soils where it has been stripped by the denudation of the present cycle, leaving less calcareous beds exposed. From what was seen along the road, this generalization on the distribution of the higher-lying soils between the two groups seems substantially correct. The *ibushi* soils vary from the mature type with its nearly black, deep surface soil and dark chocolate subsoil, to immature varieties that are light grey, very calcareous and shallow. The prevailing original vegetation seems to be *Acacia spirocarpa* savannah. Considerable areas are under cultivation and produce cotton. Amongst the abundant flowering herbs of temporarily abandoned land there are some whose distribution could probably be followed up with profit for their value as indicators.

On the promontory site above-mentioned there are several large abandoned cattle-kraals evidently of considerable age, whose floor consists of a deep deposit of dung, weathered to a friable earth and partly incorporated with the upper layers of the marl. A composite sample taken to 15 cm. depth contains 0·95% of nitrogen and 2·0% of phosphorous pentoxide together with about 7·0% of calcium carbonate. Deeper down the material is probably richer than this. It is suggested that it is worth excavating for nearby agricultural use. As each of the sites is an acre or more in extent, the total bulk of the deposits is by no means negligible and it seems a pity that they, and possibly many similar deposits elsewhere in the district, should lie unused and slowly lose value by exposure.

Phot. 9. Murram boulder, showing included fragments of banded ironstone. Samuye, Shinyanga (p. 255).



Phot. 10. Black clay with nodular calcium carbonate horizon over non-calcareous gritty clay. Valley-floor, northern Urima, at mile 22. South of Mwanza on the Tabora road (p. 260)

Soils of lower Wembere plains and Mbala steppe

On the lower plain and in the shallow valleys of the feeder streams of the Manyonga lie the accumulated erosion-products of the beds that formed the old lake floor. Their content of lime carbonate will vary according to the amount of mixing of the different materials, and there will also be detritus, that has travelled farther, from the surrounding hill country of the granites and schists. With such a mixed parentage and under the influence of varying degrees of sluggish drainage, annual flooding and redistribution of surface material by flood waters, a considerable range of clays and sandy clays is to be expected (*itogoro* and *mbuga* and their intermediates), some of which are indicated in Vageler's classification and in King and Burtt's subdivisions of the *mbuga* group.

To the north-west of the Wembere steppe and separated from it by the divide on which the Manyonga river and its northern tributaries rise is another large but more irregular area of low land which was formerly a southern lobe of Lake Victoria, connecting with the main lake through Smith Sound. Much of this area is little above present lake-level, and the drainage of the whole is sluggish and without well-defined watercourses. The central part running south from the end of Smith Sound for nearly a degree of latitude to the neighbourhood of Isaka, was described by Vageler (1912*b*, pp. 361–72) under the name of the Mbala steppe. He draws a distinction, highly significant in relation to the parent materials of the soils, between the Wembere which at an early stage became a closed drainage basin, and the Mbala which has always had an outlet to the north and ultimately to the sea. In the Wembere, basic solution products from the weathering of the surrounding rocks accumulated and were deposited. From the Mbala they were carried away in overflow waters. The difference at the present day is that between a region of mainly calcareous surface deposits having a salt lake in its lowest part, and a region of mainly leached deposits draining towards a fresh-water lake. The climatic regime of both being nowadays semiarid, the distinction does not of course apply to soil parent materials of more recent origin, nor to present-day soil formation processes as such. Soils to some degree calcareous are to be expected in the Mbala as well as in the Wembere basin. In a general way, however, the difference in physiographic history must be reflected in a regional difference in the soils. To the southern part of this Mbala steppe belong the grey-white hard-packed clayey sands that are crossed to the east of Kahama on the Tinde-Kahama road. In an irregular eastern bay (not included in the area covered by Vageler's report) is the great *mbuga* known as the Huru Huru.

Vegetation and soils of the Huru Huru mbuga

The vegetation (chiefly the grasses) and hydrological conditions of the Huru Huru are described by R. R. Staples (1931, pp. 51–3). It is mainly an open grassland with patches of widely spaced gall-acacia and a general sprinkling of small thorny bushes such as *Dichrostachys glomerata* Chiov. and *Harrisonia abyssinica* Oliv., groves of *Acacia seyal* marking sump situations and of another *Acacia* of tall spreading habit marking dry-lying 'islands'. In the dry season it is waterless; in wet weather there is surface water but not actual flooding except locally towards the end of the rains in April. Its soils are dark grey to black clays on the flats, and hard-pan soils on the gentle slopes that culminate in the *Acacia*-clad 'islands'. During a 1-day excursion there, with no opportunity to dig pits, only surface soil characteristics could be examined and nowhere was a positive reaction for carbonates obtained at the surface or by shallow digging. Having regard to the fact that the water that reaches these soils, whether by rainfall or by run-off from the surrounding higher ground, is disposed of either by direct surface flow or by evaporation, and not to any great extent by under-drainage, one would expect on deeper digging to find a horizon of slight carbonate accumulation, or at least of maximum base saturation, at $\frac{1}{2}$ m. or perhaps more, from the surface. For this reason one would classify at least the heavier of the clays as pedocals rather than as gley soils. This interesting point, from the grazier's point of view a most important one, can, however, only be settled by examining pits. As already mentioned, we must expect to have a mainly leached parent material, in so far as it is an original deposit of the old lake floor. The same applies to whatever material has been washed down since from the areas of *itongo* and *lusenye* that lie on the plateau slopes around. In so far as the *mbuga* floor is made up of fresh rock debris of the present denudation cycle, or receives seepages from such with their dissolved bases, we may expect, on the contrary, soils of well-developed pedocal morphology. Again, in degree as the soils let water through them they will tend to part with bases and become acid; beyond a certain point of imperviousness this process will cease and subsoils will be alkaline. The composition of the herbage will tend to follow these characters, and as the destiny of the Huru Huru seems to be to serve as a wet season relief grazing ground for over-stocked Usukuma, they are well worth following up in some detail, for it will obviously be of advantage (other things such as accessibility and water supply being equal) to develop chiefly those areas of the grassland that are of the highest feeding value. A reconnaissance soil survey, sufficient to settle the main issues in the classification of these soils and to indicate broadly the distribution of the different groups, should form a preliminary undertaking of great value in planning the best use of the Huru Huru *mbuga*.

PART IV. MWANZA DISTRICT

12. Seke to Mwanza

The road route from Shinyanga to Mwanza must represent one of the longest traverses through contiguous settled lands that is anywhere possible in Tanganyika. Except for a belt of gall-acacia *mbuga* 4 miles wide at Seke, no uncleared ground is crossed the whole way and little woody vegetation of any kind remains. The soils, seen only in passing from the lorry, appear to belong to groups already discussed in the Shinyanga section, mainly *ibambasi*, *itogoro*, *ibushi* and their intermediates until north of the Magogo river, when, in country broken by granite hills at intervals, brown or reddish *itongo* soils and their associated murram beds, and belts of grey sandy *lusenye* below them, begin to be encountered also in their due positions on the middle and lower hill slopes. Finally, within 15 miles of Mwanza, most of the ground consists of the hill slopes with their (often skeletal) red loams, and the heavier dark-coloured types are confined to the lower reaches of the valleys opening out towards Stuhlmann sound and Mwanza gulf. In all this country the only soil inspected in any detail was at Ukiriguru Experiment Station, 17 miles south of Mwanza.

Ukiriguru soil catena

At Ukiriguru (and the pattern is repeated throughout its neighbourhood) the soil complex is a good example of the catena or topographic sequence of types, the zones running in succession from the flanks of the rocky hills to the lowest parts of the intervening valleys. The sequence is as follows (see Fig. 4):

(1) Hill-tops and rocky parts of slopes: Scanty skeletal grey loam in crevices of rocks. Vegetation probably originally *Isoberlinia-Brachystegia* woodland, for a specimen of *Isoberlinia globiflora* was seen, but there is nothing now but a light growth of secondary bush.

(2) Zone at foot of rocks, 100–300 m. wide across the line of greatest slope, but may be locally more extensive, as on slopes of larger hills or saddles between them: Coarsely gritty brown to red-brown loam (*itongo*) of variable depth, based directly on the granite in the upper part of the zone but having a hard clinker-like murram horizon at 1·5 m. depth lower down the slope. The whole profile is slightly acid. Only remnants of the woody vegetation remain, including tamarind, *Afzelia quanzensis*, *Dalbergia melanoxylon*, *Kigelia*, *Terminalia* and *Commiphora* spp.

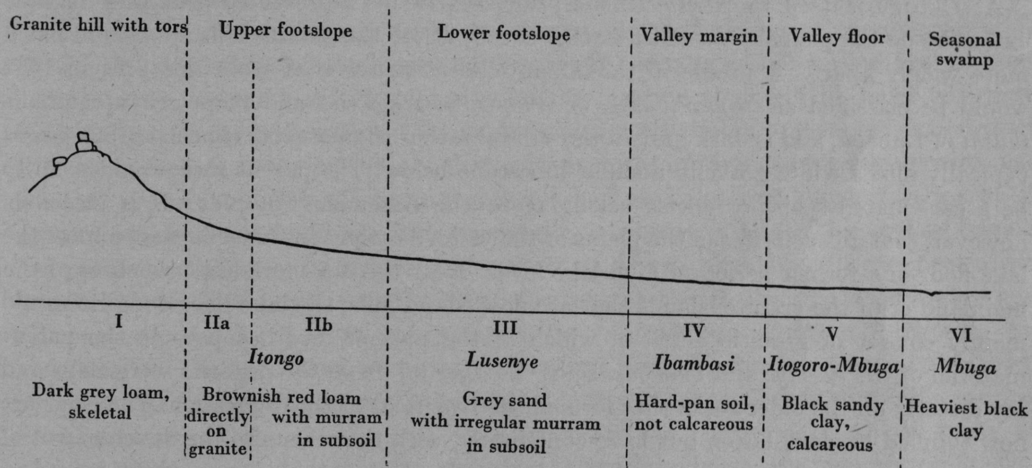


Fig. 4. Soil catena of Ukiriguru

(3) Next zone below, where the slope is perhaps 1 in 50: Very sandy pale grey *lusenye*, acid in reaction, of variable depth, sometimes based on the underlying bouldery granite, sometimes with a coarse grey-black-yellow sandy murram as an intervening horizon. The one feature or the other seems to depend on whether the underlying rock is sufficiently rotted to be porous, or is impervious. The grey colour is due to the high wet-season water-table. Natural vegetation was not seen; the chief crop in cultivation was cassava.

(4) Next zone below, approaching the floor of the valley: Dark brownish grey gritty clay with 'hard-pan' profile, termed *itogoro-ibambasi*. Seen after heavy rain, this soil was saturated in the top 40 cm., but quite dry below; water seeped out copiously at the depth named when a pit was dug into the dry subsoil. At 1 m. depth the subsoil is a dry gritty grey-yellow clay, not calcareous; the whole profile is acid, much more so in the top 60 cm. than below that depth. Original vegetation was not seen, but was probably *Acacia rovumae*, *Lannea humilis*, etc.; cultivated to grain crops.

(5) On the valley floor, but not quite the lowest part: Heavy inky black sandy clay, wet to the full depth of a 1·5 m. pit at the time of sampling and showing no hard-pan horizon. This clay does not seem to crack much in dry condition; seen wet, there were no visible structure lines. Calcium carbonate occurs at all depths in the form of particles which are so numerous from 120 cm. downwards that they give a whitish cast to the colour of the subsoil. There is no definite nodular horizon, but the white particles include

some of a large concretionary form below 120 cm. This soil is given the name *itogoro-mbuga*, and on the Ukiriguru farm was being planted with groundnuts. Ordinarily such land is grazed only, or planted to sorghums.

Phot. 10 shows the profile of a soil closely related to this, but of somewhat heavier type intermediate between (5) and (6), exposed in a valley-bottom by the cutting down of a river-bed.

(6) In swampy reaches of the valleys there are local areas of the heaviest black cracking clay, known as *mbuga ya bugado*, carrying stands of *Acacia seyal*.

(7) Towards the lake shore, the valleys open out into extensive flat lands that carry rice. These will be the lowermost members of the complete catena, but they were not seen and nothing is known of the soil type.

At Ukiriguru itself the *ibushi* soils do not seem to be represented, but they become extensive on the plains a few miles farther south, where the granite hills are spaced much more widely apart. A profile in the Amani collection received from this area in 1932 would be classified as *itogoro-ibushi*, i.e. it is rather heavier and more gritty than the *ibushi* of Lubaga, and is dark grey in the subsoil rather than greyish chocolate, but passes typically into a white gravelly nodular limestone below. The parent rock would seem to be a carbonated schist or gneiss belonging to the Basement Complex. It is probable, however, that all such sites in the plains or the valley bottoms in this area were part of the lake floor in a former period of high lake level. Near the old shore lines, whether of the mainland or of the granite islands that are now island hills, the lake-floor deposits would mainly consist of granitic detritus, which at the present day has become the parent material of the *lusenye* and *ibambasi* soils. Farther off-shore the deposits were clays and lay directly on the older rocks that formed the true floor of the depression. The clays are now thinned by denudation but have contributed with the schists to the development of the *itogoro* and *itogoro-ibushi* soils. The *mbuga* soils proper are perhaps to be regarded as of mainly contemporary formation, their parent materials being deposits of fine material eroded from the whole of the surrounding topography, whether former land or former lake floor, and now experiencing the effects of the seasonal cycle of flooding and drought. The denudation and deposition effects of the two periods, former high—and present low—lake-level, are thus both to be regarded as having shared in the exposure and redistribution of soil parent materials and in the determination of the drainage conditions that now enter largely into the control of soil development. It is an interesting question whether we should look upon the murram beds of the *itongo* zones representing, at their lower edge, the swampy shore line of the old high-level lake; but in the absence of any information on the correspondence of levels on different hillsides such a conjecture cannot be pursued, and there are no contoured maps to help. Alternatively, the murram beds are explainable as being formed along zones of seepage outfall, and they may be governed in position by the conformation and structure of each hill independently.

Practical treatment and soil trends

One cannot offer any more detailed account of these Ukiriguru soils until analytical data are available on the samples taken, but the general tendency in soil development is clear and there is a practical conclusion to be drawn. As in other parts of the central plateau region, progressive erosion, both natural and 'accelerated', is gradually diminishing the extent of red earths and kindred well-drained soil types and is driving them in, as contracting zones, upon the high points of the topography. At their expense the grey sandy soils of the lower slopes and the dark-coloured heavy soils of the bottom-lands are becoming more extensive, increasing not only in the absolute area they occupy but much more so in their relative importance as the principal agricultural soils upon which the population must depend. Upon the utilization of these lower-lying soils, and especially of the heavy types, agricultural effort and ingenuity must more and more be expended as time goes on. Of course, in the meantime, no pains should be spared in preserving the remnant zones of red earths and maintaining their fertility. But it must be recognized that their elimination by slow or accelerated erosion is a natural tendency, inherent in the topographic and climatic conditions. The soil is travelling downhill, changing its fundamental characters as it occupies successively lower positions. Thither inevitably the cultivator must follow, changing his methods just as fundamentally in adaptation to changing soil conditions. The productive lands of the future in Usukuma will have to be the *mbugas* and their sandy and 'hard-pan' fringes. At the Ukiriguru Experiment Station the opportunity exists for working out the necessary adaptations of agricultural method, and in particular the methods of heavy-land utilization that will be more and more needed. It is in these directions that its activities can be most profitably concentrated.

In this area one hears repeatedly that a given piece of land, now lying derelict, had formerly grown food, but had been abandoned because cereals no longer gave a crop on account of infestation by the parasitic weed, *Striga asiatica* O. Ktge. This, it may be said, is a problem of plant pathology, not of soils. Yet it bears directly on the subject of the last paragraph, for sorghums are the cereal chiefly grown on the heavy *mbuga* lands whose efficient utilization will be of increasing concern to the population of Usukuma; and sorghums are excluded from many such sites by *Striga*. The problem may be stated in even more general terms, for sorghums and millets are the staple food of the Wasukuma; *Striga* denies them the use of a great deal of land in the aggregate, on all soil types, for growing these crops, and thereby accentuates in high degree the overcrowding, land shortage and consequent soil destruction for which Usukuma is becoming notorious. Progress towards sound soil management and rational land utilization, in a direction (namely towards the more intensive use of permanently occupied holdings, including *mbuga* lands) to which the natural conditions and the density of the population allow of no alternative, is thus seriously checked by a plant parasite.

Soils and vegetations at Nyamahono

At the Nyamahono Seed Farm and settlement area in Uzinza, across Mwanza gulf on the lake coast, the conditions somewhat resemble those of Kahama and the less hilly parts of Unyanyembe. The residual hills are low, the red-earth zone is almost non-existent and the granite outcrops of the high ground are surrounded directly by wide zones of extremely sandy pale grey soils carrying *Brachystegia-Isoberlinia* woodland. These grey soils correspond to the *lusenye* zone at Ukiriguru but are even lighter in texture. Figures for 'moisture retention under one atmosphere suction' and for *p*H (provisional colorimetric measurements) are given below for the samples taken in the test pit in this woodland zone:

Depth (cm.)	Moisture retention (% of dry soil)	*p*H
0– 15	5·2	6·3
15– 30	4·0	5·0
30– 45	3·3	4·5
45– 65	3·2	5·4
70– 95	2·2	6·4
110–130	2·9	6·0
140–170	2·4	6·4

There is a marked acidity maximum, representing pretty severe conditions, at 30–45 cm., and a steady textural grading towards almost pure sand, with some indication of murram formation, i.e. of an occasional standing water-table, at depths approaching 2 m. The lowest sample contains an aggregated material having strong affinities with the 'grey cement' of the Central Province and Shinyanga areas. Agriculturally the soil is most unpromising except if heavily manured.

On slightly lower ground there is a *Combretum-Terminalia-Afrormosia* savannah belt, partly on very shallow soils consisting of little but a grass sod lying directly on a jagged murram pavement and quite useless for agriculture, partly on deep loamy sands, dull brown in colour and overlying a stiff brownish yellow clay at about 1·5 m. depth. These latter soils are very acid and show an unpleasant rusty and yellow gley mottling, indicating seasonal waterlogging, almost to the surface. They could perhaps be improved by draining, heavy liming and deep cultivation, but are very unattractive soils as they stand and would be expensive to bring into better condition. The vegetation is a waist-high stand of grass with scattered trees, spaced close enough to be termed a very open woodland; tree species are chiefly *Combretum gueinzii* subsp. *splendens* and *C. grandifolium* F. Hoffm., *Terminalia* spp., and *Afrormosia angolensis*.

Irregular areas in the *Combretum-Terminalia* zone are occupied by hard-pan (*ibambasi*) soils of variable profile, some overlying the murram pavement already mentioned, some having calcareous marly material in the subsoil, but all showing the characteristic horizon of hard gritty clay with almost waterproof qualities and mottled in grey, black and dark brown. The murram, where present, is taken to be not a true horizon of the present soil profile, but a mere floor (a fossil horizon from a former soil) on which material was deposited; the hard-pan profile has developed under the climatic conditions now prevailing. The vegetation of the hard-pan areas is a very short scanty grass with low trees of *Lannea humilis*, *Commiphora schimperi*, *Dalbergia melanoxylon*, and a tall spreading *Acacia*, widely scattered. Here also the prospects of successful cultivation are poor, for the *ibambasi* occurrences are too patchy and variable to be amenable to any thorough-going pan-breaking operations or other ameliorative treatment.

A broad low ridge of savannah land lying to the north-east of the farm buildings at Nyamahono deserves special mention. Its vegetation is an open park-like grassland with tree clumps and individuals including *Acacia usambarensis*, *Balanites aegyptiaca* Del., *Commiphora* spp., two species of *Markhamia*, *Dalbergia stuhlmannii* and unusually large specimens of *Lannea humilis* as well-grown trees. The relationship of this ridge to the low granite hills and ridges of the general topography was not clear; possibly it has nothing to do with them but is a former lake sand-bank. There was no pit available for profile inspection, but augur-borings showed a deep sandy loam to 120 cm., with no clay or hard-pan horizon to that depth, no gley mottling, and fair uniformity from place to place. From the vegetation one would expect affinities with the *ibambasi* or hard-pan soils, but the illuvial horizon, if present, is unusually deep down, or is not well developed owing to the sandy nature of the parent material. It is suggested that for the purposes of the farm this piece of land is worth systematic exploration with soil pits, for it seems as attractive as any seen in that area. Like the other light land it would be a good deal subject to surface packing and wash if cultivated on the flat, and it should not be expected to give good yields for more than a year or two after clearing unless handsomely treated with composting, etc. It is a less extreme textural type than that occurring here under *Brachystegia* woodland.

East of the farm buildings at Nyamahono, and crossed by the approach road from the boat-landing at Katangura, is an extensive *mbuga*. There is open treeless grassland on the wide-fringing slopes of this *mbuga*, but it carries a dense stand of *Acacia seyal* and tall grasses at the lowest (northern) part of its floor. The treeless upper part was regarded as most promising land for cotton, for there was a history of successful cotton crops on what appeared to be similar land in native occupation near Katangura. A pit midway down the slope in the treeless area, 400 m. east of the farm sheds, showed a dark grey somewhat turfy loam at the surface, with an immediate subsoil of brownish grey loamy sand mottled in rusty yellow; below, from 50 cm., is a sticky clay loam, dark brown in general colour but liberally mottled by brick-red iron oxide stains. At 1 m. the texture becomes a tough clay, with grey ground colour and a variegated mottling in blue-grey, yellow-grey, black and rusty, with black deposits (apparently of manganese dioxide) on the natural cleavage surfaces between the clay sods. Finally, at 130 cm., all oxidized colours disappear from both ground-mass and mottling, and the clay is obviously seldom aerated, though it was quite dry at the time of sampling. There is no carbonate at any depth to 1·5 m., but preliminary (colorimetric) *p*H tests on the samples taken show the following rather interesting acidity profile:

Depth (cm.)	*p*H in water-suspension
0– 15	5·2
15– 30	5·2
30– 50	5·3
55– 70	5·7
75– 90	6·1
100–115	6·7
130–150	7·1

The top soil and the subsoil to 50 cm. are thus fairly acid, the middle subsoil is moderately to slightly acid and a neutral horizon is reached at depth.

Cotton growing compared with more diversified cropping

As regards the probable behaviour of this land under cotton, one should not depend on it to do well without ameliorative treatment including either actual liming at a heavy rate, or heavy composting with material grown on the lime-rich soils of the lower *mbuga*. Texturally it is suitable, and cotton is known to tolerate indifferent drainage conditions on heavy soils, but this is usually when the soil reaction is neutral or alkaline. Here the root-system of the crop will have to attain considerable development in a medium of unfavourable reaction before reaching the neutral horizon. The soil profile is a gley type and is not attractive in an unimproved state.

The *Acacia seyal* land has a very heavy inky black cracking clay, not calcareous by surface tests but almost certainly so at depth. In the time available pits for profile examination could not be dug. This land is most probably flooded every wet season, but as with all these *mbugas*, the question whether means cannot be devised for realizing its potential fertility, in spite of annual waterlogging and forbidding physical properties, demands serious consideration.

In the report of Mr H. C. Ducker, of the Empire Cotton Growing Corporation, who visited Nyamahono in May 1935, the experimental farm here is spoken of as redundant. From the particular point of view of regarding it primarily as a multiplication station for cotton varieties, one must agree. If a proper and broader view of the purposes of the farm is taken, however, it need not by any means be regarded as redundant. Some of the soil types, it is true, have their counterparts at Ukiriguru, but the detail, and especially the proportionate extent of each type within the whole complex, differs considerably as between the two stations. It cannot be assumed that a system of farming worked out at Ukiriguru will apply in Uzinza, though there will be points enough in common to provide a valuable check on the soundness of fundamental principles. Native settlement is proceeding apace, and spontaneously, in the Nyamahono area by overflow from the Mwanza side of the lake gulf. Readjustment of the agricultural habits of the incoming settlers will be called for to meet the new conditions. The Nyamahono farm will find its function in working out the principles of a stable agricultural economy for its district, and in this economy cotton may in due time have a place. But bearing in mind the soil conditions it would be unwise to *assume from the start* that cotton will be the principal district crop and to develop the farm mainly to further that end. A study of how best to handle the different soil types, and the building up of a sound system of fertility maintenance by combining the possibilities that the different soils offer, should be the first object of the farm's existence. When, say after 5 or 10 years, it has been established that there is enough land in the district fit to carry cotton without either soil damage or disappointment to growers, and the growers themselves have been educated to their task, it will be time to proceed with the mainly administrative task of multiplying cotton-seed supplies.

As to 'combining the possibilities that the different soils offer', a tentative suggestion may be made that the heaviest *mbuga* soils are well fitted to grow a large bulk of grassy material such as uba sugar-cane or Napier grass. This could be used both as a cattle fodder after making into silage in pits, a perfectly practicable operation under semiarid conditions (see M. H. French, 1932, 1933, 1934, 1937), and as raw material for compost making, the success of which would depend largely on the necessary water being available at the right times. With the aid of cattle and compost, there would be every prospect of bringing limited areas of the sandy *Brachystegia* woodland soils into high productive condition, provided erosion losses were minimized by tie-ridging, strip-cropping and other standard means; the term *limited* being used with the intention that these areas should be treated generously and kept in permanent occupation. It is not likely that any method of rotation with bush fallow will serve at all on these soils whose initial fertility is undoubtedly at a very low level. If the *mbuga* lands can by some such scheme be fully utilized and the produce devoted to the sandy soils and the acid heavy soils, the purpose will gradually be achieved of *bringing fertility uphill,* counter-current to the natural tendencies, thus restoring, as it were, potential energy to a run-down system. The problem must be tackled in the first place in the *mbugas,* that is, literally, at the sticky end. It will be of no use endeavouring to exploit the sandy soils first as being the easiest to work, for they will not respond, and also they will be damaged by wash if cleared and cultivated by ordinary non-intensive methods in large blocks. These sandy soils cannot, in fact, be regarded as an independent agricultural unit; they are only cultivable to a reasonably productive standard if the resources of the other members of the 'catena' are brought to their aid. The true unit is a compound one, the soil complex. This important fact should not be lost sight of by those who are working out the experiment of Ideal Native Holdings in this and similar areas. To be self-contained a holding will in general have to include more than one of the local soil types, possibly even the full range.

Need for classification of land types and potential utilization

In a region such as Usukuma where for one reason or another (water supply, topography, soil, tsetse) there are great differences in habitability between one locality and another and the more habitable parts are populated to the point of overcrowding and soil damage, there is need for the utmost foresight and economy in the use of the land. This is now realized in responsible quarters, though not yet amongst the population as a whole.

Amongst the action being taken may be quoted the Huru Huru scheme for relief grazing grounds, the teaching of arable soil conservation at Government farms, on school gardens and through the more progressive chiefs, and the development of a personal responsibility for land on Ideal Native Holdings. The region is too large, however, for these and similar efforts to be brought to bear at full pressure for a long time to come. In the meantime there is need for a classified and accessibly recorded knowledge of land types and land uses, actual and potential. At present such knowledge as there is on this subject is acquired individually and partially by the various administrative, agricultural and veterinary officers whose work lies in the district; it is necessarily inexpert on technical 'specialist' matters and, if recorded at all, it is scattered in departmental files. Yet only with the aid of all such information and a definite programme based upon it can assurance be had that effort is being economically applied. A survey is required in which distinction will be made between categories such as the following, with necessary subdivisions of each: land suited for intensive, or for subsistence agriculture; for productive grazing, rough grazing, wet-season grazing; for special management as a key area for water supply; to be closed to crops and cattle and reserved for production of fuel and forest produce. No such classification can be arrived at, even approximately, by haphazard study by individual departmental officers. The first requirement, which is now in fact in course of being met, is a good topographical map. With this available, the task is one for an organized ecological survey in the widest sense. By this is meant a synthesis of the results of geological, soil, botanical, agricultural, hydrographic, hygienic and economic surveys, whose field parties, provided with any necessary laboratory support, shall work in conjunction through the region until the essential facts have been ascertained and generalizations established upon them. It is the pedologist's particular province to claim for soil survey that it shall be called upon for its proper contribution to this programme, in time for its results to play a part in the early framing of a rational land utilization policy.

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Readers interested in the vegetation types will find them illustrated and described (for the same region) in the Burtt Memorial Supplement, 'Some East African Vegetation types', *J. Ecol.* **30**, 65 (1942).

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