REPORT No. 33

COLONY AND PROTECTORATE OF KENYA

GEOLOGICAL SURVEY OF KENYA

GEOLOGY

OF THE

NORTH KITUI AREA

DEGREE SHEET 45, N.W. QUARTER

(with coloured geological map)

by

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FOREWORD

Mr. Dodson's report on what, for convenience, is called the North Kitui area, is the third report published on the regional geology of the Kitui district, having been preceded by Report No. 14 (1948) on the area west of Kitui Township and by Report No. 30 (1954) on the area around and east of the township. The ground between the latter and the North Kitui area has been geologically surveyed, and an account of it will appear in due course.

Apart from superficial deposits of recent age, and a few traces of Tertiary and Pleistocene vulcanicity connected with Mt. Kenya and the Nyambeni Range, the area is entirely occupied by rocks of the Basement System. A large proportion of the rocks are ancient metamorphosed sediments, and igneous intrusions of any kind are small and few, so that the possibility of the occurrence of various minerals in deposits of economic value is remote. Valuable minerals do, of course, also occur in sedimentary rocks, and in the present area graphite, limestones and garnets were discovered by the author. It appears, however, that none of them are likely to have any economic importance. A large piece of corundum was also brought to light during the survey and, in view of the frequency with which corundum has been submitted by prospectors from that and surrounding areas, it appears possible that more extensive search may reveal deposits of the mineral, and perhaps even of alluvial sapphires.

Tseikuru, in the northern part of the area, was during the last war the scene of an intensive search for quartz crystals of piezo-electric quality for use in radio-transmission and asdic instruments. A few hundred glass-clear crystals were found, but unfortunately most of them proved to be twinned and unsuitable for the purposes mentioned. It appears from the present survey that the discovery of further crystals is unlikely, unless underground work is undertaken on the host-rocks in the search for other minerals, when the rock crystals could be worked as a by-product. The value of good quality piezo-electric quartz crystals is high, but in the case of deposits like those at Tseikuru it is unusual for the amount of saleable quartz to be sufficient to justify extensive excavation.

Nairobi,
17th September, 1953.

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ABSTRACT

The area described in this report is situated in central Kenya and is bounded by the equator, latitude 0° 30′ S., and by meridians 38° 00′ E. and 38° 30′ E. It is approximately 1,200 square miles in extent.

The area is divisible into at least three physiographic divisions: (1) the end-Tertiary erosion surface in the eastern half of the area; (2) remnants of a plateau consisting of sediments of probable Tertiary age; and (3) the chain of hills composed of Basement System rocks, which extends from the south-eastern corner to form the Kikingo Range in the north. The earth movements responsible for the formation of a distinct change of drainage pattern, at a north-south axis roughly dividing the area into two, are described.

The rocks of the area can be divided into five groups: (1) The Basement System rocks which consist of quartzites, crystalline limestones, metamorphic and migmatitic gneisses of various kinds together with acid and basic intrusives; (2) rocks of the Mount Kenya series which are represented only by a small volcanic cone of kenyte and possibly contemporaneous intrusive dolerites and lamprophyres; (3) Tertiary sediments consisting of a basal conglomerate overlain by arkoses; (4) the Nyambeni volcanics represented by a few small outliers of basalt; and (5) superficial deposits consisting of soils, gravels and kunkar limestones.

The effects and grades of metamorphism and granitization are briefly described. An account of minerals of possible economic value found in the area is given, and the chances of future exploitation are assessed.

GEOLOGY OF THE NORTH KITUI AREA

I—INTRODUCTION

The area, which is the north-west quarter of Degree Sheet 45 (Kenya), is approximately 1,200 square miles in extent and is bounded by the equator, latitude 0° 30′ S., and by the meridians 38° 00′ and 38° 30′ E. It lies immediately east of the Embu–Meru area in which numerous basic and ultrabasic bodies have been mapped, and it was thought possible that allied or associated intrusions might be found further east. The reconnaissance survey of the area was carried out to settle this point and to investigate the occurrence of mineral deposits.

Though called the north Kitui area for the purpose of this report, the portion north of the Tana River is chiefly occupied by part of the Meru district, while the land south of the river belongs to the Kitui district. The extreme north-eastern corner is part of the Northern Province. With the exception of Atharakan settlements in the north-western corner and at Tharaka south of the Tana the area, where populated, is occupied by Africans of the Kamba tribe. The north-eastern corner is at present unoccupied, though there is evidence of past Borana settlement.

Vegetation is chiefly of the acacia-type bush, the density of which is largely proportional to the local density of population. Thus in the Katze, Muvukuni, Tseikuru, Tharaka and Kikingo areas vegetation is sparse and frequently gives way to grass-free exposures of soil or rock. Eastward the bush is extremely dense, and direct traverses are only possible by the frequent cutting of tracks. Due to the presence of more fertile soil derived from volcanics the vegetation in the north-western corner consists of a more luxurious grass covering and fewer, though larger, trees. Finally, along the banks of the Tana, Ura, Thangatha, Thanandu and Kazita Rivers, the vegetation is chiefly riverine, typified by an abundance of palm trees.

The normally scanty rainfall in the area is confined to short seasons, during which there are sudden and often violent storms. The river-beds, which are dry for the greater part of the year, when they are frequently used for the cultivation of sweet potatoes, are then suddenly transformed into raging torrents. With corresponding rapidity the water-level drops, the flow of surface water seldom lasting for more than a few hours. The suddenness of the storms, coupled with over-grazing and improper methods of cultivation, has led to the development of an alarming condition of soil erosion in the populated western portion of the area. Half a century ago Peters (1891, p. 184) described the Tharaka valleys as being highly fertile, likening them to typical European valleys.

The following table gives the rainfall figures for three localities in the south-western portion of the area. Unfortunately, no recordings of the northern and eastern portions are available:—

	Rainfall 1950 (inches)	Rainfall 1951 (inches)	Rainfall 1952 (inches)	No. of rainy days 1952	Average Annual Rainfall up to 1952 (inches)	No. of years recorded
Katze	13·18	15·53	20·22	43	23·19	10
Muvukuni ..	13·65	34·11	14·33	21	17·03	9
Tseikuru	not recorded	35·52	7·97	16	—	1

Generally the area is poorly supplied with roads which are, without exception, maintained solely by the Local Native Councils. The roads from Mwingi to Usueni and Tharaka in the south, and from Meru to Kikingo in the north, are only occasionally used by administrative officers and Indian traders resident at Muvukuni, Tseikuru and Katze. A derelict motorable track, originally cut by the Locust Control, which extends past the trigonometrical beacons Samanguli and Matemeteveni is negotiable only with great difficulty. The nature of the country, both the hilly and rocky portion in the west

and the dense bush farther east, made the cutting of temporary roads for the survey impracticable. Due to the scarcity of roads, foot traverses of up to four days' duration to the less accessible parts of the area were necessary.

Exposures in the west of the area are generally good. Eastward, however, the dense covering of bush and the depth of soil prevented accurate demarcation of geological boundaries.

Maps.—As no adequate maps of the area were available, mapping of geological boundaries was carried out on strip tracings of aerial photographs. Similarly the form-lines depicted were largely derived from air-photos. Where possible, ground control fixed points were established by plane-table survey, and plane-table re-section was employed where positions on air-photos were in doubt.

Previous Geological Work.—Following the discovery of quartz crystals by a Mkamba, Wasia wa Mbolo, in the Tseikuru area in November, 1941, the District Commissioner of Kitui submitted a few specimens to the Mining and Geological Department. During February and March, 1942, Dr. W. Pulfrey investigated the occurrence of quartz crystals in the Kitui district as a whole and produced a short unpublished paper in which he described localities investigated and offered suggestions for areas likely to be worth further investigation. Government prospecting was commenced in May, 1942, by Mr. B. A. Brannstrom at Tseikuru.

II—PHYSIOGRAPHY

With the exception of a zone of discontinuous hills which extends in an east-north-easterly direction from the south-western corner and a broad dissected zone east of it the area consists of an extensive well-preserved erosion surface (Fig. 1). The monotony of this mature plain is broken only by occasional remnants of former land-surfaces, now represented by erratically distributed low-lying hills. The plain slopes gently and uniformly to the east-south-east at approximately 11 ft. to the mile, and the height along the eastern boundary is in the region of 2,000 feet.

North of Samanguli trigonometrical beacon, Massisini, a flat-topped plateau built of fossiliferous sediments of possible Tertiary age, is a remnant of a short sedimentary phase. Dixey (1948, p. 9)* has described the presence of fossiliferous Tertiary sediments preserved by a capping of basalt forming the Merti plateau, about 70 miles north of Massisini. He ascribed the surface below the basalt to mid-Tertiary planation and an end-Tertiary age to the surrounding plains. While the "2,000-ft." surface in north Kitui probably corresponds to the end-Tertiary surface described by Dixey, the flatness of the Massisini summit can probably be attributed to the structural control exercised by the composite horizontal strata and not to mid-Tertiary planation. The 2,000-ft. surface corresponds with King's (1951, pp. 250, 350) African cycle of pediplanation.

In considering the likelihood of remnants of older land-surfaces, attention is attracted to the ranges of hills in the west, which are such a striking feature of the physiography. Careful examination, however, failed to reveal the presence of co-planar platforms or bevels in the range. The constituent hills are completely irregular in shape and none possess related summit-levels. The ranges consist of a series of steeply-dipping bands of extremely resistant quartzose granitoid gneisses, and it is their resistance to weathering which has preserved them, perhaps through a number of erosion cycles, the duration of which were insufficient at any period to effect complete planation. In the area south-east of Embu, the summits of corresponding but larger ranges have been described by Bear (1953, p. 4) as possible remnants of an end-Cretaceous plain. Isolated hills such as Makisi are typical inselbergs, arising abruptly from the surrounding plains.

The area can be divided into two sections with distinct drainage patterns, one on either side of a N.N.W.-S.S.E. line through the trigonometrical beacons Ekole and Usueni (Fig. 5). East of this line the terrain is well-drained by a mature drainage system. The rivers are shallow, of mild gradients and with few, though well-developed, tributaries. In contrast, west of the line the area is finely dissected by numerous tributaries, most of which possess steep gradients. Detailed examination of the Tana River on the western and eastern boundaries of the area reveals a series of features that explain the abrupt change of drainage pattern.

*References are quoted on p. 27.

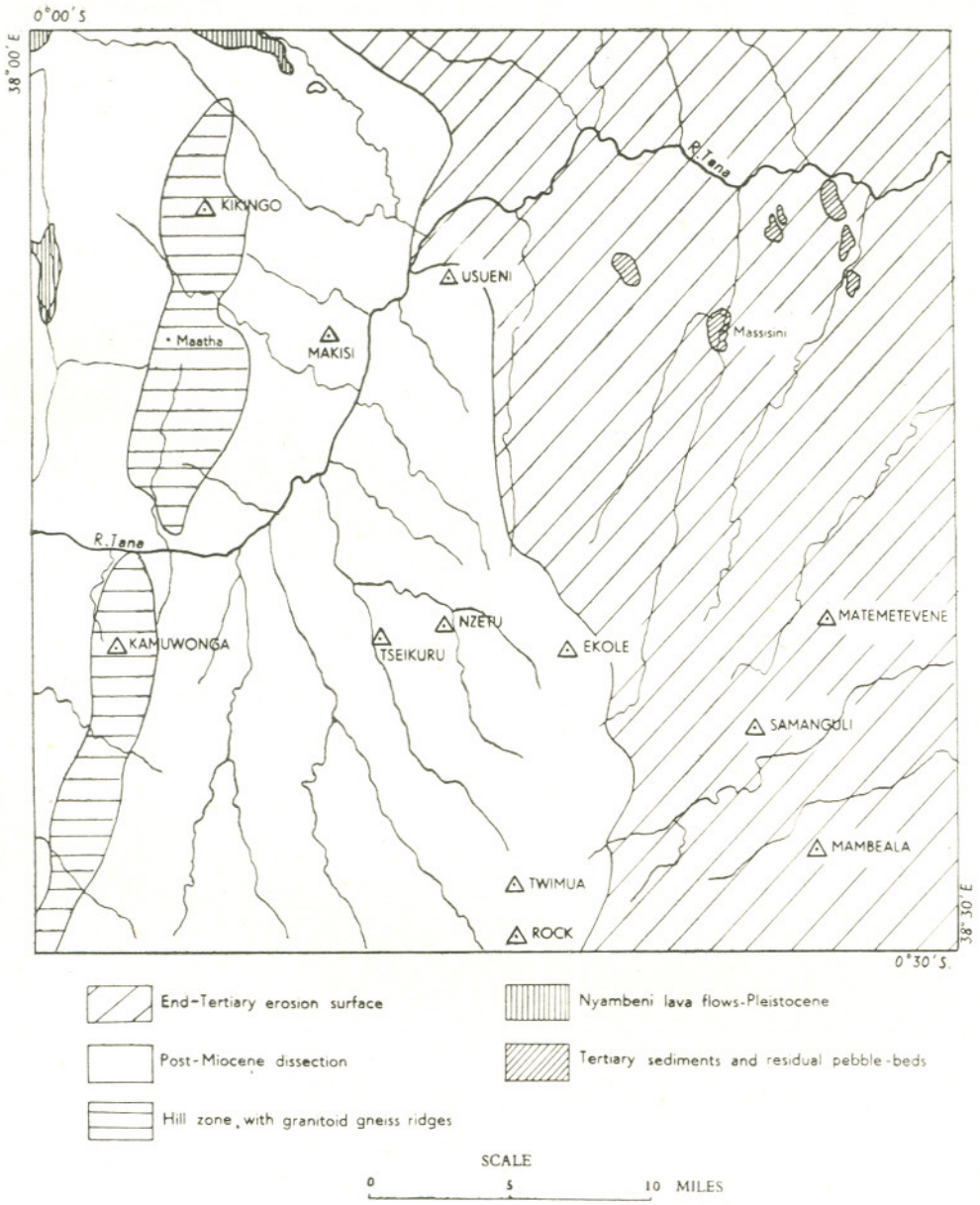

Fig. 1.—Physiographic sketch-map of the north Kitui area.

Slightly west of the area the Tana plunges down a series of steep rapids at Grand Falls. Schoeman (1951, p. 5) observed that above Grand Falls the Tana is broad and sluggish, while below the falls it has cut a deep gorge and is narrow and swift. This observation suggests that the falls are a nick-point which is retreating up-stream. The speed of retreat is rapid as is illustrated both by the fact that immediately below the falls all junctions of minor streams are not yet graded to the level of the Tana and by the length of the gorge, which extends for about eight miles. Further east, the Tana widens noticeably and its flow again becomes sluggish. Gently curving meanders and the presence of an ox-bow cut-off meander (now filled in with alluvium) indicate attainment

of maturity. On the eastern boundary of the area aggrading by the tributaries has produced large alluvial fans, the best example being that at the mouth of the Machungwa River (*see* Fig. 2).

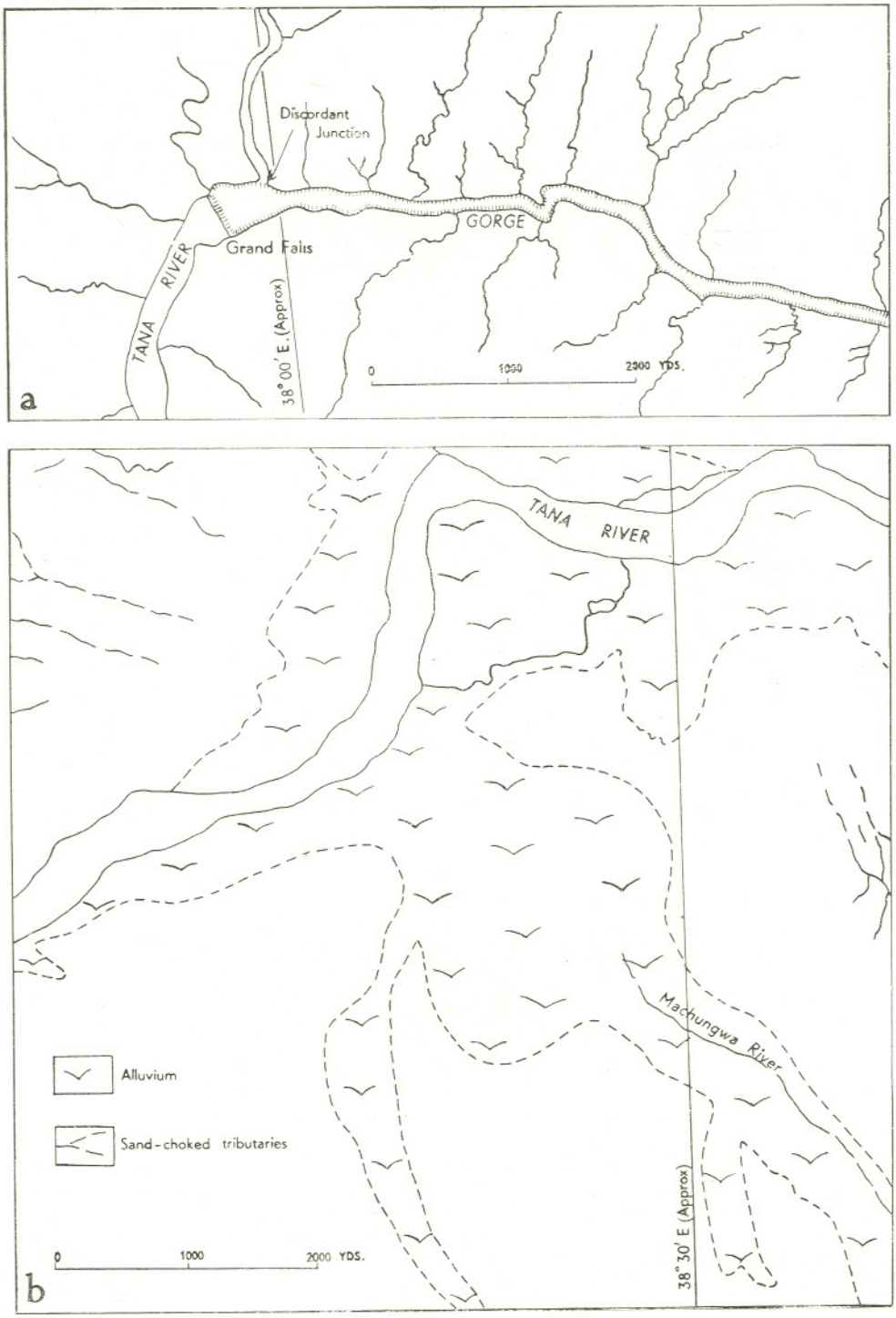

Fig. 2.—Physiographic sketch-maps of the Tana valley on the west and east boundaries of the north Kitui quarter-degree area.

(a) Retreat of nick-point at the Grand Falls on the western boundary.

(b) Alluvial fan deposits in the Kiboue District on the eastern boundary.

The contrast of drainage systems exhibiting features associated with rejuvenation in the western extreme and aggrading in the east suggests, in the writer's opinion, the possibility of gentle easterly tilting. The degree of tilting would be difficult to assess, though it is doubtful if it is greater than one degree. The axis of tilt appears to coincide with the line dividing the two drainage patterns.

III—SUMMARY OF GEOLOGY

Basement System

The geological succession in the north Kitui area consists mainly of rocks of presumed Archæan age with a small proportion of post-Archæan rocks. The earlier formations comprise rocks of the Basement System, together with minor intrusions. The younger rocks consist of a sedimentary series of probable Tertiary age, Miocene kenyte, Nyambeni basalts of Pleistocene age, and superficial sediments deposited between Pleistocene and Recent times.

The Basement System in the north Kitui area consists of a vast succession of heterogeneous para-gneisses, quartzites, crystalline limestones, calc-silicate rocks, amphibolites and graphitic gneisses invaded by minor acid and basic intrusives. The quartzites occur as narrow bands with included magnetite or the calcium-rich minerals epidote, diopside, wollastonite and garnet. The limestones which are generally salmon-coloured, are rarely free of impurities, invariably consisting of lenses of calc-silicate rocks that differ little from the larger calc-silicate lenses found in other parts of the area, where there is no limestone. In the eastern portion of the area outcrops are confined almost entirely to occasional inselbergs of homogeneous granitoid gneisses. In the western half the Basement System included gneisses of semi-pelitic and pelitic composition, which have undergone obvious metasomatism and are considered as migmatitic. In norizons rich in alumina the index mineral of high-grade metamorphism, sillimanite, has developed. Carbonaceous rocks are not abundant but two narrow lenses of graphitic gneiss were discovered. The amphibolites are of doubtful origin but appear to be highly metamorphosed calcareous pelitic sediments.

The acid intrusives consist of discordant granite lenses, and possibly concordant granites. The Basement System rocks are also cut by aplites, quartz veins and pegmatites. The basic intrusives consist of dolerites, meta-dolerites, hornblendites, pyroxenites and peridotites.

Mt. Kenya Series.—A small plug of kenyte is the sole evidence of the Mt. Kenya extrusive phase. A few concordant lamprophyre and discordant dolerite dykes are possibly related.

Tertiary Sediments.—A succession of nearly three hundred feet of sediments considered to be of Tertiary age forms the small flat-topped plateau of Massisini. The bulk of the sediments, overlying a thin basal conglomerate, is arkose derived from the disintegration of Basement System rocks and contains some fossil wood. At other localities where the sandstones have been removed by erosion the pebbles of the basal conglomerate remain as pebble beds.

Nyambeni Basalts.—Originating from volcanic cones north and north-west of the area, a few lava flows extend into its north-western corner. The thin sheets are composed of moderately porphyritic olivine basalt.

Pleistocene to Recent Sediments.—The Basement System is extensively covered by a superficial mantle consisting of a variety of reddish soils and gravels, which, in some cases are residual, but in others have been transported. Crusts of kunkar limestone rest on rocks sufficiently rich in calcium to have allowed during decomposition the release of the quantities of lime required for their formation. Along the Tana, exposed deltaic deposits consist of fine reddish silt.

(4) Pegmatites and aplites.

The succession in the south-west corner of the area appears to be as follows—

granitoid gneisses;
banded pelitic gneisses;
granitoid gneisses;
semi-pelitic gneisses;
crystalline limestone;
calc-silicate gneisses;
banded pelitic gneisses;
semi-pelitic gneisses.

(1) Meta-sediments

(*a*) *Psammitic Types*

(i) *Quartzo-felspathic Granulites*

In the Kanya valley, about seven miles north-west of Katze, a band of quartzo-felspathic rock forms a narrow but prominent ridge. Due to weathering, surface outcrops are usually confined to mounds of massive maroon-coloured boulders. The rock is tough and as the maroon staining, which is caused by iron oxides, persists to an average depth of about five inches, fresh specimens were obtained only with great difficulty. Jointing is well-developed in two planes, parallel with and normal to the strike of the foliation of surrounding gneisses.

Junctions with adjoining well-foliated gneisses are normally clear-cut, though a few isolated quartzo-felspathic lenses occur in the semi-pelitic series near the margins of the band. The granulite is practically free of intrusion by the aplites which extensively invade the surrounding gneisses. The texture of the granulite becomes perceptibly recrystallized, however, as the few junctions seen are approached.

In the hand-specimen the granulite is pale yellow to pale bluish and although well compacted, it has the homœoblastic, sugary texture characteristic of typical Basement System quartzites. Examination of a thin section of specimen 45/280* revealed that the rock is medium-grained and composed chiefly of quartz and felspar. Microcline is the predominant felspar and appears as large unaltered or slightly altered grains, or as a replacement of orthoclase. Quartz occurs either as large grains or as irregular blebs disemminated in the larger felspars. With the exception of a small amount of unaffected material, the orthoclase is highly altered. Though highly altered, a single grain of plagioclase also was recognized. The principal alteration products of the felspar are yellowish clusters of minute crystals of which the optical characters could not be determined. They are perhaps kaolinite, stained by hydrated iron oxide. A few grains of ilmenite are present and are to a greater or lesser extent altered to leucoxene. Minute crystals of zircon are abundantly "dusted" throughout the primary minerals.

Magnetite-bearing Quartzo-felspathic Granulites.—Slightly north of the hill Nthungu Thangatha a band of quartzo-felspathic granulite approximately 20 ft. in width is exposed in a narrow stream-bed. Due to the density of the surrounding bush and the overburden of soil, the width of the band elsewhere is obscure. At irregular intervals narrow seams of iron ore give a faint banding effect to the rock. With the use of a lens individual octahedra of magnetite can be recognized. In thin section (45/306) the quartzite shows an even-grained compact texture, with obvious directional orientation. The minerals present are quartz, felspar and sporadic accumulations of magnetite, but large recrystallized grains of quartz comprise the bulk of the rock. Both orthoclase and plagioclase felspar (An_{10}) remain relatively unaltered. Accessory minerals are represented by a few small grains of hornblende and sphene.

* Numbers 45/280, etc., refer to specimens in the regional collection of the department.

(ii) *Quartzites*

West of Kikingo on the western boundary of the area a band of quartzite forms a low ridge. The outcrop is largely obscured by Pleistocene lava-flows and by a thick mantle of black cotton soil produced by the weathering of the basalt. Fresh specimens (45/295) were obtainable only from a small hill slightly beyond the western boundary of the area. Close examination revealed a series of bright green to brownish-coloured bands. A thin section of the colour-banded quartzite reveals a medium- to fine-grained interlocking equigranular texture. The colour bands are due to the presence of garnet, epidote and diopside. Garnets, which in the hand-specimen appear reddish-brown, are pale greenish pink to neutral under the miscroscope. Though usually irregular to subhedral, a few scattered crystals of the garnet have dodecahedral form. Unlike the garnets in the surrounding gneisses, they are completely free of inclusions. Epidote occurs both in association with clinozoisite and as separate small rounded pleochroic grains. Larger irregular crystals of diopside are of haphazard distribution. Scapolite, replacing felspar (?), forms large patches, and judging from its maximum birefringence appears to be the calcium-rich mizzonite. A small amount of secondary calcite is also present and small crystals of accessory apatite and zircon are scattered through the quartzite.

The narrow calcareous seams (45/296) are composed mainly of well-twinned calcite grains and wollastonite crystals, with lesser amounts of diopside and a presumably calcium-rich garnet. The wollastonite occurs as stout colourless columnar crystals with well-developed cleavages parallel to (100). Some of it has undergone partial reversion to calcite either in narrow marginal zones or in irregular branching veinlets running through the crystals. A small amount of quartz is present in one part of the thin section.

Estimated volumetric modes of the psammitic rocks described are given in the table below:—

	45/280 *per cent*	45/306 *per cent*	45/295 *per cent*	45/296 *per cent*
Quartz..	43	73	78	3
Microcline	31	—	—	—
Orthoclase	15	5	—	—
Plagioclase	4	16	—	—
Calcite..	—	—	—	61
Garnet	—	—	14	7
Wollastonite	—	—	—	25
Magnetite	3	6	—	—
Diopside, epidote, zircon, apatite, etc. ..	4	—	8	4
	100	100	100	100

45/280 Quartzo-felspathic granulite, Kanya valley.

45/306 Magnetite-bearing quartzite, near Nthungu Thangatha.

45/295 Impure calcium-rich quartzite, about seven miles west of Kikingo.

45/296 Calcareous seam in quartzite, about seven miles west of Kikingo.

(*b*) *Calcareous Meta-sediments*

(i) *Crystalline Limestones*

Due to their superior resistance to erosion the limestones usually form prominent outcrops, either as discontinuous boulders or as series of low-lying hills. The limestone bodies are usually of thin lens shape. Of the several outcrops in the area in but a single instance—that of a narrow band of limestone south of Rock trigonometrical beacon—is the rock free from megascopic melanocratic impurities. The limestone there (45/319) is coarse-grained and, while normally pink, it includes tongues of white marble. A thin section shows that it consists of large, well-twinned grains of calcite with a few quartz grains in vein-like segregations. The quartz invariably shows obvious strain effects.

The impure limestones contain variable amounts of calc-silicates, either evenly disseminated or as segregations. Due to their greater resistance to weathering the often-ellipsoidal groups of calc-silicate minerals frequently project from the matrix of calcite. Specimen 45/226 was collected from such a segregation found in salmon-coloured limestone near the Nzetu River, about two miles south of Nzetu trigonometrical station. It consists mainly of dark minerals, with little calcite and quartzo-felspathic material. Microscopic examination revealed the presence of large crystals of diopside with inclusions of felspar, quartz and large apatites, and somewhat replaced by calcite. There are also irregular intergrowths of light green weakly pleochroic hornblende and some large patches of scapolite. Sphene is occasionally present in large rather irregular crystals. Specimen 45/227 was collected from an adjoining band of impure limestone and, in addition to the dark minerals, contains pinkish calcite. A thin section of the rock consists mainly of calcite, but quartz, felspar, hornblende, diopside, scapolite and large sphenes are also present. In extreme cases, such as specimen 45/230 from the Kangai valley, the impure limestones consist almost entirely of dark minerals, with only occasional segregations of calcite. The calcite is either augen-shaped or in narrow veins and is invariably salmon-coloured. Forsterite and tremolite, described by Bear (1953, p. 8) and Shackleton (1946, p. 7) from marbles in the Embu and Maralal areas, are absent from the thin sections examined.

(ii) *Calc-silicate Rocks*

Numerous lenses of rock composed of calcium-rich minerals are scattered throughout the area, but tend to be more abundant in the south-western corner. Due to the unusually high resistance of these rocks to erosion, the extent of their outcrops often appears deceptively large owing to the wide distribution of boulders. During field examination and later microscopic study of specimens, no evidence of the introduction of metasomatic material was found. It must, therefore, be assumed that the chemical composition of the rocks has been altered little from their original state, the present mineral assemblage having been formed by the intense regional metamorphism of calcareous sediments. Narrow stripes of limestone are frequently intercalated in the calc-silicate lenses.

While the greater proportion of the calc-silicate rocks consist predominantly of a single mineral, others include up to six different minerals in approximately equal proportions. Of the "mono-mineralic" types, the best examples are found on the prominent ridge, south-east of Kamuwonga. The ridge consists of minor lenses composed of garnet, epidote, diopside and hornblende with occasional intercalated limestone bands. The flanks of the ridge consist of steeply dipping impure limestones. Garnet-predominant types are most common and constitute the bulk of the hill south-east of Kamuwonga. Hornblende and diopside-rich types are less common and occur usually as small lenses. Specimen 45/278 consists almost entirely of garnet and is dark maroon, flecked with green. In thin section the garnet appears as an allotriomorphic aggregate with abundant inclusions. The larger inclusions consist of epidote, diopside, highly saussuritized felspar, calcite and quartz. Sometimes felspar and epidote form graphic intergrowths. Calcite is secondary, and replaces other inclusions. Specimen 45/222 from the Nzetu River shows typical sieve texture and features a higher proportion of inclusions. The chadacrysts consist chiefly of quartz, hornblende and primary calcite. Small crystals of zircon and apatite are included in both the garnet and quartz.

Specimen 45/276 is composed predominantly of remarkably uniform epidote. In the hand-specimen a well-defined directional orientation can be seen and planar hornblendic enrichment produces a banding effect. The hornblende is a weakly pleochroic bluish-green variety, occasionally with schiller inclusions. Accessory minerals include diopside, saussuritized felspar, occasional poikiloblastic crystals of garnet, a few octahedra of magnetite and small rounded grains of sphene.

The types with several minerals in equal abundance contain the following minerals as their more common constituents: hornblende, diopside, epidote, garnet, scapolite, calcite and clinozoisite. Sphene is a constant accessory. Quartz is frequently absent but,

when present, occurs as small interstitial blebs. Felspar is present in variable amounts and, though usually sodic andesine (An_{35}), more calcic types are frequent. The felspar is often replaced by scapolite. In specimen 45/208 the replacement has been carried to the extent that only a few isolated grains of felspar remain unaltered. Quartz is replaced by scapolite to a smaller extent. The large grains of scapolite have high birefringence, indicating enrichment in the meionite molecule. Intergrowth textures were noted in only one thin section, of specimen 45/314, which consists of a graphic intergrowth of garnet and plagioclase (Fig. 3). The garnet is fresh light brown in colour and is probably the calcium-rich grossularite variety. The plagioclase is fairly calcic, approximating to An_{60}. Accessory minerals are sphene, iron ore, altered hornblendes and clinozoisite.

Mineralization of the calc-silicate rocks is uncommon. In the south-western corner of the area, however, on the northern slopes of Marriri, bornite has been introduced. Reaction with carbonated waters has produced a discontinuous incrustration of malachite. Specimen 45/271 is a medium-grained allotriomorphic gneiss composed of quartz, felspars (orthoclase, microcline and plagioclase), epidote, clinozoisite, diopside, hornblende, scapolite, sphene and traces of malachite.

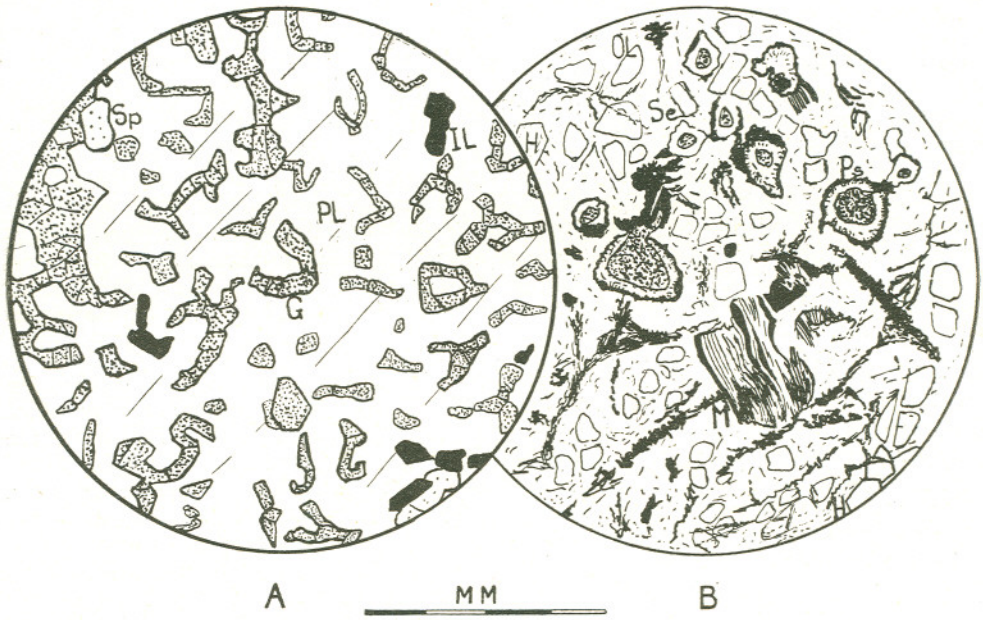

Fig. 3.—Microscope drawings of thin sections of rocks.

A.—Garnet-plagioclase intergrowth in a calc-silicate rock. Specimen 45/314, 4.74 miles west of the Tana-Ura confluence. Ordinary light. PL = plagioclase; IL = ilmenite; Sp = sphene.

B.—Altered peridotite (saxonite). Specimen 45/204, Kanondu. Ordinary light. OL = olivine; Se = serpentine; M = magnetite; Ps = pleonaste spinel; H = hypersthene.

(c) Semi-pelitic Gneisses

(i) *Hornblende-plagioclase Gneisses*

Both Schoeman (1951, p. 10) and Bear (1953, p. 13) have described hornblende-plagioclase gneisses in the areas west and south-west of the area under discussion. Numerous narrow, and a few wide, bands of similar gneisses were also recognized during the present survey. As such rock types are more readily weathered than other gneisses, outcrops are normally confined to river-beds. The existence of extensive surface deposits of kunkar limestone associated with red soils in the Tseikuru, Ekole and Muvukuni areas suggests, however, the presence of a large amount of underlying hornblendic rocks.

Specimen 45/317, from a locality about 3.3 miles W.S.W. of Kikingo, is a coarse-grained hornblendic gneiss. An irregular banding effect is caused by the presence of occasional quartzo-felspathic lenses of variable dimensions and shapes. Examination of a thin section proves the rock to be composed essentially of hornblende and plagioclase. Where the plagioclase is sufficiently unaltered to allow identification, the maximum extinction of albite twins in the symmetrical zone indicates that it is andesine. As calcite is an abundant alteration product of the plagioclase, however, it is possible that some of the most altered felspar may have been originally more calcic. Lenticular grains of quartz show strain effects. Accessory minerals are pyrite, sphene, magnetite and apatite. Another specimen, 45/235 from the Nzetu–Usueni road, has similar texture and contains small amounts of pyroxene and scapolite in addition to hornblende and plagioclase. It is probable that the chemical composition of these gneisses has altered little, the mineral assemblage being due almost entirely to the regional metamorphism of calcium-rich semi-argillaceous sediments. While it is likely that they have been more or less granitized, the extent of the role that metasomatism played is not easily assessed.

(ii) *Sillimanite Gneisses*

Two principal types of sillimanite gneiss occur in the area: biotite-sillimanite gneisses and biotite-garnet-sillimanite gneisses. These rocks are generally slightly more resistant than surrounding gneisses and often form low, discontinuous ridges consisting of thin sillimanite-bearing slabs. Invariably the sillimanite is either confined to or, at least, concentrated along the foliation planes. The sillimanite is detectable in the field as pearly-lustred pale brownish clusters which are whitish on freshly broken surfaces.

The sillimanite occurs in quasi-fluxional or felted tufts, which usually have a common orientation. Fully radiating aggregates are rare, though fan-like sheaves of needles are common. Biotite-sillimanite gneiss specimens 45/307 from the Thangatha River, east of Kikingo, and 45/277 from the Tharaka–Katze road are both rich in quartz. Few grains of quartz or orthoclase felspar are free of sillimanite needles, which either wind stream-like around the larger grains or crowd others in typical sillimanite sheaves. In specimen 45/307 a large grain of magnetite includes several small sheaves of sillimanite. Accessory minerals in the gneisses include green biotite, subhedral to euhedral magnetite, muscovite and zircon.

Specimen 45/267 from the Konyu valley is a garnetiferous sillimanite type. In the hand-specimen dark reddish-brown almandine garnets produce a marked lumpy texture. In thin section the garnets show strong porphyroblastic habit with well-developed sieve structure. While small sheaves of sillimanite are poikilitically enclosed by the garnet, the needles normally wind around the garnet porphyroblasts. Accessory minerals are similar to those previously mentioned.

(*d*) *Pelitic Rocks*

Amphibolites

Dark rocks composed essentially of amphiboles associated with pyroxene, garnet and plagioclase felspar have been variously described in previous reports. The most commonly accepted subdivision is that between amphibolites and plagioclase amphibolites—the distinction depending on the relative proportions of plagioclase. In the field there is a tendency towards confusion in distinguishing plagioclase-hornblende gneisses and plagioclase amphibolites, though the amphibolites should by definition contain a greater proportion of hornblende than the gneisses.

In the present area no evidence that the amphibolites might be derived from igneous rocks was observed. The junctions between them and the surrounding gneisses were invariably found to be gradational, and careful examination failed to reveal the presence of dolerite cores in the amphibolites. In the thin sections examined no relic ophitic textures were recognized. Accordingly the north Kitui amphibolites are regarded as derived by the metamorphism of sediments.

The *plagioclase-amphibolites* occur as fairly thick bands or lenses, normally associated with semi-pelitic or pelitic biotite-rich gneisses, and their uniformity is only broken by localized felsic or calc-silicate segregations. It is noteworthy that the same segregations occur in adjacent biotite-rich gneisses. Specimen 45/233, from the mouth of the Muvukuni River, is a dark, even-grained, strongly gneissic type. It consists chiefly of green hornblende and plagioclase (An_{30}), with a small amount of accessory quartz, sphene and ilmenite. In addition to hornblende and plagioclase, specimen 45/292, from about five miles N.N.W. of Kikingo, contains garnet and an appreciable amount of iron ore. Where in contact with the plagioclase or quartz the hornblende sometimes shows marginal intergrowth rims. The hornblende has in part replaced garnet, producing a sieve structure with hornblende forming the mesh. Pyroxene-bearing types are fairly common and specimen 45/300, from the Thangatha River, east of Kikingo, contains about 20 per cent of diopside.

The *amphibolites* occur either as segregations within plagioclase-amphibolite, or as separate bands. The latter may possibly be derived from igneous rocks but no evidence to support such a belief was noted. Specimen 45/264, from Kanzoni E.N.E. of Katze, is a typical compact strongly gneissic amphibolite. In thin section it is seen to consist of green hornblende, diopside, scapolite, clinozosite and quartz with felspar, sphene and apatite as accessory minerals. A little west of Twimua a rock (45/200) with a similar mineral assemblage occurs, though it contains a slightly greater percentage of felspar. Additional minerals found in the amphibolites and not already mentioned are garnet, epidote and calcite.

(*e*) *Carbonaceous Rocks*

Graphitic Schists and Gneisses

Of the two graphite occurrences in the area, one is schistose and the other, containing fine flakes of graphite, is gneissose. In both cases exposures are confined almost entirely to stream-beds. At the graphitic gneiss locality a few previously excavated trenches greatly assisted examination of the deposit.

Slightly north of Massisini plateau a band approximately 5 ft. 6 in. wide of compact coarse-grained graphitic schist is exposed in a river. Due to the density of the surrounding bush and the thickness of soil overburden, the extent of the deposit could not be accurately estimated during the period spent in that area. The schist consists of large, tightly compacted flakes of graphite with occasional "augen" of kaolinized felspar up to two inches long. Inclusions of quartz are seldom more than one inch and are less common than felspar. Iron oxide staining is apparent in a few of the altered felspar lenses.

The graphitic gneiss consists of a graphite-felspar horizon in rocks of pelitic facies north-east of the Tharaka D.C. rest-house. A series of cross-strike trenches revealed that the graphite-bearing gneiss is approximately 20 ft. wide. The graphite content is variable in different parts of the band and there is a marked decrease in the content of carbonaceous matter towards the margins. The graphite occurs both as small irregular plates or as larger narrow flakes up to 3 mm. in length. The groundmass consists of altered felspar and a smaller amount of quartz.

(*f*) *Hybrid Rocks*

Appinites

Hybrid hornblendic rocks classified as appinites have been described by Read (1931, p. 171), Reynolds (1936, p. 378), Wade and Oates (1938, p. 38), and Bear (1953, p. 13). Although the origins ascribed to them differ greatly in many respects, the general descriptions of the rocks themselves agree to a reasonable extent. It is agreed that the rocks are composed essentially of hornblende and felspar with or without quartz, diopside, epidote, and accessory zircon and apatite. Biotite is normally absent.

In the vicinity of Muvukuni bands of rocks occur of similar if not identical characters to the appinites. The rocks vary from coarse-grained "spotted" gneisses to finer-textured dark types, the latter frequently resembling amphibolites. The hand-specimen 45/189, from Muvukuni, has a medium-grained spotted texture caused by an abundance of hornblende clots in a felsic matrix. In thin section it is seen to consist almost entirely of hornblende, much altered felspar and a little epidote. The felspars are sometimes saussuritized making identification difficult, but their composition probably approximates to An_{35}. The rock is believed to be a hybrid type resulting from the interaction of acid felspathic magma with a solid ultra-basic biotite-free rock.

(2) Migmatites

(a) Banded Pelitic Gneisses

Banded, pelitic gneisses have been described by numerous investigators, and their field characters are well-known to anyone familiar with the Basement System rocks of East Africa. They occur as strongly banded, often highly contorted masses, consisting of a mafic host-rock with bands (or veins) of felsic material which are considered to have been introduced subsequent to the deposition of the original rock. Schoeman (1951, p. 9) described the mafic bands as schists. While there is little doubt that the biotite-rich layers are locally schistose, it is the writer's opinion that the rocks as a whole should be considered as migmatites because of the "mixing" of the dark and light-coloured components. Due to the weak resistance to weathering of these rocks, exposures are poor and are often confined solely to stream-beds. A glance at the geological map shows that rivers frequently cut courses along the bands of pelitic gneisses in preference to following the more resistant psammitic gneisses.

The banding and veining is seldom regular; more commonly it is distorted, highly irregular and frequently disrupted. Where individual banding is shattered, biotite-rich xenoliths are enclosed by the introduced material which often has the appearance of having flowed round the inclusions. Ptygmatic folding of the felsic bands produces a wide variety of structural forms from which the direction of stress at the time of the introduction of the felsic material can be deduced. In all localities examined it was observed that movement must have been in a south-westerly direction.

Typically the pelitic gneisses have a granoblastic texture and are composed of quartz, potash felspar, plagioclase and biotite. The banding is caused by alternating layers composed predominantly of either mafic or felsic material. The mafic host comprised the bulk of the gneiss, the introduced felsic layers occurring as thin bands of variable dimensions. Junctions between the contrasting bands are normally well-defined; complete mixing is infrequent. In the area mapped, due to calcic enrichment, hornblende frequently takes the place of biotite. Where enrichment is sufficiently high segregations of calc-silicate are found in boudinage structures. Specimen 45/263, taken from a "mixed" mafic felsic band on Kanzoni hill, is typical of the local pelitic gneisses. Replacive quartz has crystallized late and slightly replaces some of the plagioclase and orthoclase. The plagioclase is oligoclase-andesine (An_{30}) (throughout the pelitic rocks, the composition of the plagioclase is subject to little variation and seldom becomes more calcic than andesine (An_{40})). The potash felspar is more commonly orthoclase and in part shows marginal reaction with the earlier-crystallized plagioclase. The small amount of microcline present is partly replaced by myrmekitic intergrowths. The dark minerals consist of greenish brown biotite, green hornblende and epidote. Both primary and secondary muscovite are common constituents. As is typical of local pelitic gneisses the accessory minerals in specimen 45/263 are chiefly magnetite, ilmenite, zircon, apatite and sphene.

In the Tseikuru area a number of quartzose lenses present an unusual structural feature in the pelitic series. The lenses lie normal to the foliation and are of greatly varying size. They consist of crystallized quartz or, more commonly, of massive quartz which it is believed has been derived from the surrounding gneiss. During its migration the quartz was accompanied by basic material which, however, crystallized along the margins of the quartz bodies. The migration of the material that gave rise to quartz and ferromagnesian minerals in the lenses produced felspar around them.

(*b*) *Semi-pelitic Biotite Gneisses*

The semi-pelitic biotite gneisses occupy a large portion of the area surveyed. In the field they are massive though foliated, homogeneous rocks, with only limited local textural or petrological variations. Essentially they are composed of potash felspar, plagioclase and biotite, foliation being displayed by the orientation of the biotite. Contacts with the pelitic gneisses are invariably gradational and frequently isolated lenses of banded gneisses are enclosed in the semi-pelitic series. Faint banding is not uncommon. In the vicinity of Mazeki hill the biotite gneisses become notably mottled with a tendency towards segregation of the mafic constituents. Again, west of Kamuwonga, development of clots composed of fine flakes of biotite produces a glomeroplasmatic texture.

In thin sections the biotite gneisses are found to be medium- to fine-grained with well-defined directional orientation of the micas. The order of crystallization, consequent on granitization, is variable. In specimen 45/270, from Mavia Mutuni, the order is believed to be as follows: mafic minerals, quartz, orthoclase microcline and myrmekite, followed by a second generation of quartz. The earlier quartz occurs as smallish clouded, sutured grains and the later quartz is represented by larger clear grains with embayments or tongues penetrating adjacent felspars. The latter quartz is possibly representative of the final phase of granitization. The felspars often are more or less altered, though much of the microcline is almost fresh. The alteration consists of marginal and internal sericitization, and muscovite has in places been extensively developed at the expense of the felspars. The biotite is greenish and occasionally contains inclusions of zircon or magnetite. Accessory minerals typical of the biotite gneisses are: euhedral octahedra of magnetite, sphene and small crystals of apatite and zircon. Specimen 45/191, from near Muvukuni, and 45/258, from the hill about two miles east of Ithungi in the eastern part of the area, taken from widely separated localities, are closely similar and demonstrate the homogeneity of the semi-pelitic gneisses as a whole.

(*c*) *Psammitic Granitoid Gneisses*

The texture and mineralogical composition of psammites are more conducive, on granitization, to the development of granitoid rocks than those of the pelitic and semi-pelitic types. It is the granitoid rocks of psammitic origin which, by virtue of their superior resistance to weathering, have given rise to the more prominent physiographic features in the area. The belt of rugged topography which included the hills of Kikingo, Maatha and Kamuwonga is composed of magnetite-bearing granitoid gneisses. Eastward the monotony of the low-lying plain is broken by conspicuous tors and inselbergs composed of granitoid gneisses.

Over the large area occupied by the granitoid gneisses the rocks are remarkably homogeneous. The buff-coloured outcrops are usually massive, lacking foliation, but nevertheless retaining a faint and gneissic orientation of the constituent minerals. Usually the granitoid gneisses pass imperceptibly into biotite gneisses. Quartz or quartzo-felspathic lenticles are fairly common and are often stained a bright pinkish colour by iron oxide. The gneisses as a whole are frequently stained pink by the deposition of iron oxides liberated during the alteration of their ferromagnesian minerals.

Under the microscope the gneisses are found to be remarkably uniform. They have compact allotriomorphic textures and are found to consist of alkaline felspars, quartz and plagioclase. In a slide of specimen 45/243, from near Mambeala trigonometrical beacon, microcline replaces orthoclase, quartz and oligoclase, and the oligoclase is also more or less replaced by the other felsic minerals. Late introduced (?) quartz shows marginal intergrowths where in contact with microcline. The dark minerals in the granitoid gneisses are biotite and hornblende, while magnetite, zircon and apatite are constant accessories.

There is little doubt in the writer's mind that an appreciable proportion of the granitoid rocks in the north Kitui succession have crystallized from mobilized rocks, if not from a magma. It is rare, however, that examination of their field-relationships yields any evidence that they are of igneous origin, except when they are discordantly intrusive. Some of these rocks the writer prefers to consider as gneissic granites.

South-west of Massisini a band of garnetiferous granitoid rock has textural features that recall those of granites. The rock is a pinkish, medium- to coarse-grained, slightly gneissose type containing large garnet porphyroblasts. The garnets are normally in dodecehedra and vary from about 3 mm. to approximately 55 mm. in diameter, and each garnet is surrounded by a zone consisting wholly of felsic constituents. Since the rock contains a relatively high overall percentage of ferromagnesian mineral, it is evident that the garnets have developed at their expense. Qualitative chemical tests of the garnets proved that they contain calcium, iron and magnesium. A thin section of specimen 45/249, which does not include garnet, consists chiefly of large anhedral grains of microcline, orthoclase, hornblende and biotite. The microcline replaces orthoclase and plagioclase and frequently occurs along the common margins where later reaction rims of more sodic plagioclase have been developed. Quartz is not abundant, occurring either as small grains or as graphic inclusions and blebs in the large grains of potash felspar. Accessory minerals are iron ore, zircon, apatite and secondary calcite.

(3) Intrusives in the Basement System

(*a*) *Acid Types*

Granites

Three occurrences of intrusive granite were discovered during the course of the field-work. Their intrusive nature is indicated by discordant emplacement and by chilled contacts with the country-rocks.

In the south-western corner of the area in the Kanyu valley a pinkish medium- to fine-grained granite is exposed in several small stream-beds. The granite was mapped as a single mass, but actually it consists of several bodies ranging from over a hundred feet in width to narrow tongues a few inches thick. In a thin section of specimen 45/265 the texture is seen to be typically granitic. Microcline is the predominant mineral and replaces orthoclase, plagioclase and quartz. Both orthoclase and plagioclase are highly altered, the chief alteration product being irregular flakes of muscovite. Small crystals of greenish or somewhat bleached biotite, some of which have been replaced by chlorites, constitute the ferro-magnesian constituent. Accessory minerals are magnetite and apatite.

North of the Tharaka District Commissioner's rest-house a flat-lying intrusive granite body is aligned at right-angles to the local foliation strike. It is probable that intrusion took place along a joint plane, subsequent erosion having removed the overlying gneisses. The outcrop forms a long low ridge. The rock (45/281) is a fine-grained, greyish, biotite-rich type showing remarkable uniformity over the length of the outcrop. In thin section it is found to differ only in detail from the Kanyu valley granite. Myrmekite replaces the potash felspar to a certain extent and the quartz shows faint strain effects.

(*b*) *Basic Types*

Dolerites and Meta-dolerites

Several dolerite dykes of unknown age cut the Basement System rocks in the area. Due to superior resistance to erosion they frequently form low ridges and invariably outcrop as dark spheroidal boulders, sometimes with a crusting of iron oxide. The existence of Muvukuni hill is due solely to the presence of a dolerite intrusive which follows the foliation strike in a gentle curve from a north-north-west direction at

Muvukuni, to a northerly course south-east of Tseikuru. As far as can be seen all the dolerites are aligned parallel with the foliation strike of the gneisses. No contacts were seen. The dolerites, when examined in thin section, all showed alteration of their constituent minerals to a greater or lesser extent.

Specimen 45/183, from Muvukuni, is a coarse intergranular olivine dolerite. The plagioclase felspars (An_{45}) are highly saussuritized. The pyroxenes include hypersthene, enstatite and augite. Surrounding some of the larger pyroxenes are dactylic hypersthene-hornblende-pleonaste intergrowths. The olivine occurs as small irregular altered grains. Pyrrhotite is the only opaque mineral present and qualitative chemical tests revealed that it contains traces of nickel, probably as the ferro-nickel sulphide pentlandite. In specimen 45/214 of similar dolerite, from west of Kianchuz River, cores of olivine are surrounded by serpentine. In specimen 45/225, from south of Nzetu, a rock considered as a meta-dolerite or epidiorite, pyroxenes which appear to have originally been enstatite with well-developed schiller structures have been almost completely replaced by hornblende. Less altered grains consist of a rim of hornblende surrounding a partly altered core of pyroxene. Parts of the felspars are intensely saussuritized, and in such parts dactylic outgrowths of hornblende are prominent (Fig. 4B).

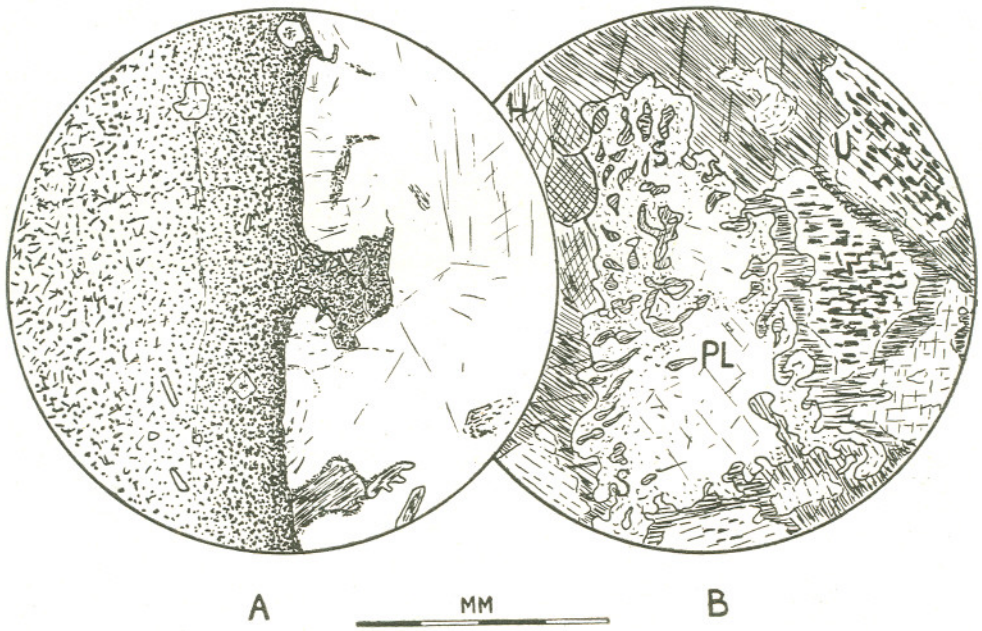

Fig. 4.—Microscope drawings of thin sections of dolerites.
A.—Basalt dyke gneiss contact. 45/248, west-north-west of Massisini hill. The chilled zone in the dolerite is narrow and the gneiss shows only slight fracturing.
B.—Altered dolerite. 45/225, south of Nzetu. H = hornblende; PL = plagioclase; U = partly uralitized pyroxene; S = saussuritized felspar.

(c) Ultrabasic Intrusions

(i) *Peridotites*

Peridotites are not abundant in the area and only two narrow bodies dissimilar in field and petrological characteristics were discovered.

Specimen 45/203 taken from a narrow dyke-like intrusion east of the kenyte at Kanondu is a lherzolite. It is a coarse-textured rock composed of olivine, both ortho- and clino-pyroxene and hornblende. Specimen 45/204, from an adjoining dyke north of Kanondu, was taken from the kenyte-peridotite junction. The olivine, which here was much more abundant than in the more easterly dyke, is considerably serpentinized,

though abundant cores of olivine remain. Hypersthene is present in large crystals and the rock is classified as a saxonite. Secondary magnetite, an alteration product due to the serpentinization of olivine, forms notable skeletal textures (*see* Fig. 3B). Olive-green pleonaste spinel occurs either as irregular grains or as cores enclosed by yellowish weakly birefringent rims, which in turn are enclosed by a periphery of finely granular magnetite. The yellowish mineral is probably a chlorite. The reaction groups probably result from interaction between the pleonaste and serpentine.

South-east of Kamuga hill a hornblende saxonite (45/302, 304) crops out in a narrow river-bed, but extensions of the outcrop are largely obscured by the extremely dense vegetation. At the river-bed the outcrop is about 30 ft. wide and it is obvious that the rock is an intrusive. Contacts are well-defined and narrow embayments, tongues and veinlets extend into the neighbouring gneisses. In the hand-specimen the rock appears to consist of dark bluish-green hornblende, coppery-coloured pyroxene with sub-metallic lustre, and large highly altered olivine crystals. The pyroxene is pink hypersthene, and the large crystals of olivine are partly serpentinized. Hornblende is an important constituent. It is pale greenish-blue and only weakly pleochroic, which possibly indicates a slight soda content and a low iron content. The hornblende occurs either as medium-sized interlocking crystals or replacing the pyroxenes. Accessory minerals are pleonaste spinel and secondary magnetite. The spinel is patchily abundant in small grains, and occasionally forms larger (2 mm.) irregular grains.

(ii) *Pyroxenites*

Specimen 45/207 from the dyke north-west of Twimua is a saxonitic olivine-bearing biotite pyroxenite, containing minute blebs of pleonaste. Large crystals of enstatite have well-developed schiller structures. In the hand-specimen the biotite flakes are a bright copper colour, and reach a maximum length of about 10 mm. Their pleochroism is strong with X = pale yellowish green, Y = pale reddish, Z = chestnut. The biotite is sometimes intimately associated with pale green to pale brown hornblende from which it is probably derived.

(iii) *Hornblendites*

The term hornblendite is used to describe rocks considered to be of igneous origin which are now composed essentially of hornblende with only small amounts of other minerals. Two occurrences of this type of rock were mapped and in each case the field relationships are similar. They occur as dark coarse-grained discontinuous outcrops, of slightly greater resistance to weathering than the felsic acid gneisses. The contacts with country-rock, where exposed, are well-defined.

In the south-western corner of the area near Kuiga a narrow, prominent, discontinuous outcrop was mapped. A thin section of specimen 45/272 from this occurrence is coarse-grained and composed principally of strongly poikilitic greenish-brown hornblende. The inclusions in the hornblende consist chiefly of diopsidic pyroxene. The hornblende is slightly "fibrous"—a form generally associated with uralitization. Small amounts of saussuritized felspar and clinozoisite comprise the bulk of the remaining constituent minerals.

A less resistant finer-grained type which occurs in the south-eastern corner of the area, four and a quarter miles south-east of Mutilia, appears mainly as discontinuous mounds of greenish rock-brash. Less altered material is exposed in small stream-beds. Microscope examination of a thin section of specimen 45/257 revealed that the rock is composed mainly of blue-green hornblende with occasional pyroxenes patchily replaced by hornblende. Some of the hornblende crystals enclose clusters of magnetite grains which are interpreted as relics of original pyroxene replaced by the hornblende. The clusters of inclusions vary from typical criss-cross patterns to dense aggregates of minute grains.

The presence of altered pyroxenes indicates that the hornblendites were probably derived from pyroxenites.

(4) *Pegmatites and Aplites*

In certain localities quartz, quartzo-felspathic and felspathic veins are abundant, and are invariably confined to the pelitic and semi-pelitic rocks, rarely appearing in the psammitic series. In the Tseikuru area a complex and extensive anastomosing system of such veins is well exposed. Generally they are more resistant than the country-rock and remain as discontinuous heaps of boulders, long after erosional decay of the surrounding gneisses.

Quartz is the most common vein-rock. In the Tseikuru area large lenticular bodies have yielded partly glassy quartz crystals up to two feet long and numerous smaller crystals of optical quality. Generally, however, the large veins, such as that north-east of Kakuranza hill, are composed of milky quartz, and are rarely mineralized. Of the included minerals, magnetite is far more common than hornblende and muscovite, and small prisms of apatite are found rarely. A few small prisms of amethyst were obtained from the Tseikuru veins in addition to colourless or white quartz crystals. The amethyst, in common with some of the rock crystal contains numerous needles of rutile. No tourmaline or apatite was found in the pegmatites.

The quartzo-felspathic veins are composed chiefly of either graphic intergrowths of quartz and felspar or largely of microcline, the microcline often being remarkably porphyritic. An unusual feature displayed on the rock face of Nzetu hill is the presence of phenocrysts of microcline within veinlets whose widths are seldom greater than the thickness of the phenocrysts. It is clear that the porphyritic crystals must have grown *in situ*. Aplites are rare and seldom wider than a few inches. They are of quartzo-felspathic composition with only small amounts of accessory iron ore.

(2) Post-Basement System Rocks

(1) Mount Kenya Series

(*a*) *Kenyte*

South-south-west of Tseikuru trigonometrical beacon a volcanic neck forms the small conical hill Kanondu. The neck consists of coarsely porphyritic kenyte, the phenocrysts of which average about 30 mm. in length and in more densely porphyritic specimens constitute up to 30 per cent of the total composition. Comparison with the kenytes from Mount Kenya further west shows strong similarity between the rocks.

Specimen 45/205, from Kanondu, has a fine-grained dark groundmass supporting large phenocrysts of porcellaneous whitish anorthoclase and, less commonly, waxy-looking greenish nepheline. Examination of a thin section proved that, in addition to the large phenocrysts, there are micro-phenocrysts of augite and olivine. The groundmass is finely crystalline and is composed of approximately equal parts of felsic and mafic minerals. The felsic minerals consist of fine acicular prisms of felspar with low extinction angle (probably anorthoclase), small euhedra of nepheline and an isotropic base that may be analcime. The dark minerals of the groundmass are pyroxene, kataphorite and iron ore.

The large felspar phenocrysts have undergone peripheral resorption. While the crystal outlines remain unaltered, the crystal faces are corroded and etched by a fine-grained border of the rock groundmass.

(*b*) *Intrusives of Presumed Tertiary Age*

(i) *Basalts*

In the vicinity of the junction of the Tana River and its tributary the Ura, north-east of Usueni trigonometrical beacon, three narrow basaltic dykes were discovered, which are considered to be of Tertiary age. A similar dyke is exposed in a river-course just west of the Massisini plateau. No stratigraphic evidence of age was found, however, and the dating must be regarded as tentative. It is possible that the dykes might be of Pleistocene age.

(4) *Pegmatites and Aplites*

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(1) Mount Kenya Series

(*a*) *Kenyte*

South-south-west of Tseikuru trigonometrical beacon a volcanic neck forms the small conical hill Kanondu. The neck consists of coarsely porphyritic kenyte, the phenocrysts of which average about 30 mm. in length and in more densely porphyritic specimens constitute up to 30 per cent of the total composition. Comparison with the kenytes from Mount Kenya further west shows strong similarity between the rocks.

Specimen 45/205, from Kanondu, has a fine-grained dark groundmass supporting large phenocrysts of porcellaneous whitish anorthoclase and, less commonly, waxy-looking greenish nepheline. Examination of a thin section proved that, in addition to the large phenocrysts, there are micro-phenocrysts of augite and olivine. The groundmass is finely crystalline and is composed of approximately equal parts of felsic and mafic minerals. The felsic minerals consist of fine acicular prisms of felspar with low extinction angle (probably anorthoclase), small euhedra of nepheline and an isotropic base that may be analcime. The dark minerals of the groundmass are pyroxene, kataphorite and iron ore.

The large felspar phenocrysts have undergone peripheral resorption. While the crystal outlines remain unaltered, the crystal faces are corroded and etched by a fine-grained border of the rock groundmass.

(*b*) *Intrusives of Presumed Tertiary Age*

(i) *Basalts*

In the vicinity of the junction of the Tana River and its tributary the Ura, north-east of Usueni trigonometrical beacon, three narrow basaltic dykes were discovered, which are considered to be of Tertiary age. A similar dyke is exposed in a river-course just west of the Massisini plateau. No stratigraphic evidence of age was found, however, and the dating must be regarded as tentative. It is possible that the dykes might be of Pleistocene age.

Specimen 45/236 from the Tana River area is a medium-grained slightly porphyritic olivine basalt. The intergranular groundmass consists mainly of interlocking felspar laths and pyroxene prisms, together with small grains of accessory minerals. The felspar is labradorite, and while normally medium-sized the laths sometimes attain a length of 5 mm. The pyroxene is slightly pleochroic brownish titan-augite. The olivine phenocrysts are often highly altered and replaced by serpentine or a carbonate. In some cases, however, carbonate patches represent vesicle infillings. Small grains of iron ore are abundant. Specimen 45/312, from the northern bank of the Tana, is also slightly amygdaloidal. The infillings are calcite, zeolitic material or a combination of both in the form of a calcite core surrounded by radiate quartz.

Specimen 45/248, from a narrow microporphyritic dyke near Massisini hill, shows a chilled contact about 3 mm. in thickness against Basement System gneiss (Fig. 4A). The rock as a whole is fine-grained, with phenocrysts mostly of augite or olivine, though a few large felspars are also present. In one of the felspars zonal structures can be seen. The metamorphic effects of the basalt on the gneiss are small. Narrow tongues of fine-grained basalt extend into the gneiss, whose larger felspars are shattered or slightly corroded at the contact.

(ii) *Lamprophyres*

Two small, probably related, lamprophyric intrusives were discovered a few miles south-south-west of Tharaka camp. Both dykes are concordant with the adjacent gneisses. At the contacts there is an intermediate zone of light greyish hybrid rock, grading evenly on one side into the Basement System country-rocks and on the other into the dark grey lamprophyres.

Specimen 45/287 is a dark compact rock composed of felspar, hornblende, biotite and accessory minerals. The felspar is largely andesine, though a small amount of orthoclase is also present interstitially or in micropegmatitic intergrowths. The plagioclase occurs as crystals up to 1½ mm. in length, many crowded with minute inclusions, and constitutes the greater portion of the rock. The hornblende is a bluish green type. Biotite is only slightly less abundant than the hornblende, which it partly replaces; the two minerals are usually closely associated. Like some of the hornblende the irregular crystals of biotite usually include magnetite, either as highly irregular medium-sized grains or as clusters of minute specks. Long, thin prisms of apatite and irregular grains of magnetite are the chief accessory minerals. A little interstitial quartz is present and sometimes forms one component of micropegmatitic intergrowths. Specimen 45/290, a more coarse-grained lamprophyre from the southern outcrop, generally resembles that already described. In addition, however, to the minerals previously described, prisms of velvety reddish hypersthene are present. Pleochroism is marked: X = reddish, Y = yellowish green, Z = blue. Because they are essentially composed of plagioclase, hornblende and biotite, these two dioritic lamprophyres may be classified as biotite-bearing spessartites.

A thin section was also prepared of the hybrid contact rock (45/288). It is composed of felspar, biotite, quartz and the accessories magnetite, sphene and apatite. The texture is finer-grained than the surrounding gneiss indicating complete recrystallization of the minerals. The felspars not forming graphic intergrowths are cloudy. Thus it is clear that the intrusions, though small, took place at temperatures sufficiently high to cause recrystallizaiton in the gneiss wall-rock.

(2) Tertiary Sediments—Massisini Series

Overlying the Basement System gneisses, a sedimentary series of probable Tertiary age forms the Massisini plateau which rises abruptly to a height of about three hundred feet above the surrounding plain. The sediments are almost horizontal, with only slight inclination towards the south-east, and consist of a basal conglomerate and fossiliferous arkoses derived from the Basement System rocks. The basal conglomerate is nearly eight feet in thickness, and some bands in it consist of well-sorted pebbles. The pebbles vary from about 5 mm. to approximately 70 mm. in diameter, the average size being about 45 mm. They normally show perfect rounding and consist mainly of vein quartz, gneiss, pegmatite and, less commonly, dolerite. The cement is a fine compact clay probably composed of weathered felspar and secondary quartz. The beds above the conglomerate consist of grey to buff-coloured arkoses containing sparse fossil remains in the upper half of the succession.

In the hand-specimen the arkoses bear a strong resemblance to the Basement System gneisses, and in thin section the similarity of mineral assemblages is notable. Specimen 45/254 has a compact medium-grained texture and is composed of rounded to sub-angular fragments of quartz, microcline, orthoclase, plagioclase, calcite, hornblende, garnet and epidote, with an overall sprinkling of small grains of iron ore. The constituent grains are crusted with thin skins of secondary quartz which acts as a cement. Where the grains are small and the coating of quartz relatively thick, a curious rosette effect is produced. Cementing by pyrite, hematite and calcite also occurs, but is rare.

Small fragments of fossil bone and wood are included in the strata. The complete fragmentation of the bone remnants makes recognition impossible, as even the larger pieces are seldom more than a few inches long. The fossil wood, though less damaged, presents similar difficulties, particularly in view of the fact that no fossil leaves or seeds were discovered.

North of Massisini in places thin pebble beds with even upper surfaces protect the underlying Basement System rocks. The beds are seldom more than six inches in thickness and consist of layers of perfectly rounded pebbles composed mainly of quartz. The whiteness of the quartz, coupled with the lack of vegetation other than grass, produces a striking feature. The beds were apparently derived from the basal conglomerate of the Massisini series which, in fact, is still preserved at Kibone where a low hill near the Tana River is capped by the original conglomerate. The cement is friable and readily weathered and it is considered that it has often been removed, allowing the pebbles to "settle" almost *in situ*. It is believed that this redeposition took place in Pleistocene times.

There is no doubt that the conglomerates are of fluvial origin. It is probable that the Massisini sediments, derived from the Basement System rocks in an area further west, were rapidly deposited in a valley, possibly with a wide pan-plain floor, during or immediately following a pluvial phase. The latter is perhaps more probable as the upper sediments are composed of only slightly chemically altered minerals.

(3) Pleistocene—Nyambeni Basalts

A series of outliers of lava in the north-western corner of the area represent the remains of flows that originated from the volcanoes of the Nyambeni range, which lies only a few miles away to the north-west. While there are no volcanic cones within the limits of the present area, several occur in the plains further north and north-west. Some of the lava outcrops have been isolated by erosion such as that in the Kazita valley near its junction with the Tana River or the discontinuous cappings forming

Kamuga hill. The lavas consist entirely of basalt closely resembling those described by Mason (p. 15) as the lower Nyambeni series. The upper Nyambeni series consisting of tephrites and phonolites, described by him from the Nyambeni range, are absent from the present area.

The basalts are typically dark bluish compact, aphanitic types, though some of the flows are highly vesicular. While the texture is usually even-grained, the basalts are sometimes porphyritic. Specimen 45/294, from the Kazita River, is typical of the porphyritic basalts. It consists of a fine groundmass of pyroxene, felspar, olivine and iron ore, with olivine and augite phenocrysts. The olivine phenocrysts are both more abundant and larger than the augites, attaining a maximum size of about 7 mm. Resorption has to a certain extent rounded their outlines. The augite is a faintly pleochroic pale mauve-coloured type, frequently with zonal structures caused by variable enrichment in titanium. Specimen 45/309, from the Thanandu River, west-north-west of Kikingo, is typical of the highly vesicular basalts. Carbonates and zeolites are common infillings, though the vesicles are largely free of secondary deposits.

(4) Pleistocene to Recent Sediments

The presumed Pleistocene pebble beds derived from the basal conglomerates of the Tertiary Massisini series have already been described (p. 20). In other parts of the area large portions of the area are covered by recent deposits of soils, sands, gravels or secondary limestones. The soils usually have strong affinities with the rocks from which they were derived. The granitoid gneisses produce yellow, gravelly, sandy soils while, proportionate to the high content of ferromagnesian minerals in the pelitic gneisses, the soils produced from them become increasingly red. The soils derived from the Nyambeni volcanics are deep chocolate-coloured and as seen from comparative crop yields, are far more fertile than soils derived from other rocks in the area. Surface limestones are fairly widespread and sometimes attain a thickness of up to ten feet as in the vicinity of Machungwa dam, west of Samanguli. The kunkar limestones are often highly resistant to erosion and form tough crusts over the underlying basement rocks. Slide 45/184 was prepared from a specimen taken in the Muvukuni area. Composed almost entirely of iron-stained calcite, it displays an unusual fine wavy banding.

Towards the eastern boundary of the area numerous rills and a few larger streams such as the Machungwa have deposited deltaic alluvial fans. The deposits consist of fine-grained reddish-brown to grey argillaceous stratiform sediments. During the dry months the sediments become hard and shale-like, though during the rainy season they become highly glutinous clay. The deposit appears to be highly fertile when moist as it supports a dense covering of vegetation after rains. Heavy mineral separations indicate a high content of hematite, magnetite and ilmenite.

V.—GRANITIZATION AND METAMORPHISM

The problem of granitization has been widely discussed in previous reports. It has been generally agreed that the Basement System consisted originally of a succession of sediments which were converted by metamorphism to gneisses and schists, and often to rocks of a granitic character by granitization. Two processes of granitization are demonstrable in the area. It is believed that *lit-par-lit* replacement was responsible for the banding of the pelitic gneisses, while the more homogeneous gneisses appear to have undergone an evenly distributed metasomatism, possibly actuated by magmatic soaking.

Planes of foliation in the area either dip steeply or are vertical, suggesting to the writer close proximity to the centre of the geosyncline in which it is considered the sediments were deposited. The presence of the index mineral of high-grade metamorphism, sillimanite, is confirmatory, particularly in view of the fact that sillimanite has been recorded further south along a zone of approximately the same strike (Crowther; Sanders; Saggerson). It must be stated, however, that this conclusion is largely conjectural and that before metamorphic index minerals are used to demarcate orogenic zones with any success, the mapping of isograds over wide areas will be necessary. The presence of sillimanite suggests a grade of metamorphism similar to that in the sillimanite zone of the Scottish Highlands.

In the sillimanite gneisses the typical mineral assemblages are either orthoclase-sillimanite or almandine-sillimanite. However, the fact that these rocks have been subject to additions of material tends to obscure the true metamorphic picture. The following rocks are considered as belonging to more or less closed systems, giving a better example of isochemical metamorphism:—

(*a*) *Amphibolites*:

Hornblende-diopside-epidote
Hornblende-almandine-diopside } plus oligoclase-andesine and quartz.

(*b*) *Calc-silicate rocks and limestones*:

Epidote-diopside-hornblende.
Epidote (clinozoisite)-diopside-calcite
Calcium-rich garnet-diopside-calcite } plus scapolite, oligoclase-andesine and quartz.

By comparison of the mineral assemblages of the sillimanite gneisses, amphibolites and calc-silicate rocks, and those described by Turner (1948, p. 76) and Turner and Verhoogen (1951, p. 456), the metamorphic facies appears to correspond to the sillimanite-almandine sub-facies of the amphibolite facies.

VI—STRUCTURES

1. Major Structures

In common with neighbouring districts the general foliation strike of the Basement System in the north Kitui area follows an approximate north-south direction, indicating directed compression in an east-west direction. The steeply inclined dip of the foliation planes remains constant to the west, although locally, as in the Nzetu area, it becomes vertical. In the south-eastern corner of the area the axes of a simple fold system follow a north-north-westerly trend. Slightly east of the Katze-Tharaka road a steep anticline is followed eastwards by an equally steep syncline. Further eastward, the repetition of stratigraphical horizons with similar dip inclinations indicates the presence of an overfold whose axis lies approximately midway between Katze and the trigonometrical beacon Twimua. Along an approximate line connecting Kikingo, Tseikuru and Twimua there is a slight flexing of the trends of foliation, which may be due to late oblique pressures.

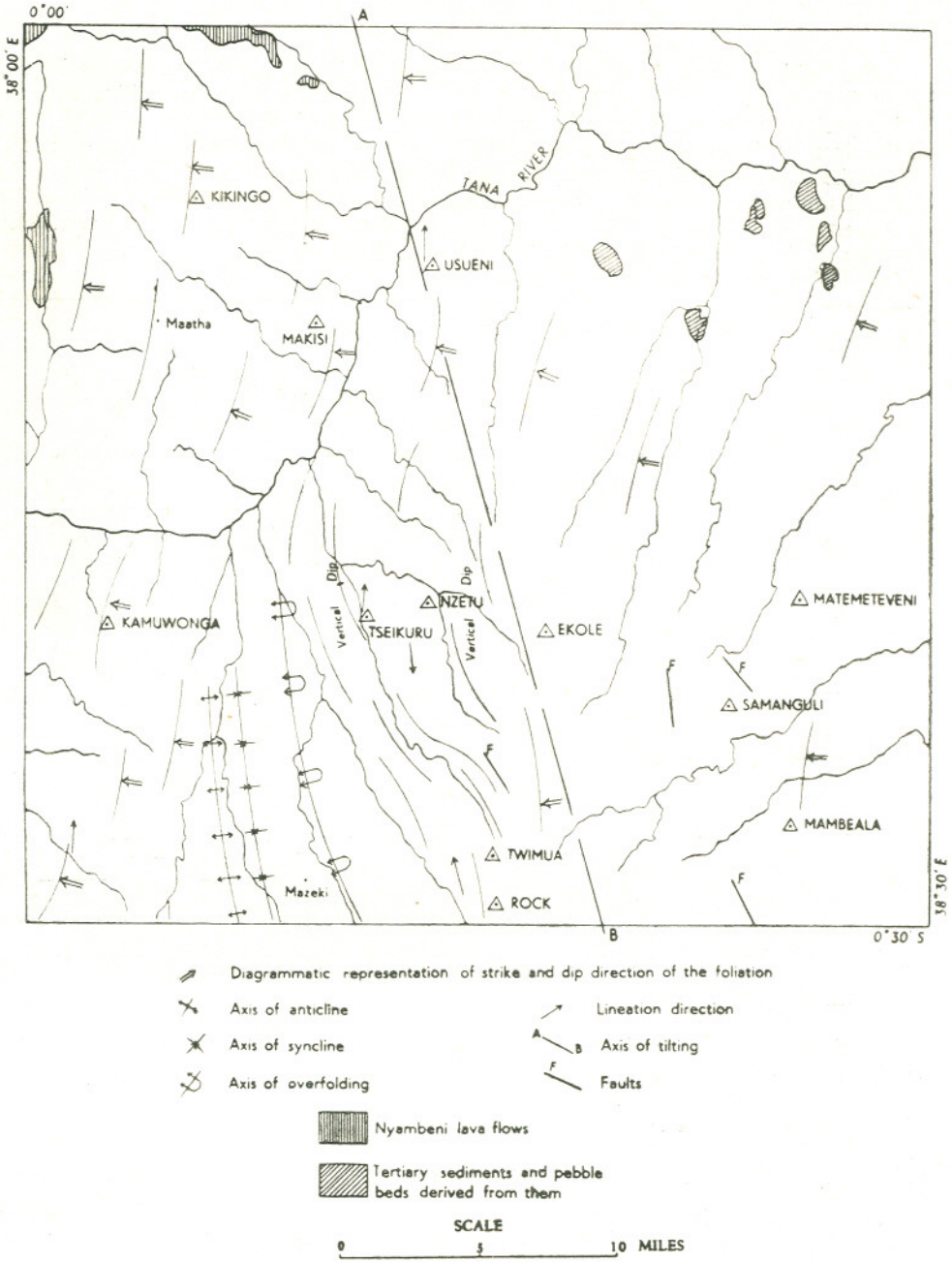

Fig. 5.—Structural map of the north Kitui area.

No major faulting was recognized, although east of Samanguli a fairly wide zone of brecciation is possibly connected with faulting on a larger scale than the minor strike faults mapped in that area. Of the minor faults, strike faults are probably more numerous, though they are far more difficult to recognize in the field. Due south of Mazeki hill definite "lines" were recognized both in the field and on air photographs, which are probably part of a cross-strike fault. Exposures are poor there, however, so that no proof of faulting could be obtained. The hill on which the trigonometrical beacon Ekole is situated is composed of massive breccia. Two small outcrops of breccia were noted further south-west, but no fault-line could be mapped.

2. Minor Structures

The pelitic rocks of the succession are sometimes highly contorted, and occasionally ptymatic folds are prominent. Lineation is usually well-developed in the pelitic and semi-pelitic gneisses, although it is rarely obvious in the psammitic rocks. Generally the strike of the lineation is within 15° east or west of true north and the pitch is generally about 23° to the north. Occasionally the direction of pitch is reversed, and is to the south. In the Tseikuru area an unusual type of lineation was discovered in a band of pelitic biotite gneiss exposed in the Kwawetu River, near its junction with the Nzetu River. The lineation pitches to the south and its inclination varies from approximately 35° to more or less horizontal in a regular curve (Fig. 6).

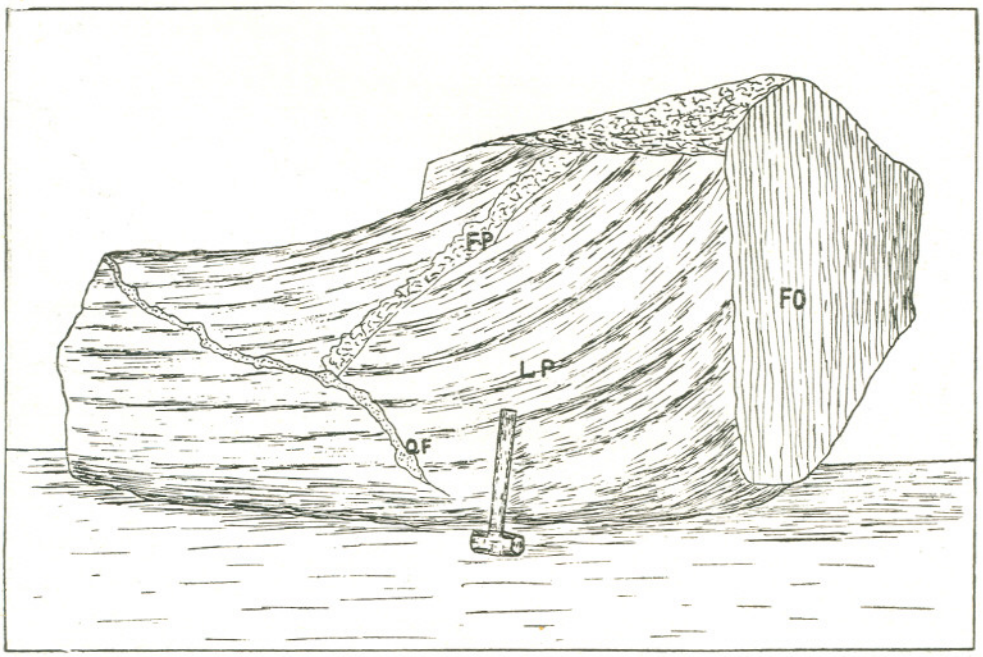

Fig. 6.—Curved lineation in a boulder of biotite gneiss from the Kwawetu River, near its junction with the Nzetu River. FO = traces of foliation planes; LP = lineation; FP = cross-fracture; QF = quartzo-felspathic vein.

Again in the Nzetu River, numerous examples of what can perhaps be termed fusiform structures, lying in the foliation planes and parallel to the strike, were examined. On first appearance as seen on cross-joints these appear to be simple quartzo-felspathic augen, but careful inspection revealed that they are rod-like along the foliation, tapering gently towards the extremities, and up to five feet in length. The most satisfactory explanation of their development is intense rolling of the gneisses.

Among the pelitic, and less commonly among the semi-pelitic gneisses, large augen and vein-like quartz bodies are arranged at right angles to the foliation (p. 18). They are probably the result of the infilling of tensional gashes.

VII—ECONOMIC GEOLOGY

1. Graphite

Two deposits of graphite were examined. The first, a graphitic schist, crops out in the river that cuts through Massisini plateau. It is about 5 feet wide and consists of flakes of graphite up to 8 mm. long with inclusions of weathered felspar and quartz. The graphite tends to be concentrated in graphite-rich bands. The second deposit, north-

west of Tseikuru, consists of much finer flakes disseminated through a soft friable matrix of decomposed felspar. The percentage of graphite present is small and the flakes are of fine size. Both deposits are far removed from good roads and in each case the Tana is the nearest source of permanent water.

2. Quartz Crystals

The occurrences of quartz crystal in the Tseikuru area, described by Pulfrey in an unpublished report (1942), were examined and the surrounding area carefully prospected for any further deposits. A great many crystals collected by Africans were examined, though without exception they were either heavily veiled or were smaller than the minimum size acceptable for piezo-electrical purposes. The poor quality of the crystals can be ascribed to the fact that during the prospecting carried out by a Government prospector in 1942 most of the better crystals at surface were removed. As no further deposits were discovered it is concluded that the area is unworthy of further prospecting, unless other minerals are discovered in the veins so that underground exploration would be required, when quartz crystals might be recovered as a by-product.

The following is a summary of the work carried out by Government in 1942. During a short investigation seven quartz crystal deposits were examined and further prospecting was recommended on at least three of the localities. A Government prospector searched the localities thoroughly and in all prospected some 100 square miles. Work was suspended in July, 1942, after more than 300 crystals had been recovered from superficial deposits. It was concluded that further prospecting would not warrant the extra expense. Two collections of crystals were sent in by the prospector and were examined in Nairobi with the following results:—

Collection No. 1.—75 per cent (by number and probably more than 90 per cent by weight) rejected as useless for piezo-electric purposes.

Collection No. 2.—96.7 per cent (by number) were rejected as useless for piezo-electric purposes.

Seventeen selected crystals were sent to Britain where a series of visual tests and etching tests on orientated plates were carried out and an unpublished report produced. The report described all but two of the specimens as being undersize and only two of the undersize crystals as containing as much as 20 per cent of useful material.

A few small crystals of amethyst were found in the quartz deposits south-east of the shop at Tseikuru. They are of poor colour and contain fine rutile needle inclusions.

3. Limestones

Of the limestones mapped all but one contain ferro-magnesian impurities. The limestone south of Rock trigonometrical beacon is free of visual impurities but, as it has not been analysed chemically its suitability for cement manufacture is unknown.

4. Copper

Strictly localized occurrences of bornite and malachite were discovered in the south-western corner of the area but, although the area was carefully prospected, no extensions were discovered. A grab sample analysed by the chemist of the Mines and Geological department revealed a copper content of 0.35 per cent. As specimens of copper ores have been found in the north-eastern part of the Embu–Meru area prospecting westwards beyond the boundary of the present area may possibly reveal small quantities of copper.

5. Corundum

While the area was being surveyed an African brought in a large crystal of corundum, alleged to have been found in the Giluni river-bed. The crystal weighed about eight pounds and was of good quality. However, despite an intensive search, including systematic panning, no further evidence of corundum was discovered.

6. Garnet

The nearly mono-mineralic segregations of garnet in the calc-silicate lenses near the confluence of the Katze and Kalange Rivers, despite the fact that the garnet is massive, might possibly be of use for abrasive purposes.

7. Precious Minerals

Concentrates panned from the alluvials of the larger streams of the area yielded no evidence of the occurrence of precious minerals. Ekole hill, composed entirely of a much brecciated rock with widespread secondary deposition consisting of quartz, siderite and pyrite appeared worthy of further prospecting. Assay proved, however, that only traces of gold are present.

8. Sands and Clays

Several large rivers south of the Tana are dry for all but a few days in the year. As these rivers are frequently up to two hundred yards wide and choked with sand, they would obviously be of value should a local demand for sands arise. Local river sorting has in places produced fractions consisting of up to 95 per cent quartz. At present, owing to great distances from commercial centres, the deposits are of no economic interest.

Bricks are at present being produced along the banks of the Katze River. Invariably the clays chosen are the dark reddish types, residual from the weathering of iron-rich pelitic rocks. The bricks, when properly burnt, are of a good quality. Until water is readily available the large reserves of red clays in the Muvukuni area are of little value for this purpose.

9. Water

The western portion of the area, which includes almost the entire pelitic succession of the Basement System, has plentiful supplies of water available in the sandy beds of the Katze, Kalange, Mataka, Nzetu and Muvukuni Rivers. The water is obtained by digging in the sand, usually for as little as six inches. In the eastern portion of the area water-supplies, apart from the Tana River, are generally poor. Pits up to ten feet depth in the beds of rivers failed to locate water except during brief periods following rains. Similarly well-constructed dams dry up between the rainy seasons. In the event of more intensive settlement several sources of water could be investigated. East of the strike fault which passes just east of Kithethea, water accumulated along the nearly vertical folia can be tapped by shallow wells. The construction of bore-holes or deep wells should provide a reasonable water-supply in that area. In the river-beds at Massisini plateau, water is available for short periods. The construction of a dam across the river would conserve available water-supplies. Finally, since the eastern portion is flat and the drainage gradient gentle, the Tana River might be tapped and water directed southwards to reservoirs.

Only one bore-hole has been sunk in the area—on the banks of the Muvukuni River north-west of Muvukuni school, where it provided a plentiful supply of brackish water. The Hydraulic Branch of the Public Works Department has found that bore-holes sunk in the banded pelitic gneisses have a greater chance of success than those sunk in the psammitic horizons.

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