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MINISTRY OF NATURAL RESOURCES
GEOLOGICAL SURVEY OF KENYA

GEOLOGY OF THE ENDAU AREA

EXPLANATION OF
DEGREE SHEET 53, N.E. QUARTER
(with coloured map)

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FOREWORD

The Endau area consists largely of an almost featureless plain, from which almost no geological information can be gathered by ordinary surface methods. From the plain, however, there stand up a few hills, of which the most important is Endau. They are remarkable in this part of Kenya in so far as they consist of intrusive rocks of syenitic and allied nature, including alkaline types. Around the syenites there are well-developed zones of fenites. The nearest known relatives of the syenites that occur in masses of notable size are found at the centre of Mt. Kenya and at Jombo in the south-east corner of the Colony. Such intrusions are frequently associated with carbonatites, but no carbonatite was discovered in the Endau area. It is probable that, if they are associated with carbonatites, the carbonate rocks have still not been exposed by erosion.

The mapping of the area did not reveal mineral deposits of any commercial interest. As in many parts of eastern Kenya the most important mineral in the area is water, and the report gives an account of what has been done in attempts to improve the supply.

Nairobi,
15th February, 1960.

WILLIAM PULFREY,
Commissioner (Mines and Geology).

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MAP

Geological Map of the Endau Area (degree sheet 53, north-east quarter). Scale
1:125,000 At end

ABSTRACT

The Endau area is approximately 1,200 square miles in extent, and is enclosed by latitudes $1^{\circ} 00'$ and $1^{\circ} 30'$ S. and longitudes $38^{\circ} 30'$ and $39^{\circ} 00'$ E.

The greater part of the area is a lightly dissected plain—the end-Tertiary peneplain—out of which rise three residual hill masses, of which Endau (4,387 feet) is the largest.

The oldest rocks, which are poorly exposed, are quartzo-felspathic granulites, biotite gneisses, calc-silicate rocks and hornblendic gneisses of the Basement System (Precambrian). Intrusive into these rocks are quartz syenites and analcite syenites, microsyenite and alkaline microgranite dykes and lamprophyres—members of an acidic alkaline igneous suite. Locally at the margin of the quartz syenite intrusions the quartzo-felspathic granulites are fenitized.

The surface of the end-Tertiary peneplain is locally underlain by poorly exposed conglomerates and sands.

No economic mineral deposits were discovered. An account of the water-supply position is given.

GEOLOGY OF THE ENDAU AREA

I—INTRODUCTION

A geological reconnaissance of the Endau area, the north-east quarter of Degree Sheet 53 (Kenya; Directorate of Overseas Surveys, sheet 152), was carried out during August and September, 1957. The area is bounded by the meridians $38^{\circ} 30'$ and 39° E. and by the parallels $1^{\circ} 00'$ and $1^{\circ} 30'$ S., and is approximately 1,200 square miles in extent.

The western third of the area, west of a general line from the upper Matia river through Engamba to Katumbi and beyond is part of the Endau location of Kitui district. The greater part of the remainder is included in the Eastern Crown Lands, which is also part of Kitui district. The north-east corner, including Kandelongwe hill, is in the Garissa district of the Northern Province.

Only the vicinity of the Endau hills is populated, by Wakamba, and sporadic cultivation is carried on along the Munyoni river as far east as Katumbi. The upper parts of Endau hill were cultivated up to a few years ago, but the whole hill has now been declared a Native Forest. The Endau vicinity is noted for the good-quality native cattle it produces, but there are no local industries or exports other than cattle.

Rainfall is low on the featureless plain, which comprises the greater part of the area, but is relatively high south-west of Endau—the rainfall at Endau during 1956 was 43.33 inches, the average for the five years 1951–1956 being 35.03 inches. Long-term rain-gauges which have recently been set up at Yendoboini and Sosoma (the latter north of the present area) suggest an annual rainfall of 10 to 15 inches in those areas.

Communications.—Two moderately good earth roads give access to Endau, one from the Garissa road via Nu, and another from Kitui via Zombe. Both enter the area from the west. From Endau rough motor-tracks pass north and south of Endau hill. The northerly one is maintained as far as Makuka, but from there onwards is a rough narrow track continuing past Engamba as far as Eyuku water-hole. A branch from this track passes northwards from Engamba to Sosoma and finally to the Garissa road. The southerly motor-track follows the Munyoni river past Katumbi to Ngomano where it forks; one very rough branch turns south and continues out of the area to the Thua river and Mutha. The other crosses the Munyoni and forks again, one branch going as far east as Ngwaniwa water-hole, the other following the Nziu river to Makuka. Further tracks, from Sosoma and Ndeyini, enter the area in the north and give access to Kandelongwe. A motor-track also leads northwards from Yanzeu water-hole in the north-eastern corner of the area and is said to connect with the main Garissa road. All these motor-tracks are narrow and partly overgrown, and are often very rough where elephants have used them in rainy seasons. They are only suitable for small robust vehicles.

Maps.—The only existing maps of the area before the present survey were the 1:250,000

South-A-37

Kitui Sheet No. _____ and the 1:500,000 sheet S.A. 372, which show little beyond

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the outlines of the hills. The topographic detail on the geological map accompanying this report was compiled by the writer from air photographs, controlled by a plane-table survey. Areas not covered by air photographs were sketchily surveyed by plane-table and compass resection, and their representation is tentative. A notable feature of the plane-table work in the area was the difficulty of fixing positions in the featureless eastern half.

Previous Geological Work.—None of the early explorers who passed through the Kitui district seem to have visited the Endau area. Champion (1912, p. 15)*, however, referred in passing to phonolite that he had observed north-east of Endau. No phonolite was seen during the present survey. In 1934 or 1935 W. D. Harverson obtained a specimen of syenite from a boulder near Endau.

The Kitui area to the west was surveyed by L. D. Sanders (1954). There is slight discrepancy between the maps of the Endau and Kitui areas in the vicinity of Endau village. This is probably due to surveying inaccuracies and personal variations in the interpretation of air photographs.

*References are quoted on p. 12.

The area to the north—the Ndeyini area, has recently been surveyed by J. B. Wright (report in preparation) and although the maps agree well as to topography there are minor discrepancies in the interpretation of soil types.

II—PHYSIOGRAPHY

The greater part of the area consists of an almost featureless plain on which are shallow widely-spaced valleys. Arising abruptly from this plain are three inselbergs—Endau (4,387 ft.), Engamba (3,100 ft.) and Kandelongwe (1,570 ft.). Of these Endau is by far the largest and is a sub-circular hill mass seven miles in diameter divided centrally by two north-south valleys, the Sikati and the Ilimukuyu. Apart from these three upstanding hill masses the only other notable features on the plain are small bald crags, no higher than 50 feet above the surrounding country, such as Kinani and Siobiliwa.

The principal drainage system of the area is that of the Nziu river and its right bank tributary the Munyoni. A further river is the Matia, which passes north of Engamba. The Nziu and Munyoni rivers, and some of the smaller ones also, have the broad flat alluvium-filled floors and meandering and braided courses characteristic of maturity. The valley floors are never more than 150 feet below the surface of the surrounding plain. The sides of the Munyoni and Nziu valleys are indented by short tributary valleys of youthful profile and cross-section. If the profiles of the tributary valleys are projected into the main valleys beneath the alluvium it seems that the alluvium is, in places, up to 100 feet deep, and that it fills up approximately half the depth of the major valleys. Evidence that the alluvium is over 80 feet deep is provided by bore-holes (p. 12), for instance, at Ngomano. The mature appearance of the major valleys is, to some extent, due to recent aggradation.

The development of the valleys could have come about in the following manner: the end-Tertiary peneplain at its maturity had widely spaced valleys, shallower and with fewer short tributaries than those of the present day. Gentle eastward tilting of the peneplain initiated a cycle of incision, deepening the main valleys and giving rise to youthful tributaries. Before this incision could proceed very far it was, however, halted by a change in the régime of the drainage resulting in aggradation of alluvium. Excluding factors such as tilting, warping or volcanic damming of drainage, for which there is no evidence in this area, the aggradation must have taken place as a result of climatic change. Progressive desiccation would convert perennial streams to tapering ones, resulting in the deposition of alluvium at the ends of the tapering streams, and, together with the development of strongly seasonal rainfall, alter the nature of the vegetation cover, and give rise to sheet erosion of valley sides and the overloading of streams with sediment.

The extensive plain, which lies at an altitude of approximately 1,800 ft. and 1,200 ft. at the western and eastern margins of the area respectively, and has an average eastward slope of 17 ft. per mile, is correlated with the end-Tertiary erosion surface of north-eastern and eastern Kenya (Dixey, 1948, pp. 16-17; Sanders, 1954, pp. 6-7). Occurring as thin layers on this erosion surface are deposits of conglomerates, pebble beds and colluvial grits. A discussion of the deposition of these peneplain deposits is given at p. 9.

The even summits of the hills comprising the southern and eastern parts of Engamba represent remnants of an erosion bevel standing at 2,200 feet. This bevel is some 600 feet higher than the level of the end-Tertiary peneplain nearby, and probably represents a remnant of the sub-Miocene peneplain. In the area to the west Sanders (1954, pp. 5-7) placed the sub-Miocene bevel high on the Nuu hills at 3,800-4,000 feet, 1,200 feet higher than the end-Tertiary surface. Some late Tertiary or Pleistocene movement certainly took place on the Mutito fault, as Sanders (p. 5) suggests, but he nevertheless places the sub-Miocene surface at the same elevation on both sides of the fault. The writer believes that the sub-Miocene bevel occurs at a level of about 3,200 to 3,400 on the Nuu hills. If this is correct it implies a post-Miocene movement on the Mutito fault of c. 800 feet, downthrowing to the east.

III—SUMMARY OF GEOLOGY

The oldest rocks of the area are quartzo-felspathic granulites, biotite gneisses, hornblende-biotite gneisses and calc-silicate gneisses which occur in the Endau vicinity. These are ascribed to the Basement System and are of Precambrian age. Intrusive into the Basement System rocks are three quartz syenite bodies, probably stocks, and associated microsyenite

and lamprophyre dykes. These form the Endau, Engamba and Kandelongwe hills. They are tentatively regarded as of late Mesozoic age. The youngest rocks are the thin conglomerates and pebble beds occurring on the end-Tertiary erosion surface. These are regarded as late Tertiary or early Pleistocene in age.

The geological history and succession in the area is summarized in the following tabulation:—

Pleistocene and Recent	Superficial soils Valley-fill clays —————Slight erosion—————
Late Tertiary (?) or early Pleistocene (?)	Pebble beds and conglomerates —————Erosion and Peneplanation————— —————Erosion and Peneplanation—————
Mid-Tertiary	
Late Mesozoic (?)	Syenite intrusives with syenite and lamprophyre dykes —————Erosion—————
Precambrian	Folding and Metamorphism Basement System

IV—DETAILS OF GEOLOGY

1. Basement System

Exposures of metamorphosed gneissose and granulitic rocks ascribed to the Basement System occur only in the western part of the area near Endau and west and north-west of Engamba.

Such rocks as were seen are comparable with those occurring in the eastern part of the south Kitui and Kitui areas (Saggerson, 1957; Sanders, 1954) and in the Mwingi area (Crowther, 1957). Little structural and stratigraphic inference can be drawn from the poor exposures in the present area.

(1) CALC-SILICATE ROCKS

Two exposures of calc-silicate rocks were found, one on the north bank of the Munyoni river at Kalungu, and the other one mile west of that locality. Both occurrences are of finely laminated rocks with alternating layers rich in hornblende, epidote, calcite and feldspar.

(2) BIOTITE GNEISSES

Biotite gneisses occur in the Kololo river immediately south-east of Endau, and on the south side of the Munyoni valley one and a half miles south-east of Katumbi. The Kololo river rocks tend to have massive outcrops and contain lenticular pegmatite bodies. They are brown to buff medium-grained rocks with faint colour layering and a crude foliation defined by biotite flakes. The Munyoni river rocks are fissile, but otherwise similar to those described.

Rocks which can be regarded as transitional between biotite gneisses and quartzo-feldspathic granulites occur on Kinani rock and in isolated exposures one mile to the north. Here there are closely interbanded leucocratic granulites without biotite and more foliated gneisses with biotite and locally hornblende. An example of the latter type which also locally shows a tendency to develop porphyroblastic feldspars was collected from the top of Kinani rock (specimen No. 53/1004*). In thin section this rock is seen to contain porphyroblastic microcline, minor twinned oligoclase, sparse brown biotite and much quartz.

(3) QUARTZO-FELSPATHIC GRANULITES

Owing to their massive structure and lack of foliation the quartzo-feldspathic granulites tend to outcrop more often than other Basement System rocks in the area. A faint foliation is, however, sometimes apparent in these rocks, and is caused by beds of slightly varying grain size. An almost ubiquitous feature is the presence of titanomagnetite grains, which locally reach $\frac{1}{2}$ cm. in diameter.

The only specimens of quartzo-feldspathic granulites collected are from the northern and north-western margin of the Engamba syenite body, and are affected by metasomatism

*Numbers prefixed by 53 refer to specimens in the regional rock collections at the Mines and Geological Department, Nairobi.

associated with the formation of that body. With only a cursory examination of the rocks of the area around Mulanganga pan and along the north-western margin of Engamba it might be difficult to separate the massive quartzo-felspathic paragneisses from the fine-grained marginal parts of the syenite. The granulites are faintly foliated, however, and often display a poor lineation. The abundance of quartz also differentiates them from the adjacent igneous rocks. Since the composition of all the Engamba granulites has been altered to a greater or lesser extent by feldspathization associated with the syenite intrusion they are described later under the heading of fenites.

(4) HORNBLende-BIOTITE GNEISSES AND PLAGIOCLASE AMPHIBOLITES

A few exposures of hornblende-biotite gneiss occur in the Kakame river one and a half miles south-south-west of Endau village and are associated with finely banded plagioclase amphibolites. These rocks continue into the Kitui area and have been described by Sanders (1954, pp. 27-28).

2. Intrusive Rocks

The hills Endau, Engamba and Kandelongwe are composed of syenitic intrusive rocks, which outcrop and weather into large rounded blocks. At some of the few places where the margin of the syenite bodies can be inferred with reasonable accuracy it is close to the base of the hills. In the case of Endau and Kandelongwe the limit of the syenite exposures corresponds closely to the margin of the intrusions. At Mulanganga and Kamuluyuni west of Engamba, however, syenites outcrop on the plain and give rise to distinctive white soils full of felspar cleavage fragments, and at these places the syenite boundaries can be inferred from the nature of the soil. Half-way between Kamuluyuni and Engamba, by the side of the motor-track, there is an area of similar white soil, but no exposures were seen there. It is possible that syenite or a similar rock underlies this soil.

The three principal syenite outcrops are much alike, both within and between themselves. At the marginal parts of the Endau and Engamba bodies, however, are local developments of a finer-grained facies, and locally this grades into a porphyritic facies. In the interior of the syenites the only variations detected in the field were in grain size and the degree of perfection of crystal form in the feldspars. Outcrops are good on all the hills, but stream sections are generally poor, for the bouldery nature of the surface rocks results in streams being choked by heaps and trains of transported rocks. Mapping in the hills is hindered by exceptionally thick bush below approximately 3,600 ft., but above this level on Endau there is pleasant forest, which is inhabited by rhinoceros and buffalo.

The intrusive nature of the syenites is indicated by their composition and texture, and is confirmed by the occurrence of numerous microsyenitic dykes in the surrounding Basement System rocks. No evidence of ring structures or multiple intrusions such as are known from comparable intrusives in Nyasaland (Stringer *et al.*, 1956, pp. 5-8) was seen, but the form of the Kandelongwe intrusion possibly suggests such structures.

Petrographically the intrusive rocks are quartz syenites comparable to perthosite and in the central part of Endau there is an analcite syenite. One of the Engamba specimens is monzonitic. These rocks are closely comparable to several syenite intrusions in Nyasaland, such as the Chambe plateau ring complex (Stringer *et al.*, 1956, pp. 11-18), and the Zomba and Mlanje syenites (Dixey *et al.*, 1955, pp. 30-31), the latter being described as orthoclase-hornblende syenite.

The commonest dykes in the Endau area are porphyritic microsyenites comparable to sölsbergites. Others contain more quartz and are microgranites allied to grorudite. Three lamprophyre dykes were seen. The occurrence of alkaline dyke rocks and of fenites at the margin of the Engamba syenite suggests that the intrusives belong to an alkaline igneous suite comparable with those that elsewhere contain such rocks as nepheline syenites and carbonatites (see Dixey *et al.*, 1955, pp. 36-40).

Direct evidence of the age of the intrusions is confined to the facts that they are younger than the Basement System folding (which is Precambrian) and older than the Miocene. The intrusions may be of late Mesozoic or Tertiary age like the Jombo alkaline igneous complex (Baker, 1953, pp. 32-48).

(1) QUARTZ SYENITES

The quartz syenites are by far the commonest types in the three syenite intrusions. They are pale grey-buff rocks in which subhedral tabular feldspars up to 10 mm. in length form nearly all the rock. Small clusters of ferromagnesian grains occur and interstitial quartz is sometimes visible in hand-specimen.

Specimens which typify the quartz syenites were collected at Kausia well and by the pipe-line one and a quarter miles north-north-east of Endau village (specimens 53/992 and 53/994A respectively). They contain turbid perthitic alkali feldspars up to 10 mm. long which often have sutured and intergrown margins. The orthoclase fraction of the perthite is invariably more turbid and altered than the plagioclase; the latter is difficult to determine, but has a refractive index suggesting albite. Rarely the perthite has patches showing lamellar albite twinning. In specimen 53/994A there are discrete small albite grains interstitially, and aggregates of a blue-green amphibole and a deeper green sodic pyroxene of low extinction angle, probably aegirine. The hornblende is occasionally intergrown with a brown biotite. Quartz occurs interstitially. Sphene is a common accessory mineral together with small amounts of opaque ore, probably magnetite.

The quartz syenite at Kamuluyuni wells (specimen 53/1006) is similar, but the perthitic structure is coarser and albite patches in the perthite are more numerous. Biotite approaching the composition of lepidomelane is more common than green hornblende and apatite occurs rarely.

The eastern part of the Engamba intrusive is quartz syenite of the normal type (for instance specimen 53/1006B from two miles west of Kalamba), but a rock obtained from the west of the summits, specimen 53/1008, differs in texture, being porphyritic. Subhedral perthite crystals with small brown biotite inclusions are common, the interstices being crowded with tabular oligoclase associated with sparse skeletal green hornblende up to 4 mm. across. Rare small quartz grains occur interstitially. Many of the hornblende grains are markedly zoned and are pleochroic in shades of pale greenish yellow to dark grey-blue. They have negative elongation and extinction angles up to 35° and are members of the arfvedsonite series. This rock tends to a monzonitic composition.

A syenite from Ekulungu, the southern part of the Engamba hills, differs from those described above. It is a medium-grained greyish brown rock (specimen 53/1013) with inequigranular xenomorphic texture, consisting of turbid alkali feldspar containing minute inclusions of blue-green amphibole prisms. Hornblende also occurs as intergranular aggregates associated with ragged iron ore grains and apatite prisms. There is no quartz. This rock has a texture suggesting slight crushing followed by limited recrystallization.

The Kandelongwe syenite contains more sodic plagioclase than the normal quartz syenites. The orthoclase is often perthitic at grain margins and oligoclase occurs as discrete grains in intergranular spaces. Quartz is rare. In specimen 53/1015 acicular blue-green hornblende occurs intergrown with some of the feldspar along the principal cleavage. These rocks are also monzonitic quartz syenites.

At the south-western extremity of the Endau syenite, in the valley half a mile south-east of Kituka hill, the stream section exposes quartz syenite with numerous dark inclusions. The inclusions range from discrete blocks up to three feet in diameter down to minute specks and streaks. Frequently a streaky intermixture of the light syenite and dark fine-grained rock is observed and there is abundant evidence that partial digestion of the dark xenoliths has taken place. The xenoliths are composed of dark fine-grained porphyritic rock of basaltic appearance. In a thin section of specimen 53/994B the rock is revealed, however, as composed of andesine microphenocrysts in a microcrystalline base of granular alkali feldspar, aggregates of pale green chlorite intergrown with brown biotite, scattered iron ore grains and aggregates, and an abundance of opaque ore dust. No quartz was seen. This rock is an unusual variety of porphyritic microsyenite, unlike any other discovered in the area.

(2) ANALCITE SYENITES

Two specimens of analcite syenite were collected on Kauwaa, the eastern part of Endau. They are 53/1000 from Kibou spring and 53/1001 from half a mile west of Kauwaa summit. The type was not differentiated from the quartz syenites in the field and its distribution is consequently uncertain. The analcite syenites are medium grey and darker in hand-specimen than the typical quartz-syenites; in texture the two types are similar. Both specimens contain macroscopically visible pyrite.

In thin section the analcite syenites are found to contain subhedral microperthite with sutured margins and occasionally showing carlsbad twinning. Refractive indices measured on cleavage fragments fall in the range 1.522–1.532, which approximates to the range of anorthoclase. The microperthite frequently contains crystals and aggregates of brown biotite and more rarely of blue-green hornblende. Clusters of grains of sphene, green hornblende and biotite occur, often with apatite and iron ore in addition. Analcite occurs in turbid brown pools in intergranular spaces and in the feldspars.

(3) PORPHYRITIC QUARTZ SYENITES AND MEDIUM- TO FINE-GRAINED QUARTZ SYENITES

Porphyritic quartz syenites and medium- to fine-grained non-porphyritic quartz-syenites occur marginally to the main intrusives as discontinuous bodies. Similar rocks occur within the Endau intrusion as small dyke-like masses, which however have irregular margins and lack chilled borders. The largest outcrops of these rocks are at the south-eastern extremity of Endau mountain and on the low hills immediately north-west of Engamba. The latter are invariably non-porphyritic.

These marginal rocks are only poorly exposed at the bases of the hills, but traverses along the southern margin of the Endau body suggest that the porphyritic quartz syenites are gradational into the quartz syenites of the main body, whereas the non-porphyritic quartz syenites, which often occur as discrete small bodies and probably dykes, may be the result of a separate and slightly younger intrusive phase. Related dyke rocks occur plentifully in the surrounding country, but are described separately.

The marginal quartz syenites differ from the main quartz syenite bodies only in grain-size and texture. They are pale grey-buff or pale brown rocks. Among the porphyritic quartz syenite exposures half a mile west of Koi a faint flow foliation was observed defined by similarly orientated small dark xenoliths up to half an inch long. At no place was a preferred orientation of feldspar phenocrysts observed. Under the microscope the rocks are seen to have the same composition as the quartz syenites described above. A typical example is specimen 53/1003 from the base of Endau, north-north-west of Matundu. This rock contains phenocrysts of perthite up to 12 mm. long and the matrix consists of subhedral perthite, rare tabular sodic plagioclase and interstitial quartz. Green hornblende is very scarce and sphene is the only accessory mineral.

At the northern margin of Engamba, due north of the central summit, is a marginal zone of porphyritic quartz syenite approximately 50 yards wide. A specimen (53/1010) shows that the rock contains rather more sodic plagioclase than most examples of this type. Ore grains commonly occur as inclusions in the feldspars and an aggregate of ore, sphene and apatite was observed. Hornblende sometimes occurs as uncommonly large skeletal crystals.

(4) QUARTZ MICROSYENITE DYKES

Microsyenite dykes are common north-west and south-west of Endau, where they cut Basement System rocks. They are rarely more than two or three feet wide and are pale brown or pale grey rocks with sparse porcellaneous feldspar phenocrysts up to 8 mm. long. Three examples may be mentioned, specimens 53/987 from the Nuu–Endau–Engamba road junction, 53/990 from 300 yards east of Endau village shops, and 53/989 from the Kakame river $1\frac{1}{2}$ miles south of Endau village. Under the microscope the phenocrysts are seen to be turbid orthoclase—perthites are very scarce. In the first two specimens mentioned the matrix is composed of interfolded orthoclase prisms up to half a millimetre in length and small amounts of interstitial quartz, but in specimen 53/989 quartz is much more abundant. Specimen 53/989 contains patches of sericitic mica and rare small crystals of a pale green pyroxene. The other dykes contain opaque needles which are probably aegirine pseudomorphosed by iron oxide.

A dyke of similar composition to those described, but containing xenoliths of quartzofeldspathic granulite, occurs on the north bank of the Nziu river 3 miles south-west of Kamuluyuni. A further dyke occurs on the Nuu–Engamba motor-track just east of the Nziu river. This rock (specimen 53/1005) is reddish grey with numerous porcellaneous feldspar phenocrysts up to one centimetre long. They are turbid orthoclase. The matrix consists of microcrystalline spherulites of alkali feldspar with interstitial quartz. Calcite and a brown amorphous mineral occur sparingly.

Dykes similar to those described above are recorded from the area to the west and were described as porphyritic trachytes (Sanders 1954, pp. 33-34). In view of their composition there can be no doubt that these dyke-rocks are off-shoots from the main quartz syenite intrusions of the Endau area.

The quartz microsyenites are comparable with sölvbergite dykes associated with the Chilwa Series alkaline-igneous suite of Nyasaland (Dixey *et al.*, 1955, p. 21) but have less sodic plagioclase than typical sölvbergites (Johanssen, vol. III, pp. 107-109).

(5) ALKALINE MICROGRANITE DYKES

Three specimens of acid dykes proved on examination to contain a sufficient proportion of quartz to be termed microgranites. One of these (specimen 53/996) from a tributary of the Kalungu river, one and a half miles south-south-west of Kanguni spring, is a reddish grey rock with quartz visible in hand-specimen. In thin section it is seen to be of medium grain with tabular euhedral altered perthite full of sericite, and rare sodic plagioclase. Quartz is well developed interstitially and forms approximately 20 per cent of the rock by volume. The quartz is accompanied by some fine-grained chalcedony. There are scarce ferromagnesian grains, probably hornblende, and some sphene and iron ores.

A curious dyke occurs one mile north-east of Mulanganga pan as a body approximately one foot wide intrusive into quartz-felspathic granulite. The margins of the dyke are highly irregular as if the dyke had digested parts of the country rock. In hand-specimen (53/1019A) the rock is of basaltic appearance. In thin section, however, it is seen to be an acid rock consisting of acicular aegirine microphenocrysts in a matrix of myrmekitically intergrown quartz and micropertite. Clusters of rounded quartz grains and minute rods of a pale greyish blue to green mineral, possibly aegirine occur in the matrix.

In a thin section of the margin of this dyke the rock is seen to be fine-grained and flow banded. The turbid feldspars have a tendency to spherulitic structure, the spherulites being arranged in bands. Between the spherulitic bands are trains of clear intersertal quartz grains. The margin of the dyke is locally ill-defined and appears to merge into the quartz-felspathic granulite forming the dyke wall. This granulite is substantially fenitized—the feldspars are turbid and dominate the quartz in amount. The texture at the dyke margin suggests slight penetration of dyke material into intergranular spaces of the metamorphic rock, following mild alkali metasomatism.

A further quartz-rich dyke-rock was found near the northern margin of Engamba hill one mile north of the western summit. In thin section (specimen 53/1012) it is seen to have the same texture as the quartz syenites. Tabular perthite crystals are abundant and clear quartz fills all intergranular spaces, forming approximately 30 per cent of the rock by volume. Greenish brown biotite occurs as ragged books and sphene, magnetite and zircon are accessory.

These quartz-rich dyke-rocks are comparable with the riebeckite-microgranites (grorudites) described from the Chilwa Series of southern Nyasaland (Dixey *et al.*, 1955, p. 22; see also Johanssen, Vol. II, pp. 102-104).

(6) ANALCITE-TINGUAITE DYKE

Only one rock of this type was seen, and this was found near the base of Endau mountain three miles north-north-east of Kauwaa. It is a hard, almost flinty, dark grey-green rock of fine grain. In thin section the rock (specimen 53/998) is revealed as microcrystalline with small acicular aegirine microphenocrysts in a base of alkali feldspar laths. An isotropic mineral of low refractive index in interstices is probably analcite.

(7) LAMPROPHYRE DYKES

Two lamprophyre dykes were found in the Munyoni valley, 1.6 and 2 miles south-east of Katumbi. A specimen of the eastern dyke (53/1021) has microporphyritic texture with 1 to 2 mm. prismatic brown hornblendes and $\frac{1}{2}$ mm. zoned augites in a fine-grained base of sodic plagioclase with interstitial zeolite. Sphene occurs in association with iron ore. The rock is a vogesite.

A further lamprophyre dyke one foot wide occurs just outside the western margin of the area in the Kakame river, $1\frac{1}{2}$ miles south-west of Endau village. A specimen (53/988) contains numerous prismatic brown hornblende microphenocrysts in a matrix of basic plagioclase full of acicular hornblende inclusions, olivine altered to calcite, iron ore and serpentine, and a mesostasis of isotropic zeolite. The rock is probably a camptonite.

3. Fenites

Fenites are produced from rocks of various compositions, but usually quartz-rich intrusives or sediments, which have been altered by alkali metasomatism in proximity to an alkaline igneous complex. African fenites and the fenitization process have recently been reviewed by Campbell Smith (1950, pp. 208–212). In the present area the fenites are not well exposed, for they occur on the plain at the margins of the syenite hill masses. They are best developed around the northern and western margins of the Engamba syenite, at the north-eastern margin of Endau, and as inclusions or screens within the Endau syenite on the ridge south of Kausia well. They are invariably derived from quartzo-felspathic granulites of the Basement System and often closely resemble the non-porphyrific marginal quartz syenites. They can, however, be distinguished from the syenites by the presence of relic fabrics such as foliation and, more often, lineation. Occasionally the fenitized quartzo-felspathic granulites develop a coarse-grained equigranular facies in which the feldspars tend to tabular form. Such a rock is specimen 53/1007 from the foot of Engamba one mile north of the central summit. This rock contains turbid micropertite with crenulate margins. There is often a marginal zone of different composition adjacent to neighbouring quartz grains. Rare oligoclase occurs in interspaces. Quartz is abundant as sub-round grains and inclusions in feldspar. The feldspars envelop the quartz grains forming the "net" texture characteristic of replacement. Small groups of greenish brown biotite crystals occur associated with opaque ore grains.

A quarter mile west of the above locality a further specimen (53/1011) was collected which is similar to that already described. In this rock, however, there are myrmekitic intergrowths between quartz and feldspar.

Two further specimens (53/1017 and 53/1018) from outcrops in the stream by the motor-track one and a half miles north-north-west of Engamba central summit differ from those described in having notable amounts of perthite. A feature of all these rocks and indeed of the quartz syenites also is the turbid nature of the orthoclase or perthite, whereas the plagioclase and quartz is invariably clear. Specimen 53/1017 is similar to those already described, but in specimen 53/1018 there is a notable advance towards igneous quartz syenite texture and composition. The rock is composed mainly of interlocking turbid orthoclase and micropertite grains; some of the latter are tabular in outline and show carlsbad twinning. Rarely lamellar-twinning sodic plagioclase occurs at the margins of the potassic feldspar. Quartz is common but not as abundant as in the other fenites—it occurs as round and irregular grains conspicuously partly replaced by feldspar, or as narrow intergranular shards. Green-brown biotite, iron ore grains and euhedral sphene are the only other minerals.

Pale grey fine-grained rocks with saccharoidal texture were mapped on the Kituku-Kausia ridge at the western end of the Endau massif. A thin section of a specimen (53/993) taken from a point three-quarters of a mile south-west of Kausia shows the rock to be fenitized quartzo-felspathic granulite differing from those described previously. The rock has equigranular texture; approximately 80 per cent of the grains are of dusty alkali feldspar, the majority of the remainder being quartz. There are scattered prismatic amphiboles, pleochroic from pale green to bottle green, and a brown to opaque mineral occurs with granules of doubtful aegirine and as intergranular films. The amphiboles are a sodic type with negative elongation.

A specimen (53/999) from the northernmost of the two ovoid fenite outcrops at the north-eastern margin of Endau closely resembles quartz syenodiorite in composition. The texture is granular-interlocking, with a tendency for albite-oligoclase to develop as tabular crystals. Dusty irregular orthoclase occurs, but is subordinate to plagioclase in amount and perfection of crystal form. Quartz is found interstitially and has ragged grains in process of replacement by feldspars. Green hornblende and greenish brown biotite are present and are sometimes intergrown, while idiomorphic sphenes are plentiful. This rock is regarded as a fenite on account of the texture, which is metamorphic rather than igneous. The abundance of sodic plagioclase is notable.

At the northern foot of Endau mountain there are numbers of scattered exposures, some of normal quartz syenite, others of finer-grained rocks which can only be described as intermediate between syenite and quartzo-felspathic granulite, and which are fenites. The latter grade locally into porphyritic syenite-like rocks and these in turn, by development of a coarser matrix, grade into normal quartz syenites of the main intrusion. There is thus

a suggestion that there is a complete gradation between intrusive rocks and fenites of various kinds. Owing to the scattered nature of the exposures and the rapid variation of rock types the geological boundaries in this part of the area are necessarily tentative.

The fenites from the northern and north-western margin of Engamba are notable in lacking aegirine and soda-amphiboles such as characterize almost all fenites. The development of turbid and replacive alkali-felspar at the expense of quartz is, however, characteristic of fenitization (*see* Campbell Smith, 1956, pp. 208–212).

4. Conglomerates, Sands and Lateritic Deposits

There is indirect evidence that much of the featureless plain that exists over most of the area is underlain by sediments. The extreme scarcity of exposures, even on the sides of the shallow valleys, and the occurrence of float pebbles and gritty transported soils on some valley sides suggest that the peneplained surface of Basement System rocks is overlain by a thin sedimentary cover.

Exposures of conglomerates are most numerous on the sides of the Matia valley near the crossing of the Sosoma–Engamba motor-track. Here weakly-cemented poorly-sorted conglomerates with quartz and pegmatite pebbles up to four inches in diameter are exposed, with a thickness of up to twenty feet. Other exposures and pebble accumulations were found at various scattered localities. The Engamba–Eyuku motor-track, for example, below the north face of Engamba runs just to the south of a low bank on which are abundant loose pebbles. The survey station at 1,550 feet three and a half miles south-east of Twambui is situated on a mound of quartz pebbles. Good exposures of brown conglomerates devoid of bedding occur on the rise to the plain on the south bank of the Munyoni river two miles west-south-west of Msemi water-hole. Scattered occurrences of pebble float in quartzose soils are found along the sides of the Nziu and Munyoni valleys from Makuka and Katumbi as far as Ngwaniwa and beyond. Generally speaking, the evidence suggests that thin conglomerates and sands occur underlying the greater part of the area marked as covered by reddish brown sandy soil and the clay soils of the plains.

Boulders of cellular ironstone and small exposures of colluvial poorly-sorted grits with ironstone zones and cappings occur frequently at the margins of the hills at the level of the plain. The better exposures are at the base of Engamba hill one mile east-north-east of the eastern summit, where exposures in a stream section show felspar grains in an iron stained matrix of sand and silt. These beds are at a slightly higher level than the heaps of quartz pebbles that occur on the pediment a little further to the north. At the base of the south face of Kalongola are further grits coloured pale grey, brown and reddish brown, and capped by cellular ironstone. On the Endau–Makuka motor-track immediately north and north-west of Syuu dam there are scattered boulders of cellular ironstone, and similar boulders are common near Mulanganga water-hole. Sheets of loose ironstone nodules are common on buff and reddish-buff sandy soils on the pediment slope at the north-east margin of Endau and at the south foot of Kituku hill, near Endau village.

Following the completion of the most recent peneplanation in the area it seems that thin sheets of conglomerate were spread widely over the present and adjacent areas (they have been seen by the writer in the areas to the west and north). Sands were also deposited and gently sloping alluvial and colluvial material deposited at the bases of hill masses. The sedimentary episode seems to have ended in the formation of widespread ferruginous surface laterite. The conglomerates must have been deposited under torrential conditions and the climate generally was probably arid, for any sort of continuous vegetation cover would have prevented widespread deposition.

The age of the beds can only be inferred in a general way from the erosional history of the whole of eastern Kenya, for no fossils have been found in them. The beds occur on the end-Tertiary peneplain of Northern Kenya (Dixey 1948, pp. 16–17) and incision by rivers into this surface in other areas is dated roughly as lower Pleistocene on the basis of artifact discoveries (*op. cit.* p. 17). The beds in the present area are regarded as latest Tertiary or early Pleistocene in age.

5. Alluvial Clays and Silts

Following the deposition of the conglomerates, sands and laterites described above, there was a short period of incision of the drainage around the margins of the hills and along

the courses of the major rivers. The Munyoni-Nziu river system was incised to a depth of approximately 200 feet below the surface of the surrounding plain. The early youthful form of this drainage system is very well shown between Ngomano and Makuka. There then followed aggradation and the partial filling of the valleys by level expanses of fluvial clays and silts. This alluvial sediment is much the same wherever it is seen—it is a brown, slightly gritty, unstratified alluvium with very scarce thin gravel lenses. The present-day stream channels are locally incised to a shallow depth in this alluvium and are occupied by meandering, braided and tapering seasonal streams.

6. Superficial Soils

Reddish brown sandy soils are found over the greater part of the plain, and support a dense growth of thorn scrub. Locally, as at Kamuluyuni and Mulanganga, the soils are buff or greyish buff and gritty in texture. These are residual soils over syenite and fenite rocks.

Along the very shallow seasonal stream channels which occur mostly in the eastern half of the area, are grey and brown clay soils which merge into the reddish brown sandy soils of the plains. These soils occur also in very shallow depressions and are due largely to swampy conditions. They are similar to but differ in origin from the brown clay soils found in the flat bottomed larger valleys. These latter soils are developed on the alluvium valley-fill that occurs in all the larger valleys, in particular that of the Nziu.

Irregular areas of black-cotton soil are found on the flat plains at several localities, the largest such occurrence being the area south of Msemei and Mulingwa water-holes. These soils are characterized by an almost complete lack of thorn scrub and by deep drying cracks. They may represent the remnants of a more widespread sheet of such soil formed during a long period of greater rainfall.

A further broad group of soils distinguished locally are the transported or valley slope soils. These are yellowish sands and yellowish brown soils, which sometimes contain ironstone nodules and pebbles derived from conglomerates. They are found on the sides of the major valleys and on the gentle pediment slopes at the margins of hills. They are formed largely of material derived from the sheet erosion of peneplain deposits (the conglomerates, sands and laterites described above).

In the vicinity of Kathua, Endau village and Kwandana the soils are usually dark humus-rich types formed in the more heavily forested area south-west of Endau, an area with a distinctive and more luxurious vegetation on account of the relatively higher rainfall it receives. The soils on the Endau and Engamba hills are similar to these, being dark brown clay-rich types characteristic of areas covered by dense vegetation. On some parts of Endau, however, where gully erosion in old cultivated areas has exposed the subsoil it is seen to be pale reddish buff in colour, and may have a bauxitic composition.

V—STRUCTURE

The exposures of Basement System rocks in the area are inadequate to allow a structural synthesis to be made. Opposed dips in the region of Endau village are suggestive of a broad anticline trending north-west—south-east and plunging to the south-east. The occurrence of vertical beds striking north-north-west on the left bank of the Nziu river west of Kamuluyuni suggests that local fold-axes parallel this direction. The disposition of the foliation in the area generally is not incompatible with north-south or north-west—south-east-trending fold axes, such as have been postulated in the area to the west (Sanders, 1954, pp. 34-42).

Only three lineations were measured in the area, and these trend approximately north-east—south-west. Lack of exposures prevents their interpretation.

A curving of the strike of the quartzo-felspathic granulites in the Siobiliwa-Syu area suggests a wedging action by the Endau intrusive. There is no evidence for such an effect, however, in the vicinity of Endau village.

Structures within the quartz-syenite intrusions are limited to jointing and small narrow shear-zones. The latter are found at the northernmost extremity of the Endau syenite, in the Miosya river, and on the north face of Engamba. In each case the shears are orientated

approximately north-south and are inclined at steep angles. The orientation of some major joints is shown on the map. The majority trend either north-north-east or north-north-west. A strongly marked set of joints on Kandelongwe trends north-west. Again the data are inadequate, but are compatible with an east-west stress system.

VI—MINERAL DEPOSITS

1. General

No economic minerals were discovered in the Endau area, and none have been discovered previously. A search was made for possible mineral occurrences at the margins of the syenite intrusives, but without success. No radioactive minerals or rocks were discovered. The alkaline nature of the intrusives and the absence on the surface of basic members of the suite suggest that a mineralization connected with the intrusives is unlikely.

2. Water

Almost all the work carried out by government agencies hitherto has been devoted to the improvement of water-supplies. A small concrete dam has been constructed below the Kwamutia spring and from this a one-inch-bore pipe carries water to Endau village, after having passed through four break-pressure tanks. This water-supply is generally exhausted by mid-morning and is inadequate for the needs of the village. The water-level frequently falls close to the level of the intake pipe in the headworks, and any fall-off in spring flow, which is in any case a mere trickle, would result in a temporary cut-off of supplies. A partial remedy for this state of affairs would be to build a small intake dam at the Mukuyuni spring nearby and to connect this by a pipe-line to the first break-pressure tank. An increase in the bore of the pipe-line would be needed to ensure a more adequate flow.

Two boreholes have been drilled near Endau village, numbers C.1300 and C.1543, the positions of which are shown on the map. The first of these boreholes was drilled to a depth of 320 feet and struck water at a depth of 38 feet, rising to 27 feet. The yield is 8,040 gallons per 24 hours. The borehole log is as follows:—

BOREHOLE C.1300

Log ft.	
0- 26	Black sandy soil
26- 43	Granitic gneiss with hornblende
43-116	Quartz-biotite gneiss
116-119	Felspar pegmatite
119-300	Quartz-biotite gneiss
300-320	Grey talcose rock

Partial analysis of water from the borehole indicated:—

	parts per 100,000
Cl	1,500
NaCl	2,600

This borehole therefore had a low yield and the water was too saline for human or animal consumption.

Borehole C.1546 was drilled a little further east to a depth of 200 feet without reaching water. The conclusions reached as a result of this drilling were that the prospects for successful boreholes are slight, on account of the salinity of the ground-water.

The greater part of the water for domestic purposes in the Endau-Kalungu vicinity is obtained from the beds of the rivers. Perennial water is obtainable at Kwandana, Kalungu and Katumbi, but further downstream in the Munyoni river the conditions are unfavourable and no wells are dug. No wells were observed in the Nziu river, which appears to be unfavourable. A group of wells was found in the Miosya river at Malalani. Numbers of small wells or rock pools occur below the north face of Engamba and at the foot of Kinani rock. These are seasonal and support a number of cattle after the rains. Further wells occur at Kamuluyuni, but seem to be disused.

Dams have been constructed at Syu and Makuka; the latter is more successful and provides a perennial water-supply from wells dug in the river bed just up-stream from the dam. The principal dry weather watering places are the Katumbi, Kalungu and Kwandane wells and the Endau reservoir of piped water. Further north the Makuka dam and the

Malalani wells provide perennial water. In the eastern two-thirds of the area there is no perennial water-supply.

Numerous seasonal water-holes occur throughout the area, some of them, such as Eyuku, Mutanda and Yanzeu, being large pans over 100 yards wide. None of them contain water all the year round, except possibly in years of exceptional rains. It is these water-holes that provide for the cattle that are driven into the Eastern Crown Lands after the rains.

During 1952-53 a number of hand-auger boreholes were drilled by the African Land Development organization in or near river-beds in the area. The approximate positions of the bore-holes are shown on the geological map. The results of this drilling were as follows:—

Borehole No.	Location	Water struck	Water rest level	Total depth
		(feet)	(feet)	(feet)
6	Kalikubu River	—	—	68
7	Kalikubu River	—	—	50
8	Ngomano (Nziu river)	—	—	80
9	Ngomano (Nziu river)	58	53	62
10	Matia river	abandoned on striking gravel		
11	Matia river	—	—	80½
12	Kalamba (Matia river)	57	56	60
13	Kalamba (Matia river)	—	—	62
14	Kalamba (Matia river)	—	—	25

The tabulation shows that perched water exists in the alluvials of the Nziu and Matia rivers, and geological circumstances indicate that water could probably be found in the Nziu river alluvium at many places along its course. No test pumping was carried out at the borings, and should a further investigation be carried out such pumping would indicate whether well-sinking is justified.

Apart from the possibility of establishing a chain of wells along the major rivers, the only other possibilities for improving the water-supply in the area are the construction of small dams and the excavation of water-holes to form tanks.

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