GOVERNMENT OF KENYA

DEPARTMENT OF AGRICULTURE, KENYA

THE SOILS OF THE NAIROBI-THIKA-YATTA-MACHAKOS AREA

Directorate of Overseas Surveys

Sheets D.O.S. (L.U.) 3013: 148/2, 148/4, 149/1-4, 150/1 and 153 and D.O.S. (L.U.) 3014, East sheet and West sheet

Forty Shillings - 1963

Part of the region of broad ridge topography on the high ground of the eastern flank of the Rift Valley. Note the high density of habitation and the high intensity of use of the ridge tops for seasonal subsistance crops and of the steep valley sides for wattle (the heavily treed areas) and coffee (the closely terraced areas).

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BY

R. M. SCOTT

Soil Surveyor, East African Agriculture and Forestry Research Organization

EDITED FOR KENYA GOVERNMENT

BY

E. BELLIS

Senior Soil Chemist, Kenya

with an appendix

A Soil Survey of the Coffee Research Station, Ruiru

BY

G. H. GETHIN-JONES

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Soils of Nairobi-Thika-Yatta-Machakos Area

R. M. Scott

INTRODUCTION

The original project, which was initiated by Gethin Jones[1] in 1952, was to study the technique of air-photo interpretation of soils and was at first confined to the Nairobi-Thika-Donyo Sabuk-Athi River rectangle, consisting of four 1:50,000 sheets. The area was chosen because it gave a variety of soils over a wide range of climatic conditions, and being situated near Muguga work could be carried on when the section was not committed to other projects. This survey was carried on intermittently until 1954 when a start was made in compiling the soil map of Kenya and Tanganyika. Over the years, requests have been made for copies of this map: in view of this, it was decided in 1958 to complete this map and to extend the area eastwards, one large soil group having already been mapped in an adjacent area by the ecology trainees under Mr. Trapnell, when they were studying a particular soil-vegetation relationship in the Yatta area. The map now covers most of the ground included in Mr. Trapnell's land use and vegetation survey of the Nairobi area and has been of value to this project. The Directorate of Overseas Surveys kindly undertook to have these maps printed.

The procedures followed in the analysis of these soils are mentioned in Appendix B.

PYHSIOGRAPHICAL FEATURES

The area included on the eight 1:50,000 maps lies between 36° 45′ E to 37° 45′ E and 1° 00′ S to 1° 30′ S and comprises about 2,346 square miles. The area can be divided physiographically into four zones:—

(*a*) the high ground of the eastern flank of the Rift Valley;

(*b*) the Athi and Kapiti plains;

(*c*) the central hill masses of the Machakos District;

(*d*) the partially dissected peneplain country of the east.

(*a*) The High Ground of the Eastern Flank of the Rift Valley

This has a steep downward slope in an easterly direction and terminates with the Athi and Kapiti plains. The drainage is consequent, follows the slope and comprises numerous streams giving rise to parallel ridges which get broader as the streams converge. The majority of these streams are still down cutting, and as a result of this the ridges have convex to uniform slopes.

(*b*) THE ATHI AND KAPITI PLAINS

The Athi plains, which are mainly underlain by phonolite lava and tuff, are flat and end in a bluff just west of the Athi River, the bluff representing the end of a lava flow. At present this plain is being dissected by down cutting rivers which flow into the Athi.

The Kapiti plains occur east of the Athi River, where the topography is more variable, from gently undulating to flat, with a number of small hills protruding above the general land surface. The underlying rocks are volcanic lavas, tuffs and basement complex. Being in a drier region where there are no permanent streams the dissection is not so severe although gully erosion can be seen.

(*c*) THE CENTRAL HILL MASSES OF MACHAKOS DISTRICT

These hills consist of the Mua, Iveti, Kanzalu range and Donya Sabuk: all tend to rise abruptly from the plains. They are all steep sided and are being actively dissected; in places this is being accelerated by poor land management.

(*d*) THE PARTLY DISSECTED PENEPLAIN COUNTRY OF THE EAST

This area tends to be very dry, the rainfall generally being under 30 in. per annum. The topography tends to be gently undulating to rolling with a central flat portion on the Yatta Plateau. The Athi River skirts the western side of this lava flow and the drainage system from the adjacent Kanzalu range is down cutting, mainly by gully erosion.

Climate

The rainfall varies from over 55 in. to under 20 in., while altitude ranges from over 6,000 ft. to under 4,000 ft. giving marked variations in temperature. Higher rainfall is usually associated with higher altitude.

METHOD OF SURVEY

The air photos (which were taken by the R.A.F. in 1948) were studied under a stereoscope before work in the field commenced and boundary lines were drawn round the various shade tones, vegetation and relief patterns. By using planned road traverses nearly all these different patterns could be investigated and, where these were related to soil, boundaries were inked on the photos. Where no road passed through a pattern, checks where possible were made on foot. The information was transferred from the photos to the 1 : 50,000 base map on return from the field. A number of representative soil profiles were taken for correlation of the soils as well as for analysis.

The Value and Limitations of Aerial Photos

The most immediate advantage of aerial photos was the ability to pin-point one's position quickly and accurately on the photo by using both relief and vegetation features. Thus any soil boundary could be fixed accurately and then transferred to the 1 : 50,000 base map. Using the stereoscope, various relief patterns such as steep slopes, rocky outcrops, plains, etc., could be delineated on the photo without having to check them on the ground.

During the survey it was found that soil boundaries could be delineated on the photos where natural vegetation or perennial crops were present. However, in areas where annual cropping and particularly subsistent cropping were practised, it was found practically impossible to detect boundaries apart from wet lands, which were often left uncultivated. This may be due to the fact that in many cases the photos had been taken just after harvesting and therefore any soil changes, as reflected by vegetative growth would not be apparent.

Generally, for a particular area, different vegetation patterns and varying shade tones (which usually indicate a different vegetation type) seen on the photos, indicated differing depths and degrees of drainage and wetness of the soil. In some cases it also indicated soils of different texture. The presence or absence of termite or other such mounds very often helped in separating soils of similar depth or wetness: a case in point would be between the black grumosolic soils on the Athi Plains and the adjacent vlei soils. These soils could also be separated by the presence or absence of *Acacia drepanolabium* which show up small specks on the grumosolic soils.

Soil Classification and General Descriptions

The classification system is based on that of the soil map of the Kenya Atlas[2], where the soils are mainly separated at world group level. However, as this survey was carried out as an exercise in the interpretation of aerial photos, the separation of soils had to be largely based on what could actually be seen on the photos. As a result, some areas have had to be mapped as composite units since, although genetically different soils occurred adjacent to one another they could not be separated on the photos. In most instances, so doing is considered justified for the very reason that such soils have so many features in common and so few differences that they support very similar biological communities. Hence the agricultural value and management requirements of each of such soils may be expected to be very similar to those of the other members of the composite unit.

Thus the soil maps do give a good general picture of the area and are a guide as to where more detailed soil studies are required.

The first separation has been made on drainage. The well-drained soils have then been subdivided into climatic regions as follows:—

1. Humid regions ... ... 40 in. and over
2. Sub-humid regions ... ... 30 in.-40 in.
3. Semi-arid regions ... ... 20 in.-30 in.

Other categories have also been introduced for lithosol and regosols and steep slopes have been delineated.

WELL-DRAINED SOILS

Humid Regions

1. Strong Brown to Yellow-red Friable Clays (Ando-like Soils)

A dark reddish-brown (5YR 3/4) high humic (5-10 per cent carbon) "A" horizon overlies a strong-brown (7.5YR 5/6) to yellow-red (5YR 5/8) weak crumbly friable clay derived from volcanic ash. Below this there may be a series of buried ash soils similar to the above, each with its humic horizon. At depth there is a red (2.5YR 4/6) subangular blocky, friable clay, being the buried soil of the former land surface.

2. Reddish-yellow Sandy Clay Loams (Latosolic Soils)

A dark grey (10YR 4/1) to dark greyish-brown (10YR 4/2) high humic (3-5 per cent carbon) "A" horizon, overlies a reddish-yellow (5YR 7/6-6/8) subangular blocky, sandy clay loam. Below this, usually separated by a stone line, pink and white weathered shistoze rock occurs.

3. Dark Red Friable Clays (Latosolic Soils)

Dark reddish-brown (5YR 3/3) high humic (3-7 per cent carbon) "A" horizon overlies a dark red (2.5 YR 3/6) subangular blocky friable clay with clay skins derived from both volcanic and basement complex rocks.

Sub-humid Regions

4. Red Friable Clays (Latosolic Soils)

Dark reddish-brown (2.5YR 3/4) humic (1.5-3 per cent carbon) "A" horizon overlies a red (2.5YR 4/6) weak subangular blocky friable clay, derived from both volcanic and basement complex rocks; stone lines usually associated with the latter.

Semi-arid Regions

5. Dark Red Sandy Clay Loams (Latosolic)

Dark reddish-brown (5YR 3/4) low humic (.5-1.5 per cent carbon) "A" horizon overlies a dark red (2.5YR 3/6) weak subangular blocky sandy clay loam. Derived from basement complex rocks.

6. Reddish-brown Sandy Clay Loams

A dark brown (10YR 4/3) low humic (.5-1.5 per cent carbon) "A" horizon overlies a reddish-brown (5YR 4/4) weak subangular blocky sandy clay loam. Although underlain by tuff, this soil is mainly derived from mantle material.

7. Yellow-red Coarse Sandy Loams

A brown (7.5YR 5/4) low humic (.5-1.5 per cent carbon) "A" horizon overlies a yellow-red (5YR 4/8) loose, structureless coarse sandy loam.

SOILS WITH SLIGHT SEASONAL IMPEDED DRAINAGE

8. Red Friable Clays with Laterite Horizon

Dark reddish-brown (5YR 3/3) to reddish-brown (5YR 4/4) low humic (.5-1.5 per cent carbon) "A" horizon overlies a red (2.5YR 4/8) weak subangular blocky friable clay—at depth massive laterite usually present. Phonolite boulders are frequently exposed on the surface.

9. Yellow-red Sandy Clay Loams with Laterite Horizon

Dark reddish-brown (5YR 3/4) to reddish-brown (5YR 4/4) low humic (.5-1.5 per cent carbon) "A" horizon overlies a yellow-red (5YR 4/8) weak subangular blocky sandy clay loam; a massive laterite horizon containing quartz gravel occurs at depth.

10. Brown Sandy Clay Loams with Laterite Horizon

Dark grey (10YR 4/1) low humic (.5-1.5 per cent carbon) "A" horizon overlies a brown (10YR 5/4) weak subangular blocky sandy clay loam; a massive laterite horizon containing quartz gravel occurs at depth.

11. Shallow Yellow-brown to Yellow-red Friable Clays Overlying a Laterite Horizon or Rock

Brown (10YR 5/3) low humic (.5-1.5 per cent carbon) "A" horizon overlies a yellow-brown (10YR 5/4) subangular blocky friable clay with iron concertions passing into a massive laterite horizon

or

Brown (10YR 5/3) low humic (.5-1.5 per cent carbon) "A" horizon overlies a yellow-red (5YR 4/8) subangular blocky friable clay passing into rock.

SOILS WITH IMPEDED DRAINAGE

12. Dark Greyish-brown Calcareous Clays (Rendzinic Soils)

A very dark grey (10YR 3/1) to dark greyish-brown (10YR 4/2) angular blocky clay overlies secondary limestone (caliche).

13. Dark Grey to Dark Greyish-brown Calcareous Clays with Light Textured Topsoil

Dark greyish-brown (2.5Y 4/2) low humic (1-2 per cent carbon) slightly compact crumbly loam overlies a dark grey (10YR 4/1) to dark greyish-brown (2.5Y 4/2) angular blocky clay. A quartz stone line may separate the above horizons. At depth secondary limestone (caliche) occurs.

14. Black to Dark Grey Clays (Grumosolic Soils)

These consist of a range of "Black Cotton" soils and include the calcareous and non-calcareous variants.

POORLY-DRAINED SOILS

15. Dark Greyish-brown, Mottled Clays (Gley Soils, Vlei Soils)

Very dark grey (10YR 3/1) to greyish-brown (10YR 5/2) humic (2-3 per cent carbon) "A" horizon, overlies a greyish-brown (10YR 5/2) angular blocky, mottled clay.

16. Dark Grey Compacted Loamy Sands (Solodized-solonetz Soils)

Dark grey (10YR 4/1) sands with deflocculated clay and a cemented loamy sand "B" horizon. At depth a black (10YR 2/1) angular blocky clay is usually present.

17. Peaty Swamps

Peaty soils subjected to seasonal or permanent water table.

LITHOSOLS AND REGOSOLS

18. Alluvium

Old river sediments as well as those now being added to the flood plain without developed morphology other than a more humic surface horizon.

19. Shallow Stony Soils with Rock Outcrops

Variously developed soils which have been subjected to geological and recently accelerated erosion and have lost their original characteristics.

The numbering of the soils follows the legend of the 1:50,000 *soil maps to this report.*

SOIL OCCURRENCES AND THEIR GENESIS

As each physiographic zone tends to have distinct soil associations, the soils will be discussed in relation to the physiographic zones, the first zone being the high ground of the eastern flank of the Rift Valley.

SOILS OF THE HIGH GROUND OF THE EASTERN FLANK OF THE RIFT VALLEY

This physiographic zone can be subdivided into three regions on a topographic basis as follows:—

A. Dissected, narrow ridge topography.

B. Broad ridge topography.

C. Gently undulating topography on very broad ridges.

A. Soils of the Region of Dissected Narrow Ridge Topography

The topography consists of narrow ridges with deep valleys having very steep uniform slopes down to the streams. The rainfall is over 50 in. per annum and during the cool season, from June to August, the area is shrouded in mist for most of the day, while the nights are cold and frost may damage crops on low ground.

Because the streams are still down cutting, the valley sides are uniform, giving uniform drainage conditions. As a result, the soils of this region fall into one main group, this being the *Strong brown to yellow-red friable clays (ando-like soils)—Soil No.* 1. These are polygenitic soils derived from a number of intermittent volcanic ash showers falling on well-developed red soils of an old land surface. Between each ash shower there must have been sufficient time for a soil to develop as buried humic horizons are a common feature. Another interesting feature is that these polygenetic soils are found on the slopes as well as the summits, indicating that the land surface was already highly dissected before the ash showers fell. The main bulk of this soil group occurs outside the mapping area; here as many as four such buried humic horizons have been seen in one profile. Within the mapped area itself, the buried soils are not so numerous and this suggests that either the area is further away from the source of ash or part of the ash-derived soil has been removed by erosion.

These ash showers must have fallen in comparatively recent times since, in general, they have remained intact on the summits and slopes, and only on the stream banks do the ash soils tend not to be present. These soils show high rainfall acceptance and therefore under natural conditions, erosion is unlikely to have been severe. Due to their low fertility they have not been persistently cultivated and this again has lessened the chances of erosion.

Due to the unconsolidated nature, the small particle size and the climatic conditions, the ash must weather rapidly. Profile descriptions and chemical analyses of this soil group can be seen in Appendix A (1*a*). A profile of a sample taken outside the area has also been included at Appendix A (1*b*).

These very acid soils are highly leached, have a base saturation of less than 10 per cent and the total exchangeable bases are less than 1 me./100 gm. in the subsoil. It will be noticed that the presence of a buried horizon is marked by a rise in organic matter.

There appears to be a tendency for the buried humic horizons to show increases and decreases of the following compared to the adjacent soil horizons.

1. Both carbon and nitrogen tend to increase but the C/N ratio also goes up, showing less mineralization.
2. Exchangeable hydrogen and base exchange capacity increase, while total exchangeable bases and percentage saturation decrease. This would be consistent with less mineralization of the organic matter of this horizon. Presumably the reduced mineralization is due to the depressed biotic activity owing to the fact that the soil is buried.

At depth the red soil of the old land surface shows a much higher clay content, a good structure and has well-developed clay skins.

These soils show a marked affinity to the hydrol-humic latosols of Hawaii[3]; there is the tendency for them to exhibit the irreversible drying effect which is a property of those soils. The clay mineral of the ash-derived soils is considered to be allophane although no analyses have been carried out to confirm this. However, the facts that these soils have a low bulk density, very high water-holding capacity and a high content of little mineralized organic matter suggest that allophane clay is present.

The soil boundaries of this soil group were found to be more or less coincided with a topographic change. Consequently the boundaries were first fixed along the road traverses and were then mapped between the roads on the basis of stereoscopic examination of the photographs.

B. SOILS OF THE REGION OF BROAD-RIDGED TOPOGRAPHY

In this region, the streams and rivers are not so markedly down cutting. The topography consists of broad flat-topped to rounded ridges separated by steep convex to uniform-sided valleys. In the upper limits of this region the valleys are narrow but lower down they broaden out. The rainfall of this region is between 40 in. and 50 in., falling in two seasons—March to May and again in November.

Three main soil groups have been recognized in this region—they are *Soil No.* 3, *dark red friable clays commonly known as "Kikuyu red Loam"*, *Soil No.* 15, *dark greyish-brown mottled clays* (*Vlei soils*) and *Soil No.* 17, *swamp peats.*

Soil No. 3, *Dark Red Friable Clays.*—This mapping unit consists of two distinct soils but it was not possible to separate them on the aerial photos. This was possibly because this group is practically wholly devoted to subsistence agriculture and as the aerial photos were taken after harvesting, any vegetative differences which might have been present have been obscured. The two soils appear very similar though differences are apparent on closer inspection. One (as described in Appendix A (3*a*) for a site outside the survey area) is characterised by a deep topsoil which may extend up to 2 ft., passing into a dark reddish-brown subsoil, becoming dark red with depth. The other (as described in Appendix A (3*b*) for a nearby site) has a much shallower topsoil of up to one foot in depth passing into a dark red subsoil. At first these differences were considered to be due to the natural erosion processes since the darker soils occurred on level ground and in well-drained depressions while the redder soils were confined to more sloping topography. However, Lyle T. Alexander[4], while on a visit to E.A.A.F.R.O. did suggest that these differences were due to volcanic ash contamination and that the ash contamination would only persist on the more level sites. This would appear to be the answer as pockets of ash have been found in depressions and therefore one can assume that the area could have been covered by a recent volcanic ash fall. Both these soils are very fertile but the ash-influenced ones show a higher fertility. They are usually very deep, over 20 ft. not being uncommon, and as a result have a good water storage capacity. They are derived mainly from volcanic rocks although similar soil derived from the *basement complex*, is found in the Kangundo area of Machakos. Although manganese concretions are occasionally formed, a massive laterite is not present in these soils.

Dark red friable clay landscape, Kiambu, with deep soil on steep valley sides. Aberdare Mountains in background.

The dark red friable clays on steep slopes have been separated on the map from those on the flatter topography as a guide for land use practices.

Soil No. 15. *Dark greyish-brown mottled clays* (*Vlei soils*).—These occur in small depressions within the ridges; the origin of these depressions may be due to minor fissuring where at the junction of two such fissures a sink hole is formed. This sink hole later could be filled by ash and colluvium and from this parent material the vlei soil could develop under conditions of impeded drainage. During the rainy season water seeps into the vlei from the surrounding soil and the vlei soils remain water-logged for two to three months of the year; sometimes having as much as a foot of water lying on the top of the soil. An interesting feature of these soils is their acidity, since one might expect them to become alkaline due to base accumulation from the seepage water. Their acidity and mottling are common features which separate the vlei soils from the black grumosolic clays. At Appendix A (15) a description is given of a dark-grey mottled clay from the nearby region of gently undulating very broad ridges. Around the edges of the vleis a laterite horizon usually forms.

These soils are easily recognized on the aerial photo by a uniform light colour tone given by the grass vegetation and by their not being cultivated.

Soil No. 17. Peaty swamps.—These soils were not studied during the survey and are a very minor soil group in this region. Where they do occur, they are of the Ithangi grass (*Cyperus emmensis*) type, and the soil is usually only covered by water during flood times. These swamp soils are very narrow and are mainly confined to the banks of streams. They can be identified on the photos by their dark tones.

C. Soils of the Region of Gently Undulating Very Broad Ridges

This region occurs under a rainfall regime of about 30 in.-40 in. per annum. In this region the ridges become broader due to the various streams joining to form rivers and the valleys though deeply incised have also widened due to lateral cutting by the rivers. In the upper part of the region, the ridge tops have a gently undulating topography with *Soil No. 4, red friable clays* being the dominant soil. Towards the plains the topography becomes flatter and poorer drainage conditions pertain resulting in *Soil No. 11, shallow yellow-brown to yellow-red friable clays overlying a laterite horizon or rock*. Here, susidiary drainage has developed along the low-lying land between the undulations, these drainage channels being marked by belts of poorly-drained soil. *No. 15, dark grey mottled clays, vlei soils.*

The undulations of the ridge tops have concave slopes and therefore, as one might expect, a catenary relationship between the soils is found: the *red friable clays* occupy the summits, upper and middle slopes of the undulation, *the shallow soils over laterite* occur on the lower slopes and finally the *vlei soils* occur in the depressions. An intermediate soil occurs between the *red* and the *shallow* soils. This is *Soil No. 8, a red friable clay with iron concretions, merging into massive laterite*. However, it only occurs as narrow bands and it was not possible to separate these on the photos. Other soils that occur in this region are *Soil No. 19, shallow stony soils with rock outcrops* on the main valley sides and *Soil No. 17, peaty swamps* in the valley bottoms.

Soil No. 4. Red friable clays.—These differ from the *dark red friable clays* of the region of Broad-ridge Topography in that they are less humic, have a lower total exchangeable base content and are less saturated. They have a much weaker structure and clay skins are not so marked. The brighter colour and weaker structure of these soils may be partly due to the lower humus status. These soils on the whole are less deep than the dark red clays and this may possibly be attributed to the lower rainfall where the weathering of the underlying rock is slower and to the fact that on the slopes a laterite cap has formed over parts of the rock surface which would protect the rock from weathering. The formation of laterite in this region is attributed to the concave slopes which give changing drainage conditions. The soil boundary between the *dark red* and *red friable clays* had to be fixed on the roads first by ground survey and these were then joined by interpolation. Within the area itself, they showed up as a darker tone compared to the other soils, while the stereoscope also showed up the high ground where they occurred. Where coffee existed, it had usually been planted up to the soil boundary, thus making mapping easy. A typical red friable clay of this region is described in Appendix A (4*a*).

Soil No. 11. *Shallow yellow-brown to yellow-red friable clays overlying a laterite horizon or rock.*—These soils mainly occur on the lower slopes or the flat lands adjoining the black clay plains. This is a composite soil group due to the difficulty of separating the soils on the aerial photos. Though it was not possible to separate the components, it is suggested that as the components support the same vegetative cover they have similar agricultural properties even though they are genetically different. The shallow soils over rock tend to be redder than their lateritic counterparts and to occur mainly at edges of *Soil No.* 14, *the black grumosolic clays.* It is thought that these are youthful soils which have developed after the removal of the black clay by erosive processes. The shallow soils over laterite have a very different genesis. These are considered to have been formed as a result of seepage water from higher ground being checked by the change of slope and poorer drainage conditions at the foot of the slope and of the deposition of iron and aluminium compounds from the seepage waters to form a laterite sheet there. As the land surface is gradually lowered by erosive processes and as drainage impedence is further extended by the laterite sheet development, so do these shallow laterite soils extend, westwards in this case. Much of this laterite formation may well have taken place under wetter conditions than now prevail. A typical *yellow-brown friable clay overlying laterite* of this region is described in Appendix A (11).

These shallow soils support a scrub grass vegetation which shows up as a light tone on the aerial photos. Termite mounds, on which vegetative growth is better because soil moisture conditions are better, are a common feature. This is especially noticeable in the sisal plantations.

Soil No. 15. *Dark grey, mottled clays, vlei soils.*—These soils have been discussed in the discussion on the soils of the region of broad ridged topography. However, in this area many of them appear to have formed in old drainage lines. It is suggested that in this case, the old drainage lines have been filled in with ash and colluvium. A typical *dark greyish-brown mottled clay* of this region is described in Appendix A (15).

Soil No. 19. *Shallow stony soils with rock outcrops.*—These occur on the main valley sides and are extremely steep, almost vertical in places. These soils are very shallow and occur mainly in pockets on slight shelves and between boulders. They differ greatly from the valley side soils of the region of broad ridged topography where, although the sides are steep, deep soils occur on them.

This soil group could be easily identified on the photos by means of the stereoscope.

Soil No. 17. *Peaty swamps.*—The main valley bottoms in this region are wider and are threaded by rivers which flow through papyrus swamps. The soils are continuously under water and have not been studied.

The papyrus shows up clearly in the aerial photos.

SOILS OF THE ATHI AND KAPITI PLAINS

This area can be divided into three regions as follows:—

A. The flat plains of the Athi.

B. The flat plains of the Kapiti.

C. The gently undulating plains of the Athi basin.

A. Soils of the Flat Plains of the Athi

The Athi plains are practically flat and to the East, end in a bluff overlooking the Athi River. This plain is traversed by a number of rivers, each flowing in an easterly direction out of the high ground of the eastern flank of the Rift Valley and cutting down over 100 ft. below the general land surface.

The soils of this region are as follows:—

Soil No. 14.—*Black to dark grey clays, grumosolic soils.*

Soil No. 11.—*Shallow yellow-brown to yellow-red friable clays overlying a laterite horizon or rock.*

Soil No. 19.—*Shallow soils on steep slopes.*

Soil No. 17.—*Peaty swamp soils.*

Soil No. 18.—*Alluvium.*

Soil No. 14. *Black to dark grey clays, grumosolic soils.*—As these black grumosolic soils also occur on the flat plains of the Kapiti they are discussed together. Listed below are some of the properties and characteristics of these soils which suggest their genesis.

1. The common exchangeable bases, namely calcium, magnesium, potassium and sodium are all of the same order irrespective of the nature of the underlying rock of the soil. This also applies to the base exchange capacity and percentage saturation.

2. On the whole these clays have a very uniform depth, varying from 3 to 4 ft.

3. They all exhibit cracking on drying.

4. In the gneissic rock areas there was a tendency for the clays to be sandier but sandier variants were also found in the volcanic areas.

5. Stephen, Bellis and Muir[5] found that the soils near Embakasi and on the Juja Sisal Estate contained the following heavy minerals:—Sillimanite, Kyanite, Garnet and Staurilite which are characteristic of metamorphic rocks of the gneissic type. These soils were underlain by phonolite at Embakasi and Tuff at Juja.

6. In the Lukenya area, black clays were seen to overlie red soils. Also in this area laterite was occasionally found under the black clay; laterite was also found underlying the black clay in the Kahawa area.

7. In areas where the black soils have been removed by erosion the underlying rock is now weathering through red.

8. In the gneissic areas there is usually a quartz stone line between the soil and rock. However, quartz stones imbedded in the soil are not uncommon within the black clays of the volcanic area.

9. Usually there is a sharp or fairly sharp contact between underlying rock and soil.

10. In the metamorphic areas of this soil group, no quartz veins have been seen within the soil: these would be expected if it had developed *in situ*.

11. The eastern and western margins of the black clay areas tend to follow the 5,200 ft. contour. The northern margin is at a much lower altitude being approximately 4,800 ft. The southern boundary however is at a higher altitude, going up to 6,200 ft., in the vicinity of the Ngong hills.

12. These soils occur both on flat sites and on appreciable slopes.

The above properties do suggest that these soils are not wholly developed *in situ*. In view of this, the following hypothesis is put forward for the formation of these soils. This area at one stage formed a large basin bounded by the Machakos hills in the east, the Ngong hills in the south and the high ground of the eastern flanks of the Rift Valley in the west, the northern flank of the basin is more difficult to define but may have been associated with the Ithanga-Kakuzi hills. Black soils do occur in the vicinity of Makuyu and may have been part of the same formation which has later suffered erosion and only relics remain. It is suggested that the lowest point of this basin was in the vicinity of Athi River Township.

During a wet cycle the basin formed a lake and colluvium and alluvium materials were deposited within this basin from the surrounding hills. As one would expect, the soil in the vicinity of the metamorphic rocks would be sandier than those near the volcanic hill masses. It would also account for sandier areas within the volcanic rock areas. The addition of ash cannot be discounted during this period.

Later, a dry period followed and the lake receded. These lacustrine deposits were then gradually converted to the present black soils. Having once formed, these soils maintain poor drainage conditions in spite of slopes, and the slow weathering of the underlying rock, under these drainage conditions has gradually given the soil the character of being weathered *in situ*.

One difficulty remains as this theory does not account for the black soils in the vicinity of Kajiado and Ngong hills. There the soils cover land ranging in elevation to fully 1,000 ft. above the general level of the Athi Plains. To account for the occurrence of the grumosols here it is suggested that subsequent to their formation there have been earth movements associated with the Rift Valley development which has raised these soils to their present altitude.

An alternative explanation which would account for the range of altitude covered by the black clays of the Athi and Kapiti Plains is that they developed under swamp conditions on the existing landscape in a pluvial period.

It is suggested that the age of these soils is considerable, as their original formation must have occurred earlier than the deep valleys formed by the down cutting of the rivers which traverse the plains. It is hard to reconcile the formation of these black clays on some of the very narrow interfluvial ridges on which they occur unless they were once part of an overall formation and now remain as relics.

On both the Athi Plains and the north-eastern portion of the Kapiti Plains near Tala the aerial photos show a circular island pattern occupying about one-third of the land surface. On investigation this pattern on the ground it was found that these islands consisted of mounds rising from about 1 to 2 ft. above the general land surface and having a diameter of about 20 yards across. Under the natural grassland vegetation the mounds carry a different species of grass to that of the intervening areas. The grass on the mounds appears to be more palatable to animals than on the non-mound area and hence they are always more grazed. There may also be the tendency for animals to concentrate on these mounds during wet weather to avoid their hooves getting clogged up with mud; this may account for the acacia gall thorn (*Acacia drepanolabium*) being absent on the mounds. Crops such as sisal and maize show great differences in growth between mound and non-mound sites; the mound areas, show vigorous growth while on the intervening areas, sisal growth is poor and maize crop failures are common. These differences in the growth of crops appear to be largely due to drainage, the mounds having a better drainage.

The origin of these mounds gives rise to some speculation; Stephen, *et al.*[5], suggested they were of gilgai origin. On the other hand there is a school of thought which considers them to be relic termite mounds.

Uneven sisal growth on black clay on Athi Plains at Juja. Note good growth of sisal which is on mound in foreground and the poor growth which is on intervening land immediately behind. The prominent hill in the background is Donyo Sabuk.

An attempt is made to put forward the varis pros. and cons. of the two theories in the following discussion.

1. I will deal first with the size and distribution of these mounds. Both the size and the distance between mounds is greater than that reported by Hallsworth, *et al.*[6], for the Australian gilgai of the "mushroom type". They have been compared with this type since no sink hole is found on the shelf between mounds. On the other hand the size can be accounted for by considering them to be relic termite mounds and the distribution is very similar to active termite mounds on well-drained adjacent soils.

2. Hallsworth, *et al.*[6], point out that the lattice gilgai do arrange themselves in parallel rows to the direction of greatest slope. He does not mention this point with the normal gilgai. These Athi mounds do tend to form parallel rows on slopes and it is difficult to see why termite mounds would do likewise unless some mounds had been obliterated by surface wash.

3. These black clays do not show any appreciable differences between top and subsoil: in the Australian gilgai, in some cases the subsoil is very different from the top soil.

4. The Athi mounds are more calcareous than the surrounds and have calcareous concertions present. However, it is difficult to say whether these concretions, some of which appear on the surface, are there by gilgai action or have been thrown up by ant-bears digging into the mounds looking for the termites which now occupy these sites (these termites are not the mound-building type). The intervening areas have few if any calcareous concretions and there appears to be no tendency for them to form lines starting at the bottom of the non-mound areas and gradually coming to the surface in the mound areas as one might expect in gilgai soils. Calcareous concertions are, on the other hand, a common feature at the base of termite mounds where they are thought to form due to the mound acting as an evaporation funnel.

5. Hallsworth, *et al.*, normally found that the topsoil of the mound was heavier than the topsoil of the non-mound areas, since the topsoil of the mound under gilgai conditions would normally be a subsoil. This relationship was not found in the Stephen, *et al.*, investigations.

6. Both found that more exchangeable sodium was present in the non-mound areas. This would be expected if the mounds had better drainage conditions.

7. Hallsworth, *et al.*, found the surface soil of the mound had an alkaline reaction and the shelf acid. This varied in the investigations carried out by Stephen, *et al.*, who also found that the swelling power of the clays in the non-mound site was not as great for the Athi profiles as those recorded by Hallsworth, *et al.*, for the Australian gilgai soils.

8. Although the Australian types generally develop again 2 to 11 years after being graded down this does not appear to be true of the Athi Plains soil as fence posts appear quite stable and do not show any sign of being displaced. It cannot be said that climatic conditions are unsuitable for gilgai soil formation at present as neither of these soils are permanently wet or dry, but they have a wet period followed by a dry hot period.

9. Under the mounds the rocks are more highly weathered than in the non-mound areas and this could be due to better drainage conditions. However, if these were termite mounds, the termites may have contributed to this.

It has also been suggested that the mounds are the product of better deep drainage resulting from fissuring of the underlying lavas.

From the above points it can be seen that more work is required before the origin of these mounds can be determined. A typical *dark grey clay* of the Athi Plains is described in Appendix A (14).

Soil No. 11. *Shallow yellow-brown to yellow-red friable clays.*—These soils have been discussed in the discussion of the soils of the region of gently undulating very broad ridges of the high ground of the Eastern Flank of the Rift Valley. On the Athi Plains these soils are mainly *yellow-red friable clays overlying rock*. They occur where the black clays have been stripped off.

Soil No. 19. *Shallow stony soils with rock outcrops* and *Soil No.* 17. *Peaty swamps.*—These also have been discussed in the discussion of the soils of the region of gently undulating very broad ridges of the high ground of the Eastern Flank of the Rift Valley.

Soil No. 18. *Alluvium.*—No work has been done on these soils. Many have developed from the drying up of papyrus swamps due either to the canalising of the river or to drier climatic conditions.

B. Soils of the Flat Plains of the Kapiti

These plains are very similar to the Athi but have no permanent rivers flowing through them; instead, a number of seasonal river beds occur which contain water for very short periods.

In the metamorphic areas, a number of small conical hills occur within the *black to dark grey clay* plains and there is one large hill mass—Lukenya.

The *black to dark grey clays* have been discussed in the discussion of the *black clays* of the Athi Plains and a profile description given in Appendix A (14).

The soils of the conical hills are discussed in the discussion of the soils of the Central Hill Mass of Machakos.

C. The Gently Undulating Plains of the Athi Basin

These occur under much the same climatic conditions as the *black clay* plains of the Athi and Kapiti, the rainfall being between 20 in-30 in. However, the topography, instead of being flat, is undulating. The soils of this region consist of the following:—

Soil No. 12. *Dark greyish-brown calcareous clays* (*Rendzenic soils*).

Soil No. 13. *Dark greyish-brown calcareous clays with light textured topsoil* (*Rendzenic soils*).

Soil No. 6. *Reddish-brown sandy clay loams.*

Soil No. 18. *Alluvial soils.*

Soil No. 12. *Dark greyish-brown calcareous clays* (*Rendzenic soils*):— These soils overlie secondary limestone or tuff weathering through lime. Within the area, pockets of chalcedony appear and it has much the same soil above. These soils occur on all parts of the terrain and are not confined to any topographic site. Appreciable amounts of coarse sand and occasional quartz and chalcedony stones are present in these soils, but are not present in the underlying limestone or tuff, which suggests that these soils are not wholly sedentary in origin even although the underlying material appears to be weathering into a black soil at present.

These soils again appear to be lacustrine in origin and it is suggested that this was the lowest part of the lake where, on finally drying out, deposits of limestone were laid down within the underlying porous tuff and that the limestone content of the rock would increase as the tuff weathered. In this way, the lack of coarse sand within the limestone could be explained.

The soils show high exchangeable potassium, being about six times greater than the black clays of the Athi and Kapiti plains. The exchangeable calcium, magnesium and sodium on the other hand are of the same order to those of the Athi and Kapiti. This high exchangeable potassium may also suggest lacustrine origin since Chamberlain[7] found at Naivasha that exchangeable potassium increased appreciably the nearer the lake shore was approached: the lake at time of sampling was receding. A typical *dark greyish-brown calcareous clay* of the undulating plains of the Athi Basin is described at Appendix A (12).

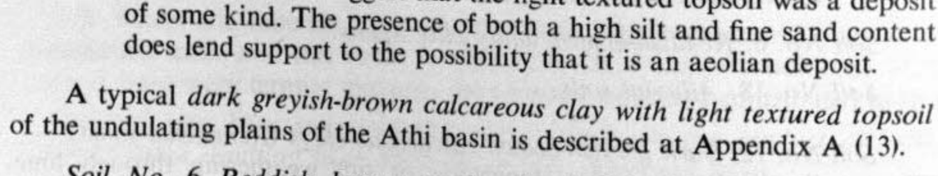
Soil No. 13. *Dark greyish-brown calcareous clays with light textured topsoil (Rendzenic soils).*—Apart from the light textured topsoil, these soils are very similar to those mentioned above. In some places there is a marked quartz stone line between the topsoil and the heavy subsoil, although this is not a common feature. However, there is an abrupt change from topsoil to subsoil. These soils tend to be situated on summits and crests of undulations but may also occur on lower slopes.

The light textured topsoil which may have been formed by the following:—

1. normal pedogenic processes associated with solonization. This is the least likely since solonetz soils would tend to occur on the lower ground.
2. a later ash deposit, which was laid down after the formation of the rendzenic soils and has subsequently been eroded leaving isolated remnants.
3. Aeolian deposits which again have subsequently been eroded. The stone line would suggest that the light textured topsoil was a deposit of some kind. The presence of both a high silt and fine sand content does lend support to the possibility that it is an aeolian deposit.

A typical *dark greyish-brown calcareous clay with light textured topsoil* of the undulating plains of the Athi basin is described at Appendix A (13).

Soil No. 6 Reddish brown sandy clay loams.—These soils occur in pockets and bands within the rendzenic soils and like them, do not appear to be confined to any topographic site. However, they did appear to occur at the same altitude throughout the area. Their distribution can best be explained by the diagram below.



It can be seen that these soils occur both on slopes in the form of bands (1) or rings (2) and on summits in pockets (3). The steeper the slope the narrower the band. Some of these bands and pockets are so small that they have not been mapped.

These soils are acid in reaction and overlie a neutral tuff which is free from calcium carbonate for at least 3ft. whereas all the other tuff contains calcium carbonate. Like the rendzenic soils they have appreciable amounts of coarse sand and occasional quartz stones which are not present in the tuff below, suggesting that these soils again are not wholly sedentary even though the tuff at present appears to be weathering. These soils have also a high exchangeable potassium content.

The diagram does suggest that these soils are relics of an old land surface which was subsequently eroded leaving remnants on the summits. The area was then covered by water-laid ash to give a tuff horizon which was in turn overlaid by lacustrine deposits. Subsequent erosion has now exposed part of this old land surface.

Another suggestion is that when the lake was receding, it became stable at one stage and a sandy shore line was formed. Because the drainage is better at this particular spot the subsequent weathering is red. Here again more investigation is required before the origin of these soils is known.

A typical *reddish brown sandy clay loam* of the undulating plain of the Athi Basin is described at Appendix A (6).

Soil No. 18. *Alluvial soils.*—These soils are confined to the Athi River and its tributaries where they flood during the wet season. In many respects these soils are not unlike rendzenic soils mentioned previously but are more friable.

The *black clays* of the Athi and Kapiti Plains showed up as dark colour tones on the air photos, with the lighter toned mounds being very prominent. The *rendzenic soils* had similar dark tones but the prominent mounds were absent. There were however, white dots, possibly termite mounds or harvester ant nests, scattered over the photos. The *rendzenic soils with a light textured topsoil* showed up white on the photos but this was also true of the *reddish-brown sandy clay loams* and could be confusing.

SOILS OF THE CENTRAL HILL MASSES OF THE MACHAKOS DISTRICT

These hills all rise abruptly from the plains and are highly dissected, especially in the upper regions. They vary in altitude from approximately 6,000 to 7,000 ft. above sea level. The rainfall is very variable, ranging from 25 in. to 50 in. per annum and active erosion is still taking place. The soils found on these hills are as follows:—

Soil No. 2. *Reddish-yellow sandy clay loams* (*latosolic soils*).
Soil No. 4. *Red friable clays.*
Soil No. 9. *Dark grey compacted loamy sands* (*solodized-solonetz soils*).
Soil No. 19. *Shallow stony soils with rock outcrops.*

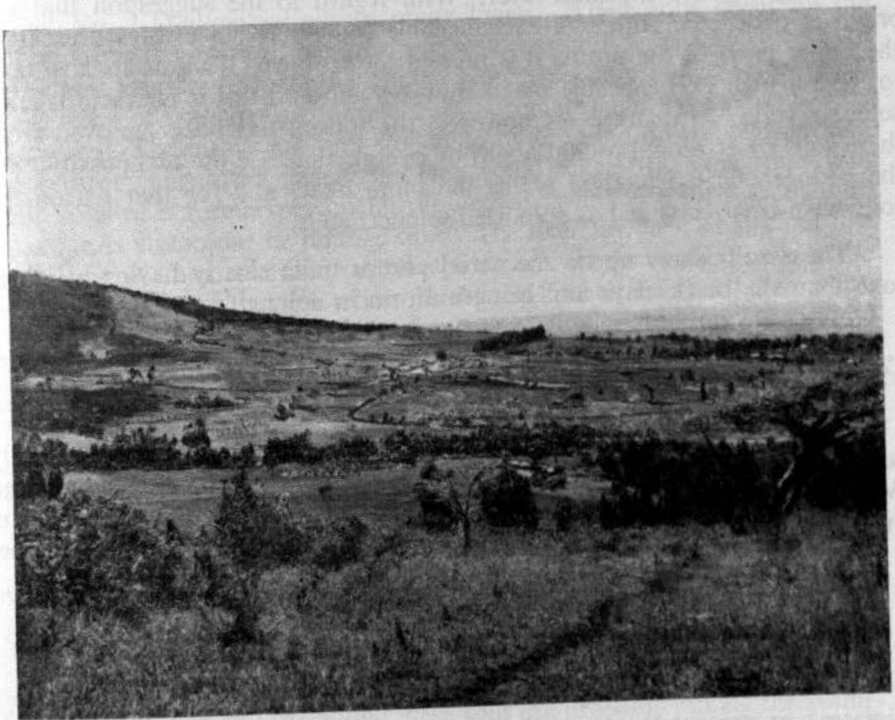
Soil No. 2. *Reddish-yellow sandy clay loams* (*latosolic soils*).—These soils have been mapped on Donya Sabuk and Iveti hills, between approximately 6,500-7,000 ft. under a mean rainfall of between 40 in. and 50 in. per annum. The topography is highly dissected, consisting of very narrow ridges with steep slopes down to the valleys. As one would expect in such a topography where erosion is marked, the soils are very variable, ranging from skeletal to developed soils, the latter occurring on the broader ridge tops where conditions are more stable. These different soils could not be separated on the air photos and have been mapped as one unit. Even though the potential evapotranspiration from these soils for most of the year is sufficient to deal with the rainfall accepted by these soils and hence leaching should not be intense, these soils tend to be very acid, low in bases and have a low saturation. Acidity is most intense and base status is lowest on steep slopes where the least soil development has taken place; where more stable conditions obtain, the base status does improve. It is thought that these soils, with time and stability would develop into *Soil No*. 3, *dark red friable clays*: these latter soils do occur near by on less abrupt topography under similar climatic conditions. However, this development is unlikely unless the present intensity of erosion is much reduced. The *reddish-yellow sandy clay loams* are characterized by having a pink to white weathered shistoze parent rock usually separated from the subsoil by a stone line. This soil group could be identified on the photos by white pockets where the subsoil was exposed, but was mainly recognized by its dissected topography using the stereoscope.

A *reddish-yellow sandy clay loam* from a Machakos hill mass outside the survey area is described at Appendix A (2).

Soil No. 4. *Red friable clays*.—Although these soils are derived from basement complex rocks, apart from having a higher sand content they have similar properties to those of the volcanic derived *red friable clays* of the high ground of the eastern flank of the Rift Valley. Stone lines may be present on the steep slopes. These soils occur on the middle and lower slopes of Donya Sabuk and the Iveti hills. They also occur on the summits and upper slopes of the Mua Hills and Kazula range. Though most of the occurrences of this soil group in Machakos District and on Donya Sabuk occur on steep slopes, where they are used for subsistence cropping, they are very intensively cultivated and used for coffee growing.

A typical *red friable clay* of the Central Hill masses of Machakos District is described at Appendix A (4*b*).

Soil No. 9. *Yellow-red sandy clay loams with laterite horizon*.—These soils occur in the drier regions where the rainfall is under 30 in. per annum. They are found on Lukenya and on the lower western slopes of the Mua Hills where slopes are convex. These soils tend to be shallow, being 2 to 3 ft. in depth overlying a laterite horizon with many quartz stones inbedded in the laterite. Due to the arid conditions they tend to have a high saturation and are considered to be mainly products of a past wetter climate. As these soils have a greater distribution in the partly dissected peneplain country of the east, they will be discussed more fully later. A *yellow-red sandy clay loam* of the partly dissected peneplain country of the east is described at Appendix A (9).



Red friable clay landscape, Kagundo Valley, with dark grey compacted loamy sand (solidized solonetz soils) and black to dark grey clays of the Athi Plains with Komo Rock, a small conical gneissic hill, in the distance.

Soil No. 16. *Dark-grey compacted loamy sands* (*solodized-solonetz soils*).—These soils occur on the lower slopes of the hill masses usually associated with drainage grooves and depressions and also on the fringes of the *black clay* plains. The rainfall is usually below 30 in. and the topography is flat to gently sloping.

There are two suggestions as to the origin of these soils, namely, (1) formed by pedogenic processes and (2) by sand wash over a black clay. The latter suggestion is that the sand wash is incorporated in the clay in such a mixture that it forms a natural cement resulting in the compacted layer. Although a black clay usually occurs at the base of this soil, this is not always the case, especially on the sloping topography and in the drainage grooves. On the other hand it can be said that both sand and clay have been washed in at the same time but one would then expect the sand to remain in the groove and the clay to be carried off in suspension. This seems likely as in this area some of the drainage grooves and dry water courses contain sand which is recovered for building purposes. Where sand wash on top of the clays has been seen, it has lain as a loose surface soil and has been incorporated within the clay giving a compacted layer. With regard to the suggestion that the origin is pedogenic, although exchangeable sodium is not always present in the upper parts of the profile it is present lower down. These soils also tend to have a high exchangeable magnesium content and this is characteristic of solonetz soils. In many cases however, the topsoil has been removed from these soils by erosion, brought about by overgrazing. Of the two possibilities, the pedogenetic explanation seems the more likely and for that reason the soils have been classified as solodized-solonetz soils.

These soils show up on the aerial photos quite clearly having a lighter tone than the black clays and being uniform in colour.

A typical *dark-grey compacted loamy sand* of the lower slopes of the Central Hill masses of Machakos District is described at Appendix A (16).

Soil No. 19. *Shallow stony soils with rock outcrops.*—These soils usually occur on the very steep slopes of these hilly areas and are formed by erosion. Within the area, pockets of deeper soil occur but these cannot be mapped on the present scale. They are easily defined on the photos under the stereoscope.

SOILS OF THE PARTLY DISSECTED PENEPLAIN COUNTRY OF THE EAST

The soils of this area are mostly the products of past more humid climates: at present the mean annual rainfall is less than 30 in.

For discussion purposes the area can be divided into two:—the central flat Yatta plateau and the partly dissected peneplain areas which occur on the flanks of the plateau.

The partly dissected peneplain areas have a gently undulating topography with the high ground tending to be flat-topped. The crests of these ridges are at an elevation of 4.500 ft. in the west, falling to about 4,000 ft. in the east. They are described as remnants of the sub-miocene peneplain[8,9].

The soils that occur in this area are as follows:—

Soil No. 7. Yellow-red coarse sandy loams.

Soil No. 5. Dark red sandy clay loams.

Soil No. 8. Red friable clays with a laterite horizon.

Soil No. 9. *Yellow-red sandy clay loams with laterite horizon.*

Soil No. 10. *Brown sandy clay loams with laterite horizon.*

Soil No. 14. *Black to dark grey clays (grumosolic).*

Soil No. 16. *Dark grey compacted loamy sands (solodized-solonetz soils).*

Soil No. 7. *Yellow-red coarse sandy loams.*—These soils occur on the high ground to the north of the area and would appear to be associated with the granitoid gneisses forming the Thatha hills. Schoeman[8] suggests that these hills are relics of late jurrasic or cretaceous peneplains and have subsequently been lowered. These soils are very similar to those found on the high ground of the central Tanganyika peneplain. This would suggest that they may well be relic soils of a former peneplain although it is not thought that they go back as far as cretaceous or jurassic times. The low clay, lack of silt and low base content of these soils do suggest great age. Their distribution on the map also suggests that they are relic soils since, where erosion has taken place, the more recently derived soils are red and have greater amounts of clay and silt. Another suggestion put forward is that they are of wind-borne origin but there is little suggestion of bedding which one might except if this were so. As little time has been spent in studying these soils nothing definite can be postulated in their origin and further study is required. They were clearly shown on the photos by the light colour tone.

A typical *yellow-red sandy loam* of the high ground of the partly dissected peneplain of the East is described at Appendix A (7).

Soil No. 5. *Dark red sandy clay loams.*—These soils occur where comparatively recent dissection of the sub miocene peneplain has taken place and are developed in situ. Although these soils are probably among the youngest soils of the area, they are of sufficient age to have developed into deep mature red soils. They are, often traversed by gravelly or stony bands along the veins of quartz which have been left as the underlying rock has weathered. They were probably developed under more humid conditions. If they had developed under the present rainfall regime leaching would have been very limited and soil formation would not have reached the stage of red earth development. Instead an accumulation of calcium carbonate at depth would have been expected. These soils have a very similar base status and saturation to *Soil No.* 8 the *red friable clays with a laterite horizon* of the Yatta Plateau.

These soils generally have a darker tone and lack visible termite mounds on the photos.

A *dark red sand clay loam* from a site a short distance outside the southern limit of the survey is described at Appendix A (5).

Soil No. 8. *Red friable clays with a laterite horizon.*—These soils are mainly confined to the relatively flat Yatta plateau although small areas do occur west of Kangundo. Laterite was found at depth in the profile examined, and since these soils occur in a dry climate—rainfall about 25 in.—it is considered that they were developed under past more humid conditions. Numerous large phonolite boulders are seen to be partly exposed on the surface within this soil group suggesting that this soil has been heavily planed by erosion in the past. This is partly confirmed by *Soil No.* 10, *brown sandy clay loams with a laterite horizon* also being present on the plateau. These latter soils are very sandy, contain large amounts of quartz stone imbedded in the laterite and hence could not have formed from the underlying phonolite: rather they are of mantle origin. As these *brown sandy clay loams* now occur only in pockets within the *red friable clays* of the Yatta Plateau, it is suggested that at one time they covered the whole or part of the plateau in this area but have since been largely removed by erosion.

The *red friable clays with a laterite horizon* have a moderate base status and have a percentage saturation of about 50.

They are recognized by the coarse scrubby thorn and termite mound pattern on the photos.

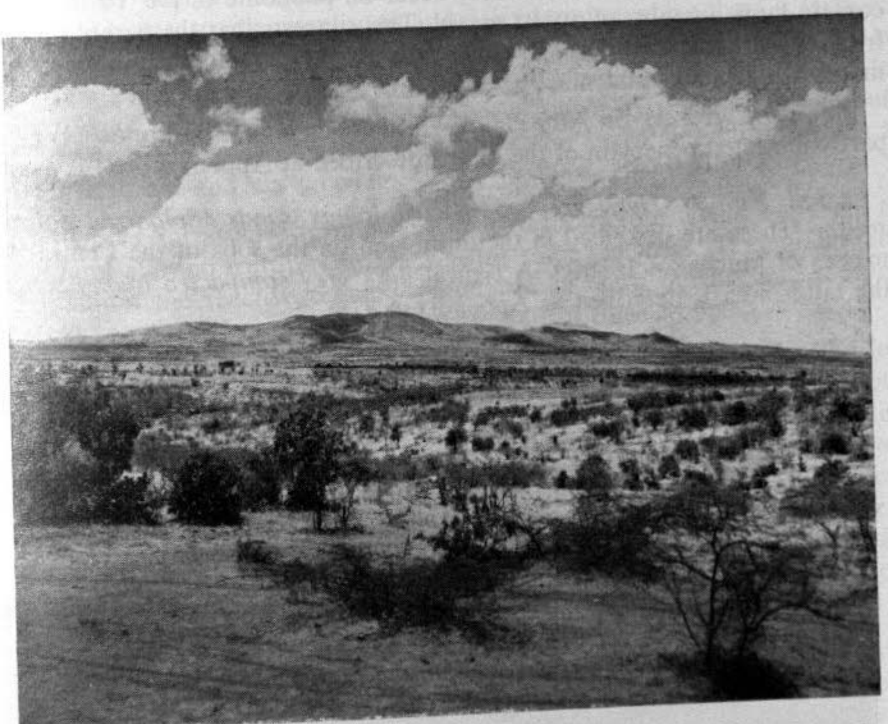
A typical *red friable clay with laterite horizon* from the Yatta Plateau is described at Appendix A (8).

Soil No. 9. *Yellow-red sandy clay loams with laterite horizon.*—These soils have been partly discussed in the discussion of the soils of the central hill mass of Machakos District.

An interesting feature of the local occurrences of these soils is that they usually are found lower down the slope than *Soil No.* 10, the *brown sandy clay loams with a laterite horizon* but above *Soil No.* 5, the *dark red sandy clay loams*. If the *brown sandy clay loams with a laterite horizon* represent the soils formed on the old peneplain, then these yellow-red soils must have developed after a later period of erosion but must be older than the *dark red sandy clay loams,* which are presumably formed after the country had been still more deeply dissected. Apart from their colour and situation, these yellow-red soils are remarkably similar to the *brown sandy clay loams with a laterite horizon.* They can be separated from the latter on the photos by the termite pattern and darker tones.

A typical *yellow-red sandy clay loam with laterite horizon* from below the edge of the Yatta Plateau is described at Appendix A (9).

Soil No. 10. *Brown sandy clay loams with a laterite horizon.*—As mentioned previously these soils occupy the high grounds which are the remnants of the sub-miocene peneplain. It is difficult to conceive that these soils have remained *in situ* since sub-miocene times unless at one stage they were very deep or unless they have been protected to an exceptional degree from subsequent erosion. The underlying laterite layer is not as thick as is normally associated with sedentary soil from miocene rocks. Rather these soils may well be developed in weathered material from the underlying laterite. This may account for the drab colour of the soil. These soils occur on the Yatta phonolites as well as over gneissic rocks of the submiocene peneplain.



Partly dissected peneplain landscape of the East with over-grazed brown sandy clay loam in foreground and one of the Central Hill Masses of Machakos District in the background.

These soils have a moderate base content and a high saturation. They can be separated on the photos by the termite pattern and light tone.

A typical *brown sandy clay loam with laterite horizon* on the Yatta Plateau is described at Appendix A (10).

Soil No. 14. *Black to dark-grey clays* (*grumosolic*).—These soils occur in low lying and depression areas and initially were developed from colluvial material under poor drainage conditions. Some are found on high ground, associated with *Soil No.* 10, *brown sandy clay loams,* while others are found on lower ground associated with *Soil No.* 9, the *yellow-red sandy clay loams.* Since it has been assumed that the *brown* and the *yellow-red sandy clay loams* are of different ages, are the *black clays* of these two different topographic sites also of different ages? This is difficult to answer and more work would be required. Some clue to this may be found by fossil remains of "Hydnora" found by Trapnell[10] under the *black clays*; these are being investigated by Dr. E. M. Van Zinderen Bakker of the University of the Orange Free State, South Africa.

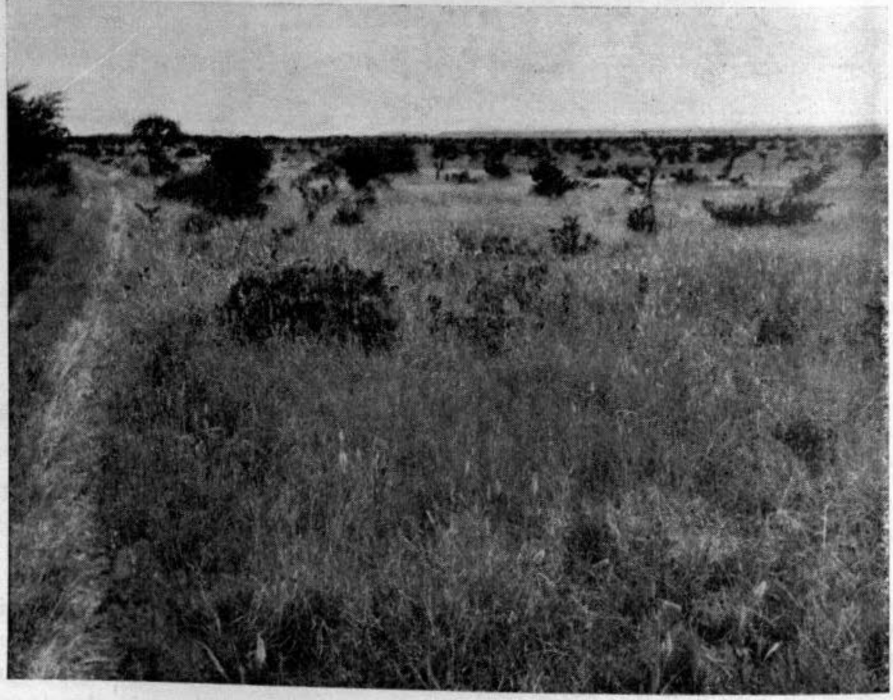
The *black clays* even when they occur on phonolite of the Yatta Plateau contain large amounts of quartz gravel. This suggests that the parent material from which they are derived must have originated at least in part from metamorphic rocks and must have been of mantle origin.

A *dark grey clay* in Athi Plains which is similar to the grumosols of the partly dissected peneplain of the east is described at Appendix A (14).

Soil No. 16. *Dark grey compacted loamy sands* (*Solodized solonetz soils*).—These are described in the discussion on the soils of the Central Hill masses of Machakos District. A typical *dark grey compacted loamy sand* of the latter area is described at Appendix A (16).

LAND USE

This again is being discussed on the basis of physiographic zones.



Grassland on black clay in the partly dissected peneplain country of the East with the phonolite lava flow of the Yatta Plateau forming the skyline.

HIGH GROUND OF THE EASTERN FLANK OF THE RIFT VALLEY

A. Region of Dissected Narrow Ridge Topography

The *strong brown to yellow-red friable clays* (*ando-like soils*) of this region are very low in bases and those bases that are present are mainly associated with the organic matter. In the past this kind of land has been devoted to tea, wattle, pyrethrum and dairy farming where there is large-scale farming but, until population pressure on neighbouring more fertile land became acute, it was little used by peasant farmers. Some wattle and food crops, such as beans, peas and maize were grown by peasant farmers but in recent years these farmers have gone in also for sheep and dairy farming and for pyrethrum and tea growing.

Under subsistance farming one or two food crops would be taken, then the land allowed to revert to bracken for some ten years. Presumably under cultivation the reactive organic matter breaks down quickly and ten years' fallow is required to restore it adequately for further cropping.

Beyond the western limit of the survey area this soil occurs in the forest reserve where it supports both plantation and natural forest. The normal Forestry Department procedure for developing plantation technique is to clear the natural forest and allow cultivation of the cleared area for one year: then seedlings are planted and the cultivators continue to take seasonal crops —principally potatoes, maize, beans and peas—in the area for a further two years. By that time the trees have grown sufficiently to stop further cultivation of crops. In this area the procedure has proved less satisfactory than in other forest areas because the crop yields obtained by the cultivators have been low.

This soil group covers the headwaters of many important rivers and future land use planners must bear this in mind. A careful study of the Soil Physics, E.A.A.F.R.O., reports on the Fort Essex catchment is recommended. It must also be realized that whatever fertility is present in the soil is associated with the organic matter, so strict soil conservation must be practised on the very steep slopes.

On present knowledge, the best use for this soil group is for perennial crops (timber and tea), dairy farming and sheep.

B. The Region of Broad Ridge Topography

This is undoubtedly the most productive region of the whole survey area since both climate and soils are favourable for plant growth. The main soils of this region are the *dark red friable clays*. These soils are very fertile and are mainly used for peasant-grown arabica coffee, maize, beans, pyrethrum, potatoes and peas. The area of coffee is increasing rapidly. In the past, the proper utilization of such land has been much hampered by the fragmentation of property which took place under traditional indigenous inheritance laws. Recently, however, the community has responded with dramatically increasing readiness to counsels that for the best to be got out of the land, cultivators must interchange their fragments with each other and so consolidate their holdings into single compact units on which a planned system of rotational cropping is followed. The grass phase which is an essential feature of the rotation makes possible a major expansion of dairying and the development of beef production. The *vlei* areas would probably be wholly utilized for coffee mulch and fodder crops and the yield of these could probably be greatly increased by ridging to improve drainage. Many of the *peaty swamps* have been cleared and are being utilized for subsistence cropping. These areas could be utilized for market gardening.

Improved enclosed and paddocked grazing on dark red friable clay on which dairying is being expanded and beef production developed in Kiambu.

C. THE REGION OF GENTLY UNDULATING VERY BROAD RIDGES

The *red friable clays* of this region are extensively used for estate-grown arabica coffee and it is on coffee grown on this soil that Kenya's high reputation as a coffee producing country was gained. Nevertheless, in the lower, more easterly parts of the region, the climate is hot and dry and the soils are too shallow for coffee production except on the more efficient and better placed farms. Many estates must rely on irrigation to keep up yields.

In these lower parts of the region, coffee on the *red friable clays* in part is replaced by sisal, pineapples and pasture.

The *yellow brown to yellow-red friable clays over laterite* are mainly used for grass production for coffee mulch or grazing. In some areas both sisal and pineapples are grown on these soils. It has been noted that ridging of this soil is practised. This is to increase soil depth.

The *vleis* are used in much the same way as in the *dark greyish-brown mottled clays* of the region of broad ridge topography but pineapples and some sisal are also grown on them. The *shallow stony soils with rock outcrops* occur on steep valley sides and should be left for grass production for grazing. The *peaty swamps* are much wider in this zone and therefore become more important. Their utilization for market gardening and for fodder crops production might be investigated.

ATHI AND KAPITI PLAINS

The Flat Plains of the Athi and Kapiti

Because of its low and poorly distributed rainfall this area is almost entirely devoted to ranching and sisal. The bulk of the soils are the *black to dark grey clays* (*Grumosolic soils*). These soils are very difficult to work and it requires heavy machinery to do this. When wet they are sticky and glutenous: when dry they are hard and massive and difficult to break and reduce to a tilth. Their water relations can be improved by ridging. This is economical for sisal not for ranching.

Cereals and green crops for silage have been grown on ridges in this soil but the rainfall is too variable for reliable farming of this kind. These soils are best utilized for dry season grazing as during the rains the cattle are liable to puddle the velt soil and to damage the grass by trampling.

The shallow *yellow-brown to yellow-red friable clays overlying laterite or rock* are used for sisal growing and grazing. For grazing they are best used during wet weather when stock should be kept off the *black and dark grey clays.*

The *shallow clay soils with rock outcrop* are used for grazing.

The *Alluvium* and the *peaty swamps* are used for sisal nurseries but can also be used for fodder crops and market gardening.

The Gently Undulating Plains of the Athi Basin

Rendzenic soils occupy most of this area and are utilized for sisal and ranching. These soils are very similar to the *black to dark grey clays* but appear to have a slightly better structure. Both the *rendzenic soil with a light-textured topsoil and the reddish-brown sandy clay loams* can be used for wet season grazing. They are being used with some success for irrigated pastures using meat processing plant effluent.

The *alluvial* soils along the Athi could be used for sisal nurseries or for fodder crop production.

THE CENTRAL HILL MASSES OF MACHAKOS DISTRICT

In the main these areas are highly dissected and suffer severe erosion. The *reddish-yellow sandy clay loams* occur in the upper parts of the hills and are used for growing some wattle and subsistence crops of maize and beans. These soils are low in fertility and as they occur in the head reaches of numerous water courses which traverse a populous part of Kenya which is singularly lacking in permanent water, their utilization for permanent crops (sisal or plantation timber) with high water conservation characteristics should receive particular attention. This may also retard the present erosion. The *red friable clays* occur lower down under a lower rainfall. Even so, these soils are closely populated and are intensively used for growing subsistence crops of maize, millet, sorghum, beans, cassava and bananas. There is a considerable acreage of arabica coffee, of market gardening and pasturage and there is some citrus. The steepness of the slopes often limits the use to which this soil can be put and necessitates strict application of soil conservation.

Intensive cultivation of red friable clays on Iveti Hills; dark grey compacted loamy sands and black or grey clay of Athi Plains in the right background.

Yellow-red sandy clay loams with laterite horizon occur on the lower slopes of these hills and are best used to provide wet season grazing for stock which otherwise would have to graze the nearby poorly drained soils. Of necessity, the deeper patches of these soils are used for growing indifferent subsistence crops of maize, millet, sorghum, cassava, pigeon pea and beans. The *dark-grey compacted loamy sands* are mainly used for grazing. They tend to be over grazed and once the ground cover is broken are very liable to become eroded.

On the *shallow stony soils with rock outcrops,* which mainly occur on steep slopes, pockets of deeper soil are found in which there are small patches of subsistence cultivation. The soil group as a whole provides some rough grazing.

Subsistence cropped land on the partly dissected peneplain country of the East with hills of the Central Hill masses of Machakos District in the background.

THE PARTLY DISSECTED PENEPLAIN COUNTRY OF THE EAST

Utilization of this country is determined partly by the lowness of its rainfall, partly by the scarcity of permanent water and partly by the incidence of tsetse fly and tick borne diseases. Parts carry good grazing and measures have been taken to improve the utilization of the grazing by the eradication of tsetse fly infestation centres and by the improvement of water supplies through construction of a large furrow drawing water from the Thika River and discharging it into sand rivers in the vicinity of Matuu, through the construction of numerous surface water storage dams and through the sinking of bore-holes. Associated with these grazing improvement measures an attempt has been made to control stocking rate. This commanded insufficient local support to be successful. The desirable grazing management of these soils is for the better drained soils—the *yellow-red coarse sandy loams,* the *dark red sandy clay loams,* the *red friable clays with laterite horizon* and the *brown sandy clay loams with laterite* horizon—to be used for wet season grazing and the more poorly drained soils—the *black to dark grey clays* and the *dark grey compacted loamy sands,* for dry season grazing. The grazing units should be laid out with this in mind.

On most of the deeper better drained soils, patches of subsistence crops of maize, millets, sorghum, beans, pigeon pea and cassava are grown and there is some estate grown sisal. Where irrigation is available the *dark red sandy clay loams* have been used for arabica coffee growing and is good for citrus and chillies. *The black to dark grey clays* should be tried for rice.

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APPENDIX "A" (1*a*)

Strong Brown to Yellow-Red Friable Clay (Ando-like Soils)

Location: Upper Kiambu near water works.
Site: Upper slope of ridge.
Drainage: Free.
Altitude: 7,000 ft.
Rainfall: 60″.

0— 5″ Reddish-brown (5YR 4/3) high humic granular to weak crumbly friable clay.
5—10″ Yellow-red (5YR 4/6) humic, weak crumbly to structureless, friable clay.
10—33″ Yellow-red (5YR 4/8) humic, weak crumbly to structureless, friable clay.
33—49″ Reddish brown (5YR 4/3) humic, weak crumbly to structureless friable clay loam, buried humic horizon.
49—71″ Red (2.5 YR 4/8) weak subangular blocky friable clay.
71″+ Red (2.5 YR 4/6) subangular blocky friable clay with clay skins.

Profile No. 47/11

Lab. No.	Depth	O.M.	C.S. F.S.	Silt	Clay	pH	% C	%N	C/N
8154 ..	0— 5″	10·1	24·8	5·4	59·7	4·95	4·58	0·46	13·2
8155 ..	5—10″	5·2	15·8	13·4	65·7	4·30	2·36	0·30	10·5
7985 ..	10—33″	5·3	7·9	12·0	57·1	4·45	2·66	0·24	11·8
8156 ..	33—49″	6·4	29·0	36·9	37·1	4·95	2·89	0·31	12·4
8157 ..	49—71″	1·6	13·4	8·2	76·8	4·60	0·73	0·05	19·4
8158 ..	71″+	0·7	10·1	10·0	79·2	4·90	0·35	0·05	9·4

Lab. No.	Depth	Ca	Mg	Mn	K	Na	Total	Ex H	B.E.C.	% Sat
8154	0— 5″	1·280	0·47	0·017	1·77	—	3·5	20·1	23·6	15
8155	5—10″	0·164	—	0·064	0·81	—	1·0	15·5	16·5	6
7985	10—33″	0·125	—	0·024	0·80	—	0·95	9·6	10·9	9
8156	33—49″	0·035	—	0·024	0·46	—	0·52	14·4	14·9	3
8157	49—71″	0·016	—	0·021	0·49	—	0·53	10·1	10·6	5
8158	71″+	0·018	—	0·020	0·27	—	0·31	8·5	8·8	3

Location:	Fort Essex.
Site:	Middle slope.
Drainage:	Free.
Altitude:	8,000 ft.
Rainfall:	85″.
0—12″	Very dark brown (10 YR 2/2) high humic crumbly friable clay-composed mainly of root mat. Very light.
12—36″	Dark brown (7.5YR 4/2) high humic weak subangular blocky to structureless fine sandy loam.
36—48″	Very dark brown (10YR 2/2) high humic crumbly to structureless fine sandy loam buried humic horizon.
48—63″	Dark brown (10YR 4/3) high humic, weak subangular blocky to structureless fine sandy loam.
63—76″	Dark yellowish-brown (10YR 3/4) high humic, crumbly to structureless fine sandy loam. Buried humic horizon.
76—88″	Yellow-red (5YR 5/8) subangular blocky friable clay with clay skins.
88—106″	Same as above.
106—118″	Dark yellowish-brown (10YR 4/4) subangular blocky friable clay with pieces of weathered tuff.
118—130″	Yellowish-brown (10YR 5/6) weathered tuff mottled red, orange and brown.

Profile No. 40/30

Lab. No.	Depth	O.M.	C.S.	F.S.	Silt	Clay	pH	% C	% N	C/N
12660 ..	0—12″	16·0	2·6	36·5	2·7	12·2	4·8	7·98	0·720	14·8
12661 ..	12—36″	8·6	6·7	33·3	32·7	13·9	4·8	4·29	0·370	15·4
12662 ..	36—48″	10·2	8·0	33·1	30·2	18·5	4·4	5·1	0·41	16·6
12663 ..	48—63″	6·5	25·7	28·0	23·3	16·5	4·8	3·27	0·333	13·0
12664 ..	63—76″	6·7	5·0	51·8	19·7	16·8	5·2	3·36	0·275	16·3
12665 ..	76—88″	1·7	5·6	21·4	18·1	53·8	5·8	0·87	0·080	14·5
12666 ..	88—106″	1·3	9·9	19·8	18·5	50·5	5·6	0·65	0·070	12·3
12667 ..	106—118″	1·3	6·6	19·2	35·8	37·1	5·6	0·68	0·055	16·5
12668 ..	118—130″	0·7	10·7	34·3	27·6	26·7	5·5	0·36	0·035	13·7

Lab. No.	Depth	Ca	Mg	Mn	K	Na	Total	Ex H	B.E.C.	% Sat
12660 ..	0—12″	1·09	1·34	0·025	1·55	—	4·0	14·4	18·4	21·8
12661 ..	12—36″	0·037	0·32	0·030	1·16	—	1·5	10·0	11·5	13·0
12662 ..	36—48″	0·020	—	0·019	0·83	—	0·87	11·4	12·3	7·0
12663 ..	48—63″	0·032	—	0·013	0·46	—	0·50	7·3	7·8	6·4
12664 ..	63—76″	0·037	—	—	0·21	—	0·058	6·9	7·0	0·83
12665 ..	76—88″	0·079	—	—	0·16	—	0·24	2·5	2·7	0·89
12666 ..	88—106″	0·13	—	—	0·19	—	0·32	3·9	4·22	0·76
12667 ..	106—118″	1·28	—	—	0·20	—	1·57	3·9	5·47	28·7
12668 ..	118—130″	1·54	—	—	—	—	1·54	3·9	5·44	28·3

Reddish-Yellow Sandy Clay Loam (Latosolic Soils)

Location: Top of Mbooni hill near A.O's. house.
Site: Summit-broad ridge top.
Drainage: Free.
Altitude: 6,500 ft.
Rainfall: 55″.

0— 5″ Dark greyish-brown (10YR 4/2) high humic litter layer, crumbly friable sandy clay loam with occasional angular quartz gravel.

15—30″ Light yellowish-brown (10YR 6/4) weak subangular blocky friable sandy clay with fine and coarse angular quartz gravel.

30—52″ Reddish-yellow (5YR 7/6) structureless compact micaceous sandy clay with angular small quartz stones and small black metallic crystals (graphite)?

52—70″ Reddish-yellow (2.5YR 7/6) structureless compact micaceous sandy clay with coarse angular quartz gravel and graphite crystals? Stone line at base of this horizon.

70″+ Pink (10YR 7/6) micaceous structureless compact sandy clay loam with graphite crystals.

Profile No. 48/23

Lab. No.	Depth	O.M.	C.S.	F.S.	Silt	Clay	pH	% C	% N	C/N
8880	0—15″	8·3	35·4	19·6	14·2	22·5	4·6	4·13	0·335	16·4
8881	15—30″	3·0	41·0	10·7	6·4	38·9	4·6	1·49	0·165	12·0
8882	30—52″	0·9	31·9	12·4	15·6	39·2	5·0	0·44	0·045	13·0
8883	52—70″	0·9	31·3	7·0	22·7	38·1	5·0	0·47	0·050	12·5
8884	70″+	0·2	32·1	16·8	16·2	34·7	4·9	0·08	0·040	2·8

Lab. No.	Depth	Ca	Mg	Mn	K	Na	Total	Ex H	B.E.C.	% Sat
8880	0—15″	0·019	0·20	0·020	0·16	—	0·40	17·1	17·5	2·3
8881	15—30″	0·010	0·24	0·0135	0·095	—	0·36	5·2	15·7	6·4
8882	30—52″	0·34	0·33	0·100	0·130	—	0·81	3·1	3·9	2·7
8883	52—70″	0·031	0·20	0·100	—	—	0·24	3·3	3·5	6·8
8884	70″+	0·010	—	—	—	—	0·01	3·4	3·4	—

Dark Red Friable Clays (Latosolic Soils)

Location: E.A.A.F.R.O. Labs.
Site: Level shelf.
Drainage: Free.
Altitude: 7,000 ft.
Rainfall: 38″.

0—4″ Dark reddish-brown (5YR 3/2) high humic crumbly friable clay.
4—14″ Dark reddish-brown (5YR 3/2) fine crumbly friable clay with occasional MnO_2 concretions.
14—23″ Dark reddish-brown (2.5YR 3/4) subangular blocky friable clay with clay skins.
23—31″ Same as above.
31—38″ Dark red (2.5YR 3/6) subangular blocky friable clay with clay skins, MnO_2 concretions present.
38—42″ Dark red (2.5YR 3/6) subangular blocky friable clay + frequent MnO_2 skins.
42—50″ Same as above.

Profile No. 47/43

Lab. No.	Depth	O.M.	C.S. F.S.	Silt	Clay	pH	% C	% N	C/N
8178 ..	0—4″	9·3	20·5	23·8	46·4	7·20	4·65	0·58	10·7
8179 ..	4—14″	3·2	20·9	28·9	47·0	7·25	1·62	0·23	9·3
8180 ..	14—23″	1·4	16·8	26·4	55·4	7·35	0·71	0·11	8·5
8181 ..	23—31″	0·9	16·8	24·7	57·6	6·75	0·45	0·09	6·7
8182 ..	31—38″	0·7	16·5	20·7	62·1	6·90	0·35	0·08	5·9
8183 ..	38—42″	0·4	26·4	16·9	56·3	5·55	0·22	0·06	4·8
8184 ..	42—50″	0·4	18·1	10·4	71·1	5·20	0·21	0·01	5·6

Lab. No.	Depth	Ca	Mg	Mn	K	Na	Total	Ex H	B.E.C.	% Sat
8178	0—4″	24·10	3·50	0·18	2·17	—	28·8	3·8	33·6	88
8179	4—14″	17·20	4·50	0·015	1·75	—	23·5	2·5	26·0	90
8180	14—23″	6·50	3·10	—	2·00	—	11·6	3·4	15·0	77
8181	23—31″	4·70	4·30	0·011	2·75	—	11·8	5·4	17·2	68
8182	31—38″	1·88	3·00	0·017	2·18	—	7·1	8·2	15·3	47
8183	38—42″	2·50	2·15	—	1·85	—	6·5	9·2	15·7	41
8184	42—50″	2·50	2·40	0·019	1·20	—	6·1	8·5	14·6	41

Location: Muguga.
Site: U/S.
Drainage: Free.
Altitude: 7,000 ft.
Rainfall: 38″.

0— 8″ Dark reddish-brown (5YR 3/4) light humic crumbly friable clay.
8—22″ Dark red (2.5YR 3/6) subangular blocky friable clay.
22—33″ Dark red (2.5YR 3/8) subangular blocky friable clay with sl. clay skin development.
33—48″ Dark red (2.5YR 3/8) subangular blocky friable clay with clay skins.
48—59″ Same as above with fragments of rotten rock.
59—75″ Same as above more rotten rock.
75″+ Weathering trachyte.

Profile No. 47/47

Lab. No.	Depth	O.M.	C.S.	F.S.	Silt	Clay	pH	% C	% N	C/N
7803	0— 8″	8·60	9·0	12·0	12·5	49·5	6·7	4·3	0·410	7·9
7804	8—22″	2·86	10·0	11·9	13·5	58·7	5·0	0·4	0·125	8·6
7805	22—33″	1·12	10·4	8·4	13·0	58·7	4·85	0·56	0·075	7·1
7806	33—48″	0·80	8·7	6·5	12·5	71·4	4·5	0·40	0·065	6·2
7807	48—59″	0·42	14·0	42·3	14·0	13·3	4·4	0·21	0·015	—
7808	59—75″	0·86	4·4	8·0	59·0	14·3	4·6	0·43	0·045	9·6
7809	75″+	0·34	13·3	35·0	15·0	20·9	4·6	0·17	0·005	—

Lab. No.	Depth	Ca	Mg	Mn	K	Na	Total	Ex H	B.E.C.	% Sat
7803	0— 8″	10·20	5·90	0·041	3·80	—	19·6	1·1	21·3	92
7804	8—22″	1·75	2·35	0·181	1·55	—	6·1	6·0	12·1	50
7805	22—33″	0·88	2·90	0·127	0·62	—	4·5	7·45	12·0	37
7806	33—48″	0·58	2·42	0·125	1·17	—	4·3	9·05	13·4	32
7807	48—59″	0·25	0·80	0·335	0·42	—	[illegible]	[illegible]	6·3	29
7808	59—75″	0·50	2·15	0·050	0·77	—	3·8	8·25	12·1	31
7809	75″+	0·06	0·18	0·035	0·42	—	1·9	5·05	7·0	27

Red Friable Clays (Latosolic Soils)

Location: Karura forest by School of Survey.
Site: Upper slope.
Drainage: Free.
Rainfall: 32″.

0—5″ Dark reddish-brown (2.5YR 3/4) sl. humic, weak crumbly friable clay.
5—22″ Dark red (2.5YR 3/6) weak subangular blocky friable clay.
22—30″ Red (2.5YR 4/6) weak subangular blocky friable clay with sl. clay skin development.
30—37½″ Red (2.5YR 4/6) weak subangular blocky friable clay with sl. clay skin development.

Profile No. 47/15

Lab. No.	Depth	O.M.	C.S. F.S.	Silt	Clay	pH	% C	% N	C/N
8482 ..	0—5″	2·80	13·6	8·8	74·8	5·5	1·40	0·180	10·3
8483 ..	5—22″	1·06	13·6	7·2	78·1	4·9	0·532	0·114	6·2
8484 ..	22—30″	0·72	11·2	9·7	78·4	4·5	0·361	0·104	4·6
8485 ..	30—37½″	0·97	11·3	9·6	78·1	4·5	0·484	0·115	5·6

Lab. No.	Depth	Ca	Mg	Mn	K	Na	Total	Ex H	B.E.C.	% Sat
8482	0—5″	4·1	3·9	0·112	1·05	—	9·0	8·4	17·4	51·7
8483	5—22″	1·2	1·95	0·064	0·51	—	3·7	9·0	12·7	29·1
8484	22—30″	0·32	2·40	0·132	0·43	—	3·3	10·3	13·6	24·2
8485	30—37½″	0·31	1·65	0·147	0·435	—	2·5	10·7	13·2	18·9

APPENDIX "A" (4*b*)

Location: West of Kangundo, Machakos—Kangundo Road.
Site: Middle slope.
Drainage: Free to sl. impeded.
Altitude: 5,500 ft.
Rainfall: 30″.

0— 8″ Dark reddish-brown (5YR 3/4) weak crumbly friable clay with coarse angular quartz gravel and occasional murram concretions.

8—15″ Red (2.5YR 4/6) weak subangular blocky friable clay with coarse angular quartz gravel and occasional murram concretions.

15—30″ Red (2.5YR 4/8) weak subangular blocky friable clay with few coarse angular quartz gravel and murram concretions.

30—57″ Massive red and black laterite.

Profile No. 48/3

Lab. No.	Depth	O.M.	C.S.	F.S.	Silt	Clay	pH	% C	% N	C/N
8830	0— 8″	1·8	20·1	17·1	9·2	41·8	6·1	0·91	0·110	12·1
8831	8—15″	1·0	15·7	21·3	10·6	51·4	6·0	0·50	0·080	8·3
8832	15—30″	0·7	13·4	16·9	12·1	56·9	6·0	0·39	0·075	6·9
8833	30—50″	0·3	56·0	14·2	4·0	25·5	6·0	0·15	0·045	4·4

Lab. No.	Depth	Ca	Mg	Mn	K	Na	Total	Ex H	B.E.C.	% Sat
8830	0— 8″	3·40	2·15	0·165	0·81	—	6·5	3·8	10·3	63·1
8831	8—15″	2·03	2·15	0·121	0·32	—	4·6	3·9	8·5	54·1
8832	15—30″	1·45	1·32	0·110	0·38	—	2·3	4·4	6·7	34·3
8833	30—50″	0·31	0·44	0·125	0·54	—	1·3	5·1	6·4	20·3

Dark Red Sandy Clay Loams (Latosolic Soils)

Location: Tawa—Mbooni road.
Site: L/S of Mbooni Hill.
Drainage: Free.
Altitude: 4,900 ft.
Rainfall: 26″.

0—12″ Dark red (2.5YR 3/6) weak crumbly sandy loam.
12—27″ Dark red (2.5YR 3/6) weak subangular blocky friable clay.
27—35″ Dark red (2.5YR 3/6) weak subangular blocky friable clay loam.

Profile No. 48/9

Lab. No.	Depth	O.M.	C.S.	F.S.	Silt	Clay	pH	% C	% N	C/N
8867	0—12″	0·8	64·8	9·8	5·3	19·3	6·3	0·465	0·060	10·3
8868	12—27″	0·9	33·4	8·8	15·7	41·2	6·3	0·44	0·060	9·7
8869	27—35″	0·6	32·2	20·3	8·7	38·2	6·7	0·29	0·045	8·6

Lab. No.	Depth	Ca	Mg	Mn	K	Na	Total	Ex H	B.E.C.	% Sat
8867	0—12″	1·18	0·74	0·098	0·62	—	2·6	1·7	4·3	60·4
8868	12—27″	1·06	0·73	0·026	0·84	—	2·7	1·7	4·4	61·2
8869	27—35″	1·95	1·50	0·085	0·32	—	3·7	1·8	5·5	67·3

Reddish-Brown Sandy Clay Loams

Location: Athi River—new Kitengela River.
Site: Upper slope.
Drainage: Free.
Altitude: 5,000 ft.
Rainfall: 23″.

0— 5″ Dark brown (10YR 4/3) crumbly sl. humic, friable sandy clay loam with occasional Fe_2O_3 concretions.

5—12″ Dark reddish-brown (5YR 3/4) weak subangular blocky friable sandy clay loam with occasional coarse quartz gravel and Fe_2O_3 concretions.

12—18″ Reddish-brown (5YR 4/4) weak subangular blocky friable sandy clay with small angular quartz stones, coarse quartz gravel and concretions.

18—30″ Reddish-brown (5YR 4/4) weak subangular blocky friable sandy clay loam passing into weathering tuff.

Profile No. 47/26

Lab. No.	Depth	O.M.	C.S.	F.S.	Silt	Clay	pH	% C	% N	C/N
9416	0— 5″	2·8	35·7	28·1	12·2	21·2	7·2	1·38	0·132	13·9
9417	5—12″	1·0	29·6	26·4	12·2	30·8	6·6	0·50	0·096	7·0
9418	12—18″	1·5	23·2	25·1	14·2	36·0	6·5	0·73	0·105	9·2
9419	18—30″	1·3	23·6	28·2	17·1	29·8	7·0	0·67	0·090	9·9

Lab. No.	Depth	Ca	Mg	Mn	K	Na	Total	Ex H	B.E.C.	% Sat
9416	0— 5″	10·5	3·05	—	3·15	—	16·7	2·4	19·1	87·5
9417	5—12″	9·1	2·75	—	3·80	—	15·6	2·4	18·0	86·7
9418	12—18″	9·5	3·20	—	4·55	—	17·3	1·9	19·2	90·0
9419	18—30″	14·0	3·05	—	6·00	0·65	23·7	1·7	25·4	93·4

Yellow-Red Coarse Loamy Sands

Location: Eight and half miles North of Kangondi on Kitui—Embu road.
Site: Middle slope.
Drainage: Free.
Altitude: 4,200 ft.
Rainfall: 30″.

0— 6″ Brown (7.5YR 5/4) weak crumbly to loose structureless loamy coarse sand.
6—16″ Reddish-brown (5YR 4/4) structureless loose loamy coarse sand.
16—32″ Yellow-red (5YR 4/6) structureless loose loamy coarse sand.
32—44″ Yellow-red (5YR 4/8) structureless, loose coarse sandy loam.

Profile No. 41/2

Lab. No.	Depth	O.M.	C.S.	F.S.	Silt	Clay	pH	% C	% N	C/N
12062 ..	0— 6″	0·9	55·3	31·6	—	6·1	5·5	0·477	0·059	10·7
12063 ..	6—16″	0·6	59·2	27·6	—	6·1	5·3	0·317	0·040	10·5
12064 ..	16—32″	0·4	60·6	26·2	—	8·1	5·2	0·209	0·030	9·3
12065 ..	32—44″	0·3	50·1	29·6	—	12·1	5·2	0·169	0·030	7·5

Lab. No.	Depth	Ca	Mg	Mn	K	Na	Total	Ex H	B.E.C.	% Sat
12062 ..	0— 6″	0·8	0·6	0·11	0·41	—	2·0	5·3	7·3	27
12063 ..	6—16″	0·8	0·5	0·051	0·39	—	1·7	5·5	7·2	24
12064 ..	16—32″	0·4	0·3	0·029	0·31	—	1·0	5·4	6·6	16
12065 ..	32—44″	0·3	0·4	0·028	0·29	—	1·0	6·2	7·2	14

RED FRIABLE CLAYS WITH LATERITE HORIZON

Location: Seven miles from Kithimani.
Site: Level.
Drainage: Slightly impeded.
Altitude: 4,300 ft.
Rainfall: 26″.

0— 7″ Reddish-brown (5YR 4/4) slightly compacted structureless sandy clay, friable.
7—16″ Red (2.5YR 4/8) weak subangular blocky friable sandy clay loam with a few quartz stones.
16—23″ Red (2.5YR 5/8) weak subangular blocky friable sandy clay loam.
23—30″ Red (2.5YR 5/8) compact structureless, friable sandy clay loam with black MnO_2 concretions passing into massive laterite.

Profile No. 48/59

Lab. No.	Depth	O.M.	C.S.	F.S.	Silt	Clay	pH	% C	% N	C/N
11610 ..	0— 7″	2·1	32·8	30·0	—	37·0	6·0	1·05	0·090	15·5
11611 ..	7—10″	1·2	24·6	29·8	—	31·0	5·4	0·62	0·070	11·8
11612	10—23″	1·0	20·7	31·7	—	32·0	5·7	0·48	0·064	10·0
11613 ..	23—30″	1·1	26·0	29·3	—	30·2	5·9	0·56	0·071	10·5

Lab. No.	Depth	Ca	Mg	Mn	K	Na	Total	Ex H	B.E.C.	% Sat
11610 ..	0— 7″	4·30	1·50	0·054	1·05	—	6·9	4·7	11·6	59·5
11611 ..	7—10″	2·70	0·61	0·12	0·54	—	4·0	4·8	8·8	45·5
11612 ..	10—23″	3·22	1·15	0·090	0·34	—	4·8	4·4	9·2	52·2
11613 ..	23—30″	3·30	1·72	0·11	0·63	—	5·7	4·2	9·9	57·6

YELLOW-RED SANDY CLAY LOAMS WITH LATERITE HORIZON

Location: Quarter mile from Yatta Camp.
Site: Slight slope.
Drainage: Slightly impeded.
Altitude: 4,000 ft.
Rainfall: 22″.

0— 5″ Dark reddish-brown (5YR 3/4) sl. compacted structureless coarse sand loam.
5—12″ Yellow-red (5YR 4/8) weak subangular blocky friable sandy clay loam.
12—18″ Yellow-red (5YR 4/6) weak subangular blocky friable sandy clay loam.
18—30″ Yellow-red (5YR 5/8) sl. compact, subangular blocky friable sandy clay loam with murram concretions.
30—44″ Laterite horizon, massive, consisting of angular quartz stones and black and red laterite.

Profile No. 48/57

Lab. No.	Depth	O.M.	C.S.	F.S.	Silt	Clay	pH	% C	% N	C/N
11605 ..	0— 5″	0·8	51·8	23·7	19·4	14·3	6·2	0·81	0·090	12·0
11606 ..	5—12″	1·1	47·5	21·5	5·1	24·8	5·9	0·57	0·070	10·8
11607 ..	12—18″	1·0	37·8	24·9	5·2	31·1	6·0	0·48	0·070	9·1
11608 ..	18—30″	1·1	35·7	17·6	13·6	32·0	5·9	0·56	0·070	10·6
11609 ..	30—44″	0·9	37·8	22·2	—	40·0	5·9	0·46	0·080	7·7

Lab. No.	Depth	Ca	Mg	Mn	K	Na	Total	Ex H	B.E.C.	% Sat
11605 ..	0— 5″	4·60	1·93	0·059	1·18	—	7·8	2·8	10·6	73·5
11606 ..	5—12″	5·0	2·35	0·10	0·94	—	8·4	3·4	11·8	71·2
11607 ..	12—18″	4·92	2·72	0·056	0·80	—	8·5	3·2	11·7	72·7
11608 ..	18—30″	4·60	2·72	0·035	0·55	—	7·9	4·0	11·9	66·5
11609 ..	30—44″	5·25	2·45	0·063	0·30	—	8·2	3·8	12·0	68·5

BROWN SANDY CLAY LOAMS WITH LATERITE HORIZON

Location: Yatta camp Kitui.
Site: Gentle slope.
Drainage: Slightly impeded.
Altitude: 4,000 ft.
Rainfall: 25″.

0— 6″ Dark brown (10YR 4/2) compact, weak subangular blocky loamy coarse sand.
6—12″ Dark brown (10YR 4/3) weak subangular blocky coarse sandy loam.
12—19″ Brown (10YR 5/4) weak subangular blocky coarse sandy loam with occasional murram concretions.
19—34″ Massive laterite with abundant quartz stones in first nine inches; lower surface consolidated, broken laterite reddish with black cores.

Profile No. 48/51

Lab. No.	Depth	O.M.	C.S.	F.S.	Silt	Clay	pH	% C	% N	C/N
11561 ..	0— 6″	1·8	61·7	22·0	4·3	10·2	6·1	0·90	0·068	17·6
11562 ..	6—12″	1·8	51·0	26·4	6·6	14·2	6·1	0·93	0·077	16·0
11563 ..	12—19″	0·8	56·2	21·2	6·4	15·4	6·0	0·38	0·065	7·8
11464 ..	19—34″	2·6	51·4	25·7	3·7	16·6	5·9	1·29	0·085	20·0

Lab. No.	Depth	Ca	Mg	Mn	K	Na	Total	Ex H	B.E.C.	% Sat
11561 ..	0— 6″	2·55	1·82	0·079	0·76	—	5·2	2·4	7·6	68·5
11562 ..	6—12″	2·60	1·62	0·089	0·66	—	5·0	2·9	7·9	63·3
11563 ..	12—19″	2·73	1·92	0·11	0·21	—	5·0	2·9	7·9	63·3
11564 ..	19—34″	2·88	3·0	0·077	0·31	—	6·3	3·5	9·8	64·3

Shallow Yellow-Brown to Yellow-Red Friable Clays Overlying a Laterite Horizon or Rock

Location: Kamiti turn-off on Thika—Nairobi road.
Site: Flat.
Drainage: Slightly impeded.
Altitude: 5,200 ft.
Rainfall: 33″.

0— 5″ Brown (10YR 5/3) sl. humic, crumbly friable caly with occasional rounded murram concretions.
5—12″ Yellow-brown (10YR 5/3) subangular blocky friable clay with occasional rounded murram concretion.
12—20″ Mainly murram concretion.
20″+ Massive murram.

Profile No. 47/16

Lab. No.	Depth	O.M.	C.S. F.S.	Silt	Clay	pH	% C	% N	C/N
8506 ..	0— 5″	3·84	18·5	26·2	51·5	5·7	1·92	0·221	11·5
8507 ..	5—12″	1·71	20·8	21·9	55·6	5·6	0·805	0·138	7·8
8508 ..	12—20″	1·43	34·0	13·5	51·1	6·0	0·714	0·125	7·6

Lab. No.	Depth	Ca	Mg	Mn	K	Na	Total	Ex H	B.E.C.	% Sat
8506	0— 5″	4·20	2·60	0·257	1·68	—	8·7	10·1	18·8	46·2
8507	5—12″	3·40	1·35	0·188	0·89	—	5·8	10·4	16·2	35·8
8508	12—20″	4·25	1·32	0·097	0·96	—	6·6	8·4	15·0	44·0

Dark Greyish-Brown Calcareous Clays (Rendzenic Soils)

Location: Five miles south of Athi Camp on Athi—Namanga road.
Site: U/S.
Drainage: Impeded.
Altitude: 5,174 ft.
Rainfall: 34″.

0—4″ Very dark grey (10YR 3/1) fine crumbly clay with fine angular quartz gravel.
4—11″ Very dark grey (10YR 3/1) fine angular blocky clay with fine angular quartz gravel.
11—19″ Very dark grey (10YR 3/1) fine angular blocky clay with fine angular quartz gravel and fragments of chalcodoney and $CaCO_3$ concretions.
19—29″ Dark greyish brown (2.5YR 4/2) angular blocky clay with abundant $CaCO_3$ concretions a little fine angular quartz gravel and few small stones of chalcodoney.
29—40″ Dominant $CaCO_3$ concretions with a little clay.
40—60″ Rotten tuff weathering through lime.

Profile No. 47/35

Lab. No.	Depth	O.M.	C.S.	F.S.	Silt	Clay	pH	% C	% N	C/N
9603	0—4″	1·8	10·4	25·0	16·0	46·8	6·7	0·92	0·107	11·4
9604	4—11″	1·4	9·8	26·5	7·8	54·5	7·2	0·68	0·080	11·3
9605	11—19″	1·5	9·5	26·7	7·6	54·7	8·2	0·77	0·063	16·3
9606	19—28″	0·7	17·9	24·6	6·1	50·7	8·3	0·35	0·075	6·2
9607	28—40″	1·0	14·8	19·3	15·1	49·4	8·6	0·50	0·070	9·5
9608	40—60″	0·2	11·8	41·3	13·0	33·7	8·2	0·09	0·035	3·4

Lab. No.	Depth	Ca	Mg	Mn	K	Na	Total	Ex H	B.E.C.	% Sat
9603	0—4″	24·5	6·60	0·005	2·95	0·90	35·0	4·6	39·6	88·4
9604	4—11″	32·0	7·00	0·005	2·50	1·45	42·9	2·6	45·5	94·4
9605	11—19″	35·0	8·20	0·003	2·40	2·00	47·6	—	47·6	100
9606	19—28″	40·0	9·60	0·010	3·25	3·20	56·1	—	56·1	100
9607	28—40″	36·0	9·00	0·003	5·80	5·80	56·6	—	56·6	100
9608	40—60″	34·5	8·40	0·005	6·40	5·90	55·2	—	55·2	100

Dark Grey to Dark Greyish Brown Calcareous Clays with Light Textured Toposil

Location: Athi Camp, Athi—Namanga road.
Site: Summit.
Drainage: Impeded.
Altitude: 5,174 ft.
Rainfall: 23″.

0— 4″ Dark greyish-brown (2.5Y 4/2) fine crumbly loam.
4—14″ Dark grey (10YR 4/1) angular blocky clay.
14—30″ Dark greyish-brown (2.5Y 4/2) fine angular blocky clay.
30—45″ Dark greyish-brown (2.5Y 4/2) fine angular blocky clay.
45″ + Kunkar.

Profile No. 47/34

Lab. No.	Depth	O.M.	C.S.	F.S.	Silt	Clay	pH	% C	% N	C/N
9599	0— 4″	3·7	7·8	29·9	31·9	26·7	7·8	1·84	0·215	11·4
9600	4—14″	2·2	11·8	24·2	16·1	45·7	7·2	1·10	0·142	10·3
9601	14—30″	0·9	9·6	22·3	15·5	51·7	7·0	0·46	0·085	7·2
9602	30—45″	0·8	7·8	28·8	16·8	45·8	8·0	0·41	0·073	7·4

Lab. No.	Depth	Ca	Mg	Mn	K	Na	Total	Ex H	B.E.C.	% Sat
9599	0— 4″	36·0	4·80	0·003	5·20	—	46·0	—	46·0	100
9600	4—14″	23·5	5·10	0·003	5·90	—	34·5	4·4	38·0	88·8
9601	14—30″	21·0	4·30	0·005	8·00	—	33·3	2·5	35·8	93·1
9602	30—45″	24·5	6·20	0·003	7·80	—	38·5	0·2	38·7	99·5

Black to Dark Grey Clays (Grumosolic Soils)

Location: Athi plains.
Site: Flat.
Drainage: Impeded.
Altitude: 5,300 ft.
Rainfall: 33″.

0—5″ Very dark grey (10YR 3/1) humic, angular blocky plastic clay cracks when dry.
5—11″ Very dark grey (10YR 3/1) angular blocky plastic clay cracks when dry.
11—19″ Dark grey (10YR 4/1) angular blocky plastic clay.
19—28″ Grey (10YR 5/1) structureless plastic clay with occasional $CaCO_3$ concretions.
28″+ Phonolite rock.

Profile No. 47/24

Lab. No.	Depth	O.M.	C.S.	F.S.	Silt	Clay	pH	% C	% N	C/N
9377	0—5″	3·1	3·7	29·6	16·9	46·7	7·1	1·57	0·180	11·6
9378	5—11″	2·5	3·1	29·4	24·4	40·6	6·5	1·27	0·140	12·1
9379	11—19″	1·5	2·2	30·3	18·7	47·3	6·6	0·75	0·086	11·6
9380	19—28″	2·0	2·0	33·8	19·5	42·7	7·6	1·06	0·133	10·6
9381	28″+	0·7	47·0	21·5	24·1	6·7	8·3	0·47	0·045	10·1

Lab. No.	Depth	Ca	Mg	Mn	K	Na	Total	Ex H	B.E.C.	% Sat
9377	0—5″	40·0	6·8	0·008	0·63	0·86	48·2	2·8	51·0	94·5
9378	5—11″	40·1	5·0	0·013	0·26	0·70	46·2	3·1	49·3	93·7
9379	11—19″	29·7	4·3	0·011	0·30	—	34·3	3·4	37·7	91·7
9380	19—28″	40·0	5·2	—	0·35	—	45·6	—	45·6	100
9381	28″+	30·0	4·7	—	—	0·78	34·7	—	34·7	100

Dark Greyish-Brown Mottled Clays (Gley Soils, Vlei Soils)

Location: Jacaranda Coffee Estate, Ruiru.
Site: Bottom.
Drainage: Impeded.
Altitude: 5,400 ft.
Rainfall: 38″.

0— 5″ Dark greyish-brown (10YR 4/2) humic, angular blocky plastic clay with orange root channels.
5—12″ Dark grey (10YR 4/1) angular blocky plastic clay with orange mottling.
12—18″ Dark greyish-brown (10YR 4/2) angular blocky plastic clay with orange mottling.

Profile No. 47/10

Lab. No.	Depth	O.M.	C.S. F.S.	Silt	Clay	pH	% C	% N	C/N
8473 ..	0— 5″	4·30	20·0	15·1	60·6	5·7	2·13	0·238	12·0
8474 ..	5—12″	3·50	17·1	22·3	57·1	5·7	1·75	0·217	10·7
8475 ..	12—18″	1·84	10·8	20·0	67·4	5·7	0·92	0·141	8·7

Lab. No.	Depth	Ca	Mg	Mn	K	Na	Total	Ex H	B.E.C.	% Sat
8473	0— 5″	8·0	2·00	0·352	0·96	1·60	12·9	12·3	25·2	51·2
8474	5—12″	10·6	2·20	0·308	0·88	1·75	15·7	10·2	25·9	60·6
8475	12—18″	12·5	2·45	0·328	0·86	1·70	17·8	8·9	26·7	66·6

APPENDIX "A" (16)

Dark Grey Compacted Loamy Sands (Solidized-Solonetzic Soils)

Location: Lower slopes of Mua Hills—west side.
Site: Lower slope.
Drainage: Impeded.
Altitude: 5,600 ft.
Rainfall: 30″.

0— 8″ Dark grey (10YR 4/1) compacted, sturctureless loamy coarse sand.
8—24″ Grey (10YR 5/1) compacted, angular blocky plastic coarse sandy clay loam with sl. yellow and orange mottling.

Profile No. 48/24

Lab. No.	Depth	O.M.	C.S.	F.S.	Silt	Clay	pH	% C	% N	C/N
8828	0— 8″	0·8	76·8	11·1	3·2	8·1	6·3	0·43	·040	14·3
8829	8—24″	—	56·5	11·9	—	31·6	6·3	0·19	·050	5·0

Lab. No.	Depth	Ca	Mg	Mn	K	Na	Total	Ex H	B.E.C.	% Sat
8828	0— 8″	2·0	0·72	0·042	0·22	—	3·0	0·8	3·8	97·4
8829	8—24″	7·4	3·30	0·019	0·57	—	11·3	1·1	12·4	91·2

APPENDIX B

METHODS OF ANALYSES USED

1. *pH* was determined using a soil: water ratio of 1:5 and measured by the glass electrode.
2. *Carbon* was determined using the wet oxidation method of Walkley and Black. Values quoted are uncorrected.
3. *Nitrogen* was determined by the Kjeldahl method.
4. *C/N ratio* is calculated from the corrected carbon value (uncorrected % C × 1.33).
5. *Organic matter* is given by uncorrected carbon × 2.
6. *Mechanical Analyses* were made using the Bouyoucos soil hydrometer. The soils were dispersed with sodium hydroxide and sodium silicate and shaken overnight in an end-over-end shaker. Clay and total silt and clay were obtained from the hydrometer readings, the coarse sand fraction was determined by sieving fine sand by decantation and silt by difference.
7. *Exchangeable Bases* were extracted using neutral normal ammonium acetate in the ratio of 1 part of soil to 10 parts of extracting solution.

   Ca, Mg, Na, K, Mn, were determined spectrographically using a Modified Lundegardh Flame Emission Method.

   Exchangeable Hydrogen was determined on the ammonium acetate extract using the Quinhydrone electrode.

   Carbon, Nitrogen, Organic Matter and Mechanical Analyses figures are expressed on percentages.

   Base Exchange data are expressed as m.e. per 100 gms.

APPENDIX C

DETAILED SOIL SURVEY OF THE COFFEE RESEARCH STATION, RUIRU

Soil survey in the Central Province of Kenya is being carried out about the Soil Association level, supplemented by more laborious and detailed survey at about the level of Soil Series and phases of same over small representative areas. The latter detailed survey is useful in that it gives the opportunity to study and map transitional soil conditions. It also shows the effects of varied and combined influences of soil forming factors and offers guidance in that one can more readily anticipate soil changes during soil mapping.

The Coffee Research Station land, comprising 658 acres situated at the confluence of the Ruiru and Komassia rivers, was chosen as a representative site for such a soil survey. The land is situated within the general belt of country where the pronounced ridges, separated by consequential streams, merge into lower country with only slightly elevated, broad ridges which contain wettish depressions or "vleis" and also much shallow soil overlying sheet laterite or "murram". This land in turn merges into the dark coloured, heavy soils of the plains. It happens that within the area surveyed, one finds most of the soil classes that occur both in the ridge country at this elevation and also those associated with a smoother topography.

Soil-forming Processes

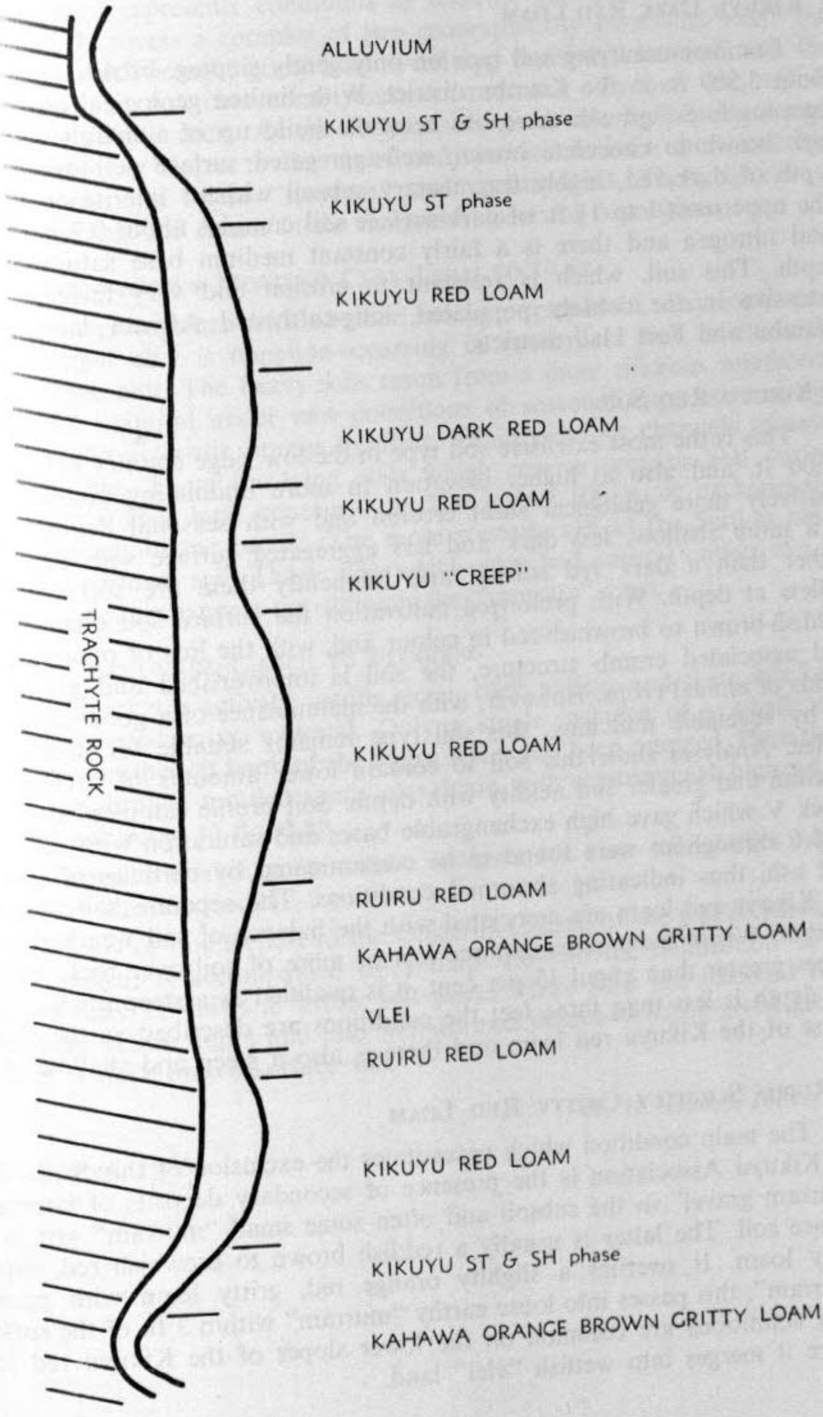
The rock formation comprises gently sloping, Tertiary trachytic lava derived from now covered over ancient fissures on the eastern flank of the Rift Valley. Under conditions of warmth and long-continued leaching under acid conditions, there has been the almost complete decomposition of the original rock minerals with the loss of silica and bases and with the accumulation of secondary iron and aluminium compounds; that is, soil weathering towards laterization. However, the residual soil is not senile and still has a fairly high base-holding capacity, and highly desirable physical properties. It is naturally-well-drained with a high pore space, and though it contains a high percentage of clay complex as shown by analysis, the latter is not as reactive as siliceous clay, and the field texture of the soil is about that of a friable loam. It has a favourable crumb structure and the surface soil is self-mulching when dry. With the retention of a highly porous surface soil with a good crumb structure, it is resistant to erosion, and, on the tops of the ridges, attains a great depth—up to 20 ft. or more.

It is interesting to note how such conditions which are applicable to mainly sedentary soils on not more than gentle slopes are modified by different topography and associated drainage. Where the land is more level, as on the broad ridge near the residential area, erosion has long been negligible. Here there has been a build-up of a foot or more of a dark brown to chocolate brown fertile surface soil over a dark red subsoil. Off the more level land, there is about 5 to 8 in. depth of a reddish-brown to brownish-red loamy surface soil over a red subsoil, often with some pisolitic "murram" below the fourth foot. The former soil conditions are similar to those of the best coffee lands immediately above Kiambu; whereas the more highly coloured soil which, incidentally, carries the greater portion of coffee at the Station, is similar to most of the lower coffee land extending from Ruiru to Thika. Within naturally-well-drained depressions and on the lower more gentle slopes, slow gravitational creep of surface soil from higher land has given pockets where there is a greater accumulation of a dark brown, well-aggregated surface soil. Where the Ruiru and Komasaia rivers on either sides of the estate have cut down valleys, there are steep slopes often with shallow soils. Where the drainage remains good, the soil is similar in morphology to that on the higher, more gentle slopes, except that the humic surface soil is less defined and more shallow. The local conditions necessitate the allocation of three soil phases to allow for steep slope, shallow soil, and a combination of both these factors. Where there has been impeded drainage in the past, mainly due to seasonal seepage waters, such as in the long depression running down the middle of the farm and on the margins of sumps, there has been a deposition of concretionary laterite or "murram". In the lowest, more protected portions where the land is still seasonally wet, the undisturbed ancient sheet laterite is overlaid by a slightly orange-brown surface soil over a brownish-orange subsoil, with bright orange and black mottling. On more sloping and generally higher land, now adequately drained, the relic laterite has disintegrated and is contributing to soil formation. Some such land is under coffee in block III. A separate classification has to be allowed for shallow, gritty, orange-brown surface soil over an orange-red subsoil with laterite concretions. Locally, a similar soil overlies an orange-strained, weathering rock following the removal of most of the once overlying murram. Such conditions occur on low sloping shelves off the lower reaches of the two rivers and also bordering the "vleis". Where material has been water-borne and deposited in depressions, the original soil structure and high colour have been destroyed and subsequent weathering under more anaerobic conditions has given rise to a compact, brownish grey, clay with orange mottling, overlaid by an orange brown clay. In poorly-drained depressions, the soil contains higher amounts of exchangeable manganese and also of sodium. It was noted that long-continued cultivation of sloping land had temporarily modified the colour and structure of the surface soil and locally there had been slight accelerated sheet erosion. This gave soil differences alongside the boundaries of different blocks of land, but it has not been possible to map them. With a knowledge of the varied genetic factors which have given rise to different kinds of soil in any area, soil sequences can be more readily anticipated and soil mapping is facilitated.

Soil Classification

The soils have been classified and mapped into seven Soil Series with additional phases to allow for seasonal impeded drainage, steepness of slope, shallowness of the soil and a combination of the latter two factors. The texture of the surface soil is normally used as a further classification of Soil Series to give soil types. In the area surveyed, except in the case of "vleis", dominated by seasonal impeded drainage, any appreciable difference in soil texture is associated with other soil conditions which necessitate the formation of separate Soil Series. Not all kinds of soil noted in this detailed survey have as yet been given generic names and are here denoted under descriptive phrases. Three of the more extensive Soil Series (or types) belonging to the Kikuyu Soil Association, for the present retain the same generic Soil Association name with added colour descriptions to denote the Soil Series.

Block diagram showing topographical relationships of soil series and phases.



The classification made is as follows:—

1. Kikuyu Dark Red Loam

Common-occurring soil type on only gently sloping, broad ridges above about 5,500 ft. in the Kiambu district. With limited geological erosion and vigorous forest growth there has been the build up of a mainly sedentary, dark brown to chocolate brown, well-aggregated surface soil over a great depth of dark red, highly fragmentary subsoil without laterite concretions. The uppermost 1 to 1½ ft. of dark surface soil contains about 0.2 per cent of total nitrogen and there is a fairly constant medium base saturation with depth. This soil, which is resistant to erosion and very fertile, is very extensive in the densely populated, long-cultivated African lands of the Kiambu and Fort Hall districts.

2. Kikuyu Red Soil

This is the most extensive soil type in the low ridge country below about 5,500 ft. and also at higher elevation in more undulating country. With relatively more geological sheet erosion and with seasonal drought, there is a more shallow, less dark and less aggregated surface soil, over a red rather than a dark red subsoil and frequently there are soft "murram" pellets at depth. With prolonged cultivation the surface soil changes from reddish-brown to brownish-red in colour and, with the loss of organic matter and associated crumb structure, the soil is impoverished and gives lower yields of annual crops. However, with the maintenance of a good surface soil or by vegetable mulching, this soil type remains suitable for deep-rooting coffee. Analyses show this soil to contain lower amounts of exchangeable calcium and greater soil acidity with depth. Soil profile samples taken from block V which gave high exchangeable bases and saturation with pH values of 6.6 throughout were found to be contaminated by particles of charcoal and ash, thus indicating abnormal conditions. The separate soil phases of the Kikuyu red loam are associated with the balance of soil weathering and erosion. Where there remains three feet or more of soil over rock, even on slopes greater than about 15 per cent, it is qualified as a steep phase. Where the depth is less than three feet the conditions are described as the shallow phase of the Kikuyu red loam and there is also a steep and shallow phase.

3. Ruiru Slightly Gritty Red Loam

The main condition which necessitates the exclusion of this Series from the Kikuyu Association is the presence of secondary deposits of laterite or "murram gravel" in the subsoil and often some small "murram" grit in the surface soil. The latter is usually a reddish brown to brownish red, slightly gritty loam. It overlies a slightly orange red, gritty loam with pisolitic "murram"; this passes into loose earthy "murram" within 3 ft. of the surface. Such conditions are common on the lower slopes of the Kikuyu red loam where it merges into wettish "vlei" land.

4. Kahawa Orange-brown Gritty Loam

This series represents conditions of extreme geological erosion giving shallow soil. It covers a complex of two geographically associated soils: the one is a brownish-orange, gritty loam overlying massive "murram" and the other is a similar soil over some residual "murram" only over and within weathering trachyte rock. At the Research Station, this Soil Series occurs both on the lower slopes to the rivers and also within once more swampy narrow depressions where "murram" had accumulated. There is also a wet phase of this Soil Series in the lowermost parts of depressions.

5. Vlei: Grey-brown Mottled Clay Loam to Clay

This Series together with another having a grey-black clay loam over a grey mottled clay is common-occurring in country of low relief in the Kiambu coffee belt. The heavy soils result from a more siliceous weathering of deposited material under new conditions of seasonal impeded drainage. There is a characteristic orange mottling within old root channels throughout the profile. These low-lying soils which receive seepage and surface waters from higher land contain 1 to 2 m.e. per 100 g. of exchangeable sodium throughout the profile. The more westerly vlei at the Station has a more orange brown soil. Those vleis which once had natural outlets can be drained by open channels cut through the "murram" rims.

6. Recent Alluvium Liable to Flooding

Both rivers are actively cutting down their valleys and there has been very little deposition of material. Only a single instance of a small strip of alluvium on the left bank of the Ruiru River has been mapped. Here there is an orange-brown, mottled sandy clay loam with a permanent high water-table and subjected to flooding.

The appendix table gives certain analyses for nine soil profiles representing the classified soils.

The copy of this Report to the Officer-in-Charge of the Coffee Research Station, Ruiru, is accompanied by a map showing the delineation of the classified soils. It shows a further soil phase where slow gravitational creep on to more gentle slopes and into well-drained depressions has given greater depth of a dark brown surface soil.

G. H. Gethin-Jones.

22nd August, 1953.

Lab. Ref. No.	Depth Sampling inches	Moisture	O.M.	Sand	Silt	Clay	C^1%	N%	C^2/N	Ca	Mg	Mn	K	Na	T.E.B.	Ex.H	B.E.C.	% Sat	pH
		Mechanical Analysis								Ex. Bases me. per 100g. Soil									
Kikuyu Dark Red Loam (Site 5 of Block 7).																			
8446 ..	0—5	5·4	4·2	14·2	9·7	71·9	2·11	0·21	13·5	4·4	2·3	0·049	0·97	—	7·7	10·1	17·8	43	6·0
47 ..	5—11	5·7	4·0	12·9	6·7	76·4	1·98	0·19	13·7	4·8	2·4	0·030	0·40	—	7·7	9·5	17·2	45	5·8
48 ..	11—16	5·8	2·6	10·7	8·0	78·7	1·38	0·13	12·4	4·5	2·5	0·015	0·24	—	7·3	6·9	14·2	52	5·8
49 ..	16—31	6·0	1·6	12·7	9·0	76·7	0·80	0·11	9·4	4·1	2·4	—	0·16	—	6·7	5·6	12·3	56	6·0
Kikuyu Dark Red Loam (Site 3 Block 10).																			
8453 ..	0—8	4·6	5·2	16·2	9·2	69·4	2·6	0·25	13·6	7·0	2·1	0·031	2·37	—	11·5	8·9	20·4	56	5·9
54 ..	8—17	4·6	3·9	18·1	8·7	69·3	1·97	0·19	13·8	5·1	2·3	0·025	0·64	—	8·1	8·5	16·6	49	5·6
55 ..	17—26	4·9	1·7	12·8	9·0	76·6	0·83	0·11	10·4	4·0	2·2	0·012	0·26	—	6·4	5·2	11·6	55	6·1
56 ..	26—40	5·8	0·6	6·4	12·2	80·8	0·30	0·07	6·1	3·4	2·3	0·095	0·36	—	6·2	5·2	11·4	54	6·7
57 ..	40—48	5·8	0·5	6·4	12·3	80·8	0·23	0·06	5·3	1·4	2·1	0·09	0·80	—	4·4	4·4	8·8	50	6·6
Kikuyu Red Loam (Site 4 below Site 3).																			
8458 ..	0—10	5·6	4·5	13·4	13·5	68·6	2·27	0·28	10·9	7·9	2·4	0·011	2·63	—	12·9	7·0	19·9	65	6·6
59 ..	10—25	5·5	2·2	13·2	11·6	73·0	1·10	0·13	10·9	5·8	3·0	0·015	0·92	—	9·8	4·4	14·2	69	6·5
60 ..	25—41	5·5	1·2	11·2	9·3	78·3	0·60	0·11	7·5	0·9	2·4	0·016	0·41	—	3·7	7·8	11·5	32	5·3
61 ..	41—52	5·2	1·0	7·1	9·5	82·4	0·52	0·07	10·3	0·4	1·4	0·008	0·40	—	2·2	7·2	9·4	23	5·5
62 ..	52—72	5·3	0·4	11·4	10·1	78·1	0·20	0·05	4·9	0·3	1·7	0·009	0·46	—	2·5	6·1	8·6	29	5·5
63 ..	72—92	5·3	0·6	12·4	8·9	78·1	0·30	0·05	8·1	0·8	1·6	0·096	0·75	—	3·2	3·7	6·9	46	5·6
Kikuyu Red Loam (Site 5 Block 5).																			
8467 ..	0—4	4·9	4·8	14·7	16·3	64·2	2·4	0·25	12·7	8·6	3·9	0·008	2·90	—	15·5	2·7	18·2	85	6·6
68 ..	4—9	4·8	2·2	11·7	19·8	66·3	1·1	0·14	10·4	8·1	1·4	0·008	1·75	—	11·3	2·6	13·9	81	6·6
69 ..	9—28	4·5	2·2	11·9	21·0	64·9	1·1	0·10	14·6	6·5	1·6	0·008	1·27	—	9·4	2·4	11·8	80	6·6
Steep Phase of Kikuyu Red Loam (Site 2 below Block 7).																			
8450 ..	0—6	5·6	3·7	13·0	11·1	72·2	1·87	0·22	11·2	7·5	2·6	0·014	2·25	—	12·4	5·6	18·0	69	6·3
51 ..	6—19	5·6	1·9	13·0	8·7	76·4	0·95	0·12	10·4	3·3	1·9	0·027	1·25	—	6·6	6·5	13·1	50	5·7
52 ..	19—34	5·5	1·2	13·1	9·5	76·2	0·59	0·09	8·8	1·0	1·1	0·025	0·74	—	3·0	9·8	12·8	23	5·1
Ruiru Red Loam over Earthy Murram (Site 8 Block 3).																			
8476 ..	0—7	6·1	4·2	18·1	18·0	59·7	2·09	0·19	14·6	7·6	4·1	0·018	2·55	0·66	14·7	6·3	21·0	70	6·4
77 ..	7—17	7·2	2·6	17·2	15·5	64·7	1·28	0·14	12·0	6·5	3·2	0·028	0·92	0·66	11·4	8·3	19·7	58	5·6
78 ..	17—26	6·8	1·93	16·2	14·2	67·7	0·97	0·12	8·5	6·0	3·9	0·020	0·68	0·36	11·0	6·5	17·5	63	6·0
79 ..	26—36	7·6	0·85	21·8	17·3	58·7	0·42	0·10	5·6	6·3	3·5	0·011	0·59	—	10·4	4·4	14·8	70	6·5
Kahawa Orange Brown Loam over Murram (Site 6).																			
8470 ..	0—4	4·6	3·1	20·2	32·0	46·2	1·53	0·155	13·0	3·8	0·9	0·200	0·46	0·90	6·3	8·1	14·4	44	5·6
71 ..	4—8	5·1	2·6	28·3	19·5	49·6	1·28	0·161	10·6	3·4	0·6	0·265	0·48	1·22	6·0	8·1	14·1	43	5·8
72 ..	8—12	5·5	—	36·6	14·4	46·6	1·20	—	—	2·7	0·7	0·090	0·44	2·23	6·2	6·4	12·6	49	6·3
Kahawa Orange Brown Loam over Murram (Site 9 near confluence of river).																			
8480 ..	0—3	5·3	3·6	32·5	20·7	43·2	1·81	0·28	8·6	9·9	2·35	0·055	1·01	0·35	13·7	10·0	23·7	58	6·1
81 ..	3—8	5·4	3·0	32·3	19·2	45·5	1·49	0·27	7·2	7·9	4·6	0·017	0·75	—	13·3	9·6	22·9	58	6·0
Grey Brown Mottled Clay of Vleis (Site 7 east of Block 4).																			
8473 ..	0—5	7·4	4·3	20·0	15·1	60·6	2·13	0·238	12·0	8·0	2·0	0·352	0·96	1·60	12·9	12·3	25·2	51	5·7
74 ..	5—12	7·2	3·5	17·1	22·3	57·1	1·75	0·217	10·7	10·6	2·2	0·308	0·88	1·75	15·7	10·2	25·9	61	5·7
75 ..	12—18	7·9	1·8	10·8	20·0	67·4	0·92	0·141	8·7	12·5	2·4	0·328	0·80	1·70	17·8	8·9	26·7	67	5·7

C^1 by Walkley Black Method (not corrected). C^2 corrected to allow for total carbon.

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NAIROBI-MACHAKOS

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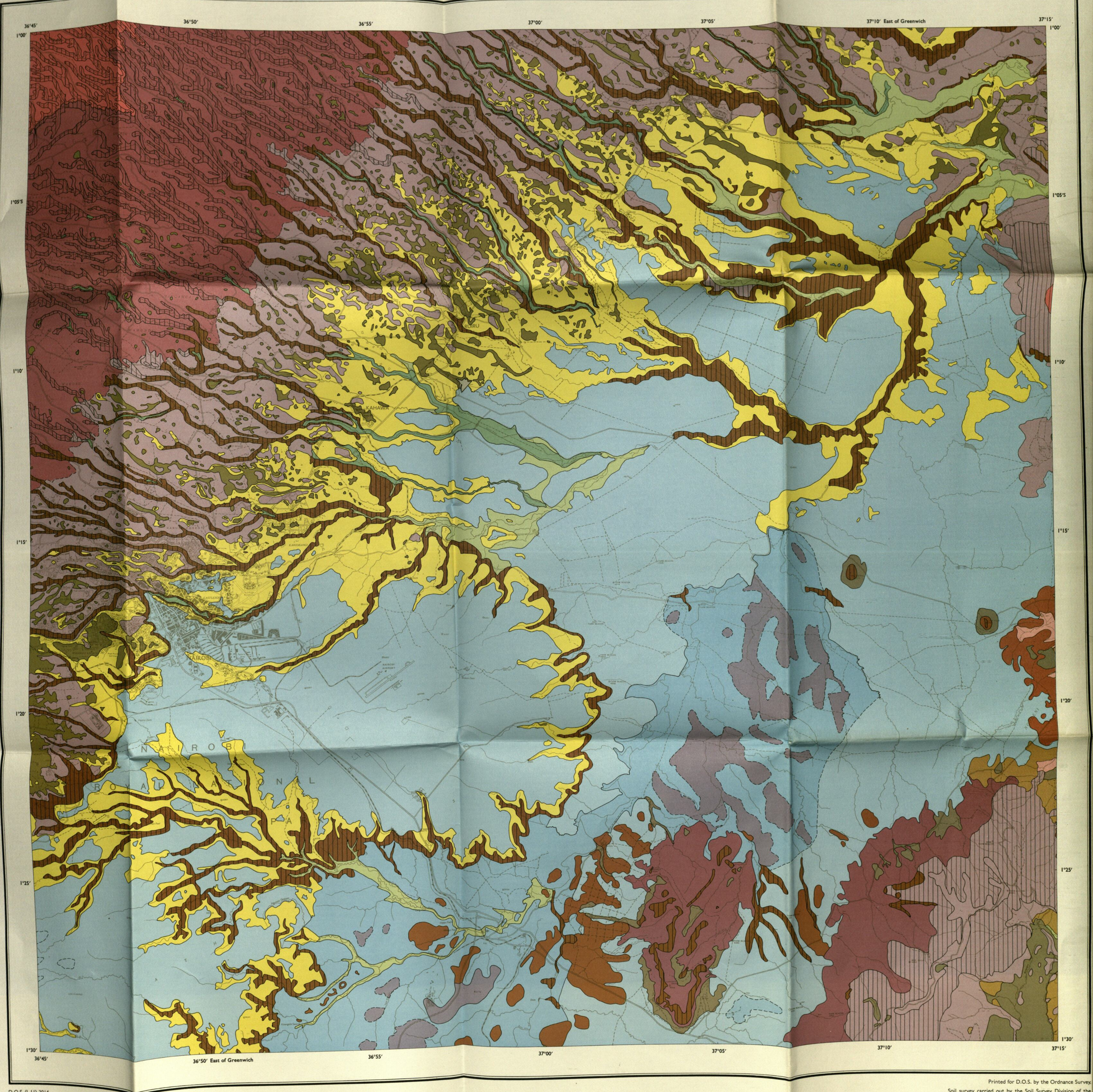

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NAIROBI-MACHAKOS

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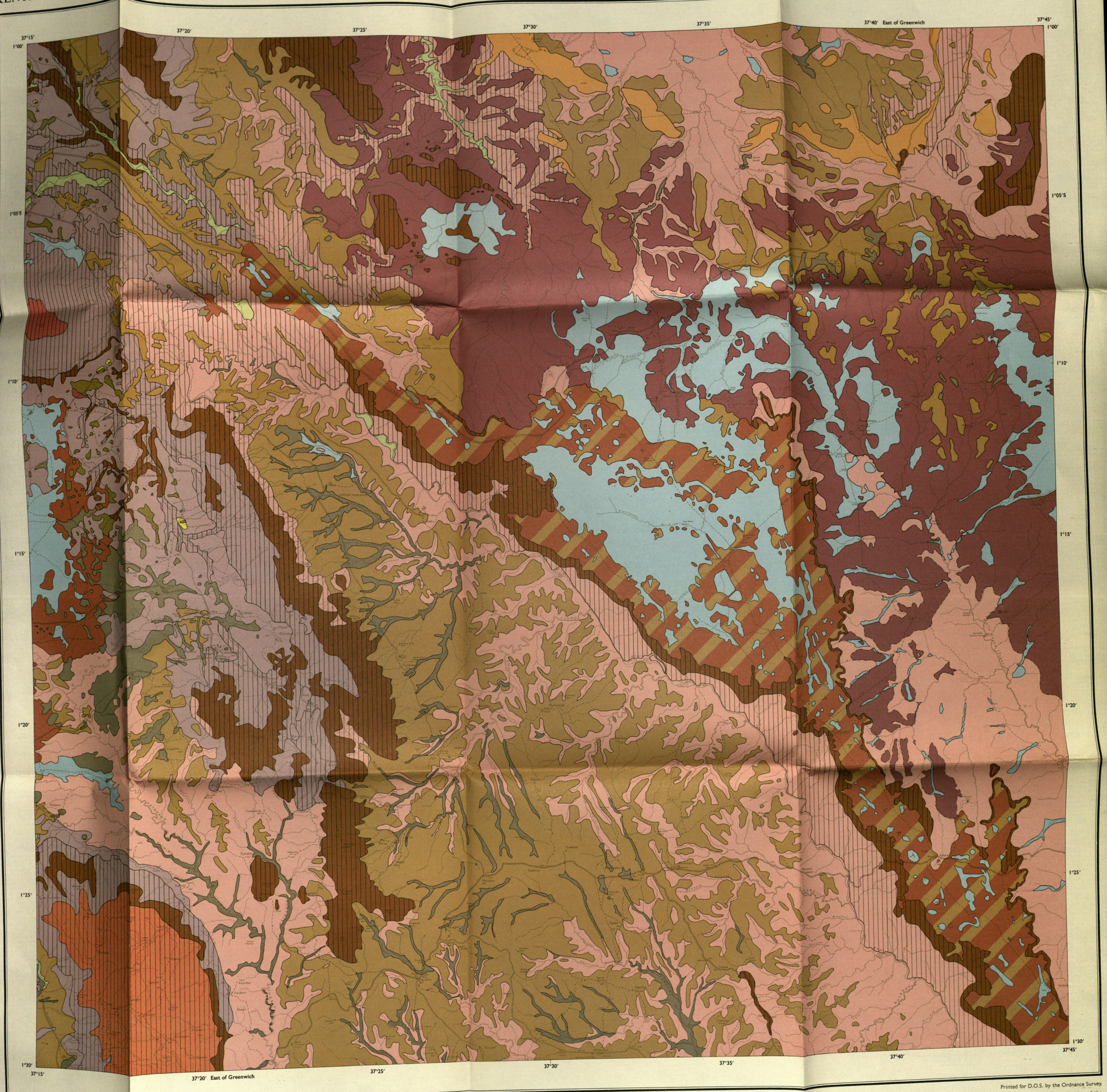

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1,000/4/63/1451/O.S.

Main Roads	Soil type boundary
Secondary Roads	Rivers
Tracks	Permanent buildings
Railways	Trigonometrical Points

- Strong brown to yellow-red friable clays (ando-like soils)
- Reddish-yellow sandy clay loams (latosolic soils)
- Dark-red friable clays (latosolic soils)
- Red friable clays (latosolic soils)
- Dark-red sandy clay loams (latosolic)
- Reddish-brown sandy clay loams
- Yellow-red coarse sandy loams
- Red friable clays with laterite horizon
- Yellow-red sandy clay loams with laterite horizon
- Brown sandy clay loams with laterite horizon
- Shallow yellow-brown to yellow-red friable clays overlying a laterite horizon or rock
- Dark greyish-brown calcareous clays (Rendzinic soils)
- Dark-grey to dark greyish-brown calcareous clays with light textured topsoil
- Black to dark-grey clays
- Dark greyish-brown mottled clays (grey soils; "Vlei Soils")
- Dark-grey compacted loamy sands (solidized-solonetzic soils)
- Swamps
- Alluvium
- Shallow stony soils with rock outcrops
- Steep slopes

NAIROBI-MACHAKOS SOIL SURVEY

WEST SHEET		EAST SHEET	
148/2	149/1	149/2	150/1
148/4	149/3	149/4	150/3

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