Report No. 32

COLONY AND PROTECTORATE OF KENYA

GEOLOGICAL SURVEY OF KENYA

GEOLOGY OF THE TAVETA AREA

EXPLANATION OF DEGREE SHEETS
64 N.E. AND 64 S.E.
(with coloured geological maps)

by

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FOREWORD

The report and maps by Mr. Bear are the first to be published of the part of southern Kenya near Mt. Kilimanjaro, since a comprehensive regional survey of the Colony was begun with the assistance of Colonial Development and Welfare funds in 1949. A report by Dr. J. Parkinson on an area including the Taita hills and extending as far north as Mtito Andei was published in 1947 but, though his work led to the discovery of the kyanite deposits at Murka and adjacent localities, it was not of so comprehensive a nature as the present report.

The kyanite deposits between Murka and the River Tsavo lie within the Taveta area as defined for the purpose of Mr. Bear's work. He does not deal exhaustively with them, however, as a memoir on kyanite in Kenya has recently been published, in which considerable detail on the deposits is given. During his work he discovered a new kyanite deposit, associated with garnet, near Longalonga, and in the report he gives an appraisal of the possible economic value of the rocks. Graphite deposits were also discovered, near Taveta, but it appears that the tonnages available are small.

Considerable attention is given to water supplies—including those of Lakes Chala and Jipe, and those of numerous large springs that are fed by underground waters derived from Mt. Kilimanjaro. It will be a surprise to many that the crater-lake Chala, which appears so small on maps of Kenya, is in fact the third bulkiest body of water in the Colony. The springs that emerge in the valleys around Taveta are also surprisingly large.

An account of other mineral deposits, including building stones and superficial limestones, is also given.

Nairobi,
28th July, 1953.

WILLIAM PULFREY,
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ABSTRACT

The report describes an area of approximately 1,200 square miles in the Taita district, enclosed by latitude 3° 00′ S., longitude 38° 00′ E., and the Tanganyika border. Three divisions are recognizable in the topography: (1) the hills south and south-west of Taveta, (2) a gently inclined peneplain extending south from the Tsavo valley to Lake Jipe and the Tanganyika border, and (3) north of the River Tsavo, volcanic country, which merges into the outermost eastern slopes of Mt. Kilimanjaro.

The rocks of the area fall into three groups: (1) Basement System gneisses, characterized by kyanitiferous and graphitic horizons in the east and by hypersthene- and garnet-bearing types in the west; south of Taveta the Basement System rocks have been invaded by small masses of basic and intermediate rocks, constituting a charnockitic suite; (2) Tertiary lavas of the Mt. Kilimanjaro volcanic pile, comprising the Rombo Series, and represented by olivine basalts, Kijabe-type basalts, and olivine soda-trachytes; and (3) Pleistocene to Recent calcareous tuffaceous grits. North of the Tsavo River the lava plain is studded with innumerable small volcanic cones composed of Kijabe basalt, whereas between Lakes Chala and Jipe there are cones built predominantly of pyroclastic ejectamenta and contaminated olivine basalts. The petrography of the rocks is briefly described and the metamorphism, granitization and structure of the Basement System are discussed.

Kyanite is being mined by Kenya Kyanite Ltd. at Murka, and the deposits are described. Occurrences of graphite, vermiculite, kyanite, garnet, lime and clay were noted and the possibilities of their commercial exploitation are assessed.

GEOLOGY OF THE TAVETA AREA

I—INTRODUCTION AND GENERAL INFORMATION

A geological reconnaissance was made of the south-east and south-west quarters of Degree Sheet 64 (Kenya) between the months of January and May, 1952. The area is bounded by latitude 3° 00′ S., longitude 38° 00′ E., and the Tanganyika border, and is about 1,200 square miles in extent. Except for the north-western sector and the north-eastern corner, which fall into the Masai extra-provincial district and the Machakos districts respectively, the entire area lies within the Taita district. The greater part of the western half of the area consists of European-owned plantations and estates but also includes small portions of Crown Land, native land units, native leasehold areas and native reserve (*see* Fig. 1). The eastern half of the area lies within the Tsavo National Park and, except for the immediate vicinity of the kyanite mines, is uninhabited and waterless. North and south of Taveta conditions are suitable for sisal cultivation, the Lumi River and Njoro springs supplying the necessary water for irrigation. North of Ziwani fruit farming under irrigation is practised, the waters of the Sainte and Njoro Rivers being utilized for this purpose. Masai *manyattas* are scattered along the upper reaches and north of the Rombo River, and skirmishes with the neighbouring Wachagga, who inhabit the foothills of Kilimanjaro in Tanganyika, are still quite common.

Virtually the whole area is infested with tsetse fly—only the north-west and south-east corners being safe for cattle herding. The cultivation of vegetables and fruit by Africans is confined to the immediate vicinity of Taveta and the lower reaches of the Lumi River. The rainfall is bi-annual and the figures summarized in the table below indicate its decrease from west to east.

Station	Elevation in feet	Total Rainfall 1950	Total Rainfall 1951	No. of Rainy days 1951	Yearly Average	No. of years recorded
*Laitokitok ..	6,500	26·97	42·88	81	28·62	15
Taveta	2,525	24·50	43·74	87	24·42	13
*Tsavo-Mzima confluence ..	2,136	—	30·65	81	30·65	1
*Maktau	3,607	12·76	25·47	59	16·57	15

Much of the area is rapidly approaching semi-desert conditions, with gully erosion predominating north-west of the Rombo River and sheet erosion over the southern plain.

Maps.—For the convenience of printing, the area mapped has been split along latitude 3° 30′ S., and is published as two separate maps, viz. the geological map of the Taveta area (Degree Sheet 64, N.E. quarter), and the geological map of the Lake Jipe area (Degree Sheet 64, S.E. quarter).

The topography of the maps is based on the cadastral sheets South A37/T IIb, c and d, and South A37/T IVb, as well as on the military map "Taveta", E.A.F. No. 1285 (1944). Form-lines were amended where necessary, but are not accurate and serve only to indicate the general land-form. Many of the hills, particularly Murka, Kevas and Longalonga, were accurately re-plotted, as were also the roads, especially those in the sisal estates around Taveta and north of the railway-line. North of the Rombo River, excluding the extreme north-west sector, the topography was taken

* Laitokitok is at the foot of Kilimanjaro, a few miles outside the north-western corner of the area. Maktau and the Tsavo-Mzima confluence are in the adjoining degree sheet on the east.

from aerial photographs, and the detail is more accurate than in the southern portion of the area. The flight runs and the principal points of the photographs are shown on the map. Geological data were plotted on a scale of 1:62,500 by plane-table resection, assisted by compass-cyclometer traverses. Local native names have been added to previously unnamed or incorrectly named features.

Communications.—The Voi-Moshi railway-line, running through the middle of the area, forms the principal means of communication in an east-west direction. The main road and telegraph line follow the railway. The area lying between the Tsavo River and the railway is well endowed with roads, and between Lake Jipe and Ziwani numerous private roads traverse the sisal estates. North of the Tsavo the country is accessible only on foot. East of Lake Jipe, however, the undulating open bushland can be negotiated quite safely in the dry season by Land Rover. Motorable tracks usable only in the dry season run from south of Lake Jipe to the south-east corner of the area, and another connects Ziwani Sisal Estate with Laitokitok.

Previous Geological Work and Prospecting.—The earliest geological work done in the area was that of G. Rose (1863),* a German, who described hypersthene-labradorite rocks from south of Taveta. In July, 1902, E. E. Walker, commissioned by the British Government to make a geological reconnaissance of British East Africa, visited the Taveta area and reported on the plentiful development of garnets in the gneissose hills to the south. No further geological work was carried out until 1940-1942, when J. Parkinson mapped the Mtito Andei–Tsavo area. His report was published in 1947 and includes an account of the work done on the kyanitiferous and graphitic horizons occurring near the eastern boundary of the present area.

During 1942 and 1943 considerable interest was taken by the late Sir Charles Markham and Col. E. S. Grogan in the economic possibilities of the *kunkar* limestones, pozzuolanas, cementstones, clays, and kyanite occurrences in the area. Unpublished reports were written on these deposits by Dr. B. N. Temperley on behalf of the East African Industrial Research Board in October, 1942, and for Sir Charles Markham by Dr. E. Parsons in August, 1943. In 1947 Dr. W. Pulfrey visited and reported on the Murka kyanite, and in 1948 Dr. Temperley was assigned the task of reporting on the Murka-Loosioto belt as the first step in a survey of kyanite deposits in Kenya. In 1950 a resistivity survey was made over visible and concealed portions of the outcrop near Kevas, but the results proved of no assistance in prospecting.

Acknowledgment.—Acknowledgment is gratefully made for hospitality received from many people in the area. Particular thanks are due to Brig. and Mrs. Blood and the staff of Kenya Kyanite Limited.

* References are quoted on p. 47.

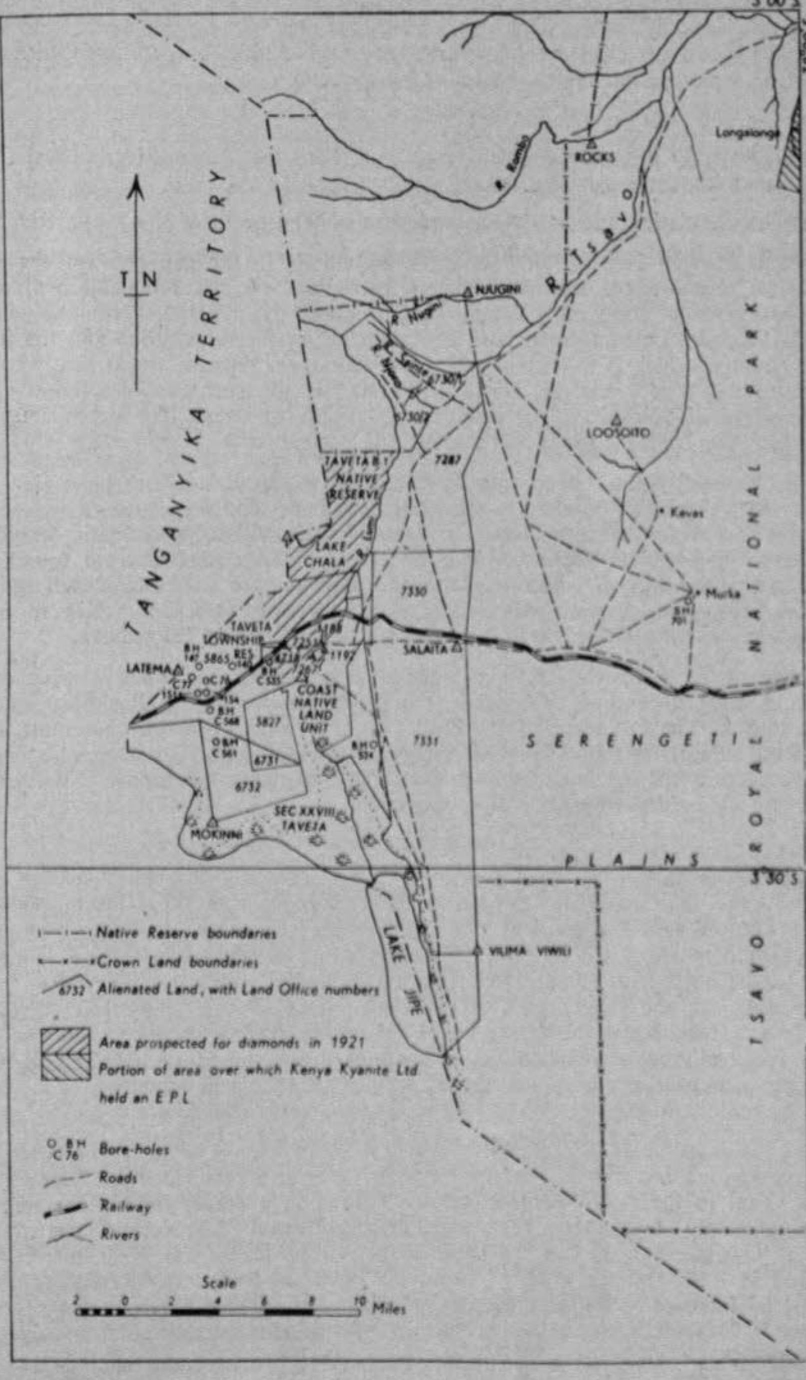


Fig. 1.—Map showing location of bore-holes and boundaries of exclusive prospecting licence areas.

II—PHYSIOGRAPHY

The area is mostly characterized by completely featureless topography, the monotony of which is only rarely broken by monadnocks and volcanic ash-cones. It does not readily lend itself to division into natural topographic units but, for convenience of description, is considered under the following sections:—

(1) The hills south and south-west of Taveta.

(2) The gently inclined peneplain extending from the Tsavo River to Lake Jipe and the Tanganyika border.

(3) The undulating and partly dissected lava plateau north of the Tsavo River.

The half-dozen isolated hills south of Taveta lie in the gap between the Pare Mountains, composed of Basement System rocks, and the Mt. Kilimanjaro volcanic pile. The highest of these hills, Latema and Mokinni, rise 1,000 ft. above the general level of the plain. Latema, Reata and El Dorro lie on the same strike and the intervening country, which is devoid of any marked drainage pattern, slopes gently to the marshes surrounding Lake Jipe. North of Taveta the hills such as Chala, Lasesia and Warombo are of volcanic origin and their grass-covered slopes and summits readily distinguish them from the forest-clad gneissic hills further south.

The Serengeti plains extend from the Tsavo River in the north to Lake Jipe, and beyond the Tanganyika border, in the south. They are gently inclined to the south-west and except for inselbergs such as Loosoito and Vilima Viwilli are devoid of prominent topographical features. The only river-beds, which are dry, are found east of Girigan and north of Loosoito. Drainage channels are rare and ill-defined and extensive tracts are covered with recent eluvial deposits sufficiently thick to mask the solid geology effectively. It is in fact typical of the *mbuga** of Tanganyika.

North of the Tsavo the terrain is studded with innumerable small parasitic cones and plugs, their appearance on aerial photographs resembling small pimples on the earth's surface. The boundary of the lavas, some of which form the outermost flows from Kilimanjaro, does not form an escarpment. North-east of the Rombo, where the lava plateau merges into the foothills of Kilimanjaro, the topography is more rugged and steep-sided gorges are not uncommon.

Drainage

The area is drained by three rivers, the Ruvu, the Lumi and the Tsavo but it is only the latter that materially influences the topography. Its source is in the hills north of Ziwani and for the first few miles its course follows the general slope of the lavas. On reaching the junction of the lavas and the Basement System it swings round to the north-east roughly following the junction, which cuts across the grain of the rocks, for the greater part of its course. Its headwaters have been deflected for irrigation, resulting in the drying up of the former Ziwani swamp, so that the flow of the river really commences only at its confluence with the Sainte. Of the tributaries entering on the northern bank the Sainte, Njugini, Rombo and Nolturesh carry water for many months each year. All tributaries on the southern bank are dry.

The main source of all the water available for irrigation is the Lumi River and the many springs that feed it. The source of the river is on the slopes of Kilimanjaro. From Ziwani to the Njoro Kubwa springs it flows in a deeply eroded channel, the bed being mainly basalt except for a small area north-west of Warombo. The average depth of this channel is 12 feet. The flow at the railway bridge was 7.33† cusecs when measured in 1931, and the gradient from this point to Ziwani is 4.7/1000. There is no material increase in the flow till the junction of the Njoro Kubwa springs, where the flow is 230 cusecs. Several other springs join the river at this point and increase

*A *mbuga* is a shallow depression often of considerable extent and usually filled by black clay soils, swampy in the rains but hard-baked and cracked in the dry season.

† All the statistics that follow were obtained from unpublished hydrological reports on the area.

the flow to 260.88 cusecs. Between the road bridge and the Njoro Kubwa the banks of the Lumi are 13 ft. high and the grade increases to 5.8/1000. The grade flattens rather rapidly and just before the river enters the swamps it is as low as 0.51/1000. The catchment area of the Lumi is of the order of 200 square miles, a quarter of which lies on the lower slopes of Kilimanjaro, where the rainfall is heavy and run-off percentage high. The river is subject to floods, often of considerable magnitude and which are a serious menace to the railway and road bridges, and to irrigation projects in the lower reaches of the river. East of Sambera the watershed between the Lumi and the Njoro is in places no more than 50 yards wide. It is not improbable that the drainage pattern in this area was affected by the Tertiary vulcanicity, resulting in the deflection into the Lumi of streams that once flowed into the Tsavo.

The Ruvu River is a tributary of the Pangani River in Tanganyika and according to the Water Executive, Arusha, has a mean flow of 128 cusecs near the outflow of Lake Jipe. Lake Jipe and its swamps have been regarded as a storage basin for the Ruvu. This is difficult to understand when it is realized that the flow of the Ruvu at Kake railway bridge, some 15 miles west of Jipe, is 1,193 cusecs.

Lake Jipe

The interterritorial boundary divides Lake Jipe longitudinally, the eastern half lying in Kenya and the western in Tanganyika. Unlike most Kenya lakes it has, at its northern extremity, both an inlet and outlet, the Lumi and Ruvu respectively. The open water surface is eight miles by two miles and is surrounded by extensive reed and papyrus swamps, which extend well up the Lumi and Ruvu Rivers. These swamps, especially at the northern end, have advanced considerably during the last 45 years. The areas of the swamp north of the Ruvu and east of Kitogato at various times of survey were:—

	Sq. miles
1906	1.9
1923	5.2
1942	8.9

The lake is shortening at its northern end and lengthening southwards through the deposition of silt at the mouth of the Lumi and along the Ruvu swamp, with a consequent rise in lake level.

Lake beds, similar to those deposited around lakes in other parts of Kenya, are not uncommon and on both the eastern and western shores sedentary soils, of metamorphic origin, extend to the high-water-mark. Transported soils, other than hillside wash, occur only at the northern and southern ends and consist of alluvium brought down by the Lumi and Wakindi Rivers. Soundings in the lake indicate that the greatest depth is only nine feet. This shallowness, the section along its bottom as shown by longitudinal soundings, its uniform width, and the ratio of its length to its width all suggest a flooded valley.

The free water surface of the lake is approximately 10,000 acres, which at an average depth of 6.5 ft. gives a volume of 65,000 acre-ft. of water. With an average evaporation loss of five inches/month a monthly loss of 4,000 acre-ft. through evaporation may be expected. To this must be added the transpiration losses due to the papyrus- and reed-covered area bordering the lake, the mouth of the Lumi and the outlet of the Ruvu. The aggregate monthly loss is not likely to be less than 8,000 acre-ft., equivalent to an inflow of 133 cusecs. These figures are interesting in that the measured inflow through the Lumi corresponds closely to the sum of the volumes of the outflowing Ruvu and the losses due to evaporation and transpiration. Losses due to percolation are difficult to assess as it is uncertain whether metamorphic or volcanic rocks form the floor of the lake.

Large numbers of small fish, *Tilapia nigra*, thrive in the lake and a fishing industry flourishes, particularly on the Tanganyika side. The lake is infested with crocodiles.

Lake Chala

Lake Chala lies six miles north of Taveta. The interterritorial boundary cuts it nearly in half—the larger portion lying in Kenya. It is a crater lake, the inner walls of which are precipitous. The lowest point on the rim is 177 ft. above the level of the lake, the highest 437 ft., and the mean height is 300 feet. The volcanic outburst that caused the vent was paroxysmal and only ashes and scoria were discharged and no lava flows. The water is clear and fresh. The sides of the crater slope down under water at angles of 45 degrees, and soundings indicate that the floor is level and 275 to 300 ft. below the water-level. The reduced level of the surface of the water is 2,763.6 ft. above sea-level. This is more than 200 ft. above the level of the low-lying land immediately south of Taveta. The area of the lake is 1,040 acres and the volume of water it holds is approximately 275,000 acre-feet. In spite of the small surface area it is the third largest body of water in Kenya being exceeded only by Lake Victoria and Lake Rudolf. No visible outlets or inlets were observed but in the north-west corner two small surface catchments, of about 100 acres, drain into the lake during the rainy season. The local inhabitants, however, report that the water-level remains constant—a phenomenon common in crater-lakes.

A gauge was established on the lake on 9th August, 1945, reading 12 ft., the reduced level of the 15-foot mark being 2,766.6 ft. above sea-level.

III—SUMMARY OF GEOLOGY

The rocks of the area fall into three groups: the Archæan rocks of the Basement System, the Tertiary volcanics and intrusives, and superficial deposits of Pleistocene and Recent age.

1. The Basement System

Rocks of the Basement System are poorly exposed and outcrops are confined to the inselbergs and the few dry river valleys and gullies. They include types derived from the metamorphism and granitization of originally calcareous, pelitic, psammitic, and carbonaceous sediments. Broadly speaking the area is characterized by a high grade of metamorphism and variable though rarely intense granitization, the predominant feature of which has been the development of felspar porphyroblasts.

South of Taveta the most conspicuous features in the gneissic hills are the abundance of garnets, the innumerable small felspar porphyroblasts on El Dorro and on the north-eastern slopes of Reata, and the development of hornblende-hypersthene-diopside assemblages on Mokinni and Latema (*see* Fig. 4, at end), and hornblende-diopside-garnet-biotite assemblages on Munyoni and Vilima Viwilli.

Nearer the eastern boundary relatively pure quartzites, overlying quartz-kyanite schists with lenticular kyanite segregations, occur in the Murka-Loosoito belt. Further north in the Longalonga area graphite-kyanite-muscovite assemblages are common and often carry subordinate fuchsite, a green chrome-bearing mica, and apatite.

Banded gneisses resulting from the metamorphism of alternating psammitic and pelitic bands as well as from granitization along selective planes are rare, but small occurrences were observed along the Lumi River north-west of Warombo and on Munyoni (*see* Fig. 5, at end). Glomero-porphyroblastic biotite-muscovite granulites, associated with streaky hornblende-biotite gneisses and sillimanite gneisses are exposed in the hills south of Longalonga, but they attain their maximum development in the adjoining quarter degree area on the east.

At some late stage during the regional metamorphic-granitization cycle lenticular bodies of basic and intermediate magma invaded the Basement System rocks south of Taveta, giving rise to the hills El Dorro, Mokinni and Kitogato. The basic rocks are confined to El Dorro and Kitogato and grade from hypersthenic peridotites in the centre to norites and hyperites at the periphery. The rocks of Mokinni and the southern slopes of Latema are derived from an intermediate magma of quartz-hypersthene diorite composition.

Strikes in the Basement System rocks are predominantly west of north, dips are moderate to steep and towards the east, prominent jointing is confined to the quartzites, and a linear fabric is rarely discernible.

2. The Tertiary Volcanics

The north-western half of the area is covered by lava flows, some of which have been erupted from Mt. Kilimanjaro, others from subsidiary vents on the plains. Successive flows in some cases, as indicated on the western wall of Lake Chala, were thin and of varying composition (*see* p. 29). The volcanics are divided into the Rombo series, and the rocks of the subsidiary cones.

(1) The Rombo Series

The rocks of the Rombo Series, as shown on the Taveta map, occupy the ground between the Tsavo and the northern boundary of the area. They form a gently sloping plateau which gradually increases in height towards the north-west, at the same time becoming more dissected. The Series has the following succession:—

3. Kijabe-type basalts and olivine soda-trachytes.
2. Melanocratic basalts with olivine and augite phenocrysts, interdigitated with subordinate flows of porphyritic picrite basalt.
1. Dense basalts.

Subordinate intercalated lavas include analcite basalts, picrite basalts, and olivine trachy-basalts. The felspathoidal lavas include nephelinites, olivine nephelinites, phonolitic trachytes, and phonolites, but none of these were found *in situ*. No associated agglomerates were observed, and tuffs (crystallo-vitric) are confined to the north-western corner of the area. The eruptive centre of the Kijabe-type basalt covers a considerable area which straddles the Rombo River and is characterized by numerous small cones. No signs exist of the original craters and the stumpy hillocks presumably represent plugs that sealed the vents at the close of vulcanicity and have proved more resistant to erosion than the rocks that once surrounded them.

The rock types of the Rombo succession conform closely to descriptions of the Simbara Series in the Nyeri area (Shackleton, 1945, p. 2) and the Samburu Series of the Maralal area (Shackleton, 1946, p. 29), and can be correlated with them.

(2) Lavas and Ashes of the Subsidiary Cones

The lavas extruded from volcanoes on the plains, such as Warombo and Lemrika, consist essentially of vesicular olivine basalt. Of the craters still in existence that of Chala, which has a diameter of one and a half miles and a depth of many hundreds of feet, is the best preserved. At Lemrika the crater is barely discernible. The cones have smoothly curved grass-covered slopes and have been built of ash, scoriaceous material and olivine basalts contaminated with lapilli and ash.

(3) Tertiary Intrusives

Between the Lumi and Marue Rivers float blocks of crinanite, a variety of olivine-analcite dolerite containing orthoclase, was observed.

3. Pleistocene and Recent Deposits

Thin superficial deposits which have accumulated since the vulcanicity ceased include boulder beds, grits, secondary limestones, clays, soils, and alluvium. Immediately outside the north-eastern corner of the area are the highly vesicular lavas of Mzima Springs. These are completely unweathered and free of vegetation, and must be of unusually recent age.

IV—DETAILS OF GEOLOGY

1. The Basement System

Exposures of Basement System rocks are confined to the areas south of Taveta, immediately east of Lake Jipe, along the Murka-Loosoito range and in the vicinity of the Longalonga hills. Lithologically these rocks can be classified as follows:—

(1) Sediments:—

(*a*) Calcareous—

(i) crystalline limestones;

(ii) calc-silicate granulites;

(iii) semi-calcareous gneisses and granulites.

(*b*) Pelitic and semi-pelitic—

(i) felspar porphyroblast gneisses and granulites;

(ii) micaceous gneisses and schists;

(iii) hornblende gneisses and granulites with varying amounts of hypersthene, diopside and garnet;

(iv) sillimanite gneisses;

(v) kyanitiferous gneisses and granulites of the Longalonga area.

(*c*) Psammitic—

(i) quartz schists and quartz-kyanite schists;

(ii) quartzites;

(iii) garnetiferous quartzo-felspathic granulites;

(iv) biotitic quartzo-felspathic gneisses and granulites.

(*d*) Carbonaceous—

(i) biotite-graphite gneisses;

(ii) muscovite-graphite gneisses;

(iii) graphite-sillimanite gneisses.

(2) The kyanite-quartz schists and kyanite segregations of the Murka-Loosoito belt.

(3) Granites.

(4) Major intrusives into the Basement System:—

(*a*) The Charnockitic suite—

(i) basic and ultra-basic types;

(ii) intermediate types;

(iii) hybrid rocks.

(5) Minor intrusives into the Basement System:—

(*a*) Pyroxenites.

(*b*) Pegmatites.

The original sediments from which most of the Basement System rocks were derived were predominantly of argillaceous composition with only small and scattered arenaceous, calcareous and carbonaceous horizons. Conglomeratic sediments as well as metamorphosed contemporaneous lava effusions and volcanic ash were not observed.

The stratigraphic sequence as observed on the northern slopes of Reata is as follows (*see* Fig. 4):—

5. Felspar-porphyroblast garnet granulites.
4. Limestones.
3. Graphite-sillimanite schists.
2. Hornblende-hypersthene-diopside-garnet granulites.
1. Quartzo-felspathic gneisses (locally garnetiferous).

On the Munyoni hills the following sequence was seen (*see* Fig. 5):—

7. Banded gneisses.
6. Hornblende-diopside granulites.
5. Biotitic quartz-felspar gneisses.
4. Biotite schists.
3. Felspar-porphyroblast gneiss.
2. Semi-calcareous gneisses and granulites.
1. Quartzite.

(1) Sedimentary Rocks of the Basement System

(*a*) *Metamorphosed Calcareous Sediments*

(i) *Crystalline Limestones*

Limestones occur in three localities, viz. on the northern slopes of Reata, 6½ miles east of Vilima Viwilli and south of Longalonga. Float blocks of limestone were found along the Prince of Wales road near its intersection with the Abyssinian road. The bands of limestone *in situ* are narrow and steeply inclined towards the east. The colour is usually white or pale grey but, particularly on Reata, the abundance of impurities has given rise to spotted and speckled marbles. They are usually medium-grained and the commonest impurities are forsterite and pseudomorphs of antigorite.

On Reata the limestones nearer the surface are cellular, the cavities being partly infilled with a brownish decomposition product which, in thin section, shows aggregate polarization and is not unlike iddingsite. Subordinate flake graphite and bent lamellæ of talc are found in the limestones east of Vilima Viwilli and on Reata.

Specimen 64/B22*, from the Reata quarry, contains numerous small crystals and grains of varying size of olive-green spinel. These grains are disseminated throughout the rock but with a tendency to be more abundant in and around the forsterite crystals. Other limestones from the same locality contain a mauve spinel. In a thin section of specimen 64/B21, the spinel varies in colour from dirty grey to pale mauve and occurs as subhedral crystals or in crudely graphic intergrowth with forsterite. In the more highly serpentinized varieties, the serpentine builds aggregates of interfering small spherulites or occurs as criss-crossing veinlets with either a herring-bone structure or with unorientated fibro-lamellar habit. The accessory ore from the limestone bands on Reata was identified by eye in the hand-specimen as pyrrhotite.

(ii) *Calc-silicate Granulites*

The calc-silicate rocks have a sparse distribution in the area, presumably indicating a deficiency of abundant calcareous lenses in the original sediments. They have the habit of relatively clean-cut rounded xenoliths or of small lenticular bands with

*Specimens numbered 64/B22 etc. are in the regional collection for degree sheet 64 of the Mines and Geological Department, Nairobi.

gradational junctions and are usually enclosed in hornblendic or, more rarely, a biotitic host-rock. The rock types as well as the properties of the minerals described by Shackleton (1946, p. 8) from the Maralal area and by Bear (1953, pp. 9-11) from the Embu area, apply equally to the occurrences in this area. The rocks consist of varying proportions of the following minerals: pale green pyroxene (usually diopside), green hornblende, yellowish epidote, scapolite, garnet, calcite, quartz, felspar and sphene. The best exposures are along the Lumi River north-west of Warombo.

(iii) *Semi-calcareous Gneisses and Granulites*

The most prominent occurrence of semi-calcareous rocks was found immediately east of Lake Jipe, where a band of garnet-diopside granulites can be traced from Vilima Viwilli to north of Munyoni. The rocks (64/B101 and 64/B102 from Vilima Viwilli) have mineral assemblages similar to those of the calc-silicate granulites but, in addition, usually contain varying but small amounts of biotite and/or muscovite. Quartz and plagioclase account for over 50 per cent of the mineral content. Subordinate amounts of microcline and myrmekite were observed in some thin sections, but they are not common constituents. In a thin section of specimen 64/B111, from south of Mbuyuni, epidote and hornblende are symplectically intergrown.

A distinct class of semi-calcareous granulite was recognized on the abandoned road near the confluence of the Tsavo and Nolturesh Rivers. They are leucocratic medium-grained rocks sporadically disseminated with small garnets, which are locally concentrated into irregular bands.

Under the microscope the texture of these granulites is found to be extremely variable, even over the small area of one thin section. In parts polygonal grains of quartz and felspar, dusted with numerous minute grains of sphene, form an almost equigranular pattern, whereas a few millimetres away large porphyroblasts of intensely sieved plagioclase with smudgy ill-defined twinning and crystalloblastic outlines have a replacive relationship to the neighbouring minerals. The latter texture has presumably resulted from partial recrystallization under intense local stress. A characteristic and most conspicuous feature of these rocks, irrespective of the textures, is the presence of innumerable granules and chadacrysts of sphene.

In a thin section of specimen 64/B181 the composition of the plagioclase was determined as An_{50}. The larger porphyroblasts have curved re-entrants and are intensely sieved with chadacrysts of quartz (not in optical continuity), sphenes of widely diverse shapes and sizes, and rare columnar zoisite. The quartz has clean-cut boundaries and strain shadows are rarely pronounced. Composite glomero-porphyroblastic clusters are common and consist of columnar aggregates of zoisite and green hornblende of ragged euhedral habit, the latter replacing the former.

In a thin section of specimen 64/B177 pale green diopside of exceedingly irregular outline has optically continuous protuberant growths extending into and wrapping around neighbouring quartz grains. It is moderately sieved and interlaminated with, as well as partly replaced by, green hornblende. The thin section of specimen 64/B179 is riddled with small grains of sphene which occur as inclusions in all the minerals but are most abundant in the quartz, plagioclase and scapolite. The sphenes have an uneven distribution and although they account for only 12 per cent by volume of the rock, the density in some areas is so high that the host minerals are barely recognizable. Ragged aggregates of biotite and hornblende, both sieved, are in many instances intimately associated. Garnet occurs as irregular grains and poorly-formed crystals. Large growths of scapolite selectively replace quartz and felspars, isolating garnets and columnar zoisite as chadacrysts. Grains of calcite and flakes of muscovite are subordinate and graphite is accessory.

The approximate modes* of some semi-calcareous rocks from the road south of the Tsavo bend are given below:—

	64/B180 *per cent*	64/B178 *per cent*
Quartz	29	17
Plagioclase	23	50
Biotite	18	+
Muscovite	1	—
Hornblende ..	—	6
Diopside	—	5
Garnet	15	4
Epidote-zoisite ..	—	16
Scapolite	9	—
Calcite	5	+
Accessory minerals	+	2

(b) *Metamorphosed Pelitic and Semi-pelitic Sediments*

(i) *Felspar-porphyroblast Gneisses and Granulites*

Although the majority of the felspar porphyroblasts have formed in rocks of originally semi-pelitic character, some have grown in rock types which may possibly have been originally of predominantly psammitic composition. For convenience of description they have all been grouped together.

Felspar-porphyroblast granulites and gneisses attain their maximum development on Reata. Smaller occurrences were noted on the two small hills immediately east of Latema and at the south-eastern foot of the larger of the Munyoni hills. Textural relationships indicate that the alkali felspar porphyroblasts were the last mineral to crystallize. Whether they owe their origin to the influx of granitizing fluids or to the recrystallization of original felspar is debatable. Harry (1952, pp. 153-155) believes that the dominant factor in the formation of the felspar-porphyroblast rocks of Glen Dessarry were declining stress, elevated temperatures and the promoting action of interstitial fluids residual from migmatization.

For the purpose of description the felspar-porphyroblast gneisses and granulites of the Taveta area may be classified as follows:—

Garnetiferous felspar-porphyroblast granulites.

Streaky biotite-garnet felspar-porphyroblast gneisses.

Fine-grained felspar-porphyroblast granulites.

Garnetiferous Felspar-porphyroblast Granulites.—Massive leucocratic rocks with abundant ovoid felspar porphyroblasts of roughly equal size form the eastern spur of Reata. The porphyroblasts are either white or flesh-coloured and their average diameter varies from five to eight millimetres. In thin section the completely subordinate role of the pyriboles and micas is singularly striking. The ferromagnesian minerals rarely exceed 5 per cent by volume of the rocks and consist of ragged flakes and scales of hornblende, biotite and diopside. The subhedral garnets are small and moderately sieved. The alkali felspars build porphyroblasts with crenulated margins, and ex-solution sub-parallel lamellæ of albite arranged *en echelon* are common. In certain sections the lamellæ cause the perthite crystals to have a chequer-board structure. Rounded droplets of quartz also occur as inclusions in the porphyroblasts but they do not show optical continuity, thus eliminating the possibility of a late and myrmekitic origin. Quartz grains outside the porphyroblasts show optical strain, myrmekite is subordinate and the accessories include numerous relatively large zircons, apatite and iron ore.

*All modes quoted in this report were estimated.

The southern summit of Reata consists of *augen gneisses*, a result of the shearing and the consequent deformation of the felspar-porphyroblast granulites. They are moderately foliated mesotype rocks in which the felspar augen average six millimetres across their larger diameter. A thin section of specimen 64/B17, from half way up the southern slopes of the hill, has mortar texture. The microcline-perthite augen, which rarely enclose blebs of quartz and flakes of biotite are embedded in a fine-grained inequigranular quartz-felspar matrix. Intensely strained quartz grains are segregated into lenticular folia which are aligned almost parallel to the narrow bands of biotite.

Streaky Biotite-garnet Felspar-porphyroblast Gneisses.—Gneissose fawn-coloured rocks with small felspar porphyroblasts, which are usually parallel to the weak foliation but occasionally cut across it, and in which small garnets are confined to thin discontinuous ferromagnesian bands, were observed on the two small hills east of Latema. The amount of alkali felspar in them greatly exceeds that of the sodic plagioclase. Both microcline and microcline-perthite porphyroblasts are present and in the latter ex-solution plagioclase does not form any systematic pattern. Orientated stringers of ragged biotite and hornblende, often intimately interleaved, and skeletal garnets, accentuate the gneissic banding. Undulose extinction is common in the quartz crystals but the strain shadows are rarely pronounced. Zircon, apatite and iron ore are accessory.

Biotite Felspar-porphyroblast Gneisses.—Biotite gneisses with large felspar augen, often two centimetres in diameter, are confined to the south-eastern foot of the larger of the Munyoni hills. The rocks (64/B88) have heteroblastic texture and consist of microcline, microcline-perthite, quartz, turbid plagioclase, myrmekite and subordinate poorly orientated flakes of biotite and muscovite. The microcline and microcline-perthite porphyroblasts generally have a replacive relationship to neighbouring minerals. They are, however, occasionally surrounded by a narrow zone of fine-grained quartzo-felspathic material, presumably a result of local brecciation. Some grains of microcline-perthite have undulose extinction and ex-solution "platy" albite is scattered and unorientated. In some instances a crude graphic structure has resulted from inclusions of optically orientated, rounded rather than vermicular, droplets of quartz in a host of turbid primary plagioclase, suggesting an origin by replacement and not by ex-solution or simultaneous recrystallization.

Fine-grained Felspar-porphyroblast Granulites.—Fine-grained granulites in which flesh-coloured microcline porphyroblasts build clusters, often of fist-size, were found as float south of the Tsavo River near its confluence with the Njugini. The larger porphyroblasts are riddled with rounded and vermiform inclusions of quartz which are presumably unreplaced relics of original grains. Biotite and muscovite are subordinate.

A detailed study of these felspar-porphyroblast rocks may reveal a relationship between the degree of strain in the quartz, the amount of myrmekite, the size of the porphyroblasts, and the degree of ex-solution in the perthites.

The volumetric modes of some representative felspar-porphyroblast rocks are given below.

	64/B10 *per cent*	64/B13 *per cent*	64/B32 *per cent*	64/B88 *per cent*
Quartz	15	19	25	18
Microcline and microcline-perthite	—	—	59	64
Perthite	15	18	—	—
Plagioclase	55	57	8	14
Myrmekite	+	+	+	+
Hornblende ..	3	3	3	—
Biotite	1	+	2	4
Garnet	7	2	3	—
Diopside	2	+	—	—
Accessory minerals	2	1	+	+

64/B10 and 64/B13. Garnetiferous felspar-porphyroblast granulites. Reata.

64/B32. Streaky biotite-garnet felspar-porphyroblast gneiss. East of Latema.

64/B88. Biotite felspar-porphyroblast gneiss. Munyoni.

(ii) *Micaceous gneisses and schists*

The micaceous gneisses and schists, considered to be the metamorphosed derivatives of pelitic and semi-pelitic sediments, are described under the following headings:—

Biotite gneisses.
Biotite-garnet gneisses.
Biotite schists.
Kyanitiferous-biotite schists.
Glomero-porphyroblastic biotite-muscovite granulites.
Muscovite gneisses.
Muscovite-garnet schists.

Biotite Gneisses.—The two best and most extensive exposures of biotite gneiss occur east of Girigan and along the railway-line east of Ziwani. They are moderately gneissose and mildly foliated rocks and are essentially the same as those described from other parts of Kenya, differing only in non-essential particulars. The biotite content rarely exceeds 25 per cent and its distribution is such that large pavements have glomero-plasmatic texture. Of eight thin sections examined, two contain more introduced felspar, predominantly microcline, than primary plagioclase; only one carries subordinate hornblende; and in two, small amounts of muscovite clearly derived from biotite, were observed. When calcite occurs it is invariably associated with the micas.

Biotite-garnet Gneisses.—Biotite-garnet gneisses are best developed on the eastern slopes of El Dorro. Northwards these rocks grade into biotite felspar-porphyroblast garnet granulites. On the other hand, poorly exposed biotite-garnet gneisses at Vilima Viwilli grade into diopside and hornblende-bearing types. They are faintly banded, mildly gneissose types in which the garnets show no preferred alignment and have often developed across foliation planes. Mineralogically and texturally these rocks are similar to the biotite-garnet gneisses in the Maralal area (Shackleton, 1946, p. 10) and the Embu area (Bear, 1953, p. 12). Essentially they consist of moderately sieved subhedral garnets, tabular biotite, quartz, oligoclase, and subordinate muscovite. Myrmekite, microcline and microcline-perthite are common in the gneisses from El Dorro but absent or only sparingly developed elsewhere in the area. On Vilima Viwilli these types carry small amounts of green hornblende, whereas those from the Tsavo bend, where there was more calcareous matter in the original sediments, are characterized by minute garnets, often enclosed in the larger quartz and felspar crystals, subordinate columnar rod-like zoisite, sparse muscovite which appears to be altering to sillimanite, and occasional isolated grains of calcite. The accessory minerals of these rocks include sphene, apatite, zircon, calcite and iron ore.

Biotite Schists.—Biotite schists were observed at only two localities. The larger occurrence, which is for the greater part covered with residual soil, lies between the two hills known as Munyoni, and the second occurrence is at Kevas. The biotite schists are melanocratic and highly decomposed. In a thin section of specimen 64/B100 from Munyoni reddish-brown biotite, green hornblende and colourless diopside are intimately associated. The diopside is traversed by numerous narrow veins of iron-oxide as a result of weathering. Granular mildly pleochroic sphenes are common and their association with the biotite suggests that they probably owe their derivation in part to titanium derived from it. Quartz and plagioclase are the only leucocratic minerals present, and apatite and iron ore are accessory.

Kyanitiferous Biotite Schists.—The biotite schists at the "New Claims" near Kevas contain subordinate kyanite and underlie the kyanite-quartz schists. This narrow band of schists is greyish in colour and has a talcy feeling reminiscent of material that has been subjected to a certain amount of shearing. A thin section of specimen 64/B7 consists essentially of ragged anhedral brown biotite and quartz, which has pronounced strain shadows and is often dusted with fine particles of iron ore, particularly nearer its margins. Acicular and columnar kyanite is subordinate and is often interfingered with biotite. Rare tabular crystals of muscovite are invariably largely enclosed by the biotites. The accessories include rods and needles of rutile, small somewhat rounded zircons and squat greenish tourmalines.

Glomero-porphyroblastic Biotite-muscovite Granulites.—On the hills south of Longalonga the biotitic rocks are conspicuous on account of their knotted appearance. These friable, mesotype rocks have irregularly scattered clots of biotite and muscovite which project prominently from weathered surfaces. They are embedded in a base of saccharoidal quartz and plagioclase and are generally rounded or ovoid in outline, averaging six to eight millimetres in diameter. In a thin section of specimen 64/B200 from south of Longalonga the glomero-porphyroblastic clusters of independently orientated platy and tabular biotite and muscovite can be seen. Minute zircons with pleochroic halos are common in the biotites. Subhedral tourmalines (ω=dark green, ε=pink and $\omega < \varepsilon$) and euhedral apatites are subordinate.

Muscovite Gneisses.—Muscovite gneisses are associated with the kyanitiferous rocks of the Longalonga belt. A low conical hill (when viewed from the west) a few miles south of Longalonga and which lies a quarter of a mile outside the eastern boundary of the area mapped, is composed almost entirely of muscovite gneisses and schists. These rocks (specimens 64/B191(*a*) and 64/B193(*a*)) are holo-leucocratic, medium-grained, and mildly foliated types which are sporadically speckled with black iron ore. Most of the exposures are highly decomposed so that good compact specimens are difficult to obtain. Under the microscope these gneisses are seen to be composed essentially of microcline and microcline-perthite, suborientated tabular muscovite with ragged relics of biotite, and moderately strained quartz. The ore, some of which is hematite, occurs as both subhedral crystals and skeletal grains, and is often associated with a green isotropic mineral (spinel ?). Minute zircons are abundant.

Muscovite-garnet Schists.—Friable, silvery, garnetiferous, muscovite schists (64/B194(*a*)) are associated with the muscovite gneisses on the hills south of Longalonga. They are thinly laminated types, devoid of felspars and composed of quartz, platy muscovite averaging two millimetres in cross-section, and isolated rusty garnets. The accessories include biotite, topaz (?) and ore.

The modal analyses of some representative micaceous gneisses are given below:—

	64/B100 *per cent*	64/B7 *per cent*	64/B193(*a*) *per cent*
Quartz	15	31	20
Alkali felspar	—	—	63
Plagioclase	19	—	—
Biotite	39	54	1
Muscovite	—	4	14
Hornblende	9	—	—
Diopside	8	—	—
Kyanite	—	8	—
Sphene	10	—	—
Accessory minerals	+	3	2

64/B100. Biotite schist. Between Munyoni hills.

64/B7. Kyanitiferous biotite schist. "New Claims", Kevas.

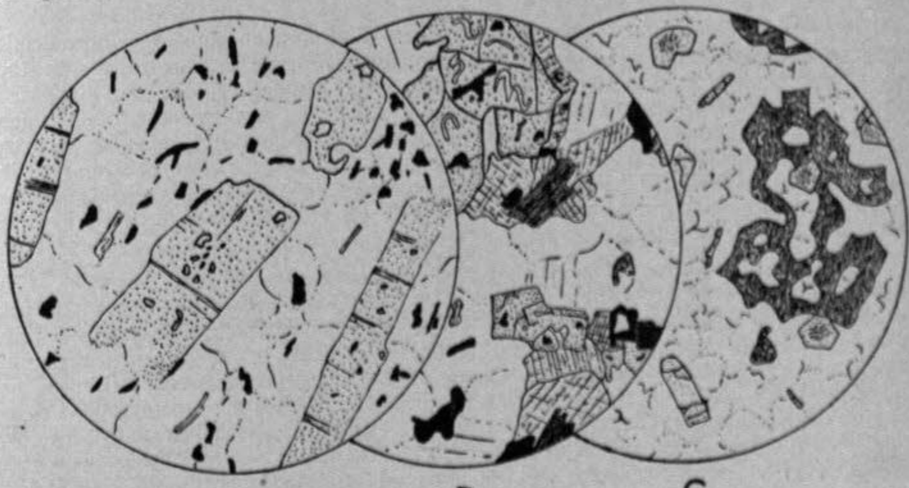
64/B193(*a*). Muscovite gneiss. South of Longalonga.

(iii) *Hornblende gneisses and granulites*

A wide variety of hornblende gneisses and granulites occurs in the area. They are for the most part concentrated in the corner between Taveta and Lake Jipe and immediately east of the lake. All the occurrences observed are conformable to the general strike of the Basement System rocks. They are tentatively considered to be derived from pelitic sediments but the possibility that some are meta-intrusives should not be overlooked. Field relations are too obscure to offer clues to their origin. These rocks are classified as follows:—

- Hornblende-garnet gneisses—
  - biotitic types;
  - diopsidic types;
  - scapolitic types;
  - hypersthene-bearing types;
  - microcline-perthite-bearing types.
- Finely-banded hornblende-biotite gneisses.
- Hornblende porphyroblast gneisses and granulites—
  - spotted garnetiferous hornblende-porphyroblast granulites;
  - platy quartzo-felspathic hornblende-porphyroblast gneisses.

The most striking features of these hornblendic rocks are the invariable presence of garnets and diopside, the subordinate amounts of quartz, and the complete absence of epidote.



A B C

Fig. 2.—Microscope drawings of thin sections of rocks from the Taveta area.

A—Kyanite-graphite schist. Specimen 64/B159, Longalonga. Ordinary light × 14. The kyanite porphyroblasts contain few chadacrysts and are well formed. The flakes of graphite are for the most part confined to the intergranular boundaries of the quartz-felspar mosaic.

B—Garnetiferous hypersthene-quartz diorite. Specimen 64/B28, one and a half miles S.E. of Latema. Ordinary light × 14. The drawing shows the relationship of the hypersthene, diopside, hornblende and biotite crystals to the larger, usually poorly formed, garnet grains.

C—Hornblende-porphyroblast gneiss. Specimen 64/B176, five miles north of Longalonga. Ordinary light × 14. The hornblende porphyroblasts are intensively sieved and lie in an equigranular mosaic of quartz and felspar with subordinate garnets and epidote.

Hornblende-garnet Gneisses.—Small patches of hornblende-garnet gneiss, free of subordinate amounts of other ferro-magnesian minerals were observed only along the Lumi River north-west of Warombo, and north-east of Vilima Viwilli. In the latter locality garnet and particularly hornblende are subordinate to the quartz and felspar, whereas those from the Lumi consist of an equigranular mosaic of approximately equal amounts of polygonal quartz and felspar, anhedral hornblende and euhedral garnet.

Biotite-hornblende-garnet Gneisses.—Along the Tsavo River, south-west of the Tsavo-Rombo confluence, the mesotype hornblende gneisses are massive, of medium to coarse grain, and have granitoid to mildly gneissose structure. They are similar in many respects to the appinitic rocks of the Embu area (Bear, 1953, p. 13) but differ in that epidote is absent and garnet present. The texture as revealed in a thin section of specimen 64/B192 is granoblastic. The bulk of the rock consists of twinned felspar (An_{44}) enclosing droplets of quartz. Flakes of biotite are intergrown with the poikiloblastic hornblende and other chadacrysts include quartz, felspar, rutile and hornblende.

Diopsidic Hornblende-garnet Gneisses.—In the majority of the hornblende gneisses and granulites a pale greenish pyroxene with optical properties conforming closely to those of diopside is developed. West of Reata there is a small occurrence of these rocks. They are fawn-coloured medium- to fine-grained granulites. The bulk of the plagioclase is untwinned and strain shadows are common. Some of the larger garnets and diopside are intergrown. Quartz is subordinate and apatite and sphene are accessory. On Vilima Viwilli and Munyoni somewhat similar types occur, but these consist of varying proportions of diopside, garnet, hornblende and biotite. There is no epidote.

Scapolitic Hornblende-garnet Gneisses.—On Loosoito melanocratic hornblende gneisses underlying the kyanite horizon were sufficiently calcareous to permit the development of a meionitic scapolite. These coarsely banded types are well-exposed in the cutting where the road on the hill takes its final turn. A thin section of specimen 64/B18 reveals cracked and irregular garnets poikiloblastically enclosing quartz, plagioclase, scapolite, hornblende, rutile and iron ore. Large plates of scapolite in the matrix in which the garnets lie have prominent cleavages and their sometimes regular outlines do not resemble the replacive habit so commonly assumed by this mineral.

Hypersthene-bearing Hornblende-garnet Gneisses.—Hornblende gneisses with subordinate amounts of hypersthene were observed on the eastern and western slopes of Reata, and in the centre of the smaller of the Munyoni hills. The bands are no more than a few feet wide and appear to be conformable to the general succession. The small exposure on the western slopes of Reata carries scattered brittle garnet porphyroblasts up to three centimetres in diameter. Under the microscope a thin section of these rocks (64/B25) is seen to consist of an equigranular mosaic of diopside, hornblende, hypersthene and plagioclase (An_{30}). No quartz was positively identified. Diopside often forms the cores of the anhedral hornblende. Although hornblende and hypersthene are frequently in contact their mutual relationship could not be resolved with any degree of certainty. Slender evidence suggests that the hornblende is the later mineral. The pyriboles form over 60 per cent of these rocks, but those with abundant garnets have a higher proportion of plagioclase, and quartz is definitely absent.

Microcline-perthite-bearing Hornblende-garnet Gneisses.—In the dry river-bed south of Salaita a distinctive class of leucocratic hornblende-garnet gneisses was recognized. They are coarse-grained, mildly foliated and of pale pink colour (64/B113). The garnets are extremely irregular in outline, riddled with chadacrysts, and often concentrated in clusters. Ragged aggregates of hornblende often with intergrown flakes of biotite, as well as plagioclase, myrmekite and quartz are present in subordinate amounts. Zircon is an abundant accessory. The composition of these rocks has no doubt been modified to a certain extent by granitization.

Finely-banded Hornblende-biotite Gneisses.—The best exposures of banded hornblende-biotite gneisses occur on the southern end of the smaller of the Munyoni hills. Towards the east they grade into biotitic quartzo-felspathic gneisses. Specimen 64/B93 is typical and consists of a granular mosaic of quartz and felspar, with irregular green hornblende and unorientated flakes of biotite. Myrmekite is subordinate and the accessories include numerous subrounded zircons, subhedral apatites and iron ore.

Hornblende-porphyroblast Gneisses and Granulites.—In the north-eastern corner of the area two small occurrences were noted of mesotype hornblende porphyroblast rocks. These types are characterized by the relative abundance of quartz and plagioclase and the absence of diopside.

Near the abandoned road south-east of the Tsavo-Nolturesh confluence spotted garnetiferous hornblende-porphyroblast granulites with innumerable rounded hornblende porphyroblasts were noted. They are presumed to have been formed by the metamorphism of originally semi-pelitic rocks. Locally a grading in the size of the hornblende spots is discernible, and where they are larger they are less abundant. The spots are mostly rounded and vary in diameter from one millimetre to five millimetres. The leucocratic component of the rock consists of saccharoidal quartz and felspar. A thin section of specimen 64/B176 has marked maculose texture and the hornblende porphyroblasts are embedded in a matrix of equidimensional granular quartz and felspar (Fig. 2 C). Small pinkish subhedral garnets and columnar epidote-clinozoisite are subordinate. Biotite is rare and the accessories consist of apatite, squat brown tourmaline and numerous small irregular grains of sphene.

Platy quartzo-felspathic hornblende-porphyroblast gneisses were observed in the neighbourhood of the Longalonga hills. In the dry river-bed south of the Tsavo-Nolturesh confluence the parallellism of the elongate crystals of hornblende is most striking. The average index of elongation of the crystals is seven. In a thin section of specimen 64/B190, from the above locality, the porphyroblasts of poikiloblastic hornblende lie in a granulose groundmass of quartz and twinned and untwinned felspar. Biotite is subordinate and apatite and iron ore are accessory. The other occurrence of these rocks is on the hill to the south of Longalonga. Here they have a streaky appearance and the lineation is not so marked. Locally, biotite becomes abundant and is usually associated with the elongate hornblendes. Along the strike these rocks grade into biotite-hornblende-porphyroblast gneisses, and finally into biotitic quartzo-felspathic gneisses. Owing to their friability no thin sections could be cut but a grain identification of the biotitic types from the hill confirmed the presence of the following minerals: quartz, felspar, hornblende and biotite, with subordinate kyanite, epidote, topaz (?), sphene, leucoxene and iron ore.

The volumetric modes of various types of hornblende gneiss and granulite are given below:—

	64/B192 *per cent*	64/B74 *per cent*	64/B18 *per cent*	64/B113 *per cent*	64/B16 *per cent*	64/B25 *per cent*	64/B176 *per cent*	64/B190 *per cent*
Quartz	5	+	12	6	+	+	19	18
Plagioclase	52 (An_{44})	42 (An_{32})	11	70	25	41	46	65
Hornblende	33	22	28	4	58	14	14	15
Diopside	—	5	—	—	17	40	—	—
Hypersthene	—	—	—	—	—	3	—	—
Biotite	3	12	—	+	—	—	+	+
Garnet	5	18	18	17	—	2	9	—
Scapolite	—	—	30	—	—	—	—	—
Calcite	—	—	+	—	+	+	—	—
Epidote	—	—	—	—	—	—	7	—
Sphene	—	—	—	—	—	—	5	—
Accessory minerals ..	2	1	1	3	+	+	—	2

64/B192 Hornblende-biotite-garnet gneiss, one mile east of the Tsavo-Rombo confluence.

64/B74 Hornblende-biotite-diopside granulite, two miles north-west of Warombo.

64/B18 Hornblende-scapolite-garnet gneiss, western slopes of Loosoito.

64/B113 Microcline-perthite-hornblende gneiss, four miles south of Salaita.

64/B16 and 44/B25 Hypersthene-bearing hornblende-diopside gneisses, Reat.

64/B176 Spotted hornblende-porphyroblast granulite, three-and-a-half miles south-east of the Tsavo-Nolturesh confluence.

64/B190 Platy hornblende-porphyroblast gneiss, two miles north of Longalonga.

(iv) *Sillimanite Gneisses*

Kyanite-free sillimanite gneisses are rare in the area. Garnetiferous biotite types from north of Munyoni are similar to sillimanite gneisses in the Nanyuki-Maralal area (Shackleton, 1946, p. 9) and the Mumoni mountains (Bear, 1953, p. 15). The habit of the sillimanite, however, is different—it occurs as individual sub-parallel slender prismatic crystals rather than as fibrolite. Relatively garnet-free biotite-poor varieties were found on the hills south of Longalonga, where they form narrow bands traceable only for a few hundred feet. The sheaves of sillimanite have pronounced parallellism and are concentrated along foliation planes. In specimen 64/B172, sillimanite accounts for 40 per cent of the mineral composition, the balance being made up of quartz, subordinate kyanite with termination fringes of sillimanite, and accessory rutile, zircon, pyrite and octahedrite (?).

(v) *The kyanitiferous gneisses and granulites of the Longalonga area*

The kyanitiferous rocks of the Longalonga belt have been briefly described by Parkinson (1947, p. 15) and in some detail by Temperley (1953, p. 50). These kyanitic rocks extend along a discontinuous north-west–south-east belt of originally sedimentary rocks, from Mgange in the south to the vicinity of Signal hill in the north. Only that portion lying between the Tsavo bend and Longalonga falls into the scope of the present report. Temperley (op. cit., p. 52) reports that "the belt includes crystalline limestones, kyanite schists, graphite schists containing both kyanite and graphite, muscovite and biotite schists including migmatites in the Taita hills, garnet schists, pyroxene-garnet schists and quartz schists which are sometimes ferriferous, garnetiferous and kyanitiferous". These rocks are not unlike the members of the Khondalite Series* of India.

Longalonga, which rises 450 ft. above the immediately surrounding country, affords the best exposures of the graphite-kyanite schists. They are mesotype to melanocratic rocks and of medium to fine grain. They are sometimes finely laminated and banded, the banding often being accentuated by the decomposition of the leucocratic component of the rock to an earthy kaolinitic material. Small cavities are not uncommon and are sometimes lined with decomposition products derived from secondary minerals. The characteristic feature of these rocks is the presence of finely disseminated particles of graphite of approximately equal size, usually less than one millimetre in diameter, in both the predominantly quartzose groundmass and the kyanite porphyroblasts. The kyanite blades are usually blue or grey and have random orientation so that no linear fabric is evident. The graphite is concentrated on the foliation planes. Locally small scattered grains of pyrite and bottle-green fuchsite are abundant. Yellowish decomposition products are conspicuous along the foliation planes and in some of the cavities.

Under the microscope these rocks reveal a variety of textures and a variable composition. The most common texture (e.g. 64/B159) is heteroblastic, when spongy kyanite porphyroblasts lie embedded in a base of irregularly sutured quartz and plagioclase (Fig. 2A). Quartz predominates in the base, which is sprinkled plentifully with flakes and scales of graphite. At the other extreme some thin sections (e.g. 64/B182) exhibit an equidimensional mosaic of polygonal quartz and plagioclase with flakes of graphite and muscovite of distinctly preferred orientation. Mineralogically the rocks consist of varying proportions of quartz, plagioclase, kyanite, graphite, muscovite, sillimanite, and apatite as well as secondary minerals and alteration products.

The *quartz* varies from small polygonal grains to relatively large partly recrystallized sutured aggregates. Strain shadows are more pronounced in the latter as are also dust-like inclusions of graphitic material. Enclosed flakes of graphite are not uncommon. Quartz is the most abundant chadacryst in the kyanite porphyroblasts. The *plagioclase* of many rocks is albite. The crystals are invariably turbid and altered to a translucent kaolin-like product. Other grains show incipient alteration commencing along cracks, as well as on cleavage and twin planes. The *kyanite* occurs as crystals in

*A series of metamorphic rock consisting of garnet-quartz-sillimanite rocks with garnetiferous quartzites, graphite schists and crystalline limestones containing calc-silicate minerals.

various stages of development from primitive amœba-like forms filled with included material to later subhedral crystals with but few inclusions. Besides fine graphite dust, quartz, plagioclase and rutile are the most common chadacrysts. Muscovite inclusions are less common and apatite is rare. In some porphyroblasts there are inclusions of black opaque microlites with a structure reminiscent of schillerization, in that they occur in parallel *en échelon* lines. *Muscovite* is usually present as suborientated flakes and rarely as large embayed plates polarizing over considerable areas. Some of the mica is greenish and is considered to be fuchsite (chrome muscovite). Some satiny micaceous material may be talc. *Apatite* is present in most of the rocks as an accessory, but in specimen 64/B185, a more leucocratic type from two miles north-west of Longalonga, small scattered, apple-green, apatite crystals are recognizable with the unaided eye. They rarely exceed two millimetres in diameter. In a thin section of this rock the apatite occurs both as broken euhedral crystals and as large irregular and skeletal grains. In some instances quartz appears to be replacing them and in others they have inclusions of rutile and plagioclase. *Sillimanite* is not common in these graphite-kyanite schists, but when present it replaces muscovite and often forms a pseudo-ocellar structure around kyanite. The *graphite* occurs as evenly disseminated flakes and scales concentrated along and lying parallel to the foliation planes. Individual flakes rarely exceed a half millimetre in diameter. The larger grains usually lie at the contacts of other minerals and only rarely occur as inclusions. Quartz, plagioclase and kyanite are often riddled with graphitic dust whereas muscovite and apatite are usually free. The proportion of flake graphite present appears to vary in inverse ratio to the muscovite. Triangular markings on the basal sections of the graphite are quite pronounced in reflected light.

A characteristic feature of these rocks is the wide variety of *decomposition products* and secondarily introduced minerals. These include cloudy translucent leucoxene which is sometimes associated with iron ore and often has a concentric ring structure (64/B158 and 64/B184(*a*)); kaolinite; an orange-coloured granular product (hydrated iron oxide ?) with extreme birefringence and aggregate polarization and which often forms mantles around the pyrite grains and lines cavities (64/B193 and 64/B159); a pale yellowish-brown isotropic mineral, in appearance not unlike collophane, and which occurs either as veins or as larger masses with accordion-like structure (64/B183); an opaque iron ore with concentric structure in which the concentic shells are separated by open-spaces which may be shrinkage cracks (64/B184); and a spherulitic mineral which, in addition to its radiate structure, often has concentric lines or dots that appear to indicate interruptions at various stages of growth (64/B158). This radiate arrangement is often extremely regular so that a perfect black extinction cross appears when a thin section is viewed between crossed nicols. Irregular growths comparable to rough sheaves are more common, and the mutual interference of adjacent growths has resulted, in some instances in irregularly-shaped coalescent spherules. The mineral composition of these growths could not be positively ascertained, but their refractive index is less than that of quartz, and they are tentatively considered to be secondary opal. The possibility that some of these products are fossils is eliminated by the fact that their delicate structures would not have survived the high degree of metamorphism to which the rocks have been subjected.

The variable composition of the kyanite-graphite schists is indicated by the following approximate modes:—

	64/B184 *per cent*	64/B182 *per cent*	64/B158 *per cent*	64/B188 *per cent*
Quartz	15	77	48	5
Plagioclase	24	+	24	15
Kyanite	25	—	5	22
Sillimanite	4	—	—	—
Muscovite	2	12	+	58
Fuchsite	—	—	+	—
Graphite	7	9	8	+
Rutile	+	+	—	+
Apatite	5	1	—	—
Decomposition products	15	+	15	—
Accessory minerals	3	1	—	—

Specimens 64/B184 and 64/B182, kyanits-graphite schists, from two miles north-west of Longalonga.

Specimen 64/B158 graphite-kyanite schist, Longalonga.

Specimen 64/B188 muscovite-kyanite schist, two and a half miles north-west of Longalonga.

Kyanite granulites and gneisses associated with the kyanite-graphite schists of the Longalonga belt but in which graphite is either absent or occurs only as an accessory include—

Kyanite-garnet granulites.

Garnet-muscovite-kyanite-staurolite granulites.

Kyanite-muscovite gneisses.

Biotite-kyanite-tourmaline gneisses.

Kyanite-garnet Granulites.—These handsome rocks, which occur in a lens three miles south-west of Longalonga, underlie the main kyanite-graphite horizon. The lens is associated with crystalline limestones, and its outcrop is marked by prominent jagged isolated ribs though much of it is obscured by secondary limestones. The garnets which are euhedral and of about equal size, averaging five millimetres in diameter, are embedded in a groundmass of kyanite, quartz and ilmenite and amount to approximately 50 per cent of the rock. The microscope reveals that sillimanite is far more abundant than field inspection suggests. It is of the fibrolite variety and often replaces kyanite leaving only small relic cores. Sillimanite completely enclosed in plates of muscovite is not uncommon. The salmon-coloured garnets are crowded with chadacrysts of quartz, rutile and iron ore amounting in many cases to 30 per cent of their volume. It is interesting to note how seldom sillimanite and kyanite occur as inclusions in the garnets, indicating the attainment of equilibrium, all the alumino-silicates being used upon the formation of garnet at any particular point. The quartz rarely shows intense strain. Biotite is subordinate and when chadacrystic is fresh and unaltered, whereas flakes in the groundmass are usually chloritized in variable degrees.

Garnet-muscovite-kyanite-staurolite Granulites.—Granulites of this composition are poorly exposed on the eastern bank of the dry river-bed some four miles north of Longalonga. The occurrence is small but the rocks are conspicuous on account of their small glistening plates of muscovite and large scattered garnet porphyroblasts. In a thin section of specimen 64/B186 the garnets carry up to 40 per cent of included material consisting of quartz, plagioclase, iron ore, biotite, staurolite and apatite. The blades of kyanite are moderately sieved and the quartz around them occurs as a polygonal mosaic. The tabular and platy muscovite has random orientation and many of the crystals are curved. Staurolite, comparatively free of inclusions, occurs as small discrete euhedral grains and large poorly formed crystals. They have pleochroism, X = colourless, Y = pale yellow and Z = golden yellow.

Kyanite-muscovite Gneisses.—Friable greenish kyanite-muscovite gneisses were found as float blocks in the dry river-bed north of Longalonga. Both pale green and colourless muscovite are distinctive in the hand-specimen and surround brittle porphyroblasts of grey kyanite. A thin section of specimen 64/B188 reveals that the flakes of muscovite are arranged in a descussate texture, the plagioclase is twinned and dusted with fine opaque inclusions ,and the kyanite, except for inclusions of rutile, is relatively free of chadacrysts. The quartz is unmistakably biaxial with a small optic axial angle and in some cases encloses parallel flakes of muscovite.

Biotite-kyanite-tourmaline Gneisses.—The only occurrence of kyanite rocks with abundant biotite occurs on the hills south of Longalonga. They are intimately associated with the biotite-hornblende and the muscovite gneisses. A thin section of specimen 64/B192(*a*) consists of quartz, plagioclase, biotite, muscovite completely enclosing slender needles of sillimanite with sub-parallel arrangement, rutile and decomposition products. Large blue kyanite crystals and small black tourmalines, although not present in the thin section, are conspicuous in the field.

(c) *Metamorphosed psammitic sediments*

(i) *Quartz schists and quartz-kyanite schists*

The following account is based on an unpublished departmental report on the kyanite of the Murka-Loosoito belt by Temperley.

On Loosoito he recognized four beds comprising "the kyanite group". They are:—

White bed—quartz-schist.

Porous bed, Massive bed } quartz-kyanite schist.

Basal bed—quartz-kyanite schist with kyanite-rock segregations.

In his description of these beds Temperley reports:—

"The *white bed* is a pure quartz-schist, devoid of kyanite and easily distinguished and sharply divided from the beds below.

The *porous bed*, which is only seen in the middle part of the high ridge, seems to be a local variation of the top part of the massive bed below it. It is a quartz-kyanite schist which weathers in such a way that the bedding planes are emphasized by differential leaching, the surface roughened and the texture made porous. Only a very few small and impure segregations of kyanite rock and a few thin films of kyanite on bedding planes have been found in this formation.

The *massive bed* is a brown quartz-kyanite schist which runs the whole length of the hill and is the principal cliff-forming bed. It breaks into huge, smooth-faced, rectangular blocks along widely-spaced joint planes. The bedding planes are inconspicuous. The brown colour of this and most other rocks (on Loosoito) is due to limonite produced by the weathering of iron-bearing minerals in the rock. In the second step down at the southern end of the hill one of the layers of the massive bed is highly ferruginous. Crystals of pyrite are visible in it and it weathers to a greenish crust presumably due to the presence of ferrous salts. A sample of the pyritic schist was assayed for gold and found to carry 0.6 dwt. At a very few points segregations of kyanite rock were found in the massive bed. They occur in its upper part.

The *basal bed* . . . is not everywhere clearly divisible from the massive bed and is somewhat variable in character. It is the most important bed, for most of the segregations of kyanite-rock occur in it and it appears to be the bed richest in disseminated kyanite. It is a quartz-kyanite schist but is generally distinguishable from the massive bed by being paler in colour and having more conspicuous bedding planes. It weathers more quickly than the massive beds and so gives rise to an undercut cliff at many points. At some points it is fissile and tends to split into thin plates."

On Kevas the kyanite group is divisible into two members, the white bed (pure quartz schist) above, and the massive bed (more or less ferruginous kyanite-quartz schist) below. At Murka and the Kopje the beds cannot be divided into distinctive layers and the formation consists entirely of kyanite-quartz schists.

In thin sections of specimens 64/B162 and 64/B163, *quartz schists* from Loosoito and Kevas respectively, the quartz occurs as large but not intricately sutured crystals. Strain shadows are rarely pronounced but many grains are biaxial with optic angles of approximately 10 degrees. Sub-parallel lines of minute inclusions are considered to be gas bubbles. Zircons and euhedral brown rutiles are common, the former often concentrated into small clusters comprising six to twelve grains. A dark grey almost opaque mineral which is occasionally in contact with minute zircons is tentatively considered to be octahedrite. Other accessories include rare flakes of muscovite, small ragged grains of kyanite, isolated needles of sillimanite, apatite and iron ore.

The *quartz-kyanite schists* are holo-leucocratic, medium-grained rocks with glistening sub-parallel platy to tabular kyanite crystals generally aligned parallel to the foliation. A thin section of specimen 64/B197 from Murka contains less than 10 per cent kyanite. The kyanite is free from included material but intimately intergrown with quartz. The accessory minerals are the same as those found in the quartz schists. There are, however, fewer zircons and octahedrite (?) is more abundant.

(ii) *Quartzites*

Quartzites *in situ* were observed only south-west of Munyoni where they form a narrow band, less than 10 ft. wide, which is intermittently exposed for a few hundred feet. The most striking macroscopic features of these rocks (64/B114) are their black colour, vitreous lustre, and the presence of scattered rounded crystals of a pale pinkish pyroxene. Locally they are mildly schistose. The rocks consist of approximately equal proportions of quartz and pyroxene. The black colour is presumably due to minute ferriferous or manganiferous inclusions in the pyroxene.

North of Longalonga there is much quartzite float and five miles south of the hill a small projecting rib, which may indicate a concealed lens, was observed. These quartzites have medium-grained granulitic features due entirely to recrystallization and not to crushing or shearing, and are characterized by abundant muscovite and occasional fairly large grains of rose quartz. Twinned slightly kaolinized felspars are subordinate. Accessories include zircons, rutile, minute garnets and iron ore. Quartzites, differing only in non-essential details, have been described by Parkinson (1947, p. 14) from the vicinity of the Tsavo bend.

(iii) *Garnetiferous quartzo-felspathic granulites*

Rocks mapped in the Taveta area which consist almost entirely of quartz and felspar are assumed to have been derived from impure sandstones and arkoses. They are widespread, commonly occurring as poorly-exposed flattish pavements. The rocks consist of salmon-coloured garnets, quartz, microcline, myrmekite, microcline-perthite and plagioclase. The garnet content rarely exceeds 15 per cent and is usually much less. Sub-rounded relatively large zircons, apatite, sphene and iron ore are accessory.

(iv) *Biotite quartzo-felspathic granulites*

Biotite granulites similar to the garnetiferous quartzo-felspathic types are also common, though poorly exposed. Their mineral compositions are identical with those of the garnetiferous granulites except that biotite takes the place of garnet. The biotite content is low, never exceeding 5 per cent.

(*d*) *Metamorphosed carbonaceous sediments*

Occurrences of graphitic rocks, formed by the metamorphism of originally carbonaceous pelitic sediments, are not uncommon. Besides the Longalonga deposit, in which graphite, kyanite and muscovite are associated, occurrences of biotite-graphite gneisses were observed along the Lumi River north-west of Warombo, muscovite-graphite gneisses east of Vilima Viwilli and graphite-sillimanite schists on Reata.

(i) *Biotite-graphite gneisses*

The small outcrop of biotite-graphite gneisses on the western bank of the Lumi River is intimately inter-fingered and inter-layered with the biotite gneiss host-rock. Individual lenses are rarely more than a foot thick and the graphite is confined to a 10 ft. zone. The gneisses are highly decomposed, friable rocks which disintegrate easily when handled. Laterally from the outcrop they are concealed by residual soil. Many graphite flakes are one to two millimetres in diameter and the biotite content is much higher than casual field inspection indicates. Grain counts (64/198(*a*)) revealed the following composition:—

	+60	*−60+90*	*−90*
Quartz and felspar	31	70	66
Biotite	28	17	24
Graphite	34	8	6
Garnet	4	1	+
Accessory minerals	3	4	4

(ii) *Muscovite-graphite gneisses*

Float blocks of muscovite-graphite gneisses were found in the immediate vicinity of the limestone band east of Vilima Viwilli. They are compact, unweathered, relatively hard rocks. A thin section of specimen 64/B196(*a*) consists of quartz, turbid felspars, flakes of muscovite and talc (?), subordinate subhedral apatite and flake graphite, and accessory rutile and hematite. The graphite flakes rarely exceed one millimetre in diameter and are estimated to amount to 5 per cent by volume of the rocks.

(iii) *Graphite-sillimanite schists*

Narrow bands six to eight feet thick of graphitic schists were observed immediately south of the highest point of Reata, and lower down on the western slopes. They are melanocratic fine-grained rocks varying from friable types to hard quartzose varieties. Banding is often distinct, narrow discontinuous leucocratic bands being composed of sillimanite, kaolinized felspars and pyrite. Thin sections of specimens 64/B15 and 64/B24 consist predominantly of a sutured mosaic of partly recrystallized and strained quartz and turbid felspars. The sillimanite occurs as long sub-parallel prismatic crystals with numerous cross-fractures and nearly square basal cross-sections in which cleavages are prominent. The graphite is evenly disseminated as minute scales and flakes. Accessories include rutile and pyrite. Volumetric modes indicate the following composition:—

	64/B15 *per cent*	64/B24 *per cent*
Quartz	50	78
Felspar	18	4
Sillimanite ..	10	6
Graphite	20	12
Accessory minerals	2	+

64/B15 and 64/B24. Graphite-sillimanite schists. Reata.

(2) The Kyanite-quartz Schists and Kyanite Segregations of the Murka-Loosoito Belt

The Murka-Loosoito kyanite belt has been described in considerable detail by Temperley (1953, p. 16) and much of the following account is based on his findings.

In considering the origin of the kyanite-quartz schist and the kyanite-rock segregations the following facts are significant:—

(*a*) The great variation of the kyanite content both laterally and horizontally.

(*b*) The kyanite-rock segregations have not grown at the expense of kyanite in the surrounding schists.

(*c*) The presence of topaz, tourmaline and pyrite indicates the influence of pneumatolytic and/or hydrothermal mineralization.

(*d*) Whereas the nature of occurrence of the kyanite-rock masses suggests that they grew in the schists while deformation was taking place, they are most abundant where the regular bedding and jointing of the overlying schists is disturbed.

(*e*) The kyanite rocks and associated quartz schists are devoid of any signs of granitization.

Of the above facts the greatest difficulty is to account for the variation in the kyanite content. Temperley (op. cit., p. 78) considers that this may be due to either a variation in the composition of the original sediment at the time of its deposition, to modifications in the composition of the sediment before regional metamorphism, or to changes in its composition during metamorphism. Of these three possibilities he is inclined to support the third. It seems more reasonable to the writer to attribute the origin and the variability of the kyanite content to the variable operation of all three processes, i.e. that the kyanite probably formed in dominantly siliceous rocks which, at the time of their deposition, contained variable amounts of argillaceous material that prior to metamorphism was altered to clays of the appropriate composition. The kyanite-rock segregations are considered to be a result of metamorphic differentiation. Read (1952, pp. 11-12) suggests that the occurrence of great bodies of aluminium silicates and sometimes alumina within migmatitic complexes may be solved by the "subtraction proposal". On the current explanation of such bodies as metamorphosed bauxites he considers that ". . . the formidable problems of palæogeography and stratigraphy have not been adequately, if at all, regarded." He suggests that the occurrences might be due to subtractions connected with metamorphic differentiation operating on a grand scale in the setting of migmatization.

For the purpose of description the kyanitic rocks of the Murka-Loosoito belt are classified as follows: —

(i) Kyanite-quartz schists.

(ii) Kyanite-rock segregations.

(iii) Corundum-kyanite rocks.

(iv) Topaz-kyanite rocks.

(i) *Kyanite-quartz schists*

The extremely erratic vertical and horizontal distribution of the disseminated kyanite in the schists has given rise to both quartz-kyanite and kyanite-quartz schists. No stratigraphic distinction exists between types. The greater kyanite content of the kyanite-quartz schists enables the relationship between the kyanite and quartz to be studied in more detail. Thin sections reveal that the kyanite, usually free of included quartz, has frayed and skeletal outgrowths intimately intergrown and replacing quartz. Finely inter-laminated blades of kyanite and quartz were also observed, but are not common. Occasionally some of the smaller kyanite crystals are fringed with films of fibro-lamellar and a scaly kaolinitic mineral which rarely penetrates in lobes well into their interiors. Whereas rutile occurs equally abundantly as chadacrysts in both the quartz and kyanite, euhedral octahedrite (?) is confined solely to the quartzose fraction. Specimen 64/B208, from the "New Claims" at Kevas, was taken from near the base of the kyanite-quartz schists. The rock is highly sheared and consists essentially of flamboyant radial aggregates of sillimanite with cores of kyanite, and quartz grains which are almost completely replaced by sillimanite.

(ii) *Kyanite-rock segregations*

Kyanite boulders or segregations in the form of ellipsoidal and lenticular masses occur within the kyanite-quartz schists at Murka and to a lesser extent at Kevas. These segregations vary in size from aggregates or augen composed of a few crystals to bodies 100 ft. long, 25 ft. in diameter, and weighing several hundred tons. The major axes of the lenses are parallel with the bedding. Individual crystals are often two to three inches long and display a wide variety of colours including white, blue, green and grey. Tints of blue and green are the commonest. The structure is either descussate, radial or spheroidal. Under the microscope the rocks (64/B53) are seen to consist of interpenetrating blades of kyanite, with subordinate amounts of muscovite, sillimanite, quartz and kaolin, and accessory rutile and iron ore. Coarse twinning is not uncommon in the kyanite crystals and they occasionally enclose ragged flakes of muscovite. The scale-like aggregates of kaolin are usually interstitial and rarely inter-fingered with tabular kyanite. It is sometimes intimately associated with muscovite from which it appears to be derived. Radial aggregates of fibrolitic sillimanite are also often associated with muscovite, whereas slender individual needles are sometimes enclosed in quartz. In a thin section of specimen 64/B189(*b*) small columnar aggregates of intensely pleochroic (colourless to reddish-violet) dumortierite were identified.

(iii) *Corundum-kyanite rocks*

Corundum-bearing kyanite segregations have never been found *in situ* but boulders of float existed both at Murka and near the Kopje. The only thin section sliced during the present work, of specimen 64/B64 from the Kopje, contains abundant kyanite and sillimanite and subordinate clusters of granular corundum. Some of the corundum grains are bi-axial and they sometimes occur as inclusions in the kyanite and sillimanite. There is no quartz.

(iv) *Topaz-bearing kyanite rock.*

These rocks have a sporadic distribution throughout the kyanite belt, and where the topaz is relatively abundant it is easily recognized by its saccharoidal texture. In a thin section of specimen 64/B189, from the "Leopold Claims" near Kevas, it was found that some of the topaz is idiomorphic against kyanite, and that allotriomorphic rutile replaces topaz. No quartz was observed in the slide.

(3) GRANITES

No granites *in situ* were observed in the area. Float blocks of relatively coarse-grained pinkish granites were found however, near the road south-east of the Tsavo-Njugini confluence. They are considered to be a product of the rheomorphism of granitized sediments. The only thin section sliced (specimen 64/B206) has hypidiomorphic texture and consists predominantly of large crystals of patchily perthitic microcline, orthoclase and turbid twinned albite. The quartz shows pronounced strain shadows and is partly replaced by microcline. The subordinate minerals consist of variably chloritized muscovite enclosing anhedral rutiles, intimately associated with calcite, myrmekite and scattered flakes of biotite. Subhedral zircon and iron ore are accessory.

(4) MAJOR INTRUSIVES INTO THE BASEMENT SYSTEM

The Charnockitic Suite

Rocks of the charnockitic suite are confined to the area south and south-west of Taveta. They are strongly resistant to erosion and form the prominent hills Mokinni, Kitogato and El Dorro. The Mokinni body is conformable to the neighbouring Basement System gneisses and granulites. The disposition of the Kitogato and El Dorro intrusives is more difficult to ascertain owing to the lack of undisturbed exposures, though they appear to have been emplaced as vertical pipe-like bodies.

The following indirect evidence suggests that these intrusives are post-Basement in age:—

(*a*) The basic intrusives have relatively unmodified cores with fresh olivines.

(*b*) No stringers or veins of granitic and/or pegmatitic material were observed within the intrusive masses.

(*c*) Under the microscope no evidence of granitization was recognized.

The growth of corona structures, particularly in the hypersthene tilaites, and the irregular contact zone of hybrid rocks possibly suggests some connexion with at least the culminating stage of regional metamorphism. The two principal components are readily distinguishable in the field. Within these components minor, but nevertheless significant, variations can be recognized, but owing to inadequate exposures it was not possible to map them individually. Around the margins of the basic intrusives reaction between the country-rock and the hot magma has resulted in a motley assemblage of hybrid types.

(i) *Basic and ultrabasic types*

The two hills El Dorro and Kitogato consist of basic intrusives with ultrabasic cores. From the centre outwards the rocks comprising the intrusives consist of the following types:—

Hypersthenic peridotites.

Hypersthene tilaites.

Biotitic hyperites.

Norites.

Hypersthenic periodites (Saxonites).—The small cores of the intrusives are composed of coarse-grained, holo-melanocratic, relatively fresh rocks, the characteristic macroscopic feature of which is the abundance of green spinel. In a thin section of specimen 64/B44 they are seen to have xenomorphic-granular texture and to consist of olivine, hypersthene, enstatite, hornblende, plagioclase, spinel and subordinate diopside, biotite and calcite. The most striking feature is the nature of the plagioclase crystals. Individual crystals are large and have gently curved outlines. Blurred polysynthetic and carlsbad twinning is common and many of the crystals are intimately associated with secondary calcite. Every grain of plagioclase is riddled with innumerable minute sub-orientated rods of spinel.

The hypersthene is markedly pleochroic and the cores of the larger crystals are crowded with orientated microplakite—brownish isotropic crystals of rectangular and platy habit. The somewhat fibrous habit of the colourless enstatite is accentuated by schillerization and delicate, though ill-defined, polysynthetic lamellation is common. Both pyroxenes poikilitically enclose crystals of olivine. The ferriferous olivine is remarkably fresh and is rarely veined with bastite. Trains of magnetite inclusions are, however, not uncommon. Hornblende, pleochroic from brown to green, is secondary and forms reaction rims between the plagioclase and hypersthene crystals. Some of the hornblende is partly uralitized. The green spinel occurs as inclusions in hornblende, hypersthene and plagioclase. In the latter the inclusions are rodlike whereas in the two former the spinel is found as scattered irregular grains often of vermiform and sigmoid habit. The brown biotite is subordinate and invariably associated with hornblende. A colourless fibrous mineral which poikilitically encloses subhedral olivines is tentatively considered to be a pyroxene closely related to the diopside-hedenbergite series.

Hypersthene tilaites.—Microscopically these rocks differ from the hypersthenic peridotites in that they are finer-grained, large grains of green spinel are absent and plagioclase is visible. Thin sections of specimens 64/B36 and 64/B38 reveal that hypersthene is subordinate to enstatite and that the plagioclase (An_{72}) is relatively free from insets of spinel. Olivine-green spinels are present and one of their more common forms is that of a core with minute antennæ-like outgrowths projecting into and intergrown with the surrounding minerals. Vermicular intergrowths of spinel with hornblende, olivine and hypersthene were observed. Biotite present is strongly pleochroic from straw-yellow to reddish-brown and is replacing hornblende. Some brown hornblende appears to be primary and poikilitically encloses crystals of olivine and biotite. Discontinuous reaction rims around the plagioclase grains are common and consist of hornblende or intergrowths of hornblende and spinel or augite and spinel. Plagioclase and olivine are occasionally in direct contact without any reaction borders having formed. Diopside is subordinate and the accessory ore minerals include pyrite and chalcopyrite.

Biotitic hyperites.—Mesotype granular rocks (64/B46) consisting of hypersthene, diopside, calcic plagioclase, secondary green hornblende, and subordinate biotite, have been classed as hyperites. Some of the diopside crystals are fringed with bastite and often contain inclusions of microplakite. Calcite is sparingly present and iron ore and apatite are accessory.

Norites.—These rocks (64/B39) are essentially the same as the hyperites, differing only in that biotite is absent and hypersthene far more abundant than diopside. The plagioclase (An_{60}) has coarse lamellar twinning and contains numerous hair-like microlites orientated in sub-parallel lines which intersect at 105 degrees. Dustlike inclusions are also common. Rutile, apatite and iron ores are accessory. Fine-grained leucocratic aplite-like veins of beerbachite cut across these norites.

The modal compositions of some representative specimens of the basic and ultrabasic intrusives are given below.

	64/B39 *per cent*	64/B48 *per cent*	64/B46 *per cent*	64/B36 *per cent*	64/B44 *per cent*
Plagioclase	64	58	66	12	6
Ortho-pyroxene	24	13	11	61	50
Clino-pyroxene	4	21	8	3	+
Hornblende	7	3	6	8	12
Biotite	—	—	5	+	+
Olivine	—	—	—	12	23
Spinel	—	—	—	3	8
Calcite	—	—	—		+
Accessory minerals	1	5	4	1	1

64/B39. Norite. El Dorro.

64/B48. Hyperite. Kitogato.

64/B46. Biotite hyperite. Kitogato.

64/B36. Hypersthene tilaite. El Dorro.

64/B44. Hypersthene peridotite (saxonite). Kitogato.

(ii) *Intermediate types*

The intermediate rock types of the charnockitic suite are quite distinctive and are readily distinguished in the field from the more common hypersthene-hornblende gneisses. They are confined to Mokinni, Toll hill and the south-eastern slopes of Latema. The three classes recognized are:—

Hypersthene diorites.

Hypersthene-quartz diorites.

Garnetiferous hypersthene-quartz diorites.

The *hypersthene diorites* are moderately fine-grained, melanocratic rocks which weather to small spheroidal masses reminiscent of dolerites. In a thin section of specimen 64/B56 they are found to have allotriomorphic-granular texture and to consist of plagioclase (An_{36}), hornblende, hypersthene and diopside. Biotite and calcite are sometimes present in subordinate amounts. The accessories observed in one or other of the slides prepared include apatite, zircon, sphene, and iron ore.

The *hypersthene-quartz diorites* (specimens 64/B54 and 64/B57) are medium-grained mesotype rocks which are usually granular but locally exhibit a faint banding. Under the microscope the quartz and plagioclase form an irregular mosaic in which the ferromagnesian minerals occur both as scattered ragged flakes and composite clusters. Strain shadows are common in the larger quartz grains and many are biaxial. Olive-green hornblende builds irregular skeletal grains and poorly formed crystals and often replaces pale green diopside. The subhedral hypersthene is distinctly pleochroic and devoid of schillerization. Discrete flakes of biotite are subordinate, and apatite, sphene and iron ore are accessory.

Garnetiferous hypersthene-quartz diorites were found on the south-eastern slopes of Latema. They are medium-grained, moderately gneissose, melanocratic types, with evenly disseminated garnets (Fig. 2 B). In a thin section of specimen 64/B58, from Latema, the gneissic banding is accentuated by lenticular folia of partly recrystallized and intensely strained quartz and plagioclase. The garnets are of extremely irregular outline and are vermicularly intergrown with quartz and felspar. Biotite occurs as ragged aggregates and some flakes are interleaved with the larger and more abundant anhedral diopside. Hornblende, hypersthene, orthoclase and calcite are subordinate.

Typical diorite rocks were estimated to have the following compositions:—

	64/B55	64/B56	64/B54	64/B57	64/B58	64/B28
	per cent	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*
Quartz	—	+	24	22	18	4
Orthoclase	—	—	—	—	+	—
Plagioclase	56	57	54	51	35	51
Hypersthene ..	12	16	9	5	2	17
Diopside	9	8	4	1	11	10
Hornblende ..	19	12	6	16	1	2
Biotite	—	+	—	2	4	2
Garnet	—	—	—	—	21	9
Calcite	+	1	—	—	2	+
Accessory minerals	4	6	3	3	6	5

64/B55, 64/B56. Hypersthene diorites. Northern slopes of Mokinni.

64/B54, 64/B57. Hypersthene-quartz diorite. Toll hill and Mokinni respectively.

64/B58, 64/B28. Garnetiferous hypersthene-quartz diorites. Latema.

(iii) *Hybrid types*

The hybrid rocks are characterized by variable textures, the commonest being maculose resulting in an irregularly mottled appearance. The melanocratic component responsible for the mottling is sometimes elongated into flow structures which, although sporadic in distribution and inconsistent in direction, locally impart a crude banding to the rocks. Two distinct types of hybrids were recognized, viz, spinel-bearing hybrids and garnetiferous hybrids.

Of these two types, the *spinel-bearing hybrids* have the more complex and irregular structures. In a thin section of specimen 64/B43 from Kitogato the texture is heteroblastic and gneissose. Ill-defined banding is present, some parts consisting predominantly of groups of equigranular green hornblende and diopside, surrounded by a mosaic of polygonal twinned plagioclase (An_{60}). Other patches consist of composite clusters comprising hypersthene, hornblende, spinel, diopside and interstitial plagioclase as well as delicate spinel-hornblende and spinel-hypersthene intergrowths of petaloid outline. The larger spinels include both vermiform and sigmoid types and most commonly occur as inclusions in the hornblende crystals where they are often aligned parallel to the gneissic banding. Some plagioclase crystals have small chadacrysts of euhedral diopside and hypersthene. In a thin section of specimen 64/B35 from El Dorro aggregation of the ferromagnesian minerals into irregular clusters has resulted in a glomeroporphyritic texture.

The outermost rim of the ultrabasic rocks of Kitogato consists of irregular nodules and small masses of *garnetiferous hybrids*. They are mesotype, granular rocks of medium grain. The garnets have a sporadic distribution. They build grains up to five millimetres in diameter, many of which have cores of pyrite. Thin sections of specimens 64/B42 and 64/B49 from Kitogato, consist of plagioclase, garnet, hornblende, diopside and subordinate discrete grains of spinel. The pale pink garnets are irregular in outline, intergrown with hornblende, diopside and iron ore, and riddled with chadacrysts of plagioclase. Hypersthene is absent.

(5) Minor Intrusives into the Basement System

(*a*) *Pyroxenite*

In the dry gully one mile north of Vilima Viwilli thin veins of green pyroxenite traverse the granitoid gneisses. Individual veins pinch and swell but rarely exceed one foot in width. Thin sections of specimens 64/B85 and 64/B86 consist essentially of interlocking poorly developed crystals of augite, some of which have prominent diallage partings. Fibrous aggregates of talc and a ferriferous amphibole with pronounced cleavages are subordinate. Secondary quartz is sparingly developed.

(b) Pegmatites

The only pegmatite observed *in situ* during the survey is near the road south of the Tsavo-Nolturesh confluence and is considered to be an intrusive rather than a segregation. It consists predominantly of white felspar intergrown with subordinate quartz. Large striated euhedral crystals of black tourmaline are common. Isolated flakes of muscovite, scattered acicular blue apatites and rare garnets are discernible in freshly fractured specimens. No signs of metalliferous mineralization were observed.

2. The Tertiary Volcanics

Volcanic rocks cover approximately a third of the area. Their contact with the rocks of the Basement System is not exposed nor is it marked by any topographical feature. The volcanics are divided into the Rombo Series, a succession similar to the Samburu series of the Maralal area and the Simbara series of the Nyeri area, and the rocks of the subsidiary cones.

(1) The Rombo Series

The lavas comprising the Rombo series consist of the following types, which are arranged in stratigraphical sequence, the dense basalts being at the base:—

(*e*) Olivine soda-trachytes.

(*d*) Kijabe-type basalts.

(*c*) Vesicular olivine basalts.

(*b*) Melanocratic basalts with olivine and augite phenocrysts.

(*a*) Dense basalts.

A section along the western wall of the Lake Chala crater revealed the following sequence, which embraces the three lower members of the series:—

7. Highly vesicular mildly porphyritic olivine basalt.	group c
6. Vesicular olivine basalts.	
5. Porphyritic and vesicular picrite basalts.	group b
4. Basalts with olivine and augite phenocrysts.	
3. Olivine trachybasalts.	group a
2. Dense basalts.	
1. Fissile sparingly porphyritic olivine basalts.	

(a) Dense basalts

The best exposures of dense basalts are along the Tanganyika boundary west of Ziwani. They are black to greyish-black rocks which are non-porphyritic and devoid of vesicles. Generally they break with a sub-conchoidal fracture and when faintly banded, as they occasionally are, tend to be somewhat fissile. Only two specimens were sliced—64/B66 and 64/B67, both from Lake Chala. They are holo-crystalline, sparingly micro-porphyritic types with sub-ophitic texture. The microphenocrysts of subhedral ferriferous olivine account for only 5 to 10 per cent of the total volume of the rocks and have suffered varying but not intense resorption by the base melt. Most crystals have peripheral mantles of iddingsite and complete pseudomorphs are not rare. The lathy felspars of the groundmass show a fluxional arrangement and are separated by microgranular ore and flecks of yellowish augite. In the thin section of specimen 64/B67 minute scales and flakes of brown basaltic hornblende are irregularly scattered throughout the groundmass but are usually associated with grains of iron ore. Small patches of smudgy chlorite and scaly antigorite are considered to be alterations of hornblende and olivine respectively. Secondary calcite is sparingly present.

Certain dove-grey to dark grey, fine, granular lavas overlying and intercalated within the dense basalts have been classified as *olivine trachybasalts*. The trachybasalts are finely crystalline rocks intermediate between trachytes and basalts, containing microphenocrysts of olivine and augite in a groundmass of labradorite and orthoclase. The trachybasalts from the area north of Taveta vary from dense faintly banded types to mildly vesicular and sparingly porphyritic varieties. Under the microscope these lavas are characterized by sub-trachytic texture and the predominance of plagioclase over the ferromagnesian minerals. The latter consist of yellowish granules of olivine, often as microphenocrysts, which are rarely as intensely altered to iddingsite as in the basalts; colourless augite; flakes of biotite and small crystals of brown hornblende. The fluxionally orientated plagioclase laths enclose hair-like microlites. Orthoclase and iron ore are subordinate and apatite is an accessory.

Between the Lumi and Marue Rivers lava float blocks consist of heavy greenish-black rock (64/B147) with abundant felspar phenocrysts. In a thin section of specimen 64/B147 phenocrysts of labradorite (An_{56}) and microphenocrysts of olivine and iron ore are seen to be embedded in a fine granular groundmass composed of untwinned and indistinctly twinned plagioclase, orthoclase containing numerous microlites, brown hornblende, biotite, augite, olivine, iron ore and green chlorite.

(*b*) *Melanocratic basalts with olivine and augite phenocrysts*

Basalts with olivine and augite phenocrysts are comparatively widespread as float blocks but occur *in situ* only around Taveta and along the Tanganyika border, from west of Ziwani to south of Usere. When weathered they give rise to a reddish soil and are easily recognized in the field. They vary from sparingly porphyritic, mildly vesicular types (64/B125 from one mile east of T.N.W., west of the Ziwani sisal estates) to moderately vesicular, highly porphyritic varieties. These rocks are similar in most respects to the melanocratic basalts of the Nyeri area (Shackleton, 1945, p. 17). The pale grey to dark grey groundmass is either dense and compact or finely granular, and in many flows the phenocrysts amount to 25 per cent of the total volume of the rock. The phenocrysts consist of ferriferous olivine, partly or wholly altered to iddingsite, and euhedral titan-augite which is often zoned and has concentric rows of inclusions. The porphyritic augite is usually lighter in colour than the mauvish titaniferous augites of the groundmass. The groundmass consists of criss-cross felspar laths with a sub-ophitic relationship to minute granules of augite, olivine and ore.

Generally, but not always, an increase in the vesicularity is accompanied by a decrease in the plagioclase content and the rocks grade into *picrite basalts* (specimen 64/B123 from 2 miles east of T.N.W.). These subordinate flows are of finer grain and often carry isotropic material in the groundmass.

Between the Sainte and the Njugini Rivers and between Sambera and the Tanganyika border, some of the melanocratic basalts are studded with olivine and felspar phenocrysts which project prominently from the weathered surface. Augite occurs only as scattered microphenocrysts. The plagioclase phenocrysts and microphenocrysts rarely enclose patches of the groundmass or crystals of olivine and are of both lathy and tabular habit, the latter invariably being the more corroded. Specimen 64/B140 from three miles north of the Sainte-Njugini confluence is a sparingly vesicular *analcite basalt* with scattered phenocrysts of olivine and plagioclase. A thin section of this specimen reveals that colourless and pale yellowish analcite lines some of the sparse vesicles and small amounts were also detected in the cryptocrystalline groundmass.

(*c*) *Vesicular olivine basalts*

Olivine basalts of varying degrees of vesicularity contribute appreciably to the succession, and are not confined solely to the flow overlying the melanocratic porphyritic basalts. Good exposures are found at Kitobo spring and around Warombo. The vesicles vary from microscopic cavities to rounded and ellipsoidal spaces which measure up to 15 mm. along their greatest axes. They often form a high proportion of the total volume of the rock, and are occasionally partly infilled with thin films of calcite or analcite. The rocks are invariably sparingly porphyritic, and under the microscope they are found to have typical basaltic textures. A parallel fluidal texture, with plagioclase laths in flow lines, winding around microphenocrysts, is often developed. The micro-phenocrysts consist of euhdral colourless olivine and glomeroporphyritic groups of subhedral augite, often forming rough ray-like clusters. The plagioclase varies from fluxionally arranged laths to minute microlites. Secondary minerals observed in one or other of the thin sections prepared include chlorite, calcite and iddingsite. In thin sections of specimens 64/B4 and 64/B77, from Warombo and

Kitobo respectively, the texture is intersertal and the smaller criss-cross plagioclase laths are separated by weakly birefringent matter that does not stain when treated with weak acid followed by organic reagents and is considered to be felspar.

(d) Kijabe-type basalts

The type rock is that from Kijabe hill, described and analysed by Shand (1937, pp. 265-267), and which Shackleton (1945, p. 16) considers should include olivine basalts characterized by abundant plagioclase phenocrysts and an alkali residium of either zeolite, analcite or orthoclase. Two characteristic textural features of examples collected in the present area are the sub-parallel alignment of the plagioclase phenocrysts and the numerous equidimensional rounded vesicles which average one millimetre in diameter. There is usually, but not always, a correlation between the amounts of phenocrystic plagioclase and the degree of vesicularity.

They are easily recognized in the field, the only rocks with which they may be confused being the olivine soda-trachytes. The latter, however, are porphyritic dove-grey rocks with irregularly-shaped vesicles and unorientated alkali felspar phenocrysts.

The Kijabe-type basalts (64/B133, 64/B137 and 64/B156) occupy a considerable area north of the Tsavo River where the terrain is studded with innumerable small plugs, which finally choked the vents through which the lavas poured. The plagioclase phenocrysts often amount to more than 25 per cent by volume of the rocks and the groundmass in which they are embedded is either dark grey or greyish green (Fig. 3 A). Individual phenocrysts three centimetres in length are not uncommon. In hand specimens the copper ores, chalcopyrite and iridescent bornite, are sparse but, nevertheless, conspicuous. Under the microscope these basalts are seen to be essentially the same as those described by Shand and Shackleton and consist of twinned labradorite phenocrysts, microphenocrysts of olivine and a holo-crystalline groundmass of plagioclase, augite, olivine, iddingsite and iron ore with subordinate orthoclase and bleached yellowish hornblende. The plagioclase of the matrix is predominantly of lath-like habit but when interstitial it encloses weakly birefringent hair-like microlites. Treatment with acid and dye yielded no evidence of the presence of felsic under-saturated minerals.

Variations of these basalts, but differing only in non-essential details, include amygdaloidal types (64/B134) and others which, in addition to the plagioclase, contain phenocrysts of ferriferous olivine and mauvish titan-augite (64/B145 and 64/B148). In the former the ovoid amygdales are filled with porcellanous and earthy calcite associated with subordinate analcite, and in both types olivine microphenocrysts commonly occur as insets in the phenocrystic plagioclase.

The chemical composition and norm of a Kijabe-type olivine basalt from Kijabe hill, as determined by Shand, is as follows:—

	per cent
SiO_2 ..	46·74
Al_2O_3 ..	18·88
Fe_2O_3 ..	3·11
FeO ..	7·15
MnO ..	0·18
MgO ..	3·16
CaO ..	9·30
Na_2O ..	4·17
K_2O ..	1·67
TiO_2 ..	2·44
P_2O_5 ..	1·29
F ..	0·11
CO_2 ..	0·16
H_2O- ..	1·07
H_2O+ ..	0·63
	100·06
less O=F	0·05
	100·01

Norm	
Or ..	10·01
Ab ..	28·82
An ..	27·52
Ne ..	3·69
Di ..	7·58
Ol ..	8·08
Mag ..	4·41
Il ..	4·56
Ap ..	3·25
$CaCO_3$ ..	0·30

Norm symbol II, 5, 3, 4 (Andose)

Analyst: S. J. Shand.

(e) Olivine soda-trachytes

Olivine soda-trachytes were found on the foothills of Kilimanjaro, in the extreme north-western corner of the area. They are dove grey, moderately vesicular rocks with scattered phenocrysts of felspar and olivine. In the field they are not unlike the Kijabe-type basalts but differ in that the vesicles are lenticular and no parallelism of the larger phenocrysts is discernible. Weathered surfaces are usually covered by a thin chocolate brown veneer.

Specimen 64/B150, from two miles north west of Usere, has hyalopilitic texture. The felspar phenocrysts, many of which have delicate gridiron twinning, are considered to be soda-orthoclase. Embayed outlines are common and some of the microphenocrysts have a peripheral zone of iron ore dust. The olivine crystals are of a pale yellow colour and contain poikilitic inclusions of euhedral apatite. Microphenocrysts of augite and ægerine-augite and rounded lapilli (?) were observed, but are rare. The groundmass consists of colourless glass with minute flecks of brown hornblende and a greenish unidentified mineral, microclites of felspar and granules of iron ore.

Crystallo-vitric tuffs, not dissimilar in appearance to the soda-trachytes, were found in the same locality. In a thin section of specimen 64/B149, the most conspicuous feature is the irregular outline and angularity of the intratelluric felspar crystals, some of which are broken. The peripheries of many of the smaller crystals are highly charged with iron ore dust. The refractive index of these felspars is so near to that of Canada balsam that they are considered to be soda-orthoclase or perhaps analbite. The felspar, olivine and iron ore crystals, which are estimated to amount to 15 per cent by volume of these tuffs, are imbedded in a predominantly glassy matrix that is intensely impregnated with iron ore dust and tuffaceous (?) material. Minute flecks of a faintly pleochroic brownish mineral, considered to be hornblende, are evenly disseminated throughout the groundmass, except for the immediate vicinity of some of the iron ore and olivine crystals, where they have been aggregated into peripheral mantles. Flow structures are pronounced (*see* Fig. 3 B) and are sometimes accentuated by trains of broken crystals.

(f) Felspathoidal lavas

Felspathoidal lavas occur only as widely scattered float blocks and include the following types:—

(i) Mela-nephelinites and vesicular melilite-bearing nephelinites.

(ii) Olivine nephelinites.

(iii) Phonolitic trachytes.

(iv) Phonolites.

(i) *Mela-nephelinites and vesicular melilite-nephelinites.*—Isolated mela-nephelinite boulders were found north of the Motoinya River and between the Tsavo and Rombo Rivers. They are porphyritic pitch-black to greenish-black rocks (64/B191 and 64/B154) with phenocrysts of white porcellanous nepheline and black acicular pyroxene, which in some specimens is titan-augite and in others is ægerine-augite. The nephelines are weathered out of, and the pyroxenes project prominently from, the exposed reddish-brown surfaces. Thin sections show that the euhedral nepheline phenocrysts have normal rectangular and hexagonal cross-sections and are segregated into relatively compact glomero-porphyritic groups. Individual crystals have independent orientation and adjacent crystals are often interbladed. Concentric zones of dust-like inclusions are not uncommon. Many of the nephelines are altered along cleavage planes and cracks to an isotropic zeolitic mineral or to highly birefringent micaceous liebnerite. Delicate well-defined zoning and chadacrysts of small euhedral apatites are a common feature of the mauvish subhedral titan-augites, but are absent from the yellowish-green ægerine-augites. The groundmass consists of mossy ægerine-augite, small crystals of nepheline, subhedral pseudo-anisotropic perovskite, iron ore and a brownish unidentifiable mineral not unlike iddingsite. The sparse vesicles are lined with calcite and analcite.

Float blocks of vesicular melitite-bearing nephelinites are associated with the melanocratic basalts near their contact with the Kijabe-type basalts between the Sainte and Njugini Rivers. The roughly equal-sized cavities are small and rounded and are sometimes partly infilled with calcite. The phenocrysts are dull-black acicular titan-augite and have random orientation. Glistening pitch-like ore (ilmenite ?) is sparingly disseminated throughout the rocks and is conspicuous to the naked eye. The only specimen sliced, 64/B141, has hypocrystalline texture and consists of two generations of nepheline and titan-augite, tabular melilite, colourless and brown analcite with numerous divergent microlites, iron ore and brownish alteration products. Many of the lathy pyroxenes of the groundmass are fringed with ægerine.

(ii) *Olivine Nephelinites.*—Olivine nephelinites were found around Lemrika, on the Tanganyika border west of Taveta, where they are associated with olivine basalts and cinder cones. They are holo-melanocratic rocks of fine-granular texture and with rounded vesicles and calcite amygdales. Scattered pseudomorphous iddingsite gives the rocks a speckled appearance. In a thin section of specimen 64/B76 microphenocrysts of augite and olivine are found to lie in a holo-crystalline matrix. The colourless olivines have mantles of iddingsite and the augites often build stellate clusters. The groundmass consists of granular and interstitial nepheline, colourless and yellow analcite, scales and flakes of a barkivikitic amphibole, augite and ore, some of which is pyrite. The amygdales have an outer rim of an isotropic zeolitic product and cores of calcite.

(iii) *Phonolitic trachytes.*—A spotted leucocratic rock (64/B139) was found between the Sainte and Njoro Rivers. It has tentatively been classified as an alkali trachyte, being composed of the following minerals: turbid, twinned alkali felspar, ægerine, analcite, iron ore and secondary calcite. The spotted aspect results from the aggregation into synneusis structures of the green scales of ægerine.

(iv) *Phonolites.*—Phonolites (64/B51) were found near the swamps south of El Dorro. They are mildly porphyritic types with phenocrysts of anorthoclase in a groundmass of nepheline, lathy orthoclase, green ægerine, dark brown sodic amphibole, and iron ore.

(2) Rocks of the Subsidiary Vents

Isolated subsidiary cones are common in the area bounded by the Tanganyika border and a line from Lake Chala to Lake Jipe. Except for the Lake Chala vent none of their craters are preserved. The cones are conspicuous and easily identified by their grass-grown, bush-free, smoothly curved, and not infrequently, symmetrical slopes. The cones are covered with accumulations of scoriaceous rubble and cindery material, and natural erosion is responsible for the characteristic radial scars seen on the steeper slopes.

(a) *Scoriaceous lavas*

Girigan and Salaita are composed of extremely tough scoriaceous material. Such cellular lavas also contribute appreciably to the composition of the other cones. Two types have been distinguished:—

(i) Homogeneous chocolate-brown cellular lavas in which the vesicles, which amount to more than 50 per cent of the total volume of the rocks, are rounded and vary from five to ten millimetres in diameter.

(ii) Relatively heavy, irregularly banded, minutely vesicular lavas.

Both are of basaltic composition and contain no tuffaceous material, shards or lithic fragments. The small scale banding of the second type is well-defined and results from successive thin layers of brown vesicular lava and black dense lava. This banded aspect is accentuated locally by the infilling of the vesicles with calcite and zeolite in certain bands.

(b) *Basaltic lavas with engulfed volcanic ejectamenta*

Fairly heavy though moderately porous rocks (64/B63 from Lasesia), of various shades of purplish-brown, conspicuously studded with crystals of olivine and augite, are common on and around many of the subsidiary cones. They are considered to have been formed by the incorporation of lapilli and crystals of olivine and augite in partly solidified lava. The volcanic ejectamenta are not always completely fused into the groundmass and are often separated from it by discontinuous shrinkage cracks. The highly ferruginous matrix contains microlitic and lathy plagioclase and glass. Some of the vesicles are lined with radial natrolite.

3. Tertiary Intrusives

Boulders of *olivine analcite-dolerite* were found at the confluence of the Lumi and Marue Rivers. They are medium-grained melanocratic rocks with glistening platy felspars and scattered isolated vesicles partly infilled with a greenish serpentinous product. In thin section, specimen 64/B144 is seen to have typical ophitic texture. Olivines are mantled and veined with iron ore and bastite. Anhedral mauvish titan-augite crystals are sometimes twinned but rarely zoned, and inclusions of olivine are not uncommon. Apatite is abundant and has crystallized as long, sometimes sub-parallel, slender needles as well as squat euhedral crystals. The needles are common in both the plagioclase and pyroxene but terminate abruptly against the olivine and iron ore. Variably chloritized biotite is subordinate and occurs as scattered flakes and scales often associated with iron ore. Interstitial pools of a colourless isotropic mineral are considered to be analcite. Orthoclase with well defined carlsbad twinning accounts for perhaps 10 to 15 per cent of the total volume of the rock. These rocks conform both mineralogically and texturally to descriptions of crinanite.

4. Pleistocene and Recent Deposits

Superficial deposits of Pleistocene to Recent age include calcareous tuffaceous grits, lacustrine deposits at Lake Jipe, alluvium along the Tsavo River, and secondary limestones around Warombo and Salaita and between Salaita and Vilima Viwilli.

(1) Calcareous Tuffaceous Grits

Calcareous tuffaceous grits extend from Chala to Lake Jipe but are best developed between Taveta and the Lasesia hills, where prominent exposures are visible in the numerous dry river-beds. On the western wall of Lake Chala they overlie the vesicular basalts and are some 20 to 30 ft. thick. The junction of the lavas and grits is marked by a loosely consolidated boulder bed consisting of both volcanic material and Basement System rocks. The two hills on the Tanganyika boundary south-west of Lake Chala consist of calcareous grits that have been tilted by faulting. Closely-spaced rectangular jointing is pronounced, the two vertical sets having directions of 205° and 115° magnetic.

On the whole the rocks are poorly sorted and form portion of a partly waterlain, partly wind-blown deposit, in which every gradation exists from grit of equal particle size to pebbly grits and conglomerates. Locally a rude stratification is discernible and the calcium carbonate content, which is extremely variable, is generally more abundant in the finer-grained varieties.

A grit (64/B61(*a*)), from a dry river-bed north of Taveta, is well-cemented and consists of 25 per cent sub-rounded lava fragments, in which the olivine is fresh and unaltered; 45 per cent material derived from Basement System rocks, including quartz, felspar, hornblende, diopside, biotite and garnet; and 30 per cent interstitial calcium carbonate (Fig. 3 C). Specimens 64/B61 and 64/B62 are pebbly grits from immediately inside the Tanganyika border, north-west of Taveta. The volume of pebbly material greatly exceeds that of the cementing medium. The rocks are partly cemented types in which lava fragments predominate and are often up to five millimetres in diameter. Calcium carbonate is wanting and the cementing material consists of a fibrous zeolitic mineral which forms rims around the pebbles. The cement is incomplete and open spaces between the grains are numerous. Minerals derived from Basement System rocks are the same as those in the calcareous grits, with the addition of sphenes and hypersthene.

West of Warombo pebbles form only a small proportion of the total volume of these rocks. The pebbles are rounded, highly decomposed and embedded in a predominantly calcareous matrix, which is discoloured by tuffaceous material and ferruginous alteration products. Some of the larger pebbles are of scoriaceous lavas that have pozzolanic properties.

(2) Fluvio-Lacustrine Deposits around Lake Jipe

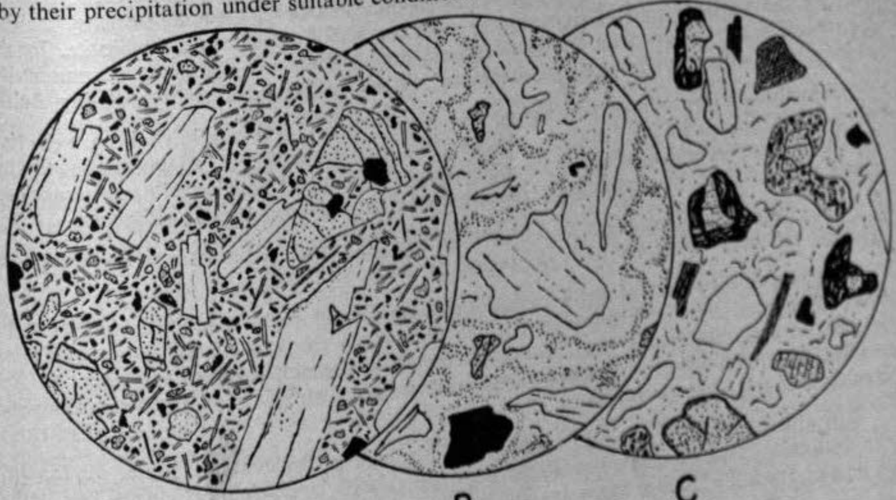
Evidence suggests that Lake Jipe is a recently flooded valley. High-level lake beds, similar to those deposited around lakes in other parts of Kenya, are absent. The superficial deposits surrounding the lake, excluding the sedentary soils, are of fluvio-lacustrine origin and are represented by calcareous and ferruginous clays, greyish earthy limestones, and white gritty limestones. All are admixed with carbonaceous material. They are fairly well-sorted and relatively fine in texture, but features such as cross-bedding and graded bedding were not observed.

(3) Alluvium along the Tsavo River

Faulting with upthrows to the west has effected the grade of the Tsavo River immediately west of the Yu-Uni Falls which lie one mile outside the north-eastern corner of the area. This has caused the formation of a flood plain one mile wide and six miles long on which alluvium has been deposited and black cotton soil has formed.

(4) Secondary Limestones

Secondary limestones are widespread but are most common between Salaita, Warombo and Vilima Viwilli. As revealed in drainage channels at the side of the Voi-Taveta road they rarely exceed two to three feet in thickness and are usually concealed beneath varying, but not great, thicknesses of overburden. They occur in sheets or as concretionary and botryoidal masses, soil-filled cavities being common in the last. Colours vary from white to chocolate-brown and are dependent to a certain degree on the composition of the underlying formations from which the limestones have been derived. Undigested fragments of Basement System rocks are common. The surface limestones were formed by the transportation of capillary attraction, through the porous soil and sub-soil, of calcium salts in solution, followed by their precipitation under suitable conditions.



A B C

Fig. 3.—Microscope drawings of thin sections of rocks from the Taveta area.

A—Kijabe-type basalt. Specimen 64/B137, from one mile south of source of Sainte River. Ordinary light × 14. Sub-parallel plagioclase phenocrysts are embedded in a groundmass of lathy plagioclase, olivine and iron ore.

B—Tuff (crystallo-vitric). Specimen 64/B149, from three miles north of Useri. Ordinary light × 14. Sub-angular intratelluric felspar and olivine crystals lie in a cryptocrystalline groundmass consisting predominantly of glassy material, flecks of hornblende and granules of iron ore. Flow structures are pronounced.

C—Calcareous tuffaceous grit. Specimen 64/B61a, from three miles north-west of Taveta. Ordinary light × 14. The grains are cemented with calcium carbonate and consist of fragments of volcanic rocks and minerals derived from Basement System rocks.

V—GRANITIZATION AND METAMORPHISM

Some of the Basement System rocks of the area have been granitized to variable degrees depending on several factors, the most significant of which were the composition, structure, texture and grain size of the rocks involved.

The quartzites, limestones, and basic and ultra-basic intrusives formed resisters that have remained more or less unchanged in a terrain of moderately granitized rocks. Their resistance to granitization is considered to be a function of their degree of compaction rather than their insusceptibility to replacement. They were not large enough, however, to have materially influenced the advance of the migmatitic front or to have protected other masses of rocks from the effects of granitizing fluids; nor have diverse metamorphic mineral assemblages, other than those due to the original composition of the sediments, developed on opposite sides of them. A possible minor exception to the last rule occurs on Reata where garnetiferous felspar-porphyroblast granulites are confined, for the most part, to the eastern side of the limestones. This may be interpreted as due to the local damming of the granitizing fluids. An objection to this suggestion lies in the fact that the porphyroblasts are perthite and not, as is far more common in granitized rocks, of microcline or microcline-perthite. In addition, modal analyses suggest that the original sediments from which these rocks were derived may have been of predominantly psammitic composition and of possibly low porosity, and the porphyroblasts may be a result not of introduced material, but of the recrystallization of the original felspars. The large microclines and microcline-perthites of the other felspar-porphyroblast rocks developed predominantly in the foliation planes but also occasionally transverse to them. They are considered to represent the earlier phases of granitization and to be synkinematic.

In the rocks of originally pelitic and semi-pelitic composition granitization manifests itself by the presence of replacive microcline, microcline-perthite and myrmekite, and by the variable and often complete replacement of hornblende by biotite. In the Longalonga kyanite-graphite belt the conversion of biotite and sillimanite to muscovite, evidence of which is common, is interpreted as due to the influx of granitizing fluids.

North-west of Warombo, along the Lumi River, granitization along selective planes has given rise to banded gneisses (*lit-par-lit* replacement gneisses). South-east of the Tsavo-Njugini confluence float blocks were found of a relatively coarse-grained granite, a product presumably of rheomorphism of metasomatized sediments.

The mineral assemblages in the relatively ungranitized sediments of the Basement System reflect a moderate to high degree of metamorphism.

In the eastern half of the area sediments, originally high in alumina and potash, have developed mineral assemblages which fall within the kyanite-staurolite sub-facies of the amphibolite facies. The production of such assemblages depends more on the original composition of the sediments rather than on definite temperatures and closely defined stress conditions.

In the noritic and dioritic members of the charnockitic series south of Taveta, the following assemblages representative of the gabbro facies (equivalent to the metamorphic granulite facies) were recognized:—

1. Plagioclase-hypersthene-garnet.
2. Plagioclase-hypersthene-diopside.

According to Turner (1948, p. 102) the metamorphic conditions that lead to the development of the granulite facies are still imperfectly understood, but they are considered to develop essentially under "dry" metamorphic conditions.

Hornblende is commonly present in the Taveta rocks, sometimes secondary after pyroxene, and in other cases apparently in equilibrium with the associated minerals. Those types in which garnet is associated with hypersthene, diopside, plagioclase and hornblende are considered to be in a state of chemical disequilibrium. The hornblende reaction rims around the pyroxene crystals in the ultra-basic types, assuming that they are metamorphic and not magmatic reaction rims, indicate incomplete adjustment of the granulite facies assemblage to conditions more typical of the amphibolite or pyroxene-hornfels facies (Turner, 1948, p. 103).

In the Murka-Loosoito belt enrichment in alumina, involving metamorphic differentiation by the concretion and/or solution principle, is considered in part at least to be responsible for the formation of the lenses and segregations of kyanite.

VI—STRUCTURES

The dominant aspect of the structure of the Basement System rocks is their north-south trend with moderately steep easterly dips.

North of Longalonga the strata have been disrupted by faulting and anomalous northerly dips were mapped. Exposures are too limited to postulate the nature of the faulting involved. Parkinson (1947, p. 4) noted the marked diversity of the strikes in the neighbourhood of the Tsavo-Mzima confluence (three miles outside the north-east corner of the present area) and provisionally suggested overfolding and thrusting of the strata from the north-west.

On the summit of Reata minor faulting coupled with intense shearing has produced garnetiferous leucocratic mylonites (specimen 64/B14) and minor displacements in the graphite and limestone bands. The shear-zone was traced for a few hundred yards and it was found to decrease rapidly southwards.

A common belief that the kyanite of the Murka-Loosoito belt owes its position to thrusting and overfolding is partly substantiated by field evidence. In two localities, viz. Murka and Kevas, evidence of movement along the kyanite horizon were noted. They appear however to be local disturbances that could hardly have played a major role in the genesis of the kyanite.

Comparatively closely spaced jointing is confined to the quartz schists and quartz-kyanite schists and is developed approximately parallel to the dip and strike of the strata. Lineation was observed only in the extreme north-eastern corner of the area, pitching at 20° to 25° in a direction a few degrees east of north.

VII—ECONOMIC GEOLOGY

Economic interest was first aroused in the area as early as 1921, when L. Gilbert applied for a sole prospecting licence covering an area of 25 square miles in the immediate vicinity of Taveta (*see* Fig. 1) for the purpose of prospecting for diamonds. Rumours of diamonds in the Taveta district are still rife although no records exist of diamonds ever having been found. Stories of the existence of diamonds in the area no doubt arose through the incorrect identification of the locally biotitic hypersthene peridotites of El Dorro and Kitogato as kimberlite. Kimberlite, however, is a brecciated, porphyritic mica peridotite characterized by cognate xenoliths of certain deep-seated ultra-basic rocks, and does not resemble the Taveta peridotites.

1. Non-metallic Minerals

(1) Clays

The clays of the area were reported on by Dr. B. N. Temperley for the Industrial Research Board in October, 1942, and the following account is based on his investigation. Of the deposits visited only two were considered worthy of more detailed examination.

(a) Ziwani clay

This deposit occurs in the now drained and dried up Ziwani swamp, which lies ten miles north of Ziwani siding and is accessible by means of a good road. It is a blue-grey alluvial clay derived almost wholly from the disintegration of volcanic rocks. The distribution of the clay has not been properly investigated but it appears to be a fairly homogeneous deposit that is several feet thick and more than a square mile in extent.

Tests conducted on this clay by the late Sir Charles Markham in connexion with pottery manufacture indicate that, when washed, almost all of it passes through a 40-mesh screen. It settles quickly and is easily dried to the required consistency. It is, however, rather heavy on the wheel but is improved by the addition of sand or ground felspar, both of which are available locally. The chief trouble in the use of the clay arises from the difficulty of drying the green ware slowly enough. A few pots shut together in a small cupboard dry satisfactorily but when spread out on open shelves insufficient humidity causes them to crack even when the air is kept damp by saturated blankets.

(b) Jipe clay

Of the clays deposited around Lake Jipe, experiments have been conducted on those near the middle of the eastern shore. This point is accessible by a good level road but lies 12 miles from the railway line and 15 miles from the siding at Taveta. There is a large quantity of clay available but, being derived from both volcanic and metamorphic rocks, it is likely to vary considerably from point to point. Tests indicate that it is calcareous, highly colloidal and contains a good deal of organic material. It needs washing in order to remove grit, calcareous concretions, shells, etc. When stirred in water, it requires the addition of a settling agent to accelerate precipitation. No method has been found at Taveta to reduce the clay in mass to a state of dryness satisfactory for the manufacture of pottery.

The proper investigation of clays involves detailed prospecting to determine both vertical and horizontal variations in the deposits. Hand-augering and/or pitting on a relatively closely-spaced grid are recommended for superficial deposits, such as occur in the Taveta area. Too much stress cannot be laid on the fact that all samples collected should be absolutely representative. Clays should be tested for such properties as plasticity, texture, colour, strength, shrinkage, porosity, fusibility, firing changes and specific gravity. By far the most satisfactory method of testing clays is by judging the quality of the manufactured product.

(2) Garnets

Garnets are a common constituent of the Basement System rocks in the area, and are particularly abundant south of Taveta. Nowhere were they observed in sufficiently high concentrations to warrant further investigation.

(3) Graphite

Occurrences of graphite were observed in the following localities:—

(*a*) Along the Lumi River, north-west of Warombo.

(*b*) Associated with the limestone band east of Vilima Viwilli.

(*c*) In the Longalonga hills.

(*d*) Reata.

Although some flake graphite that would closely approximate the specifications of crucible manufacturers could be recovered from the first two localities, the tonnages available are small, and the deposits are of an irregular and erratic nature and the overall grade is low.

In the Longalonga hills and on Reata the graphite is fine-grained and it could perhaps be economically recovered only as a by-product to kyanite or sillimanite mining. The marketability of fine-grained graphite is limited and depends more on its purity than flake size.

(4) Kyanite

The kyanite occurrences of the Murka-Loosoito belt were first recorded by Parkinson in 1940, and in October, 1942, claims were pegged on Murka by Sir Charles Markham. The claims were transferred to a newly-floated company, Kenya Kyanite Ltd., in November, 1946.

Claims on Kevas and Loosoito were registered by Mrs. Lloyd-Greame in June, 1948, and were transferred to a new company, East Africa Minerals Ltd., in November, 1949, and subsequently to Kenya Kyanite Ltd. in March, 1953.

In September, 1950, Kenya Kyanite Ltd. pegged 50 claims in the Longalonga area in order to prospect for eluvial kyanite. In April, 1951, these claims were incorporated into an area of 21 square miles over which the Company was granted an exclusive prospecting licence, which was renewed until April, 1953, but abandoned in December, 1952. The south-western corner of the exclusive prospecting area fell in the present area (*see* Fig. 1).

Kyanite production in Kenya began in 1943. The production since then, according to records in the Mines and Geological Department, is given in the table below. Two companies have been concerned, Kenya Kyanite Ltd. and East Africa Minerals Ltd., and, in 1948, Mrs. Lloyd-Greame. Production has come entirely from the Murka-Loosoito belt. The production of calcined kyanite (mullite) was begun by Kenya Kyanite Ltd. in 1950 and since then almost the entire output has been mullite.

Production of Kyanite and Mullite in Kenya

Year	Tonnage (long tons)	
	Kyanite	Mullite
1943	287	—
1944	612	—
1945	444	—
1946	2,631	—
1947	14,447	31
1948	14,600	—
1949	23,263	—
1950	8,834 (estd.)	2,311
1951	2,639	8,000
1952	961	7,475

(a) The Murka-Loosoito Kyanite belt

Kyanite is being mined at Murka and was until recently worked at Kevas. These deposits, as well as many of the other known deposits in Kenya, are described in a comprehensive memoir by Temperley (1953), and any detailed redescription would be superfluous.

At Murka, Kenya Kyanite Ltd. have developed a flotation process for recovering kyanite from quartz-kyanite schist consisting of 30 to 70 per cent kyanite, the rest being largely quartz. At Kevas, East Africa Minerals Ltd. experimented with jigs in an attempt to recover kyanite from second-grade kyanite rock (called K_2 at the mines, meaning kyanite rock with quartz attached).

Unfortunately the costs of mining, milling, flotation and calcining as well as the detailed flow sheet of the mine at Murka are not available for publication*. Details are, however, included in Temperley's memoir (op. cit., p. 9) of plants employed for recovering kyanite from various ores in other parts of the world. Of these, the installation at Baker Mountain, Virginia, was designed to treat −48 mesh, ground and deslimed, quartz-kyanite schist in a 10-cell, No. 2 Minerals Separation, 12-in. subæration counter-flow machine. This process, with perhaps minor modifications, such as dry tabling or electrostatic separation for removing rutile and iron ores, might possibly be successfully employed for some of the deposits in Kenya. Details of the flow sheet are available in the files (M/2018/III/146) of the Mines and Geological Department, Nairobi.

The specifications of chemical composition insisted on by most purchasers of kyanite are as follows:—

Constituent	% by weight on dry basis
Al_2O_3	minimum 59·00
SiO_2	maximum 39·00
Fe_2O_3	maximum 0·75
$CaO+MgO+K_2O+Na_2O$	maximum 1·00

Besides these chemical limitations, rigid specifications govern the size of lump kyanite and kyanite fines.

The successful economic exploitation of disseminated kyanite deposits, in which the kyanite content is extremely erratic, could be enhanced by a strict control of mill feed. Systematic sampling coupled with a drilling programme may enable a broad zoning of the ore-bodies to be made. By selective mining a predetermined mill feed could be maintained, thus increasing mill efficiency and stabilizing production costs and profits. The levelling of profits may be important in income tax assessments.

(b) The Longalonga belt

The only serious investigation of the kyanite deposits of the Longalonga belt has been made by Kenya Kyanite Ltd. who held an exclusive prospecting licence over an area of 21 square miles, with the hill Longalonga near its south-western corner, between April, 1951, and December, 1952.

Colluvial kyanite occurs in the soil and sub-soil particularly at the foot of the dip-slopes of the hills. Kenya Kyanite Ltd. sank a number of pits at the base of the hills in order to investigate the possibility of recovering it. Results were, however, disappointing, discouraging factors being the erratic and low percentage of kyanite and the abundance of associated limonitic and manganiferous concretions which give rise to ore-dressing problems. Full agreement is given to Temperley's (1953, p. 49) observation that as the sources of massive kyanite become exhausted, so the possibility of recovering kyanite from these graphitic schists or their residual products will have to be investigated in greater detail. Although the graphite of the schists is fine-grained, thus effecting its marketability, its recovery as a by-product might yield sufficient returns to compensate for the low kyanite content of the deposits.

(c) The kyanite-garnet rocks south of Longalonga

The most important discovery made in the area during the survey was of a deposit of garnet-kyanite rocks three miles south-south-west of Longalonga, conformable to the surrounding Basement System strata. The bulk of the deposit is concealed by thin superficial secondary limestone but small masses *in situ* were observed about a quarter of a mile south of the main occurrence.

* In September, 1954, the mill flow sheet of the mine at Murka was made available for publication and has been included as an appendix (*see* p. 47).

Microscopic investigation of the ore reveals that sillimanite is far more abundant than field inspection indicated and that the garnets are crowded with inclusions of quartz, iron ore and rutile. Heavy medium separation of a representative sample of the crushed rock gave the following results:—

Mineral	*Per cent by Weight*
Garnet	55.5
Kyanite and sillimanite	20.5
Quartz, mica and accessory minerals	24.0

Kyanite is used in the manufacture of special refractories and garnet, which is marketed largely as an abrasive, is in increasing demand as a substitute for quartz sand in sand-blasting, in an endeavour to reduce the incidence of silicosis. Both these minerals can be concentrated from their ores by means of flotation. In the U.S.A. experiments have been conducted on an ore containing 13 per cent kyanite, 8 per cent garnet, 30 per cent mica and 45 per cent quartz and felspars, with minor amounts of sulphides and carbonaceous material. It was desired to recover the kyanite and garnet as a high-grade concentrate that could then be treated electro-magnetically in order to separate these minerals into products of marketable grade (Mines and Geological Department file, M/2018/III/145). The ore proved amenable, after grinding and desliming, to flotation in the presence of fatty acid and a small quantity of sulphuric acid. Double cleaning of the rougher concentrates was necessary in order to obtain the desired high-grade product.

The value of the Longalonga kyanite-garnet deposit for commercial exploitation is affected by the following:—

(*a*) Although a certain number of the inclusions in the garnets would be released by grinding and removed by flotation, many combined particles would, neverthless, find their way to the concentrates. The demand for and price of such garnet concentrates can only be ascertained by submitting samples to the buyers.

(*b*) Besides the accessory primary iron ores, the garnet crystals are usually fringed with films of limonite. Unless flotation can reduce the Fe_2O_3 content to less than 0.75 per cent the saleability of the kyanite will be adversely affected.

At the current prices (garnet £40/ton c.i.f. and kyanite £15/ton c.i.f.) one ton of the kyanite-garnet ore, assuming an 80 per cent mill efficiency, is worth approximately £19. This figure is sufficient to cover all mining, beneficiation, transport and handling costs, etc. and still leave a handsome margin of profit. Until the deposit is opened up along its strike by trenching and the persistence of the ore in depth is tested by shafts no reliable estimation of the available ore reserves can be given. It should, however, be stressed that the prime factor governing the value of the deposit is the marketability of the garnet.

(5) Limestone, Cementstone and Pozzolana

The *kunkar* limestones, primary limestones, pozzolana and cementstones of the area around Taveta were investigated by Temperley in November, 1942, and by Parsons in 1943, and their findings are embodied in unpublished reports.

Although enormous tonnages of secondary limestone are available, particularly between Warombo, Salaita and Vilima Viwilli, north and south-west of Lake Jipe and at the eastern foot of Mokinni, the grade is erratic and on the whole prospecting results have been discouraging. The following analyses have been made on the limestones of the area:—

	(i)	(ii)	(iii)	(iv)	(v)
	per cent	*per cent*	*per cent*	*per cent*	*per cent*
SiO_2	10·15	17·22	16·91	n.d.	n.d.
Fe_2O_3 and Al_2O_3	2·80	4·70	14·32	n.d.	n.d.
MgO	0·10	0·17	8·38	trace	trace
CaO	46·50	78·11	28·11	n.d.	n.d.
Loss on ignition	n.d.	n.d.	0·42	n.d.	n.d.
Moisture	n.d.	n.d.	3·26	n.d.	n.d.
CO_2	38·60	n.d.	28·16	n.d.	n.d.

n.d.=not determined.

(i) Salaita kunkar. Picked sample, collected by Col. Grogan, and analysed in the Industrial Research Laboratories.

(ii) Calculation of (i) free from CO_2, by Dr. B. N. Temperley.

(iii) Taveta cementstone. Analysed at the Industrial Research Laboratories.

(iv) Lake Jipe, secondary earthy limestone. Analyst, J. Furst.

(v) Reata, crystalline limestones. Analyst, J. Furst.

An examination of a supposed cementstone, six miles south of Taveta, was recently made by L. D. Sanders. He reported that it lies in an old lake bed and consists of a bed, 12 in. to 18 in. in thickness, of porous magnesian limestone. Analyses indicated a content of up to 25 per cent of $MgCO_3$.

The possibility of utilizing the calcareous tuffaceous grits as cementstones is handicapped by their variable composition, as well as by the fact that the calcium carbonate is coarsely interstitial. An intimate contact between the silicates and carbonates of cementstones is highly desirous, if not essential, and in the case of the grits grinding, and therefore bricketting, prior to calcining, would be necessary.

Tests have been conducted by Col. Grogan on various volcanic ashes and vesicular lavas from the area to determine whether they have pozzolanic* properties when mixed with lime produced by calcining kunkar from Salaita. The experiments were hindered by lack of lime-burning and grinding facilities. The best material, however, was found to be the scoriaceous lava of Girigan. Good, but less easily crushed material, occurs at the foot of Salaita. Large quantities of both are available.

Prospecting and sampling procedure, recommended on p. 38 for investigating occurrences of clay, applies equally to limestone deposits.

(6) Miscellaneous Minerals and Rocks

Some of the kyanite-graphite schists of the Longalonga area contain subordinate amounts of *apatite*. The occurrences observed are of no more than scientific interest, but detailed prospecting of the Longalonga hills, the bulk of which lie outside the area, may reveal larger and richer deposits.

Immediately across the interterritorial border north-west of Taveta, pebbly tuffaceous grits are being quarried for *building-stone*. The deposits extend into Kenya but apparently the quality of the material decreases eastwards because, although they are nearer to the railway siding at Taveta, only small abandoned workings were observed. The stone is easily dressed but lacks strength.

Local concentrations of *iron-pyrites* were observed on the Kitogato hills. For a mineral of such low value the occurrences are too small to warrant further investigation.

*Pozzolana is volcanic material used in the manufacture of hydraulic cement.

In August, 1942, *mica* was discovered in a pegmatitic body on the Voi-Taveta road, 14 miles east of Taveta. The discovery was not considered to be of economic significance. Hydration and alteration of biotite has resulted in the formation of *vermiculite* in a number of widely scattered localities. The vermiculite is usually of the golden brown variety and exfoliates readily, but is often admixed with unaltered biotite. All the deposits observed are small, erratic and of low-grade.

2. Water

One of the most valuable sources of water in Kenya lies in the Taveta area. Large volumes of water of exceptional purity are derived through diverse means from a common source—the rainfall and melting snows of Kilimanjaro, from which the bulk of the water flows beneath the surface, issuing as springs at comparatively widely scattered localities.

History

A comprehensive report on the water-supplies of the Taveta area in connexion with irrigation was made in 1931 by A. E. Tetley, then Hydraulic Engineer of the Public Works Department. A further report was submitted to Government by Messrs. Harris and Sampson in 1934. The irrigation project was later taken up by the Agricultural Production and Settlement Board, but on the formation of the Taveta Committee, the control of works was transferred to that body in March, 1943. Major H. Hughes made a preliminary survey of the area and submitted a report, in November, 1942, in which he strongly recommended further investigation. In April, 1943, reports on the Taveta Irrigation Scheme from the point of view of soil data, suitability of crops and recommendations were produced by members of the Scott Laboratories. The Taveta and Ziwani Irrigation Projects were again reported on by P. V. Chance, Irrigation Adviser, in August, 1943. He considered the schemes to be straightforward and small, devoid of any great technical difficulties and with secure supplies. The most recent investigations were made by J. Scott in 1943, and included the potentialities of Lakes Jipe and Chala.

The following information is a digest of facts extracted from some of the above reports.

Rivers

Hydrological details concerning the Lumi and Ruvu Rivers have already been discussed in the section dealing with drainage (*see* pp. 4-5).

Springs

There are three groups of springs in the Taveta area, the most important of which are the Lumi Springs, comprising the Lenonya on the eastern bank of the river, and the Njoro Kubwa, Maji ya Waleni and "Homers" on the western bank. These springs increase the flow of the river from 5 to 300 cusecs in four miles. The largest of the springs is the Njoro Kubwa, and the aggregate discharge of the group is 290 cusecs. The second group of springs forms the headwaters of the Njugini, Sainte and Njoro Rivers. The two latter streams unite to form the Tsavo River and in August, 1945, their aggregate flow was 23 cusecs. These springs are often called the Ziwani Springs since the Ziwani Irrigation Scheme utilizes most of their water. The third group of springs is known as the Kitovo Springs. They lie west of the Latema-Reata ridge and issue from the lavas and outwash gravels at the base of Kilimanjaro. Their total discharge is 42 cusecs. The following table gives essential data on these springs.

	Latitude S.	Longitude E.	Height above sea-level	Distance in feet along contour over which the springs are spread	Aggregate discharge in cusecs
Lumi.. ..	3° 25′	37° 41′	2,400	9,000	290
Ziwani ..	3° 12′	37° 44′	3,200	6,000	23
Kitovo ..	3° 27′	37° 36′	2,350	6,000	42

There is a possibility that other springs discharge underwater into the north-east corner of Lake Jipe, the evidence being a patch of extremely clear water occupying about one and a half square miles in that vicinity. This water is clearer than that flowing in from the Lumi.

Lakes

Detailed descriptions of Lake Jipe and Lake Chala, particularly the hydrological aspects, are to be found on pp. 5-6.

The proposed scheme to lead the waters of Lake Chala to Mombasa by gravity has been abandoned in favour of the Mzima Springs project, now in the process of construction. Apparently one of the major difficulties, besides the necessity of either erecting large pumping facilities or excavating adits, is inability to assess accurately the recharge of the lake.

The best economic use that could be made of Lake Jipe would be to build a barrage across its outlet, provided an adequate site is available (which is doubtful) and to use the stored waters to feed the power-station at Pangani Falls in the dry season. Kenya would benefit as Mombasa derives some power from that station. The utilization of the waters of Lake Jipe for irrigation purposes in Kenya could only be effected by pumping. Even if the expense of pumping could be justified there are other considerations that must be given full weight. A widespread, though erroneous, conception is that irrigation merely involves bringing water to the land and it will flourish. The effect of the soluble salts on the soil, an important factor especially in poorly drained areas, is hardly ever taken into consideration.

Bore-holes

The records of the Public Works Department, Nairobi, show that up to November, 1952, 11 bore-holes had been sunk in the Taveta area. Of these only one was drilled through the Basement System, and although it was continued to a depth of 720 ft., the yield was negligible.

The following table summarizes the information on water bore-holes in the area:—

Bore-hole No.	Locality	Depth of B.H. in feet	Depth at which water was reached in feet	Rest-level of water in feet	Estimated yield gal./24 hr.
C 76	1 mile E. of Latema ..	100	50	43	50,000
C 77	½ mile E. of Latema ..	50			nil
140	2¼ miles E. of Latema ..	110·4	98	48	72,000
147	1 mile N.E. of Latema ..	110	98	48	72,000
151	1¼ miles S.E. of Latema ..	190	?	?	?
154	1¼ miles S.E. of Latema ..	170	160	100	40,000
C 524	1 mile S.W. of Girigan ..	175	44, 143	43	52,800
C 535	Taveta	120	98	97	100,000
C 561	1½ miles S. of Reata ..	219	118	97	72,000
C 568	1 mile W. of Reata ..	170	115, 124, 150	114	100,000
C 701	Murka	720	475	405	2,200

3. The Possibilities of the Area

The reserves of economically exploitable quartz-kyanite schists in the Murka-Loosoito belt appear to be enormous, but tonnages and grade can only be accurately computed after systematic drilling, sampling and assaying.

Until further detailed and systematic investigation is conducted on the limestone and clay deposits, they cannot be wholly excluded from the possibility of commercial exploitation. Of the limestone deposits examined those with the lowest MgO content (they only carry traces) occur on Reata and near Mata, north of Lake Jipe. The latter has the larger reserves and presents fewer mining difficulties, but is some 10 miles from the nearest railway siding.

The water resources of the area are perhaps its most valuable unexploited asset, but benefits can accrue only when reports are superseded by practical work.

Except for the garnet-kyanite deposits the geological reconnaissance of the area has not revealed any new minerals of economic importance. Geological conditions favourable for more intensive prospecting are confined to the north-eastern sector of the area. Although systematic prospecting is not recommended over the rest of the area, chiefly because of the lack of exposures and the abundance of young lava flows, the accidental discovery of deposits is not impossible, but it is unlikely that they will be related to any physiographic feature.

VIII—BORE-HOLE LOGS

The following information was obtained from the Public Works Department and is an unmodified copy of the driller's logs of the bore-holes in the Taveta area.

Depth *feet*	Thickness *feet*	Lithology
		C76. TAVETA SISAL ESTATES
43	43	Soil.
63	20	Lava boulders.
77	14	Blue lava and lava pebbles.
85	8	Clay.
89	4	Blue lava.
100	11	Clay.
		C77. TAVETA SISAL ESTATES
26	26	Soil.
38	12	Blue lava.
50	12	Lava gravel.
		140. TAVETA SISAL ESTATES*
3	3	Red soil.
13	10	Volcanic ash.
34	21	Volcanic boulders.
97	63	Volcanic rock.
106	9	Cavity (loose sands ?).
110	4	Clay.
		151. TAVETA SISAL ESTATES†
54	54	Soil.
64	10	Volcanic boulders.
136	72	Volcanic rock (lava).
170	34	Volcanic ash.
		C524. GIRIGAN
2	2	Purplish clayey and sandy soil.
27	25	Buff-coloured sandy gravel composed of volcanic minerals and rock fragments.
53	26	do.
101	48	Deep brown vesicular basalt or basaltic tuff.
143	42	Deep red, slightly sandy, soil—gneissic soil baked by lava.
155	12	Light cream-coloured gneissic detritus.
175	20	Grey mottled quartz-biotite schist.

* Bore-hole No. 147, situated approximately one mile west of bore-hole No. 140, passed through a similar succession.

† Bore-hole No. 154 is situated approximately 10 ft. from No. 151 and passed through a similar succession.

Depth *feet*	Thickness *feet*	Lithology
		C535. TAVETA STATION
2	2	Deep red, coffee-coloured, clayey soil.
9	7	Chocolate-coloured clayey soil.
14	5	Light grey, ill-sorted, volcanic ash and rock fragments.
23	9	Light brown old land surface material—heterogeneous pebbles and clay.
35	12	do. but lighter in colour.
43	8	Light brown phonolite with obsidian fragments.
46	3	Dark grey phonolite or basalt.
64	18	Light grey lava with much volcanic glass. Phonolitic obsidian.
98	34	Dark grey basalt.
101	3	Red weathered vesicular basalt.
117	16	Black vesicular basalt.
120	3	Black basaltic ash.
		C561. TAVETA SISAL ESTATES
45	45	Sample lost.
80	35	Black basalt.
97	17	Red clayey sand—old land surface.
118	21	Light chocolate-coloured sandy clay.
137	19	Brown mottled, grey, weathered basalt.
166	29	Grey coarse basaltic pebbles.
180	14	do. but finer and with some red clay.
184	4	Red clay of gneissic origin. Old land surface.
187	3	Red mottled yellow sandy Basement System detritus with garnets and hornblende.
193	6	do. but coarser and more clayey.
206	13	do. but coarser and with basaltic pebbles.
215	9	Brown mottled yellow heterogeneous sand of metamorphic and volcanic origin.
219	4	Drab mottled yellow metamorphic detritus, with quartz, hornblende, and epidote.
		C568. TAVETA SISAL ESTATES
14	14	Chocolate brown clayey soil.
23	9	do. but lighter and with more felspar fragments.
32	9	do. but with fragments of weathered lava.
37	5	Black mottled vesicular basalt. Much quartz, derived from vesicles ?
72	35	Brownish brick-coloured sandy clay—old land surface ?
75	3	Light grey coarse fragments of vesicular basalt. Most vesicles infilled.
80	5	do.
115	35	Black fresh basalt.
127	12	do. but less vesicular.
150	23	Light grey vesicular basalt.
170	20	do. but slightly less vesicular.
		C701. MURKA*
720	720	Granitoid gneiss.

* No granitoid gneiss was observed in the area and it is more likely that bore-hole No. C701 passed through biotite gneisses and/or banded gneisses.

IX—APPENDICES

Through the courtesy of Kenya Kyanite, Ltd., the mill flow sheet at the kyanite mine at Murka was made available for publication in September, 1954. Minor modifications, expected to be introduced in the plant in the near future, have been included in the flow sheet shown in Fig. 6 (at end).

1. Summary of Flow Sheet

(1) *First-grade Kyanite (K1)*
Hand-sorted, followed by three-stage crushing to −5 mesh; calcination and bagging.

(2) *Kyanite Schist*
Three-stage crushing to −5 mesh; one stage closed-circuit grinding to −44 mesh; desliming, conditioning with oleic acid and sodium silicate, and froth flotation in a 7-cell (double) Spitzkasten machine; wet tabling (James tables) to remove rutile, followed by dewatering, drying and grinding to 200 mesh prior to pelletization in a pan pelletizer using molasses as a binder. Finally calcination and preparation for the market by crushing, screening (5 mesh, 10 mesh, 16 mesh and 30 mesh) and bagging.

The kyanite concentrates produced by froth flotation from the schists have a higher alumina content than the massive kyanite (K_1) now being won from the hill (60 per cent Al_2O_3 compared to 58 per cent). The flotation cells are rated at an output of four tons per hour, and the mill recovery lies between 50 per cent and 60 per cent.

Products

CKU — Ungraded, all −5 mesh, calcined kyanite ore.
CKUF — Ungraded, all −5 mesh, mixture of calcined kyanite ore, plus CP.
CP — Calcined flotation concentrates from RF.
CPW — Calcined pellets, whole.
RF — Raw kyanite flotation concentrates (all −44 mesh).

2. Pelletization and Calcination

The manufacture of suitable refractory bricks necessitates the use of both fine particle size calcined flotation concentrates as well as coarser mullite as grog.

The mullite is produced by pelletizing the raw flotation concentrates using molasses as a bond, and by rotation within a water-molasses liquor in a pan pelletizer. Experiments have proved that the most efficient pelletization is effected when the concentrates are reduced to −200 mesh. These pellets are then fired in a rotary kiln which can be regulated by adjusting either the speed of rotation or the angle of repose, to produce a hard-fired pellet or a softer, more porous grog. Some manufacturers prefer the latter.

The conversion of kyanite to mullite involves considerable expansion and begins slowly at between 1,100°–1,200° C., but is almost instantaneous at a temperature of approximately 1,550° C. The kyanite from Murka, being in a well-crystallized state, tends to decrepitate during this conversion, producing fines which, in stationary kilns, choke the air passages to the charge. This difficulty can be overcome by the use of rotary kilns which are at present in use at Murka.

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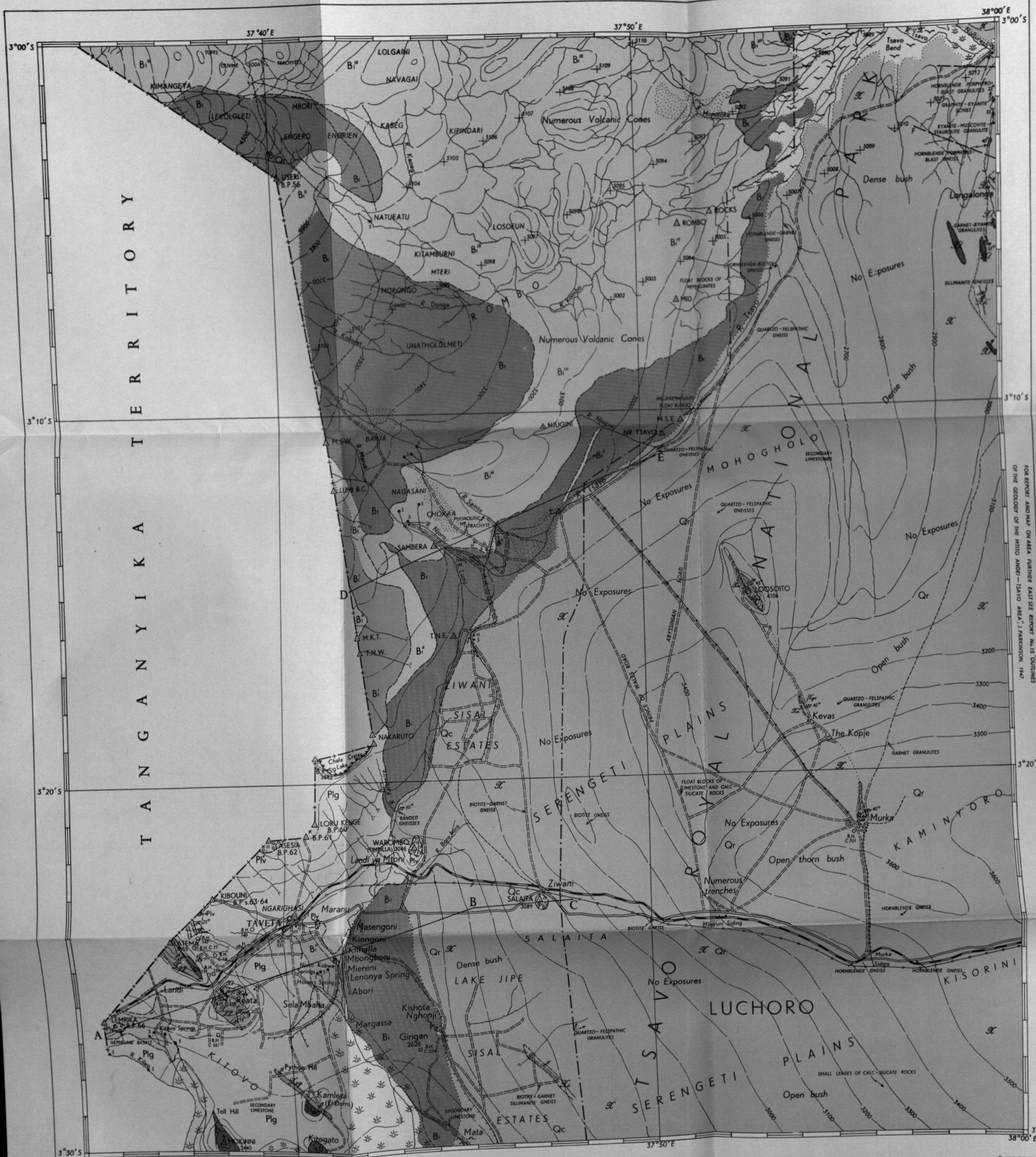
*Reference not consulted in original.

G.P.K. 82—750—1/54

GEOLOGICAL MAP OF THE TAVETA AREA

DEGREE SHEET No.64, NORTH-EAST QUARTER



EXPLANATION

RECENT
- Alluvium
- Qr Reddish brown soils; Qc Calcareous crustal deposits; Black cotton soils — Superimposed on formation colour

PLEISTOCENE
- Plg Calcareous tuffaceous grits
- Plv Ash and scoriaceous lavas
- Plv Vesicular olivine basalts

ROMBO SERIES

PLEISTOCENE TO MIOCENE
- B‴ Kijabe-type basalts
- B″ Melanocratic basalts with olivine and augite phenocrysts
- B′ Dense olivine basalts
- B Olivine basalts (undifferentiated)

BASEMENT SYSTEM

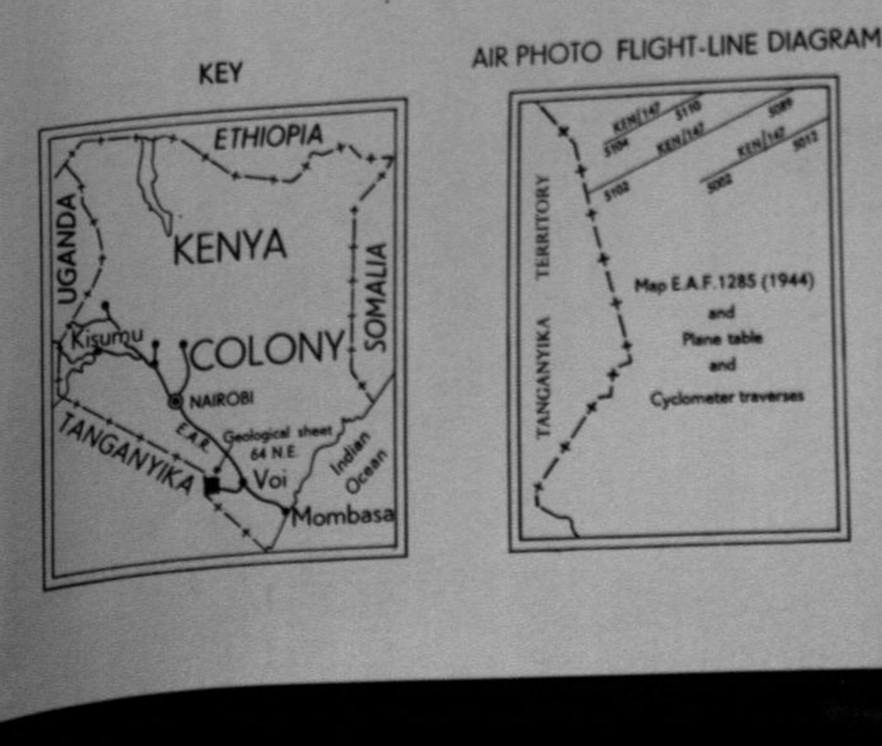
ARCHÆAN
- Crystalline limestones
- Semi-calcareous granulites with pyroxene, amphibole, quartz, plagioclase and garnet
- Quartz schists
- Semi-pelitic gneisses and schists with quartz, plagioclase, kyanite, muscovite and graphite
- Augen gneisses
- Felspar porphyroblast gneisses and granulites
- Biotite gneisses; Biotite garnet gneisses
- Quartzo-felspathic gneisses
- Hornblende-biotite gneisses
- Undifferentiated Basement System rocks

INTRUSIVES
- Di Diorites with charnockitic affinities
- U Ultra-basic and basic intrusives

- Geological boundaries, approximate
- Geological boundaries, inferred
- Faults
- Dip of foliation
- Vertical foliation
- Pitch of lineation
- Volcanic vents, crater recognisable
- Volcanic vents, no crater remains

- Main roads
- Secondary roads
- Tracks usable by motor vehicles in dry weather only
- Railway
- Railway, narrow gauge
- Canals
- Form-lines
- Trignometrical stations, altitudes in feet above sea-level
- Principal points of aerial photographs
- Marshes
- Springs, permanent
- Springs, seasonal
- Bore-holes
- Aerodrome
- H. Houses F. Factories S. African shops
- Telegraph line
- Pipe line
- Boundary of Tsavo Royal National Park

Magnetic declination 3°05′ S.



MINES & GEOLOGICAL DEPARTMENT
KENYA COLONY

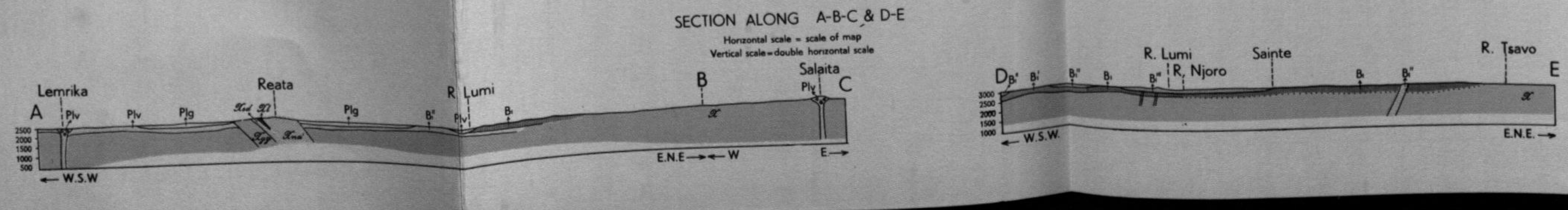
Scale 1 : 125,000

1 inch = 1·972 miles or 1·014 inches = 2 miles

GEOLOGICALLY SURVEYED BY L. M. BEAR, GEOLOGIST
Between January and April 1952
Photo-litho, Government Printer, Nairobi, 1954

SECTION ALONG A-B-C & D-E

Horizontal scale = scale of map
Vertical scale = double horizontal scale



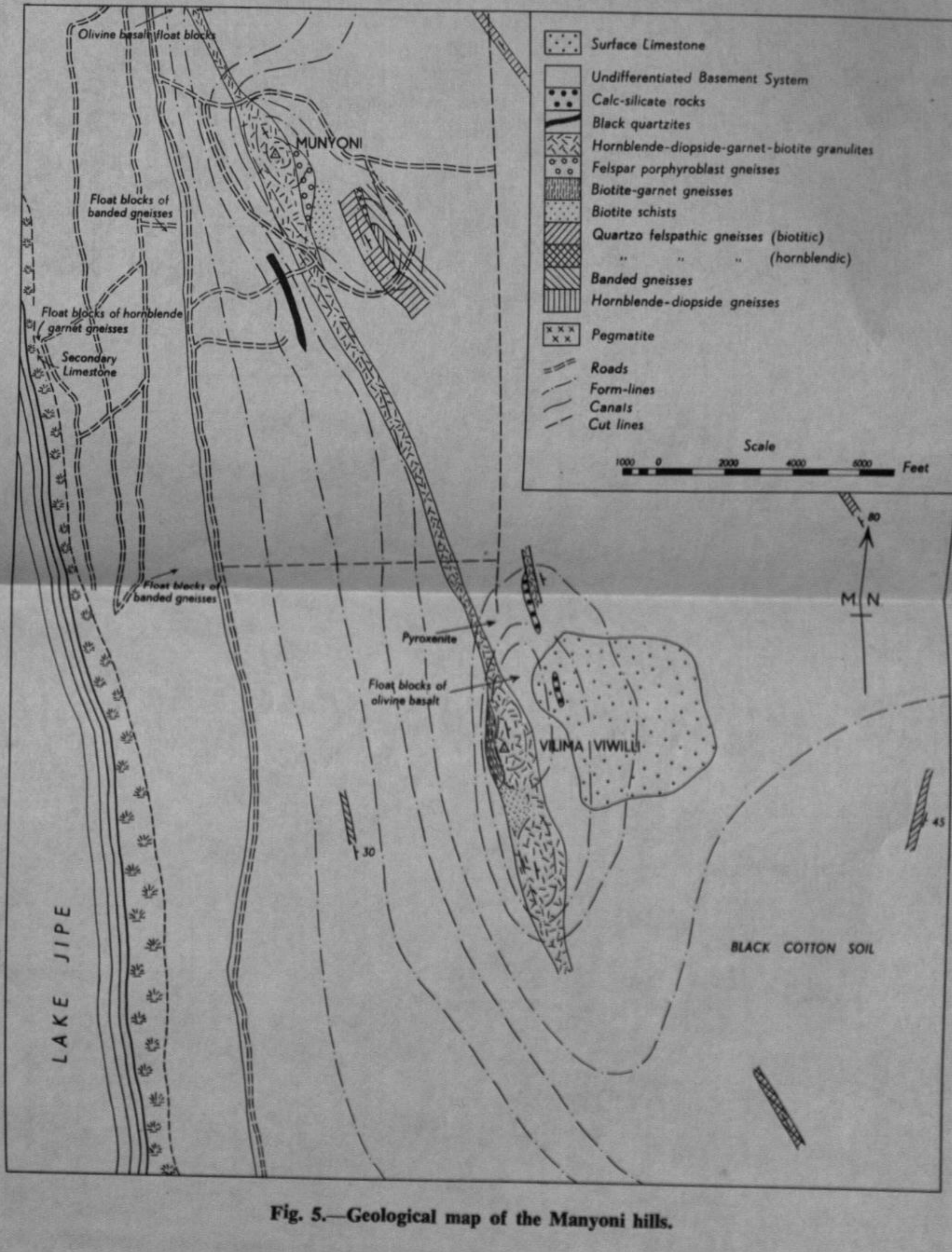
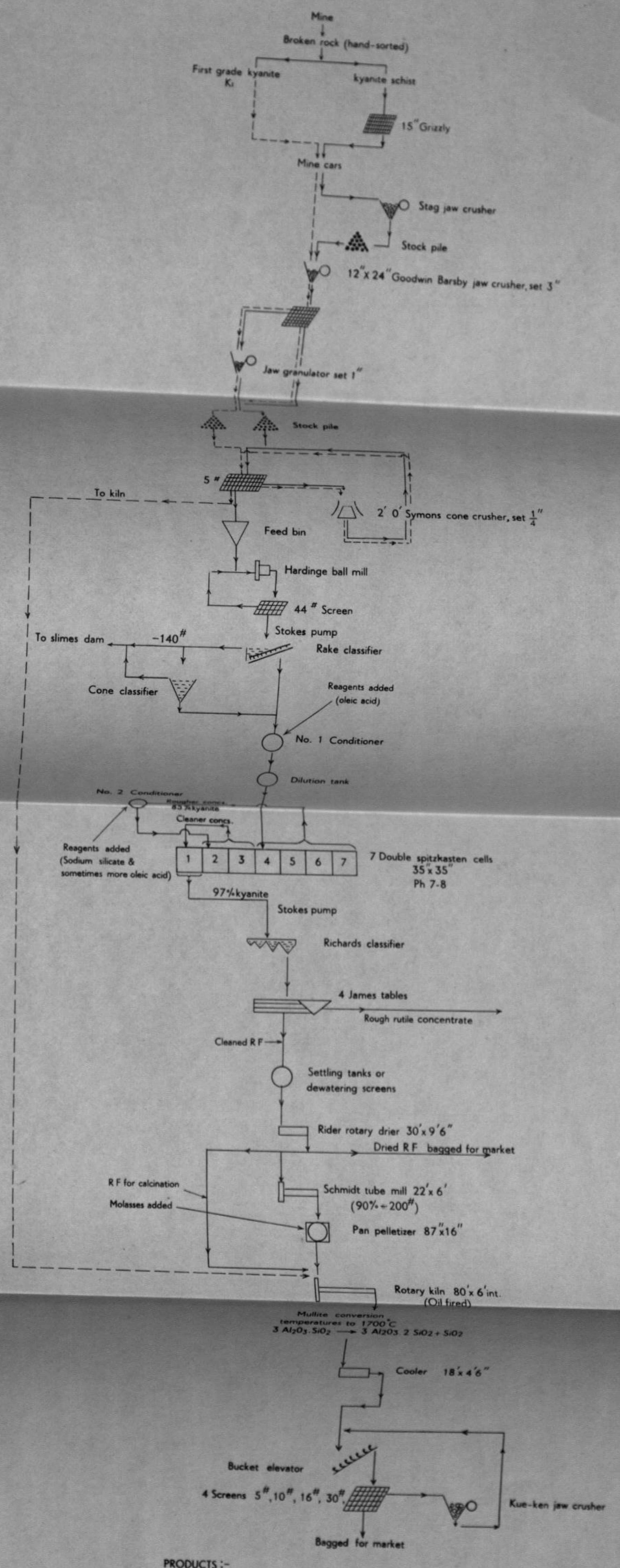


Fig. 5.—Geological map of the Manyoni hills.

MILL FLOW-SHEET OF KYANITE MINE AT MURKA



PRODUCTS :-

CKU — Ungraded, all-5# calcined kyanite ore
CKUF— " " mixture of calcined ore plus CP
CP — Calcined flotation concentrate, from RF
CPW — " pellets (whole)
RF — Raw kyanite flotation concentrates (all minus 44#)

Fig. 6.

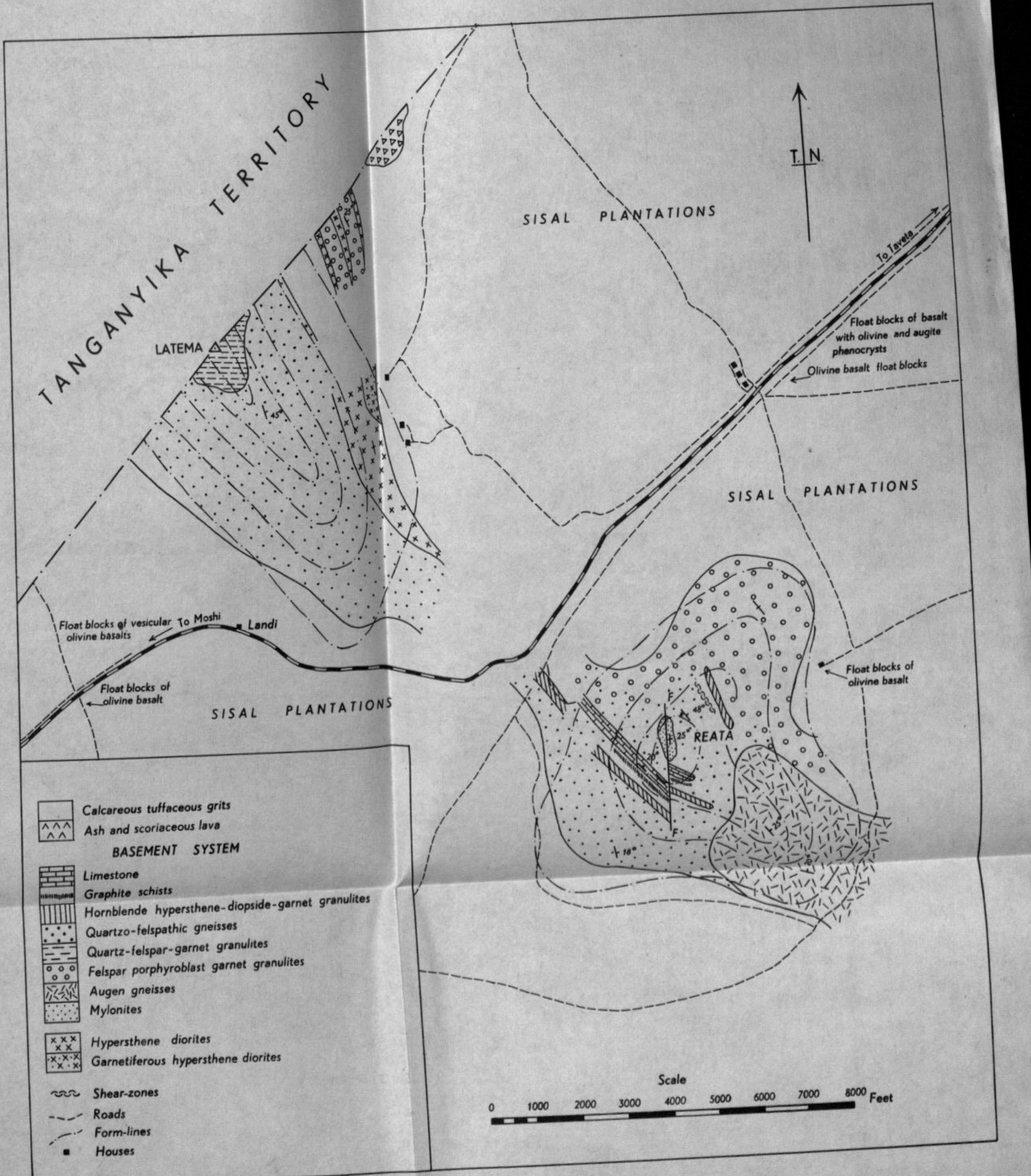
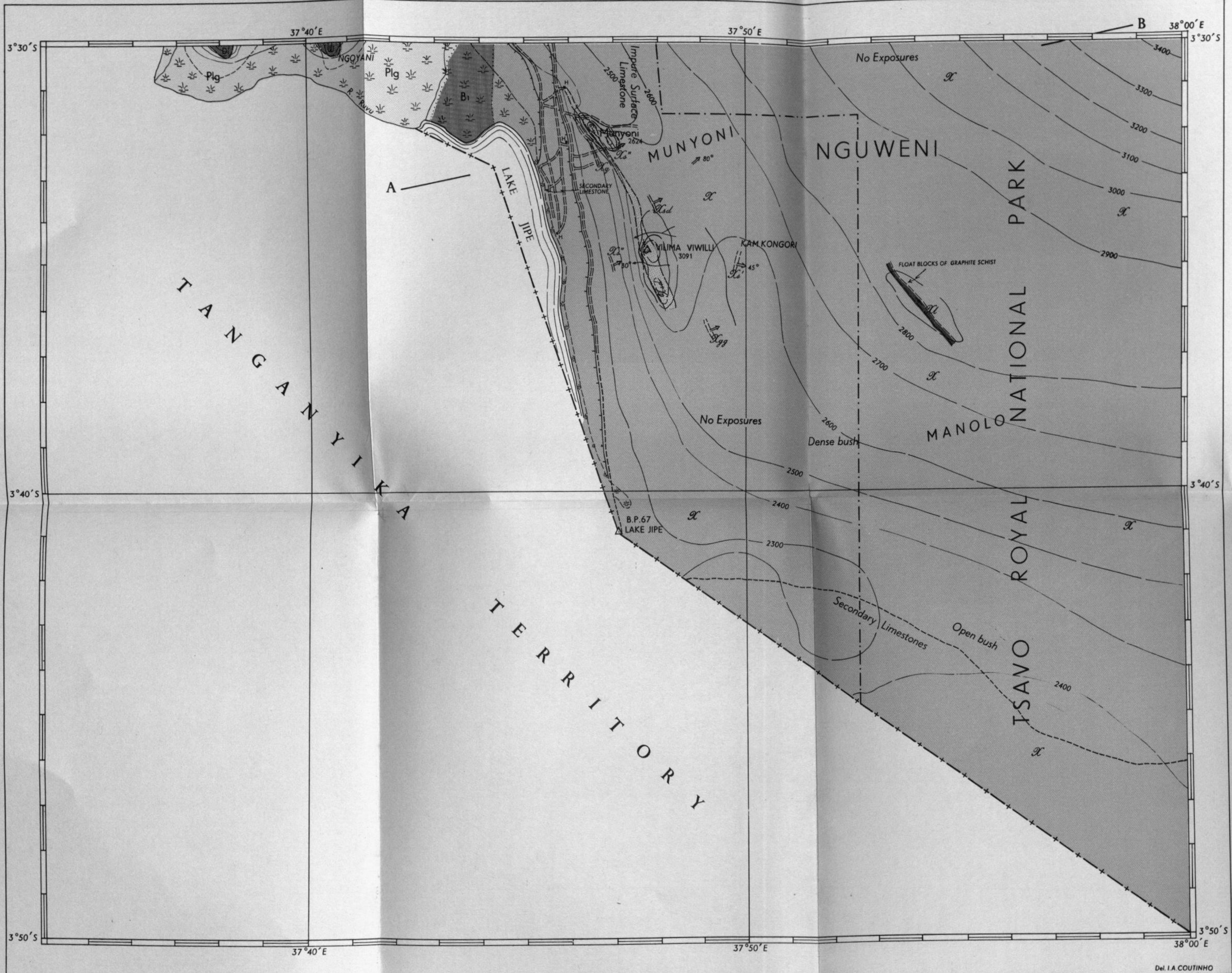


Fig. 4.—Geological map of the Reata-Latema area.

GEOLOGICAL MAP OF THE LAKE JIPE AREA

DEGREE SHEET No.64, SOUTH-EAST QUARTER



EXPLANATION

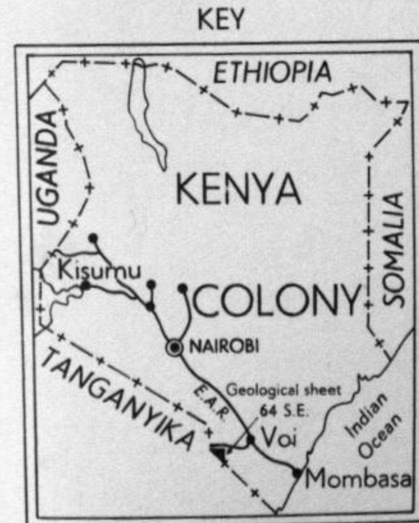
PLEISTOCENE	Plg	Calcareous tuffaceous grits
		ROMBO SERIES
PLEISTOCENE TO MIOCENE	B₁	Olivine basalts (undifferentiated)
		BASEMENT SYSTEM
ARCHÆAN		Crystalline limestones
		Semi-calcareous granulites with pyroxene, amphibole, quartz, plagioclase and garnet
		Quartzites
		Biotite gneisses, Banded gneisses; Quartzo-felspathic gneisses
		Undifferentiated Basement System
		INTRUSIVES
	Di	Diorites with charnockitic affinities
	U	Ultra-basic and basic intrusives

Geological boundaries, approximate
Geological boundaries, inferred
Dip of foliation
Vertical foliation

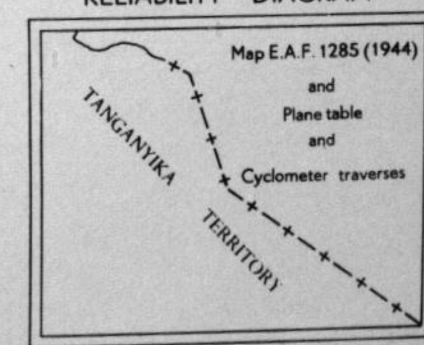
Secondary roads
Tracks usable by motor vehicles in dry weather only
Canals
Form-lines
Trignometrical stations, altitudes in feet above sea-level
Marshes
Houses
Boundary of Tsavo Royal National Park

Magnetic declination 3°05′S

KEY



RELIABILITY DIAGRAM



MINES & GEOLOGICAL DEPARTMENT
KENYA COLONY

Scale 1:125,000

1 0 1 2 3 4 5 6 7 8 9 10 MILES

1 inch = 1·972 miles or 1·014 inches = 2 miles

GEOLOGICALLY SURVEYED BY L. M. BEAR, GEOLOGIST
Between January and April 1952

Photo-litho, Government Printer, Nairobi, 1954

SECTION ALONG THE LINE A-B
Scale same as that of map
Vertical scale=Horizontal scale