Report No. 51

COLONY AND PROTECTORATE OF KENYA

MINISTRY OF COMMERCE, INDUSTRY AND COMMUNICATIONS
GEOLOGICAL SURVEY OF KENYA

GEOLOGY
OF THE
KASIGAU-KURASE AREA

DEGREE SHEETS 65, S.E. AND 68, N.E. AND S.E. QUARTERS

(with two coloured geological maps)

by

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FOREWORD

The part of Kenya south of the railway between Mackinnon Road and Voi is little known to most modern residents of the country, though in the Colony's early days it was well-known to travellers for its dreaded Taru desert, over which it was necessary to pass on foot to reach the fertile regions in the Taita hills and in Northern Tanganyika. This report gives an account of the geography and geology of much of that area. It follows a report (No. 49, 1960) describing the area south of the Taita hills, which flanks it on its western side, and will be followed by a report (No. 54) dealing with the Voi area, which lies north of it. The area is sparsely inhabited, except in a few favoured spots, such as round Kasigau mountain, where water is sufficiently abundant to maintain a small population.

Much of the area is underlain by ancient gneisses, schists and crystalline limestones, the marbles being particularly abundant in the southern part. Dr. Saggerson shows that these old rocks have probably been subjected to two periods of folding, in the first of which they were considerably overturned. In the eastern part of the area, and notably at Kilibasi hill, which has been described by some previous authors as composed of the ancient gneisses, there are grits, sandstones and shales of the sediments of Karroo age that form a belt parallel to the coast of Kenya. The author shows that there is evidence that at one time these sediments extended much further inland, almost to the Taita hills. Unfortunately, as in the rest of the Coast, there is here no evidence that the occurrence of workable coal seams in the Karroo beds is likely.

Various traces of valuable minerals, including copper ores, graphite, sillimanite and kyanite were discovered during the mapping, but it appears unlikely that any will prove to be present in sufficient quantities or in a suitable state for commercial extraction. The chief mineral resource of the area is its limestones which, however, are unlikely to be wanted as abundant limestones are present in more favourable areas elsewhere, nearer to centres of use.

An account of the water-supplies is given in the report, and leads to the conclusion that though some water might be obtained from bore-holes, the most promising method of improving supplies is by the construction of numerous small dams.

Nairobi,
8th January, 1958.

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CONTENTS

LIST OF ILLUSTRATIONS

MAPS

ABSTRACT

The report describes an area of approximately 2,050 square miles extent south-east of Voi in the Coast Province of Kenya, bounded by longitudes 38° 30′ E. and 39° 00′ E., by latitude 3° 30′ S. on the north and by the Kenya-Tanganyika border on the south. The eastern part of the area consists of the end-Tertiary peneplain, west of which rise several groups of hills and ridges whose bevelled tops are residuals of at least four earlier erosion surfaces, the highest being tentatively correlated with the end-Cretaceous surface of central Kenya.

The rocks of the area mainly consist of highly folded Basement System crystalline limestones and gneisses of Archaean age. Two series of gneisses are recognised, the rocks of both being representative of the amphibolite facies. A gabbro and hornblendite were seen to invade these rocks. In the east and south-east of the area sediments of upper Carboniferous-Permian age overlie the gneisses unconformably or are down-faulted against them. Recent deposits are represented by soils, sands and gravels of Pleistocene to Recent age which thinly cover much of the area.

A detailed account is given of the petrography of the rocks and the metamorphic and sedimentary history of the crystalline rocks and Palaeozoic sediments is discussed. The structure of the area is also described. The economic possibilities of the area with respect to mineral deposits and the prospect of finding coal, oil and water-supplies are reviewed.

I—INTRODUCTION

The area described in this report is situated between 30 and 85 miles from the Kenya coast and comprises the south-east quarter of degree sheet 65 and those portions of the north-east and south-east quarters of degree sheet 68 that lie within the Colony. It is bounded by longitudes 38° 30′ E. and 39° E., by latitude 3° 30′ S. on the north, and by the Kenya-Tanganyika border on the south, and has an area of approximately 2,050 square miles. In addition a small part of Tanganyika along the Umba river near south-east corner of the area was examined. The area is covered by sheets Nos. 196 and 199 of the Colonial Survey directorate.

The object of the geological reconnaissance, which was made between the months of June and December 1955, was threefold; firstly, to search for mineral deposits of economic value in the crystalline gneisses and limestones of the Basement System which form the greater proportion of the area; secondly, the evaluation of the Duruma Sandstones sediments as a source of oil; thirdly, to examine the same sediments for coal-bearing strata. The presence of coal pockets in the Taru Grits has been known since 1911 and in 1921 the Coastal Mining and Exploration company began an exploration of an area near Taru (a few miles north-east of Kilibasi) for workable coal but met with no success. Bore-hole records and regional geological surveys of the ground east and north-east of the present area made it appear most unlikely that coal beds of economic value would be found during the survey.

The results of the survey are illustrated by two maps, one of the northern part called the Kasigau sheet, and the second of the southern part named the Kurase sheet. In the report the two areas are considered together.

Maps. In the preparation of the geological maps aerial photographs, on a scale of approximately 1:30,000, and taken in 1950 by the R.A.F., and in 1954 and 1955 by an air charter company, were used. Observations were plotted on to kodatrace overlays of runs of aerial photographs, controlled by a plane-table survey which in turn was based on the Survey of Kenya's trigonometrical stations at Sagala, Maungu, Kasigau and Kilibasi. The Directorate of Colonial Surveys' preliminary plots $\frac{\text{South A37}}{\text{U/IV/NW}}$ (196/1) and $\frac{\text{South A37}}{\text{U/IV/NE}}$ (196/11) were also used for the part of the area approximately north-east of the Kenya-Uganda railway. Final reduction of the kodatrace strips was made photographically.

The form-lines shown on the maps were based on barometer readings taken at varying intervals during the survey and are approximate only. Heights were constantly checked against known altitudes on the railway and corrected for diurnal variation.

It should be noted that the trigonometrical station Sagala has been incorrectly named Ndara on earlier topographical maps. In addition Kasigau is a native land unit, the main peak of the mountain being named Nyangala.

Communications. The Kenya-Uganda Railway, which passes through the north-east corner of the area, the adjacent Mombasa-Nairobi road and the Mombasa Pipe-line road form the principal lines of communication. Communications in the remainder of the area are poor. Three motorable tracks in regular use radiate from Kasigau; an old locust track runs for fifteen miles in a south-westerly direction. Tracks also radiate from Kilibasi, including a hunter's track from Kilibasi to Kurase, which runs south-westerly from Kilibasi. Another hunter's track connects the hill Kivuko with the Pikapika-Mackinnon Road track.

During the survey a motorable track was constructed southwards from the Kilibasi-Kurase track to a point within four miles of the Kenya-Tanganyika border, along which there is a very poor survey track. Two other tracks, which branch east and west from the north-south track were constructed during the survey and are indicated on the map. A system of game tracks connects the main water-holes in the area but they are rarely wide enough to be motorable.

The township of Voi is situated on the railway seven miles north of Sagala, and Mackinnon Road, also on the railway, lies one mile to the east of the eastern border of the area.

Population. The area lies in the Coast Province of Kenya and is administered from district headquarters at Kwale and Wundanyi. The Boundary between the two districts extends from Mackinnon Road station to Kilibasi and thence south-westerly to the summit of Kavuma hill just outside the south-west corner of the area, and is indicated on the maps. The area is sparsely inhabited and only at Sagala, Maungu, Kasigau and Kilibasi, where permanent water exists, is there any concentration of population. The populated part of the area forms less than ten per cent of the whole. At Kilibasi a few scores of Waliangulu, who are a branch of the coastal Duruma tribe, eke out a miserable existence centred on the water-holes at the foot of the hill. At the other three localities the Africans, who are members of the Taita tribe, are able to cultivate small holdings and graze their cattle and goats close to the mountain sides. The administration has, however, found it necessary from time to time to render assistance by supplementing food supplies. A recent medical survey has revealed that in the Taita native reserve only those people living at Kasigau, of which there are about 1,500, do not suffer from malnutrition. Both at Sagala and Kasigau, the hills rise to more than 5,000 feet above sea-level, and it is possible to grow banana and paw-paw trees and, on the upper slopes, oranges and pineapples.

The area abounds in game of all kinds including elephant, rhinoceros, buffalo, eland and most species of gazelle. The presence of such game has attracted hunters for many years and many of the motorable tracks owe their existence to their activities. Signs of poaching are particularly common in the Kurase area. Here the Waduruma and Tanganyika tribes can enter the area without fear of molestation and construct their traps to catch the smaller animals on which they live, while they hunt the larger animals such as elephant and rhinoceros. The trophies obtained from the latter are smuggled to the coast, where they are sold for considerable profit.

Nomadic tribesmen from Tanganyika occasionally enter the south-western part of the area during rainy periods to graze their cattle, and signs of their habitations are not lacking between Murinjo and Kurase.

Climate and Vegetation. Rain falls mainly in the periods April-June and October-November, at the change of the monsoons. It is at these periods that water-holes are full and the animal density greatest. During the drier periods, however, the larger animals migrate either northwards to the Sabaki river or southwards to the Umba river in Tanganyika where permanent water is obtainable. At only one place, the Chief's Camp at Rukanga (Kasigau), have rainfall figures been recorded and there only during the last few years, but at Voi and Mackinnon Road figures have been kept over a period of several years. The average annual rainfall figures in inches for these three places are 36·15 (4 years), 21·27 (50 years) and 28·12 (43 years up to 1950) respectively. A combination of high temperatures and low rainfall over most of the area does not permit the growth of luxuriant vegetation and a large part of it can be classified as semi-arid desert. In fact, early pioneers and writers referred to the Kilibasi and north-easterly parts of the area as the Taru Desert. Over the Karroo sediments the vegetation consists of dense thorn and cactus scrub but on the crystalline gneisses the bush is more open and with low trees, while on the crystalline lime-stone ridges there is thick, often impenetrable bush, including sansevieria. Towards the Tanganyika border there are large stretches of open grassland. The upper slopes of Kasigau are covered by a thick damp forest where lichens and mosses abound. The mountain is often shrouded in clouds and mists throughout the day except at the very driest periods of the year. Sagala, another high hill, has only remnants of forest on its upper parts, the local population having stripped the slopes nearly bare of trees. An effort is now being made by Agricultural officers to re-afforest the hill to protect the soil against excessive erosion. It is around such hills that any kind of settlement can be made, the remainder of the area being fit for grazing only.

Rock exposures. The rocks are well exposed in the region of Maungu and Kasigau, at Sagala and around Kilibasi. Elsewhere exposures are poor and mainly confined to isolated hills such as Matsimbani, Mwachinjoro and Kurase, and to low ridges formed mainly of crystalline limestones with interbedded gneisses. Poor and infrequent outcrops and scattered float blocks on much of the sand-covered plains allow little interpretation of the nature of the underlying strata.

General. Parts of the area lie within the Tsavo Royal National Park, the boundary of which is shown on the map. The boundary runs along the northern side of the railway and another section of it bounds a small portion of the area mapped, south-west of Kasigau.

During the 1914–18 war the area was the scene of military activity and Kasigau was fortified successively by the British and the Germans, the latter having invaded the Colony from Tanganyika. Gun emplacements can still be seen on Kasigau and the aerial photographs reveal the location of the old road (not shown on map) that runs south-west from the mountain and was used by the German forces.

Acknowledgements. The author thanks the Director of the Geological Survey of Tanganyika for permission to map in reconnaissance style the Umba river section near Mwakijembe. Thanks are also due to the staff of the Kenya Police at Mackinnon Road for assistance, readily given, in the repair of Survey transport.

II—PREVIOUS GEOLOGICAL WORK

Some of the earliest travels through the area were those made by the missionaries Rebmann (in 1847) and Krapf (in 1849 and 1851) who journeyed to the Taita and Usambara mountains and Ukambani. During his first journey to Taita in 1847 Rebmann visited Kadiaro (Kasigau) describing this solitary mountain mass as "stretching about one league and a half from south to north and near its centre reaching its highest summit which consists of an enormous mass of rock and is, for the most part, completely perpendicular" (Krapf, 1860, p. 225).* R. Thornton (1862) in a letter to Sir R. I. Murchison described the area between Mombasa and Kilimanjaro. He referred to the Taru grits and the "deep circular cavities in which we often found water" and to Kasigau, "a high, narrow precipitous mountain composed of old, crystalline metamorphic rock in thick beds dipping to the east at about 5°." He also commented on the gently undulating plain to the south and west of the mountain.

Charles New, a missionary explorer, travelled through the area in 1871 while making a journey from Mombasa to Lake Jipe via Kasigau. Like other explorers he commented on the dry and uninhabited country and the permanent water-holes (presumably) at Kilibasi. His return journey took him via Sagala and Buchuma (Forbes-Watson 1951, pp. 30 and 63–64).

J. Thomson in a description of his journey to Taveta in 1883 mentions in particular the 200 miles of flat, desert-like country with its sterile soil and glaring red sand, between the coast and Mount Kilimanjaro (Loftus, 1951, p. 9).

On his return to the coast in 1888, after an expedition to central and northern Kenya, Von Höhnel passed through the area and described the physiographical features of Sagala, Maungu, Kizima and Kilibasi, mentioning in particular the vertical cliffs of Kasigau (Von Hohnel, 1890, p. 3). The map that accompanies his report indicates the position of these hills with reasonable accuracy.

Other travellers to visit the area included Von der Decken and A. Kersten in 1869 (Von der Decken, 1879), Hildebrandt (1879), and H. Meyer (1890), all of whom collected various rocks which included Duruma sandstones, and crystalline limestones, biotite and hornblende gneisses and pegmatites from Maungu and Ndara. Petrographical descriptions of a number of these rocks were given by Roth (1864), Beyrich (1878), Hyland Shearson (1889), and Tenne (1890). Later Stromer von Reichenbach (1896) summarised the researches of all the early travellers to this part of Kenya, but did not himself visit East Africa.

C. W. Hobley (1894, p. 123; 1895, pp. 545–561) stopped at Maungu and Sagala on his way to the Taita hills in 1892. On his return journey he noted the crystalline limestones of the Mugeno ridge, the mountains of Kasigau and Rukinga, and recognised the boundary between the Basement System rocks and the Duruma Sandstones near Kilibasi.

Walcot Gibson (1893, pp. 561–562) made a journey from the coast to Lake Victoria towards the end of the nineteenth century. He passed through the area and considered that there was an unconformity between the coastal sedimentary rocks and the metamorphic series, though he did not realise that much of the junction is faulted. At about the same time, in 1893, J. W. Gregory (1896, p. 68) began his first journey through Kenya from Mombasa and, towards the end of March, camped at Maungu "on a terrace at the height of 2,200 feet, about 500 feet above the plain". The following day he reached Sagala (Ndara)

*References are quoted on pp. 58-60

where he camped near a stream and waterfall—a rare sight in this part of Kenya, except during heavy rains such as he experienced during this part of his journey. Gregory correctly described the rocks forming the hills as Archaean gneisses (*op. cit.*, p. 227). In a later account (Gregory, 1921, p. 33) he defined the position of the Basement System-Karroo junction near Mackinnon Road, but incorrectly stated that "it continues, E. of Kilibasi, to the southern frontier".

In 1902, E. E. Walker (1903), a British Government geologist, stopped overnight at Maungu and examined the gneisses forming the hill. He commented "Maungu is composed entirely of gneisses with quartz, felspar and black mica developed. The last mineral often occurs in bands, so that the whole rock takes on a banded structure and may be described as a banded gneiss. Coarse veins with the same mineral—pegmatites—are very common but no mineral of any value is found in them."

Later, in 1905, H. B. Muff (Maufe), then of the Geological Survey of Great Britain, made a geological survey along the railway from Mombasa to Kisumu. In his report, published in 1908, he made reference to hornblende-biotite gneisses at Maungu and Sagala and recognized the presence of garnet in the rocks at the latter locality. E. Fraas spent a short time in the area and incorrectly considered that rocks of Karroo age outcropped between Voi and Maungu and that the hills at Maungu were composed of horizontally bedded sandstone (Fraas, 1908). Muff in a later paper (1915, p. 275) disagreed with Fraas and referred to his own work carried out in 1905.

In 1910, G. L. Collie (1912) made a journey from the coast to Uganda and noted the gneissic monadnocks at Maungu and Voi. A year later (1911) Krenkel wrote of the gneisses extending westwards from Mackinnon Road and referred in particular to Maungu (Krenkel, 1911, p. 256). The map accompanying a report by Behrend (1918) incorrectly shows the Duruma Sandstones extending across the present area and as far west as Lake Jipe. Krenkel again referred to the inselberg of Maungu and to Ndara in a later publication (Krenkel 1925, p. 253) and to the unconformity between the coastal sediments and the underlying gneisses (*op. cit.*, p. 298). His map (facing p. 342) follows Behrend in showing too wide a distribution of the Duruma Sandstones.

An exclusive prospecting licence to search mainly for coal and oil was granted in 1921 to the Coastal Mining and Exploration Company, over an area of 20,000 square miles in Coast Province, which included the whole of the present area. The result of the geological survey carried out for the Company by J. Scott, W. Mackinnon and E. Parsons proved disappointing and nothing of economic value was discovered, though Parsons produced the first comprehensive map of the coast from the Tanganyika border to the R. Galana.

H. G. Busk and J. P. de Verteuil rapidly examined the coastal area in 1937 on behalf of two oil companies, and their unpublished report (1938) includes a geological map on which is indicated the approximate position of the Basement System—Duruma Sandstones boundary.

A summary of the coastal succession was given some years ago in a review by B. N. Temperley (1952) and was later followed by a revised review by W. Pulfrey (1958).

III—PHYSIOGRAPHY

The Kasigau-Karuse area is generally one of low relief, the configuration of which has been influenced by the strike of the Basement System gneisses that underlie the greater portion of it. Stromer von Reichenbach (1896, p. 29) in his description of the northern part of the area referred to it as the Taita Steppe, while the low-lying barren country between the Tanganyika boundary and the Tana river (160 miles to the north-east) is called by the Swahili name, Nyika, which means "the barren desolate region". Crossing the area from north-west to south-east and parallel to the strike of the gneisses is a series of rounded, crystalline limestone ridges, which generally have proved more resistant to erosion than the intervening gneisses, some of which are granitoid. The limestone ridges, which rarely rise more than 300 feet above the surrounding sandy plains, are conspicuous and thickly covered with bush that is in marked contrast to the vegetation of the remainder of the area. Small intervening gneissic ridges and monadnocks, of which Lola, Kurase, Tugwe and Mwachinjoro are typical examples, represent outcrops of the rocks associated with the limestones. To the east of the limestone ridges a number of groups of hills stand up from the sandy plains and include Sagala (which may be regarded as an outlier of the south-eastern part of the Taita hills), the Maungu hills, Kasigau, Rukinga and Kizima (Figs. 1 and 2), whose present topographies have been influenced by the irregularity of their individual geological structures. Kilibasi (2,752 ft.), situated in the east-central part of the area is an isolated hill composed of resistant Duruma Sandstones and is visible for great distances although it is dwarfed by Kasigau (5,393 ft.), which is formed of Basement System gneisses and dominates the whole region (*see* plates I, II and XIII).

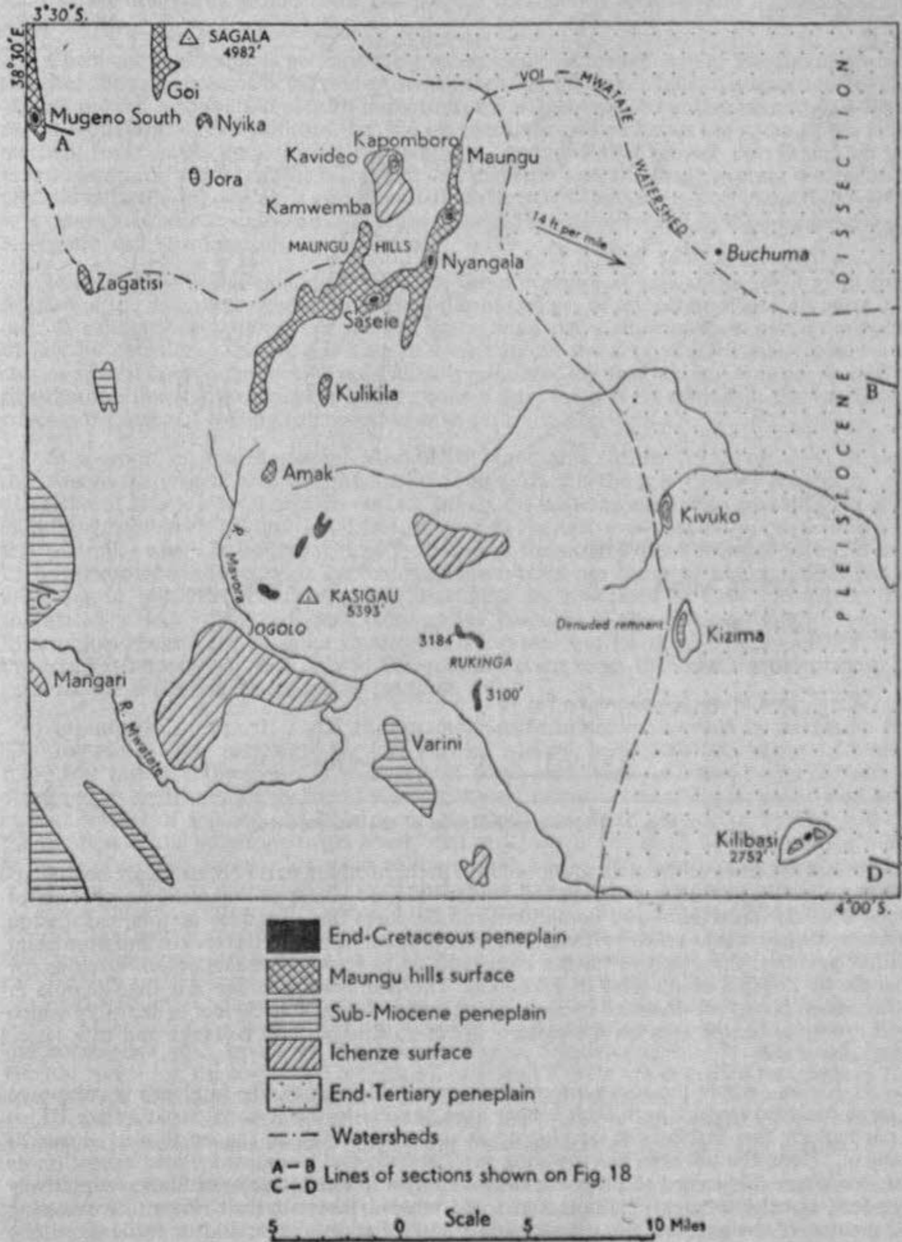


Fig. 1—Physiographical map of the Kasigau area.

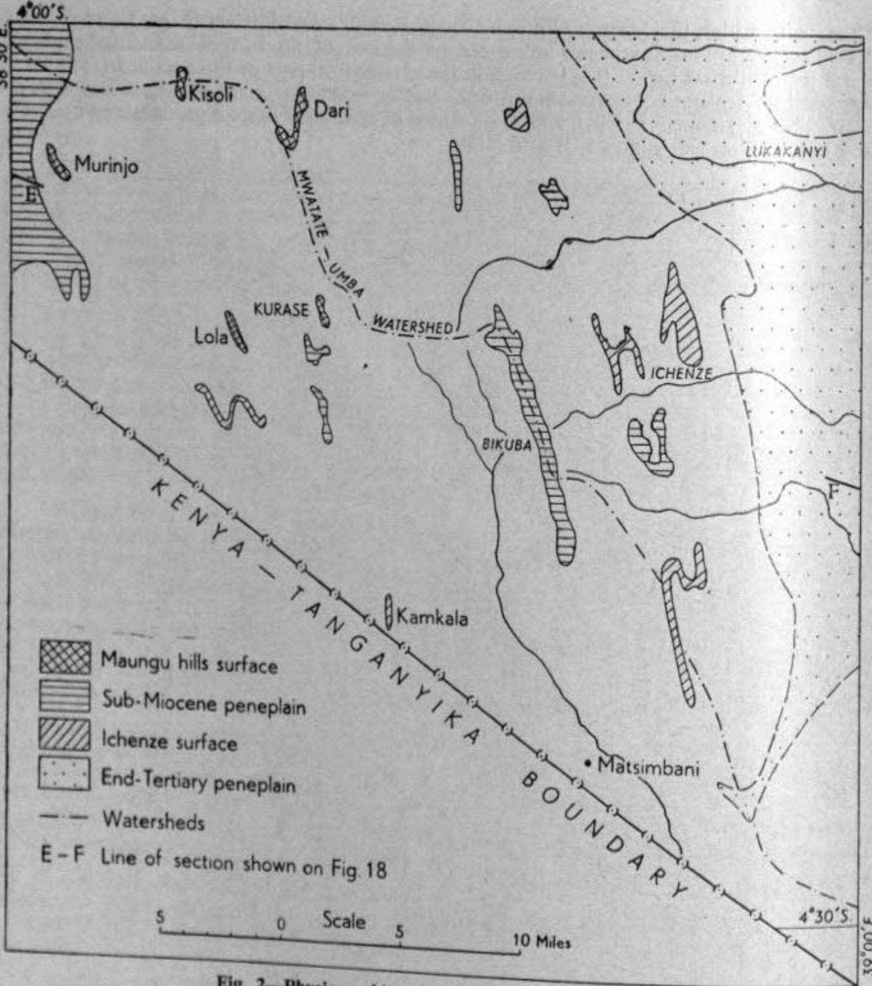


Fig. 2—Physiographical map of the Kurase area.

Round the bases of the main groups of hills in the northern part of the area are pediments that slope gently to the surrounding soil-covered plains. These pediments are a product of lateral erosion under semi-arid conditions and on them fine examples of tors, exfoliation domes and whale-backs are to be found. Beyond the pediment zone it is rare to find prominent residual features, the outcrops having been reduced to rock-pavements at soil level, as for example at Zagana, south-west of Pikapika. The pediments average less than a mile in width and in places are dissected by steep-sided gullies, often 20 to 50 feet in depth, of which good examples can be seen on the eastern slopes of Kasigau and Rukinga and to a lesser extent elsewhere.

At Kizima, where the rocks are resistant granitoid gneisses, the inselberg is composed of large rounded masses, with their longer axes parallel to the regional strike (plate III, *a*) A particularly fine inselberg is developing at the present day on the north-west slopes of Kasigau. Here, the hill area has towering vertical cliffs and is almost isolated except on its east side where it is joined to the main mountain by a low col. Such residuals are relatively joint-free, but the tors, exfoliations domes and whale-backs owe their origin to weathering and erosion of the gneisses along major joints and foliation planes, and in particular along longitudinal joints where lateral erosion is at a maximum. At Kizima a single, but interrupted ridge, contains examples of all three; on the south there is a near-hemispherical exfoliation dome, which gives place northwards to whale-backs, which in turn are being eroded to form isolated blocks (Plate IV). Weathering of these features is assisted by curvilinear joints sub-parallel to the weathered surfaces, and disintegration is by the shedding of successive plates of rock of variable thickness. In the more homogeneous types scaling by separation of thin shells of rock is equally important. Residual boulders commonly lie on such exfoliation surfaces and form part of the rock debris seen on and surrounding the whale-backs.

Chemical weathering is perhaps the greatest single factor influencing the denudation of this area, flowing streams being non-existent except on the larger hills, Kasigau and Sagala. Hydration and carbonation play an important role in this type of weathering and to a lesser extent oxidation. It is significant that the magnesium-rich limestones are some of the most resistant rocks in the area. Under the semi-arid conditions that prevail, rain falling on the limestones quickly flows off the hill slopes and disperses into the sand covering the gneisses. Occasionally where jointing is common it flows through limestones and in such cases the limestones are more easily weathered and saw-edged ridges so typical of the Mangari, Dari, Kivindara and Kamkala hills are produced.

Because of deficient rainfall in the area, the prevalence of clear skies for a great proportion of the year, high evaporation, great diurnal ranges of temperature and, in parts, the lack of suitable vegetation cover such as grass, wind plays an important part in erosion, mainly by deflation. The wind is able to sweep across the area without interruption and carries with it large quantities of sand already produced by weathering. It is partly due to this that the limestones remain as conspicuous ridges, for it is on them that the vegetation cover is thickest, so helping to prevent erosive action by the wind.

In a report on the Mariakani–Mackinnon Road area, Miller (1952, pp. 3–4) showed that east of the present area the principal erosion surface is the end-Tertiary peneplain. An extension of this low-level erosion surface bevels the eastern part of the present area with elevations between 1,400 and 1,100 feet, sloping to the east-south-east at approximately 14 feet per mile, which is less steep than the slope of the same surface recognized by Miller. Laterite exposed at the roadside approximately four miles north-east of Maungu and kunkar limestone in soils near Lukakanyi and Buchuma are presumed to have formed on this surface. The lack of an erosional scarp at the junction of the more resistant Basement System gneisses and the Duruma Sandstones is indicative of the intense peneplanation that the area has undergone. It is only in Pleistocene-Recent times that streams have begun to excavate the softer sediments east of the fault.

As indicated in figs. 1, 2 and 18 four other surfaces are represented by bevels on the hills and are roughly parallel to the end-Tertiary surface, being 200, 500, about 1,050 and 1,250 feet higher respectively. The lowest of these older surfaces, the Ichenze surface, is preserved as remnants on the north-west-south-east ridges between Jogolo (near Kasigau) and south-east of Bukuba, on Ichenze, on Kamkala near the Tanganyika border, and on the summits of the limestone ridges south-west of Kurase. The small hills west of the main Maungu range and Kivuko are relics of the same surface. The next higher surface, which is believed to be part of the sub-Miocene surface of Kenya, bevels the main limestone ridges as well as the rise south of Murinjo and the limestones south of Kurase. The monadnocks Kizima, Jora and Kapomboro are also bevelled by the same surface, while the tops of the east and west spurs on Kilibasi occur at this level. Approximately 1,000 feet above the end-Tertiary surface is a third bevel, the Maungu hills surface, which is probably the equivalent of the Mashoti surface, recognized in the area south of the Taita hills (Walsh, 1960, p. 5). Most of the summits of the hills forming the Maungu range occur at the same level and correspond with bevels on the Mugeno range, Sagala, Zagasiti, Murinjo and Dari. The hill Nyika (on the south side of Sagala), Lola and Kurase are degraded remnants of the same surface. Representatives of an even higher surface presumed to correspond with the end-Cretaceous surface of other parts of Kenya, are probably represented by the summist of Mugeno south, Nyangala and Saseie, and the shoulders of Rukinga and Kasigau.

North-west of the area a datum level is provided by the surface on which rest the Yatta plateau lavas, which are presumed to be of Miocene age (Schoeman 1948, p. 3; Dodson, 1953, p. 3). This sub-Miocene surface stands approximately 500 feet above the end-Tertiary peneplain and the surface that bevels such hills as Varini and Bikuba can be correlated with it. It is possible that the Taru hills, near Mackinnon Road, a little east of the present area are also bevelled by this surface. In Nyanza Province, Shackleton (1951, pp. 377–378) has shown that this sub-Miocene surface is 300–500 feet above the end-Tertiary peneplain and is equivalent to the mid-Tertiary Buganda peneplain (*op. cit.*, p. 380). In the Takabba-Wergudud and El Wak-Aus Mandula areas, Saggerson and Miller (1957, p. 6) and Baker and Saggerson (1958, p. 5) recognized a surface lying approximately 200 feet above the end-Tertiary bevel. It is suggested, therefore, that the Ichenze surface is of a similar age.

The Maungu hills surface is not at present datable but it is suggested that it represents a subsidiary bevel due to uplift at the time of completion of the end-Cretaceous peneplain, which is considered to be the highest surface recognizable in the area. This high surface, standing 1,200 feet above the end-Tertiary peneplain, is comparable in its relationships with the end-Cretaceous peneplain which has been recognized at numerous places in Kenya. The mountains, Kasigau (5,393 ft.), Sagala (4,982 ft.) and Rukinga (3,100 ft.), whose summits are considerably higher than the end-Cretaceous surface were hills that probably existed during the Mesozoic era. Comparable high ground occupied various parts of Kenya during that time and included what are now the Cherangani, Karissia and Nyiro hills.

Not a single permanent river flows through the area and only during the heaviest rains is water to be seen in the principal water-courses. At these times the water flows along restricted stretches of the stream-courses, eventually disappearing into the soil mantle or being held up in water-holes, which are frequently found in the courses. The distribution of drainage in the north is determined by a low east-west watershed which separates the northerly-trending tributaries of the Voi river, ten miles to the north of the present area, from the east-south-east water-courses that form the headwaters of the Mwachi river in the area to the east of Kilibasi. A second watershed in the southern part of the area separates the northern drainage from the south-trending stream-courses, which are tributaries of the Umba river in Tanganyika Territory. The Mwatate is the main river-course in the area and together with the other large stream-courses drains the area between the watersheds.

The Mwatate trends in a south-easterly direction near Mangari on the western borders of the area but bends to the north-east in the vicinity of Varini, where it is joined by the Mavora which passes south-west of Kasigau. It is thought that the Mavora was originally the head of the water-course that continues south of Kilibasi. It is suggested that during a period of uplift in the Pleistocene period a tributary of the Mavora cut back through the Jogolo-Varini limestone ridge and beheaded the Mwatate, which at that time flowed in a south-easterly direction, forming a principal tributary of the Umba river. The lower reaches of the old Mwatate valley are probably represented by the south-trending stream-course west of Bikuba ridge.

The Mwatate east of Mangari is approximately 400 feet lower than the Mwatate-Umba watershed between Kisoli and Dari. So, at the time the river flowed continuously south-eastwards it must have been on a surface about 500 feet above the end-Tertiary surface and before the initiation of the divide near Kisoli or Dari. Further east, the Mavora river makes a sharp bend eastwards seven miles west-south-west of Kilibasi. This bend is probably an elbow of capture, the east-trending stream-course south of Kilibasi having beheaded the formerly south-easterly-flowing Mavora river, the abandoned valley being probably represented by the southerly stream-course approximately eight miles south-west of Kilibasi.

It is likely, therefore, that the original Mwatate and Mavora rivers were south-easterly-trending streams flowing across the sub-Miocene surface, which at the period of its completion sloped gently to the south-east. Subsequent uplift in late Tertiary times increased the erosion power of east or east-south-easterly flowing streams whose headwaters are now represented by the stream-courses in the Kilibasi–Ichenze area. These streams were at one period sufficiently active to enable their headwaters to cut back into the limestone ridges and so form the gaps seen at the present day.

Faulting has played a not inconsiderable part in the erosion of some of the hills. The extremely high vertical cliffs on the upper slopes of Kasigau (Plate V, *b*) are controlled by faults whose throw must have had a large vertical component. These cliffs have probably persisted since pre-Cretaceous times, the amount of erosion on such faces being extremely limited. The streams now flowing from the mountain on the south-western and south-eastern sides are too small to have eroded the large arenas from which they flow. Gaps in a number of the limestone ridges, the low col in the centre of the Rukinga hills and the straight south face of Kilibasi are all topographical features that have been influenced by faulting.

During the Pleistocene, down-cutting by stream action was responsible for the dissection of part of the end-Tertiary peneplain near the eastern border. In more recent times lateral erosion, under semi-arid conditions, has been the controlling factor in the denudation of the Kasigau area.

IV—SUMMARY OF GEOLOGY

The geological succession in the area mapped is:—

Recent	Soils, sands and alluvium.	
Pleistocene	Terrace gravels.	
———	unconformity———	
Tertiary ?	Phonolite (dykes ?)	
———	(intrusive contact)———	
Upper Permian	Lower Maji ya Chumvi Beds Upper Taru Grits	Duruma Sandstones (part).
Lower Permian to Upper Carboniferous	Lower Taru Grits	
———	unconformity ———	
Precambrian (?)	Ultra-basic and basic intrusive rocks.	
———	intrusive contact ———	
Archaean	Kasigau Series Kurase Series	Basement System.

The greater part of the area is occupied by metamorphosed sediments of the Basement System. Outcrops from numerous hills in the north, where Kasigau dominates the whole area, and in the south are generally confined to isolated hills and a series of low ridges that trend north-west-south-east. Consequent on compression the original sediments are highly folded. They are also partly granitised.

Age-determinations carried out recently at Oxford University on felspar porphyroblasts obtained from rocks from the Kasigau Series at Maungu and Nyangala gave the following results:—

	1	2
K_2O wt. per cent	13·2	12·60
A^{40} p.p.m. (not corrected for atmospheric contamination)	0·435	0·350
Age m.y.	490	425

(1) 65/235, felspar porphyroblast from migmatite, Maungu.
(2) 65/244, felspar porphyroblast from granitoid gneiss, Nyangala.

The correction for atmospheric argon is almost invariably less than 5 per cent, and therefore the ages can be given as 490 $\pm$ 25 m.y. and 425 $\pm$ 25 m.y. respectively. These ages indicate the last period of granitization that affected the rocks of the Kasigau Series and suggest that this occurred during the lower part of the Palaeozoic era.

The area is characterized by the presence of numerous and extensive bands of crystalline dolomitic limestones which are associated with kyanite and sillimanite gneisses. The occurrence of these two alumino-silicates in the same rocks suggests that the sillimanite isograd postulated by Sanders (1954, p. 150) passes through this area.

Intrusions of hornblendite and gabbro into rocks of the Kasigau Series are considered to be of Precambrian age.

During the late Palaeozoic era sediments of the Duruma Sandstones were deposited in the eastern part of the area under lacustrine and deltaic conditions. They were formed as a result of uplift and block-faulting of the Basement System gneisses, and cyclic deposition in the Lower Taru Grits is believed to be a result of intermittent uplift during this period. The deltaic deposits in the upper beds indicates in-filling of lakes and a probable encroachment of the sea close to the eastern border of the area during Permian times. At a later period these beds were gently folded and considerably faulted.

Between Cretaceous and Pleistocene times the area was subjected to repeated peneplanation and five bevels can be recognised. Lowering of sea-level at times during the Pleistocene period is considered responsible for the dissection of much of the end-Tertiary peneplain in the eastern part of the area.

Superficial sands and soils of Recent age are widespread and conceal the greater proportion of the Basement System rocks. In dry river-courses the soil is heavy and dark, and grey alluvial soils are extensive. In hill regions boulder-strewn slopes give place quickly to pediments that slope gently to the surrounding plains.

V—DETAILS OF GEOLOGY

1. The Basement System

The rocks of the Basement System are considered to be the metamorphosed equivalents of originally sedimentary rocks, the presence of minor sedimentary structures (ripple-marks and current bedding), staurolite, aluminous rocks, and carbonaceous, dolomitic limestones being proof of sedimentary origin. All the gneisses mapped have strong foliation, which is practically unaffected by migmitization; only at Maungu is the fabric obliterated.

In the Kurase area and the western part of the Kasigau area associated calcareous and pelitic rocks are characterized by numerous crystalline dolomitic limestones. A tectonic study suggests that a series containing limestones of a lenticular nature has been repeatedly folded, and provides evidence for the stratigraphic succession suggested below. These rocks are termed the Kurase Series, after the principal locality in the southern part of the area. A single crystalline limestone outcropping near Mackinnon Road may be part of this series, and it is likely that the same series has been recognised in the eastern part of the Voi area (Sanders, report at the press). It is considered that the succession established by Joubert (1957, p. 32) in the Namanga-Bissel area is equivalent to the same series.

East of the prominent Mugeno-Mwakijembe limestone ridge is a distinct group of rocks that do not outcrop in the Kurase area. These open-folded pelitic, calcareous and semi-calcareous rocks, named the Kasigau Series, are considered to overlie the Kurase Series. They form all the main groups of hills between Sagala and Kizima. No evidence of disconformity or unconformity between the two series has been recognised. The approximate position of the boundary between the two series is shown on figs. 8 and 9. The rocks comprising the Kurase and Kasigau Series probably outcrop in the Taita hills to the north-west of the present area. In his description of the Mtito Andei-Tsavo area (of which the Taita hills are a part), Parkinson, (1947, p. 3) considered the Archaean gneisses to be the equivalent of his Turoka Series of southern Kenya (Parkinson, 1913). It seems likely, however, that the Turoka Series forms only a part of the Mtito Andei-Tsavo area, being equivalent to the Kurase Series.

For descriptive purposes the rocks of the Basement System in the whole area are classified into the following groups:—

Calcareous	Crystalline limestones. Calc-silicate granulites. Hornblende-garnet-scapolite gneisses. Calc-silicate gneisses. Hornblende gneisses. Granitised calc-silicate gneisses.
Pelitic	Kyanite-bearing gneisses. Muscovite-quartz-felspar para-gneisses with quartz-sillimanite *faserkiesel*. Sillimanite-garnet para-gneisses. Biotite gneisses. Graphite gneisses. Garnetiferous para-granulites. Garnet-biotite para-gneisses.
Semi-pelitic	Biotite gneisses. Hornblende-garnet gneisses. Garnetiferous hornblende-biotite gneisses.

Psammitic	Quartz-felspar para-granulites. Quartz-felspar-muscovite para-granulites.
Migmatitic	Migmatites with semi-pelitic host-rock.
Anatectic or Palingenetic	Granitoid gneisses.

Pegmatites and aplites are considered with the last division for convenience, though they may in fact be considerably younger than the Basement System.

The rocks of both the Kasigau and Kurase Series are described together to avoid repetition in petrographical descriptions.

The stratigraphical succession of the Basement System in the area is as follows:—

KASIGAU SERIES

			Thickness (*approximate*) (*feet*)
Granitoid gneiss (Kizima)			1,500
Kyanite-biotite-garnet gneiss (Kamwemba)			1,000
Hornblende-diopside-epidote gneiss Banded biotite-hornblende gneiss Quartz-felspar gneiss Banded-biotite-hornblende gneiss Quartz-felspar gneiss Banded-biotite-hornblende gneiss		(Nyangala)	1,000
Biotite gneisses with garnetiferous calc-silicate granulites (Makiboro)			1,000
Kyanite-biotite gneiss Biotite-garnet gneiss Muscovite gneiss Kyanite-muscovite-biotite gneisses with graphitic and pyrite-rich bands Muscovite-quartz-felspar gneiss Kyanite gneiss with quartz-sillimanite *faserkiesel* at the base Muscovite-quartz-felspar gneiss with quartz-sillimanite *faserkiesel*. Kyanite-garnet gneiss Biotite-garnet gneiss Muscovite-quartz-felspar gneiss with quartz-sillimanite *faserkiesel* at the top.		(Saseie and south Nyangala)	800
Hornblende gneisses with calc-silicate granulites (Kisamani and Kidodongoni)			400
Biotite gneisses with calc-silicate bands Biotite-hornblende gneisses		(Kulikila)	1,200
Kyanite-gneiss (Makaramba)			100
Hornblende-biotite gneisses	800′	(Kasigau Sagala and Rukinga)	4,150
Fissile biotite-hornblende-garnet gneisses	850′		
Hornblende-garnet-scapolite gneiss	700′		
Hornblende-biotite-garnet gneisses with calc-silicate granulites.	800′		
Striped and banded hornblende-biotite-garnet gneisses.	1,000′		

KURASE SERIES

	Thickness (*approximate*) (*feet*)
Pelitic gneisses (including kyanite, graphite and quartz-rich gneisses) with thin limestones (Lola, Kurase and Mwachinjoro)	3,500
Crystalline limestones with thin, interbanded pelitic gneisses (Mugeno, Bikuba, Kivindara, Kisoli and Murinjo)	2,000
Pelitic gneisses (including kyanite, graphitic and quartz-rich gneisses) (Matsimbani and Ndara)	2,500

Thicknesses quoted are only approximate and numerous gaps occur in the sequence quoted due to lack of exposure. Nowhere was any evidence seen or the base or the top of the system.

(1) Metamorphosed Calcareous Sediments

(a) *Crystalline limestones*

The limestones form the most frequent outcrops in the area, giving rise to a series of low, heavily-bushed ridges that trend north-west-south-east across the area. They are particularly noticeable in the Kurase area where almost every ridge is formed of limestone and often overlain by a superficial layer of kunkar. Rarely are intervening gneisses exposed, except as small isolated hills or as small outcrops in gullies. One major limestone horizon can be traced for over 80 miles from Mugeno in the north-west to Mwakijembe in the south-east. The other numerous outcrops, often traceable along the strike for many miles, are considered in certain cases to be the same band repeated by folding, but there is little doubt that more than one horizon is represented. This is clearly the case at Lola and a few miles north-east of Matsimbani where a number of thin limestones are interbedded in a series of pelitic gneisses. The limestones usually have a moderate dip to the east though a number of westerly dips were recorded. They vary in thickness from a few inches (as seen on the north side of Kulikila) to over 600 feet; thicker outcrops such as are seen at Mugeno, west of Sagala, and at Ichenze, sixteen miles east of Kurase, represent close multiplication by folding.

The exposures of the crystalline limestones are generally poor due to the overlying kunkar but some ridges such as Mangari, west-south-west of Kasigau, consist of prominent tombstone-like outcrops. These well-exposed rocks are invariably black in colour due to a thin weathered crust that coats them. The limestones, which usually contain disseminated graphite flakes, are medium-grained rocks and generally white, but often dark grey when rich in graphite. Fine banding in them is emphasised by graphitic and calc-silicate lenses and sometimes by phlogopite. Where strong movements have occurred within the limestones, particularly in proximity to fault-zones, the limestones are dense, extremely fine-grained rocks in which thin graphitic bands and lenses are sheared and sometimes contorted. An excellent example, specimen 68/48*, was obtained from the band ten miles east-north-east of Kurase.

In thin sections the limestones are found to consist mainly of calcite, associated with quartz, graphite, phlogopite, diopside, forsterite and apatite. One specimen, 65/256 from Kwapilo, south-west of Kasigau, is a fairly coarse-grained rock containing scapolite, faintly pleochroic amphibole, diopside, and forsterite marginally altered to iddingsite. Other minerals recognised in hand-specimens include garnet and a rare lustrous, pale-green mica. Wollastonite frequently occurs as knots of variable size. Analyses of a number of crystalline limestones from different parts of the area are quoted on page 53, the specimen localities being shown on figs. 16 and 17. The analyses indicate that the majority of the limestones are dolomitic. One limestone, from two miles east of Tugwe, has a low magnesia content but is probably of only local occurence for the same band, when traced southwards for a few miles, is found to be dolomitic. This suggests that there is some lateral variation within the limestones. The crystalline limestones probably formed originally under marine conditions, as mixed precipitates of calcium and magnesium carbonates, which later changed to the more stable form, dolomite. The pure dolomites have remained apparently unchanged under metamorphism, while the alumina and silica of the more impure rocks have combined with some of the magnesia resulting in the formation of various magnesian minerals.

(b) *Calc-silicate Granulites*

The calc-silicate granulites occur as thin lenses, bands and small segregations in gneisses associated with the crystalline limestones and, more rarely, interbanded with the gneisses that form the hills between Sagala and Rukinga. Hornblende-diopside gneisses and some plagioclase amphibolites also represent original calcareous sediments.

*Numbers prefixed by 65/ and 68/ refer to specimens in the regional collections of the Mines and Geological Department, Nairobi.

Many of the calc-silicate granulites are dense, melanocratic rocks, having a granulitic texture, with pyroxene, plagioclase felspar and garnet as the principal constituents together with accessory sphene, titaniferous magnetite, hornblende, epidote, calcite and rare tremolitee. A thin section of specimen 68/59, from seven miles north-north-east of Matsimbani, revealed the presence of hypersthene forming an intergrowth with hornblende and biotite. The proportion of felspar in the granulites varies considerably. It generally occurs as sub-idioblastic grains exhibiting albite and pericline twinning and ranges in composition in different slides from oligoclase to andesine, but in specimen 65/349, from the east face of Sagala, it is sodic bytownite of composition An_{70}. A colourless or pale-green diopside is characteristic of these rocks, often showing alteration to hornblende. In specimen 65/258, from two miles south of Kasigau, however, light green hornblende is poikiloblastic, containing sphene and relics of colourless diopside. Idioblastic or sub-idioblastic garnets are common in these rocks, often comprising over thirty per cent of the constituents and colouring the gneisses deep-red or even purple. They contain numerous inclusions.

A calc-silicate band, three feet thick, exposed on the north side of Kulikila contains thin inclusions of crystalline limestone and pyroxene-rich gneiss.

It is common to find loose blocks of granulite lying on the limestone ridges, where they are often the only indication that calc-silicate rocks are present. A large number of such blocks are seen on Mai, south-west of Kasigau, the most common being composed of forsterite, diopside, labradorite, garnet and quartz. Specimen 65/323A from the same locality contains the following unusual assemblage, plagioclase–hornblende–garnet–hypersthene and spinel. Yet a third assemblage represented by specimen 68/25, from two miles south-west of Kurase, contains abundant xenoblastic diopside with garnet, scapolite and calcite.

(c) *Garnet-hornblende-scapolite para-gneisses*

A band of gneisses over 500 feet thick is exposed on Rukinga and what is considered to be the same horizon was recognised on Kasigau (fig. 19), Amak and again on Sagala. The rock has a very marked influence on topography, forming prominent features that on upper slopes are nearly devoid of vegetation. Jointing sub-parallel to strike and foliation divides the rocks into massive blocks which have been reduced by weathering to bald surfaces as can be seen on all these hills. One of the most characteristic is Goi at the southern end of the Sagala range, where this type of gneiss forms a steep-sided spur over 1,800 feet in height. Other examples include Are and the summit of Kasigau, both of which are isolated, rounded blocks of striking appearance.

The garnet-hornblende-scapolite gneisses are characteristic rocks of medium colour, rich in resinous garnets that locally form garnetiferous porphyroblasts up to 2 cms. across. Specimens 65/283 and 65/285 from the north-east spur of Rukinga are typical. Some parts of the band on various hills are more leucocratic than the remainder of the rock, being poor in hornblende but often profusely spotted with pin-head garnets, as seen in specimen 65/282 from the north-west spur of Rukinga. In other exposures, melanocratic streaks and stripes rich in hornblende are not uncommon. These rocks are sometimes coarse-grained, in which individual garnets vary in size up to 7 mm., and contain chadacrysts of quartz, hornblende and magnetite. An analysis of the garnet from specimen 65/283 indicated a CaO content of 9·38 per cent. Felspar is more common in these rocks than in the calc-silicate granulites and is oligoclase showing replacive margins against quartz, but in turn is itself partly replaced by scapolite. The scapolite occurs either interstitially, where it replaces felspar, or as sub-idioblastic crystals measuring up to 2 mm. Quartz and prismatic hornblende, which in specimen 65/260 from Kasigau is blue-green, are the other principal constituents. Accessories include apatite, clinozoisite, sphene, magnetite, very rare rutile and chlorite. Pyroxene, which is present in some specimens of the gneiss, is absent from the rock at Rukinga.

Similar rocks, interbanded with biotite gneisses and thin limestones, outcrop in the Lola hills, where they are characterised by strongly pleochroic biotite with X = pale pinkish brown, Y = red-brown, Z = blackish-brown.

(d) *Calc-silicate gneisses*

Calc-silicate gneisses occur as thin melanocratic bands associated with hornblende and biotite-hornblende gneisses (of semi-calcareous and semi-pelitic origin) particularly at Amak, Kidodongoni and Rukinga and on Kasigau. Others are inter-banded with pelitic gneisses and thin crystalline limestones north-east of Matsimbani and at Lola. A much thicker band underlies the garnet-hornblende-scapolite gneisses at Sagala, Kasigau and Rukinga while a similar rock forms the summit of Nyangala. Most are dense, melanocratic, well-jointed rocks with their gneissose structure emphasised by thin felspathic bands. Others are more coarse-grained rocks, in particular that at Nyangala, where it is a massive rock which on weathering forms large sub-rounded blocks.

The calc-silicate gneisses have crystalloblastic textures, the principal constituents being pyroxene, hornblende, and felspar, though in specimen 65/251 from Amak pyroxene is absent, abundant hornblende, felspar and a little garnet being the main minerals present. A pale-green diopsidic pyroxene is characteristic of most of them and is often poikiloblastic towards hornblende and quartz and shows alteration to hornblende. The proportion of hornblende varies in different examples, usually comprising about fifty per cent of the coloured minerals. The hornblende is poikiloblastic, and strongly pleochroic from yellow to deep-green and is often secondary after pyroxene. Fresh plagioclase felspar is a common constituent in the banded varieties, but is only interstitial in the melanocratic rocks such as are exposed on Nyangala. In the banded rocks it forms xenoblastic crystals ranging in composition in different rocks from An_{50} to An_8, those occurring in gneisses which have hornblende in preponderance (such as specimen 65/251) being more calcic. In specimen 65/288 from Kidodongoni the felspar shows evidence of straining in bent twin lamellae and irregular extinction. Dark resinous garnets often intergrown with hornblende, diopside and quartz, are frequently associated with these gneisses, occurring in small concentrations in certain bands as in specimen 65/255 from Kasigau, or sparsely distributed throughout the rocks. Sub-idioblastic epidote is a common accessory and at Nyangala forms epidote-rich lenses, the mineral comprising a significant proportion of the rock. In specimen 65/247 from Nyangala it is pleochroic from colourless to pale yellow-green and sometimes encloses small rounded grains of felspar. Accessory minerals in these rocks include xenoblastic quartz, scapolite, calcite, sphene, apatite and black iron-ore.

(*e*) *Hornblende Gneisses*

A number of hornblende gneisses considered to be rocks derived from semi-calcareous sediments are mainly found at Amak, Kidodongoni and on the lower slopes of Kasigau. At these localities they frequently contain small melanocratic lenses of calc-silicate granulite and are interbanded with calc-silicate gneisses, which they closely resemble.

These hornblende gneisses are biotite-free and are usually melanocratic rocks with well developed gneissose textures emphasised by felspar-rich streaks and bands. They have been partly migmatised but retain their original banded structure and for this reason are described here (migmatitic structures in these rocks are described in a later section). Thin sections indicate that they are granoblastic aggregates of hornblende and plagioclase with subordinate garnet and quartz. Specimen 65/252 from Amak is typical and is characterized by fresh medium andesine that partly replaces quartz. The hornblende is strongly pleochroic from pale yellow-green to deep olive-green and occurs in irregular to sub-idioblastic crystals with poor terminations, associated with small pale pink irregular to idioblastic garnets. Accessories in different slides include scapolite, sphene, apatite, epidote and black iron ore.

(2) Metamorphosed Pelitic Sediments

Rocks considered to be metamorphosed pelitic sediments occur in separate parts of the area, one in the Maungu hills, (Kasigau Series) and the other among the limestones in the southern part (Kurase Series). Their evolution has probably followed slightly different courses during metamorphism, in part due to migmitization of the Maungu rocks.

Kyanite, graphite and biotite are typical minerals in these rocks and sillimanite is present in many bands at Maungu, where it occurs in quartz-sillimanite knots or *faserkiesel*.

A number of the kyanite rocks in the Kurase Series are highly siliceous and may, in fact, represent impure quartzitic rocks, but are considered here for convenience. The *faserkiesel* are associated with light-coloured muscovite gneisses and granulites and with kyanite-biotite gneisses in a region of weak granitization that developed during migmatization. The pelitic group is invaded by potash-rich pegmatites and aplites; *lit-par-lit* injections are abundant. This occurrence of quartz-sillimanite *faserkiesel* in regions of granitization is significant, and has been previously described by Shackleton (1946, p. 9) and Sanders (1954, p. 13) in other parts of the Colony and by Read (1931, p. 154) in central Sutherland.

Garnetiferous sillimanite bands are interbedded with crystalline limestones at Kivindara, but sillimanite is less frequent among the kyanite-bearing gneisses further south. The presence of staurolite in some of the gneisses is indicative of their sedimentary origin. Rutile is a common mineral in those rocks containing the alumino-silicates and probably indicates a relatively high titanium content in the original sediments, rather than its introduction by metasomatizing fluids, although its preponderance over sphene might suggest high-grade metamorphism in these rocks. Garnet-bearing pelitic rocks are widespread throughout the area and usually exposures consist of leucocratic well-jointed granulites forming numerous thin bands in melanocratic rocks. At Nyangala rare garnet porphyroblasts were noticed in biotite and kyanite-biotite gneisses that are otherwise garnet-free.

For the purposes of description the metamorphosed pelitic rocks are divided into the following groups:—

(*a*) Kyanite-bearing gneisses.

(*b*) Muscovite-quartz-felspar gneisses with quartz-sillimanite *faserkiesel.*

(*c*) Sillimanite-garnet para-gneisses.

(*d*) Muscovite para-gneisses.

(*e*) Biotite gneisses.

(*f*) Graphite gneisses.

(*g*) Garnet para-granulites.

(*h*) Garnet-biotite para-gneisses.

(*a*) *Kyanite-bearing Gneisses*

Kyanite gneisses are exposed in a number of places in the area but particularly in the Maungu hills, where the principal occurrences were seen on Saseie and Nyangala. Other important outcrops occur in the southern part of the area and include Mwachinjoro and Matsimbani, while bands associated with graphitic gneisses were observed one mile east of Ndemkungo, where they were traced for only short distances. Examples of the more siliceous kyanite gneisses occur in the Mwachinjoro area.

(i) *Kyanite-graphite gneisses*

Between Kamkala and Ndemkungo near the Kenya-Tanganyika border a number of kyanite-graphite gneisses form good but scattered exposures of which Mwachinjoro, a small conical peak nearly 100 feet high, is the most prominent. Rare gully sections reveal the presence of thin interbanded crystalline limestones which are probably lenticular, while persistent limestone bands form exposures south-west of Mwachinjoro and east of Ndemkungo.

The Mwachinjoro band is a grey, siliceous, granulitic rock containing abundant flakes of graphite, and kyanite either as small plates or as small ovoid bodies measuring up to 5 mm. in length. On weathered surfaces these ovoid bodies impart a curiously knotted appearance to the gneisses and it was observed that their larger axes roughly parallel the lineation.

In thin sections (68/70) the Mwachinjoro rock consists mainly of an even granular mosaic of quartz with kyanite, and flake graphite. Small scattered needles of sillimanite are also present, usually as inclusions within the quartz and felspar, but occasionally associated with the kyanite. Wisps of sericite are probably secondary after sillimanite. Rutile and magnetite are accessory minerals. The kyanite forms colourless blades. In the kyanite knots the kyanite forms large aggregates exhibiting undulose extinction and containing a few small quartz crystals and innumerable, carbonaceous inclusions which in some cases render the kyanite nearly opaque. The carbonaceous inclusions occur mainly as granules and small flakes that are in marked contrast to the large graphite flakes present elsewhere in the rock (fig. 4*a*). The kyanite knots probably were originally alumina-rich pellets in a sediment.

(ii) *Kyanite-muscovite gneisses*

Fissile kyanite-muscovite gneisses associated with crystalline limestone bands outcrop two miles south-west of Mwachinjoro. Muscovite is a prominent constituent forming glistening stout flakes that are associated with flakes of lustrous graphite. In a thin section (68/71) a specimen is seen to be composed of irregular tabular kyanite crystals sieved by quartz grains, and occasional prisms of staurolite in an uneven mosaic of quartz.

(iii) *Kyanite gneisses*

Kyanite gneisses were seen in one locality, Matsimbani, in the south-eastern part of the area, where they form a low isolated hill that is conspicuous in an area of few outcrops. The field relationships suggest that these leucocratic gneisses are part of a pelitic sequence mainly consisting of graphitic gneisses. Specimen 68/67 is coarse-grained, consisting largely of a crystalloblastic aggregate of quartz, and kyanite idioblasts. Fine hairs and colourless needles of sillimanite are enclosed within the quartz (fig. 3*b*).

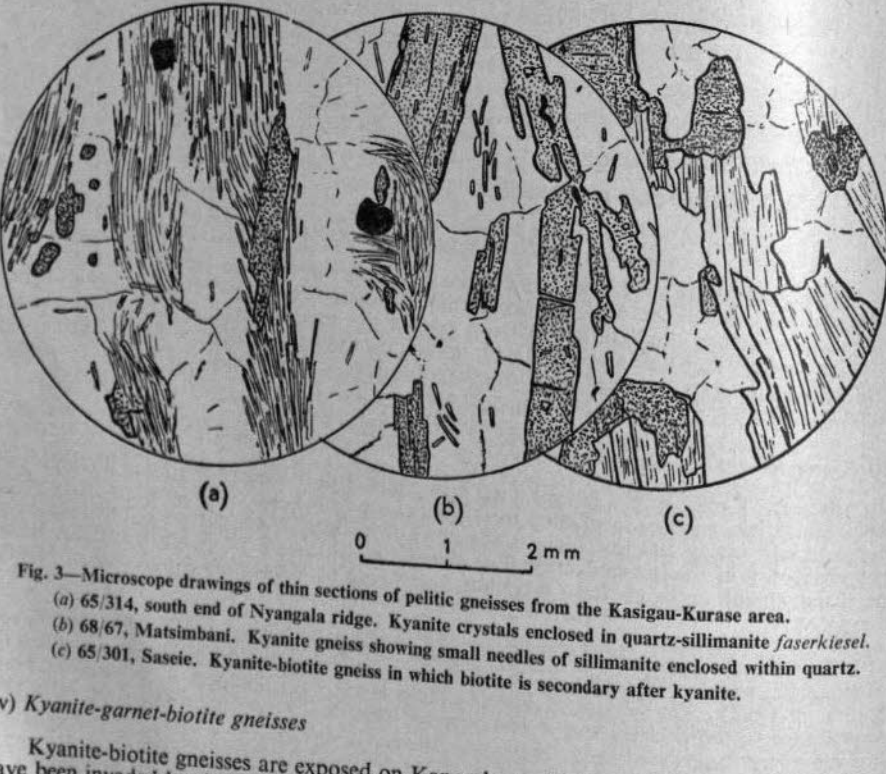


Fig. 3—Microscope drawings of thin sections of pelitic gneisses from the Kasigau-Kurase area.
(*a*) 65/314, south end of Nyangala ridge. Kyanite crystals enclosed in quartz-sillimanite *faserkiesel*.
(*b*) 68/67, Matsimbani. Kyanite gneiss showing small needles of sillimanite enclosed within quartz.
(*c*) 65/301, Saseie. Kyanite-biotite gneiss in which biotite is secondary after kyanite.

(iv) *Kyanite-garnet-biotite gneisses*

Kyanite-biotite gneisses are exposed on Kapomboro, Saseie and Nyangala, where they have been invaded by thin streaks and lenticles of pink to white potash felspar and quartz. At the first locality they are associated with leucocratic rocks and are sprinkled with deep red garnets. The kyanite which is in small pale blue crystals is generally confined to darker schistose bands. On Saseie and Nyangala, kyanite occurs in numerous bands mainly associated with black biotite gneisses, into which they grade rapidly, and which at the southern end of the Nyangala ridge overlie sillimanite gneisses. These kyanite-rich rocks are bluish-black and coarse-grained. Small dark-red garnets not always seen in thin sections are observable in hand-specimens. Weathered, flaggy surfaces are common and expose thick bands of kyanite-bearing rock, the blades of greenish blue kyanite measuring up to two inches in length and exhibiting good orientation.

Microscope examination of a typical specimen from Saseie (65/301) reveals that these rocks consist of stout irregular crystals of kyanite, plagioclase, quartz and biotite. The biotite crystals range in size up to 3 mm. in length and are markedly pleochroic from pale yellow-brown to brownish black. The kyanite is generally in tabular plates and has a typical sieve structure due to numerous quartz inclusions. Ragged biotite flakes have partly replaced the kyanite (fig. 3*c*). The rock from Kapomboro (65/240) is finer-grained and contains much less kyanite and a correspondingly greater proportion of quartz and felspar. Garnet is prominent in it and muscovite forms small ragged flakes.

(v) *Kyanite gneisses with quartz-sillimanite faserkiesel*

Among the pelitic gneisses at Nyangala are schistose, pale green kyanite gneisses containing quartz-sillimanite *faserkiesel*. They are particularly noticeable where they outcrop together with muscovite gneisses. Weathering of the titano-magnetite grains, which are common in these rocks, has stained them pink. When associated with the kyanite-biotite-garnet gneisses, however, the kyanite *faserkiesel* gneisses are darker coloured with blue-green kyanite folia containing the white *faserkiesel* which, unlike those described in the following section are flat, plate-like bodies with diffuse boundaries. They vary in size from one to twelve inches in length and their longer axes parallel the lineation of the gneisses. The rocks also contain garnet-bearing layers. In thin slices (65/314, 65/316) it is found that the *faserkiesel* consists of a quartz mosaic containing scattered magnetite, rutile and biotite crystals together with felted mats of fine, sillimanite needles. In some cases relic kyanite crystals associated with the mats are partly altered to sillimanite, while in other cases kyanite blades are enclosed within the sheaves and show no alteration, though the kyanite is undoubtedly of earlier origin than the sillimanite. Muscovite is present in some specimens and there is a suggestion that it pseudomorphoses, in part, the sillimanite (65/316).

(*b*) *Muscovite-quartz-felspar Gneisses with Quartz-sillimanite faserkiesel*

Thick bedded leucocratic gneisses outcrop beneath the kyanite gneisses at Nyangala. They are muscovite-quartz-felspar gneisses characterized by white quartz-sillimanite *faserkiesel*, that vary in size but are usually two to three inches in length. Rare one-inch pods of dirty-green apatite were also observed in these gneisses. The *faserkiesel* are small, flattened, ovoid bodies, the major axes of which parallel the lineation of the host-rock while the minor axes coincide with the regional 'a' tectonic axis (Plate VI). Many of the ovoids are rich in quartz and are speckled with titano-magnetite grains, when the sillimanite is not easily recognised in the hand-specimens. Other specimens (e.g. 65/305) consist of sillimanite knots associated with muscovite, with quartz less abundant. Muscovite is widely scattered throughout the gneisses, but is also locally concentrated into small folia or pods approximately the size of the *faserkiesel*. In these cases the rocks are comparable with the pseudo-sillimanite gneisses described by Sanders (1954A, p. 13).

The host-rock is composed of a xenoblastic aggregate of quartz, oligoclase and microcline, the felspars having replacive margins against the quartz. Rutile, magnetite, muscovite and brown mica are common accessory minerals while close to the margins of the *faserkiesel* sillimanite needles and kyanite crystals are not uncommon (fig. 4*c*). Thin sections of the *faserkiesel* indicate that they consist of fibrous sheaves and radiating bunches of colourless slender sillimanite needles within a mosaic of quartz crystals and titano-magnetite. In one slide, of specimen 65/305, sillimanite replaces muscovite, sheaf-like aggregates of sillimanite being enclosed within stout crystals of the latter mineral (fig. 4*b*). Other slides (65/312) contain small, scattered irregular kyanite crystals some of which are enclosed within the sheaves of sillimanite (fig. 3*a*). Muscovite was also seen to replace sillimanite in some slides.

(*c*) *Sillimanite-garnet para-gneisses*

Between Kivindara and Dari sillimanite-garnet gneisses are interbanded among crystalline limestones. They are extremely hard and quartzose, coarse-grained, and speckled with red-brown aggregates of garnet (68/34). Sillimanite occurs in large sheaves over three inches in length and is concentrated in thin folia, thus emphasising the gneissosity. Magnetite and ragged brown biotite flakes are common accessories. The sillimanite occurs as long and short needle-like crystals which are crudely orientated and enclosed bv the quartz.

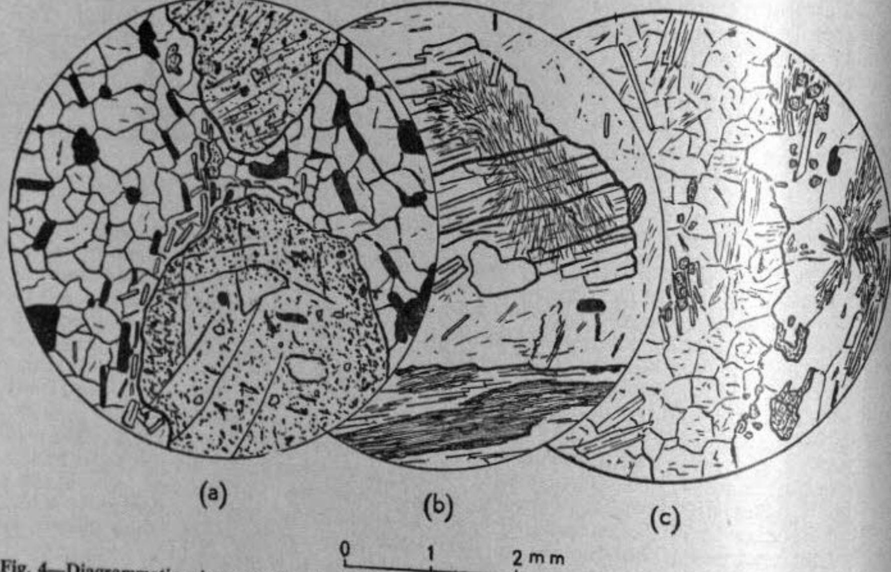


Fig. 4—Diagrammatic microscope drawings of thin sections of pelitic gneisses from the Kasigau-Kurase area.
(*a*) 68/70, Mwachinjoro. Kyanite knots in kyanite-graphite gneiss showing relic sillimanite needles.
(*b*) 65/305, south end of Nyangala ridge. Sillimanite secondary after muscovite in quartz-sillimanite *faserkiesel*. The muscovite plates enclose hairs of sillimanite which forms a sheaf-like aggregate.
(*c*) 65/312, south end of Nyangala ridge. Margin of sillimanite *faserkiesel* and muscovite-quartz-felspar gneiss, showing sillimanite and kyanite crystals.

(*d*) *Muscovite Para-gneisses*

Leucocratic, flaggy, muscovite para-gneisses form thin bands in metamorphic pelitic rocks at the south end of Nyangala spur and on Saseie, where they grade into quartzo-felspathic gneisses. Lustrous, white muscovite is the characteristic mineral of these gneisses and occurs as thin folia between quartz-felspar bands. Locally some of these gneisses are graphitic, while pyrite was also seen associated with them on Nyangala. A yellow-brown skin of hydrated iron ore covers the weathered pyritiferous gneisses and penetrates the intergranular spaces of the rocks for short distances.

In thin sections these para-gneisses show a granoblastic aggregate of felspar, quartz and muscovite. The mica occurs in stout flakes of variable size up to 3 mm. in length and partly replaces the felspar which is poikilitically enclosed by it. The plagioclase is sodic oligoclase. In specimen 65/308 from Nyangala the plagioclase forms a xenoblastic mosaic with abundant microcline which, unlike the plagioclase, is fairly fresh and replaces both quartz and plagioclase. Graphite, pyrite, magnetite and abundant rutile are common accessories. The pyrite in specimen 65/308 has been marginally and sometimes entirely hydrated, a yellow alteration product resulting. The rock is also traversed by thin veins of the same material, which in addition forms small prismatic crystals (fig. 7*b*).

(*e*) *Biotite Gneisses*

Typical hornblende-free biotite gneisses outcrop on Saseie and on the Nyangala ridge. In hand-specimens they are soft fissile rocks characterized by lustrous black biotite, which locally forms coarser-grained biotite schist lenticles of considerable extent. Locally both gneiss and schist lenticles are studded with resinous dark-red garnets. Thin sections of these rocks show that they are composed of coarse-grained crystalloblastic aggregates of oligoclase, replacive microcline and quartz, with abundant biotite. The biotite is strongly pleochroic with X = yellow-brown, Y = brown, Z = greenish black. Accessory minerals recognized in different slides include titano-magnetite, apatite, clinozoisite, chlorite (secondary after biotite) muscovite and rare zircon. With increase of muscovite these biotite gneisses grade into muscovite-biotite gneisses as seen at Igoilacha.

(*f*) *Graphite Gneisses*

Exposures of grey, graphitic gneisses outcrop in numerous places in the southern part of the area between Kurase and Kamkala and in gullies three miles north of Matsimbani. One band, which forms a low ridge a mile east of Ndemkungo, was traced for a few miles, while south-south-east of that hill a thin band was mapped interbedded with crystalline limestones and kyanite-graphite gneisses. Other outcrops form isolated exposures, the most notable being that east of Kamkala. Numerous graphite gneiss lenses form thin screens within the crystalline limestones.

The graphite gneisses are light-coloured rocks, often with a thin oxidized skin, though they generally have a fresh appearance when broken open. Like the quartzo-felspathic granulites many form upstanding ribs of rock, although gneisses rich in graphitic folia, such as are represented by specimen 68/21 from one mile east of Ndemkungo, are more easily eroded. The bands that are resistant to erosion are quartz-rich varieties and hand-specimens reveal the presence of long irregular lenticles free from graphite, separating altered felspathic bands containing abundant flakes of graphite that measure up to 3 mm. Some of the graphite gneisses when they are sheared are flinty, weakly gneissose rocks with an irregular fracture when broken.

In thin sections these rocks are found to be mainly composed of a heteroblastic mosaic of plagioclase and quartz. The plagioclase is often untwinned but specimen 68/30 from one mile east of Ndemkungo, contains twinned medium oligoclase. Other specimens contain perthitic microcline in addition (e.g. 68/66, from three miles north of Matsimbani). These minerals are associated with graphite flakes which parallel the foliation though, in sheared specimens, the graphite is extremely fine-grained and disseminated throughout the rock, occasionally being enclosed by the other minerals or forming an irregular graphite sheath round them. Accessory minerals include biotite and epidote and, in specimen 68/66, pyrite.

(*g*) *Garnet Para-granulites*

The garnetiferous para-granulites are leucocratic rocks composed largely of quartz and felspar, but sprinkled with dull-red garnets, which in some rocks like those that form Kurase are concentrated in thin streaks and aggregates that emphasize the foliation. With decrease in the garnet content the rocks grade into the psammitic quartz-felspar granulites which have a similar appearance, regular block-jointing being characteristic of both types. The garnetiferous gneisses form thin resistant bands and are associated with pelitic rocks and crystalline limestones. At Kurase, where the hard garnetiferous rocks form a number of bare, rounded hills peculiar to that area the garnet content has reached notable proportions. Spheroidal weathering of this type of rock is not uncommon (Plate V (*a*)).

Thin sections show that the garnet para-granulites consist of microcline, plagioclase, quartz and garnet in a crystalloblastic mosaic. The plagioclase, which is a medium oligoclase and shows myrmekitic growths and replacement of quartz round the margins, is present in approximately equal proportions with perthitic microcline. Both felspars are dusty with alteration products. The garnets are pale pink, enclosing large rounded quartz grains, and are severely cracked, as in specimen 68/26 from three miles south-east of Kurase. Quartz is a prominent constituent of these rocks, occurring as small and large, xenoblastic grains that emphasize the gneissose texture and are often concentrated in folia. Black iron ore and biotite are common accessories while, in specimen 68/21 from Kurase, hypersthene is an important constituent.

(*h*) *Garnet-biotite Para-gneisses*

These are light to dark, well-foliated, flaggy, biotite-rich gneisses which are variably sprinkled with garnets. Occasionally the rocks have a sugary appearance. They mainly occur within pelitic gneisses associated with crystalline limestones at Mugeno, and in the southern part of the area, and in the pelitic and semi-pelitic successions that form part of the principal hills near Kasigau. They are to be distinguished from the biotite gneisses which are much darker rocks, and much richer in biotite.

The essential minerals in the garnet-biotite para-gneisses include biotite, plagioclase, garnet and quartz. Red-brown or dark greenish brown, strongly pleochroic biotite occurs in flakes concentrated in foliation planes. In specimen 68/12 from Murinjo it is associated with muscovite and a little ragged chlorite. The composition of the plagioclase felspar ranges from andesine to oligoclase in different rocks. It exhibits pericline and albite twinning and is partly sericitized. The garnets are small, pink idioblastic crystals with rare poikiloblastic inclusions of quartz. Apatite and iron ore are the usual accessories and calcite was noticed included within the felspar of specimen 68/12.

(3) Metamorphosed Semi-pelitic Sediments

A number of partly migmatitized gneisses of semi-pelitic origin occur throughout the area, but mainly in the hills of the Kasigau area and as isolated exposures in the sandy plains. They are striped and banded gneisses, consisting of rapidly alternating leucocratic and melanocratic bands of different thicknesses. Individual exposures are seen to contain variable proportions of hornblende and biotite, and usually garnet, though garnet is not always present. The semi-pelitic gneisses occur both below and above the prominent band of calcareous gneisses exposed in the hills between Sagala and Rukinga, the upper gneisses being more easily accessible and best seen at Kidodongoni, Amak, Kulikila and Makiboro. Similar gneisses form the isolated hills of Tulema and Lwalaluandere south of Rukinga, and Zagana, west of Kizima. The group includes:—

(*a*) Biotite gneisses.

(*b*) Hornblende-garnet gneisses.

(*c*) Garnetiferous hornblende-biotite gneisses.

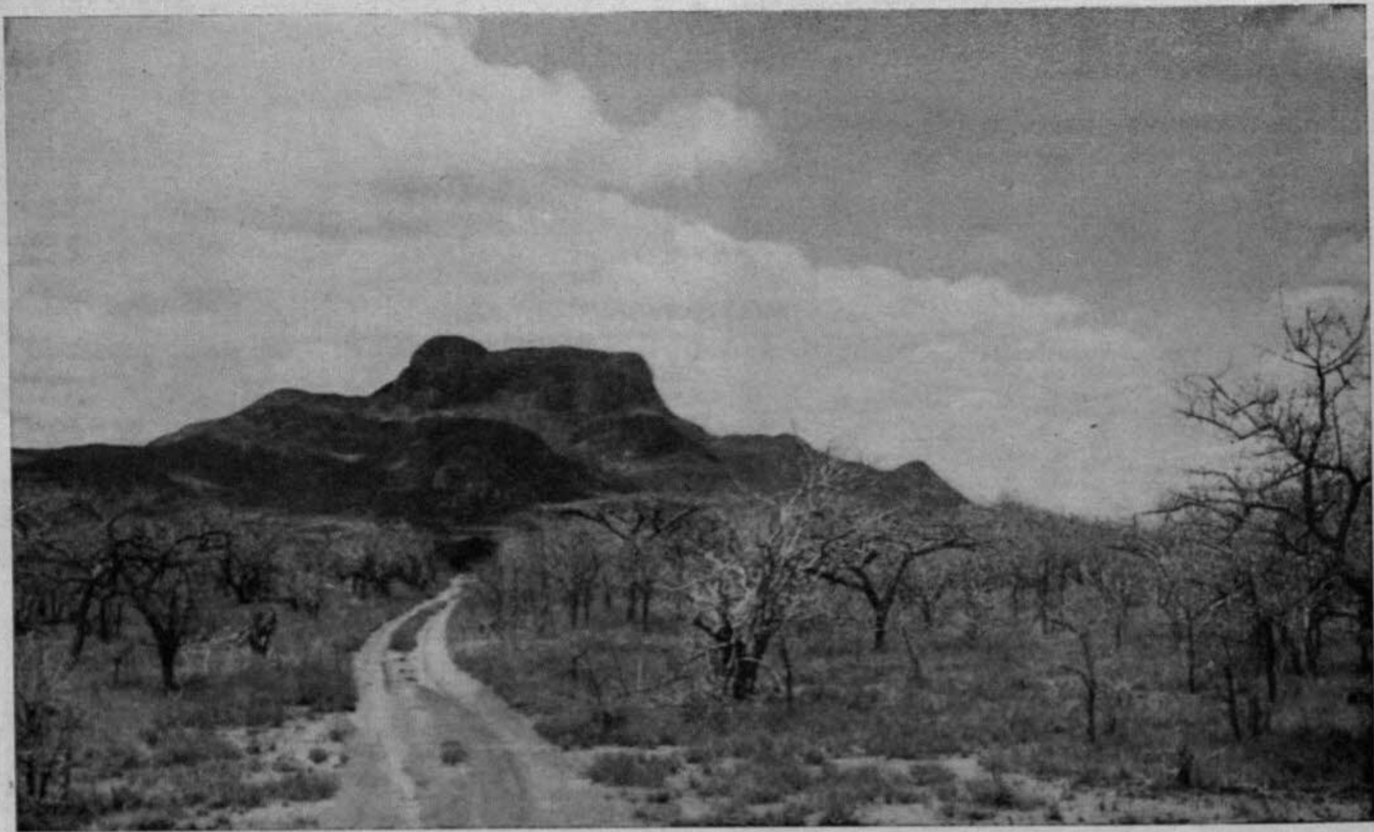
(*a*) *Biotite Gneisses*

The biotite gneisses are grey-brown flaggy, fine-grained rocks and occasionally granulitic. Their sedimentary origin is confirmed by ripple-marking which has been preserved in biotite gneisses above Makwasinye at Kasigau. They contain considerably less biotite than the gneisses of pelitic origin but more than the metamorphosed psammitic sediments. They are associated with hornblende-biotite gneisses in the northern part of the area and form isolated exposures or are interbanded with the garnet-biotite gneisses in the Kurase Series. A typical example occurs at Kwandemukungo, six miles south-west of Kurase. In thin section these rocks show a granoblastic mosaic of plagioclase, microcline and quartz with dark-brown biotite.

(*b*) *Hornblende-garnet Gneisses*

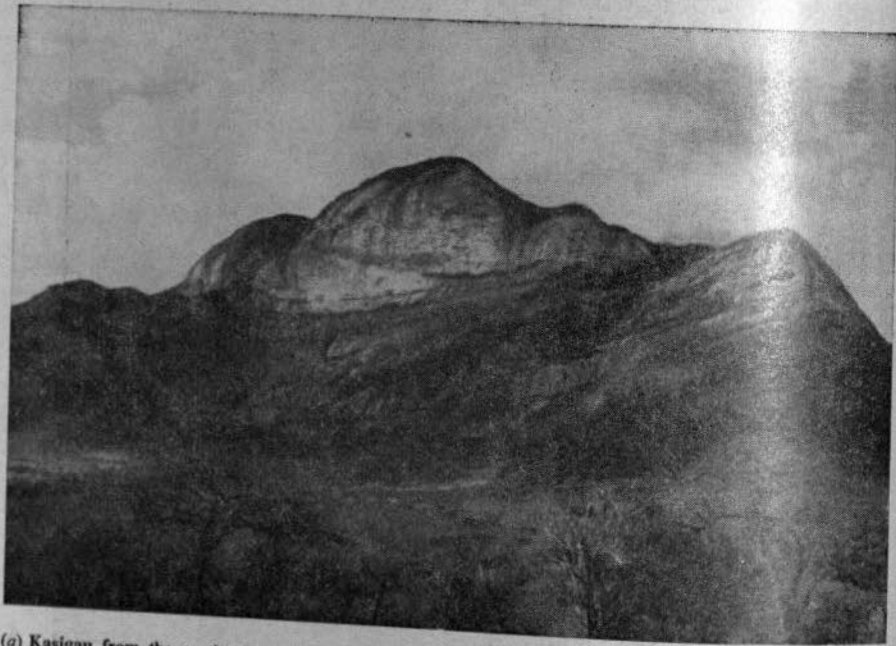
Flaggy hornblende-garnet gneisses of intermediate colour are commonly associated with the other rocks of semi-pelitic origin, all of which are well-exposed on the upper slopes of the south-eastern spur of Kasigau. Other outcrops are seen on the northern slopes of Kasigau and at Rukinga and Sagala. These rocks weather very similarly to the hornblende-biotite gneisses and are therefore difficult to distinguish on some of the thickly bushed or scree-covered slopes. The bands are similar in appearance to the prominent garnet-hornblende scapolite gneisses seen in these hills (particularly when weathered) and often thin sections are the only means by which the two types can be distinguished. Thin sections indicate that they are crystalloblastic aggregates of plagioclase, hornblende, garnet and subordinate quartz. The hornblende is generally concentrated in folia and occurs as xenoblastic or sub-idioblastic crystals, usually with poor terminations. Rounded pale pink garnets are present in most of these rocks, many being highly poikiloblastic and displaying typical sieve structure, as in specimen 65/279 from the summit of Kasigau. In specimen 65/339 from Sagala the garnet is idioblastic and is directly associated with hornblende, which has crystallised round it. These two minerals, which are crudely orientated, impart a strong gneissose texture to the rock. The plagioclase is mostly twinned oligoclase, often enclosing small quartz droplets. In specimen 65/339 quartz and felspar are concentrated between the hornblende-garnet rich folia, the quartz sometimes forming large elongated crystals. Apatite and black iron ore are common accessory minerals.

Plate I

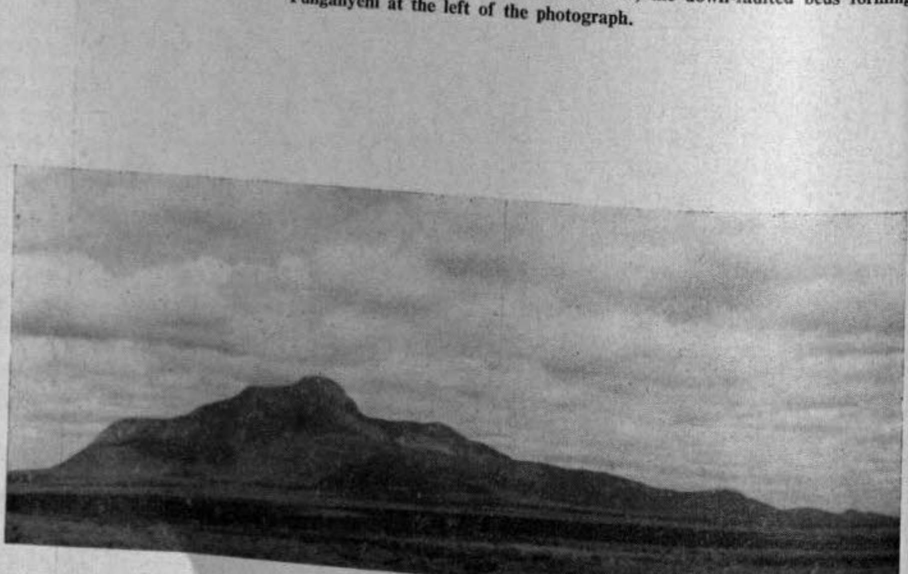


Kasigau

Plate II



(*a*) Kasigau from the south. The cliff is considered to be a fault feature, the down-faulted beds forming Funganyeni at the left of the photograph.



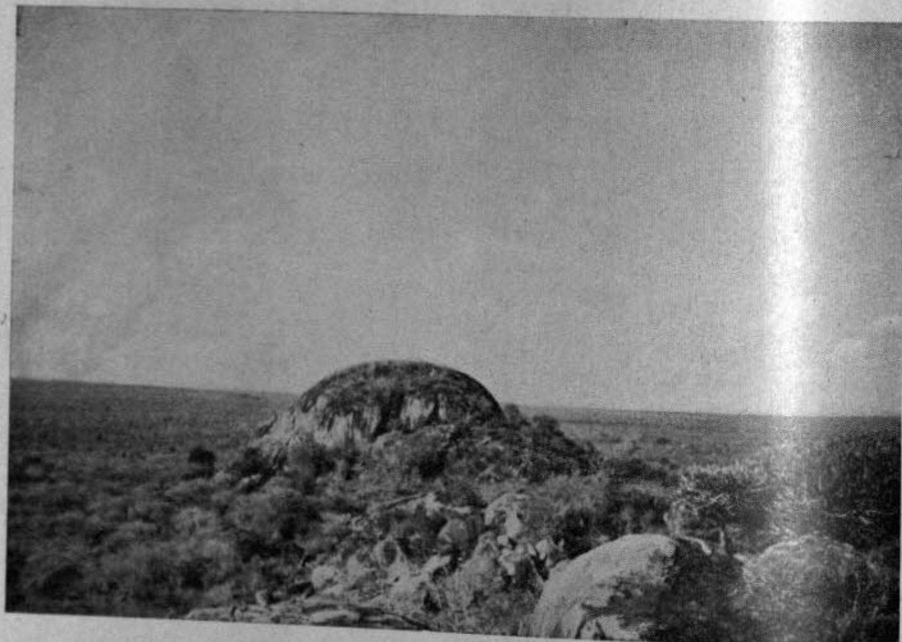
(*b*) Kasigau from the east. The northerly plunge of the fold that forms the upper part of the hill is visible. It is more gentle on the north side of a fault which passes to the right (north) of the main peak.

Plate III

(*a*) Kizima. A group of hills of granitoid gneiss plunging gently to the north.

(*b*) Synclinal structure at Nyangala, near Maungu. A band of quartz-felspar gneisses is visible in the middle of the hill, of which the summit is formed by hornblende-diopside-epidote plagioclase gneisses.

Plate IV



(*a*) An exfoliation dome of granitoid gneiss at Kizima.

(*b*) Jointing developed in thick plates in granitoid gneisses at Kizima.

Plate V

(*a*) Spheroidal weathering in garnet gneisses, Kurase.

(*b*) Vertical cliffs on the Jora face, Kasigau.

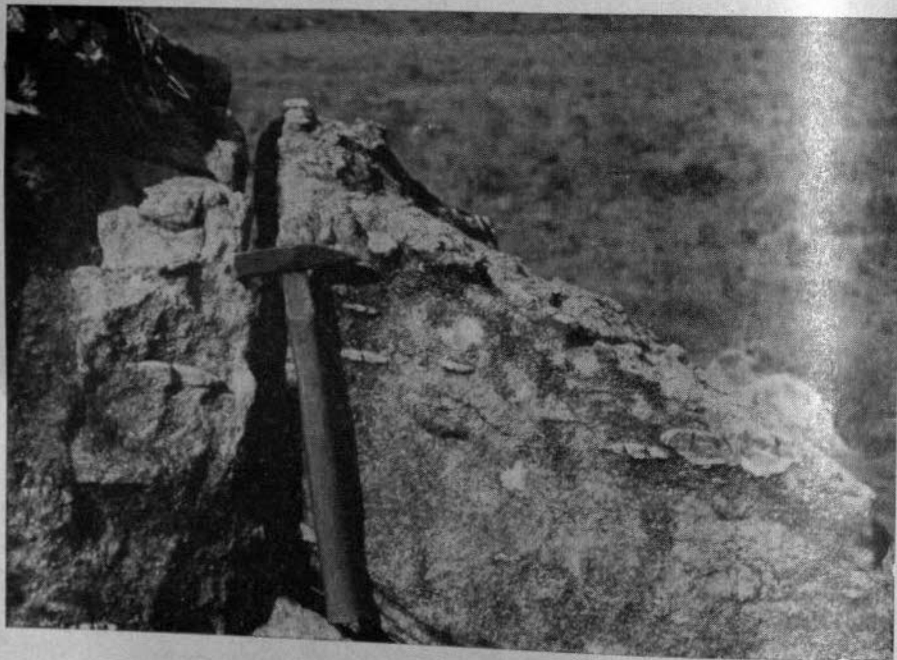


Plate VI—(*a*) and (*b*) Quartz-sillimanite *faserkiesel* in muscovite-quartz-felspar gneisses at Nyangala. Preferred orientation of the *faserkiesel* is apparent in both photographs.

Plate VII—Progressive stages in migmatization.

(*a*) *Lit par lit* injections in biotite gneisses at Nyangala.

(*b*) Ptymatic vein following the foliation of the country-rock at Nyangala.

(*c*) and (*d*) Contorted migmatites of Maungu, showing plastic deformation.

Plate VIII

View of Kilibasi from the south showing the prominent west and east spurs that form the opposing limbs of a shallow syncline in Lower Taru Grits.

(c) Garnetiferous hornblende-biotite Gneisses

Hornblende-biotite gneisses are the more common rocks of this group, often forming large whale-back outcrops particularly on Kasigau and at Manjuga, the southern hill of the Rukinga group. They have a marked banded and striped appearance due to planar concentration of the ferromagnesian minerals, which are commonly associated with garnet.

These gneisses are typically melanocratic and often fissile due to the presence of folia of lustrous black or brown biotite, but more granulitic when poor in biotite. Resistant examples among them, rich in hornblende, grade into hornblende-garnet gneisses and more rarely into hornblende-diopside gneisses. Some of the melanocratic streaks in the hornblende-biotite gneisses have central zones of calc-silicate granulites rich in diopside, while at Zagana small local segregations of epidote were observed. In the outcrop north of Buchuma the rock has small pink microcline porphyroblasts developed in the leucrocratic bands, imparting an augen texture.

The garnetiferous hornblende-biotite gneisses are heretoblastic rocks in which hornblende and biotite are intimately associated. The hornblende occurs as pale to olive green, pleochroic, xenoblastic crystals which, in specimen 65/286 from Zagana, are intergrown with and partly enclose smaller crystals of biotite. The latter mineral, which occurs as poorly terminated crystals, is stronly pleochroic from brownish yellow to blackish brown. In thin sections it is seen that oligoclase is the most common mineral, associated with quartz. It forms myrmekitic intergrowths with, or marginally replaces, quartz or encloses large rounded crystals of it. Zircon, prismatic apatite, black iron ore, hematite, sphene and epidote are minor constituents.

(4) Metamorphosed Psammitic Sediments

The few metamorphosed psammitic rocks recognised in the area were seen mainly in the Maungu hills in the northern part, where they are associated with pelitic gneisses, though a number of thin quartz-felspar gneisses are interbedded in the Kurase Series, one band outcropping along the summit of the Lola ridge. These rocks are invariably leucocratic, weathering white but often iron-stained red or pink. They are extremely resistant to erosion and are responsible for the prominent topographical features seen in the Maungu hills. At Lola the resistant band, twenty feet thick, has preserved the underlying calc-silicate gneisses and thin limestones from erosion. Others occur as upstanding ribs along the banks of stream-courses. Strong longitudinal and transverse jointing within them is common, causing them to break into large, rectangular, flaggy blocks that are readily distinguishable from the associated gneisses. These rocks are highly granitized and are only distinguished from migmatitic granitoid gneisses by their field relationships and lack of ferromagnesian-rich streaks and lenses.

The metamorphosed psammitic sediments include:—

(*a*) Quartz-felspar para-granulites.

(*b*) Quartz-felspar-muscovite para-granulites.

(*c*) Granitised calcareous grits.

(a) Quartz-felspar Para-granulites

At Nyangala two bands are exposed, one of which can be recognized readily from the main road (Plate VIII (*b*)). Other granulites are interbanded with the quartz-felspar-muscovite gneisses that form resistant outcrops on the easterly face of Saseie. These granulites are leucocratic rocks, with a colour index less than 5, and contain biotite and titano-magnetite as the main accessories. Microcline, which has been introduced into the granulites as a result of migmatization, forms variable proportions in different rocks and has replacive margins against original quartz and felspar. Specimen 65/303 from Saseie consists of a crystalloblastic mosaic of quartz and felspar of which microcline forms the greater proportion, while the same mineral is much less prominent in the granulite from Nyangala (specimen 65/245). In the latter rock quartz and polysynthetically twinned plagioclase are partly replaced by the microcline, which extends penetrative lobes into them. The plagioclase is oligoclase and itself replaces the xenoblastic quartz and encloses small rounded pools of it. Titano-magnetite in sub-idioblastic grains is the most common accessory, and is often partly altered to limonite. Small ragged, unorientated biotite flakes, sphene and (in specimen 65/245) hornblende, are the other accessories.

(*b*) *Quartz-felspar-muscovite Para-granulites*

These rocks are similar in appearance to the quartz-felspar granulites but are distinguished by their muscovite, which is scattered along foliation planes, though it is also often concentrated in thin streaks along which the gneisses break easily. Outcrops occur at Saseie, Nyangala, Lola and south of the last-named hill, where they are associated with quartz-felspar granulites.

In thin sections these granulites are found to consist of a xenoblastic mosaic of quartz, perthitic microcline, oligoclase and muscovite. In specimen 65/306 from Nyangala, the felspars are dusty with sericitic alteration products. The plagioclase shows replacive margins against grains of clear quartz, while the microcline replaces both minerals. Thin sections that do not include the muscovite-rich folia contain only sparsely distributed flakes of muscovite. Black iron ore is the main accessory, though specimen 68/16 from Lola contains a significant proportion of flake graphite.

(*c*) *Granitised calcareous Gneisses*

A granitised calcareous gneiss occurs two miles south of Maungu station, where it is exposed on the northern slopes of the second of the Maungu hills. A similar rock forms the lower slopes of Kavideo, west of Maungu hill. These gneisses are extremely leucocratic even-grained rocks with crystalloblastic texture and speckled with magnetite grains, some measuring up to 3 mm. Specimens 65/236, 237 and 238 mainly consist of xenoblastic, twinned oligoclase which is partly altered to sericitic muscovite and is dusty with small granular inclusions. The plagioclase crystals are often replaced by interstitial quartz and microcline. Titano-magnetite is common and of irregular to sub-idioblastic habit, while calcite is another important constituent in specimen 65/236. The calcite occurs interstitially as a late replacive mineral and exhibits sutured margins in contact with the felspars and occasionally encloses relics of that mineral. Brown biotite and hornblende are present in small amounts, while garnet is recognisable in hand-specimens. Sphene, which in specimen 65/237 measures up to 1 mm. in length, and apatite are accessory. Secondary alteration along cracks has resulted in the formation of a golden-yellow hydrated iron-ore which occurs as small crystals and seed-like aggregates. Although the rock contains calcite and quartz no wollastonite was formed during metamorphism, probably because the temperature did not rise sufficiently high. The sericitic muscovite is mainly an alteration product of the felspar and may be partly due to potash enrichment, as is suggested by the presence of microcline. The rock is considered to have been fairly pure, calcareous grit consisting of felspar and quartz with carbonate as the main impurity.

(5) Migmatites

Unlike many other parts of Kenya the present area contains little evidence of severe migmatization. Most of the rocks between Maungu and Kasigau have been partly migmatized, but they retain their original banded structure and such rocks are not here included as migmatites. Pavements of migmatitic gneiss are exposed at Zagana and seven miles north of Buchuma station where the rocks are banded as a result of quartz-felspar injections along foliation planes. Felspar porphyroblasts are frequently developed. In other rocks wavy foliation, ptygmatic veining, *lit-par-lit* injections, granitoid folia, potash felspar porphyroblasts, amphibolite schlieren, pegmatitic segregations and veining, and boudinage structures are all migmatitic phenomena that are present to a greater or lesser degree, but which rarely obliterate the original banded structures in the gneisses.

Only Maungu hill exhibits evidence of intense migmatization, and good exposures can be seen in a quarry face on the north side of the hill. Here the rock fabric has been practically obliterated and renders foliation dips unreliable. The rocks, which are of semi-pelitic origin, have been injected and permeated by potash-rich fluids that are represented by irregular quartz-felspar veins containing prominent microcline porphyroblasts. Plate VII illustrates examples of this type of migmatization. In Plate VII, fig. *c*, it can be seen that the original foliation, emphasized by hornblende and biotite-rich bands, has been preserved in part, but an amphibolitic band has been partly digested by granitic material. Plate VII, fig. *d*, illustrates a case where the process has been carried a stage further, the rock being highly contorted, witnessing the plastic state through which it has passed. Thin sections of specimens from Maungu quarry (65/233) display crystalloblastic textures. The felspars are highly sericitized and contain granular inclusions with linear arrangement. The plagioclase is oligoclase in various stages of replacement by microcline that has been introduced into the rock. Pleochroic biotite occurs in flakes with ragged ends, associated with small green prismatic hornblendes. Quartz is a prominent constituent occurring as xenoblastic crystals and as inclusions within the felspar.

(6) Anatectic or Palingenetic Rocks

(a) *Granitoid Gneisses*

Granitoid gneisses form few outcrops in the area, but are noticeable for their effect on topography. Eight outcrops were mapped and include Tugwe, Kale, Buguta, Kivuko, Pikapika-Kizima, and Gorujo in the Kasigau area, and Gorigori in the north-eastern part of the Kurase area. On weathering these rocks form typical tors, whale-backs and exfoliation domes whose configurations are controlled by strong jointing, of which excellent examples are to be seen at Kizima (Plates III (*a*), and IV).

These granitoid gneisses are considered to be granitized pelitic and semi-pelitic sediments which have acquired their present composition by alteration in the solid state. No evidence such as is common in migmatite zones was seen to suggest that they reached a high degree of plasticity. They conform to the structural pattern in the area, e.g. it was observed that the granitoid gneisses at Kizima form the nose of a fold, so accounting for the more extensive outcrop than is seen elsewhere.

The granitoid gneisses are medium to coarse-grained rocks with a very weakly gneissose structure, usually picked out by orientated flakes of biotite and occasionally hornblende. In thin sections the granitoid gneisses exhibit xenomorphic-granular textures in which microcline is a principal constituent. The microcline, which is often perthitic, replaces and partly surrounds or contains relics of plagioclase felspar (65/287, Pikapika). The plagioclase is a medium oligoclase and is rarely replaced by quartz which forms lobe-like embayments into the felspars, as seen in specimen 65/287, but more often the plagioclase replaces the quartz. The oligoclase is sometimes marginally altered in some slides to albite; association with muscovite was noted in specimen 65/295 from Buguta. Small, strongly pleochroic flakes of biotite are present in many specimens particularly those from Pikapika and Kale (65/287 and 65/294). Accessory minerals include sphene, apatite, ragged hornblende, titano-magnetite and leucoxene (secondary after ilmenite).

(b) *Pegmatites and Aplites*

The pegmatites and aplites are considered here for convenience. It is considered that a large number of these veins invaded the Basement System rocks at the time of metamorphism and granitization, but others may have been emplaced at a much later date and on more than one occasion.

Pegmatites.—Pegmatites are common throughout the area but are best seen in the hills of the northern part, where exposures are good. They occur in all rock types of the Basement System, but are particularly developed in the Maungu hills where they are associated with migmatites. Many are irregular and lenticular segregations, while others are dyke-like intrusions. At Nyangala pegmatites form concordant injections which, traced along the strike, are also seen to have a cross-cutting nature. These pegmatites are frequently associated with quartz-felspar-muscovite gneisses. Some pegmatites have distorted the foliation planes as illustrated in Fig. 5*a*. It will be noticed that in this case large hornblende crystals within the pegmatite maintain the general foliation direction of the host-rock.

The pegmatites are quartz-felspar-rich bodies often containing large pale pink felspars which, in the Maungu area, are perthitic microcline, though on Kasigau orthoclase pegmatites were noted. Little mineralization accompanies the pegmatites but minor occurrences were seen. In the hornblende-biotite gneisses many of the smaller lenticular segregations contain large hornblende crystals and less commonly books of biotite. Titano-magnetite veins occur in a number of the thinner pegmatites, a notable occurrence being seen on the north face of Mokolomba, a small hill on the north-west slopes of Kasigau, where a vein parallels the walls of the pegmatite. At the southern end of the Nyangala ridge a number of copper-bearing pegmatites have invaded pelitic gneisses that have become impregnated with malachite and azurite for a few inches on either side. Other minerals associated with a pegmatite at the same locality include kyanite, garnet, titano-magnetite, biotite and muscovite. It is considered that the pegmatite has assimilated kyanite-rich country-rock during the period of its emplacement.

An interesting pegmatite occurrence is exposed on the west side of the Nyangala ridge In parts, the pegmatite has invaded the country-rock parallel to the foliation planes but in one exposure is seen to be discordant, as illustrated in Fig. 5*b*. Here it is three feet thick and is surrounded by a biotite-rich selvedge, approximately six inches in width, containing numerous potash felspar porphyroblasts which become increasingly abundant as the pegmatite margin is approached. At the southern end of the exposure the pegmatite thins considerably becoming a concordant injection one inch thick and is associated with a number of similar veins sub-parallel to one another. These are *lit-par-lit* injections. A number of these veins have been ptygmatically folded but occur with others that show no tortuosity. The contortions have been formed without corresponding crumpling of the foliation planes of the country-rock and it appears that the fold amplitude, which is remarkably constant in one example (Plate VII (*b*)) is controlled by pre-existing structure in the host-rock. A similar occurrence is figured by Kuenen (1938, fig. 2A, p. 14). Wilson (1952, p. 19) has shown that ptygmatic structures can be classified into three structural groups and it is considered that the example from Nyangala illustrated is one in which the contortions resulted from primary buckling during injection into static country-rock, so that they have no tectonic value. The axial planes of the ptygmatic folds in the example illustrated in Plate VII all plunge northwards and it is rare to find axial planes plunging in other directions in other veins. It is presumed that during injection the vein was confined between walls more rigid than itself but eventually encountered resistance which impeded further progress (as suggested by Wilson, *op. cit.*, pp. 7–11). The restraining influence would cause the vein to buckle, the ptygma so formed being overturned with continued pressure. The northerly inclination of the axial planes of the folds in this example would suggest that the pressure and therefore injection was from the north.

Aplites.—Aplitic veins are of more widespread occurrence than the pegmatites from which some of them are off-shoots. Many have been emplaced along foliation, and other "S" planes and joints in the gneisses, particularly where there have been minor movements, while others form thin cross-cutting ptygmatically folded bodies (Plate VII (*a*) and fig. 5*c*). They are considered to represent the final phases of injection that accompanied regional metamorphism and folding.

(7) METAMORPHISM

The rocks of the Basement System are considered to be sediments that suffered intense regional metamorphism, probably in the Archaean era. A period of sedimentation was followed by crustal downwarping accompanied by severe folding, though most rocks in the area mapped remained relatively ungranitized despite the great depth to which it is assumed they were forced during metamorphism.

The sediments involved in this regional transformation included limestones, dolomites, shales, sandstones and marly beds. No evidence was found to suggest the presence of volcanic rocks, though it is possible that certain hornblendic gneisses of the Maungu hills may represent lavas intercalated within pelitic sediments.

All the metamorphic rocks of the Kasigau-Kurase area fall into the amphibolite facies (and mainly into the sillimanite-almandine subfacies)* which characterizes medium and high-grade regional metamorphism.

Typical mineral assemblages include:—

sillimanite-plagioclase-biotite-quartz.
kyanite-garnet-biotite-plagioclase-quartz.
kyanite-muscovite-quartz.
biotite-hornblende-plagioclase-microcline-quartz.
garnet-hornblende-diopside-plagioclase-quartz.
garnet-diopside-calcite-plagioclase.
diopside-calcite-forsterite.
garnet-hornblende-epidote-plagioclase-quartz.
hornblende-garnet-diopside-scapolite-plagioclase-quartz.

*The facies classification adopted in this report follows Turner, 1950.

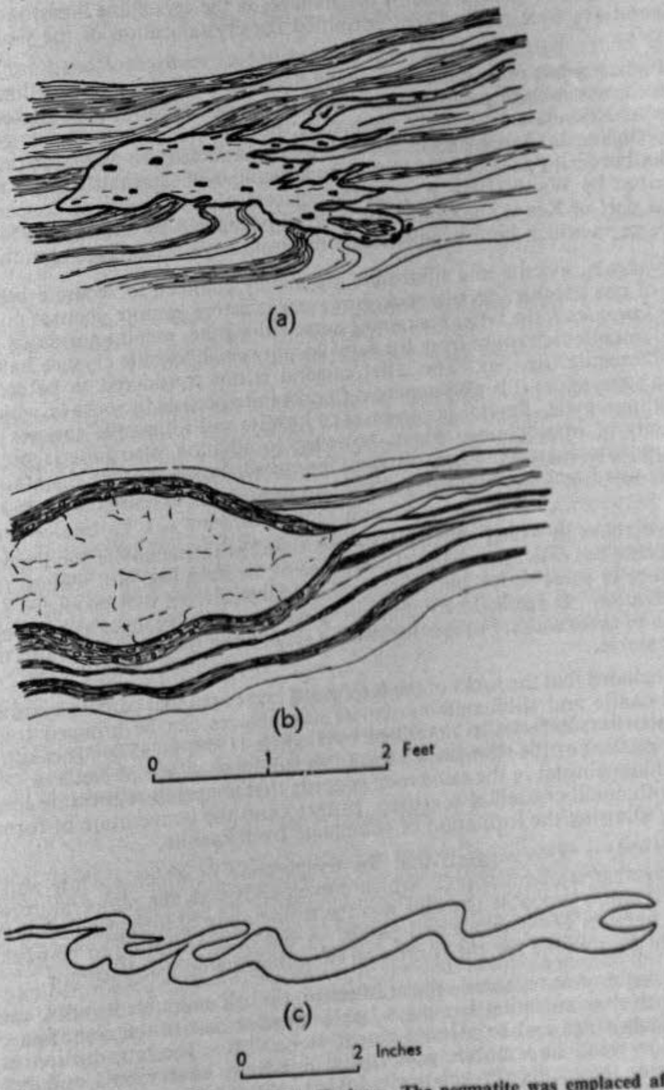


Fig. 5—(*a*) Pegmatite in biotite-hornblende gneiss, Kasigau. The pegmatite was emplaced after the folding of the host rock.

(*b*) Pegmatite in biotite gneiss, Nyangala. The pegmatite was emplaced when the host-rock was no longer plastic.

(*c*) Ptygmatically folded aplitic vein, Nyangala.

The last-named assemblage, which is typical of a prominent marker horizon that outcrops on Sagala, Kasigau and Rukinga, occasionally contains epidote and more rarely zoisite. Hornblende-rich rocks are common in the Maungu hills and that forming Nyangala peak (Plate III (*b*)) is characteristic. Here large epidote lenses, interbanded in melanocratic rock rich in diopside and hornblende, are probably the product of high shearing stress. Turner (1950, p. 87) considers such conditions to be responsible for the presence of a sodic andesine, which is a common constituent of these rocks in this area.

The absence of diopside-tremolite assemblages in the crystalline limestones suggest that high temperatures were reached that permitted the crystallization of the wollastonite seen in these rocks.

The highest grade of metamorphism is indicated by the presence of sillimanite in some rocks, and the assemblage garnet-sillimanite-quartz in pelitic bands intercalated in dolomitic limestones at Kivindara is typical. Sillimanite, however, is nearly always associated with kyanite, at Nyangala, Saseie and in the vicinity of Mwachinjoro and Matsimbani near the Tanganyika border. The occurrence of the two alumino-silicates in the same rocks has also been described by Walsh (1960, p. 9) in the adjacent area to the west. It seems, therefore, that in this part of Kenya the sillimanite isograd postulated by Sanders (1954 B, p. 150) is in fact a zone in which both kyanite and sillimanite have crystallized simultaneously.

At Nyangala, kyanite and sillimanite are mainly confined to separate beds but within a few feet of one another. In one rock, however, schistose kyanite gneisses contain quartz-sillimanite *faserkiesel*, the latter containing some sillimanite, pseudomorphous after kyanite. In other sillimanite-rich rocks from the same locality small kyanite crystals have crystallised with the sillimanite (fig. 3*a*). The latter mineral is not considered to be secondary after kyanite. In some slides it is also apparent that kyanite persists in rocks in which sillimanite is replacing muscovite. Similar occurrences of kyanite and sillimanite gneisses were mapped in the vicinity of Mwachinjoro where, however, in addition, staurolite is present in some kyanite-muscovite-quartz gneisses. It must be noted, however, that the staurolite occurs scantily and was found in only two thin sections examined. In these instances it is probably a relic.

In those rocks in which sillimanite is associated with muscovite (and rare biotite) the alumino-silicate has often formed at the expense of the mica (fig. 4*b*). Potash felspar makes its appearance in these rocks, but must be distinguished from that produced as a result of later granitization. It seems likely that rising metamorphic grade was responsible for the composition of these rocks, but did not reach a stage when the assemblage sillimanite-potash felspar was stable.

It is concluded that the rocks of the Kasigau-Kurase area that contain kyanite-muscovite, kyanite-sillimanite and sillimanite-muscovite assemblages can be grouped together in the kyanite-muscovite sub-facies as described by Francis (1956, p. 357). This sub-facies is, in part, the equivalent of the sillimanite almandine sub-facies of earlier authors. The presence of both alumino-silicates in the same rock suggests that temperature-pressure conditions were such that both could crystallize together. In rare cases the temperature of formation was a little higher, allowing the formation of sillimanite from kyanite.

Barth (1952, p. 338) suggests that the temperature at which epidote and plagioclase crystallize together is about 400°C., which corresponds with the temperature of formation of kyanite. It seems probable that this was the temperature of formation of the hornblendic and kyanite gneisses of Nyangala and Saseie. A rise in temperature to between 450°C. and 500°C. would be suitable for the formation of sillimanite and wollastonite.

Migmatization was recorded only at Maungu, though undoubtedly alkali metasomatism associated with migmatization has played an important part in the alteration of the rocks of the Nyangala ridge and to a lesser extent at Kasigau. The introduction of microcline has been widespread and mobile potash-rich injections have veined and permeated the gneisses forming these hills. Ptygmatically folded aplites at Nyangala suggest that the centre of migmatization was to the north, probably in the adjacent area. Similar felspathization (microcline enrichment) under static conditions has resulted in the formation of granitoid gneisses in the Pikapika area.

The period of migmatization and granitization in the north was accompanied by the selective introduction of potash into gneisses at Nyangala. With declining temperatures retrogressive metamorphism was responsible for reactions which can be traced in some of the rocks. Billings, as quoted by Wyckoff (1952, pp. 50–51), maintains that the assemblage muscovite-sillimanite is a stable relationship. In the present area, however, sillimanite is occasionally replaced, sometimes completely, by muscovite and the evidence for granitization being strong, the rocks in which such replacement occurs are considered to represent a reversion from the kyanite-muscovite sub-facies. The formation of sillimanite *faserkiesel* is attributed to metasomatic redistribution during the period of diaphthoresis (Sanders, 1954 A, p. 37).

2. The Duruma Sandstones

The Duruma Sandstones were named by Stromer von Reichenbach (1896, p. 22). In the area mapped they comprise arkosic grits, conglomerates, sandstones and carbonaceous shales deposited under lacustrine and deltaic conditions. They dip gently to the east, and cover the most eastern part of the Kurase area and the south-eastern corner of the Kasigau area. Two divisions were recognized, forming only the lower part of the complete Duruma Sandstones succession as described in adjacent areas (see Miller, 1952, pp. 7–13 and Caswell, 1953, p. 9):—

			Estimated Thickness (feet)
Duruma Sandstones	Middle	3. Maji ya Chumvi Beds (in part) ..	1,500
	Lower	2. Upper Taru Grits	4,000
		1. Lower Taru Grits (in part) ..	1,350

During the survey a number of loose blocks of Duruma Sandstones sediments were discovered at various places on the surface where there are Basement System exposures. The localities are shown on fig. 6 and on the geological maps, and are two miles south of Buchuma, one mile east of Buguta, twelve and sixteen miles south-west of Kilibasi, and at Mangari on the western border of the area. The blocks include grits, pink sandstones and hard fissile shales and as it is considered that they have not been transported by human agency, it is likely that patches of Palaeozoic sediments overlying the metamorphic rocks are concealed by the sand that covers large stretches of the area. The occurrence of the blocks at Mangari, close to the Mwatate river-course, suggests a source to the north-west closer to the Taita hills. This is the furthest west that rocks of the Duruma Sandstones have been recorded in Kenya and, although sporadic in their occurrence, they indicate that the deposits had a much wider extent in the past.

(1) Taru Grits

The Taru Grits are composed of grits, sandstones and shales with subordinate coarse conglomerates and lower and upper divisions, comparable with those described by Miller (1952, pp. 7–11), were mapped.

(a) Lower Taru Grits

The lowest members of the Duruma Sandstones exposed in the area are typically arkosic grits and sandstones with thin black carbonaceous shales. Good exposures are to be seen at Kilibasi where over 1,300 feet of sediments are exposed (Plate III (*b*)). Here massive dark-grey, coarse-grained bands consisting of angular unsorted fragments of variable grade, repeatedly pass upwards into sandstones overlain by black shaly beds. It is possible to recognise a number of such cycles of deposition, in the beds involved in each cycle measuring approximately 100 feet in thickness. The junction between each cycle is very marked, a coarse grit resting directly on thin shales or black, coaly layers up to one inch thick. Scour and fill structures are common at the top of the sandstones, the scoured-out hollows being infilled by shales and the whole overlain by undisturbed shale beds.

Coarse pebbly conglomerates are locally developed in the grits and are considered to represent old stream-courses. Grits and conglomerates similar to those seen at Kilibasi are exposed at the roadside at Lukakanyi and along the courses of the Kisoka and Ndokoko rivers.

In thin section the arkosic rocks are seen to consist mainly of angular fragments of quartz and felspar that are only moderately sorted. The felspar, which includes microcline and plagioclase ranging from albite to calcic andesine, comprises up to 40 per cent of many of the rocks. Associated minerals include biotite, muscovite, hornblende, chlorite, pyrite, magnetite, garnet, apatite, rutile, zircon, graphite and rare sillimanite. The graphite is a common constituent of all these rocks and large flakes are clearly visible in hand-specimens. The cementing material is ferruginous in some cases (65/353 from Kilibasi) but is often calcareous. In other specimens (68/35 from two miles south of Kilibasi) limonite pseudomorphosing pyrite cubes form a significant proportion of the rocks.

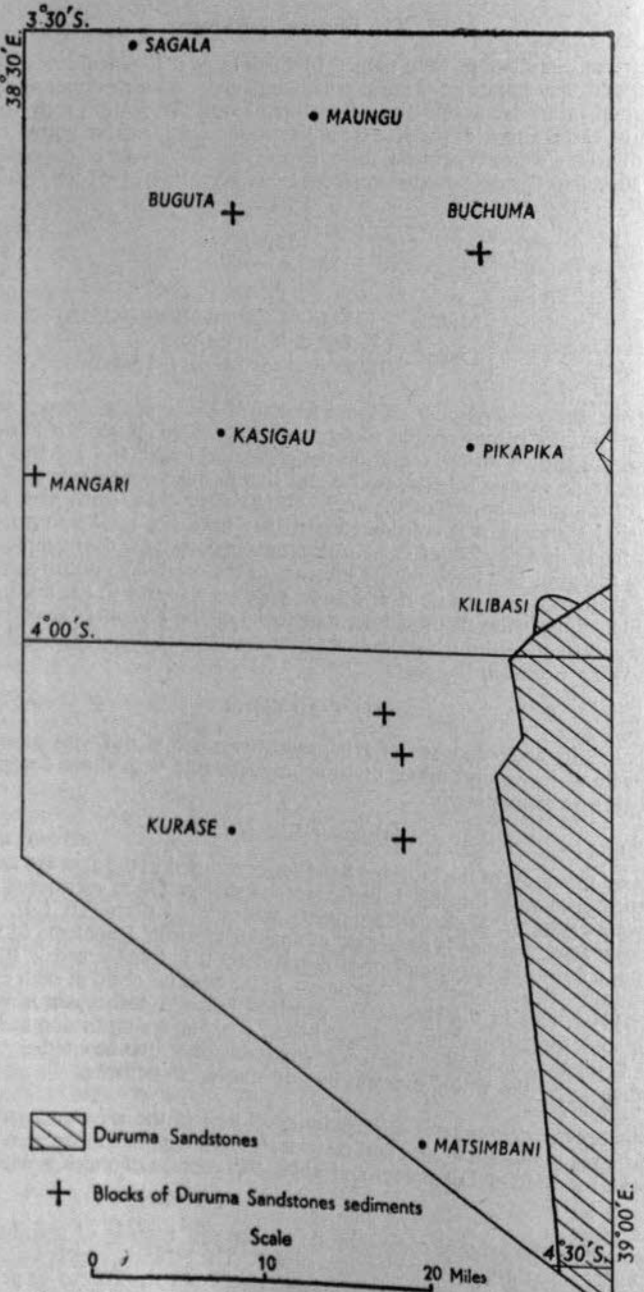


Fig. 6—Localities of loose blocks of Duruma Sandstones sediments in the Kasigau area.

The massive grits and sandstones are traversed by numerous intersecting master joints which are conspicuous on extensive pavements of weathered rock. On weathering these joints become widened into large fissures and, at intersections of such joints, large circular holes appear which are frequently filled with water. The weathering of ovoid concretions in these rocks also leaves numerous holes which on coalescence form water-holes of considerable size. Such hollows in conjunction with joints, are undoubtedly responsible for the permanent water-holes or *ngurungas* over 20 feet deep at the southern foot of Kilibasi It is this source of water that is frequently mentioned by early travellers in the Colony, for Kilibasi was one of the main staging places on the route from Mombasa to the interior of Kenya as well as on the Arab slave-route to Tanganyika. Early writers, as reported by Stromer von Reichenbach (1896, p. 23), have variously described these holes as the result of weathering-out of tree-stumps (Von der Decken), pot-holes (Kersten), and the weathering out of cavities (Hans Meyer). Stromer von Reichenbach, although he had never visited East Africa, considered Von der Decken's theory to be correct, but Meyer was the more correct in his conclusion.

(*b*) *Upper Taru Grits*

Overlying the lower grits is a series of yellow-brown sandstones, felspathic sandstones with subordinate grits, and dark banded shales. The soft, fissile and friable nature of these rocks gives rise to gently undulating country in which exposures are generally poor. Harder and more massive grit bands occasionally form prominent outcrops, but it is only in the dry stream-courses that the shales and sandstones are exposed.

The mineral assemblages of the rocks of the upper group are similar to those of the lower group, though the beds are generally more fine-grained, more calcareous, and sometimes contain large limestone fragments, as in specimen 68/45, from three miles north-west of Bidimwoli. Quartz grains are very angular indicating that the material forming the sediments had not been carried far and was probably derived from the neighbouring Basement area to the west. At Bidimwoli the sediments are characterized by greenish black shaly silts and fine-grained sandstones which exhibit extremely regular and delicate undisturbed banding. Thin sections of a banded shaly silt (68/42) indicate that the bands represent regular cyclic deposition, in which particles of silt grade form light-coloured bands, which are overlain by heavily iron-stained bands about one-tenth of their thickness, each cycle measuring about 0·25 mm. (fig. 7*c*).

In the present area the uppermost beds of the Taru Grits probably grade rapidly into the overlying Maji ya Chumvi Beds. They are practically undistinguishable from the exposed Maji ya Chumvi Beds.

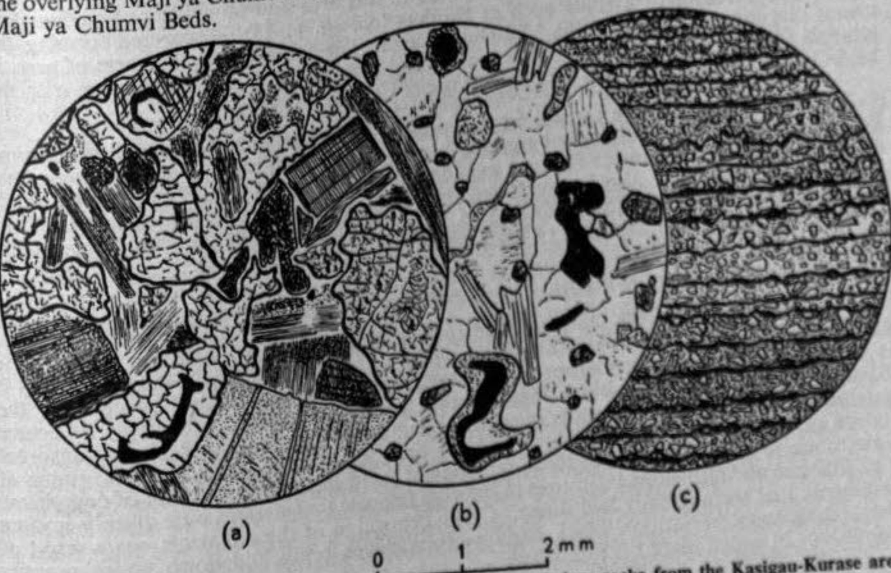


Fig. 7—Diagrammatic microscope drawings of thin sections of various rocks from the Kasigau-Kurase area.
(*a*) 65/296, Buguta. Gabbro. The drawing, which is a composite sketch, illustrates clouded felspar rare cummingtonite and aggregates of zoisite, epidote and garnet.
(*b*) 65/308, south end of Nyangala ridge. Pyritic muscovite-quartz-felspar gneiss. The pyrite is often surrounded by, or completely replaced by hydrated iron ore. Rutile forms a notable proportion of this rock.
(*c*) 68/42, five miles south-east of Lukakani. A rhythmically banded shaly silt from the Upper Taru Grit.

(2) Maji ya Chumvi Beds

This formation, of which probably only the lowest members are represented in the area mapped, is poorly exposed and nowhere was it seen directly overlying the Taru grits. The beds are presumed to underlie the sandy plain in the southern part of the Kurase area, and the postulated position of the base is suggested on the geological map.

Exposures were seen in a single dry water-course, ten miles east of Matsimbani. Here the rocks consist of a few feet of thin, yellow and buff fissile sandstones and siltstones with intercalated shales. They are soft and friable, weather with an orange to black crust, and contain numerous flattened clay nodules (up to two inches in diameter) and unidentifiable plant fragments.

(3) The Age and Correlation of the Duruma Sandstones

No identifiable fossils were obtained from the Duruma Sandstones in the present area, though poorly preserved plant remains were observed at a number of horizons in both the Taru Grits and the Maji ya Chumvi Beds. Sufficient evidence has, however, been obtained from neighbouring areas to indicate their age and correlation.

Remains of the plants, *Voltzia* sp. and *Ullmannia* sp., of upper Permian to Rhaetic age, were reported by Gregory (1926) from a bore-hole in the upper Taru Grits at Samburu, 25 miles north-east of Kilibasi. Shales in the Galana valley (30 miles to the north of the present area,) had been previously considered as part of the Taru Grits (Miller, 1952, p. 11), and as they yielded *Palaeanodonta fischeri* Amal. of Permian age the lower part of the grits was also dated as Permian (Gregory, 1921, p. 57). Sanders (1959, p. 31), however, has shown that these shales are probably part of the Maji ya Chumvi Beds and that the entire Taru Grit sequence underlies them. The downward range of the Taru Grits may, therefore, be greater than was earlier thought. Sanders considers that the upper part is lower Permian and the lower part upper Carboniferous.

The base of the Taru Grits is not exposed in this area and no evidence was found to suggest the presence of a tillite such as Sanders (*op. cit.* p. 15) discovered forming the lowest division of the grits in the Mid-Galana area. The considerable thickness of grits at Kilibasi suggests that, here, their base is close and that, therefore, on comparison with the Mid-Galana sequence they are probably of upper Carboniferous age.

The sediments that are considered to represent the lower part of the Maji ya Chumvi Beds were identified on lithological grounds by comparison with rocks in adjacent areas that are considered to be of upper Permian age (e.g. Caswell, 1953, p. 17). The Duruma Sandstones in this area may also be correlated with the two lower lithological divisions of the Tanga beds of Tanganyika (Stockley, 1936 p. 7), which in turn can be shown to be equivalent to the Sakoa and Sakamena beds of Madagascar (Besairie, 1946, p. 17).

(4) Sedimentation during the deposition of the Duruma Sandstones

The composition of the Duruma Sandstones indicates that they were derived from the metamorphic rocks of the Basement System which lie to the west. Sedimentation, which it is believed began in upper Carboniferous times, was probably initiated by uplift of the Basement System rocks by block faulting, thus providing an adequate supply of coarse detritus which was deposited under lacustrine conditions. The coarse arkosic and unsorted nature of the lower beds in particular and the presence of large graphite flakes, grains of limestone and massive current-bedded units suggest rapid infilling of the basin of deposition. The siltstone and sandstone inclusions in the grits indicate that streams were quickly eroding sediments that were already laid down. Cyclic deposition of the sediments was a result of marked seasonal variations, black carbonaceous shales being laid down under swampy conditions in which plant life flourished.

This period of rapid deposition was followed by more quiescent conditions, during which the sandstones and shales of the Upper Taru Grits were deposited. Similar conditions prevailed into lower Maji ya Chumvi times, during which subsidence must have kept pace with deposition though the presence of ripple-marking, current bedding and plants suggests continuous deposition in shallow water.

3. Intrusive Rocks of Post-Basement System Age

Three intrusive rocks of post-Basement System age were seen during the survey. A basic rock invades crystalline gneisses at Buguta and an ultra-basic rock at Kasigau, but no restricted age can be ascribed to them. A third rock presumed to be intrusive, a phonolite, was found as a loose block together with Karroo rocks along the Umba river. It is probable that this rock is a minor intrusive derived from the alkaline centres at Jombo or Mrima situated 22 miles east-north-east of Mwakijembe. The centres pierce middle Duruma Sandstones, and Baker (in Caswell, 1953, p. 47) in describing the complexes attributed their age to the interval between the late-Jurassic and the middle Pliocene.

(1) Olivine-Garnet Hornblendite

The ultra-basic rock at Kasigau was found on Mambago ridge which forms its northern slopes (fig. 19). The occurrence is small, mainly consisting of boulders weathered *in situ*, suggesting a pipe-like form for the body, though in depth it may have been emplaced as a thin sheet parallel to the strike of the country-rock (basic sills are known in the Taita hills, a few miles further north). Specimen 23/268 is a heavy, brownish-black rock in which the grains are somewhat incoherent, so that the rock crumbles easily. It is medium-grained, exhibiting a hypautomorphic granular texture, and little altered. Green hornblende, the principal constituent, is strongly pleochroic from bright green to pale yellow-green. Associated with the amphibole is pale pink garnet containing numerous inclusions of black iron ore and small hornblende and olivine crystals. Occasionally the olivine is altered to iddingsite, while the hand-specimen shows patchy alteration to serpentine. The olivine, which is colourless to pale green, occurs also in inter-granular spaces in the rock. A volumetric analysis of the rock, determined by point counter is given below.

	1	A
	%	%
Hornblende	58	58
Garnet	30	32
Olivine	6	—
Iron ore including magnetite ..	6	6
Other minerals	—	4

1.—Specimen 23/268, Kasigau.

A.—Eclogite-amphibolite, Graubunden in the Alps (Streckeisen, 1928).

The rock is an olivine-garnet hornblendite and with an increase in the olivine content and loss of the garnet would become a cortlandite. The rock described by Streckeisen is coarse-grained and derived from a dyke-like mass.

Saxonite.—A small ultra-basic intrusive outcropping in the Kurase area was discovered by a member of the Anglo-American Prospecting Co. (Africa) Ltd., in 1957. The precise locality of the intrusion is unknown but it probably occurs on the south-eastern side of the limestone ridge Ruara. The rock, a saxonite (68/80) is a heavy, green, medium-grained rock containing fairly fresh olivine, pale, slightly pleochoric bronzite, and rare labradorite. Kelyphitic borders of enstatite and of green spinel have formed at the junctions of olivine and felspar crystals, while alteration of the pyroxene has resulted in the formation of brown hornblende. A little granular iron ore is present.

(2) Gabbro

Approximately 100 yards west of the track at Buguta is a small conical hill some fifty feet in height, consisting of a bouldery outcrop of dense, green-brown, spotted gabbro. The intrusion was traced by small outcrops and scattered boulders to the north foot of Kulikila where it can be seen to invade Basement System gneisses irregularly. The rock is much altered but originally consisted mainly of felspar and a ferromagnesian mineral (now represented by amphibole) forming a hypautomorphic-granular texture (specimen 65/296, fig. 7*a*). The felspars are now variably clouded due to immense numbers of inclusions, consisting of minute opaque grains, which in some instances may be titaniferous. Much of the felspar has been replaced by aggregates of zoisite, epidote and garnet, which exhibit irregular margins against the clouded felspars, and sometimes enclose relics of them. The aggregates are usually colourless but some of the epidote is tinged pale green. The minerals forming the aggregates are generally better crystallized than is usual in saussurite, a common alteration product of gabbros. The amphibole is cummingtonite pleochroic from orange-brown to pale yellow, exhibits prominent partings and is occasionally schillerized. It is probably secondary after original pyroxene and of metamorphic origin. A volumetric analysis of the rock determined by point counter gave 43 per cent felspar, 48 per cent "saussurite", 7 per cent amphibole, and 2 per cent magnetite.

(3) Phonolite

Six miles south-east of Mwakijembe village on the river Umba in Tanganyika Territory, small float blocks of phonolite occur, together with blocks of Karroo sandstone and shale. Specimen 68/79 is micro-porphyritic, light grey in colour, fissile and partly vesicular. Microphenocrysts of soda orthoclase and pyroxene are set in a holocrystalline groundmass. Zoned aegirine-augite prisms up to 3 mm. in length in the matrix are pleochroic, being paler in the centre, with extinction angles ranging from 17° at the margin to 40° at the centre. Partly altered nepheline occurs as small prismatic crystals with typical hexagonal and rectangular cross-sections. Accessory minerals include magnetite, apatite and calcite. The matrix consists of partly iron-stained analcite.

4. Pleistocene

Between Tugwe and the river Mavora, the Mwatate river-course is incised in a shallow valley which is considered to be a product of end-Tertiary times (see p. 8). The presence of an incised course, however, suggests that uplift took place in Pleistocene times, so enabling vertical downcutting to be extremely vigorous. It was during this period of incision that a terrace of Pleistocene gravels was left thirty feet above the river-bed. A remnant of the terrace occurs approximately three miles east of Tugwe on the south bank of the river-course. The gravels composing the terrace consist of rounded pebbles of various types of gneissose rocks and crystalline limestone that are common in the area.

During the survey a visit was paid to Mwakijembe on the river Umba, in Tanganyika Territory. Here the meandering river is deeply incised to a depth of about 25 feet below the surrounding alluvial flood-plain, which represents an old flat valley floor. In places at approximately 10 feet above present water-level a terrace is exposed on which parts of an abandoned river-course can be seen, and represents an intermediate level of the river. At least two periods of uplift (or drop in sea-level) are, therefore, indicated near Mwakijembe.

As the observations made are isolated it is not possible to draw any general conclusions on the Pleistocene history of the area, except to say that it has been subject to erosion consequent upon uplift, or more likely, changes in sea-level, which are known to have occurred a number of times during the Pleistocene period (cf. Caswell, 1953, pp.53–55).

5. Recent Deposits

Recent deposits in the area consist of red-brown sandy soils, which are a product of weathering of the Basement System gneisses that form the hills. They conceal a large proportion of the area and rarely are outcrops to be seen on the sandy plains, except along shallow stream-courses or as monadnocks. The deposits have formed either *in situ* (where weathering of the underlying rocks is taking place mainly by 'rotting') or by accumulation. In times of heavy rain, sheet-flooding washes quantities of sandy alluvium across the plains where it is quickly deposited and rarely transported great distances, due to the lack of any permanent drainage.

Red soils seen along the Nairobi-Mombasa road are ferrallitic and consist largely of coarse quartz grains. Lateritic ironstone, of which only a single occurrence was noted in the area mapped, is a product of leaching of such soils under conditions of seasonal rainfall. None of the red soils are considered to be of great thickness and probably extend only a few tens of feet in depth. They contrast with the thicker deposits of the hill pediments where steep-sided stream gullies expose coarse gravels and soils to depths of fifty feet.

Grey alluvial soils occur in certain stream-courses where drainage is poor and it is along such courses that black cotton-soils form when the drainage is negligible. Such soils are often calcareous and give rise to small sheet of kunkar or calcareous concretions. Good examples of such deposits can be seen four miles north-west of Maungu, seven miles north-east of Pikapika, in the Mwatate river-course and in the stream-course between Kasigau and Rukinga. Kunkar limestone invariably covers the crystalline limestone ridges and is in many cases the only indication of the underlying rock. The kunkar limestones, in part, may be peneplain products, but it is considered that the greater proportion has been formed in Recent times as a result of poor drainage and chemical weathering.

Gullying and associated phenomena are more active on the Karroo sediments where there are some streams for short periods after heavy rains. Here streams have been rejuvenated during Pleistocene uplift and in parts are grading their courses, temporarily depositing dark grey alluvial soils along them.

VI—STRUCTURE

For the purposes of description the structures of the Basement System rocks and the Duruma Sandstones are dealt with separately. The principal structural features of the area are shown in Figures 8, 9 and 10.

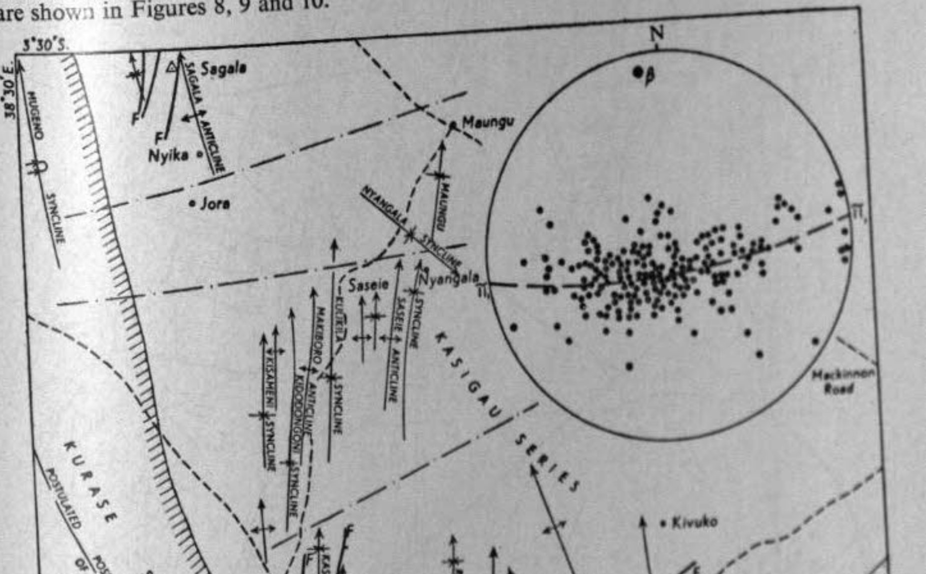


Fig. 8—Structural map of the Kasigau area showing faults and fold axes. Inset: Stereographic projection of 200 poles to foliation planes in the Kasigau Series. The great circle π_1 passing through the poles and the pole β to the great circle are also shown.

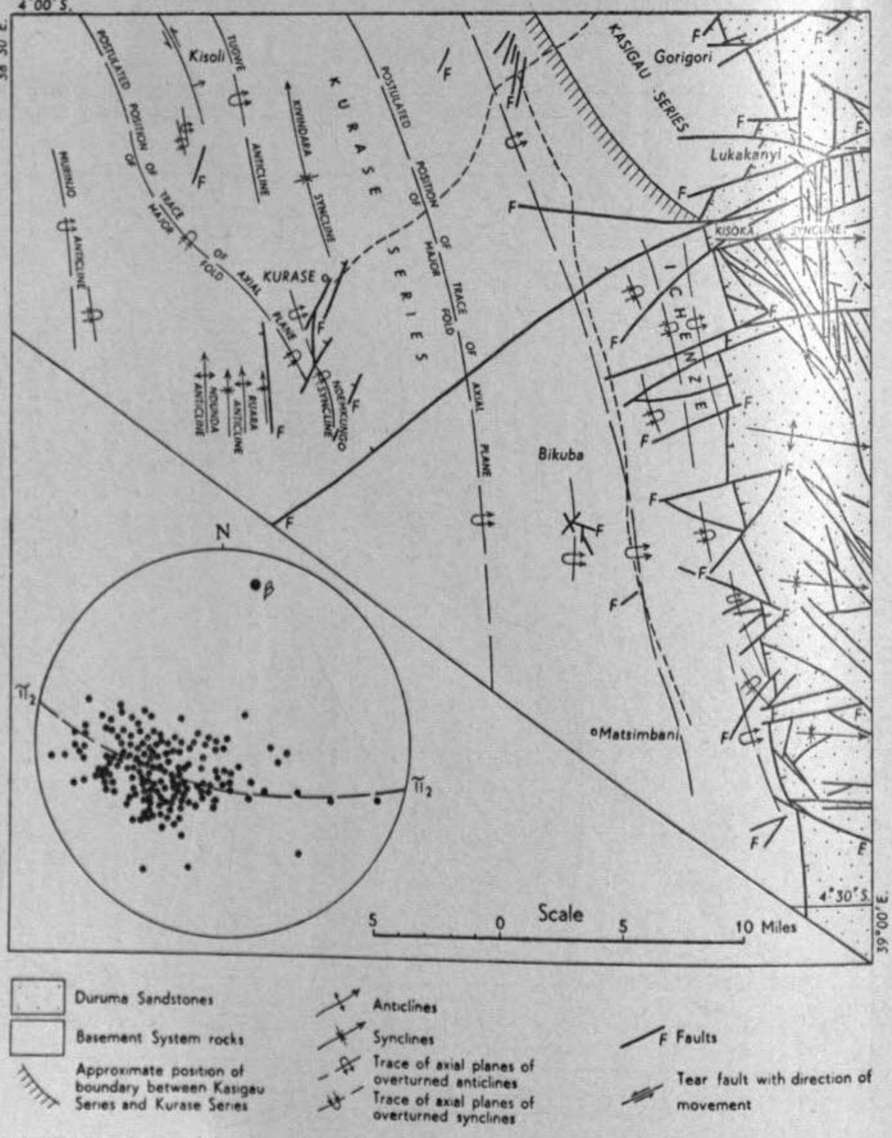


Fig. 9—Structural map of the Kurase area showing faults and fold axes. Inset: Stereographic projection of 214 poles to foliation planes in the Kurase Series. The great circle π_2 passing through the poles and the pole β to the great circle are also shown.

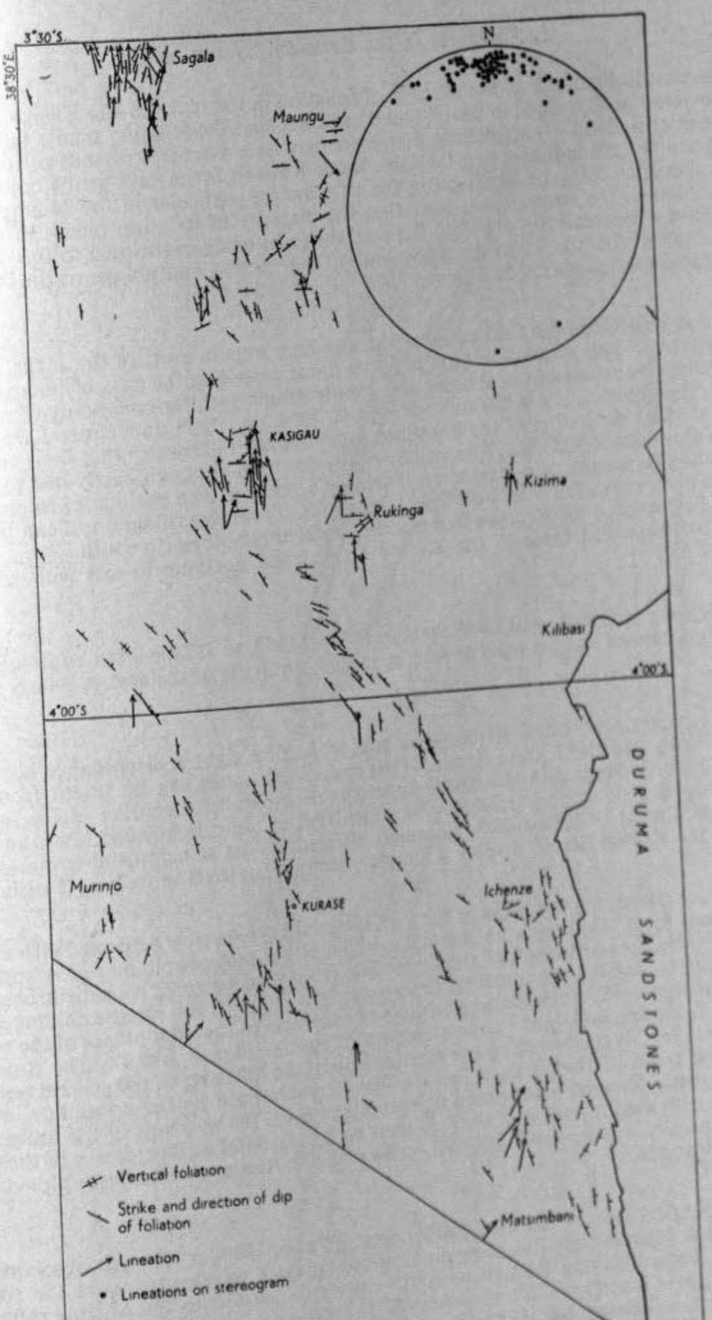


Fig. 10—Structural map of the Kasiagu-Kurase area showing foliations and lineations.
Insert: Stereographic projection of 64 lineations.

1. Structures in the Basement System Rocks

Geometrical analysis of the attitude of foliation in the rocks of the Kasigau Series and Kurase Series as illustrated in figs. 8 and 9 indicates that the foliation planes fall along two great circles π_1, and π_2, suggesting that there may have been two periods of folding. The stereogram in fig. 8 indicates that the folds in the Kasigau Series have gentle opposing limbs and in fact such folds are observed in the field and in particular in the Maunga hills. In fig. 9, however, the stereogram shows that the majority of foliation planes in the Kurase Series have a moderate dip of 30° to the east, the folds being overturned to the west. From the position of the β poles to the great circles the direction and plunge of the fold axes in the respective series can be determined (cf. Phillips, 1954, p. 61).

It was possible in the field to record strong lineations in most of the rocks, but rarely in the marbles. This visible lineation includes linear grooving, the axes of micro-folds, and the parallel elongation of hornblende and biotite grains and less commonly of quartz and garnet. The lineation is a b lineation (cf. Weiss, 1954, pp. 10–11 and Turner, 1950, p. 180). Fig. 10 shows a projection of the lineations measured, and illustrates that their trend is not uniform throughout the area. The scatter of the lineation although partly due to spread in the foliation (a feature of b tectonites) is mainly a result of two periods of folding. The β poles are observed to fall within the arc of lineations. From these diagrams it can be deduced that the fold axes in the Kasigau Series are orientated almost north-south with a plunge of 12° to the north and those in the Kurase Series trend north-north-east with a northerly plunge of 18°.

A tectonic profile as used by Wegmann (Weiss, 1954, p. 19) has been constructed from the geological maps and the style of folding in different parts of the area is clearly indicated (fig. 11).

The tectonic profile and stereograms suggest at first sight a discordance between the Kasigau Series and the Kurase Series. That individual bands can be traced from Sagala southwards to Rukinga and that these approximately parallel the strike of the limestones and yet exhibit little or no overfolding, is considered to indicate however that the Kasigau Series folds consist of beds which, although affected by the same crustal compressions as disturbed the Kurase Series, display a simpler, tectonic style. The folding is disharmonic.

It is considered that the rocks in the area were initially severely deformed into a number of recumbent folds. Although no definite criteria, either megascopic or microscopic, were found to enable the correlation of the limestones from zone to zone, it seems probable that a set of beds containing a number of limestones is a guide to the intense folding that the area has undergone. The postulated positions of the traces of the axial planes of the principal recumbent folds are indicated in the structural diagrams (figs. 8 and 9). The overturning of the folds is readily confirmed by the relationship of the fold axes to the general north-west to south-east trend of the rocks, a feature that is emphasized by the crystalline limestone bands. In gently plunging overturned or recumbent folds the outcrops of the limbs form a small angle with the projection of the fold axes on a horizontal surface; hence in the present case the generally north-west-south-east strike and the north-north-easterly plunging fold axes and lineations.

The geological map of the area further west (Walsh, 1949, p. 8) and observations in the Taita area suggest that the Mugeno limestone passes westwards across the southern flank of the Taita hills and then turns south-eastwards parallel to the Mgama ridge. The extension of these limestones in a south-easterly direction is speculative (due to lack of outcrop and thick soil cover) but it is suggested that the limestones pass again into the present area, where they are involved in a number of small recumbent folds whose limbs are represented by the Mangari-Kisoli, Kivindara, and neighbouring ridges. In the south-western corner of the area what are considered to be the same limestones appear to form the nose of a recumbent highly faulted syncline, whose westerly limb is represented in part by the intricately folded limestones of the Murinjo ridge.

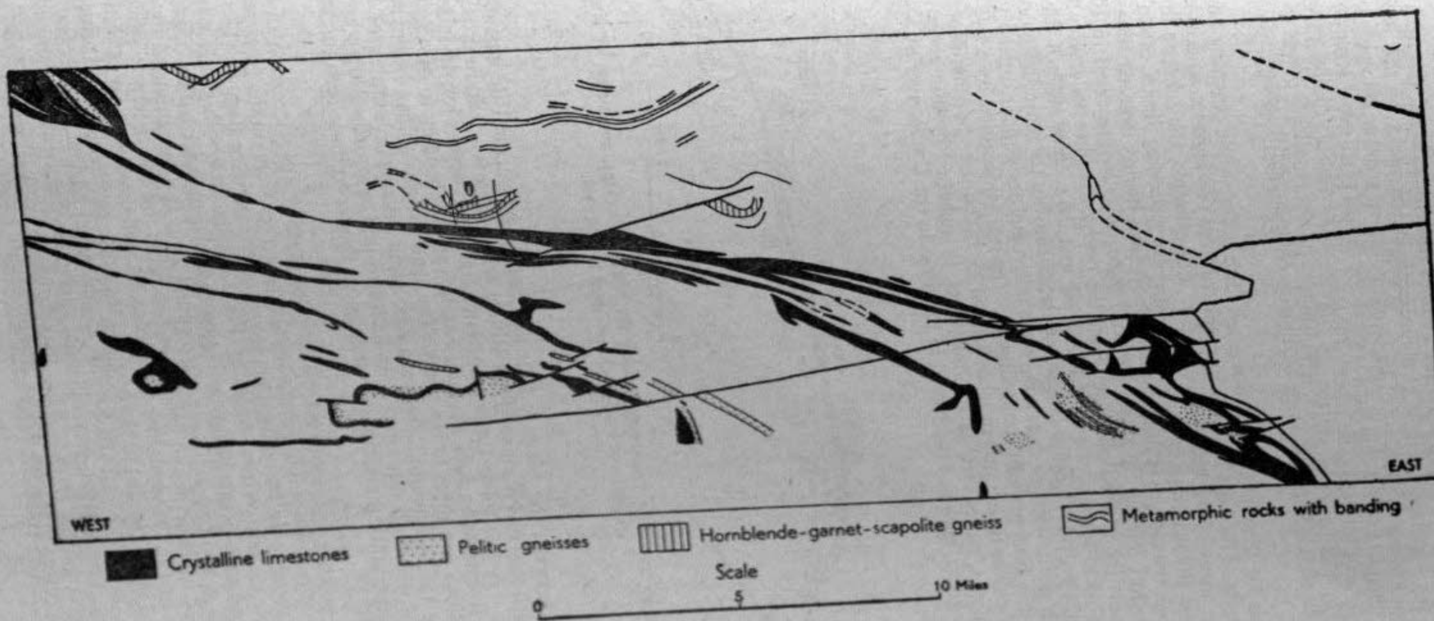


Fig. 11—Tectonic profile of the Kasigau-Kurase area.

After the main deformation a second period of folding affected the area and was responsible for the apparently simple structure seen in the rocks of the Kasigau Series. Nowhere in this series was evidence of large recumbent or overturned folds observed, but it is likely that detailed examination would reveal evidence of small-scale structures indicating the earlier recumbent folding. The effect of the second period of folding can also be seen in rocks of the Kurase Series in which open folds with axes parallel to those of the folds in the Maungu hills were mapped at Dari, Kivindara, Ndunda and Ruara.

Throughout the limestones numerous small folds occur, while pinching and swelling is common and parts of the beds have become isolated from one another, and in any case it is most likely that many of the beds are lenticular. For example, the Ichenze limestone and that forming the Bikuba ridge probably represent the opposing limbs of an overturned anticline although the closure is not complete, movement having isolated limestone blocks during the period of folding. Evidence for such movements is illustrated in Fig. 12. The diagram represents the Mai-Kisoli ridge where the limestones dip moderately to the east-north-east. The rocks forming the main Kisoli hill and the eastern edge of the Mai ridge, the strike of which provide evidence of tear, are detached from the main limestone band and have moved in a north-westerly direction, while horizontal movement on the western side of the tear fault has been towards the south-east. The tear is occupied by a five to ten foot thick sheet of crystalline limestone which has a dip of 35° to the east. In other cases movement along bedding planes, particularly in the limestones, is suggested by thin zones of fracture parallel to the bedding, such as are exposed in the rocks in the Umba river at Mwakijembe.

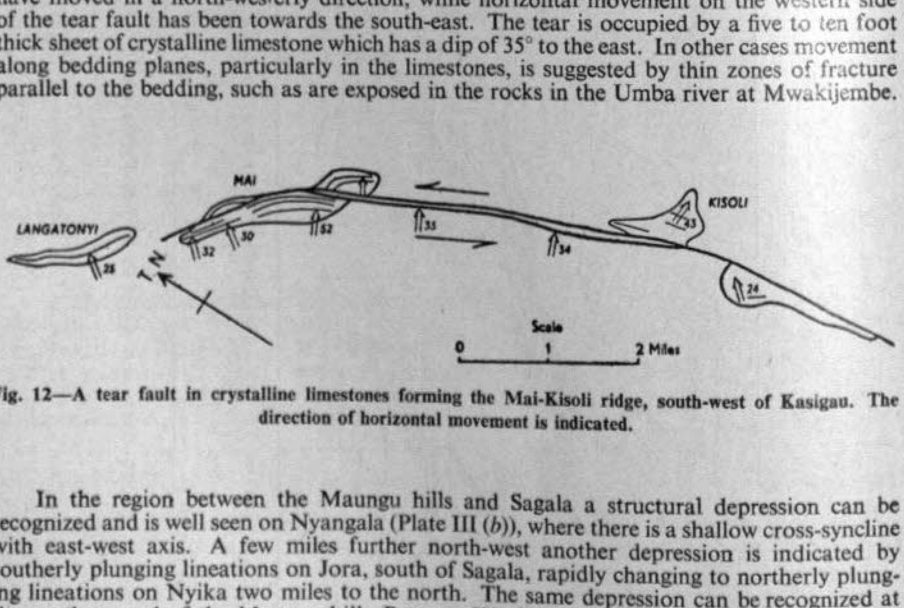


Fig. 12—A tear fault in crystalline limestones forming the Mai-Kisoli ridge, south-west of Kasigau. The direction of horizontal movement is indicated.

In the region between the Maungu hills and Sagala a structural depression can be recognized and is well seen on Nyangala (Plate III (*b*)), where there is a shallow cross-syncline with east-west axis. A few miles further north-west another depression is indicated by southerly plunging lineations on Jora, south of Sagala, rapidly changing to northerly plunging lineations on Nyika two miles to the north. The same depression can be recognized at the northern end of the Maungu hill. Between Kisoli and Pikapika a number of folds are recognized, many of which die out along lines indicated on the structural diagram. These lines are probably structural culminations or depressions similar to those seen further north.

Joints.—Owing to the paucity of rock outcrops of much of the succession in the area the greatest number of records of joints made during the survey were on the Kasigau Series, and particularly on those rocks that have a tendency to be massive or flaggy. The majority of the joints recorded are near-vertical fractures (Fig. 13) associated with gentle warping of the Kasigau series, one set of joints being nearly perpendicular to the lineation *b*, and therefore *ac* joints. These *ac* or cross-joints are often conspicuous features enlarged by erosion and are well-developed in the granitoid gneisses at Kizima, in the quartz-felspar gneisses on Nyangala and Saseie and in the crystalline limestones. A well-developed set of joints comprises the longitudinal joints parallel to the *b* axis of the north-south folds and is responsible for the elongated whale-back features of Kivuko, Pikapika and Kizima. Two sets of north-west-south-east and north-east-south-west diagonal joints are symmetrically disposed about the *a* axis and form a conjugate system. They may represent shear fractures caused by the east-west compressive forces that gave rise to the north-south folds.

Faulting.—Few faults were actually seen during the mapping of the Basement System rocks and many have been inferred from the disposition of the crystalline limestones and associated gneisses. It is assumed that there have been two periods of faulting—one post-Basement System—pre-Duruma Sandstones, and the second post-Duruma Sandstones. It is assumed that many faults have affected only Basement System rocks while others have disturbed both these and the overlying sediments in the eastern part of the area. Faults of the latter period are described in a later section (p. 50).

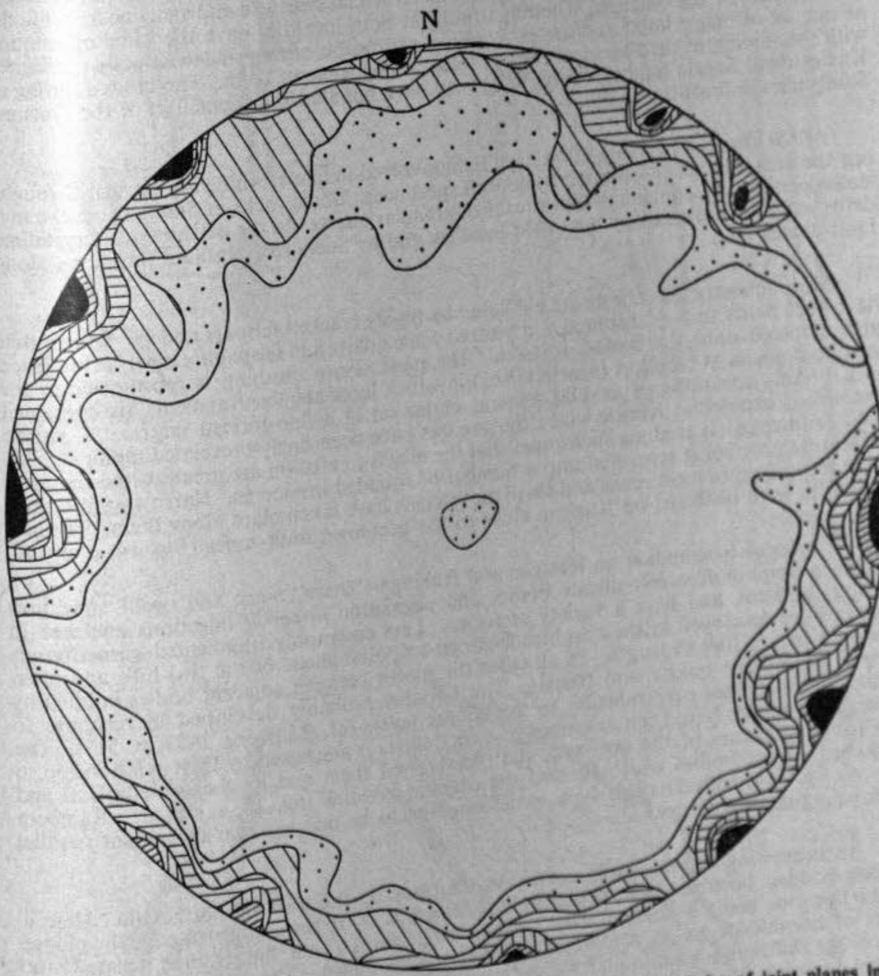


Fig. 13—Equal-area stereographic projection on the lower hemisphere, of 228 poles of joint planes in the Kasigau-Kurase area; contours 1, 2, 3, 4, 5, 6 per cent per 1 per cent area.

In an area of intense folding under certain conditions relief is obtained through rupture, though crystalline limestones will tend to flow rather than break at an earlier stage than other types of rocks. This perhaps accounts for the fact that few fractures were mapped in areas in which limestones form the principal outcrops. Some faults however, of which examples can be seen at Kurase, have displaced both limestone and gneiss, while, in the east considerable faulting has affected both Basement System rocks, including the limestones, and the overlying sediments. At Kasigau a number of beds have been gently folded and subsequently faulted (fig. 19 at end) so that the rock sequence is repeated three times. It is considered that erosion along high-angle fractures is responsible for the lofty cliffs on the upper slopes of the mountain (Plates II (*a*) and V (*b*)), which are a topographical expression of the amount of vertical movement that has taken place along the faults. These faults appear to have their greatest throw near the centre of the mountain which is an upfaulted block (Plates I and II (*a*)), and the maximum composite throw along associated faults on the western side of the mountain is of the order of 4,000 feet. High-angle faults have affected similar beds at Sagala where they cut across an anticlinal structure and syncline forming the western part of the outcrop. The main faults at both localities have the same orientation as one set of major joints and are probably an expression of movement, directly associated with the folding of the Basement System rocks, along some of them. The block-faulting of Kasigau and Sagala (and the Taita hills) may have initiated the deposition of the Duruma Sandstones sediments.

Minor structures.—Rocks that have been involved in late crushing are present throughout the area and are represented by several specimens. Some rocks at Saseie show the first stages of crushing, containing thin streaks of granular quartz. In the marbles post-crystalline deformation is indicated by bent twin lamellae and by finely recrystallised limestone along fault-planes.

More intense crush effects are exhibited by highly cracked felspars and by garnets that have been partly torn or shattered and fissured while quartz and felspar are newly crystallized and moulded onto the broken surfaces. The most severe crushing is represented in the granitoid gneiss at Gorigori (near Kilibasi) in which large angular fragments are contained in a breccia consisting of angular mineral grains set in a fine-grained matrix. A second example is exposed at Kurase where the gneisses have been finely brecciated along a NE.-SW. fault-zone. It is along such zones that the effects of erosion are greatest, the outcrops at Kurase now being separated into a number of rounded inselbergs. Narrow aplitic veins were recognized in most rocks and small movements have taken place along them. The best examples were observed on Kasigau close to the presumed fault-zones (Fig. 14, *a* and *b*).

Boudinage is abundant on Kasigau and Rukinga. These "pinch and swell" structures occur in amphibolitic calc-silicate bodies and pegmatitic *lit-par-lit* injections enclosed in various gneisses, and have a variety of forms. Less commonly fragmented garnetiferous boudins are developed in the hornblende-garnet-scapolite gneiss of the two hills and often measure over a foot in length. In all cases the spaces between adjacent bodies is filled by newly crystallized quartz and felspar. The boudins probably developed in response to compressive stresses perpendicular to the boudin layers (cf. Ramberg, 1955, p. 517). The Kasigau examples have been deformed and rotated, as is suggested by their relationship to the foliation planes of the host-rock that flow round them and by the sub-elliptical and detached garnet bodies which formed the original boudins (fig. 14, *c* and *d*). Ramberg (*op. cit.*, p. 514) considers this type of deformation to be due to shear-movement parallel to layering in adjacent rocks.

An interesting exposure was visited on the track on the west side of Sagala. Here a weakly-banded, hornblende-garnet-scapolite gneiss dips 31° to the east-north-east, the plunge of the lineation being 9° to the north. Cutting the gneiss is a thin, fine-grained melanocratic sheet of hornblende gneiss containing small felspathic augen. The foliation in this sheet, which has diffuse boundaries and varies in width from a few inches to over one foot, dips nearly due west at 43°. Along the eastern margin of the sheet the foliation in the host-rock has been bent as indicated in the diagram (fig. 15). The diffuse boundaries of the sheet, the bent foliation of the host-rock and the general field relationships suggest a tectonic origin for this structure. The melanocratic sheet is a zone along which the foliation of the country-rock has been transposed. Prisms of hornblende have been rotated into planes parallel to the zone during movement, which judging from field examination appears to have been up the plane of foliation of the sheet. It is considered that transposition of the foliation has occurred at a late stage during the folding of the area, but while the rocks were still in a plastic state and after the regional lineation had been implanted.

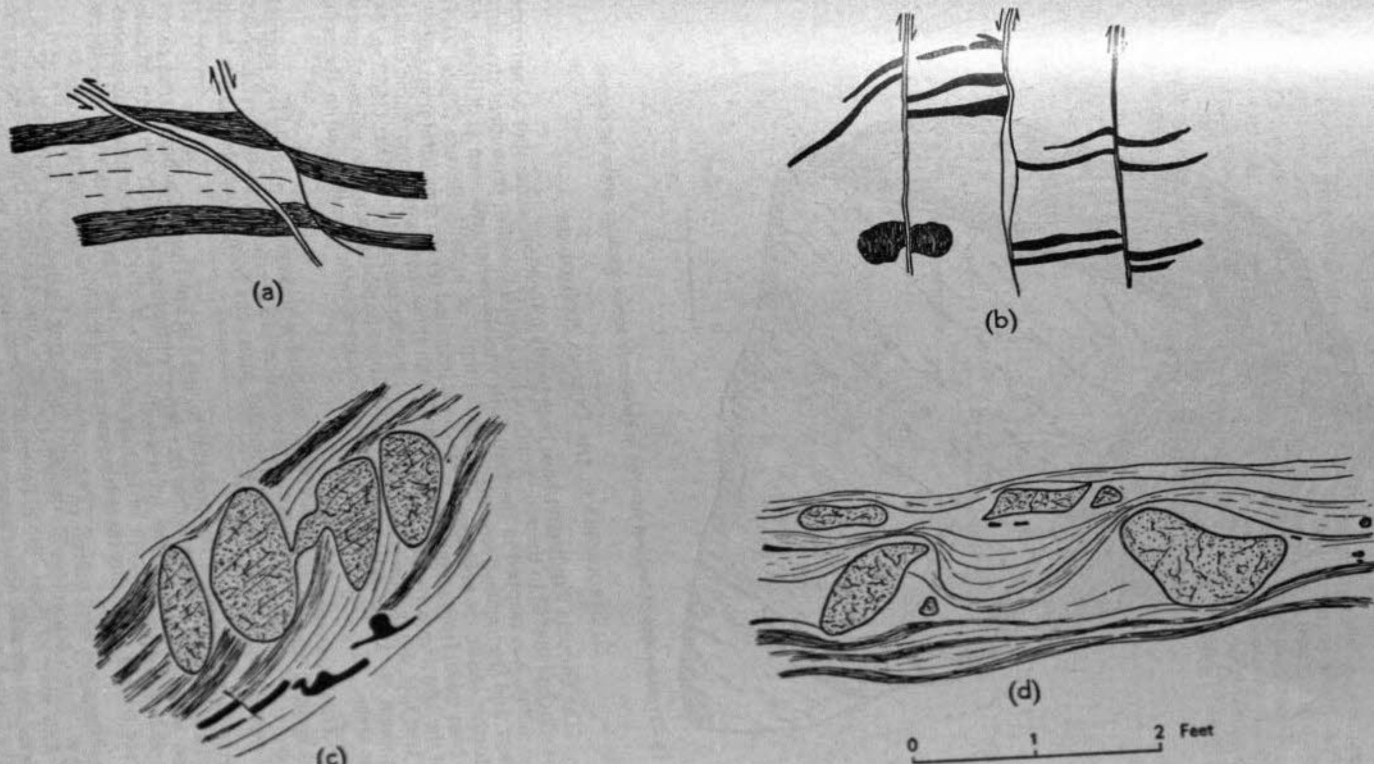


Fig. 14—(*a*) and (*b*) 'S' planes developed in finely banded gneisses on Kasigau. The arrows indicate the direction of movement. (*c*) and (*d*) Deformed and rotated garnetiferous boudins in hornblende-garnet-scapolite gneiss on Kasigau.

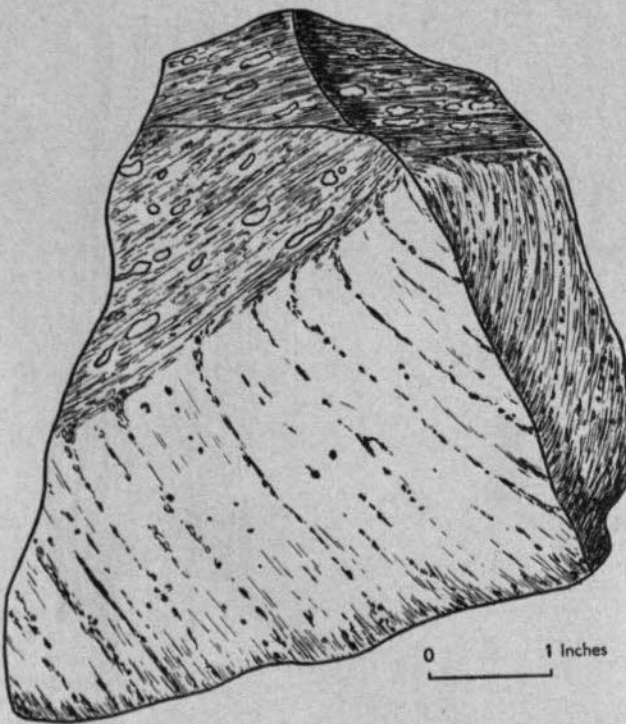


Fig. 15—Transposition of regional foliation in hornblende-garnet-scapolite gneiss at Sagala.

(2) STRUCTURES IN THE DURUMA SANDSTONES

Folding.—The Duruma Sandstones have been gently folded into a number of anticlines and synclines which plunge 8° to the east. South of Lukakanyi the most prominent structure, the Kisoka syncline, was mapped in the Taru Grits while another was seen at Kilibasi hill where the west and east spurs form the opposing limbs of a gentle flexure (Plate VIII). Other folds further south, the positions of which are indicated on the structural map (fig. 9), have mainly been taken from aerial photographs, which show them with remarkable clarity. The trends of the fold axes correspond with similar structures mapped by Miller (1952, p. 14) and Caswell (1953, p. 49) in Lower and Middle Duruma Sandstones in the adjacent areas to the east, though N.–S. and NE.–SW. trending structures were also mapped in the sediments in their areas.

Faulting.—The Basement System-Duruma Sandstones junction is probably a normal fault except at Kilibasi where the sediments are considered to overlie the metamorphic rocks unconformably. Only at Gorigori, where granitoid gneiss has been brecciated, is the fault thought to be exposed.

It is believed that this faulting was probably initiated in pre-Upper Carboniferous times before sedimentation began. Subsequent to this period of faulting, possibly between Middle Cretaceous and Middle Pliocene times (cf. Caswell, 1953, p. 49) the Duruma Sandstones were folded and later faulted. South of latitude 4° 20′S. the Taru Grits may have been carried below the surface, assuming there is no overlap of the Maji ya Chumvi beds.

The fault pattern has been influenced by the underlying gneisses and NW.–SE., N.–S., and ENE.–WSW. faults are common. Relatively steep dips recorded during the survey are associated with some of them. Both Basement System rocks and Duruma Sandstones have been affected for considerable distances by the ENE.–WSW. fractures, the majority of which step the faulted junction between them.

VII—ECONOMIC GEOLOGY

Unfortunately a great deal of the area is obscured by sandy soils and the fewness of the hills greatly restricts the possible number of economic occurrences which can be prospected by ordinary means. Should any deposits of value be found in the future, the Nairobi-Mombasa railway and road will provide two excellent means of communication. A small ultra-basic intrusive exposed on the northern spur of Kasigau revealed nothing of importance, but the possibility of mineralization in depth cannot be ruled out. No evidence of major intrusives with accompanying mineralization was found. Figures 16 and 17 show the distribution of minerals and water-supplies in the area mapped.

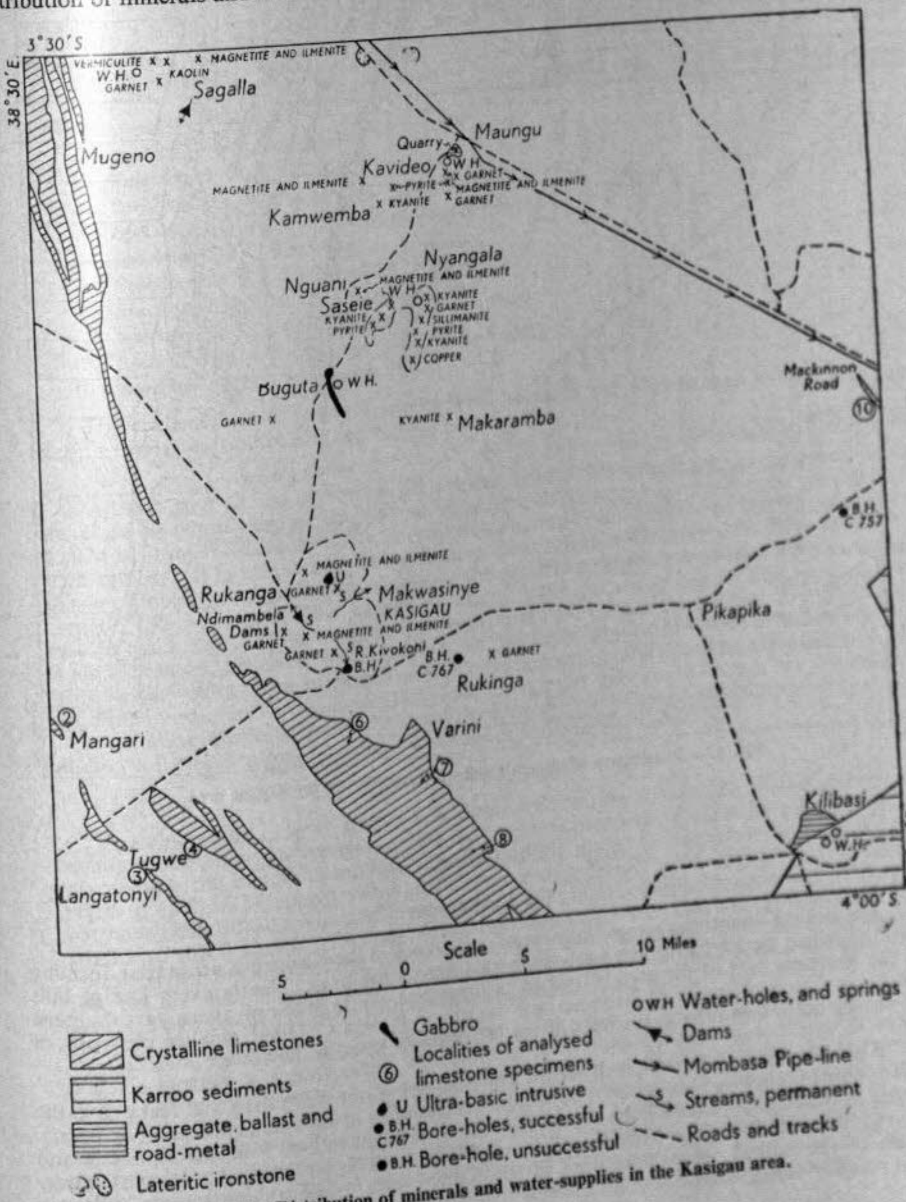


Fig. 16—Distribution of minerals and water-supplies in the Kasigau area.

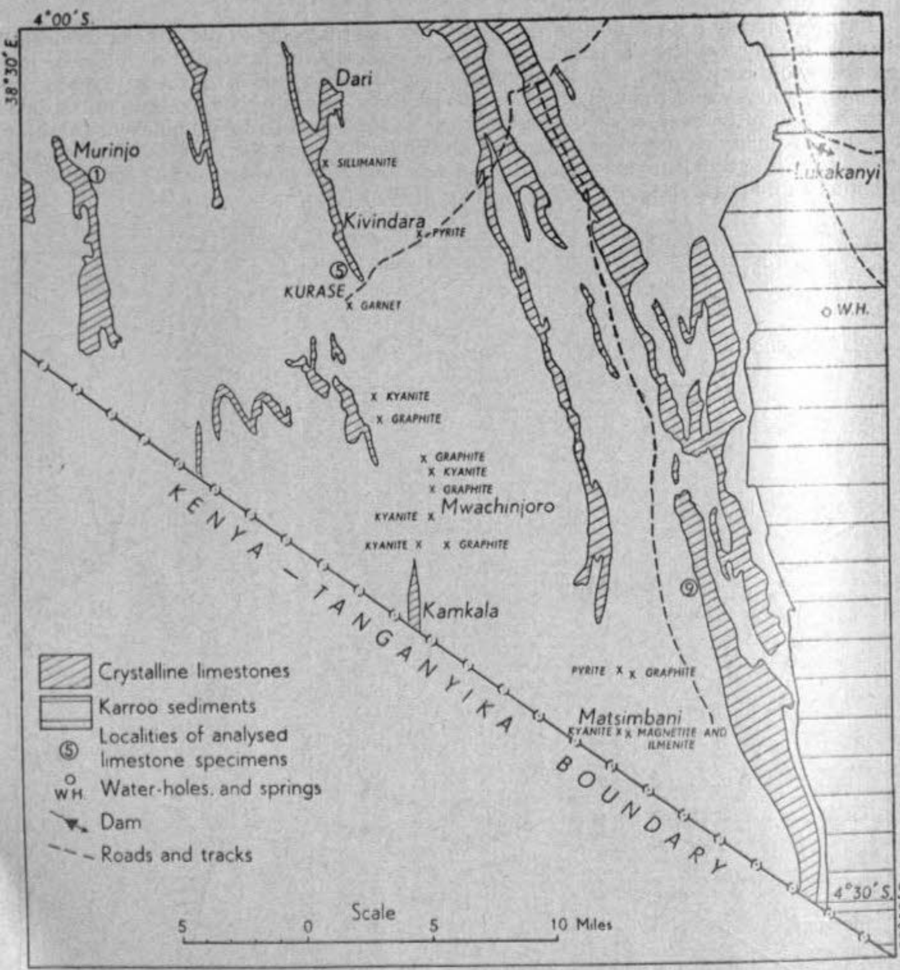


Fig. 17—Distribution of minerals and water-supplies in the Kurase area.

1. General

(1) Limestones

Crystalline limestones are of widespread occurrence in the Kasigau-Kurase area, forming parallel ridges that trend north-west-south-east across the area. Nearly every line of hills in the southern part of the area is formed of limestone, while in the northern part the most extensive outcrops occur at Mugeno and south of Kasigau. Other smaller outcrops of limestone occur one mile south-west of the Mackinnon Road water-tower.

The limestone outcrops usually form low hills rising not more than 300 feet above the surrounding plains, and are covered by variable thicknesses of superficial limestone (kunkar). Those in the Kasigau area can be reached by the tracks that radiate from the mountain and are readily accessible. The Mugeno ridge and Mackinnon Road limestones are within easy reach of the railway. The limestones in the Kurase area, however, are remote and only two roughly-constructed tracks give access to that region.

Generally, the crystalline limestones are medium-grained, relatively fresh rocks containing disseminated graphite flakes, small calc-silicate lenses and other mineral impurities, occasionally in the form of knots. A number of analyses made on hand-specimens collected from different localities gave the following results:—

	1	2	3	4	5	6	7	8	9	10
	%	%	%	%	%	%	%	%	%	%
R_2O_3	0·60	0·21	0·26	0·18	0·30	0·21	0·23	0·18	0·18	0·40
CaO	43·22	47·79	32·28	53·33	44·46	31·02	32·55	32·55	32·60	50·64
MgO	10·64	8·77	19·40	0·63	11·06	19·74	19·34	19·55	18·99	0·63
Insoluble	1·39	0·25	0·36	1·88	0·34	3·23	0·75	1·14	1·27	6·60
Loss on ignition	44·26	43·75	46·95	43·03	44·39	45·08	46·53	45·58	46·39	41·20
TOTAL	100·11	100·77	99·25	99·05	100·55	99·28	99·40	99·00	99·43	99·47

1. Specimen 68/10, Murinjo.
2. Specimen 65/327, Mangari.
3. Specimen 65/322, Langatonyi.
4. Specimen 65/324, 2 miles east of Tugwe.
5. Specimen 68/32, Kivindara.
6. Specimen 65/259, 3 miles south of Kasigau.
7. Specimen 65/329, 2 miles south of Varini.
8. Specimen 65/331, 12 miles west of Kilibasi
9. Specimen 68/60, 7 miles north-east of Matsimbani.
10. Specimen 65/239, Mackinnon Road.

The specimens with lower numbers were taken in the western part of the area, and those with higher numbers in the central part. *Anal.:* Mrs. R. Inamdar.

All but two of the crystalline limestones have a high magnesia content and would therefore be of no use for the production of British Standard portland cement. Specimen 65/324 is, however, a remarkably pure limestone, and could be used in the manufacture of such cement. It is impossible to say from present information whether a large tonnage of this good-quality limestone is available, as the same band further south has a high magnesia content, indicating a marked lateral variation in the particular band. The locality is not easy to reach and haulage costs would be prohibitive at the present time. The Mackinnon Road limestone, however, which apart from insoluble impurities is also a high-grade limestone, is very close to the principal lines of communication and could be exploited with ease. Unlimited resources of magnesia-rich limestones exist and could be put to a number of uses including mortars, internal plasters, renderings, whitewash, agricultural purposes including soil stabilization, pozzolana-lime mixes and sand-lime bricks.

(2) COPPER

A single occurrence of copper was discovered during the survey, at the southern extremity of the Maungu-Nyangala ridge. To facilitate prospecting one square mile of country surrounding the deposit was closed by the author under Government Protection Notice No. 2 of 1955. The copper minerals present consist mainly of malachite and rare azurite that have been introduced into biotite gneisses by a quartz-felspar pegmatite that runs subparallel to the foliation. The pegmatitic injection is part of the late metasomatic effects accompanying migmatitization, and it seems likely that the copper minerals were segregated from the gneisses. The malachite often exhibits a replacement relationship towards biotite or occurs as fibrous, compact crystals in intergranular veins.

Malachite staining was seen in a number of localities over a strike of half a mile. Only a single locality was prospected, however, as it showed the most promising values. An analysis of a grab-sample of the richer material taken at the time of the survey gave 8·2 per cent Cu. Two prospecting trenches were dug across the deposit. These proved disappointing and showed that the malachite is disseminated over a width of 3½ feet and that the richer occurrences are sporadic. Analyses carried out on chipped samples taken over the whole width of the vein gave values between 0·20 and 1·50 per cent Cu. As a result of this work it was decided that further prospecting was not warranted at the present time.

This deposit is one of a number of similar occurrences that outcrop over a distance of fifty miles between Tsavo, to the north of the area mapped, and the Maungu hills. There may be other occurrences further south hidden by the soil mantle that conceals the greater proportion of the area.

(3) Coal and Oil

The presence of thin layers of coal in the Taru grits of the coastal region of Kenya has given rise to many speculations in the past as to the possibility of finding economic coal-bearing strata within the coastal sediments. In the present area, where these sediments are poorly exposed, carbonaceous beds were noted within shale and grit bands in the Taru grits, but no evidence of any major coal-bearing horizons was discovered.

Any evaluation of the possibility of the occurrence of oil cannot be made unless the coastal area is assessed as a whole. It can only be placed on record that flexures do exist within the sediments, which contain potential reservoirs and cap-rocks. The presence of innumerable faults, however, would tend to rule out the likelihood of finding oil in the area under consideration. Pulfrey (1956) has recently made an appraisal of the search for oil and natural gas in Kenya.

(4) Garnet

Garnets of variable size are widespread throughout the area, particularly east of the main limestone ridges. They occur in every kind of gneiss, often forming as much as 10 per cent of the rocks, and occasionally are concentrated in boudins and segregations in the Kasigau, Maungu and Rukinga hills. Small local concentrations are to be found in the sandy stream-courses that cross the pediments surrounding the hills.

(5) Graphite

Graphitic gneisses are extremely common in the area south and east of Kurase, where good examples can be seen as a' Mwachinjoro. These gneisses contain variable quantities of graphite and their economic importance is considerably reduced by the presence of abundant quartz and/or kyanite in them. Graphite is also disseminated throughout the crystalline limestones and occasionally forms thin bands in them, but no associated graphitic schists such as are seen in other parts of Kenya were found.

(6) Kaolin

Kaolinised felspar-rich gneisses of the Basement System outcrop on the upper western slopes of Sagala. The kaolin has resulted from the decomposition of rock *in situ* and is of restricted occurrence. No economic value is attached to the deposit.

(7) Lateritic Ironstone ("Murram")

Only one deposit of lateritic ironstone was seen in the area, on the south side of the main Nairobi–Mombasa road, five miles north-west of Maungu station. "Murram" has already been removed from the site by the Ministry of Works for repairing roads, and it is estimated that only a limited tonnage remains. Other lateritic ironstone deposits might exist between Maungu and Mackinnon Road but none were seen during the survey.

(8) Magnetite and Ilmenite

At Mokolomba, a small hill on the lower north-western slopes of Kasigau, a pegmatite has veined a garnet-biotite gneiss parallel to the foliation. Within the pegmatite is an irregular vein of titano-magnetite of variable width up to one inch. A second magnetite-rich rock (65/273) outcrops on the Funganyeni ridge, which forms the south-western spur of Kasigau. Here the magnetite is concentrated in thin, discrete bands and lenses a few inches in length within a quartz-felspar gneiss, suggesting that the rock is a metamorphosed fissile sandstone in which iron-ore was segregated in thin bands. At Matsimbani in the south-eastern part of the area close to the Tanganyika border, kyanite gneisses have been invaded by quartz-rich pegmatites containing iron ore. Iron ore has also crystallized along foliation planes adjacent to the pegmatites. Many of the gneisses in the area though not heavily mineralized, are stained red as a result of the oxidation of fine-grained iron ore in them.

An analysis of titano-magnetite from a pegmatite in the Sagala-Ndara hills gave the following result (Muff, 1908, p. 20).

	%
SiO_2	1·42
Fe_2O_3	66·98
FeO	21·01
MgO	0·25
CaO	0·33
$H_2O\pm$	0·55
TiO_2	8·70
P_2O_5	0·30
MnO	0·26
SO_3	0·02
BaO	0·62
Total	100·44

Anal.: Imperial Institute, London.

Many stream sands in the area contain iron ore minerals but no economic concentrations were seen.

(9) Pyrite

Pyritiferous graphite gneisses outcrop in gullies two miles north of Matsimbani. Pyrite was also seen associated with kyanite gneisses near the copper occurrence at the southern end of the Nyangala spur and in graphitic quartz-felspar gneisses, four miles east of Kurase. Although no commercial value is attached to the deposits, the pyrite forms a significant part of these gneisses. Where the pyrite has been hydrated, the alteration product forms thin yellow films (and rare prismatic crystals) between the mineral grains and coats the weathered rock surfaces with a yellow-brown skin (*see* fig. 7*b*). This yellow, hydrated iron mineral is very common in rocks of the Maungu hills, in particular on Maungu, Nyangala, Saseie and the four small hills two miles west of Maungu.

(10) Sillimanite and Kyanite

Sillimanite and kyanite occur in gneisses forming the Maungu-Nyangala ridge. Kyanite comprises up to about ten per cent of the biotite gneisses exposed there, but the sillimanite is usually confined to *faserkiesel* and is rarely seen elsewhere. Both alumino-silicates also occur in gneisses associated with the limestones in the Kurase area, and kyanite gneisses form Matsimbani hill. Although considerable tonnages of the rocks are available no economic importance is attached to them.

(11) Vermiculite

Vermiculitic mica occurs as small books in pegmatites associated with a hornblende-garnet-scapolite gneiss on the west side of the Chief's office on Sagala. The rock is highly weathered and the mica is readily removed from the face of the outcrop, the larger pieces averaging 15 to 20 mm. in length. Crude exfoliation tests conducted at a temperature of about 900°C for a few seconds showed that pieces approximately 5 mm. thick exfoliated to six times the original size and others ½ mm. thick exfoliated twenty times. The quantity of vermiculite available is small and the occurrence has no commercial value.

(12) Road-metal, Aggregate and Ballast

An excellent supply of good road-metal can be obtained from Buguta, twelve miles south-west of Maungu station. On the west side of the Kasigau track part of a gabbro dyke forms a small conical hill of which the rock is particularly suitable for surfacing macadamized roads.

A quarry on the north side of Maungu hill has been used in the past by the Ministry of Works for road-metal for earth roads, for which it is suitable in so far as it can be easily broken down by hand. The Taru grits yield material for aggregate and are being used for that purpose at Mombasa, and also for ballast on the railway. Some of the grit bands at Kilibasi, where quarrying would be comparatively simple, could also be used for either purpose.

2. Water-supplies

The only permanent streams in the area are those flowing down the steep slopes of Kasigau and Sagala. Kasigau summit, which is rarely free from cloud and mist, supports a luxuriant forest and thick soil cover that prevent rapid erosion on the summit and allow percolation to feed a water-table. The water-table spills over at a lower level to form the main streams, the Mwedawaisi at Rukanga, the Kivokoni at Bungule and the Mwamadungi at Mwakasinye, and another less persistent stream at Jora. It is at these localities that the population congregates. The streams quickly disappear into the sandy pediment at the foot of the mountain slopes and much valuable water is lost, as it does not reappear in the Mavora stream-course to the south of the mountain. To assist the local Africans in storing water, two small-capacity concrete dams—the Ndimanbela dams—have been constructed above Rukanga village to which a piped supply of water is delivered. At the other localities, however, the water is collected from enlarged holes in the stream-courses and no attempt has been made by the residents to conserve their principal means of existence. The stream-courses lend themselves to crude damming by boulders and earth which would provide more adequate supplies during the very dry periods. At Sagala, another peak often shrouded in cloud, water flowing in gullies on the western slopes is sufficient to support a few settlements in a valley half-way up the mountain side. A small catchment high up on the southern side of the hills supplies the inhabitants at Machete, Nyika, and Jora and minor stream-courses on all sides of Sagala provide suitable but limited water-supplies for those inhabitants who live at the base. There are flowing streams during the rains, but in the drier periods of the year it is necessary to dig for water in the sandy stream-beds.

The remaining water-supplies in the area consist of water-holes in rock catchments on or round the base of hills, and small depressions in the soil cover in the more open country between the limestone ridges where drainage channels are to be found (nearly all are shown on the geological maps). In addition there are water-holes used by the game animals in the area; they are reached by systems of interconnected tracks which are motorable in short stretches, and are a witness to the number of animals using the tracks and to the size of the water-holes. The water-holes in the hill region are not numerous and are generally to be found along weathered joints or in depressions in the rocks. Some of these fissures and depressions contain water for many weeks after the rainy periods and are used by man and animal alike. Such water-holes exist at Buguta and on the Maungu hills. At the latter locality water has accumulated by percolation along foliation and joint planes into the col between Saseie and the north-south Maungu ridge, providing water for the inhabitants of the Marungu location. A col on Maungu hill provides a natural storage basin referred to by Gregory (1896, p. 66).

Permanent water-holes or *ngurungas* exist at Kilibasi, where weathering along intersecting joints and of ovoid concretions has produced large circular pools, often twenty feet deep. Wherever the grit bands of the Taru Grits outcrop water accumulates along the joints, permitting members of the Duruma tribe who live to the south of Kilibasi to eke out a poor existence. As part of the Coast Hinterland scheme, dams are being constructed in various stream-courses and at Lukakanyi, near the eastern border of the area south of Kilibasi, an earth dam has been constructed across a river-course in which massive grit bands outcrop.

Three bore-holes have been drilled in the northern part of the area, but all have been abandoned. That at Bungule (Kasigau) reached a depth of 240 feet, but was unsuccessful and was not logged. Details of the remaining two bore-holes supplied by the Ministry of Works are as follows:—

Bore-hole C 757—7 Miles NE. of Pikapika

Total depth—300 feet. Depth from surface at which water was struck—125 feet. Depth from surface to which water rises—75 feet. Estimated yield per 24 hours—1,200 gallons (now saline).

Depth in feet	*Lithology*
0 — 2	Soil.
2 — 16	Coarse red sand, kunkar and gneissose detritus.
16 — 25	Partly silicified, gneissose detritus.
25 — 32	Hornblende gneiss.
32 — 146	Garnet-hornblende gneiss.
146 — 170	Biotite gneiss.
170 — 235	Quartz-felspar-biotite gneiss.

Bore-hole C 767—Rukinga

Total depth—244 feet. Depth from surface at which water struck—125 feet. Depth from surface to which water rises—125 feet. Estimated yield per 24 hours—10,000 gallons.

Depth in feet	*Lithology*
0 — 25	Pink coarse quartz fragments.
25 — 50	Biotite gneiss.
50 — 75	Biotite-hornblende gneiss.
75 — 100	Biotite gneiss.
100 — 150	Biotite gneiss with pink felspar.
150 — 219	Biotite gneiss.

Two analyses of the water from Rukinga bore-hole gave:—

	At 220 feet depth Parts per 100,000	*At 240 feet depth Parts per 100,000*
Alkalinity (as $CaCO_3$)—		
Carbonate	Nil	Nil
Bicarbonate	58·5	57·6
Chlorides as Cl	450·0	440·0
Sulphates as SO_4	41·56	40·49
Nitrites	present	present
Nitrates	trace	trace
Calcium	13·5	13·4
Magnesium	30·8	30·3
Total hardness	160·49	159·19
Total solids	846·25	841·5
pH	7·7	7·9

Anal.: Government Chemist, Kenya.

The analyses indicate a highly mineralized water containing magnesium salts which would cause gastric disturbances in cattle and human beings and is therefore unsuitable for drinking purposes.

The lack of suitable water-supplies and poor rainfall make the area practically uninhabitable. Temporary water-supplies will not support a much larger population than there is at present, unless adequate dams are constructed to conserve water. Bore-holes drilled in localities most favourable for the retention of underground water indicate that supplies do not exist or that they are too saline for human consumption. In the case of the bore-hole north-east of Pikapika there was no recharge even though it had been sited in a natural drainage course. To suggest possible bore-hole sites in the area underlain by Basement System rocks without much more detailed work is unwise owing to the inadequate exposures. The fault-zone between the Basement System and the Duruma Sandstones is likely to collect water seeping downwards from the gneisses and from the stream courses that cross it, but the water is likely to be saline, as was found in a bore-hole drilled near the fault-zone east of Mackinnon Road. The Taru Grits, where they have been folded into shallow synclinal basins pitching to the east, provide suitable conditions for the existence of aquifers. Thick sandstone bands are lacking, however, and the best water-supplies are likely to be found when such bands occur east of the area mapped.

In 1956, the new Mombasa pipe-line began supplying water from Mzima Springs to Mombasa township. As only a portion of the water can be used at Mombasa it would be possible, in principle, for water to be taken from the pipe-line at various places. The railway and townships could thus benefit from the scheme, for in past years difficulty in maintaining water-supplies has been experienced.

At present the railway uses a piped supply of water from the Taita hills. An analysis of a sample of this water collected from Maungu station in 1953 gave:—

	Parts per 100,000 *except the* CO_2 *figures which are parts per million*
Alkalinity (as $CaCO_3$)—	
Carbonate	Nil
Bicarbonate	4·1
Chlorides as Cl	1·2
Sulphates as SO_4	trace
Nitrites	Nil
Nitrates	Nil
Calcium	0·6
Magnesium	0·65
Iron	0·24
Silica	3·0
Total hardness	4·2
Carbon dioxide	2·8
Total solids	9·0
Dissolved oxygen	0·288
pH	7·1

Anal.: Government Chemist, Kenya.

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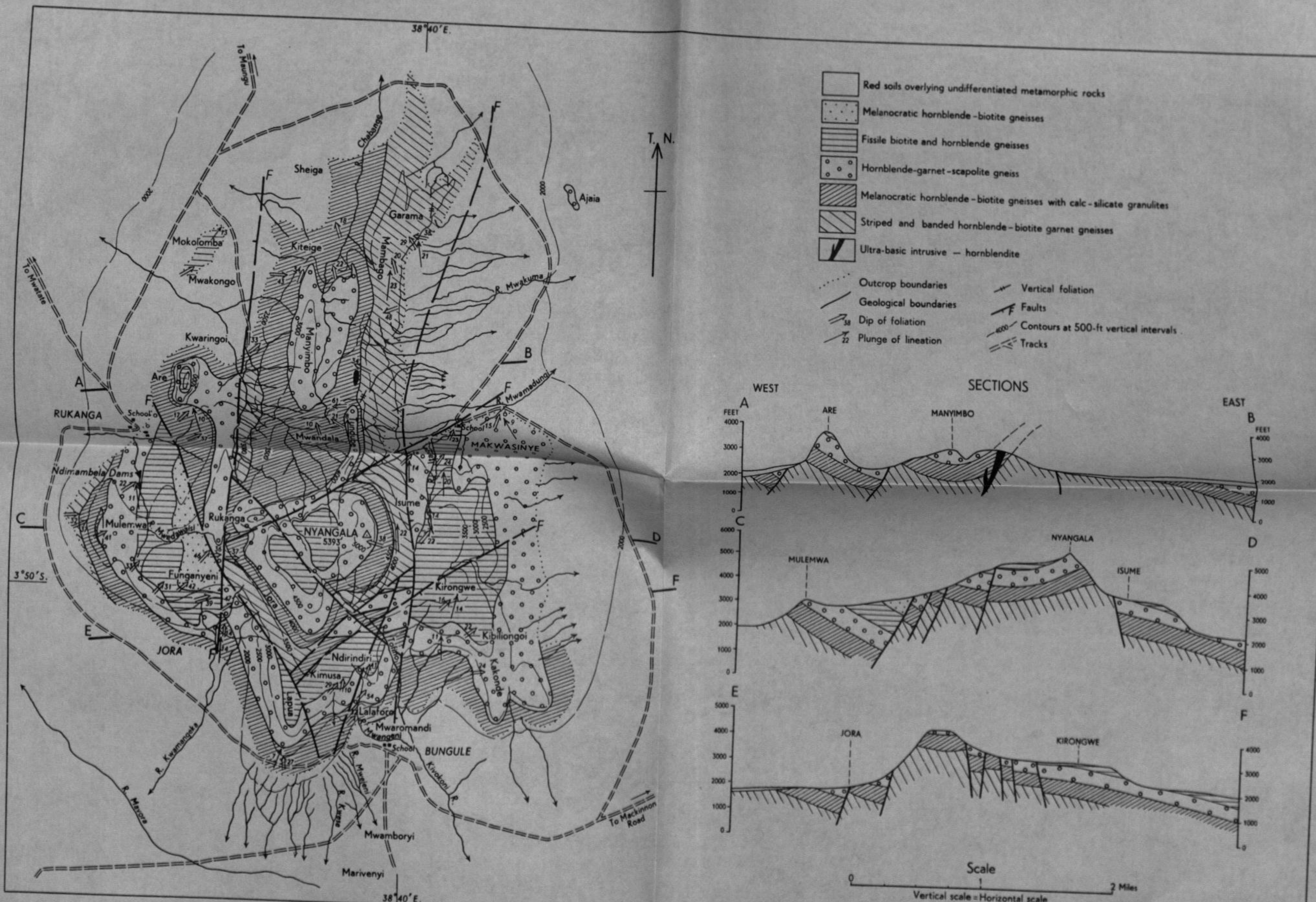
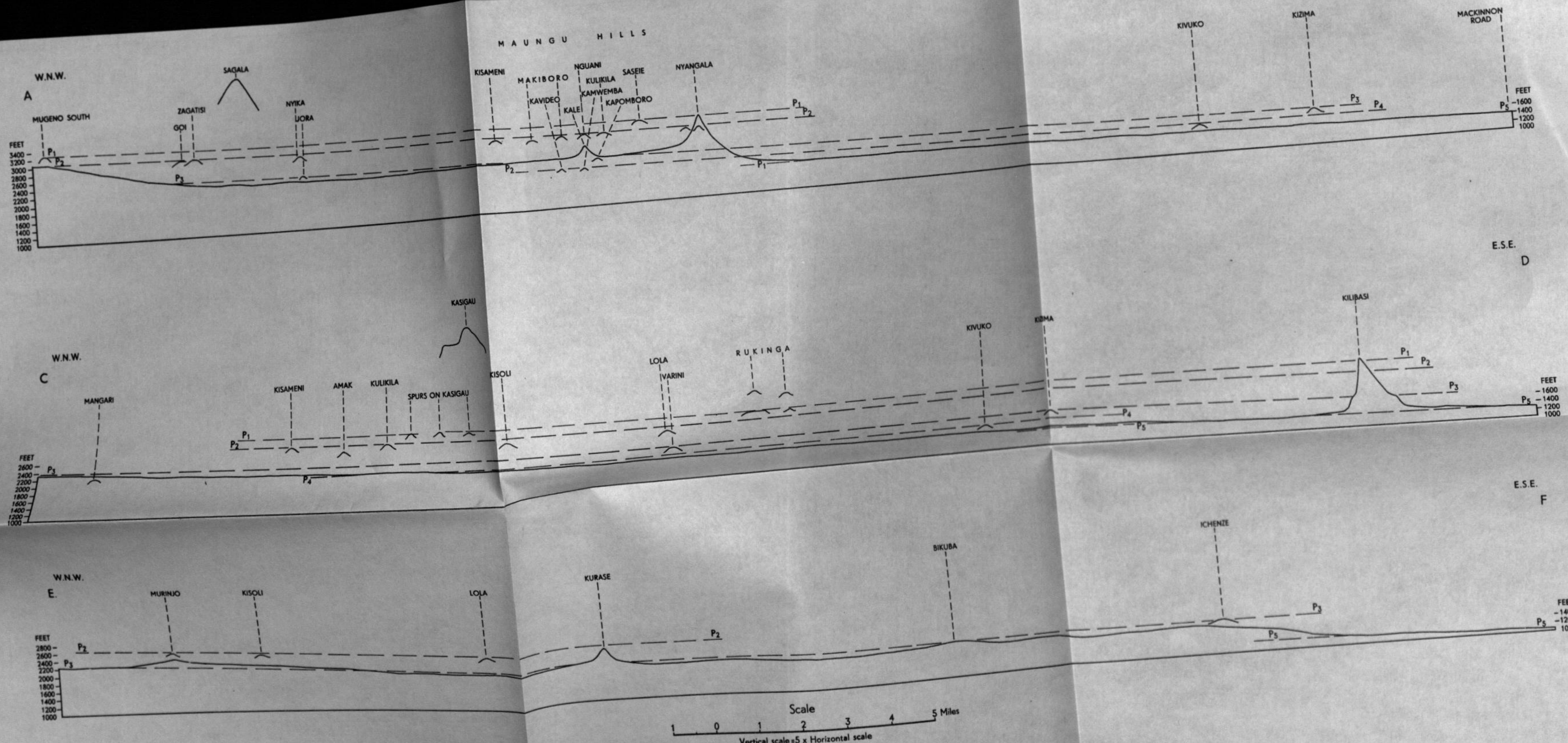


Fig. 19.—Geological map of Kasigau mountain.



P_1 End-Cretaceous peneplain

P_2 Maungu Hills surface

P_3 Sub-Miocene peneplain

P_4 Ichenze surface

P_5 End-Tertiary peneplain

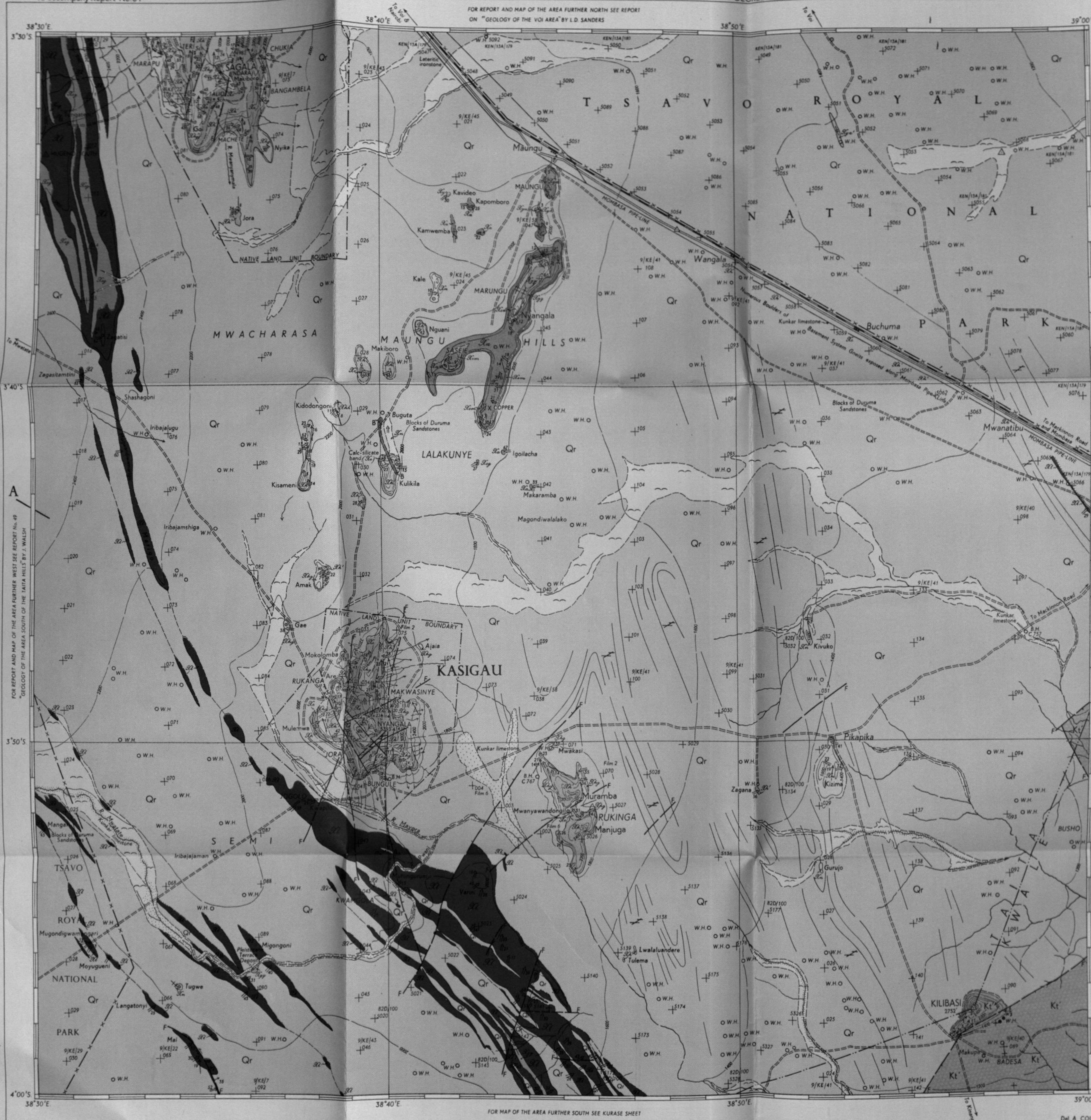
A–B Lines of sections shown on Figs. 1 & 2

Fig. 18.—Erosion surfaces of the Kasigau area.

GEOLOGICAL MAP OF THE KASIGAU AREA

To accompany Report No.51

DEGREE SHEET No.65, SOUTH – EAST QUARTER (Directorate of Colonial Surveys Sheet No.196)



EXPLANATION

QUATERNARY
- Sandy alluvium
- Black-cotton soils
- Qr — Red-brown sandy soils overlying undifferentiated Basement System rocks

LOWER PERMIAN TO UPPER CARBONIFEROUS

DURUMA SANDSTONES
LOWER TARU GRITS
- Kt — Arkosic grits, sandstones and carbonaceous shales

ARCHÆAN

BASEMENT SYSTEM
(not arranged in stratigraphical order)
- Undifferentiated Basement System rocks (in section)
- Crystalline limestones

Calcareous
- Melanocratic hornblende gneisses with numerous calc-silicate bands and lenses
- Hornblende-garnet-scapolite gneisses
- Hornblende gneisses
- Hornblende-diopside gneisses with epidote lenses
- Migmatites with calcareous host-rocks

Pelitic
- Kyanite, sillimanite, biotite and graphite gneisses
- Muscovite-quartz-felspar gneisses
- Biotite-garnet gneisses
- Migmatites with pelitic host-rocks

Semi-Pelitic
- Biotite-hornblende gneisses (locally garnetiferous)
- Migmatites with semi-pelitic host-rocks

Psammitic
- Quartz-felspar gneisses and quartz-felspar-biotite gneisses
- Granitoid gneisses

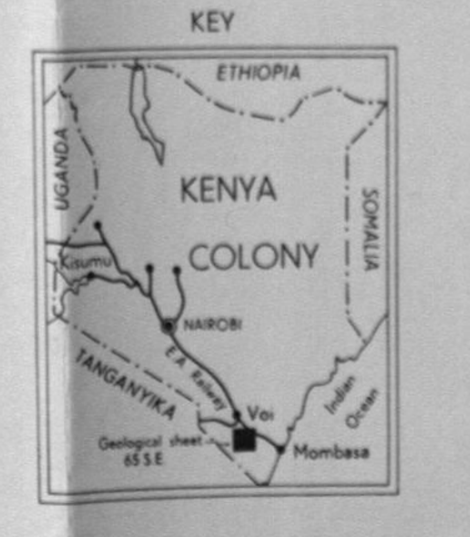
PRECAMBRIAN?

INTRUSIVES
- Uh — Hornblendite
- B — Gabbro

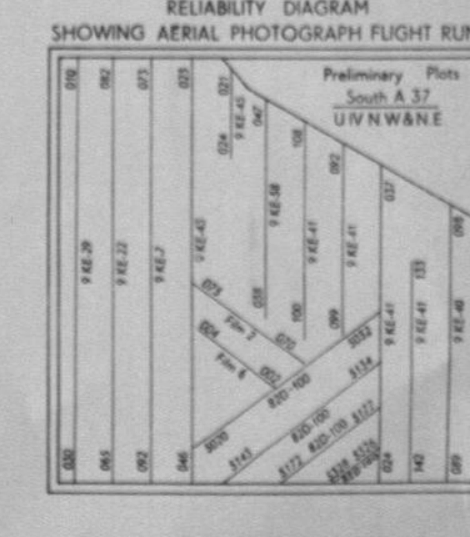
Geological boundaries, observable
Geological boundaries, approximate
Geological boundaries, inferred
Dip of bedding
Horizontal beds
Dip of foliation
Vertical foliation
Horizontal foliation
Plunge of lineation
Faults, inferred
Tear-fault with dip and direction of movement
Mineral deposits
Railway
Nairobi – Mombasa road
Motorable roads and tracks
Form-lines at 200-ft. vertical intervals below 3000-ft.; above 3000-ft. at 500-ft. intervals
Trigonometrical and survey beacons
Plane-table resected points
Principal points of aerial photographs
Structure lines taken from aerial photographs
W.H. Water-holes, permanent
W.H. Water-holes, seasonal
B.H. Bore-holes
Sch. African houses and schools
District boundary
National Park boundary
A — B Line of section

Magnetic declination 3° W.

KEY



RELIABILITY DIAGRAM
SHOWING AERIAL PHOTOGRAPH FLIGHT RUNS



MINISTRY OF COMMERCE & INDUSTRY
MINES & GEOLOGICAL DEPARTMENT
KENYA COLONY

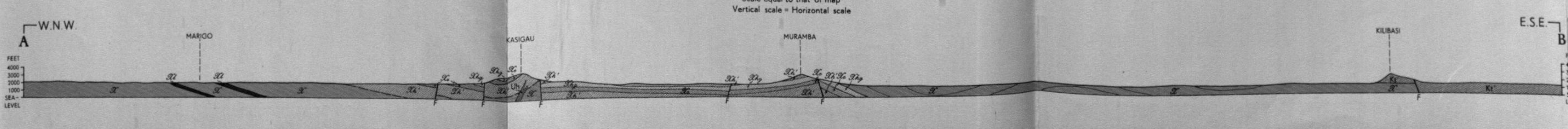
Scale 1:125,000

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

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

GEOLOGICALLY SURVEYED BY E.P. SAGGERSON, GEOLOGIST,
Between June and December 1955

SECTION FROM A to B
Scale equal to that of map
Vertical scale = Horizontal scale



GEOLOGICAL MAP OF THE AREA SOUTH OF THE TAITA HILLS

DEGREE SHEET No. 65, SOUTH-WEST QUARTER & parts of DEGREE SHEET No. 65, NORTH-WEST QUARTER &
DEGREE SHEET No. 68, NORTH-WEST QUARTER (Directorate of Colonial Surveys, Sheet No. 195 and part of Sheet No. 189)

MINISTRY OF COMMERCE & INDUSTRY
MINES & GEOLOGICAL DEPARTMENT
KENYA COLONY

GEOLOGICALLY SURVEYED BY J. WALSH, GEOLOGIST,
Between January and July 1955