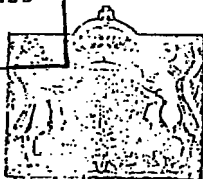


R/0013

KENYA SOIL SURVEY PROJECT
M.A. — National Agricultural Laboratories
P.O. Box 30323. NAIROBI

REPORT No. 13



LIBRARY
MINING AND GEOLOGICAL DEPARTMENT AND PROTECTORATE OF KENYA
NAIROBI

MINING AND GEOLOGICAL DEPARTMENT

GEOLOGICAL SURVEY OF KENYA

OUTLINES OF THE GEOLOGY

OF THE

MTITO ANDEI—TSAVO AREA
KENYA COLONY

(WITH COLOURED MAP)

by

J. Parkinson, Sc.D., M.Inst.M.M.

GROUNDWATER SURVEY (K) LTD.

Phone: 573659-577799
Fax: 573659- NAIROBI

LIBRARY
MINING AND GEOLOGICAL DEPARTMENT
NAIROBI

MEMORANDUM

1947

PRINTED BY THE GOVERNMENT PRINTER
NAIROBI

Price Sh. 2

CONTENTS

	PAGE
I—PRELIMINARY; Physiography, Drainage, the Taita Hills, Communications ..	1
II—OUTLINE OF GEOLOGY; Sequence and Stratigraphic Table, Age, Structure; Distribution of Basement System Sediments in Kenya ..	3
III—THE ORTHO-GNEISSES AND THEIR ASSOCIATION WITH HORNBLENDE-SCHISTS	7
IV—THE PARA-GNEISSES—	
(1) General	9
(2) Para-Gneisses Associated with Mzima Argillaceous Schists. Right Bank of River Tsavo	10
(3) Para-Gneisses occurring in the Central Part of the Tsavo Traverse ..	11
(4) The Maktau Hills	12
(5) Graphitic Gneisses, Athi River	12
V—THE PARA-SCHISTS AND ASSOCIATED ROCKS—	
(1) The Mzima Bend Section	13
(2) Petrography of the Rocks of the Mzima Bend and the Loosoito Range	13
(a) The Quartzites	13
(b) Kyanite-quartz Schists	15
(c) Kyanite-graphite Schists	15
(d) Rocks of doubtful origin, akin to hornfels	16
(3) The Volcanic Sub-Group	17
(4) The Schist Series near Mgange, north-west of the Taita Hills ..	18
(a) Quartzites	18
(b) Graphite-Kyanite-Schists	19
(c) Compact Graphitic Rocks with Garnet	19
(d) Actinolite Schists	20
(5) The Crystalline Limestones	21
VI—COMPOSITE GNEISSES OF THE TAITA HILLS	21
VII—SUMMARY OF GEOLOGICAL CONCLUSIONS	23
VIII—ECONOMIC MINERALS	23
IX—REFERENCES	24

APPENDICES

I—Graphite Deposits, Tsavo	24
II—Kyanite Deposits, Murka	29
III—Magnesite Deposits, Kinyiki	31
IV—Other Mineral Deposits at Kinyiki—Asbestos, Quartz, Felspar, Vermiculite, Corundum and Sapphire, Miscellaneous Minerals	32
V—Mica	37
VI—Miscellaneous Minerals—Limestone, Clays, Rose Quartz, Copper, Kaolin, Minerals of the Taita Hill	38

ADDENDUM

Mineral Production Figures subsequent to the Report	40
---	----

FOREWORD

The name of Dr. Parkinson will need no introduction to East African geologists—he may justifiably be called the doyen of those who have worked in East Africa during the last thirty years or more. He began the work that led to the present report in June, 1940, when he made a detailed examination of deposits on the western flank of Kinyiki Hill, near Mtito Andei. Subsequently he mapped extensive portions of the country south of Mtito Andei, paying particular attention to the Tsavo valley and the Taita Hills, and returning to Kinyiki when underground exploration was begun there. The survey continued until May, 1940, when Dr. Parkinson returned to Nairobi to carry out petrographical and other work. Soon after, he was unfortunately taken ill, and after hurriedly completing his report and map, he was compelled to resign his appointment.

As the period during which the survey continued was insufficient to allow a complete examination of the area, a small amount of data gathered by earlier official observers has been added to Dr. Parkinson's map. In addition, several appendices have been written to describe in more detail the mineral deposits, particularly the interesting suite of rocks and minerals found at Kinyiki Hill.

The work carried out by Dr. Parkinson and the prospector who worked with him was financed by a grant from the Colonial Development Fund.

WILLIAM PULFREY,
Senior Geologist.

Nairobi, February, 1946.

CONTENTS—(Contd.)

LIST OF ILLUSTRATIONS	PAGE
FRONTISPIECE—Ngulia II and Kitchwa ya Tembo, Tsavo Valley, looking west. Text Fig. 1 interprets the profile seen in this photograph.	
FIG. 1—Section of Kitchwa ya Tembo, showing mode of thrusting along the Tsavo Valley	5
FIG. 2—Diagrammatic section of the suggested roof-pendant of Basement System Sedimentary Rocks	6
FIG. 3—Brecciation of hornblende schist by microcline gneiss, below railway bridge, Mtito Andei	8
FIG. 4—Intrusions of biotite-gneiss and pegmatites, Meruga Road, near Yale, Taita Hills	21
FIG. 5—Section at the west end of the Meruga Road, Taita Hills, showing the composite nature of the gneisses	22

ILLUSTRATIONS IN APPENDICES

FIG. 6—Graphite deposits, Tsavo	25
FIG. 7—Geological map of Kinyiki Hill, near Mtito Andei	facing page 32

MAP

Preliminary geological map of the Mtito-Andei-Tsavo area; scale 1:250,000—in end folder.

OUTLINES OF THE GEOLOGY OF THE MTITO ANDEI-TSAVO AREA

I—PRELIMINARY

PHYSIOGRAPHY

Taken as a whole, the district, over 2,000 square miles in extent, covered by the reconnaissance survey lies to the west of the railway from Mtito Andei to Voi, and extends westwards to the Chyulu Range and the eastern slopes of Kilimanjaro. There are no maps of this area which can justly be said to be accurate within a mile. The Taita Hills must be looked upon as a geographical entity, and a reasonably accurate sketch-map was prepared on a scale of 1:62,500 and approximately correct form-lines inserted. The country is closely populated and fruit and vegetables are grown for the Mombasa market, under the guidance of the Agricultural Station at Wundanyi.

The area consists of a plain sloping gradually to the south-south-east, broken by sharply rising hills with a tendency south of the River Tsavo to a linear arrangement. Volcanic rocks overlie the gneisses of the southern part of the Yatta Plateau (elevation about 3,000 ft.) and in the Chyulu Range to the west (6,000 to 7,000 ft.).

With the exception of the Taita Hills to the south and the neighbourhood of the Voi-Taveta railway, the country is uninhabited and practically waterless; a desolate expanse of thorn-scrub and occasional flat-topped acacias. In addition to the lava plateaux mentioned, outliers from the Kilimanjaro association of flows and puyes occur as isolated remnants in the neighbourhood of the upper reaches of the Tsavo and along the Mzima River.

Besides the peneplain forming the "floor level" of the area, traces of a second appears just discernible along the sides of the hills north of Voi and on the western flanks of the Taita Hills, but levelling must be done before this can be considered as established.

DRAINAGE

Apart from the Athi River, which does not materially influence the physiography of the area under consideration, drainage is effected normally by the Tsavo River alone, such tributaries as exist being dry except the Mzima on the northern bank and the headwaters on the lower slopes of Kilimanjaro, which do not in themselves influence the area. No tributary entering on the southern bank carries water, except as occasional freshets. These broad sandy channels, rarely contained between high banks but occupying shallow grooves, are the "Laks" or "Luggas" of the Northern Frontier District, a convincing witness here as there to the heavy rainfall of the past. The greater part at least of the Mgange Lak, which traverses the thorn-scrub country from its source in the Taita Hills for some 20 miles north to the Tsavo River, has, as far as it is possible to judge by appearances, been dry for a number of years. The country is, in fact, rapidly approaching the semi-desert state through which the Northern Frontier is now passing on its way to a complete stage of desolation. On the other hand, the channel north of Mtito Andei Station a few years ago contained flowing water for some months, at least, of the year. It is now apparently uniformly dry. Water holes, small and more or less precarious in existence and duration, are found at various and rare intervals and form a meagre supply for animal life. The Taita Hills must be taken as an exception to the destitution elsewhere universal in the area and it is there and along the Taveta-Voi Branch Railway that any human beings are found, a fact not wholly accounted for by the eastern boundary of the Game Reserve running near the edge of the hill country as far south as the Tsavo. The Tsavo River, for twelve to fifteen miles up-stream from the railway, runs in a general direction across the grain of the rocks, which is characteristically constant a few degrees west of north.* It then enters a stretch between Ngulia and Rhodesian Hill where, owing to a marked change of dip, it approximates to a strike stream.

*Along the 90 miles stretch south of Marsabit in the Northern Frontier District where similar rocks are well exposed the strike varies only slightly from a north and south direction.

Passing westwards beyond the entrance of the Mzima by a small waterfall, the diminishing Tsavo is found to have changed direction, flowing first round a quadrant of a circle concave to the south, known, for the sake of brevity, as the Mzima Bend,* and then more or less parallel with the general strike.

The Taita Hills—(Parkinson, 1943), are an irregular range forming the divide between the Voi River and a few insignificant streams which rapidly die away to the south and the dry northerly directed channels leading to the Tsavo. They are distinguished by their steep and almost precipitous slopes culminating in a series of picturesque peaks reaching 7,000 ft. or more. The ground sinks to the south in three ridges, divided by steep valleys which rapidly flatten out before reaching the lower ground, and are traversed by three steep roads much used by the inhabitants for conveying vegetables to the railway which runs from Maktau on the west, elevation 3,600 ft., to Voi Station at an elevation of about 2,000 ft. The relatively narrow flattenings at the base of each valley and the valley sides themselves, wherever practicable, are densely cultivated.

In the upper reaches aneroid readings give drops of about 450 feet to the mile along the two westerly streams, the Bura and the Mwatati.

The Voi River, the most southerly of the three main streams, rises near the Wesu hospital as a group of very small streams having high grades marked by miniature waterfalls. These are probably discontinuous except during the wet season and the river proper cannot be said to commence its perennial course until the Agricultural Station at Wundanyi is reached. Thence it descends in a series of small rapids until Msau (2,320 ft.) after which a gentler grade takes it in 4½ miles to the main road (2,140 ft.).

A few rivulets emerge from springs along the northern flank of the hills by the side of the Meruga Road between Mgange at the head of the Bura Valley and Wundanyi. These are important from the agricultural standpoint, as they enable farming to be carried on along the edge of the hills. Passing northwards beyond this narrow belt of native cultivation, water, except for a few holes in the rainy season, is absent until the Tsavo is reached, but close to the hills on every side the utility zone, as one may term it, could be considerably increased by a supply from shallow wells, or gravity flow from catchment areas in the hills.†

In this connexion details have been taken from the logs of the water-wells sunk by the Department of Public Works, at Taveta and Mwatati on the Voi Branch Railway, and Kedai west of Ndi, and elsewhere.

Sincere thanks are due for much information ungrudgingly given by the Department of Public Works. Out of 13 wells studied, all but three were drilled in crystalline rocks. The deepest was 400 feet, the shallowest 100 feet, the average depth 223 feet, the average yield over 42,000 gallons in 24 hours. There seems little doubt that the greater part of the southern foot slopes of the Taita is water-bearing and locally richly so and one may infer the same for the ground beyond the northern slopes and the western flanks. For instance, of the wells sunk by the Kedai Fibre Estates, ten miles west of Ndi, one was very brackish, two others gave 28,800 gallons per 24 hours, the fourth 60,000 gallons of good water. The yield was considered to be permanent. The wadis or laks running north to the Tsavo, say, one mile from the point of issue from the hills, would be worth testing.

COMMUNICATIONS

The main railway forms the principal means of communication on the east, and the southerly part of the area is reached by the Voi-Moshi branch line, which is its southern boundary. Main roads follow the railway from Voi northwards and along the branch line. A telegraph line is operative along both railways.

*This change in direction is no doubt largely due to the changed strike on the north side of the fault at this point.

†The Maktau Station and the few inhabitants of that place with their cattle are supplied by a pipe line from the hills about nine miles away by gravity flow. Such cases could be considerably increased; for instance, a new reservoir to supply the railway is filled from such high level ground, a few miles from Voi on the far side of the hills.

In order to facilitate the work of the survey, rough tracks for cars were made—
(a) along the Tsavo Valley,

(1) from Signaller's Camp to Refugee Camp, 21 miles (thence 18 miles to the Taveta-Voi road),

(2) Signaller's Camp to Tsavo Railway Bridge, 35½ miles.

(b) from Muktau (3,607 ft.) to Mgange Camp (2,890 ft.) 12½ miles in a direct line, and,

(c) Mgange Camp to Kedai Sisal Estate (2,600 ft.), about 8 miles.

Additions were also made to the southern end of the road connecting Signaller's Camp on the left bank of the Tsavo to Mtiito Andei Station.

These routes together with the principal streams of the Taita Hills, were surveyed by prismatic compass, range finder and tape. In this work I have to acknowledge substantial help from Mr. B. A. Brannstrom.

II—OUTLINE OF GEOLOGY

Sequence and Stratigraphic Table.—The sequence established is given in the tabulation below. It must be regarded as largely conjectural.

Pleistocene and Recent.

Alluvium.—Deposits of red sandy earth of considerable depth which form a large proportion of the flat and slightly undulating ground covered with thorn trees and spare vegetation between the more hilly regions.

Wide, flat valleys of sandy clay are the equivalent of the "mbugas" of Tanganyika Territory.

?Lower Pleistocene.

Basalts.—Not discussed in this report. Portions of the area examined which are covered by basalt are, however, shown on the map.

Age Unknown.

Dunite.—An intrusive boss to the north of Mtiito Andei Station. Not touched on here.

Archaean (Basement System).

Pegmatites, and scattered exposures of ortho-microcline-gneiss typically associated with hornblende-schists which for the greater part are regarded as intrusive. The second feldspar of the gneiss is usually albite or albite-oligoclase.

Argillaceous Sedimentary Series

Crystalline Limestones.

Kyanite-Schists.

Graphite-Schists, and schists containing both kyanite and graphite or either as dominant minerals.

Muscovite- and Biotite-Schists, including migmatites of the Taita Hills.

Garnet-Schists, Pyroxene-Garnet-Schists, etc.

Quartz-Schists, ferri-ferous, garnetiferous and kyanitiferous.

"Volcanic Group". A series of epidote-hornblende-schists with scapolite, and garnets.

Arenaceous Sedimentary Series.—Sandstones and arkoses which have undergone penetration soaking. With them may occur beds of almost unaltered quartzite, which have undergone little metamorphism beyond the quartzite or quartz-schist stage.

AGE

The Archaean rocks are believed to be of approximately the same age as the Turoka Series of the Magadi Branch Railway and the Suk Hills, as judged by lithological characters, association and degree of metamorphism. They form part of the Basement System of Kenya, and correspond with what has been called the Lower Basement Complex in Tanganyika, which has been described (Grantham *et al.* 1940, p. 18) as distinguished by the presence of normal sediments, the occurrence of crystalline

- (C) It is worthy of remark, that the conspicuous low flat-topped hill of Kangetchwa, of somewhat circular shape and about four miles in diameter, is composed of a microcline gneiss and other rocks characteristic of the para-gneiss group and is situated due south of Ngulia. (See p. 9). Owing to transport and other difficulties, a close examination of Kangetchwa and its surroundings could not be made but at least the possibility of its representing a klippe should be considered.

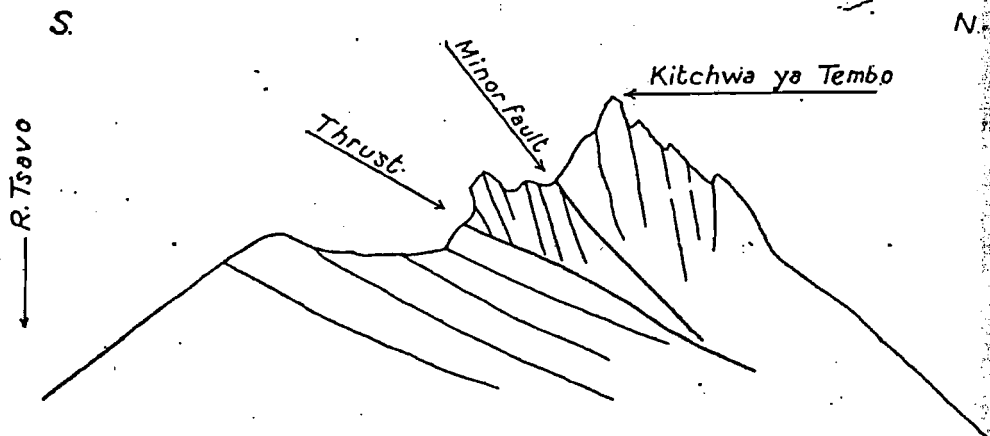


FIG 1

Section of Kitchwa ya Tembo, showing mode of thrusting a'long the Tsavo Valley.

DISTRIBUTION OF BASEMENT SYSTEM SEDIMENTS IN KENYA

The area of deposition of the rocks now under consideration, which for convenience we may call the Tsavo Basin, is probably connected under the lavas of the Kapiti Plains with the sections already described near Turoka Station on the Magadi Branch Railway. (Parkinson, 1913, p. 534.) If not actually connected, it can be separated from it only by a relatively narrow barrier. Some 200 miles to the north is the basin of deposition running south from the neighbourhood of Marsabit to the northern Uaso Nyiro. This north-south belt of ancient sediments is buried by lavas to both east and west, but to the north-east is probably connected below the flows with the parashists of Ajow (where there are also massive quartzites) and Buttellu. This we may name the Laisamis Basin. On the west are the lavas south of Lake Rudolf dividing it from the Basement System rocks forming the Suk and Chemorongi Hills. As far as the writer's personal observations go, the more southerly basins, Turoka and Tsavo, especially the latter, contain a higher proportion of arenaceous gneisses than the more northerly. With these the "slabby gneiss of Laisamis", half way between Archer's Post and Marsabit, and similar rocks in the neighbourhood, should be included. (Parkinson, 1920, pp. 20, 21 and references there given.)*

The close petrological resemblance between the rocks of this portion of the Basement System, wherever so far studied, indicates not only continuity or approximate continuity of the areas of deposition but similar provenance of clastic materials.

It is difficult not to suppose also a similarity, practically an identity, in the intensity and physical conditions under which the agents of metamorphism and metasomatism worked.

*During the journey through the Northern Frontier Province in 1914-15, the true character of the arenaceous gneisses was not properly realized. (Parkinson, 1920, p. 26). In the same way some of the Turkwal Gorge gneisses (Glenday and Parkinson, 1926, p. 606) stated to be ortho-gneisses may prove, on further work, to be of sedimentary origin.

Regional metamorphism is obvious and, taking into account the facts recorded by others working in still more wide-spread localities,* the similarity in the history of the rocks covering so much of the central part of the African continent becomes remarkable. It is tempting to consider the possibility that this sedimentary section of

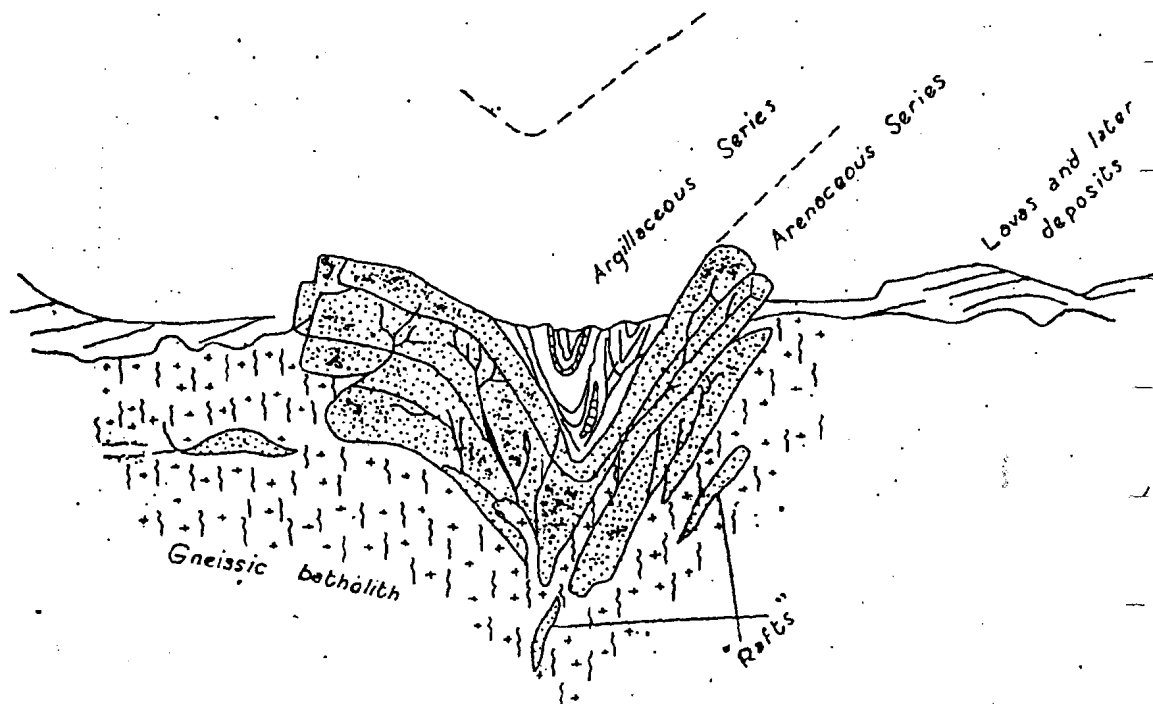


FIG. 2

Diagrammatic section of the suggested roof-pendant of Basement System Sedimentary Rocks.

the Basement System is a gigantic roof pendant of which, speaking generally, the central argillaceous heat-affected core, and the surrounding metasomatically affected arenaceous envelope are left eroded for inspection. The necessary huge batholiths, acting under essentially identical physical conditions which alone could have attained such a result have not been found, at any rate in adequate dimensions. The great bulk of the encasing reservoir (with its supposed albite-oligoclase-microcline-quartz magma) except where it has perforated the roof pendant by protruding tongues, has been removed by erosion or buried under later sediments and lavas.

In the areas described, all of which except one were personally examined by the writer in the old days of "foot safari", this section of the rocks of the Basement System, comprising para-schists and paragneisses having close petrographical affinities, has been found at intervals from the northern end of the Suk Hills to the Voi-Taveta railway, a distance of over 400 miles, and from the Suk Hills to Buttellu on the west of Eil Wak, about 300 miles in an approximate east and west direction, that is over an area of 120,000 sq. miles. On the other hand no reason exists to show that the sedimentary phase of the System stops where the last exposure has been seen. It scarcely needs saying that a large proportion of this enormous area is buried by lavas, old lake deposits and alluvium, and that much of the System remains to be differentiated. Rocks of the Nyanzian and later Pre-cambrian Systems are apparently absent throughout the area.

*In an earlier paper (Glenday and Parkinson, 1926, p. 609) "deposition of the sediment in a geosynclinal area" and that "the tilted and folded beds sunk deeply into the viscous uprising magma" were suggested. The hypothesis now put forward on fresh data is essentially that formerly suggested.

III—THE ORTHO-GNEISSES AND THEIR ASSOCIATION WITH HORNBLENDE-SCHISTS

At various points along the eastern end of the Tsavo traverse, igneous rocks occur. They are typical hornblende-schists and acid gneiss associations which exhibit evidence of brecciation and assimilation of the basic partner by the more siliceous on a fairly large scale.* A later section in this report on the Taita Hills describes similar relationships.

In the Tsavo Valley at the road bridge hornblende-schists predominate. They are locally garnetiferous and associated with slabby finely banded gneiss having a general foliation trending 332° to 342° . A short distance to the west, where the traverse road crosses a dry tributary to the river, the brecciation is clear.

Thin quartz-felspar veins indicate considerable permeation of the type which gives rise to migmatites, while the whole is cut by broad pegmatite veins at right angles to the foliation. Faults with a throw of an inch or two, near which now and again minerals show slight bending, indicate that the rock was nearing the solid state at the time of movement.

The gneiss (I.94.Sl.107)† intrusive into this association in its least contaminated form near the Tsavo Road bridge, is a compact rock not necessarily showing a marked foliation. It is spotted with small nests of biotite. The thin section shows it to be largely composed of microcline, which usually exhibits a fine microperthitic structure, and is associated with accessory plagioclase (an acid oligoclase). Characteristically thin rims or veins of another species of felspar, probably albite, edge the larger crystals or even form borders to grains of quartz. The latter appears as rounded blebs and occasional large grains. Apatite is an accessory.

A second instance (I.91.Sl.1.) of intrusive gneiss occurs one mile south-east from the Tsavo Road bridge. This is a hard, compact reddish-brown rock, showing faint banding. It contains a large proportion of microcline in addition to an acid plagioclase. Rare magnetite and zircon are accessory minerals.

A uniform, massive, medium-grained, dark grey rock (I.92.Sl.106), showing no foliation in the hand specimen, closely associated with the streaky hornblende-schist group is exposed at the road bridge over the Tsavo. It has the appearance of a highly contaminated rock. Only one small grain of microcline was detected in the slide. The oligoclase is often only partially twinned probably as the result of the pressure which has produced crush-shadows in the few irregular grains of quartz. The interest of the rock lies in the ferro-magnesian minerals which consists of pale green augite altering patchily to hornblende, some apparently original hornblende and irregular plates of biotite. Magnetite is a conspicuous accessory constituent and apatite and sphene occur rarely. Foliation is noticeable in the arrangement of the dark minerals.

About $5\frac{1}{2}$ miles west of the Tsavo railway bridge the track crosses a wide tributary and exposes an excellent section of banded and gnarled ortho-gneisses with pegmatite veins and hornblende-gneiss inclusions. The general trend of the foliation is 330° . These rocks when traced up this side-valley lose much of their conspicuous structure and pass into hornblende-biotite-gneisses, locally well-banded or slightly contorted containing thin pegmatite veins and having garnets associated with the hornblende.

At $8\frac{1}{2}$ miles from the bridge, the same relationship as near the road bridge itself is shown. The strike of the foliation is 336° .

Again at $11\frac{1}{2}$ miles from the bridge in the bed of an important tributary,‡ the Mgange Lak, fluxion and local gnarling are well seen. The general trend of the foliation is 344° . A short distance upstream along the dry bed the brecciation of a hornblende-schist by an acid ortho-gneiss and associated assimilation are seen, the rocks becoming locally garnetiferous as before.

*For similar associations in the north and south of the Northern Frontier District see Parkinson, 1920, p. 21.

†Numbers I.94, etc., refer to specimens in the museum of the Mining and Geological Department, Nairobi. Sl. 107, etc., refer to thin section numbers.

‡In existing maps this channel is mapped as rising close to Mgange Camp on the N.-W. flanks of the Taita Hills, a distance to the Tsavo River of nearly 20 miles in a straight line.

An extremely good section, showing the effects of intrusion on a rock still plastic, can be seen along the stream bed of the Mito Andei from the road crossing downstream to the railway bridge and beyond. At the sharp bend of the road just south of this crossing the strike of the gneiss (of almost binary composition) is 245° , and the dip of the foliation to 341° . It is a massive well-foliated rock (I.150.SI.97), having coarse feldspathic streaks and clots. A thin section shows it to be an ortho-microcline-gneiss, containing small flakes of biotite with olive-green to black pleochroism. Two or three small garnets and a few grains of apatite complete the section. Microcline constitutes about 25 per cent of the rock. The remaining feldspar has a refractive index rarely as high as that of balsam and is probably albite. It is both twinned and untwinned. A closely similar rock (I.158.SI.116), occurs in the quarry between the road crossing and the railway. It contains about 20 per cent of microcline. A certain amount of zoning is shown by the feldspar of both specimens.

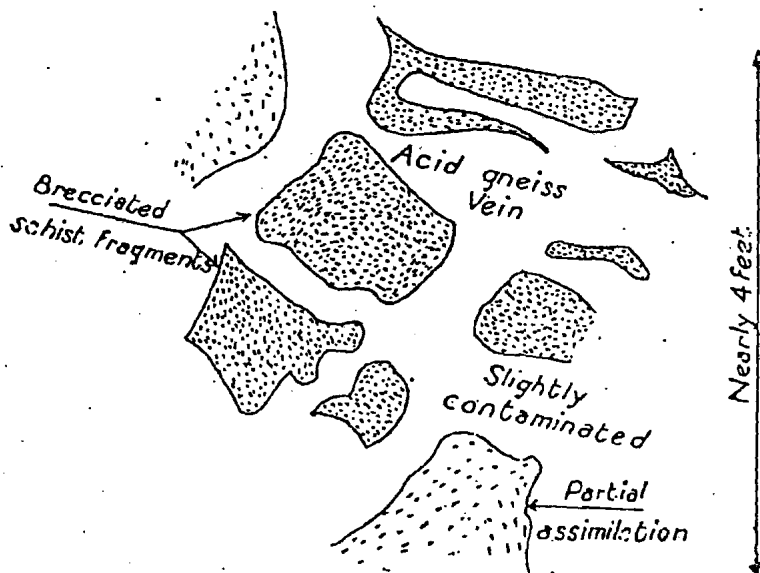


FIG. 3

Brecciation of hornblende schist by microcline gneiss, below railway bridge, Mito Andei.

At some 100 yards from the road, going downstream, the strike has changed to 275° , swings more sharply to a more usual direction and at the bridge is 313° . This change in strike, conveniently called a "swirl" and containing within itself minor fluxional movements, was noted in one place as swinging from 270° to 331° in little over 50 yards.

The basic element in the association appears just below the road crossing and near the bridge shows the characteristic steps, after marked brecciation, of partial assimilation and the beginnings of permeation. The intruding veins of acid gneiss, frequently at right angles to each other, appear in various shades of grey according to the quantity of material absorbed. The schist involved in the mixture is presumably the hornblende-schist developed on the west side of Kinyiki Hill.

The railway cutting at Kinyiki Camp at mile 179/6 on the railway, shows hornblende-schists with granitoid bands, striking 350° and dipping eastwards at about 65° . This association continues to mile 171/9, when the rocks become markedly migmatitic with the development of much mica.

In any of these instances where igneous rocks appear alone to be concerned, the possibility of sediments now altered almost beyond recognition being also involved must not be forgotten. They might occur either as inclusions in various stages c

dissociation or in lit-par-lit complexes. It is impossible on the other hand to conclude that the structures just described are due to later additions of magma distinct from the rest of the assemblage.

The quiet permeation which give rise to migmatites and the more rapid and energetic intrusions which give rise to brecciation and the various stages of assimilation, occur side by side and no doubt took place practically simultaneously.

There is a tendency for the migmatites and brecciation gneisses to occur on the east and south of the area, suggesting propinquity to the edge of the magma reservoir, or in other words, that they represent the products of peripheral permeation.

IV—THE PARAGNEISSES

(1)—GENERAL

In considering the origin of the massive paragneisses which are distinctive of much of the country, great difficulty is felt, as elsewhere when dealing with similar rocks, in distinguishing true ortho-gneisses from granitized sandstones and arkoses.*

Much of the uncertainty is naturally due to the multiplicity of stages in the process of alteration, from the commencement of gaseous permeation to or together with actual magmatic intrusion.

With this process the mineral microcline seems possibly to be connected and its presence in a rock having sedimentary features is regarded as evidence of metasomatic action or additions. A few examples will show the range of variations. An early stage in such alteration may possibly be seen in the presence of a few grains of microcline in a quartzite containing albite in small untwinned crystals. The specimen (I.136.Sl.7) was collected about $\frac{1}{4}$ mile from Mubugoni in the direction of Bulutoni on the north-east flank of Ngulia. The quartz grains are fairly equi-dimensional, and average about .012 in. long; the microcline, of more irregular shape, averages .038 in. and shows a tendency to a linear arrangement.

A higher percentage of microcline scattered sporadically through the slide, occurs in a rock collected close at hand (Sl.114). The quartz is frequently very irregular in outline and variable in size.

Neighbouring specimens (I.136.Sl.6) from Bulutoni water-hole shows microcline to be only an accessory constituent. At Mubugoni water-hole about two miles to the south-south-east it is the principal feldspar and the preponderating constituent. This rock (I.162.Sl.122) taken from the side of Ngulia contains a few porphyritic feldspars however and must be considered as igneous. In both rocks there are almost no ferromagnesian minerals.

Kangetchwa, ten miles south of Ngulia, is in part composed of microcline-gneiss (III.109.Sls.112, 112a) associated with rather fine-grained pegmatites. The plagioclase, either twinned or untwinned, is probably albite. Quartz is conspicuous, and muscovite in sieve-like crystals and locally biotite with a strong pleochroism make up the rest of the rock.

Well foliated hornblende schists are associated with the gneisses.

The sharply rising hills characterizing the eastern half of the area from Mtito Andei to the Taita Hills may be considered here. They comprise a rock series similar to that characteristic of the Suk Hills. (Glenday and Parkinson, 1926, pp. 591-606.)

The group wherein are included certain quartzites may be bracketed with others to the west as microcline-albite-oligoclase paragneisses which taken as a whole occupy a position in the series of considerable importance.

The following have been examined. (The hills are considered in order roughly from north to south):—

*Recent publications of the Geological Survey of Southern Rhodesia contain valuable observations on these types of gneisses. (See, for example, Tyndale-Biscoe, 1940.) A report on the geology of the Dodoma Area in Tanganyika (Wade and Oates, 1936, p. 23) should also be consulted.

1. Gneiss from the trigonometrical station of Kamboyo south-south-west of Mtito Andei railway station (I.138.SI.92). Microcline is rare, the quartzes large and irregular in outline and the main feldspar near to albite. Other minerals are biotite, white mica, sphene and magnetite.

2. Gneiss from south of Kenani Station (I.147,148.SIs.94.95). The slides of these rocks show no microcline. They are garnet-gneisses containing a plagioclase near to oligoclase-andesine. In habit they are massive, very well foliated, inconspicuously to markedly banded and contain a few pegmatite eyes and bands.

At the first landie south of Kenani, the gneisses (I.154.118) also contain no microcline and ferro-magnesian minerals are scarce. The strike of the foliation is 160° .

Outcrops near the main road south of Kenani Station consist of massive hornblende-gneiss having a tendency to exfoliate in slabby fragments together with various biotite gneisses which outcrop at intervals on or near the road as far north as Mtito Andei. The strike of the foliation is 170° . Streaks of hornblende aggregates an inch or so thick and quartz-feldspar bands which are often garnetiferous occur in places in these gneisses.

3. Ngulia consists of massive para-gneiss similar to that forming the long ridge running southward from Kamboyo to Rhodesian Hill.

4. The hill, a trigonometrical point known as "Bump", 13 miles east-north-east of Kangetchwa consists in part of very basic hornblende-schist.

5. At the Sisal Estate, Kedai, banded acid gneisses outcrop in the river bed and are cut by rather coarse pegmatites and inter-banded with hornblende-schists.

These rocks and those of the hills north-east of the Taita Hills are placed in the lower portion of the sequence, i.e. in the Arenaceous Series.

(2) PARAGNEISSES ASSOCIATED WITH MZIMA ARGILLACEOUS SCHISTS RIGHT BANK OF RIVER TSAVO.

These rocks form the ground bordering the road leading down to the alluvium of the right bank of the Tsavo about half a mile east of the junction of the Mzima. The thickness of the group is of the order of 2,000 ft. They are markedly slabby, solid, compact rocks containing only a small proportion of any of the ferro-magnesian minerals as small inconspicuous grains. At first sight, they strongly recall the paragneisses of the left bank of the river eastwards from Signaller's Camp, differing from them, however, in that as far as seen they do not contain microcline, which is so characteristic of those paragneisses. Some are considered to be of igneous origin. In one such rock (SI.77) the principal constituent of the thin section is a feldspar. It is slightly kaolinized and usually untwinned, or only partially so, and is characteristically albite-oligoclase or albite. A few irregular grains of magnetite and some filmy white mica developed apparently along planes of movement are accessory minerals. The presence of a little quartz vermiculé forms a distinction from the granitoid gneisses of the eastern part of the traverse. In the hand specimen plates of muscovite are conspicuous on parting planes.

On the other hand another section (SI.76) shows predominate (very dusty) quartz, and is thought on that account and general appearance to be a para-gneiss. It consists of an interlocking mosaic of quartz and feldspar, twinned and untwinned, the latter in part at least albite. The slide shows quartz vermiculé. Accessory minerals are muscovite, biotite with very strong absorption, garnet in small rounded grains, zircon, and magnetite, the commonest. The quartz shows a tendency to semi-rounded outlines.

Other gneisses may be wholly or in part of sedimentary origin and the feldspar again, at least in part, is albite. (III.10, SI.92). A rock collected about $\frac{1}{4}$ mile to the west of these, may perhaps be regarded as the almost purely sedimentary end of a series representing graduations from an orthogneiss to a feldspathic quartzite. Amongst the grains of quartz (average diameter .01 in.) which comprise almost all the rock are some of water-clear oligoclase about .03 in. long. They have the appearance of being moulded on to the other constituents and must be of later growth, enclosing for instance,

blebs of quartz. Accessory minerals are epidote, magnetite, apatite, brown mica and some muscovite, which is in part secondary. It is suggested that this rock shows the commencement of that permeation which has so materially altered other sediments of the area.

Two and three-quarter miles west of Signaller's Camp on the right bank of the Tsavo and occurring as an isolated exposure, it is a well-foliated, fine-grained, yellowish rock (III.22.SI.62) which appears rather laminated without the laminae having essential differences in constitution. The foliation is marked by crystals of two micas. Muscovite occurs in relatively large, ragged plates and appears occasionally as an intergrowth giving a vermiculé appearance. The biotite has the intense absorption, olive-green to black, which characterizes this mineral in other rocks of the area. The quartz occurs in large elongated grains, and most of the feldspar is untwinned and apparently oligoclase.

This rock, though differing considerably in appearance must be considered as having a relationship to those just described and those following.

(3) PARAGNEISSES OCCURRING IN THE CENTRAL PART OF THE TSAVO TRAVERSE

Paragneisses in the central part of the Tsavo Traverse, approximately mid-way between the Tsavo railway bridge and Signaller's Bridge, may be subdivided into groups according to locality.

1. Gneisses from the left bank of the Tsavo between Signaller's Camp and Kitchwa ya Tembo. Microscopically these gneisses are seen to contain small flakes of hornblende and two micas. They are rather fine-grained and friable, unlike the majority of the paragneisses which are essentially hard and contain ferromagnesian minerals only rarely. They have a sedimentary habit of weathering, and the dip, in general terms, is to the north-east at about 30° . They contain streaks of pegmatite and are closely associated with hornblende-schists. Both appear frequently in road sections.

A specimen from a point $2\frac{1}{2}$ miles east of Signaller's Bridge (SI.32) contains no biotite but flakes of a hornblende which shows a blue-green element in the pleochroism. A similar colour distinguishes the mineral in certain gneisses from Suk (Glenday and Parkinson, 1926, p. 602). Large irregular crystals of quartz, large crystals of oligoclase, and possibly a little orthoclase are present. Epidote, sphene and rarely small apatite crystals are accessory minerals.

A second specimen (I.122, SI.31) collected two miles east of Signaller's Camp, shows the hornblende replaced by biotite, and some white mica which may be in part secondary. Microcline is present, and the plagioclase is occasionally bordered by a feldspar of another kind or possesses a core of different composition to that of the outer zone. These facts, which are far from uncommon, are mentioned to show that additions (implying solution and migrations of feldspathic material) have taken place since the earlier stage of consolidation. Other instances are described in their place.

2. Gneisses from the Tsavo Valley south-east of Kitchwa ya Tembo. These rocks and those in the following sub-sections may be considered typical of the paragneisses of this part of the traverse. Closely similar gneiss occurs at Bulutoni water-hole. They are hard rocks, slabby in habit, brown or white to pink in colour, of uniform grain and occasionally containing a few specks of biotite or magnetite and plates of muscovite collected on the planes of foliation.

A specimen (I.130: SI.25) from the river, 15 miles west-south-west Tsavo railway bridge is a brown weathering fine-grained slabby paragneiss having microcline as the dominant constituent. The plagioclase, which is apparently albite, is frequently bordered by a rim of translucent feldspar showing a refractive index less than balsam. No twinning was noticed in this rim.

A second example (I.131: SI.36) on the river 14 miles west-south-west of the Tsavo railway bridge, is a brown weathering slabby quartzitic-looking microcline-gneiss in the field. Its outcrops would be continuous with those of the

gneiss mentioned above were the strike maintained for about three quarters of a mile. The presence of a large number of rounded detached-looking grains of quartz in it suggest a sedimentary rock.

Between these outcrops and a point about a mile further east there are slabby binary gneisses in an apparently horizontal attitude forming a marked ridge on both banks of the river. Immediately to the east there are quartz-microcline gneisses (I.132.SI.26,37) containing twinned and untwinned albite,* and quartz which tends to have globular outlines and is very dusty, the dust particles being frequently gathered into parallel lines. There are no phenocrysts. A few flakes of very deep grass-green hornblende are an accessory.

At about a quarter of a mile further to the east a tributary enters from the south and contains slabby biotite-gneisses, occasionally garnetiferous, which higher up the lak are associated with slabby hornblende-gneisses and pegmatite bands.

(4) THE MAKTAU HILLS

The group of three hills about 2½ miles north of Maktau Station on the Voi-Taveta branch railway are composed principally of gneisses, closely related to those of the Taita Hills. They include types varying considerably in degree of coarseness and composition ranging from hard, rather fine-grained, compact and uniform rocks showing little sign of foliation in hand specimens to coarse quartz-felspar ortho-gneisses (III.106.SI.98) with xenoliths of medium grained more or less banded biotite-schists. The xenoliths occur in various stages of dissolution and absorption. In the fine-grained acid end of the series, microcline is fairly common and is associated, as is usually the case, with an albite-oligoclase or oligoclase. The quartz forms relatively large, irregular grains, showing incipient crush shadows. Brown mica having strong absorption and a little white mica, possibly in part secondary, are inconspicuous constituents. Small grains of microcline occur in a second slide. These rocks are probably paragneisses, whereas those containing xenoliths are certainly of igneous origin. The more basic part of a banded gneiss examined (III.105; SI.123) is a fine-grained biotite-hornblende-schist. The specimen sectioned contains no microcline, and felspar is represented by an acid plagioclase. Apatite is a common accessory.

Microcline gneisses (III.111.SI.105) occur with other rocks, largely of sedimentary origin, some ten miles distant from the Maktau Hills, on the north-west flanks of the Taita Group. As at the former locality they are associated with "pepper and salt" types of gneiss and thin bands of pegmatoids. A specimen about 1½ miles from Mgange Camp is a medium grained gneiss, the foliation well marked by streaks of ferro-magnesian minerals, principally biotite, having strong pleochroism from greenish-yellow to black. Microcline is an inconspicuous accessory, and oligoclase is the second felspar. A few small grains of epidote and rarer apatite are inconspicuous constituents.

(5) GRAPHITIC GNEISSES, ATHI RIVER

A belt of graphitic gneisses is developed over a long strike on or near the right bank of the Athi River between the latitudes of Kibwezi and Tsavo. It is considered as an earlier zone of graphite deposition, and with the exception of a graphite gneiss at Kitchwa ya Tembo, its rocks do not resemble the graphite-bearing types of the Argillaceous Group, described on a later page. The strike is approximately 336° roughly parallel to the course of the river and deposition along the zone took place at more than one period, as several graphite-bearing horizons were found, the principal about 40 ft. wide. Specimens from near the junction of the Mbululu and Athi are massive well-foliated rocks, often containing small phenocrysts of felspar, the whole sprinkled plentifully with flakes of graphite. One (I.166.SI.136) from this locality consists of a rather coarse aggregate of quartz and oligoclase (showing a little perthitic intergrowth) and is almost devoid of ferro-magnesian minerals.

A rather finer-grained rock (I.167.SI.137) from the same locality contains graphite in the usual flakes, about .03 in. long, having the characteristic rough edges and

*The presence of albite-oligoclase is a possibility, as a felspar occurs having a refractive index identical with that of balsam.

rectangular outline. This rock is one of the very few examined from this district which shows cataclastic structure in the form of a network of tiny veins of granulated quartz and felspar together with strain shadows in the larger crystals. The plagioclase is oligoclase, faintly and partially twinned in many instances.

V—THE PARA-SCHISTS AND ASSOCIATED ROCKS

(1) THE MZIMA BEND SECTION

The schist area, embracing the Loosoito Range and the Mzima Bend with its southerly continuation to Longa-Longa Hill may be considered first. The following is a slightly generalized section of the rocks exposed along the Mzima Bend, taken in apparent descending order from east to west.

1. Well-foliated biotite-gneiss.

2. Psammitic para-gneisses (Nos. III.3-8; Sl. 75-78 Pegs. 439/442) without microcline and with almost no biotite. These are underlain by a thin bed of epidote-quartzite (Sl. 143). There is then a gap at the *nibuga* near the entrance of the Mzima River, where black sandy soil and scattered basalt outcrops are found. Basalt occurs also at the mouth of the Mzima.

3. A thin bed of fine-grained quartzite (Peg 447. III. 10. Sl. 144), overlying the "Volcanic Group", comprising hornblende, epidote and garnetiferous schists. This group is correlated with epidote and other schists of "Signaller's Camp" and in the Tsavo Valley east of Kitchwa ya Tembo.

4. Slabby quartz-schists, ferriferous and garnetiferous and associated with tourmaline and other pegmatites. The locality here is known as "Fortifications" (Peg 449). The schists overlie fine-grained well-foliated slightly banded biotite-gneiss.

Gap.

5. Coarse muscovite-pegmatites.

6. Small exposure of friable mica-schist.

7. Thin-bedded quartz-schist with muscovite, including band of biotite-rich schist. The branch track to Longa-Longa turns south here (Peg 456).

Gap with lava outcrops along the main track.

8. Thin beds of marble alternating with dominant kyanite-schists and some mica-schists. Another branch track turns off to the south here.

Gap of nearly a mile, followed to the south by:

9. Fine-grained micaceous banded schist. About one mile north-north-west of this outcrop, along the strike there is a group of laminated quartzites (III. 40. Sl. 121, 121a). Mica and kyanite-schists, garnetiferous muscovite-schists form a low ridge with occasional hills overlooking flat sandy ground as far as the River.

The northern boundary of the eastern part of this section is the east and west Tsavo Valley fault or thrust.

(2) PETROGRAPHY OF THE ROCKS OF THE MZIMA BEND AND THE LOOSOITO RANGE

(a) The Quartzites

It should be noted at the outset that the "Argillaceous Group", so-called to distinguish it from the ortho-gneisses and para-granitoid gneisses of the eastern section of the Tsavo traverse, nevertheless frequently includes quartzites or quartzose schists containing a noteworthy proportion of silica. The principal outcrop of such rocks—the Loosoito, Kevas and Murka Hills which together form a broken and isolated strike ridge about ten miles long south of the Ethiopian Refugee Camp—may be considered first. The hills are built of many varieties of kyanite-schist and quartz-schist with considerable variation in the proportion of the two dominant minerals. The strike, running through the three hills, curves slightly from 347° at Loosoito to 332° at Kevas and again to 335° at Murka. The dip is to the east at about 40° to 45° . Like the hills at Maktau this ridge rises sharply from a sandy scrub-covered plain which gives no

geological information. The quartzites are the coarsest found in the area but where examined are not associated with conglomerate bands. Typically they weather with a rough almost scoriaceous surface, bedding being indicated by differences in the sizes of the constituent grains. It is suggested that they were deposited near the edge of the basin.

Fragments of hornblende-schist, locally markedly garnetiferous, lie scattered along the western slopes and an exposure of the parent rock is found about a third of the way up the hill. It shows a laminated streakiness of the basic and-acid elements and semi-pegmatoid eyes round which the foliation of the gneiss bend. This composite gneiss is considered to be probably a sill.

Specimens of quartzites or quartz-schist of different types were examined from the locality called "Fortifications" about three-quarters of a mile west from the Mzima River junction. Characteristically, these schists are well-banded and dark-coloured, and regular alternations of ferriferous and quartzose material are common. The presence of red garnet in some quantity is not rare and flakes of graphite occur in several instances as a minor constituent. The slabby habit is very marked. This quartzite group underlies the so-called "Volcanic Sub-Group" mentioned below.

One or two points are noteworthy, such as the extraordinary irregular or amoeboid shape of the quartz crystals which show no elongation along the foliation, while the inclusions they contain and the associated garnets are markedly orientated (Sl.60). This peculiarly leads to the conclusion that the rock has been subjected to a process akin to annealing, which allowed of considerable movement in the molecules of the dominant minerals without disturbing the structure impressed at an earlier period on the other constituents or the inclusions they contain. Other slides (III.15.Sl.59) from the same locality show that the foliation planes have a tendency to flow round the garnet porphyroblasts in which polysynthetic twinning is evident (c.f. Harker, Fig. 100 A. p. 220). The foliation planes are marked by a larger proportion of graphite flakes than the surrounding laminae.

Two thin beds of quartzite overlie the "Volcanic Sub-Group", one just above it at Peg 447 (III.10.Sl.144) and the other at Peg 442 (III.9.Sl.143). The latter is an epidote-quartzite separated from the first by a small *mbuga*. The first is a brownish-grey, rather sugary-looking rock of distinctly fine-grain containing a little microcline and acid plagioclase. Accessory minerals are muscovite (rare), magnetite, epidote (rare), and small flakes of biotite having a pleochroism from a red-brown to almost black.

The epidote-quartzite, a very fine-grained, sugary-looking white rock, shows a streaky lamination due to the segregation of pale yellow epidote which is greenish-grey in thin section and has strong pleochroism. Minute zircons are common scattered through the quartz.

A typical fine-grained quartzite (III.17, Sl.57, Peg 460) with abundant well-orientated flakes of biotite occurs at the eastern end of the Tsavo bend to the north of the thrust. The slide contains minute fragments of almost colourless detrital garnet in noteworthy quantity, and also minute zircons. It can scarcely be doubted that this quartzite and others of rather unusual composition occurring on the same side of the fault and a short distance down the road to the west are derived from the same source. In these (Sl.64,65,66) minute zircons are extremely abundant though the garnets present certain differences. These types are now briefly described. They include an extremely well developed group of conspicuously laminated (i.e. bedded) quartzites (III.40.Sl.121,121a),* associated with mica-schists, which outcrop about one mile south of Peg 464 on the Tsavo traverse (on the branch track from Peg 456). One slide shows a mass of slightly kaolinized felspar, often untwinned and doubtless near to albite-oligoclase, in crystals measuring up to approximately .03 in. across, interspersed with quartz grains, the smaller of which are fairly uniform in size, markedly rounded, and about .005 in. across, the larger grains being about .01 in.

*Note the differences between these quartzites (See Parkinson, 1921, p. 25) and those conspicuous at Ajow, west of Eil Wak.

A little pyrites and a few flakes of white mica are among the accessory minerals. This more felspathic band gives place to the commoner type of quartzite composed of clearly defined grains of which only a few are feldspar, none apparently being microcline. A second slide shows more marked differences in the size of the quartzes defining the lamination, the larger among them exhibiting strain shadows. Feldspar is represented by a few water-clear crystals, indefinitely twinned. Flakes of graphite are common. In the hand specimen a row or two of flattened quartz pebbles about half an inch long are noteworthy.

A quartzitic rock of unusual type may be included here. It is a rather slabby iron-grey schist (I.165.SI.135) outcropping about 1½ miles on a bearing of 35° from Bulutoni water hole north of Ngulia I and contains an estimated amount of 25 per cent graphite and about half that amount of muscovite in long thin flakes. A certain amount of untwinned, water-clear feldspar may occur in this rock as in others but the great majority of the grains appear to be quartz.

A lath-shaped mineral has been so altered into an isotropic brown substance as to be unidentifiable by me.

The presence of quartzites amongst the para-gneisses north of the Tsavo is a not uncommon occurrence and it is suggested as a possible explanation that the arkoses which apparently form the greater part of the substance of the hills are interbedded with sandstones wherein the felspathic constituent was lacking and which hence were less receptive to the action of the agents of metasomatism.

(b) *Kyanite-Quartz Schists*

The kyanite forms extremely irregular outlines, discontinuous in a thin section. The crystals are embayed or subdivided by quartz grains but are relatively free from inclusions (c.f. Glenday and Parkinson, 1926. Pl. 40. Fig. 5). The quartz has a tendency to be markedly elongated parallel to the foliation but except for cracks and occasional strain shadows does not show marked signs of pressure. In some slides (SI.72) sillimanite occurs in minute needles oriented parallel to the foliation, and often forms ragged termination fringes on crystals of kyanite. It suggests, in combination with the less spongy character of the latter mineral a rather higher degree of metamorphism than is usually the case with the rocks outcropping near the Mzima bend. Sphene is an accessory, and minute crystals of magnetite appear to be characteristic. Rarely, yellow-brown crystals of rutile are seen. Hematite in minute brown-red flakes is noticeable in some slides associated with streaks and clots of magnetite, typically very closely associated with the skeleton kyanite.

Schists from Murka Hill are kyanite-quartz associations (SI.99).^{*} The characteristic mineral forms long blade-like crystals with ragged terminations but without the host of inclusions that distinguishes it elsewhere. In the specimen sliced, it considerably exceeds the quartz in quantity. Small honey-brown crystals of rutile, often idiomorphic, are an accessory mineral. The hand specimen is a cream-coloured fibrous rock showing the quartz as occurring in short strings and lenticles as well as embedded in the kyanite mass.

(c) *Kyanite-Graphite-Schists*

The introduction of wisps and dust of graphite if present in sufficient quantity may almost entirely obscure the body of the kyanite; so that it only becomes apparent between crossed nicols (III.29.SI.79). For field purposes, owing to the incomplete crystallization of the dominant constituent, the term "incipient" kyanite is used.

Such a rock (III.28.SI.78a) outcropping between the Tsavo River and the low hill called Longa-Longa contains ragged, extremely spongy porphyroblasts of kyanite, in a matrix of small fairly uniform quartz grains, abundant flakes of graphite and well-marked muscovite. The strong foliation bends round the kyanite and the porphyroblastic order appears to be, kyanite, muscovite, graphite, quartz, though a few small grains of the third mineral are included in the first.

^{*}Cf. the kyanite-quartz schist of the Tiroka R. area (Parkinson, 1913, p. 538).

A typical schist. (III.32.SI.67) from Longa-Longa shows rather better formed kyanite, but still with plentiful inclusions tending to be concentrated in an outer zone. Muscovite, abundant specks of graphite and a constituent believed to be altered scapolite, are also present.

(1) Rocks of doubtful origin, akin to Hornfels

The origin of these rocks is difficult to determine. They form small, scattered outcrops along half a mile of track at the Tsavo bend north of the Tsavo Valley thrust. Exposures are far from good, but they are as a whole of hard, quartz-felspar rocks in which some of the important constituent minerals are often not visible to the naked eye. Garnet and epidote are distinctive, and pyroxene in irregular flakes, occasionally altering to pale hornblende, is characteristic of some varieties. Minute crystals of zircon occur in nearly every slide.

The first of these rocks (III.25.SI.65, etc. Peg 465), differing slightly from the rest, is white and speckled with hornblende porphyroblasts up to one quarter inch long. The crystals constitute almost a quarter of the rock and lie with slight foliation in a very fine-grained matrix consisting of dusty ill-sorted quartz, enclosed in a feldspathic mesh through which are scattered pale pink garnets about .01 in. in diameter. A few small grains of semi-idioblastic epidote, minute crystals of sphene and zircon are the accessory constituents. The felspar (oligoclase) shows zoning and irregular patchy twinning.

The second (SI.64. Peg 465) is essentially of the same generic type; the garnets are more irregular in shape and spongy in texture, .04 in. in length or larger, and grains of epidote or zoisite are commoner. The felspar, often untwinned, is an oligoclase. This rock differs from the last in the presence of almost colourless pyroxene which has been partly replaced by a very pale hornblende.

The third (SIs.66,66a. Peg 467) is a variation of the same type, and is a garnet-pyroxene-scapolite rock. Irregular groups of small, rather rounded garnets, with linear arrangement are associated with small prisms of epidote and a little almost colourless pyroxene, as before. The very pale green hornblende by which the latter has been partly replaced shows a faint blue element in its pleochroism. The presence of scapolite and occasional grains of a carbonate are noteworthy differences from the two previous rocks. Minute grains of zircon are again very numerous.

About 200 yards to the east, also on the north side of the supposed fault, a rather friable though massive iron-grey hornblende-schist (III.24.SI.102. Peg 463-464) shows some relationship, not macroscopically but microscopically to the preceding rocks. It is fine-grained and the hornblende is just visible to the naked eye. It forms about a quarter of the rock, is apparently original and has normal pleochroism. The accessory constituents are small idioblastic garnets averaging about .01 in. in diameter, and zircons. Many of the felspar grains show wavy crystallization and zoning; their general composition is that of an oligoclase. In addition there is another mineral mixed haphazard with the garnet, and occurring characteristically in translucent cubes. It lacks the pinkish granulated surface of the garnet and usually measures not more than .005 in. across. The mineral is isotropic and has a refractive index distinctly higher than garnet. It is left undetermined—in most characters it agrees with perovskite.

Certain pyroxene-garnet-gneisses found in the eastern part of the Tsavo traverse, not far from the main-road bridge are comparable with those just described.

Of these the first (I.95.SI.27, Peg 62) was collected three-quarters of a mile south-east of the commencement of the Old Military Road.* It is a compact grey rock, with slightly greasy lustre showing very slight foliation, of which the constituent minerals are almost indistinguishable to the naked eye. In this section the rock is seen to be a pyroxene-garnet-gneiss, the pyroxene occurring in wisps and flakes largely altered

*For the purpose of this traverse, the Old Military Road, a product of the 1914-18 War, commences at a point on the Tsavo a little under three miles from the Tsavo railway bridge. It was followed (with an unimportant diversion to the east of Signaller's Camp) until it ended near the junction between the Mzimba and Tsavo Rivers. From its eastern end a new motor track was constructed eastward connecting to the main Kenani-Voi road.

into green hornblende. The garnet has no spongy texture and forms fairly compact rounded grains or is partially idiomorphic. Elongated, finger-like crystals of quartz are conspicuous. Microcline is absent and the feldspars as usually is the case are oligoclase to oligoclase-andesine. Magnetite and apatite are accessory minerals.

The second slide (Sl.43) was cut from a rock outcropping $1\frac{1}{2}$ miles from the commencement of the Old Military Road. It is a pyroxene-garnet gneiss and quartz is the dominant constituent, and as in the previous slide builds extremely elongated crystals, no doubt having consolidated under pressure and slight movement. The fragmentary-looking pyroxene, bluish-green in colour, is partially altered to green hornblende though part is probably original. The feldspar, generally only partially striped, is water-clear and of the same composition as in the last slide. Magnetite, sphene and apatite are accessory minerals.

(3) THE VOLCANIC SUB-GROUP

These rocks, essentially of basic composition and presumed to be of volcanic origin on account of varied composition and fine banding, are readily distinguished in the field by their clots and streaks of a pale yellow mineral identified as epidote. They pass by gradations into a foliated acid biotite-gneiss containing pegmatoidal veins.

They have been found in three places between the Tsavo road bridge and the bend of the river west of the Mzima junction. These occurrences will be discussed in order from east to west.

(a) Some nine miles west-south-west of the road bridge at Tsavo there are outcrops of a pyroxene-scapolite-epidote-gneiss (Sl.18), which is taken as a characteristic type. It consists of a matrix of quartz and oligoclase formed round earlier feldspar cores. Epidote occurs as an irregular mesh-work of unoriented, equisized grains which are sometimes enclosed in pale green pyroxene, now altered almost entirely into hornblende. The scapolite forms platy crystals having well-marked cleavage and high double refraction. It shows early stages of alteration. Accessory constituents are a carbonate, sphene, rare apatite and scattered minute crystals of zircon.

In a variation (I.108b, Sl.17) of this rock the pyroxene is seen to be completely transformed into skeleton plates of dark grass-green hornblende. The amount of carbonate, which is probably dolomite, is greater than in the previous slide, and the section shows a wider distribution of conspicuously zoned, but rarely twinned, water-clear secondary feldspar grown around eroded cores and forming a matrix which has corroded the other minerals. This zonal feldspar is oligoclase. Epidote is plentiful and scapolite builds smaller crystals than in the previous rock.

A second variation (I.108a, Sl.16) is more basic. It contains ragged plates of hornblende, possibly secondary, and a considerable quantity of equisized grains of unoriented almost colourless epidote. Scapolite is less common. As before, the untwinned oligoclase acts locally as a matrix to the other constituents which it has corroded to some extent. The feldspar is difficult to distinguish in ordinary light from the quartz.

Another specimen (I.108, Sl.15) almost identical with the last, is a pale greenish-white rock composed for the most part of minute granules of sugary epidote flecked with dark foliated crystals of hornblende. The epidote occurs in thin section as an almost colourless aggregate intergrown with plates of spongy, strongly pleochroic hornblende, .08 in. or more in length. The hornblende shows the blue-green element in its pleochroism which distinguishes the same mineral in the schists of the Suk Hills, (Glenday and Parkinson, 1927, p. 793) but only rarely in those of the country under consideration.

Dark grey, fine-grained hornblende-schists (I.107 and I.109), are closely associated with those just described.

(b) The second locality is at Signaller's Camp on the left bank of the Tsavo and almost under Rhodesian Hill. In many specimens the rocks are typical fine-textured, non-banded hornblende-schists, occasionally marked by lenticles of feldspar and quartz, and tinged with yellow owing to the presence of epidote. They are in their essential character, the same or closely related to the rocks just described.

In a typical specimen (Sl.46) original pale green pyroxene is common. Even in the limits of a single section, variation occurs rapidly from a hornblende-schist to a scapolite-pyroxene-schist containing accessory carbonate. The scapolite is altered to a fibrous, brown, opaque mineral referred to pinitite. The felspar (albite to acid oligoclase) is strongly zoned round corroded cores, the exterior portion having a refractive index almost exactly that of balsam. Sphene and a few grains of apatite are accessory constituents. Quartz is rare or absent. The principal features of this rock are repeated in another (Sl.47) from the immediate neighbourhood wherein corrosion by the zoned felspar is conspicuous. Twinning is common in the crystals, the structure running through the corroded core into the outer zone. There is a slightly blue tinge in the pleochroism of the hornblende for vibrations parallel to Z, which is rather characteristic in schists collected in the Suk country (Glenday and Parkinson, 1927, p. 793 *et seq.*). Carbonate is far from common, but granules of sphene are rather more plentiful than usual, and there are a few grains of apatite. The scapolite shows the fibrous brown alteration product in various degrees, certain crystals being in part almost opaque. In formation it preceded the hornblende.

In this exposure a thin irregular band of quartzite is intercalated in the basic schists. It contains some rather dusty albite-oligoclase and distinctive tufts of pale green actinolite, 5 mm. or less in length.

(c) At the third site ("Fortifications"), rocks (Sl.63) containing scapolite, epidote, hornblende and a carbonate in a feldspathic (oligoclase) matrix occur as before. They form a well-marked belt, 300 to 350 ft. in width overlying ferriferous quartz-schists and overlain in turn by a slabby quartzose gneiss (cf. metamorphosed sediments of the Magadi Railway, Parkinson, 1913, p. 538). With them are associated hornblende-epidote-schists, wherein the quartz and felspar form a mosaic, the latter not acting as a matrix to the other constituents as in neighbouring rocks. Minute zircons and a few grains of apatite are the usual accessory minerals (Sl.61).

As a variation to this series is a fine-grained, compact rock (Ill.12a, Sl.100, Peg 449) containing much epidote of a colourless variety, and hornblende and carbonate as important constituents. The latter is apparently dolomite. The grass-green hornblende forms skeleton plates, occasionally a quarter of an inch long which in the specimen mark the foliation by aggregation into thin streaky bands. The epidote, macroscopically without conspicuous arrangement, forms pale yellow clusters.

(4) THE SCHIST SERIES NEAR MGANGE, NORTH-WEST OF THE TAITA HILLS

A representative series of rocks from the Mgange Camp area, north of the Taita Hills has been examined. Natural sections are not plentiful and pits had to be dug—usually in very hard ground. The exposures thus made are reached by a track from Maktau which skirts the Taita Hills and connects with Ndi Station on the main railway line. With the exception of the road east of the Kedai sisal plantation, the track runs near very few outcrops.

The schists of Mgange are no doubt of the same series as those of the Mzima bend, and one may legitimately infer a continuous basin of deposition for seven or eight miles between the two. The Mgange rocks are, however, distinguished from those of the Mzima bend by the characteristic commonness of graphite, an absence of crystalline limestones, a diminished quantity of kyanite and the conspicuous appearance of actinolite in fan-like groups or as well-foliated crystals half an inch long. In one consisting almost entirely of actinolite, a few flakes of graphite are associated.

(a) *Quartzites* are found as thin beds representing metamorphosed silts in the otherwise argillaceous group. They contain hornblende, biotite, garnet and plagioclase as accessory minerals. One such rock (Ill.89, Sl.139) may be taken as a type. It is of a friable nature, light grey in colour, and finely laminated containing conspicuous graphite flakes, and spangled with small idiomorphic garnets which are replaced by irregular flakes of hornblende along certain bands. The graphite is distributed fairly evenly throughout the rock. Graphite dust enclosed in the quartz is irregularly distributed, some grains being crowded with graphite granules, others almost free of them. The felspar, which is generally not twinned, has a refractive index higher than balsam and is no doubt oligoclase.

This rock resembles a hornblende-plagioclase-quartzite (III.93.Sl.111) from the same locality, in which hornblende is distributed evenly as small ragged flakes throughout the section and shows a faint tinge of blue in its pleochroism.

Another quartzite (III.96.Sl.134), originally a fine silt, from Mgange, shows a little interstitial microcline wedged between the quartz grains. This is apparently the only felspar and may be a product of metasomatism.* The grains are of fairly uniform size unlike those of quartz which vary considerably and show strain shadows. White filmy mica, probably developed along slip planes, a red-brown strongly pleochroic mica (length .006 in.) in small rectangular, well-foliated flakes, a few crystals of graphite and a considerable number of minute crystals which may be zircon, are accessory minerals.

(b) *Graphite-kyanite-schists*.—A large variety of schists similar to those of the Mzima bend occur, and many are of argillaceous constitution, carrying graphite and kyanite. The graphite, apart from dusty inclusions, typically forms flakes having an average length of about .012 in. and breadth a tenth of that. Their edges are seen to be serrated in thin section. In one rock (III.88a.Sl.126) the section consists almost entirely of graphite (say 60 per cent) and quartz slightly clouded with graphite dust. Seen with the naked eye it has a uniform dark iron grey colour. Small almost colourless garnets, with graphitic inclusions are an accessory constituent.

A second example (III.97.Sl.128) is a massive graphitic-schist with marked foliation amounting almost to lamination. It contains kyanite which shows as lath-shaped crystals as much as .2 in. in length set in a pale yellowish matrix consisting of quartz and a partially altered, colourless allotriomorphic mineral forming thin irregular belts or aggregates parallel to the foliation. This second constituent is probably untwinned cordierite. The kyanite shows relatively few inclusions and has a pale blue to greenish tinge. The rock contains as fairly common constituents flakes of graphite and non-idiomorphic pyrites. Minute idiomorphic crystals of deep red-brown rutile and minute zircons are rare accessories.

In a third specimen (III.84.Sl.124) a colourless amphibole is sometimes closely associated with the kyanite as a felted mass. Such groups alternating with layers predominantly composed of quartz produces characteristic lamination and a thin slabby habit. The rocks are dark grey in colour, the foliation being marked by porphyroblasts of kyanite up to a quarter of an inch long. As a rule the matrix is unresolvable by eye or lens—in the slide the quartz grains barely average 1/100 in. long. Graphite flakes are fairly uniformly distributed.

(c) *Compact Graphitic Rocks with Garnet*.—In these rocks (III.79.Sls.125,125a), all occurring as far as yet seen near Mgange Camp, foliation is absent in the hand specimen and the fracture has a dull black almost silky lustre. In thin sections, traces of foliation can be made out here and there, marked by thin laminae and streaks consisting for the greater part of quartz. Slide 125 consists mainly of very fine dust, granules and flakes of graphite with a few conspicuous porphyroblasts of idiomorphic red garnet, containing only a few rare specks of graphite. In one instance the garnet is considerably cracked yet retains its form and is nearly a quarter of an inch across. A few crystals almost obliterated by graphitic dust show an elongated outline and such indications of cleavage and double refraction as indicate kyanite, while here and there an unmistakable crystal occurs. Between the graphite specks, irregular pin points of quartz, .001 in. across or slightly over, are detectable with crossed nicols.

Another specimen (III.79.Sls.130,132a) is essentially similar to the last but rather finer in grain. It is dull black in colour, sparkles with minute flakes of graphite and contains well-foliated crystals of kyanite. A few rusty, red spots are probably remnants of garnet. The quartz occurs in narrow approximately parallel streaks relatively free from graphite and thus indicates a foliation not otherwise visible. Graphite flakes forming a close mixture with it, seldom exceed .01 in. in length. "Ghosts" or incipient crystals of kyanite are found as before and may attain a length of .2 in.

A much more schistose rock (III.88.Sl.131) is thinly slabby in habit and conspicuously garnetiferous in some laminae. It contains approximately 33 per cent of

*In ordinary light the felspar has a faint pinkish tinge which allows it to be picked out easily from the quartz. Thus seen it gives the impression of a residual mineral in many cases.

graphite flakes, which are rather more lumpy in outline than usual. The thin elongated crystals of kyanite, not always easy to distinguish from the matrix, are markedly foliated. As before the pale red garnets contain little graphite and are here only partially idioblastic.

In another specimen (III.82.Sls.132-133) a rapid alternation between graphitic and aluminous laminae, shows that it is essentially the same as those already described, namely a compound of quartz and graphite containing incipient kyanite crystals full of inclusions. With the exception of a few spaces occupied by predominant quartz, the graphite is scattered evenly throughout the rock. The kyanite layers representing a different source of material consist of a felted aggregate of that mineral in a quartz matrix containing accessory flakes of graphite. Rare granules of zircon and brown-red rutile are found.

Another specimen (III.85.Sls.109,109a) is a compact rock, iron-grey in colour and possessing but little schistosity, which has small brownish-red garnets (about .07 in. in diameter) in a close-grained matrix, the constituents of which are irresolvable to the naked eye. The whole sparkles with specks of graphite. It has the appearance of being crushed. The exiguous translucent matrix in which the garnets are closely set is composed of quartz and probably feldspar and crowded with graphite flakes and dust. It shows evidence of bending in conformity with the outlines of the garnets. The garnets are practically free from graphite flakes, although containing very numerous minute inclusions of an unidentified translucent mineral in characteristic blebs. There is also a noticeable quantity of a constituent with prismatic outline, now almost opaque with greenish-brown decomposition products, which may be kyanite. The habit and double-refraction as far as can be seen agree with this mineral, which is common in many of the associated rocks. The garnets are greatly cracked and the cracks filled with opaque matter. Crystals of mineral considered as kyanite occur as oriented feebly translucent inclusions in some of them.

(d) *Actinolite Schists*.—One specimen (III.91.Sl.115) is a heavy dull-grey, well laminated schist, the constituents of which are usually too small to determine by the naked eye. Some layers, rather under half an inch thick, are seen in thin section to be composed practically entirely of tremolite or actinolite associated with a few flakes of graphite. The principal mineral, builds long lath-shaped colourless crystals, and has a maximum extinction angle of about 20°.

Other rocks contain kyanite and tremolite in a felted mass, the two minerals being not always easy to distinguish from one another. One example (III.80a.Sl.141) is macroscopically greyish-black, heavy, well-laminated, with thin "stony" layers.

Another specimen (III.90.Sl.140) is an iron-grey schist, in which the foliation is marked by numerous well-formed crystals of kyanite, up to .2 in. long, with silvery lustre on the planes of cleavage due to the presence of graphite. The greater part of the slide consists of kyanite with graphite dust segregated in streaks and zones parallel to the vertical axis and in lines along the partings almost at right angles to it. Crystals have in several cases separated at the partings and the cracks or fissures thus formed have become filled with graphite and other minerals. Alteration in the direction of the principal cleavage indicates movement after the kyanite at least had crystallized. The matrix consists of a fine quartz mosaic crowded with graphite specks. Locally it exhibits patchy polarization due to re-crystallization, recalling a "Fruchtschiefer". Now and again part of the outline of such an incipient individual can be distinguished as a definite boundary and the polarization colours are then those of kyanite. There is also some evidence of the replacement of kyanite by quartz. In the felt of kyanite crystals characteristic lozenge-shaped cross sections of hornblende can be distinguished.

A second slide (III.90.Sl.151) cut from this specimen shows some slight but interesting differences. The same rectangular "ghost" crystals are visible here and there in polarized light, and as before are, much masked by graphite dust. The larger kyanite crystals contain conspicuous lumps and flakes of graphite, but show a fan-like structure, with apparent local replacement by quartz between the kyanite filaments. These are frequently much bent. A few acicular, honey-brown crystals of rutile are noteworthy.

(5) THE CRYSTALLINE LIMESTONES

Marbles are found, either as isolated exposures or in belts consisting of several separate beds, at several places in the area. They are perhaps best developed near the Voi River where it crosses the Taveta Road near the junction with the Mbale (Taita Hills) Road. The marbles from here have been shown by Miss Hitchins, Government Chemist and Assayer, to contain a considerable amount of magnesian carbonate, varying in samples analysed from 38.79 per cent to 42.56 per cent. The most northerly outcrop seen in the Taita Hills, north of Msau, contains 5.8 per cent of iron, alumina, etc., the highest shown in any of the analyses made. The section, as is common on the steep slopes of the Taita Hills, is considerably slipped, but the marble appears to be about six feet thick and intercalated between mica-schists strung with acid veins. The dip is apparently almost due north.

Marbles were also found on the Tsavo River traverse about four miles west of Tsavo where the section, much obscured, appeared to be:—

Fine-grained biotite-gneiss.

Marble traversed by a pegmatite vein.

Binary gneiss.

Marble.

Biotite para-gneiss.

Marble.

?Quartzite.

An ortho-gneiss.

The beds are vertical, and the strike conforms with the usual direction, i.e., slightly west of north.

Small marble beds closely associated with kyanite-schists cross the Longa-Longa track running south from the western part of the main Tsavo traverse. Magnesian and calcareous carbonates in one sample were found to be 42.83 per cent and 55.88 per cent respectively. The rock contained only fractions of 1 per cent of either insoluble material or of oxides other than lime and magnesia.

The marble on the main road south of Kenani Station contains a marked proportion of graphite which probably accounts for the high percentage of insoluble material, viz. 7.20 per cent. The magnesian content is slightly lower than the other specimens analysed—33.15 per cent.

Taken as a whole the marbles are rather coarse, grains averaging about .2 in. across.

VI—COMPOSITE GNEISSES OF THE TAITA HILLS

The essential composition of the Taita Hills results from the impregnation of a great thickness of sedimentary rocks of, in general, an argillaceous type by an acid magma and its volatile constituents, which accomplished a complete renovation of the original deposits (cf. Parkinson, 1943 and 1944).

The intrusive relationship of the invading rocks can be seen in two exposures on the Bura Road—at the west end of the Meruga Road and at the hairpin bend of the Wusi Road south-west of the C.M.S. station.

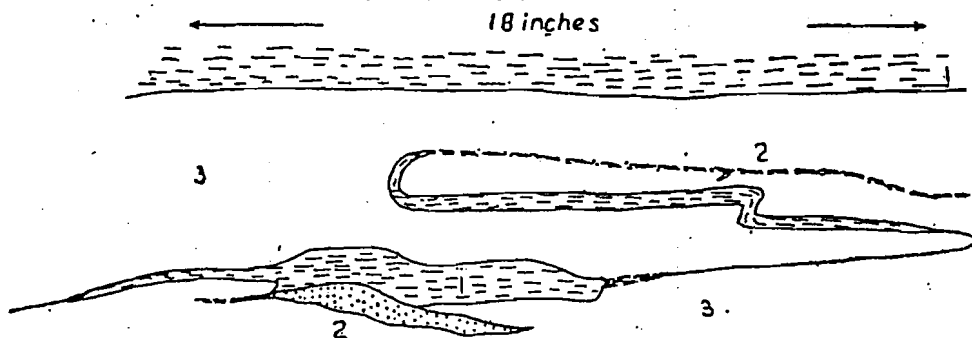


FIG. 4

Intrusions of biotite-gneiss and pegmatites, Meruga Road, near Yale, Taita Hills: 1, Biotite-gneiss; 2, Pegmatitic aggregate of quartz and feldspar; 3, very dark grey biotite hornblende gneiss.

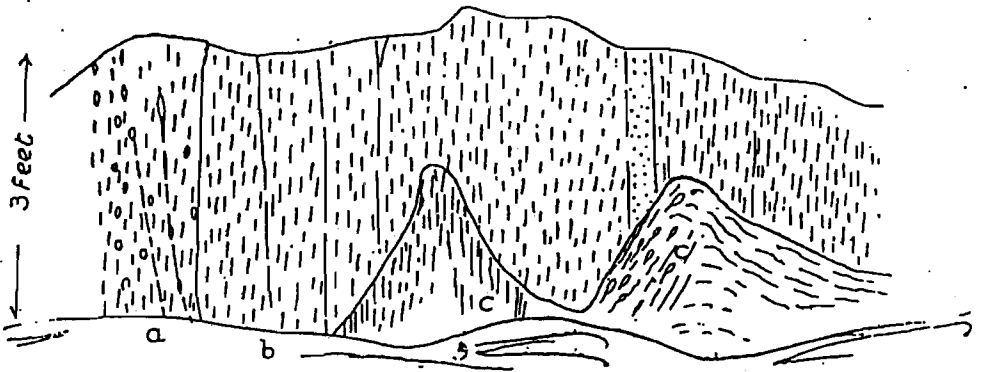


FIG. 5 .

Section at the west end of the Meruga Road, Taita Hills, showing the composite nature of the gneisses; (a) biotite augen-gneiss; (b) acid gneiss, with some biotite; (c) biotite gneiss, becoming porphyritic at c'.

At these localities the intruding rock is (a) a compact fine-grained gneiss speckled with biotite flakes, and (b) a rather coarse quartz-felspar aggregate with large phenocrysts of felspar and occasionally small nests of mica, occurring as veins or ovoids parallel to or slightly transgressing the general direction of foliation. Although innumerable variations occur, the essentially consanguineous nature of the intrusions is apparent throughout. The road sections show these hard resisting rocks alternating with more extensive exposures of fine buff or terra-cotta soil wherein frequently the bands and foliation of the now decomposed host rock can be plainly discerned.

In some instances, fracture of a part of the host rock took place when it was almost in a solid state and was accompanied by the breaking off of fragments, now represented by wisps and films of micaceous material, which have been drawn out in the direction of movement and frequently partially absorbed. Such action may be very local, though variations in the basicity of the mica-schists are doubtless due to such assimilation. Presumably the earliest phase was that of the introduction of volatile constituents from an underlying magma.

The intimate relation existing between the two principal types of acid intrusion militates strongly against the earlier or compact quartz-felspar schist being a felspathic quartzite, for which it might be mistaken. The late J. W. Evans suggested the term "pegmatoid" for such quartz-felspar aggregates as are characteristic of these composite gneisses. Partially disintegrated remnants of them can often be seen clearly when other traces of the original structure have entirely disappeared. Excellent examples of this state can be seen in cuttings on the Bura Road where the original rock is reduced practically to a sand, sufficiently compact to stand in a vertical face, but in which "ghosts" of the all but destroyed micaceous xenoliths are clearly visible. The writer believes that far more of the soil of such areas is decayed schist than would be thought probable at first sight.

It is noteworthy that there is no transition zone from hard to soft rock. The harder rocks form definite ridges which extend for miles and form the highest ground. As an explanation, it is suggested that they occupy positions of original easy permeation by an acid magma or of fluids derived from it, the introduction of new material in the form of *lit-par-lit* injection producing a reinforced condition capable of resisting stress. On the whole the process was characteristically gentle. Uniform grey gneisses and occasionally augen-gneisses are the almost perfect hybrids, and show no trace of permeation or intrusion except in the nature of the rock finally produced.

The most characteristic topographical feature of the district are the massive "beds" of "hard" rock which form, for instance, the Vuria and Yale ridges, and it is possible that, if a contour map of the hills were available, the "tectonic" structure of the whole would become much clearer. A sketch map based on prismatic compass traverses with added form lines has been prepared on a scale of 62,500 and shows this possibility.

It should be noted that no granitic mass has been seen in the area representing the batholith from which the apophyses of acid gneiss and pegmatoids have been derived. An interesting distinction between this area and the valley of the Tsavo is the abundance of vein and float quartz in the latter, whereas in the former both are rare.

VII—SUMMARY OF GEOLOGICAL CONCLUSIONS

1. The rocks dealt with in this preliminary survey are mainly metamorphosed sediments of the Basement System.

In Kenya, similar rocks are found in:—

(a) the Suk Hills;

(b) west of Eil Wak;

(c) south of Marsabit;

(d) in the Machakos District and probably elsewhere in the Colony. These various basins of deposition cover collectively an area of approximately 120,000 square miles and one would imagine, failing contrary evidence, that they were lain down in a continuous sheet of water, or, that the barriers between adjacent basins were narrow.

2. Throughout this great area the degree of metamorphism was uniform.

3. Volcanic rocks are scantily represented.

4. Arenaceous gneisses predominate over much of the area.

5. Crystalline limestones, usually with a high magnesium content, occur sporadically throughout and the argillaceous and calcareous beds tend to be thin and lenticular, indicating quiet deposition influenced by currents.

6. It is considered probable that the Basement System rocks as seen in Kenya, and their doubtless very extensive southern extensions form a roof pendant, which was partly immersed in a batholith of earlier date than the emplacement of the great Central Batholith of Tanganyika.

7. It is put forward, but as a suggestion only, that the intrusive orthogneissic dykes exposed near Mtito Andei, along the lower reaches of the Tsavo River, west of the railway bridge, and in many places in the Taita Hills, may indicate propinquity to one wall of the encasing batholith.

8. The altered sediments of the Tsavo Basin have been divided into two groups, which have not been seen together in natural contact. They comprise an earlier group of arenaceous facies, originally probably arkoses, and, a later group largely formed of argillaceous sediments. It would appear possible that the former has been subjected to the process known as "penetration by soaking".

Further work may prove an unconformity between the two groups, showing that the lower arenaceous sub-division formed the surface upon which the argillaceous sediments were lain down. The petrological characters of the two groups which are markedly different, as well as the types of deposition, indicate physical changes which give some support to this suggestion.

VIII—ECONOMIC MINERALS

KYANITE

Kyanite is chiefly found on the western side of the southern part of the area, e.g., at Mzima (Longa-Longa) and in the Loosoto and Murka Hills. The mineral occurs in quantity at these localities but is always full of inclusions. Large white crystals with blue centres were not seen save in exceptional instances. Microscope examination shows that usually it is little more than a skeleton, the principal impurity being finely divided iron, or graphite. The outcrops are within about ten miles of water and transport.

ASBESTIFORM TREMOLITE

Narrow veins of this type of asbestos have been found in actinolite-schist on the north side of the Taita Hills in the Mgange district. It is quite probable that intensive prospecting in this neighbourhood would result in more extensive deposits being found.

GRAPHITE

Graphite as a rock constituent is widely spread in the Argillaceous Group in schists of various sorts and as specks in crystalline limestones. Contamination with flakes of mica is common. If sufficient tonnage could be found in localities favourably situated with respect to transport and water the mineral would probably be worth working. The graphite gneisses extending along the right bank of the Athi are at present (1941) under examination with a view to their economic exploitation.

MICA

Pegmatites are widely distributed but seldom show mica in sufficiently large books to be of value. Rather more favourable indications were seen near Mgange in the foothills of the Taita and it is possible that additional prospecting might prove successful.

IX—REFERENCES

- Glenday, V. G. and Parkinson, J., 1926.—"The Geology of the Suk Hills." *Quart. Journ. Geol. Soc. London*, LXXXII, part 4, pp. 586–614.
- and —, 1927.—"The Kateruk Series and Associated Rocks of the Northern Suk Hills (Kenya Colony)." *Quart. Journ. Geol. Soc. London*, LXXXIII, pp. 790–799.
- Grantham, D. R., Temperley, B. N. and McConnell, R. B., 1940.—"Explanation of the Geology of Degree, Sheet No. 17 (Kahama)," Bull. No. 15, Department of Lands and Mines, Geol. Div., Tanganyika.
- Harker, A., 1939.—*Metamorphism*. London.
- Parkinson, J., 1913.—"On a group of Metamorphosed Sediments situated between Machakos and Lake Magadi in British East Africa." *Quart. Journ. Geol. Soc. London*, LXIX, pp. 534–539.
- , 1920.—"Report on the Geology and Geography of the northern part of the East African Protectorate." *Col. Rep. Misc.*, No. 91. Cmd. 729.
- , 1943.—"A note on the Taita Hills, Kenya Colony." *Geog. Journ. C.I.*, No. 4, pp. 161–162.
- , 1944.—"Discussion (p. 153) on Yu Chi Cheng's paper—The Migmatite area around Bettyhill, Sutherland." *Quart. Journ. Geol. Soc.* XCIX, parts 3 & 4, pp. 107–148 (paper read 1942).
- Stockley, G. M., 1943.—"The Pre-Karoo Stratigraphy of Tanganyika Territory." *Geol. Mag.* LXXX. No. 5, pp. 161–170.
- Tyndale-Biscoe, R., 1940.—"The Geology of the country around Gwanda." Bull. No. 36, *Geol. Surv. of S. Rhodesia*.
- Wade, F. B. and Qates, F., 1938.—"An explanation of Degree Sheet No. 52 (Dodoma)," Short Paper No. 17, Department of Lands and Mines, Geol. Div., Tanganyika.

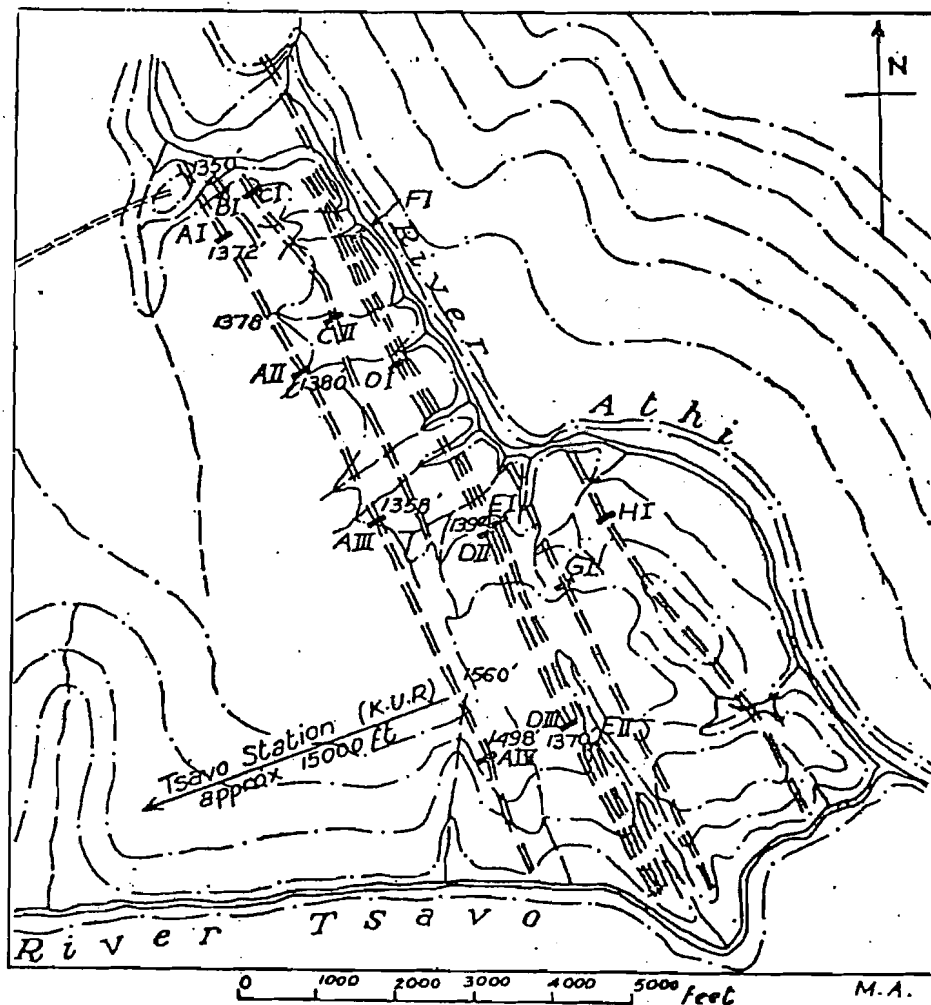
APPENDIX I

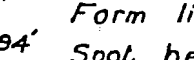
GRAPHITE DEPOSITS, TSAVO

Introduction.—During the course of his geological survey of the Mtito Andei-Tsavo area, Dr. Parkinson discovered an extensive belt of graphite gneisses west of the confluence of the River Tsavo and the River Athi, and near Tsavo station on the Kenya-Uganda Railway. Though the gneisses are low grade ores several considerations suggested that they were worthy of more detailed examination. Preliminary work had shown that several graphite bands are present and that the group extends over at least 15 miles. Bands containing sufficient graphite to be probably workable appeared to vary from 20 to 50 ft. in thickness, so that sufficient quantities of ore for large scale operations could be anticipated. Other factors were favourable for mining operations, viz., ample perennial water supplies are available from the River Tsavo, the deposits are close to Tsavo railway station which is only 136 miles by rail from Mombasa, and the ore appeared to contain no white mica and little dark mica, the principal "gangue" minerals being quartz and felspar.

At one locality a graphite-quartz vein cross-cutting the gneisses was found. The graphite in it is massive and made up a considerable part of the vein, which is, however, of too restricted extent to be of more than mineralogical interest.

Prospecting.—Further investigation of the deposits was considered advisable, but Dr. Parkinson was unfortunately compelled to relinquish his appointment owing to ill-health. Field work was, however, carried on by a prospector, in the north-western angle of the Tsavo-Athi confluence, as that is the most advantageously situated portion of the belt. The graphite-rich horizons were traced and mapped, and several cross-trenches were dug to a depth of ten feet for sampling and to determine the width of the bands.





Form lines
 Spot heights by aneroid
 Graphite bearing
 formations - A.B.C.D.E.F.G.&H.
 Cross trenches
 Paragneisses,

Surveyed by B.A.Brannstrom

FIG. 6

Graphite deposits, Tsavo.

This investigation revealed the presence of eight graphite-rich bands, indicated by letters A to H on Fig. 1. The strike of the bands was found to be generally about 335° and the dip steep to vertical. Some bands were traced continuously over a distance of two miles. Over much of the strike the overburden was one foot or less in depth, and in many places the gneisses were exposed at surface. At other places they were decomposed to depths of up to six feet and yielded friable ore. At greater depths blasting was necessary to penetrate the rock, though it was obvious that it would be readily amenable to crushing. By aneroid it was determined that the highest parts of the bands varied from 20 to 240 feet above the river beds.

Sampling and Assay results.—In all 15 trenches were excavated, and samples, taken in horizontal cuts over lengths of 10 feet, were obtained from 10 of them. The samples were crushed and the graphite floated off and the approximate percentage of carbon in the concentrate determined. The results were as follows:—

% OF EXTRACTABLE GRAPHITE.

TRENCH.	East End of Trench.			West End of Trench.		Average for Trench.
	0-10 ft.	10-20 ft.	20-30 ft.	20-40 ft.	40-50 ft.	
AI	6.26	3.83	2.85	3.70	3.47	4.0
A.III	5.50	4.87	1.87	5.14	—	4.3
A.IV	6.97	9.03	7.77	—	—	7.9
BI	5.83	—	—	—	—	5.8
C.I	6.24	7.68	—	—	—	6.0
C.II	4.75	4.19	—	—	—	4.4
D.I	6.93	5.70	—	—	—	6.3
D.II	5.66	9.47	6.72	5.15	(0.54)	6.7
D.III	8.12	8.94	5.84	6.64	—	7.4
E.II	6.62	4.67	—	—	—	5.6

Weighted overall average value = 5.8 per cent.

These results were obtained by flotation of -30 mesh material in a small laboratory cell using pine oil as frother, the concentrate being washed, dried, ignited at a low temperature (about $400^{\circ}\text{C}.$) and finally ignited at $900^{\circ}\text{C}.$ to burn off the carbon. No great accuracy can be claimed for the results, but they were sufficient for the purpose.

Petrography.—Examinations of thin sections by Dr. C. S. Hitchen disclosed that the principal constituents of the ore are quartz, feldspar and graphite, the latter in characteristic flakes, attaining in some cases a diameter of five mm. Subordinate biotite, some of which is bleached, was noted and minute amounts of sericite. The feldspar was found to be of potash and soda lime varieties,* mainly fresh but in part affected by kaolinization that has spread along cracks and cleavages. Zircon is present as an accessory.

Experiments on the extraction of the graphite.—Experiments were carried out by Hitchen to determine the amenability of the ore to flotation. It was found that a good separation could be effected using pine oil (up to 1 lb. per ton, a figure that was considered to be considerably in excess of what would be required in mill practice) as a frother, and 1-3 lb. per ton of sodium silicate as a depressant. With ore crushed to -40 mesh an initial separation of 98 per cent was obtained, using pulp densities of 7-10 per cent solids. Using -30 mesh ore the separation appeared to be about 90 per cent.

Further tests showed that if the froth was allowed to stand for a period of a half to one hour a considerable amount of gangue fell away from it, suggesting that the use of shallow settling tanks between rougher and cleaner cells would be advantageous. In addition it was found that on crushing the ore to about -10-mesh the greater part of the graphite and feldspar was reduced to a finer grade, the coarser fraction consisting of quartz grains containing little graphite. From this it was judged that partial reduction followed by screening prior to flotation would materially reduce the cost of extraction.

*Dr. Parkinson found only oligoclase in his slides, though in one case it was slightly perthitic.

This investigation revealed the presence of eight graphite-rich bands, indicated by letters A to H on Fig. 1. The strike of the bands was found to be generally about 335° and the dip steep to vertical. Some bands were traced continuously over a distance of two miles. Over much of the strike the overburden was one foot or less in depth, and in many places the gneisses were exposed at surface. At other places they were decomposed to depths of up to six feet and yielded friable ore. At greater depths blasting was necessary to penetrate the rock, though it was obvious that it would be readily amenable to crushing. By aneroid it was determined that the highest parts of the bands varied from 20 to 240 feet above the river beds.

Sampling and Assay results.—In all 15 trenches were excavated, and samples, taken in horizontal cuts over lengths of 10 feet, were obtained from 10 of them. The samples were crushed and the graphite floated off and the approximate percentage of carbon in the concentrate determined. The results were as follows:—

% OF EXTRACTABLE GRAPHITE.

TRENCH.	East End of Trench.			West End of Trench.		Average for Trench.
	0-10 ft.	10-20 ft.	20-30 ft.	20-40 ft.	40-50 ft.	
AI	6.26	3.83	2.85	3.70	3.47	4.0
A.III	5.50	4.87	1.87	5.14	—	4.3
A.IV	6.97	9.03	7.77	—	—	7.9
BI	5.83	—	—	—	—	5.8
C.I	6.24	7.68	—	—	—	6.0
C.II	4.75	4.19	—	—	—	4.4
D.I	6.93	5.70	—	—	—	6.3
D.II	5.66	9.47	6.72	5.15	(0.54)	6.7
D.III	8.12	8.94	5.84	0.64	—	7.4
E.II	6.62	4.67	—	—	—	5.6

Weighted overall average value = 5.8 per cent.

These results were obtained by flotation of -30 mesh material in a small laboratory cell using pine oil as frother, the concentrate being washed, dried, ignited at a low temperature (about 400°C.) and finally ignited at 900°C. to burn off the carbon. No great accuracy can be claimed for the results, but they were sufficient for the purpose.

Petrography.—Examinations of thin sections by Dr. C. S. Hitchen disclosed that the principal constituents of the ore are quartz, felspar and graphite, the latter in characteristic flakes, attaining in some cases a diameter of five mm. Subordinate biotite, some of which is bleached, was noted and minute amounts of sericite. The felspar was found to be of potash and soda lime varieties,* mainly fresh but in part affected by kaolinization that has spread along cracks and cleavages. Zircon is present as an accessory.

Experiments on the extraction of the graphite.—Experiments were carried out by Hitchen to determine the amenability of the ore to flotation. It was found that a good separation could be affected using pine oil (up to 1 lb. per ton, a figure that was considered to be considerably in excess of what would be required in mill practice) as a frother, and 1-3 lb. per ton of sodium silicate as a depressant. With ore crushed to -40 mesh an initial separation of 98 per cent was obtained, using pulp densities of 7-10 per cent solids. Using -30 mesh ore the separation appeared to be about 90 per cent.

Further tests showed that if the froth was allowed to stand for a period of a half to one hour a considerable amount of gangue fell away from it, suggesting that the use of shallow settling tanks between rougher and cleaner cells would be advantageous. In addition it was found that on crushing the ore to about -10-mesh the greater part of the graphite and felspar was reduced to a finer grade, the coarser fraction consisting of quartz grains containing little graphite. From this it was judged that partial reduction followed by screening prior to flotation would materially reduce the cost of extraction.

*Dr. Parkinson found only oligoclase in his slides, though in one case it was slightly perthitic.

A sample of concentrates containing 84.8 per cent carbon produced by the method described was sent together with samples of the ore to the Imperial Institute. These were submitted to a refractories company who reported that the deposits were worthy of exploitation and suggested that, if available, friable surface ore should be worked and treated in launders as has been the practice on some Madagascar mines. It was later stated that the Tsavo material was the most promising Colonial graphite that had been examined.

Commercial exploitation.—As the deposits appeared worthy of serious consideration applications were invited from the public in May, 1942, to work a concession in the north-west angle between the River Athi and the River Tsavo. In January, 1943, a special licence was issued to Messrs. Kitmag, Ltd., covering an area of 160 square miles, and including all the known deposits. Preliminary sampling had indicated that over the area tested ore averaging about seven per cent graphite could be expected.

As a result of experiments it was decided that the following method of extraction should be adopted provisionally:—

1. Crush to 14 mesh.
2. Soak 12 hours in water.
3. Flotation (in batch tests the proportions found most satisfactory were: ore, 4½ lb., water, 2½ gal., pine oil, 10 drops).
4. Dry concentrate.
5. Screen dried concentrate on 20, 40, 60 and if necessary on 90 mesh sieves.
6. Roll each grade, to flatten graphite and comminute quartz and felspar.
7. Re-screen each grade, when most of the gangue is passed, graphite being retained and yielding concentrates of 85 per cent or more carbon content.

The undersizes from the -60 mesh or -90 screenings were to be retained for further treatment. The screen analyses of products obtained by this process was:—

	Per cent
+ 20 mesh I.M.M.	15.7
-20 I.M.M. + 40 mesh B.S.	37.4
-40 B.S. + 60 mesh B.S.	46.9

(Complete sets of screens of one system were not available).

When work was begun on the concession a pilot plant capable of dealing with one ton of ore per day was erected. Subsequently a further special licence was granted to Messrs. Kitmag, Ltd., for a period of two years over an area of 44 square miles, covering the deposits north of the River Tsavo.

Plant was erected including a two head stamp battery, flotation cells, rolls, vibrating screens and driers. Provision was also made for obtaining an air-floated fraction during screening. The stamps proved unsatisfactory and it was realized that rolls would give a more satisfactory comminution of the ore. Full scale rolls were not obtained, however, and the mine continued to operate as best it could with the inefficient plant already installed.

The grades of graphite obtained, in relatively small quantities, are indicated by the following test results:—

Grade of Concentrate.	Treatment.	% C.	% Moisture.	Remarks.
1. +20 mesh	Once rolled	88.1	—	—
-20 + 40 „ „		85.1	—	—
-40 + 60 „ „		75.8	—	—
2. +20 „ „	Twice rolled	92.6	—	—
-20 + 40 „ „		91.0	—	—
-40 + 60 „ „		83.9	—	—
3. -20 + 40 „ „	Thrice rolled	91.1	0.24	Lubricant type.
-40 + 60 „ „		88.8	0.24	
-60 + 80 „ „		95.3	0.32	
4. +20 „ „	Twice rolled	94.3	0.61	Crucible grade.

The size grading of some of the concentrates (crucible grade) is shown by the results of three tests detailed below:—

SCREEN GRADING.				WEIGHT %.		
				Test 1.	Test 2.	Test 3.
	+20 mesh I.M.M.	..		4.4	5.7	4.4
—20 I.M.M.	+30 „ B.S...	..	{	41.1	21.6	19.8
—20 B.S.	+40 „ B.S...	..			30.2	34.6
—40 B.S.	+60 „ B.S...	..		35.0	35.4	33.7
—60 B.S.	+90 „ B.S...	..		15.7	4.8	5.0
—90 B.S.	„ ..	..		3.3	2.2	2.2
				99.5	99.9	99.7
Carbon Content				90.4%	84.7%	84.6%

It is reported that the mine has been closed for production since April, 1945. Interest in Europe is, however, still maintained in the deposits, and in the latter part of 1945 a bulk sample of the ore, presumably for extraction tests, was sent to England.

Production.—The production from the mine according to returns in the files of the Mining and Geological Department is as follows:—

MONTH.	Ore Treated Tons.	Crucible Grade in lb.	Foundry Grade in lb.	Lubricant Grade in lb.	Stove Polish in Number of Blocks.
1944.					
June	No record	336	—	—	—
July	„ „	145	564	—	—
August	„ „	3,360	8,960	—	—
September	„ „	—	8,960	2,390	—
October	220	—	—	2,630*	—
November	390	—	11,300*	—	576*
December	432	6,319*	—	—	—
1945					
January	none	—	11,200	—	800*
February	230	20,160	(lb. concentrates)		—
March	none	3,920	1,120	1,120	2,690 (1,730*)
May	none	—	—	1,120	—

* Denotes sales.

The value of these products is not known but is probably of the order of £1,500.

Constitution of the ash residue.—The ashes obtained by calcination of samples submitted for carbon determination were examined under the microscope. Minerals identified were generally small grains of red iron ore, quartz and felspar, occasional grains of cf. ilmenite, white mica, cf. clinozoisite and rutile, scattered large flakes of biotite and abundant plates of a colourless feebly birefringent mineral that was thought to be probably a dehydrated kaolinite. The latter frequently occurs as skeleton plates, and evidently it is in the rock intimately intermeshed with the graphite flakes, so that its elimination by ordinary processes of ore-dressing is impracticable.

Partial analysis of a sample of ash gave the following result:—

Analysis of ash from -20 and -20+40 mesh samples in equal amounts.
(Ash 10 per cent)

									Per cent
SiO ₂	..	..	..	..	..	..	..	..	64.29
Al ₂ O ₃	..	..	..	..	..	..	..	..	21.13
Fe ₂ O ₃	..	..	..	..	..	..	..	..	5.14
MgO	..	..	..	..	..	..	..	..	1.86
CaO	..	..	..	..	..	..	..	..	2.78
Na ₂ O	..	..	..	..	..	..	..	..	0.58
K ₂ O	..	..	..	..	..	..	..	..	3.16
TiO ₂	..	..	..	..	..	..	..	..	0.84
Total	..	..	..	..	..	..	..	..	99.78

Analyst, Miss A. F. R. Hitchins,
Chemist and Assayer.

Apparently no petrographic examination was made of the samples before analysis, and it is difficult to derive from it any reliable idea of the proportions of the minerals present. Assuming, however, that it had the constitution of ashes previously examined, it appears probable that the platy colourless mineral forming the greater part of the residues, is more akin to pyrophyllite than kaolinite or at least to a more highly silicated member of the hydrous aluminium silicate family. The optical properties of the dehydrated mineral in no way suggest pyrophyllite, though correspondence would not be expected after the mineral has been subjected to calcination, at a temperature sufficiently high to allow the elimination of the total carbon content.

APPENDIX II

KYANITE DEPOSITS, MURKA

Introduction.—It will be apparent from Dr. Parkinson's report that he discovered numerous occurrences of kyanite-bearing rocks among his Argillaceous group of the Basement System. It is clear from the description he gives that he realized that the deposits most likely to be of economic value were those on Murka Hill in the south-western part of the area. In 1942, Messrs. Markham and Co., became interested in the production of kyanite refractories and Sir Charles Markham who was prospecting the area concluded that the deposits on Murka are extensive, including considerable tonnages of readily worked boulders at the base of the hill, and worthy of exploitation. As a result mining claims covering the deposits were pegged in October, 1942. Since then the deposits have been worked discontinuously according to demand, and research has been carried out in connection with calcination to convert the kyanite to mullite for use in refractories. Messrs. Markham and Co. announced the production of mullite refractories in January, 1943, and at a later period they have been made by the Industrial Management Board.

Geology of the Deposits.—Dr. B. N. Temperley of the Geological Survey of Tanganyika visited Murka in October, 1942, while acting as geologist for the East African Industrial Research and Development Board. He was able to spend only a few hours at the locality but determined that the kyanite deposits occur as interbeds in a series of siliceous gneisses, with a dip of about 30° to the north-east, i.e., the western face of the hill is a scarp slope, and the eastern face a dip-slope. He found that one of the kyanite-rich beds forms the crest of the hill which extends, at an altitude of about 300 feet above the surrounding plain, over about 1,000 yards, and as a low ridge that continues to the north of the hill. Huge segregations of almost pure kyanite ranging up to several hundreds of tons in weight were noted, particularly at the southern end of the hill, where they were considered to have fallen from the outcrops on the ridge. Temperley considered that the segregations have survived disintegration owing to their lack of foliation and freedom from easily disintegrated minerals. He concluded that reserves are extensive.

In June, 1943, the deposits were re-examined by Dr. E. Parsons. He confirmed generally the findings of previous investigators, and noted that the kyanite segregations vary from a few inches to six or seven feet in diameter, and have "skins" of kyanite

gneiss containing quartz and rutile. The kyanite of the segregations is of bluish type, and between contiguous masses there are felts of white kyanite that were shown microscopically to be remarkably pure. Dr. Parsons found that segregations of workable size were rare at points more than 250 yards north of the southern end of the hill. On its south side he discovered two extensive pockets and was able to trace at least three indistinct bands on the west face, the bands thinning and fingering out to the north. He mapped three zones of massive detrital kyanite on the low ground south of the hill and considered that they represent the remains of more readily weathered kyanite gneiss bands rather than material fallen from the massive kyanite zones on the present hill.

Kyanite deposits that appear to be closely similar to those of Murka have also been described from Nyasaland (*Bull. Imp. Inst.* XXXVI, No. 4, 1938, p. 495).

Constitution and composition of the ore.—Separation in heavy liquids of ground samples of the ore yield heavy fractions consisting mainly of kyanite with a few rutile grains, and light fractions consisting mainly of quartz but sometimes with a little mica and felspar. Separations made at various times gave the following results:—

	1	2	3	4	5
Moisture	0.25	—	—	—	—
Light fraction	2.8	8	16.8	0.6	0.88
Kyanite and a little rutile	96.95	92	82.8	99.4	99.12
Totals	100.00	100	99.6	100.0	100.00

1. A hand-picked sample, bromoform separation.
2. Average hand sample, bromoform separation.
3. Run-of-mine ore, before hand-picking, bromoform separation.
4. Bromoform separation of a sample from a shipping consignment: dried and crushed to -60 mesh.
5. Separation by washing in water of another portion of the same sample, as No. 4, dried and crushed to -60 mesh.

It was found that with a little hand-picking, ore of 90-95 per cent. purity could be consistently obtained.

Two chemical analyses of the material are available (analyses of other kyanites are quoted for comparison):—

	1	2	A	B	C
SiO ₂	37.38	35.88	36.8	34.66	31.07
Al ₂ O ₃	59.65	61.00	63.2	60.84	65.52
Fe ₂ O ₃	0.56	0.30	—	0.07	1.50
MgO	0.07	0.08	—	n.d.	0.04
CaO	0.27	0.12	—	n.d.	0.34
Na ₂ O	n.d.	0.24	—	n.d.	n.d.
K ₂ O	n.d.	0.12	—	n.d.	n.d.
Loss on ignition ..	0.60	0.60	—	0.90	—
TiO ₂	1.09	1.48	—	1.18	1.43
Totals	99.62	99.82	100.0	97.65	99.90

1. Representative sample taken from a 300 ton consignment. Analyst, Miss A. F. R. Hitchens, Government Chemist and Assayer.
 2. Hand sample, analysed in London. Firing tests on this material at 1,300°C., gave satisfactory results.
- A. Pure kyanite.
- B. Indian kyanite. Quoted from *Journ. Amer. Ceramic Soc.* 19, No. 1, 1926.
- C. Average analysis of calcined Indian kyanite. Quoted from *Bull. Imp. Inst.* XXXVI, No. 4, 1938, p. 497.

These results indicate approximately 94 and 96 per cent. purity in the two Kenya samples respectively. It is noteworthy that the bulk of the impurity is TiO_2 (as rutile), that has no adverse effect in use, so that the kyanite can be considered as virtually one or more per cent purer than the figures quoted.

Conversion to mullite.—Extensive experiments on the conversion of kyanite to mullite have been carried out by the East African Industrial Research and Management Boards, and by the end of 1944 consistently high rates of conversion were being obtained in the commercial kilns of the latter Board. It was also found possible to produce a grog with mechanical strength comparable with that of commercial samples of mullite. High grade refractories are being manufactured by the Management Board from this mullite.

Production.—The production between January, 1943, and January, 1945, according to records in the files of the Mining and Geological Department was a little over 936 tons. The value of this in Kenya must be of the order of £3,500.

APPENDIX III

MAGNESITE DEPOSITS, KINYIKI

Introduction.—The geology of Kinyiki Hill which lies a few miles north of Mito Andei station is not dealt with by Dr. Parkinson in his report. So far as is known the occurrence of valuable minerals there was first appreciated by a prospector who, in 1936, pegged mining claims covering the hill on behalf of the Kenya Asbestos Co. The claims were kept extant by various people under the same company name until May 1940, when they were transferred to Kenya Magnesite Ltd., who are the present holders.

A sample of magnesite from the claims was examined and analysed by the Imperial Institute in 1939 and was pronounced to be of high quality (*Imp. Inst. Ann. Rep.* for 1940, p. 37).

Geology of Kinyiki Hill.—The hill and its surroundings were examined in 1936 and again in 1940 by C. S. Hitchen who reported that it stands about 250 feet above the surrounding plain and consists of a pipe-like intrusion of dunite piercing hornblende schists. He found the dunite to be frequently carbonated at surface, but when fresh unusually free from serpentinization and spinel segregations. The intrusion is the host of extensive rafts of hornblende schist, grading into hornblende granulites and amphibolites. It is cut by pegmatites in the eastern part of the hill (Fig. 7).

Magnesite.—Deposits of amorphous magnesite are present almost everywhere on the hill, and occur as anastomosing veins and veinlets running in all directions through the dunite. The veins vary in size from stringers to bodies 12 to 18 in. in thickness. One seen on the hill top had a thickness of about a foot and could be traced over a distance of 75 ft. On the west side of the hill several veins are 6 to 8 in. in width and persist laterally for 20 to 30 ft.

During his second visit Hitchen had the opportunity to measure sections in adits and opencasts, and found that the magnesite-rich dunite appears to occur in layers or zones 10 to 15 ft. in thickness. The average of 42 measurements made at intervals in one adit showed that approximately 26 per cent of the wall-rocks consisted of magnesite. This was presumably on a magnesite-rich zone and cannot be taken as representative of the hill as a whole. It appears that magnesite veinlets are less frequent on the northern part of the hill. In trenches on the south-west of the hill, dunite was exposed containing about 10 per cent of magnesite, but mostly in veinlets from a half to three inches wide. During working the total magnesite content was found in places to diminish to six per cent with low silica ore constituting about one half.

During his earlier visit Hitchen noted that asbestos veins which are also emplaced in the dunite were capped by magnesite, and that in some of the thinner magnesite veins a relict cross-fibre structure could be seen. He suggested that the latter may represent replacements of asbestos veinlets.

Chemical composition and mineralogy of the magnesite.—Several partial analyses of the magnesite are available and are quoted below:—

	I	II	III	IV	V	A	B
	%	%	%	%	%	%	%
SiO ₂	—	2.48	10.75	0.29	—	0.43	—
Al ₂ O ₃	1.81	0.19	0.71	0.18	—	—	0.10
Fe ₂ O ₃		0.28	0.64	0.28	—	0.06	
MgO	40.36	—	—	—	—	46.28	47.10
MgCO ₃	—	96.41	86.07	97.47	—	—	—
CaO	3.39	—	—	—	0.62	—	0.40
CaCO ₃	—	1.02	1.89	0.29	—	—	—
Moisture	—	0.36	0.14	0.06	—	—	—
P ₂ O ₅	—	nil	nil	nil	—	—	—
CO ₂	—	—	—	—	—	51.72	52.90
Insoluble	8.02	—	—	—	—	—	trace
Totals	—	100.74	100.20	100.09	—	98.49	100.50

I. A grab sample. The MgO content is equivalent to 84.39 per cent. MgCO₃, and the CaO to 6.41 per cent CaCO₃.

II. Grab sample from an adit. Analyst, C. S. Hitchen.

III. Sample from quarry on south side of hill. Analyst, C. S. Hitchen. Much of the silica is present as encrustations and in druses.

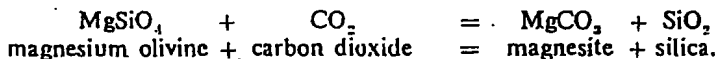
IV. Sample from upper quarries. Analyst, C. S. Hitchen.

V. Sample from Kinyiki Hill, exact locality unknown.

A. Magnesite, Transvaal. Quoted from "Magnesium, magnesite and dolomite", *Imp. Inst. Rep.*, 1939, p. 51.

B. Mysore magnesite, "trade sample". Quoted from *ibid.*, p. 64.

Hitchen judged from the samples he analysed that silica in an "inherent" state usually constitutes less than one per cent of the ore, the remainder being quartz or chalcedonic silica in veinlets, encrustations and vugs. Later he formed the opinion that much of the ore would be found to contain 10 to 15 per cent of silica, but believed it could be reduced to 6 to 8 per cent by cobbing and suggested that it could be decreased generally to 3 per cent or less by flotation. Operators have been inclined to consider the presence of silica as a surface phase that would disappear as the hill was pierced. This, however, is unlikely—chemical considerations indicate that some silica must be expected, though portions of course may have migrated in solution. The reaction leading to the formation of the magnesite may be conveniently expressed by the simplified equation:—



By selective working parcels of magnesite have been extracted from the deposit that contained 3.5 per cent SiO₂ or less.

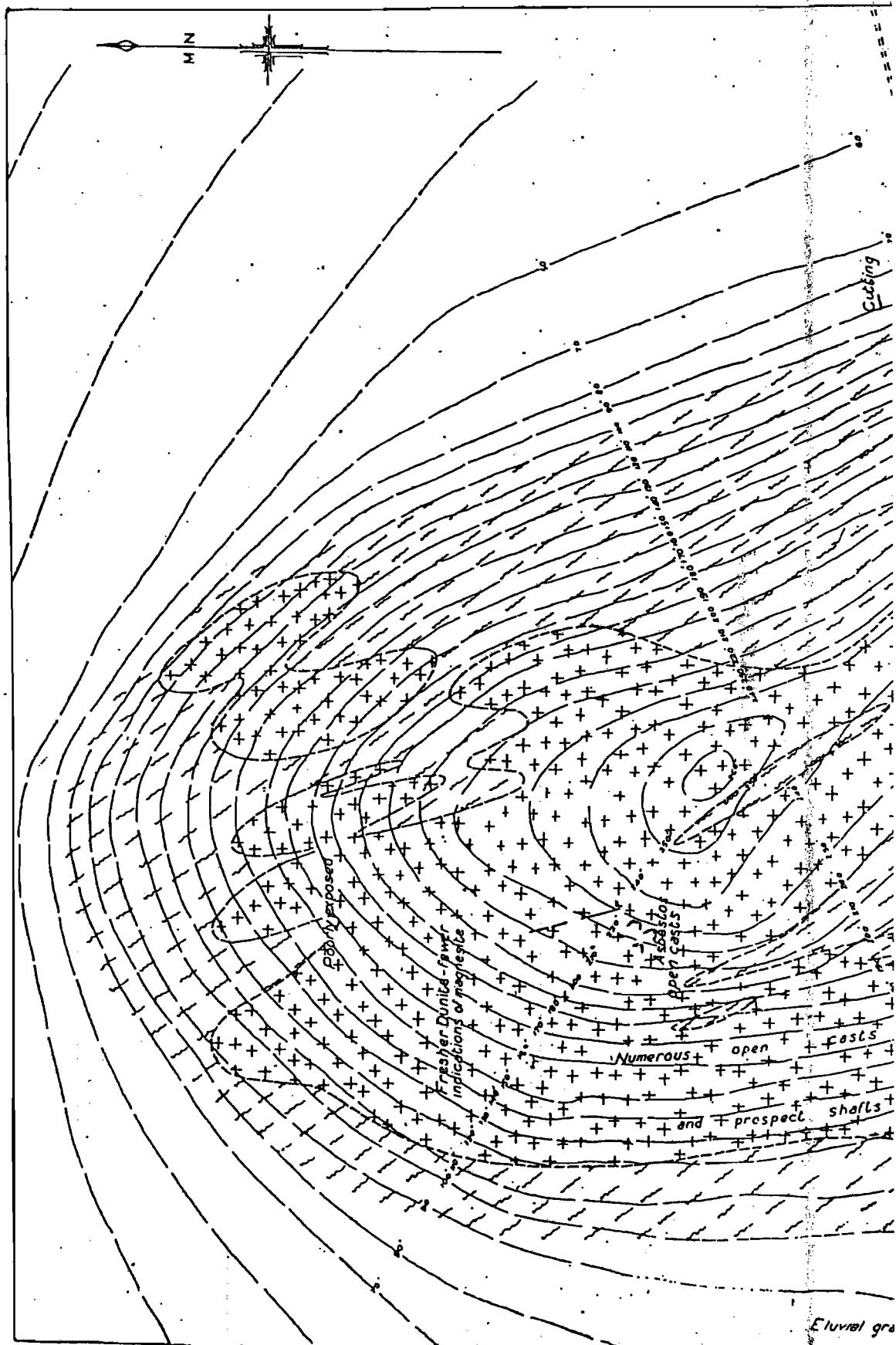
Production.—Records indicate that about 327½ tons of Kinyiki magnesite has been shipped or sold, though it is certain that considerably larger tonnages have been taken from the ground in attempts to obtain supplies conforming with high-standard and rigid specifications. In 1940 the price realized was Sh. 55 per ton at the coast. The total value of production is not known, but is probably of the order of £1,300. Serious production ceased in the early part of 1941.

APPENDIX IV

OTHER MINERAL DEPOSITS AT KINYIKI

1.—Asbestos

Several veins of asbestos have been found in the dunite of Kinyiki Hill. They ramify through the intrusive and consist of two main types, (a) irregular deposits with irregularly arranged short fibres and (b) cross-fibre veins with long fibred asbestos.



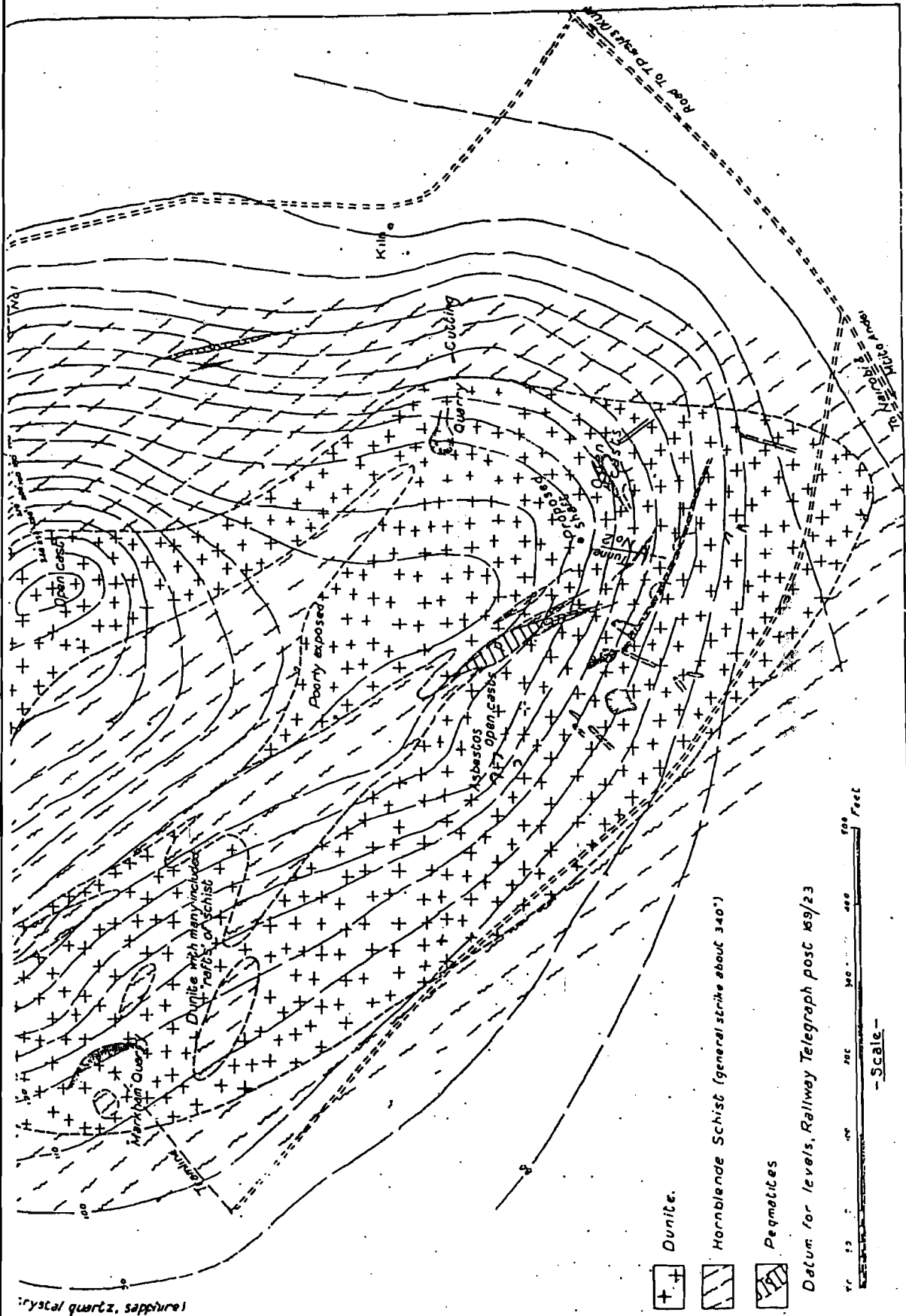


FIG. 7

The latter are of less frequent occurrence, and are best seen on the south-west flank of the hill. Fibres as much as 8 in. in length have been seen in the larger deposits. Veins on the western slope unusually silky fibres 2 in. in length have been seen. It is reported that good quantities of asbestos suitable for lagging occur on the southern slopes. It is believed that there are six veins of the longer fibred material, usually two to three feet in width.

The deposits were examined by C. S. Hitchen in 1936 who concluded that the asbestos was formed by the metamorphism of parts of the hornblende rafts that are emplaced in the dunite. From chemical and optical tests he identified the mineral as the amphibole anthophyllite. At surface it is frequently replaced by magnesite, and Hitchen believed that these magnesite veins with relict cross-fibre structure possibly represent original asbestos veins, perhaps of chrysotile variety.

Chemical composition.—One analysis of the mineral is available and is quoted below beside a comparative analysis.

	I	A
	Per cent	Per cent
SiO ₂	48.72	56.16
Al ₂ O ₃	0.76	2.65
Fe ₂ O ₃	7.05	—
FeO	n.d.	14.13
MnO	trace	0.91
MgO	27.23	23.19
CaO	4.98	1.51
H ₂ O	n.d.	2.38
Loss on ignition	10.82	—
Totals	99.56	100.93

I. Asbestos, Kinyiki. Analyst, Miss A. F. R. Hitchins, Government Chemist and Assayer. (This analysis was incorrectly stated in the Annual Report of the Mining and Geological Department for 1936, where (p. 25) silica was quoted 10 per cent in excess of the correct figure, and Fe was quoted as Fe₂O₃.)

A. Anthophyllite, Kongsberg. Quoted from Dana "System of Mineralogy", sixth edition, 1892, p. 385, analysis No. 2.

From the analysis it may be judged that the sample used was contaminated by magnesite or dolomitic material.

Conductivity test.—The Kenya and Uganda Railway conducted an insulation test on asbestos from Kinyiki in 1935. Using 25 per cent lime as a bond and canvas wrappings, a steam pipe (4½ in. diameter, 46 in. long and ¼ in. thick) connected by a 1 in. copper pipe, 10 ft. 4 in. in length, to a boiler under a constant pressure of 105 lb. per sq. in. of steam and fitted with a drain cock fixed on the open position, was lagged with the asbestos to give an outside diameter of 6 in. The temperature in the pipe farthest from the steam entry was taken by a pyrometer and the external temperature of the lagging by a thermometer suspended ¼ in. from the pipe lagging and protected from draughts. The test was repeated with the pipe unlagged, the thermometer being lowered to the same distance from the pipe. The results obtained were as follows:—

	Thermometer readings	Pyrometer readings
	°F.	°F.
(a) with lagging	97	275
(b) without lagging	144	265

Production.—The bulk of the output has been sold locally. It is estimated from departmental records that between June, 1936, and the end of 1939, approximately 80 tons were produced. Between the latter part of 1941 and the early months of 1945 production was considerably increased and records indicate an output of about 800 tons of powdered asbestos and 24 tons of asbestos wool.

II—Quartz

Quartz of two kinds has been worked on Kinyiki Hill—massive quartz and quartz crystal for piezo-electric purposes. The former has been derived from the pegmatites that cut the southern part of the hill. It is estimated that the production has been of the order of 95 tons, all of which has been consumed locally for ceramics purposes.

Piezo-electric quartz was discovered at Kinyiki by a prospector in 1936 while pitting gravels underlying three to six feet of red soil on the west flank of the hill. (See Annual Report for 1937, p. 29.) A remarkably perfect crystal, about 2½ lb. in weight, was unearthed and forwarded to England, where it was reported to be of very good quality. The deposits were examined by C. S. Hitchen who concluded that they were water-borne gravels and that the source might be some distance away. Prospecting continued below the hill and it was found that possibly usable crystals were of rare and sporadic occurrence. A second large crystal was found and on examination in England was stated to be free of electrical and optical twinning and internal fractures and as good as medium quality Brazilian material. This crystal was 9 cm. high, 6.5 cm. diameter, and weighed 825 grams. Plates cut from it gave excellent results.

It became necessary to define the source of the crystals, and in February, 1938, the deposits were re-examined by W. Pulfrey who concluded that the gravels are not water-borne, but eluvial, and that the quartz crystals are derived from quartz-rich pegmatite veins, one of which was located by trenching. In 1940, a further examination was carried out by Dr. Parkinson. He found that the crystals occur in a restricted area on the low ground at the western foot of the hill and are derived from late hydrothermal quartz veins that have been deposited in fissures in the Basement System rocks. Extensive work was carried out in the search for workable deposits including the cleaning of old trenches and the excavation of more than 46,000 cu. ft. of ground. Subsequently three cross-strike trenches were dug and as a result two more veins of quartzose pegmatite were uncovered. Pits were sunk in the three veins known, but the two southernmost petered out at shallow depths. Attention was then concentrated on the northern vein and three shafts were sunk on it to depths of 32, 22 and 21 ft., and connected by about 120 ft. of driving at depths of 20 to 30 ft. In all 3,000 cu. ft. of ground were excavated but no pockets of quartz crystals were found. The work showed clearly that the pegmatites are invaded by later quartz veins, containing in places epidote and chlorite, and presumably of hydrothermal origin. The hydrothermal nature of the crystals recovered is perhaps also indicated by the fact that some of them were found to be naturally etched. Though no crystals were found in the underground excavations, a parcel of 17 lbs. of crystals was recovered from a portion of the collapsed outcrop of the same vein. Work was discontinued in 1942.

Production.—It will be obvious that the production has been small. In addition to the two crystals mentioned above, production included:

- (1) a fine crystal weighing 2 kilos, that was retained by claims operator;
- (2) a parcel of 12 crystals with weights ranging from 580 to 149 grams (June, 1938). Of these, three only were found to be usable, but it was noted that from the 14 crystals submitted by this time, five had proved usable—a ratio comparable with that found elsewhere;
- (3) a parcel of 26 crystals shipped in 1940. The largest of these weighed 18½ oz., 16½ oz. and 13½ oz. (approximately 524, 467 and 382 grams respectively). All were found to be relatively free from optical twinning and in most cases without serious electrical twinning;
- (4) a fourth parcel of 26 crystals, totalling six kilos in weight, shipped in 1941. They included a crystal of 2,084 grams weight which, however, was too flawed to be of use. The bulk of the remainder were of small size, but several of them were found to be remarkably free from twinning, and were stated to be of quality equal to the best Brazilian material. Ten crystals from the parcel were found to be about 100 per cent useful for piezo-electrical purposes.

III—Felspar

Felspar has been sporadically worked in the pegmatite lenses that cut the southern part of Kinyiki Hill. Occasional specimens that have been examined in thin section proved to be microcline-microperthite. It has also been recorded (*Annual Report for 1936*, p. 25), however, that cleavelandite (a lamellar variety of albite) is developed in the outer felspathic zones of some of the pegmatites.

Production.—Records indicate that approximately 115 tons were produced between October, 1943, and March, 1945. It is believed that the whole was consumed locally for ceramics purposes.

IV—Vermiculite

It was early recognized that deposits of vermiculite are associated with the other minerals of Kinyiki Hill. They occur in two forms (a) the less valuable, as large plates of vermiculitized mica in the pegmatites and (b) as veins and pockets in most of the magnesite and asbestos workings. The latter are closely associated with the rafts and xenoliths of hornblende-schists enclosed in the dunite, and presumably owe their origin to metamorphic and metasomatic action by the dunite. They are stated to be well developed on the southern side of the hill.

Samples from the deposits were sent in 1937 (*Annual Report for 1937*, p. 25) to London and it was reported that they were equal in quality, when cleaned, to material then being imported from the U.S.A. and Russia. The samples were crude material and had not been treated or beneficiated in any way in Kenya. Tests on them gave the following results:—

	Sample A	Sample B	Sample C
Crude, weight in lb. per cu. ft.			
Undried	42.5	Almost no moisture	Moisture 1.2 per cent
Dried	40.5	40.67	73.17
Exfoliated, weight in lb. per cu. ft. . .	8.8	7.14	16.25

It was considered that by treatment the bulk density of the exfoliated product could be improved by at least one pound per cu. ft.

In 1944, more tests of the material were carried out in the laboratory of the Mining and Geological Department. Again crude unprocessed material was used for the tests. The bulk density of samples including $+\frac{1}{2}$ in. material was found to be $77\frac{1}{2}$ to $78\frac{1}{2}$ lb. per cu. ft. and excluding the $+\frac{1}{2}$ in. fraction, $68\frac{1}{2}$ lb. per cu. ft. The moisture content was 6 to 7 per cent corresponding with dry bulk densities of $63\frac{1}{2}$ to $64\frac{1}{2}$ lb. per cu. ft. The $-\frac{1}{2}$ in. fraction of the sample when screened yielded the following results:—

Screen.	Weight %
+20 mesh I.M.M.	27.4 (dry screening of air dried sample).
—20 I.M.M. +30 " B.S.	13.1
—30 B.S. +12" " B.S.	42.2
—120 BS	17.2
	99.9

The coarsest grade was found to contain some magnesite and dunite grains and the —30 mesh grades contained much olivine, magnesite, anthophyllite, etc. The finest grade incorporated 30 to 40 per cent of such impurities.

The crude sample and fractions screened from it were expanded in a muffle furnace at a temperature of 1,000°C. Periods of ten minutes were allowed for each heating, which was certainly far in excess of the optimum exfoliation period. The exfoliated products were gently screened, the results being as follows:—

Sample	Bulk Density		Screen Grading				Total
	lb. per cu. ft.	+ 20	- 20 + 30	- 30 + 120	- 120		
Total	17	63.2	17.8	17.4	1.6	100.0	
- ½ in. + 20 mesh ..	15-17½	25.8	17.3	44.6	12.0	99.7	
- 20 + 30	18	28.1	54.0	15.4	1.8	99.3	
- 30 + 120	21	0.5	8.2	88.3	2.6	99.6	
- 120	25½	0.2	0.4	29.9	69.2	99.7	

The -30 mesh material consisted in all cases mainly of thin flakes or non-micaceous mineral. Expanded flakes had a biscuit colour with silvery reflections.

Production.—The total output of crude material, has been of the order of 25 tons.

V—Corundum and Sapphire

The discovery of corundum at Kinyiki was announced in the Annual Report for 1936 (page 26). It was found as surface blocks on the west side of the hill. Subsequently when soils and gravels from excavations were being washed gem-quality sapphires, derived from disintegrated corundum crystals, were obtained in small quantities. In 1939, in a pit sunk on the western contact of the dunite, corundum was found in situ. It occurred as a nest of long hexagonal crystals with gently curved faces, associated with vermiculite, ilmenite and granular hornblende, and may reasonably be ascribed to the desilication of the schist wall-rocks by the dunite. One of the crystals was about three feet in length. Rare small patches of sapphire quality were found inside the crystals when they were broken open. The corundum crystals were considerably intergrown with corundophilite and pink margarite.

Other occurrences of corundum might be expected at the extensive dunite contacts on the hill—both at the major contact and those of the numerous xenoliths. Large plates of corundophilite have indeed been found some distance away from the known occurrence of corundum, and suggest other deposits. It is probable, however, that any deposits found will be of small extent. It is likely too, that sapphires would not be recovered from corundum deposits in situ, but only where natural disintegration and cleaning has liberated gem fragments and allowed them to become part of eluvial deposits.

Production.—The production of gem sapphires in 1937 and 1938 realized £236.

VI—Miscellaneous Minerals

Copper.—Traces of copper in the form of carbonate staining have been found in the schists around Kinyiki Hill. It appears to have no economic significance.

Beryl.—Crystals of beryl have been reported as occurring in the pegmatites (Annual Report for 1936, p. 25). They are presumably of occasional occurrence only.

Ilmenorutile.—Hitchen has recorded (Annual Report for 1936, p. 26) the presence of eluvial ilmenorutile on the lower western slopes of the hill.

Uvarovite (Chrome Garnet).—Some years ago, Sir Edmund Teale found a small fragment of uvarovite on Kinyiki Hill. So far as is known this is the only record of the occurrence of chromium minerals there.

APPENDIX V

MICA

Mica has been worked in pegmatites near Rhodesian Hill in the Tsavo Valley and near Mgange Camp, north-west of the Taita Hills.

1. *Rhodesian Hill*.—Claims were pegged in 1938, but apparently little work was carried out until 1940, while no production was recorded until 1943. During the 1940 prospecting two opencasts were excavated and mica samples from them were pronounced by London authorities as of good quality. At depths of three feet mica was found to be plentiful and in large books, but usually weathered. In 1943, assistance rendered by the Mining and Geological Department, led to the discovery of another pegmatite containing pockets of ruby mica. It was proved over a strike of 50 ft. and the mica pockets were found at a depth of 10 ft.

On another pegmatite, selvages of mica were found ranging from 1 in. to 12 in. in width. The mica was pale green and reasonably free from spotting, though much was badly striated. The pegmatite was excavated over a distance of 150 ft. by the Government Prospector and to a depth of 15 ft., but the mica at lower depths was found to be striated and more spotted and stained than the surface crystals.

Two parcels of mica submitted to the Ministry of Supplies' purchasers in 1943 were graded as follows:—

Size grade	First consignment, approx. wt. per cent			Second consignment, approx. wt. per cent		
2	2	..	..	—		
3	5	..	..	1.5		
4	8	..	..	7.4		
5	20	..	..	14.5		
5½	5	..	..	11.6		
6	45	..	..	46.5		
7	10	..	..	14.1		
Thins	5	..	..	—		
Thins and unspotted cleanings	—	..	..	4.3		

The first consignment was reported as containing much spotted and green mica with smaller proportions of brown and ruby type. The later consignment contained a good proportion of ruby mica.

Production.—From records in departmental files it appears that production before November, 1943, was about 120 pounds of cut mica. Between November, 1943, and March, 1945, working was sporadic and about 560 pounds of cut mica were sold, the total value being about Sh. 1,900. One consignment realized an overall price of Sh. 4 per pound, but the estimated average for all consignments was about Sh. 3/50 per pound.

2. *Mgange*.—A single prospector worked mica in pegmatites during 1944 near Mgange Camp. Production was small but the mica realized prices in excess of those obtained for mica from other localities. A book sent to the purchasers for an opinion weighed 22 lb. and yielded 3½ lb. of cut mica (an extraction of 17 per cent) of good stained ruby mica type that realized more than Sh. 9 per lb. The remainder of the book was cross-grained and described as useless.

Two subsequent consignments of (1) 16 lb. 14 oz. and (2) 125 lb. 3½ oz. of cut mica yielded Sh. 178/94 and Sh. 1,087/57 respectively (i.e. approximate averages of Sh. 8/70 and Sh. 10/50 per pound).

The gradings of the two consignments were as follows:—

				<i>Consignment 1</i>		<i>Consignment 2</i>	
				<i>Per cent</i>		<i>Per cent</i>	
Extra specials	..	..	—	..	..	..	1.1
Specials	..	..	—	..	..	..	0.6
1	..	..	11.9	..	..	..	6.4
2	..	..	24.1	..	..	..	13.7
3	..	..	14.8	..	..	..	9.3
4	..	..	17.4	..	..	..	18.1
5	..	..	10.4	..	..	..	21.2
5½	..	..	2.9	..	..	..	9.6
6	..	..	—	..	..	..	7.5
Thick thins	..	..	(3-5) 12.5	..	..	(3-6)	6.0
Thin thins	..	..	(3) 5.9	..	..	(3-6)	6.4
F.S.	..	..	—	..	..	..	1.5
G.S.	..	..	10.0	..	..	..	24.9
S.	..	..	30.7	..	..	..	17.3
H.S.	..	..	40.7	..	..	..	43.8
Thick thins	..	..	12.6	..	..	..	6.0
Thin thins	..	..	5.9	..	..	..	6.4

It will be noted that the proportions of size grades was more than usually biased towards larger sizes.

The pegmatites were not carefully explored and it is considered that the prospector closed down prematurely. The total value of mica obtained from the pegmatite during the short time it was worked was about Sh. 1,300.

APPENDIX VI

MISCELLANEOUS DEPOSITS

1. *Limestones*.—The various occurrences of crystalline limestones are described in Dr. Parkinson's report. In addition there are deposits of kunkar limestones at several localities, especially south of the Taita Hills, near Makindu, and east of Kinyiki. It is believed that limestone from the Makindu deposits will be used for the preparation of lime at Kinyiki.

2. *Clays*.—Clays suitable for the manufacture of bricks and tiles have been discovered by Markham & Co., in the Mtilo Andei area. In the past clays near Voi were used by the B.E.A. Corporation for the manufacture of mangalore type roofing tiles. They were reported to be of good quality.

3. *Rose Quartz*.—A pegmatite containing rose quartz was found several years ago north-west of Tsavo. So far as is known no production was made.

4. *Copper*.—Copper carbonate staining has been noted in several places north and south of the River Tsavo near Tsavo. It appears probable that the carbonates are derived from chalcopyrite contained in pegmatites.

5. *Kaolin*.—Twelve deposits of kaolin were discovered and mapped in the hills a few miles west of Ndi. They are discontinuous and scattered over a highly eroded area a little more than one square mile in extent. Other occurrences were noted in the hills further west.

Inspections of samples showed that, in most cases, the kaolin has been derived from the decomposition of para-gneisses and schists; and, in some instances, perhaps from granite. The prospector found that some of the deposits are underlain by red clay and earth, and it appears likely that such occurrences are slipped masses. The kaolin itself was not typical of redeposited material.

Grading analyses showed that the kaolin varies considerably from deposit to deposit, viz.:—

Number of Deposit.	Moisture %	Sand + 60 mesh %	Fines.	Kaolin.	TOTAL.	REMARKS.
1.	—	—	—	—	—	Very impure.
2.	1.3	55.4	30.9	11.8	99.4	Off-white. Derived from parashist.
3.	0.5	63.5	25.0	10.0	99.0	Pale buff. Derived from coarse gneiss. Quartz iron-stained.
4.	0.9	50.9	32.5	15.5	99.8	Brownish-buff. Derived from paragneiss. Quartz non-stained.
5.	—	—	—	—	—	Very impure.
6.	1.6	49.0	31.5	17.1	99.2	White. Derived from granito or granitoid gneiss.
7.	0.6	68.9	24.9	5.6	100.0	White. Derived from paragneiss.
8.	1.3	63.8	24.0	10.7	99.8	Pinkish-buff. Derived from coarse pink granite or gneiss.
9.	1.8	61.7	22.5	13.7	99.7	Off-white. Derived from coarse granite or granitoid gneiss.
10.	0.5	61.8	29.9	7.6	99.8	White. Derived from paragneiss.
11.	1.1	59.7	28.5	9.0	99.2	Pale buff. Derived from paragneiss.
12.	—	—	—	—	—	Pink. Very impure.

To test the refractory qualities of the various samples small cylinders of the "fines" obtained were made, thoroughly dried, and then fired in an oil furnace, maintained at 1,400°C. for several hours. All the test-pieces proved to be refractory at that temperature, and yielded generally white or mottled "biscuit" types of refractories:—

Deposit No.

Result

2	..	..	Buff. Medium strength "biscuit" type.
3	..	..	White. Stony, due to incipient fusion.
4	..	..	Mottled. Medium strength "biscuit" type.
6	..	..	White. Medium strength "biscuit" type.
7	..	..	White. Soft "biscuit" type.
8	..	..	White. Soft "biscuit" type.
9	..	..	White. Medium strength "biscuit" type.
10	..	..	Light grey. Hard stony type.
11	..	..	Mottled. Medium strength "biscuit" type.

ADDENDUM

MINERAL PRODUCTION FIGURES FOR THE MITTO-ANDEI-TSAVO AREA SUBSEQUENT TO THE COMPILATION OF THE REPORT. THE FIGURES ARE BASED ON DEPARTMENTAL RETURN RECORDS

Mineral	Period	Quantity Produced	Aproximate Value
		<i>Tons</i>	<i>Sh.</i>
Asbestos ..	June—December, 1945 ..		8,215
	1946	Powder .. 17.40	2,516
		Wool .. 2.50	808
	January—June, 1947 ..	Powder .. 6.75	2,145
		Wool .. 2.50	812
Graphite ..	October, 1945	1.50	—
Felspar ..	1945	108.00	7,020
	1946	43.00	2,808
Kyanite*	1945	444.00	1,624x $\frac{f}{f}$
	1946	2,380.00	9,428 $\frac{f}{f}$
	January—August, 1947 ..	9,777.00	781,600
	June—December, 1945 ..	14.30	1,120
Magnesite ...	1946	60.00†	13,450
	January—June, 1947 ..	40.35	3,280
Pegmatite ..	June—December, 1945 ..	10.00	650
	1946	20.00	1,300
Quartz ..	June—December, 1945 ..	96.00	6,240
	1946	135.50	8,824
Vermiculite ..	June—December, 1945 ..	10.00	750
	1946	0.50	89

* The percentage distribution of the kyanite sold between January and August, 1947 was as follows:—

U.S.A., 54.9; U.K., 23.7; Belgium, 13.2; France, 3.6; Australia, 1.5; Palestine, 1.5; Local, 0.8; Holland, 0.7.

† Includes 10 tons calcined magnesite.