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GOVERNMENT OF KENYA

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GEOLOGY
OF THE
BARAGOI AREA

DEGREE SHEET 27, NE. QUARTER
(with coloured geological map)

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FOREWORD

The Baragoi area has been examined, during the last few years, by a handful of prospectors, who have discovered various minerals of interest, including mica, asbestos, magnesite, chromite, talc, graphite, beryl and radio-active minerals. Of these only mica and beryl have been worked, and only to a small extent. The area is, however, obviously interesting from the point of view of mineral occurrences, and future prospecting will gain much assistance from the map presented with this report. Some of the minerals are associated with ultra-basic intrusives and their metamorphic derivatives, and the mapping has shown that the intrusions lie in well-defined zones. The mica, beryl and radio-active minerals occur in pegmatites, and are sporadic. The radio-active minerals containing uranium are usually of the refractory kind, and occur in the pegmatites like plums in a cake and so far have not been seen in large quantities. Radio-active monazite is also present occasionally.

The report gives a detailed account of the structural geology of the area, supported by geometrical analysis of the facts recorded in the field. A knowledge of the structure may well be of considerable importance, should workable mineral deposits be discovered.

Nairobi,
9th July, 1958.

WILLIAM PULFREY,
Chief Geologist.

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ABSTRACT

The report describes an area 1,189 square miles in extent in north-central Kenya bounded by the parallels 1° 30′ N. and 2° N., and by the meridians 36° 30′ E. and 37° E.

The greater part of the area is a lightly dissected plain—the sub-Miocene surface—at a level of 4,000 to 5,000 ft., on which are scattered mountain residuals rising to between 5,000 and 7,000 ft. To the west the country is dissected and descends to the Suguta valley (c. 1,400 ft.). The north-eastern and south-eastern corners of the area are also dissected and in process of being bevelled to form an extension to the end-Tertiary peneplain (c. 3,200 ft.).

Approximately half the area is composed of Basement System rocks which are regionally metamorphosed and partly granitized meta-sediments and migmatites. Basic and ultra-basic igneous rocks, granitic stocks and dykes and sills formed by granitization occur as intrusives into the Basement System.

Resting on thin Miocene sediments in the western half of the area is a succession of basalts, tuffs, phonolites and alkali trachytes, dipping westwards towards the Suguta fault-trough, which is a part of the Gregory Rift Valley. The volcanic rocks are affected by Pleistocene faulting.

The Basement System rocks are folded about more or less north-south axes. Minor structures within the major folds are also described.

Several small occurrences of economic minerals are discussed.

GEOLOGY OF THE BARAGOI AREA

I—INTRODUCTION

General.—For the purpose of this report the Baragoi area is defined as the north-east quarter of degree sheet 27 (Kenya), bounded by latitudes 1° 30′ N. and 2° N., and by longitudes 36° 30′ E. and 37° E. It is 1,189 square miles in extent and all but a small part in the north-west corner (Turkana District) falls into the Samburu District. The Samburu area is administered by the District Commissioner at Maralal, under the Provincial Commissioner, Rift Valley Province, at Nakuru. The area, however, is Crown Land, and has not been gazetted as a District, and legally forms part of the Northern Province. For all practical purposes the Samburu area may be regarded as a Native district, with an established African District Council. Samburu District is a "closed area" under the Outlying Districts Ordinance, and permission must be obtained from the District Commissioner before entering it.

The Baragoi area is populated by pastoral Samburu and Turkana, the latter having migrated in the past from their own district on the west side of the Suguta valley in search of better grazing. They are permitted to stay by virtue of having been born in the area or by having entered at some later stage, and are now included on the Samburu tax-roll. The Samburu occupy the best grazing in the area, the El Barta plains, and have grazing rights as far west as the line Lopet-Nachola-Kowop. The Turkana on the other hand are not allowed east of the line marked by the Maralal-Baragoi road, Baragoi and Kowop.

The climate of the area is generally pleasant on the undulating plains-country around Baragoi. Towards the west, and in the north-east and south-east corners where the ground is below 3,000 ft. above sea-level, the climate is semi-arid. Rainfall is conspicuously controlled by the Musei (Ndoto) mountains to the east. It is commonplace to observe long streamers of clouds passing across the area from the peaks of the Musei range (c. 8,000 ft.). During rainy seasons this phenomenon is accentuated and there is a belt of comparatively high rainfall extending from Lesirikan across to Baragoi. Grass, and to a lesser extent thorn trees, flourish in this belt whereas only a few miles to the north or south and at the same altitude the country is drier. The rainfall figures for Baragoi given below are, therefore, not typical of the area as a whole.

Rainfall at Baragoi

(From the published records of the East African Meteorological Department)

1954—22.11 inches
1955—20.34 inches
Average for 16 years—19.63 inches

Baragoi is the only township in the area, and consists of some dozen shops owned principally by Somali traders. A District Clerk controls a few Tribal and Grazing Guards; there is a small Kenya Police post and a Game Rangers post. Recent developments include the establishment of a Roman Catholic Mission with an associated boys' school and a hospital erected by the African District Council.

The geological survey was carried out between June and December, 1955, and the information in this report refers to conditions as they were during that period.

Communications.—All motor roads and tracks are shown on the geological map (at end). The principal road is that from Maralal to Baragoi, which is maintained in fair condition. The other tracks in the area, including the Baragoi-South Horr road, are usually rough and motorable with difficulty. Crossings of rivers are unmade and travellers may need to do some spade-work to allow passage. All parts of the eastern half of the area are easily accessible on foot or from a vehicle. In the western half, however, the country is rugged and broken and camel or donkey safaris provide the only means of access.

Maps.—The topography of the map (the area of which corresponds with sheet No. 65 of the Directorate of Colonial Surveys) was compiled from air photographs and controlled by plane-table survey based on a number of fixed points. Altitudes were determined by aneroid barometer and are generally accurate to within 20± ft., except in the western third of the area, where the accuracy is generally within 75± ft. The form-lines are based on these altitude observations and give an outline of the topography.

Place names have been added to previously unnamed features, and existing names have been corrected where possible. Most features in the central part of the area have both Samburu and Turkana names, but since both are usually understood locally, there is no need to distinguish between names in the two languages. Features often have graphic names, and are commonly named by association with some event in the past, the names being applied to rivers or hills near the locality of the event. Some examples are:—

Ol Doinyo Luwarak	=	The hill of many hyenas.
Soit Olbayen ..	=	The stone (hill) of the elders.
Soit Nyiro	=	The dark stone (hill).
Ayena Aturkan ..	=	The river of Turkana (a Turkana).
Ol Doinyo Nakwawi	=	Nakwawi's hill.
Echua Etom ..	=	The spring of the elephant.
Ngume Malo ..	=	The pass of the Kudu.
Aka Aiteputh ..	=	The place where the grey cow was found.
Nouyarot	=	The long climb (the place of).

Previous Geological Work.—It is probable that von Höhnel was the first European to pass through the area, in early 1888, together with Count Teleki (von Höhnel, 1938, p. 22)*. Rosiwal (1891) described the rock specimens collected by the expedition, but it seems that no rocks were collected from the Baragoi area.

H. S. H. Cavendish travelled along the Suguta valley with H. Andrew on their return from Lake Rudolf in 1897, and described the saline swamps at the north end of the Suguta river (Cavendish, 1898, p. 392).

The last of the early explorers who passed through the area *en route* to or from Lake Rudolf was C. H. Stigand†.

The El Barta plains and the North Marti plateau (Lopet plateau) are mentioned briefly by Dixey (1948, pp. 14, 16), who ascribed the plains to mid-Tertiary peneplanation. R. M. Shackleton (1946), while mapping the Nanyuki-Maralal area to the south, visited the Baragoi area and described an altered quartz porphyry east of Lamerok, a rock which apparently occurs as a dyke in the Basement System (*op. cit.*, p. 18). He also referred to metagabbro, amphibolites, talc and tremolite rocks in the Baragoi vicinity (*op. cit.*, pp. 19-20). Shackleton noted the continuation of basalts forming the lowest part of the Tertiary volcanic sequence northwards into the Baragoi area, and called it the Samburu Series after the name of the hills in the west of the area as shown on the military map (E.A.F. No. 1168, Maralal N.W.). A Kapiti-type phonolite was found on the summit of Lamerok hill (*op. cit.*, p. 34) and he regarded the basalt outliers west of Baragoi as belonging to the Laikipian basalts (*op. cit.*, p. 39).

Late in 1954 L. M. Bear (a government geologist) and D. Hobden (a government prospector) carried out surveys of asbestos, mica, copper, chromite and radio-active mineral occurrences in the area.

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* References are given on pages 73-74.

† C. H. Stigand, 1910. To Abyssinia through an unknown land. An account of a journey through unexplored regions of British East Africa by Lake Rudolf to the Kingdom of Menelon.

II—PHYSIOGRAPHY

1. Areas of Distinctive Physiography

(1) The El Barta Plains (the upper Baragoi River Drainage Area)

The gently undulating plains in the east-central part of the area are bounded to the east by the western slopes of the Musei mountains (Plate I, fig. 1) and pass westwards, northwards and southwards into lower lying, more dissected country. They occur at a level of between 4,000 and 4,700 ft., and a few well marked "inselbergs" such as Koitokol, Ngoriche, Lamerok and the Kowop hills rise above them. The surface of the plains is gently undulating and almost completely free of trees of any kind. The shallow valleys are partly filled by loess-like soil derived from the adjacent slopes by mild sheet erosion.

(2) The Muran and Lgerei (Lanana-Masegeta) Drainage Areas

North-east and south-east of the El Barta plains eastward draining river systems have partly dissected the plain, more effectively in the north-east than in the south-east. The Kileshwa-Sachati river system has incised into the plain, with the isolation of the Lolenyok ridge and the capture of some of the headstreams of the Baragoi river. In this area the rivers are graded to a base-level of 3,200 ft., this being the level of the sandy alluvial plain occurring in the north-east corner of the area.

(3) The Volcanic Area in the West

The physiography of the volcanic area is controlled primarily by its structure and, to a lesser extent, by the variable resistance to erosion of the rocks of which it is composed. Horizontal or gently dipping "plateau" phonolites and basalts occur forming the Lopet, Tirr Tirr and Emuru Akirim plateaux. Between these relatively resistant plateaux the volcanics are extensively dissected by the west-flowing drainage into the low-lying Suguta valley. The degree of dissection is particularly marked on the olivine and augite basalts between the Tirr Tirr plateau and the Baragoi river, and increases perceptibly towards the west. As can be realized from Fig. 1 the drainage on these basalts is conspicuously controlled by meridional faulting, and tilting of the fault-blocks to the west. This also applies to a lesser extent to the Nanganyamonyen river system and the western edge of the Tirr Tirr plateau. The intensity of dissection in these areas is due largely to the climate, which is almost arid, and to the moderately steep gradient into the Suguta valley, which enclosed trough-like valley is the recipient of most of the drainage from the El Barta plains, which are approximately 3,000 ft. higher in altitude.

The Nagoriagwen basin is essentially an erosional "window" exposing the Basement System beneath the volcanic rocks in the crest of the "Samburu monocline" (Shackleton, 1946, p. 46), the flexure that has resulted in the westward dip of much of the lava succession.

The Suguta valley, only a small part of which falls in the present area, lies at an altitude of approximately 1,250-1,300 ft. above sea-level, i.e. at much the same level as Lake Rudolf further to the north. The valley is tectonic in origin, being bounded on both sides by youthful fault escarpments, and floored by red clays and boulder and gravel fans. These superficial deposits overlie a great thickness of lacustrine and fluviatile deposits, for the whole valley was originally a part of Lake Rudolf, as is evidenced by the presence of a flight of beach terraces on a number of ash cones just west of Kanganya. The floor of the valley is frequently flooded in rainy seasons, for it is the recipient of the drainage of a considerable area, extending south of Lake Baringo and including the Kamasia hills and the flank of the Rift Valley around Eldama Ravine and Molo. The floor of the valley is occupied by the meandering, braided Suguta river, which ends its course in the shallow swampy Lake Nakula north-west of the area mapped

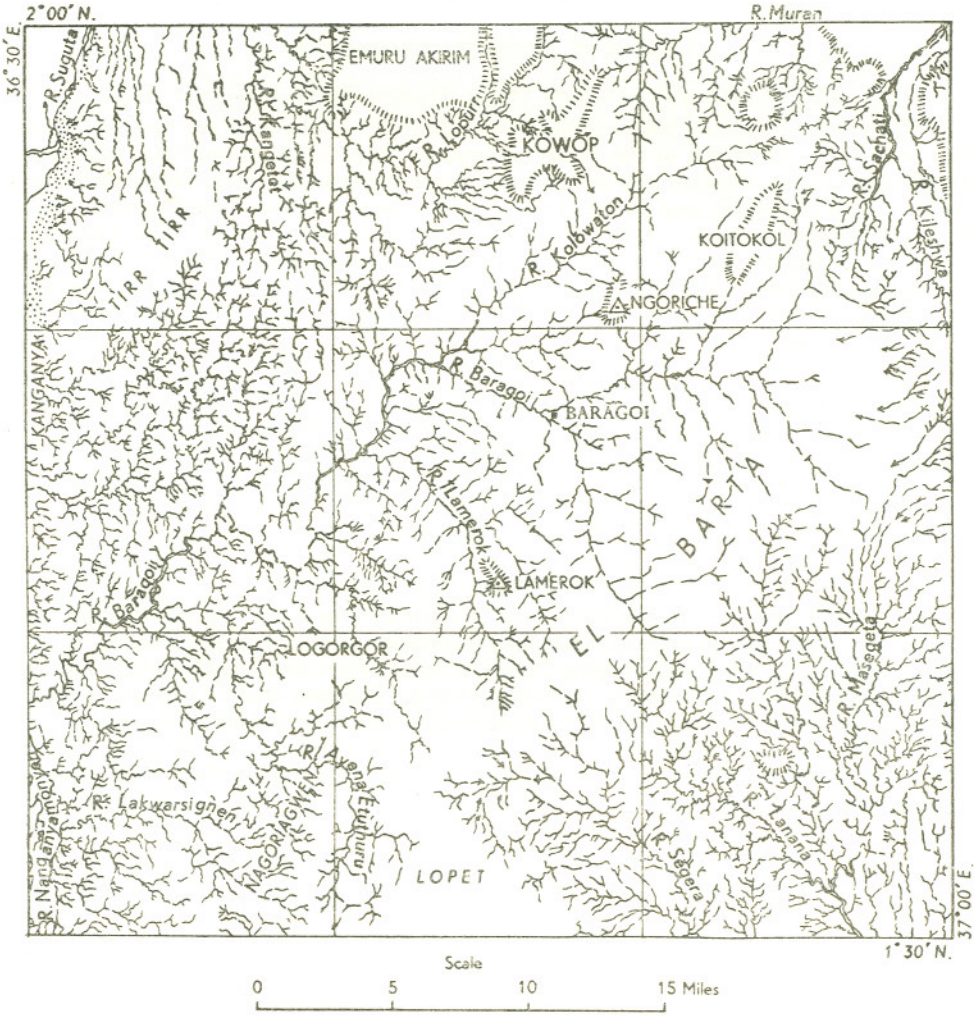


Fig. 1—Drainage patterns in the Baragoi area

2. Physiographic Evolution of the Area

Immediately east of the area is the Musei massif, which is part of a long chain of mountains extending from near Isiolo through Uaraguess, the Matthews range and the Musei ranges to Nyiro mountain and the Ol Doinyo Mara massif. Nyiro, immediately north of the map-area, reaches a height of nearly 9,000 ft. and the rest of the chain reaches heights of between 7,500 and 8,500 ft., there being a well marked tendency for summit levels to decrease to the south-south-east (cf. Shackleton, 1946, pp. 44-45; Dixey, 1948, pp. 12-13 and Fig. 1). These summit levels are regarded as representing an ancient erosion surface named the Cretaceous peneplain by Shackleton and the 7,200-7,500 ft. peneplain by Dixey. The surface is not represented in the present area, but the highlands that enclose it on two sides must have had a powerful influence on its physiographic evolution. They formed a barrier which, in retarding the dissection of the sub-Miocene peneplain, as represented by the El Barta plains, helped to preserve this surface to the present day.

The sub-Miocene peneplain stands at an elevation of 4,500-4,600 ft. east of Baragoi but can be traced westwards to successively lower levels till it passes beneath the volcanic rocks. The westward slope of the surface is scarcely perceptible in the centre of the area but is marked in Nakefenda, 12 miles north-west of Baragoi, where the moderately dissected country has hills all terminating at an even summit level, a level that slopes westwards at approximately 9 degrees.

At the time of the onset of the Tertiary vulcanicity, which probably began in the Miocene, the sub-Miocene peneplain was a moderately smooth surface, with peneplain gravels and fluviatile sands and grits in its hollows. It is not known what the form of the drainage was at the time, but it is likely that it was towards the north or north-west. Following the first eruptions of basalts and tuffs—the volcanic rocks of the Samburu Series—slight westward tilting began and probably continued throughout the eruption of the Rumuruti phonolites and the later porphyritic olivine and augite basalts. There was then a pause in the vulcanicity, and depression of the area now occupied by the Suguta valley resulted in a marked increase in the westward tilt of the volcanic rocks. After a little erosion had taken place, a renewed outburst of vulcanicity formed the Tirr Tirr Series, a group of lavas extending as far north-east as the west faces of Kowop and Nyiro mountains. This vulcanicity was followed by further tilting, this time with a more northerly component, and was accompanied by normal faulting downthrowing to the east, breaking the western part of the volcanic area into narrow tilted fault-blocks. The faulting was soon followed by trough faulting along the Suguta, giving rise to its deep narrow valley, and which must have initiated the period of vigorous consequent drainage and erosion that is seen in process at the present day.

While these events were taking place in the western part of the area the headwaters of the fast-flowing Muran and Lgerei rivers were breaking through the Ol Doinyo Mara-Musei-Matthews range mountain barrier and dissection of the El Barta plains began. Of the two river systems the Muran appears to be the more vigorous and has given rise to a flat sandy plain in the north-east corner of the area, a plain which is considered to be a part of the great end-Tertiary peneplain of Northern Province (cf. Shackleton, 1946, p. 46; Dixey, 1948, pp. 12-18).

III—SUMMARY OF GEOLOGY

The greater part of the area is covered by Precambrian metamorphosed sedimentary and igneous rocks, and by migmatites and granitic intrusives derived from the metamorphic rocks by granitization. The metasediments include marbles, quartzites, quartzo-felspathic granulites, biotite gneisses and granitoid biotite gneisses. Igneous rocks are especially common and were emplaced or extruded among the metasediments and became involved in the regional metamorphism and localized granitization that affected all the Precambrian rocks. They include altered ultra-basic igneous rocks such as serpentinites and tremolite-anthophyllite sills with magnesite veins and chromite segregations, basic igneous rocks now represented by amphibolites and plagioclase amphibolites, foliated stratiform and stock-like granites, and aplite and pegmatite veins regarded as derived from the metamorphic complex by granitization. Migmatitic varieties are widespread adjacent to the mobilized granites. The whole complex has been involved in deformation, recrystallization and folding approximately contemporaneous with the regional metamorphism and granitization.

Resting on the Precambrian metamorphic complex with unconformity are Tertiary and Quaternary volcanic rocks and lake and fluviatile sediments associated with the Rift Valley, which is represented here by the Suguta valley. The volcanic rocks, which include porphyritic basalts, olivine and augite basalts tuffs, agglomerates and phonolites thin towards the east, and are involved in a flexure which gives them a westward dip

toward the Suguta valley of up to 30 degrees. Overlying the tilted volcanics with unconformity is the Tirr Tirr Series, composed of basalts and trachytes. The whole of the volcanic sequence in the western part of the area is affected by Pleistocene faulting which was also responsible for the formation of the Suguta fault-trough.

Late Pleistocene basalts occur as thin sheets on the sub-Miocene erosion surface west of Baragoi and form two stocks in the Lanana valley. The lake beds and fluviatile terraces in and adjacent to the Suguta valley were also formed during the Pleistocene, and are regarded as the beds laid down when the Suguta valley was the site of an extensive lake, which has since almost completely dried up.

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

Recent ..	Lava in Suguta valley. *Drying up of the Suguta lake.*
Pleistocene	Lake and fluviatile beds of Lake Suguta Olivine basalts. *Faulting, erosion, formation of Suguta rift.* Tirr Tirr Series (basalts and trachytes).
Pliocene ..	*Westward tilting and slight erosion.* Olivine and augite basalts (Laikipian basalts ?). Lake and fluviatile sediments.
Miocene ..	Rumuruti phonolites. Porphyritic basalts (Samburu Series). Sub-volcanic sediments. *Formation of sub-Miocene erosion surface.*
	Long period of repeated erosion and uplift.
Precambrian	*Granitization, folding, intrusion of syntectic granites.* *Intrusion of basic and ultra-basic bodies.* Basement System (and basic extrusives).

IV—DETAILS OF GEOLOGY

1. The Precambrian Rocks

(1) General Considerations

The oldest rocks in the area are the gneissose and schistose metamorphics outcropping in its eastern half, and are similar to the Basement System rocks of medium grade of regional metamorphism that have been described from many parts of Kenya. The metamorphic complex of the Baragoi area is composed of rocks of several ages, that is—sediments, pre-metamorphic basic intrusives and largely post-metamorphic syntectic granites with associated aplites and pegmatites, and there is no evidence to suggest the ages of the sedimentary, basic intrusive and metamorphic-tectonic-syntectic events. There is sound evidence, however, that regional metomorphism, folding and granitization were overlapping concurrent events, and that the sequence was as follows:—

(1) Sedimentation, probably accompanied by the extrusion of basic volcanic rocks,

(2) Intrusion of basic and ultra-basic igneous masses,

(3) Regional metamorphism, deformation, folding and granitization, immediately followed by

(4) Intrusion of syntectic granites together with aplites and pegmatites.

In the present report it is proposed to include only the metasediments and migmatites derived from them in the Basement System, as opposed to previous practice, which has been to include all of the rocks of the metamorphic complex, whatever their age and origin, in the System (cf. Sanders, 1954, pp. 7-8).

The age of the Basement System and of the pre-metamorphic and syntectic episodes is unknown. The most that can be concluded with certainty from a consideration of the geology of East Africa is that it is pre-Bukoban and pre-Karroo in age, but it is likely that it is also pre-Nyanzian. Recent work (quoted by Holmes and Cahen, 1956, pp. 12-15) indicates that pegmatites emplaced in the Basement System in parts of south-central Kenya have absolute ages of about 480 million years. It is agreed, however, that this young age cannot be that of the Basement System (*op. cit.*, p. 36), but that the metasediments are older. For this reason the Basement System and the intrusive episodes associated with it are regarded as Precambrian in age.

(2) The Basement System

The rocks of the Basement System comprise marbles, quartzites, quartzo-felspathic granulites, mica gneisses, granitoid gneisses, augen gneisses, hornblende-biotite and hornblende-garnet gneisses, graphitic schists and various migmatites.

A generalized succession across the northern part of the area together with thicknesses of the major units is given below. The thickness of the beds varies widely, as indeed does the composition, where the metamorphic rocks are involved in zones of granitization.

	Approx. thickness (feet)
Gneissose granite (Sartim)	2,000
Hornblende migmatites	400–600
Plagioclase amphibolites, with amphibolite and altered ultra-basic sills ..	4,000–5,000
Granitoid gneisses	1,000–1,500
Biotite magmatites	1,000
Plagioclase amphibolites (with amphibolites and muscovite-biotite gneisses locally)	3,000
Biotite gneisses	800
Hornblende migmatites	1,800
Biotite migmatites	3,000

(*a*) *Marbles.*—A zone of marbles occurs between Tangar and Nderentei on the El Barta plains. The rocks do not outcrop well and cannot be followed far along the strike. Most of the marbles of this zone have small scattered graphite flakes and are massive, pale greyish blue coarse-grained rocks of dolomitic appearance. A continuation of the marble zone occurs five miles further south, west of the Barenyiro ridge, where one of the limestones contains lenses of pegmatite surrounded by soft pale green sheaths of tremolite and talc. Disconnected lenses of graphitic marble occur approximately one mile south-east of Baragoi.

Marbles without graphite are seen near the western contact of the Butabut granitoid gneiss; one and a half miles south of Naligwei; and west and north-west of Nachola hill. Further exposures were found on the south-west ridge of Gurika mountain on the east side of the area and also in the Kileshwa valley further north, where two or more marbles occur associated with quartzites and graphite in the Gurika and Kileshwa folds, and a marble occurs among the granitized rocks in the Nakefenda vicinity.

Calc-silicate rocks are scarce. A thin strongly folded bed of garnet-hornblende-calcite rock occurs two and a half miles south-west of Barenyiro. A further distinctive

occurrence is on a low hill crossed by the motor-track two and a half miles east-south-east of Ildebessare pan. The rocks here are violently contorted quartz-rich hornblende- and garnet-bearing marbles, the quartz occurring as discrete granulitic lenses weathering into upstanding ribs on the rock surface. A similar rock occurs among hornblende migmatites one mile north-west of Morilem.

A specimen of the more calacareous part of the rock east of Ildebessare was collected (27/245)*. It is a pinkish grey marble with ill-defined streaks of minute granules of garnet and epidote in a quartzose calcite matrix carrying sparse graphite flakes. Crystals and aggregates of a brown mica are also present, as well as granules of green amphibole.

(*b*) *Quartzites.*—The principal quartzite occurrences are about the nose of the Atagirion anticline north of Nachola. The rocks outcrop well but occur as sporadic lenticular bodies which are distinctive in having a deep grey-brown colour, coarse inequigranular texture and no semblance of bedding. A specimen of the main quartzite outcrop (27/230) from two miles north of the lower Kolowaton river shows interlocking quartz grains ranging from $\frac{1}{2}$ millimetre to 7 millimetres in size. There are rare but large felspar grains and all the minerals are speckled with fine magnetite, which gives the rock its distinctive colour.

Similar quartzites outcrop on either side of the low ridge south-west of Nagiss. The quartzites here are lighter in colour and exhibit a strong lineation picked out by crenulations on iron-stained foliation surfaces.

Occurring in the nose of the Gurika and Kileshwa folds north of Lesirikan is a distinctive quartzite. In the Kileshwa river it is a flaggy, locally fissile rock, light in colour and with a prominent lineation. In thin section (specimen 27/268) the rock is seen to be a felspathic granitized quartzite with narrow bands of differing grain size. The bands are alternately quartz-rich and quartz-poor and show signs of preferred orientation of the optic axes of the quartz grains. The quartz grains of the quartz-poor bands "float" as rounded isolated grains in an enveloping felspathic matrix forming a "net-texture" that is characteristic of granitized quartzose rocks. Orientated flakes of biotite and altered mica define some bands. The rock shows clear evidence of deformation, but apart from orientation in the fabric and the presence of optic strain, the light-coloured mineral shows no effects of deformation. The granitization must therefore have taken place after the rock was deformed and must have been accompanied by a certain amount of recrystallization.

Small quartzite beds are widespread among the hornblendic gneisses and frequently show structures resembling autobrecciation. In a few cases exposures sufficed to prove that some of these quartzites have developed from zoned pegmatites or quartz veins by shearing. This origin is not proved for all these bodies, and some of the more even-grained types may be of sedimentary origin.

A pyritiferous quartzite occurs close to the hornblende-epidote rocks below Kisima ridge, three miles south-west of Baragoi. In thin section (specimen 27/191) the rock is seen to contain 30 per cent of oligoclase occurring as interstitial material, partly enveloping inequigranular quartz grains. Rounded pyrite grains are common and sparse muscovite flakes and small epidote crystals were observed.

A yellowish brown quartzite with well marked granulitic texture occurs in the gorge immediately north of the Ayena Etuthuru plateau.

(*c*) *Quartzo-felspathic Granulites.*—The term granulite is used here as a textural term to denote sedimentary quartzo-felspathic rocks "poor or lacking in mica and with

* Numbers prefixed by 27/ refer to specimens in the collection of the Mines and Geological Department.

flat lenticles of elongated quartz grains" (Turner, 1948, p. 205). Such rocks are not widespread in the Baragoi area and can easily be confused with orthogneisses of similar appearance and texture developed by the deformation of quartz-rich aplite dykes and sills. The sedimentary granulites can usually be identified by their more conspicuous and regular foliation, and by their concordance with the surrounding gneisses.

The quartzo-felspathic granulites are characterized by moderate to fine-grain size, and often have a reddish or yellowish brown colouration. Micas are sparse and other ferromagnesian minerals are frequently lacking. The only planar elements in the rock fabric are usually the flat lenses of "granulitic quartz". A typical example of these rocks occurs on a low ridge immediately south of Nagiss, about seven miles south of Baragoi. The rock (specimen 27/205) is foliated and contains irregular lenses of quartz grains averaging five millimetres in length and one millimetre in thickness. Oligoclase occurs only in the granular matrix between the quartzose lenses, together with muscovite. The quartz lenses are greatly elongated in the direction of the lineation (*b*) and the orientation of the muscovite flakes suggests that the fabric has been produced by simultaneous slip on two surfaces intersecting in *b*. A somewhat similar rock, but without such well developed granulitic texture, occurs as a wide zone in the Ayena Etuthuru valley west of the Lopet plateau. This rock (specimen 27/337) has minute flakes of biotite, shows replacement textures, and can be described as transitional to the granulitic biotite gneisses.

Between the Lanana river and Kangura, and extending north-westwards towards Tipaku, are numerous problematical quartzo-felspathic rocks. Some are granulitic and flaggy, particularly those in the small anticline near the Lanana river, while others towards Kangura have sporadic felspar augen and seem to grade into aplitic and pegmatic types. Many could be equally as well described as sheared pegmatites or aplites as granitized quartzo-felspathic paragneisses. On the grounds of their flaggy outcrop and the occurrence of a little biotite, the granulites of the Lanana fold are, however, tentatively regarded as metasediments. Typical of these rocks is specimen 27/244, from 4½ miles south-east of Laregel, which has elongated large quartz grains, smaller aggregates of sodic plagioclase, a little microcline, sparse micas and rare garnets.

The reddish-brown-weathering granulites in particular are identical with those fully described by Shackleton (1946, pp. 11-12) from the area north of the Karissia hills.

(*d*) *Biotite Gneisses.*—Biotite gneisses are not widespread in the present area, but occur in several isolated occurrences. The main outcrops occur along the Kangetet river south of Emuru Etuku, in the core of the Kowop anticline, forming the nose of the Butabut anticline, and on the long ridge south of the Lanana river. In addition there are numerous thin localized bands of biotite gneiss, found usually associated with hornblende-biotite gneisses or granitoid gneisses. Among the hornblende-biotite gneisses of the Kolowaton river section, and in the migmatitic rocks of the Loburr and Lanana rivers and on the Ildebessare ridge biotite gneisses sometimes containing garnet are seen to have developed by granitization and shear. These transformations are described in the section dealing with the hornblende migmatites of the Loburr river, where the process is well seen (p. 14).

The biotite gneisses are also commonly associated with granitoid gneisses; the distinction between them made by the writer being mainly of grain size and microcline content. The granitoid gneisses have a granular texture, and a poor gneissosity is imparted by isolated biotite flakes; they characteristically outcrop as rather massive rounded boulders. The biotite gneisses on the other hand are well foliated, frequently flaggy, and are rather darker more fine-grained rocks. Under the microscope textures in the two types are frequently seen to be similar and comparable rocks have been described as "psammitic gneisses and granulites" (Schoeman, 1948, p. 22; Bear, 1952, p. 12).

A typical biotite gneiss is specimen 27/173 from the river two miles south-east of Ngoriche. The rock is medium- to fine-grained and well foliated with diffuse quartzo-felspathic lenticles with biotitic folia. Quartz is more plentiful than felspars, which consist of irregular oligoclase (An_{14}) and small interstitial microcline grains. The microcline is seen to be replacive against quartz and plagioclase. Biotite occurs plentifully as ragged brown strongly pleochroic flakes together with less abundant muscovite, epidote and rare garnet.

Specimen 27/255, from 1½ miles north-west of Morilem, i.e. on the east side of the hornblende migmatite outcrop south-east of Ildebessare, is representative of biotite gneisses that seem to have developed from hornblende rocks as a result of felspathization and associated metasomatic changes. Sodic plagioclase dominates in the slice and microcline is rare. Plentiful brown biotite is associated with euhedral epidote and zoisite, occasional hornblende and rare garnet. Occasional quartz-plagioclase myrmekitic intergrowths occur interstitially.

An example of a leucocratic biotite gneiss occurring among granitoid gneisses was seen on the summit of Gurika mountain. The rock (Specimen 27/260) is traversed by pink granite-like veins with diffuse margins. In thin section microcline is seen to dominate over quartz and sodic plagioclase. Biotite is common and of much coarser grain size than in the specimen already described, while muscovite is rare. Well marked replacement textures are present (*see* p. 15).

Biotite gneisses with notable amounts of garnet are rare, and occur usually in association with thin bands of biotite gneiss in granitized hornblendic rocks. Such rocks as were seen are essentially similar to the garnetiferous paragneisses described by Shackleton (1946, p. 10), and have the textures and composition of the normal biotite gneisses, with garnet and rarely a little hornblende in addition. An example is specimen 27/284, a mesotype strongly foliated and lineated rock from the centre of the Kowop mass. It occurs among muscovite-biotite gneisses and schists. In thin section the textures are seen to be cataclastic—angular inequigranular quartz occupies much of the slice. Garnets occur as elongated aggregates of grains altering to biotite. Deeply-coloured biotite occurs as irregular flakes between quartz and plagioclase grains and is also intergrown with muscovite, which occurs as large poeciloblastic plates.

(*e*) *Granitoid Gneisses.*—The granitoid gneisses are believed to be granitized sedimentary rocks, and can usually be distinguished from foliated granites. There is, however, a close resemblance between the gneissose granites and the granitoid gneisses, and it seems likely that the one type grades into the other locally. The granitoid gneisses are generally faintly foliated and can be seen to occur as conformable beds. They are not surrounded by zones of migmatites as the gneissic granites often are. The features distinctive of the gneissic granites are described below (p. 29).

The most important outcrops of granitoid gneisses are on the Leroi-Gurika-Luwa Lakairap ridge, in the Kowop mass and at Butabut. The Uass Aibarr granitoid gneiss is similar to that of Gurika. These rocks form ridges and isolated hills as is characteristic wherever such rocks occur in the Basement System throughout Kenya. Their resistance to erosion is due to their poorly foliated, massive nature.

The granitoid gneisses are generally buff to pale yellowish brown in colour, of medium grain size, and contain rather sparse small well-orientated flakes of biotite. Occasionally lenticles of "granulitic" quartz occur and magnetite in process of oxidization to martite are so common as to be diagnostic of the granitoid para-gneisses. Identical rocks have been described from many areas in Kenya, for example as quartz-felspar para-granulites from Kitui (Sanders, 1954, p. 19). Schoeman (1951, pp. 11-16) gave a full description of "migmatites", the leucocratic portions of which have the same composition and textures as the granitoid gneisses of the present area.

The essential minerals of the granitoid gneisses are microcline, oligoclase, quartz, biotite and iron oxides. Rarely muscovite is found in small quantities. The textures are inequigranular and xenomorphic. Microcline is clearly late in crystallization and characteristically replaces plagioclase and quartz. Representative specimens are 27/279 and 27/352, from the north and south ends of the Kowop ridge. Specimen 27/352 is sparsely garnetiferous.

Whereas the Kowop, Gurika and Luwa Lakairap granitoid gneisses are stratiform bodies apparently resulting from the felspathization of arenaceous sediments, the small granitoid gneiss outcrop three miles west of Ngoriche shows contrasting features. Its outcrop is sub-circular and it does not form part of a stratigraphical formation. The hornblende-biotite gneisses that enclose it on three sides have a quaquavrsal dip away from the body, which is well foliated at its margins but coarser-grained and granite-like in the centre. These observations might suggest that the granitoid gneiss is a deformed granite dome, possibly associated with the granitization phenomena and granite dykes occurring in the Kolowaton river immediately to the north. Unfortunately exposure on the plain hereabouts is poor, and the only evidence can be gained from one or two stream sections. The dissimilarity between the granite dykes of the Kolowaton river section and the granite gneiss in question and the lack of granitization phenomena at its margins on the south-east and south-west sides militate against the view that it is intrusive in origin. The hornblende-biotite gneisses enveloping the gneiss are, however, intensely deformed and have developed secondary foliation, complex slip-folds and shear-zones, and it is possible that evidence of the intrusive nature of the granitoid gneiss has been obliterated by deformation.

(*f*) *Augen Gneisses.*—Augen gneisses occur as a discontinuous zone along the western margin of the Gurika-Soit Nyiro granitoid gneisses. They are more biotitic than the adjacent granitoid gneisses and contain felspar *augen* up to one and a half inches long. Foliation is pronounced and the rocks have slabby outcrops. Immediately south-east of Lesirikan the augen are well-formed prisms of microcline, but generally the porphyroblastic felspar occurs as granular aggregates in the form of elongated flattened spheroids.

A conspicuous feature of the zone is the occurrence of areas of pegmatitic rocks poor in biotite. North of Soit Nyiro, on the summit of Gurika, on the south-east slope of Adawacheke hill and at Lesirikan, pegmatites with diffuse contacts occur in the augen gneisses. The pegmatitic areas are irregular, and appear to grade imperceptibly into the gneisses, as can be well seen in the excellent exposures near the wells at Lesirikan. Outside the Lesirikan-Soit Nyiro zone other localized occurrences of pegmatites and augen gneisess can often be seen to be due to the deformation of pegmatites by intensive shearing, leading to the breakdown of quartz into fine granular streaks, the potash felspars tending to remain as ellipsoidal augen. An intermediate stage in the deformation is the production of pegmatite breccia.

The augen gneisses have textures similar to those of the granitoid gneisses, the augen being composed usually of granular microcline aggregates. Specimen 27/251, from the river-bed immediately west of Soit Nyiro, shows fractured quartz and sodic plagioclase in process of replacement by microcline. Biotite occurs closely associated with minor amounts of granular epidote.

Other augen gneisses occur in the Lopurr river section, among the hornblendic migmatites. They are described under hornblende migmatites (p. 13).

(*g*) *Muscovite-biotite gneisses and muscovite gneisses.*—The only important outcrop of these rocks is in the Kowop hills. A zone of muscovite-biotite gneisses, occasionally with garnet, and muscovite schists with thin concordant pegmatites form the western side of the Kowop ridge, and extend along the western limb of the Kowop anticline.

Distinctive muscovite gneisses occur in two narrow bands among the hornblende migmatites 2½ miles north-west of Sartim hill. Specimen 27/275 from this locality is pale reddish brown in colour and full of parallel plates of muscovite up to 6 millimetres in diameter. In thin section quartz and sodic plagioclase occur in equal amounts to form a xenomorphic-granular matrix. Poecilitic muscovite plates are plentiful, and garnet crystals are not uncommon. The reddish colouration of the rock is due to hematite dust, usually at and near the margins of the quartz and plagioclase grains. Rounded patches of replacive opal are common.

(*h*) *Hornblende-biotite Gneisses.*—The hornblende-biotite gneisses are differentiated for purposes of description from the inter-banded hornblende and biotite gneisses. Many honblende-biotite gneisses occur among the hornblende migmatites in the form of narrow beds and as transitional rocks among the migmatites, but the hornblende-biotite gneisses described below are larger more or less homogeneous bodies in which hornblende and biotite occur together.

The principal occurrences of hornblende-biotite gneisses are north-east and north-west of Soit Olbayen in the limbs of the Soit Olbayen syncline, and at the nose of the Butabut anticline where they are cut through by the upper Kolowaton river, in the Lebanyuki valley south-west of Ngoriche, and in the lower Kolowaton valley north-west of Soitoniron hill. The gneisses are often friable, mesotype well-foliated rocks, containing thin beds of biotite gneiss and zones richer in hornblende. They are, however, generally more uniform in appearance than other occurrences of these rocks. Darker beds without mica are invariably plagioclase amphibolites and, in fact, the hornblende-biotite gneisses are essentially lighter-coloured, slightly more felspathic biotite-bearing plagioclase amphibolites. A specimen from immediately south of Soit Olbayen is typical of the hornblende-biotite gneisses, although it does not occur in one of the larger outcrops. The rock (specimen 27/209) is medium grey in colour and well foliated, with scattered sieved porphyroblastic hornblende crystals. In thin section it is found to be composed of highly sutured inequigranular quartz grains with optical strain shadows, set in a granular matrix of angular quartz and oligoclase grains. Small flakes of biotite are scattered throughout the rock, and irregular small grains of hornblende occur also, while epidote is scantily represented. One small microcline crystal was seen.

The origin of these rocks is in some doubt. It seems likely that they have developed from plagioclase amphibolites, since these occur as thin beds throughout the outcrops. On the other hand the gneisses seem generally to be free of epidote, a characteristic mineral in the plagioclase amphibolites. Bear (1952, pp. 13-14) described comparable rocks from the area south-east of Embu and considered that they may be derived from basic meta-intrusives (plagioclase amphibolites) by soda metasomatism.

(*i*) *Hornblende-garnet Gneisses.*—Garnetiferous hornblende gneisses occur mainly east of Baragoi, and are best exposed in the small river one mile south-west of the township. The exposures are somewhat scattered and the boundaries drawn on the map are tentative. The rocks in the river section are interbedded with thin granulitic biotite gneisses and are strongly contorted. Biotite-garnet gneisses occur also, and all the rocks have a moderate amount of pegmatite in narrow diffuse streaks.

Several exposures of garnetiferous rocks occur by the side of the motor-track to Lesirikan, north and north-west of Gelai hill. They are banded and striped rocks of migmatitic appearance, having diffuse thin layers of granular felspar with large hornblende crystals up to two inches in diameter. Narrow cross-cutting hornblende-bearing veins occur, and are replacive, for they do not offset the banding of the rock. Garnet occasionally occurs in the felspathic layers as well as in the darker bands. Locally the rocks have a strong lineation defined by a preferred orientation of hornblende prisms and by minute corrugations of the quartzo-felspathic layers. A specimen (27/171) of

this type was taken from the roadside north-north-west of Gelai. It is a streaky light and dark rock, which contains minute garnets in the hornblendic layers. A thin section of the leucocratic part of the rock shows locally a strong directional texture marked by muscovite flakes and greatly elongated grains and sutured aggregates of grains of quartz which are set in a xenomorphic-granular matrix of oligoclase (An_{11}) and small quartz grains. The dark part of the rock consists of fine-grained hornblende and biotite with small scattered garnets.

Small outcrops of garnetiferous hornblende gneisses and augen gneisses occur in the Baragoi river one and a half miles east-south-east of Lokongori pan, and associated with the marble bed four miles north-north-west of Tangar.

(*j*) *Quartz-graphite Schists.*—Graphitic schists occur together with limestones and quartzites in the Kileshwa valley and between Uass Aibarr and Adawacheke hill. They are folded in the Gurika anticline and the Kileshwa syncline, and in the axial region of the latter fold are intensely sheared, disrupted, and mixed with tectonic inclusions of other rocks, principally schistose hornblende rocks and lenses of marble.

On the col between Uass Aibarr and Adawacheke the graphitic rocks occur between two limestone horizons and consist of soft laminated quartz-opal-graphite schists, biotite schists and gneisses and narrow bands of green quartz-hornblende schists. Two specimens of the graphitic rocks from this locality, specimens 27/266 and 27/265 contain angular quartz grains and turbid opaline quartz in the form of crude lenticles surrounded by interleaved muscovite and graphite flakes. The graphite flakes are generally from half to one millimetre in size and make up 16 to 22 per cent by weight of the rocks. The graphite-rich bands, which are usually two or three feet wide, total some 30 feet in thickness out of a total thickness of several hundred feet of interbedded graphitic and micaceous schists.

The graphite schist-limestone association was repeatedly mapped by Shackleton (1946, p. 9) in the area to the south, and it is obvious from an examination of Shackleton's map that there are graphitic horizons at the margins of the long body of pelitic schists and gneisses which pass into the Gurika granitoid gneiss of the eastern part of the Baragoi area.

(*k*) *Migmatitic Rocks—General.*—The migmatites are widespread, and grade into ungranitized rocks on the one hand, and into more or less homogeneous granitic rocks on the other. As a result the boundaries drawn on the map are of necessity approximate. Moreover, the migmatites are of several kinds depending on the nature of the original rocks. South of Ildebessare and in the Lopurr river the hornblende migmatites contain appreciable amounts of biotite gneiss, which are clearly developed by transformation from hornblendic rocks. Occasionally leucocratic granular garnetiferous rocks occur as concordant bodies in the migmatites; pegmatites, mostly diffuse concordant bodies, are numerous.

(*l*) *Hornblende Migmatites.*—The principal occurrences of these rocks are to the west of the Lanana river, south of Morilem hill; in a zone extending north and south of the Luwamara granite; in a core of the Gurika anticline, south-east of Lesirikan; in a core of the Morilem syncline, south-east of Ildebessare; north-west of Ngoriche, in the Kolowaton river; in the Baragoi river, south-west of Nachola; and a large area in the region of Atagiron and Sibukwe, south of the Emuru Akirim plateau.

The area of migmatites seen near the Kolowaton river north-west of Ngoriche is complex. Exposures in a small stream at the northern end of the Lokongori meta-gabbro show the meta-gabbro containing xenoliths of hornblende gneiss and streaks of hornblendic and amphibolitic rock. In the Kolowaton river no recognisable meta-gabbro is seen—the rocks there are migmatitic hornblende gneisses traversed by dykes

of hornblende and biotite granite. There are, however, numerous exposures of a distinctive migmatitic amphibolite, a dark medium-grained rock with much biotite and some hornblende, which contains large ovoid or prismatic sieved felspar porphyroblasts in lenticular aggregates. This rock is traversed by foliated sill-like bodies with diffuse margins of hornblende granite and biotite granite. At one place a transition from the migmatite to coarse granular granitoid hornblende gneiss was seen over a distance of 60 yards. Nearby in the river section other exposures are of migmatitic amphibolite fragments in a matrix of hornblende granite. A selvage of hornblendite occurs round each migmatite "inclusion" and the "inclusions" are elongated in the general foliation.

Further east in the section, close to the point where a shear-zone crosses the valley, are excellent exposures of leucocratic, almost homogeneous felspathic hornblende migmatites traversed by biotite granite dykes. The migmatites are traversed by irregular dyke-like bodies of gneissose hornblende granite with diffuse margins, containing partly replaced xenoliths of migmatite. Both the migmatites and the gneissose granite dykes are cut by biotite granite dykes, the latter having sharp contacts. Plate III, fig. 1 illustrates the relationship between the coarse intrusive biotite granite of one of these dykes and the almost unaltered hornblende gneisses at this locality. Locally the xenoliths shown in the illustration are diffuse and the surrounding granite carries hornblende. The tendency of the granite to inject the gneiss *lit-par-lit* is also notable.

Forty yards to the west of this locality the migmatites are light-coloured felspathic rocks with hornblende. Foliation and compositional banding are only faintly discernible and the rocks approach the composition and texture of hornblende granite. The occurrence of diffuse pegmatitic bodies containing large hornblende crystals is characteristic in these rocks.

In the section exposed along the small right bank tributary of the Kolowaton river south of Naligwei, in the same migmatite zone, a number of structural features occur. Migmatitic hornblende gneisses ranging from comparatively unaltered dark rocks to medium-grained, patchy, felspathic granitized types are mixed with pegmatitic material and cut across by small thrusts and shears. Elongated biotite granite lenses several feet wide occur as tectonic inclusions plunging to the north. In the shear-zones patches of granite occur as ramifying bodies developed by replacement (Fig. 2). Granitization is well demonstrated, and in one exposure a slightly migmatitic amphibolite was seen to be transformed to hornblende granitoid gneiss over a distance of 12 yards.

The principal feature of such transformations is the development of small felspar augen, which gradually increase in size and number till the rock is coarse-grained and granitic in appearance, and contains diffuse lenticular hornblendic "ghosts".

The conditions obtaining in the Lopurr river granitization zone differ slightly from those elsewhere. In the Lokuto-Sibukwe area there are biotite migmatites with associated hornblende migmatites, the former apparently occupying the core of the broad Atagirion anticline. The migmatites are generally characterized by a tendency to homogeneity of composition—all are light-coloured and felspathic, bedding is irregular and individual beds are characteristically lens-like in form. Pegmatitic material is abundant, commonly forming approximately 50 per cent of the rocks by volume, and small bodies of apparently "mobilised" granitoid rock are widespread. West of Lokuto and east of Sibukwe the rocks are predominantly hornblendic and the degree of granitization decreases, except in the immediate vicinity of the Nakefenda granites. In this granitization zone as elsewhere, the more highly granitized rocks are characterized by the transformation of hornblende to biotite.

Near Sibukwe the hornblende migmatites are nearly homogeneous, being rather coarse felspathic hornblende-biotite gneisses. Locally pegmatitic texture is developed and hornblende prisms one inch long occur, and adjacent to the pegmatitic zones the gneisses commonly have porphyroblastic alkali felspar. All these rocks are traversed by

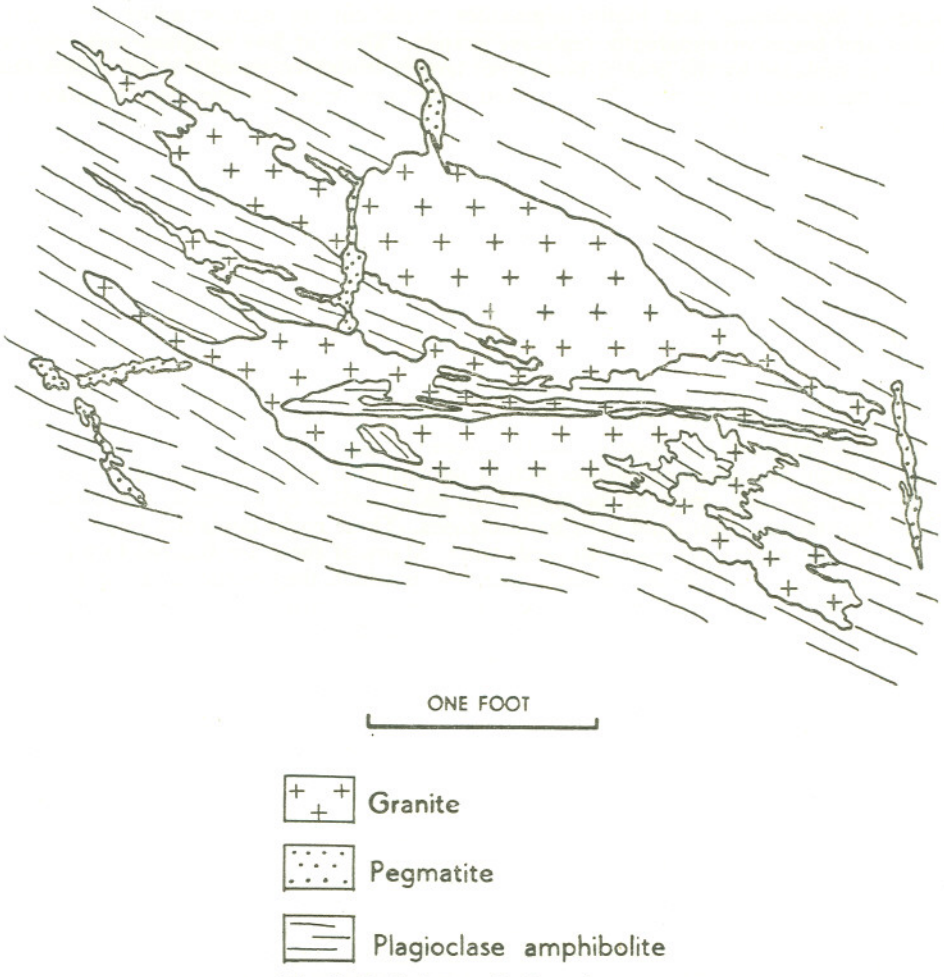


Fig. 2—Replacive granite in a shear-zone

stringers, veins and lenses of pegmatite which grade locally into aplites. Specimen 27/306 is typical of the base-rock of the less thoroughly granitized hornblende migmatites. It is homogeneous in hand-specimen, well foliated, mesotype, and is a hornblende-biotite gneiss. In thin section it is seen that the rock contains much inequigranular microcline associated with and containing sparse small sub-angular quartz grains. Deep green hornblende is seen intergrown with biotite. Sphene and apatite are present as accessory minerals, in unusually large crystals, sphene being particularly abundant.

The Lopurr river section west of Lokuto is especially interesting. At Lokuto wells the biotite migmatites are penetrated by a sill-like granitoid gneiss, which has small off-shoots cutting across the foliation. To the west the rocks become less migmatitic and are interbanded biotite- and hornblende-gneisses, changing further west to hornblende gneisses with thin epidotic amphibolite lenses. The more easterly of the Nakefenda granites is emplaced in these rocks. It is a homogeneous coarse-grained biotite-bearing augen granite margined on both sides by medium-grained hornblende-biotite gneisses with felspar augen. West of the granite are mixed rocks which are

laminated hornblende- and biotite-migmatites much cut by narrow aplite veins and patches and lenses of apparently replacive granite. More or less irregular small aplite bodies are replaced by the granite bodies but larger, straighter, parallel-sided aplites cut through the replacive granite. These mixed rocks give place further west to massive, unfoliated, grey coarse-grained hornblende migmatites with augen. These rocks locally contain hornblende porphyroblasts and appear to invade the laminated migmatites. A thin section of this rock (27/310) shows that it is composed of aggregates of poecilitic green hornblende, biotite, quartz apatite and sphene, and large ragged biotite crystals surrounded by interlocking oligoclase grains with a small amount of quartz and biotite. The porphyroblastic crystals are sub-idiomorphic oligoclase. Microcline is absent. Further west again, between the two granites marked on the map, the hornblende migmatites are spotted, banded mesotype rocks, with occasional bands of biotite migmatites and swarms of aplite sills.

At the eastern contact of the western Nakefenda granite there is no gradation of migmatite to granite—the contact is sharp and has the appearance of being a shear along the foliation. This granite locally invades augen hornblende migmatites at its western margin and contains patches rich in unorientated xenoliths and thin screens of hornblende migmatite. West of the granite the rocks consist of extremely contorted and sheared hornblende migmatites with biotitic zones. These rocks contain a large number of cross-cutting pegmatites, some 80 yards wide. Many of these are sheared to a greater or lesser extent, as are the hornblendic gneisses in which they occur, and the result is a pinkish brown rock studded with porphyroblastic felspars of various shapes and sizes. In every case the pegmatites are unzoned and devoid of micas.

The migmatites of the area south-east of Ildebessare are exposed in numerous exfoliation pavements. Pegmatitic material is intimately mixed with them and they are crudely banded on a macroscopic scale. The less migmatitic rocks are dark plagioclase amphibolites with diffuse parallel streaks of pegmatite. The amphibolitic lenses and bands are traversed by narrow pegmatite tongues continuous with the concordant pegmatite layers. Locally *boudinage* structures are apparent in the pegmatite. Two and a half miles south-east of Ildebessare the rocks are strongly migmatitic. A large pavement exposes crudely banded rather coarse migmatites, cut across by two late pegmatites. Small irregular granitic patches appear to replace parts of the rock, and narrow streaks of pegmatite cut across the principal foliation to give a secondary foliation. Locally zones of rock with differing foliation are in juxtaposition and this is thought to be due to the development of a new foliation by shear. Locally the concordant pegmatite layers are medium- to coarse-grained and contain scattered large hornblende crystals. Amphibolite layers are usually more heavily veined with pegmatites, the structures suggesting the growth of pegmatites in fractures and small shears. It is obvious that the amphobolitic layers were more structurally competent than the felspathic layers. A typical finely veined migmatite (specimen 27/258) was collected three miles south-east of Ildebessare. The foliation is puckered and wavering on a small scale. In thin section dark laminae are seen to consist of intergrown hornblende and biotite, some of the hornblende crystals being sieved by small quartz grains. Rarely clinozoisite occurs with the hornblende. The light-coloured laminae consist of irregular mosaics of quartz and twinned plagioclase (andesine An_{40}) and larger crystals of microcline. Some of the plagioclases are zoned, and some have bent twinning. Small pink sieved garnets are present.

On the east side of the migmatite outcrop there is an exposure of rock resembling an igneous breccia. The rock contains many irregular diffuse bodies of felspathic hornblende rock. Here and there are irregular bodies with pegmatitic texture and it is in these that quartz appears. The rock gives the impression of having passed the stage of migmatitic veining and of being on the way to homogeneity. Nearby are banded

and veined migmatites, in which stock-works of pegmatite veins extend from the pegmatite bands into the darker rocks. The pegmatite fraction in these rocks is rarely fine-grained and aplitic, and discrete aplite veins are totally absent.

Rather similar migmatization phenomena were observed in the Masegeta river section north of Luwamara. The banding is not so distinctive, however, the rocks being hard amphibolites with random knots and streaks of coarse felspathic rock containing large hornblende crystals. Locally the coarse felspathic rock dominates, when the amphibolites occur as spherical lens-like or sausage-shaped masses in the felspathic matrix.

A notable feature of the more intimately permeated migmatites is that their textures are essentially similar to those of other leucocratic rocks which are practically unaffected by granitization, and to textures in foliated granites known to have been intrusive. This similarity is notable in other areas (cf. Bear, 1952, pp. 19-20; Schoeman, 1951, pp. 11-17). The question of the genesis of the migmatites is discussed in the section dealing with granitization (p. 50).

(*m*) *Biotite Migmatites.*—Biotite migmatites are not widespread in the area; the two main occurrences are at Kangura and in the Lokuta-Sibukwe section of the Lopurr river. Minor occurrences are on Gelai hill (not shown on the map) and in the Lanana river. The biotite migmatites are similar to the biotite gneisses but, although they are foliated, they do not have the foliation partings and slabby outcrop of the gneisses, but usually outcrop as exfoliation surfaces. They contain lenses, stringers and veins of pegmatite and are variable in grain size. The form and distribution of micro-pegmatite bodies in the biotite migmatites in the Lanana river are illustrated in Fig. 3. The elongated stringers of pegmatite are, in this instance, slip folded and, in some cases, continuous with an irregular cross-cutting pegmatite. There is a suggestion of a second injection of pegmatite along the side of the first but this is not well shown. The pegmatites characteristically approach granitoid gneiss in appearance locally and sometimes contain scattered felspar augen in zones rich in diffuse pegmatites. Under the microscope they show textures similar to those of the biotite gneisses, from which they can be distinguished only by field appearances.

(3) Igneous Rocks—General

Igneous rocks, together with doubtful types that are tentatively included with them, are widespread in the area, more so perhaps than in any other metamorphic complex of similar size that has been geologically surveyed in Kenya up to the present. They range from sill- or stock-like highly altered ultra-basic intrusives akin to the peridotite-serpentine complexes characteristic of orogenic belts (Turner and Verhoogen, 1951, pp. 239-252), through shonkinites to widespread plagioclase amphibolites and amphibolites and their derivatives, which are regarded as metamorphosed gabbroic, doleritic or basic volcanic rocks.

Large numbers of dykes occur, most of which have been involved in the deformation of the whole complex, and which range from intermediate foliated dioritic rocks to slightly foliated granites, aplites and pegmatites. These latter acid intrusives are much younger than the others, and evidence is brought forward below to show that they are the mobilised products of granitization.

(4) Pre-metamorphic Intrusives

(*a*) *Serpentinites, Talc-tremolite-actinolite Rocks; Altered Ultra-basic Intrusives.*—Metamophosed ultra-basic rocks outcrop as narrow sills over a wide area and occur in a well marked zone extending from the vicinity of Nachola hill, south-eastwards to the Lanana river and Morilem hill. A part of the zone continues south-eastwards beyond the southern limit of the area to Siambu hill, while other discontinuous sills pass round



Fig. 3—Structures in biotite migmatites five miles south-west of Lawun

the nose of the Morilem syncline and continue northwards, occurring on the Barenyiro ridge and Nakwawi, and pass east of Nderentei and Koitokol to outcrop prominently at the north end of the Lolenyok ridge. A further zone of rather larger irregular lenticular bodies occurs in the Segera-Kangura area, and there are outcrops in the Kileshwa valley south-west of Leroi mountain.

The rocks are soft more or less homogeneous unfoliated bodies, coloured in shades of brown and greenish brown. Radiate structures are frequently seen in them, as is a faint small-scale reticular texture. Due to the felted texture of the rocks they are resistant to weathering and outcrop well, even on the plains where other outcrops are few or absent. The larger bodies in the Kangura zone, at Morilem, and in the Kileshwa valley are traversed by numerous thin magnesite veins and contain scattered amphibolite lenses. In various places they are invaded by quartz veins, pegmatites, aplites and intrusive plagioclase amphibolites.

The sills in the vicinity of Nachola are particularly numerous and form a ridge on Soitoniron hill. They here consist of variable mixtures of tremolite and anthophyllite, some of which has been altered to talc. The sills commonly contain lenses and slips of chlorite schists, studded with octahedra of magnetite up to one centimetre in diameter. These schists frequently contain anthophyllite in addition to chlorite, and are foliated in planes transverse to the foliation of the surrounding gneisses. They were produced by shearing.

Some nearly pure talc rocks were seen as irregular bodies in tremolite-anthophyllite rocks on the ridge one mile south of Nagiss and in the north-eastern part of the area, at the north end of the Lolenyok ridge. Talc is common as a minor constituent in the larger altered ultra-basic bodies such as those at Nakwawi, Morilem and north-north-west of Tangar.

One of the more interesting of these bodies occurs at Kangura as an irregular elongated body more than two miles long and up to three-quarters of a mile wide. The central part of the body is cut by a reticular pattern of magnesite veins up to three-quarters of an inch in thickness. The main mass is of uniform dull greenish brown serpentine, locally with carbonates, talc schists and actinolite rocks. Small rounded remnants of basic rock prove on examination to be plagioclase amphibolites and epidote amphibolites with strongly marked poecilitic textures (specimens 27/238/3 and 27/238/2 respectively), and containing pyroxene and hornblende with opaque inclusions, yielding schiller structures (specimen 27/238/6). These rocks are described in greater detail on p. 24. The southernmost part of the intrusive is characterized by the abundance of talc veins associated with chlorite schists, and contains several chromite veins up to four feet wide and 20 feet long. The chromite contains micaceous scales of a lilac-coloured mineral tentatively identified as stichtite ($MgCO_3$. 5 Mg $(OH)_2$. 2 Cr $(OH)_3$. 4 H_2O). The somewhat smaller ultra-basic intrusive south-east of Kangura also contains a small rounded body of chromite, and is generally similar to the Kangura intrusive. The intrusives north and north-west of the Kangura body are composed of tremolitic carbonate rocks rather than serpentine. Talcose lenses and chlorite schists are common in them, but there appear to be no magnesite veins.

The Morilem-Luwarak zone of altered ultra-basic rocks is one of the largest in the area. West of Morilem hill and at Luwarak it consists largely of talcose tremolitic rocks with irregular serpentine relics, but on Morilem hill the whole mass is serpentine. This serpentine (specimen 27/254) consists of a microscopic network of cross-fibre chrysotile about brown-stained antigorite cores. A little carbonate occurs as accessory mineral and there are occasional large aggregates of opaque iron (?) ore. This rock is comparable to a talc-carbonate serpentine (specimen 27/253) from the ultra-basic sill-like body one mile north-east of Morilem. Some of the basic rocks found as blocks and lenses at the north-east edge of the Morilem intrusion prove to be epidote amphibolites (specimen 27/254/2). In the upper part of the hill there are magnesite veins up

to six in. wide, but 10 to 15 yd. apart. No chromite was observed among the rocks of the Luwarak-Morilem zone.

On Barenyiro hill a variety of rocks are exposed, and are tabulated below giving width of outcrop, the sequence being in order from east to west:—

	Width of outcrop (feet)
Amphibolite	50
Serpentine with magnetite-chlorite-anthophyllite schists	c.50
Epidote amphibolite	0–12
Serpentine with chlorite schists and numerous magnesite veins	c.100
Hard coarse-grained amphibolite	0–10
Serpentine with carbonate veinlets	c.15
Amphibolite	0–2
Talc-calcite-phlogopite serpentine	3
Plagioclase-zoisite amphibolite	12–15
Garnetiferous plagioclase amphibolite	5

On the hill south of Barenyiro the rocks are somewhat different—plagioclase-zoisite amphibolites occur at the east side of the outcrop and are followed to the west by two bands of soft coarsely stellate tremolite rock with talcose serpentine lenses and patches. Immediately west again are hornblende gneisses and then amphibolites.

A small but distinctive serpentine occurs two miles south-south-east of Nderentei. The body is approximately 200 yards wide and consists of homogeneous pale yellowish grey spotted rock with a fine network of black lines on the surface (specimen 27/195). A thin section shows that it is serpentine with mesh structure with irregular streaks and patches of calcite containing opaque iron ore in, around and between the meshes, and with veinlets of fibrous chrysotile surrounding cores of almost isotropic serpentine (probably serpophite). The margins of the body are composed of serpentine with envelopes of talc schists.

Nakwawi hill is formed largely of serpentine, much of it being talcose and associated with friable actinolite rocks and thin coarse-grained amphibolites. The serpentine of the ridge is crossed by numerous east-west veins of fibrous tremolite. Magnesite veins occur also, but are rare.

The only other occurrences of altered ultra-basic rocks of any size are in the Kileshwa valley, four and six miles south-south-west of Leroi mountain. The more southerly and smaller of the two bodies contains lenses and veins of soft white asbestos exposed in small prospect pits. The main part of the intrusive is of brown serpentine cut by many narrow magnesite veins, and in which a long-fibre anthophyllite asbestos vein occurs. Large stellate tremolite aggregates occur within actinolite rock locally. The anthophyllite asbestos occurs in two forms, as long narrow veins of pinkish buff cross-fibre material, and as soft friable white radiating fibres in lenses up to two ft. wide and four ft. long.

The more northerly ultra-basic body forms a prominent hill, and consists of serpentine or partly serpentinized rocks with numerous thin slips of chlorite schist and many magnesite veins. A specimen of partly serpentinized rock from this hill (specimen 27/287) shows aggregates of epidote grains in a matrix of ruptured and inequigranular actinolite, with scattered diopside grains, small sheaves of tremolite and trains of magnetite grains. The whole rock is traversed by narrow sub-parallel veinlets of yellowish green serpentine, the veinlets being frequently along inter-crystalline boundaries.

Several fine-grained dyke-like, vertically foliated amphibolites cross the summit ridge of the hill from east to west. Specimen 27/288 was taken from one of these dykes, and in thin section is seen to contain an appreciable proportion of calcic plagioclase situated between aggregates of elongated hornblende prisms. Small granules of epidote

are sparsely distributed in the plagioclase, but iron ore grains are plentiful and frequently have outgrowths of sphene. Plagioclase amphibolites of this type were noted at the margins of several of the ultra-basic intrusives in the area, notably on Morilem hill, and in the two bodies of the Kileshwa valley just described, and appear to be metamorphosed dykes and sills, probably of doleritic composition.

A general observation on the ultra-basic intrusions is that serpentinite forms most of the larger bodies, but is often absent from the narrow sills, which are composed of talc-tremolite-carbonate schists with anthophyllite or actinolite, or both. These latter rocks are derived from pre-existing serpentinites by hydrothermal alteration aided by deformation and shearing. The original rocks were certainly peridotites or dunites, as is indicated by the occurrence of chromite relics, and were probably accompanied by smaller gabbroic or pyroxenitic bodies, now altered to plagioclase amphibolites and amphibolites.

The rarity of unaltered relics of olivine- or pyroxene-bearing igneous rocks testifies to the completeness of the transformations that have taken place. This is in contrast to most other areas where basic or ultra-basic igneous rocks occur in the Basement System, and where the parageneses involved can be observed. One such area is West Suk, where Searle (1952, pp. 19-41) mapped small lenticular altered peridotite bodies with generally similar mineral assemblages to those of the sills of the Baragoi area. Hydrothermal alteration appears to have been more effective than serpentinization in the West Suk intrusives, and they are generally zoned bodies characterized by the occurrence of asbestiform amphiboles, and talcose varieties occasionally containing relics of olivine and hypersthene. The mineral transformations outlined by Searle (*op. cit.*, p. 21, p. 27), are probably similar to those that affected the Baragoi rocks.

(*b*) *Shonkinites.*—A group of exposures of unfoliated dark massive rocks with clusters of small visible biotite flakes occurs west of the motor-track three and a half miles south-west of Nderentei. A thin section of a specimen (27/233) of these rocks shows that they are shonkinites.

The shonkinite consists largely of pale reddish grey schillerised bronzite in interlocking grains reaching two millimetres in diameter. Biotite, pleochroic from straw to deep brown occurs as interstitial irregular replacive growths between bronzite grains, and locally there are fine-grained intergrowths of biotite and bronzite between the two minerals. Occurring as scattered inclusions in the bronzite are olivine grains, which are frequently clustered about ore grains. All the larger olivine grains are altered to iddingsite along cracks. They are surrounded by reaction coronas wherever they occur in contact with the alkali felspar that comprises the bulk of the remainder of the rocks. Next to the olivine in these coronas is an aggregate of clear grains which are possibly enstatite. This zone is succeeded by another consisting of minute bottlegreen pleonaste granules in a matrix of fibrous amphibole occasionally associated with biotite flakes. Other intergrowths occur locally between biotite and the alkali felspar. The felspar occurs in slightly turbid untwinned crystals of late crystallization or in aggregates of grains with sutured margins and patchy polarization, and appears to be an alkali type. The approximate composition of the rock by volume is as follows:—

	per cent
Bronzite	40
Biotite	30
Felspar	20
Olivine	5
Opaque ore	5
Apatite	—

The contacts of the shonkinite were not seen, but coarsely speckled plagioclase amphibolites with varieties having felspar augen were seen in the river section a few hundred yards to the north-east.

(*c*) *Amphibolites.*—Comparatively few of the many amphibolites in the area are wide enough to be marked on the map. They occur as narrow bands and lenses among the plagioclase amphibolites, as broken angular blocks together with pegmatitic material in the hornblendic migmatites, and occasionally associated with the altered ultra-basic intrusives, as at Nachola hill.

The largest amphibolite occurrence is the coarse dark rock which forms an irregular lens-like body between Barenyiro and Nderentei. The rock is dark greenish grey in colour, coarse-grained and crudely foliated. In a thin section of specimen 27/183, from the north end of the body, the rock is seen to be composed of pale green fibrous actinolite with rare ore grains. A somewhat similar-looking rock, specimen 27/192, occurs on a hillock by the Lamerok river two miles north-west of Lamerok hill. It contains abundant green hornblende that is locally porphyroblastic, reaching 1.5 centimetres in length, and many epidote and rarer bright green pleonaste inclusions. Pale green pyroxene is partly replaced by hornblende, and the matrix consists of aggregates of locally intergrown hornblende and epidote together with groups of quartz grains of variable size. Sphene occurs as an accessory mineral. This rock is almost certainly derived from a basic intrusive. Coarse actinolite rocks occur also on Nachola hill and on Laregel hill.

Amphibolites with fibrous textures and, locally, schistose partings occur among the serpentinites and associated rocks. They have been in places sheared and converted to chlorite-magnetite schists.

Many of the amphibolites are transitional to plagioclase amphibolites and have identical textures, but epidote is generally absent. In the migmatitic zones it is repeatedly observed that the amphibolites are resistant to both plastic deformation and granitization. They occur as disrupted lenses, coated by coarse quartzo-felspathic material containing large hornblende crystals (*see* Fig. 4). Similar material heals cracks and fractures.

Apart from the presence of colourless pyroxenes in some of the amphibolites there is little to indicate the nature of the rocks from which they have been derived. No relic textures were observed, but the occurrence of the amphibolites as bodies of considerable extent, the presence of pyroxene, and their resemblance to amphibolites among the ultra-basic intrusives strongly suggests that they are metamorphosed basic igneous rocks, and it follows that the plagioclase amphibolites with which they are so closely associated must have a similar origin.

(*d*) *Plagioclase Amphibolites.*—This group of rocks is the most extensive in area and is the matrix in which most of the other rock types occur. The plagioclase amphibolites are generally poorly exposed in river sections and present a variety of appearances in the field, but in thin section they are seen to be a moderately homogeneous group.

In the Baragoi, Lebanyuki and Kolowaton rivers the plagioclase amphibolites occur together with thin amphibolites and hornblende-biotite gneisses. It is obvious in many cases that the appearance of biotite is due to felspathization and shearing. Increasing felspathization leads to the development of mesotype and leucocratic gneisses, often with sieved porphyroblastic hornblende augen.

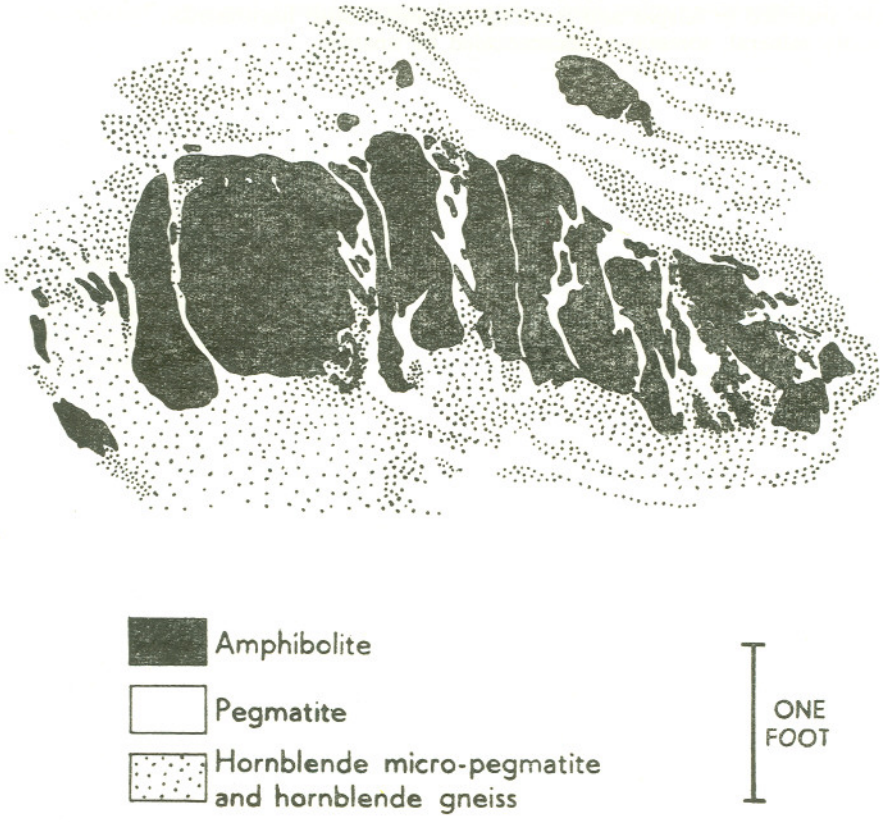


Fig. 4—Disrupted amphibolite lenses in migmatite

The development of garnet in these rocks is rare, a distinction from other areas, and where garnet occurs it appears to be in granitized derivatives of the plagioclase amphibolite.

Some of the plagioclase amphibolites described below are unquestionably intrusive. They are not distinguishable in hand-specimen or thin section from the other types and it is possible that most, if not all, of these rocks are metamorphosed basic intrusive rocks. None of them retain igneous textures, having suffered varying degrees of deformation, thermal metamorphism, granitization and recrystallization.

The commonest plagioclase amphibolites are mesotype to melanocratic poorly foliated rocks. Fine-grained varieties are usually faintly laminated and coarser-grained types are often mottled or streaky with small aggregates of granular felspars. Occasionally visible epidote occurs and rarely streaks of green epidosite rock are seen.

In thin section the plagioclase amphibolites show poeciloblastic textures, hornblende enclosing granular aggregates of plagioclase. Occasionally quartz-bearing types have granular xenoblastic textures. The amphibole is a medium blue-green pleochroic form frequently seen to be in process of alteration to a pale feebly pleochroic uralite. Where pale uralitic hornblende is present epidote in variable amounts almost invariably accompanies it. The epidote occurs as clusters of granules in plagioclase or at the

margins of the hornblende crystals. Zoisite occurs in about half the rocks and is usually included in felspar and is rarely in contact with hornblende. Sphene is a usual accessory mineral, sometimes accompanied by apatite.

Plagioclase occurs in these rocks in the form of anhedral aggregates, often in lenses. It is commonly twinned, rarely zoned and commonly contains granular or rod-like inclusions of zoisite. It varies in composition through the range of andesine (An_{43}-An_{30}). Quartz appears in only six of the 22 thin sections studied, and usually occurs as isolated rounded grains included in hornblende and as clusters of small grains together with plagioclase. In a specimen from the Kolowaton river north-west of Ngoriche, however, it occurs in notable amount as elongated "granulitic" aggregates. It is notable that many of the quartz-bearing plagioclase amphibolites, even those with much epidote, do not appear to have developed albite as is usually the case when rocks containing intermediate or basic plagioclase are strongly sheared (Wiseman, 1934, p 399).

A typical granitized plagioclase amphibolite is described here to illustrate the changes accompanying granitization. It occurs a little south of the Lgerei motor-track three miles south-east of Ildebessare. The rock (27/258) is crudely laminated in hand-specimen, granular felspathic lenticles alternating with schistose hornblende and biotite-rich layers. In thin section the dark layers are seen to be composed of green hornblende intimately intergrown with brown biotite. Some of the hornblende crystals are much sieved by small quartz grains. Plagioclase (andesine An_{40}) dominates quartz in amount and occurs as grains tending to porphyroblastic habit. The texture in the quartzo-felspathic laminae tends to be "granulitic". Garnets containing quartz inclusions occur in the slice. The development of replacive plagioclase and the occurrence of biotite and garnet are considered to be characteristic of the partly granitized plagioclase amphibolites and it is probable that much of the hornblende-biotite gneiss in the area has been formed in this way.

Among the plagioclase amphibolites that are known to be of igneous origin, those found in the Kangura serpentine are of unusual interest (*see* p. 19). The thin section of specimen 27/238/3 shows basic plagioclase grains of 4-5 millimetres diameter intergrown with pale green pyroxene, the latter being locally replaced by green hornblende. The texture is striking and resembles graphic intergrowth. Groups of hornblende crystals occur together with small apatite grains. A thin "skin" of epidote separates pyroxene from plagioclase throughout the slice, and similar "skins" occur about ore grains enclosed in plagioclase. In the slice of specimen 27/238/4 from the same locality green hornblende dominates the pyroxene in amount and epidote is associated with pyroxene. Basic plagioclase is less common and contains inclusions of hornblende and epidote. Apatite is not uncommon.

Shackleton (1946, p. 19) described from near Baragoi, a "meta-gabbro" which is perhaps related to the plagioclase amphibolites described above. He apparently named the rock metagabbro on account of its coarse speckling. He also described plagioclase amphibolites (op. cit., p. 21) as widespread in the northern part of the Nanyuki-Maralal area, and noted that pyroxene granulites were commonly associated with them. Pyroxene is not normally found in notable amounts in the plagioclase amphibolites of the Baragoi area, but in view of the associations of the plagioclase amphibolites and the constancy of their appearance in the field, it is considered likely that they are metamorphosed basic igneous rocks, possibly including basic lavas and pyroclastics. This

conclusion is supported by the following analysis of a typical plagioclase amphibolite, specimen 27/219 obtained from a point one and a half miles south-west of Nachola hill:—

	%
SiO_2	50·64
Al_2O_3	18·75
Fe_2O_3	1·40
FeO	3·70
MgO	9·05
CaO	10·32
Na_2O	3·48
K_2O	1·05
H_2O+	1·56
H_2O-	0·14
TiO_2	0·40
P_2O_5	0·12
MnO	nil
	100·61

Norm	%
or	2·08
ab	10·40
an	22·20
di	7·17
hy	26·90
ol	7·65
mt	9·63
hm	6·79
il	0·94
ap	5·28
	99·04

Analyst—J. Furst, 4–9–56.

This analysis most closely resembles the composition of gabbro as quoted by Johanssen (1937, p. 221).

(*e*) *Metagabbros.*—The rocks grouped together as metagabbro in the present map-area are variable in texture and composition. This is particularly true of the rocks of the Baragoi-Lokongori zone where the metagabbros have been subjected to varying degrees of granitization and deformation. They are distinguished from the plagioclase amphibolites by their coarse grain size, mottled appearance and lack of regular banding. They grade locally, however, into crudely banded rocks resembling some plagioclase amphibolites, in which foliation is moderately well developed and felspars occur as augen. One and a half miles north-west of Ngoriche metagabbro passes into hornblende migmatites and locally migmatites occur along the eastern margin of the same metagabbro. Field evidence of granitization consists of the development of felspathic hornblende gneisses, which in texture locally approach granitoid types and elsewhere are laminated with felspathic and hornblendic laminae. In such occurrences the appearance of biotite together with or in place of hornblende is common. The transformation of metagabbro into granitized and deformed foliated hornblende-biotite gneiss with occasional epidote or garnet is well seen in the Baragoi river south-east of Lokongori.

Typical metagabbro occurs in the Baragoi river east and west of the road crossing. The rocks here (specimen 27/175) are coarse grained and contain hornblende crystals up to one centimetre long. The light parts of the rock consist of granular basic plagioclase. These are probably the rocks referred to by Shackleton (1946, p. 19) as metagabbro. Foliated varieties of metagabbro with augen are represented by specimen 27/170, from the side of the motor-track to Nderentei water-hole, approximately five miles due east of Baragoi. The specimen consists of elongated augen of granular felspar containing unbroken relics of the porphyroblastic felspars from which they were derived, with narrow streaks and lenses of schistose hornblende-biotite rock between the augen. The augen consist of aggregates of andesine (An_{37}) with small brown biotite flakes, small hornblende crystals and epidote granules. The dark folia are of hornblende in interlocking grains associated with much sphene and biotite. The biotite is intergrown with the hornblende.

The metagabbros become more leucocratic towards the north—near Lokongori water-hole they are massive, with scattered half-centimetre hornblende porphyroblasts set in a fine-grained plagioclase matrix. Locally to the south-west of the water-hole strongly foliated varieties occur, and in these the hornblende crystals are seen to have broken up as a result of shear and to have formed streaks composed of fine-grained hornblende and biotite. Plagioclase also often occurs as granular augen in these rocks. Further north the metagabbros begin to show signs of more severe granitization and become crudely banded into alternating hornblende-biotite gneisses and homogeneous hornblendic granitoid gneisses. Close to the motor-track west of Ngoriche there are scattered rounded outcrops of granular granitoid gneiss containing small diffuse lenticles of hornblende-biotite gneiss. These rocks are interpreted as granitized metagabbros. A thin section of specimen 27/178 of granitoid gneiss contains several elongated quartz grains 7-8 millimetres long and 1-4 millimetres wide, which show local preferred orientation of strain shadows, and quartz and plagioclase grains often exhibit patchy preferred orientation of optic axes. Small muscovite flakes and scattered microcline grains are present. None of the hornblende and biotite visible in the hand-specimen appears in the slice.

One mile and three miles south of Nderentei water-hole different augen gneisses of metagabbroid affinities occur close to limestone outcrops. The gneisses are characterised by the occurrence of diffuse pegmatitic streaks and porphyroblastic microcline up to two inches long, in matrices of mesotype hornblende-biotite gneiss. The outcrops are massive and foliation is not so well developed as lineation. The microcline porphyroblasts are pale grey due to the inclusion of minute biotite flakes in the cleavage planes. A thin section of a specimen (27/182) from the more southerly of the occurrences shows a large replacive microcline crystal set in a rather fine-grained matrix consisting of granulitic quartz aggregates and scattered quartz grains, sodic plagioclase and microcline with abundant biotite, hornblende, apatite and sphene and small granules of epidote. Replacement of quartz and plagioclase by microcline is well seen.

Near the river-crossing of the motor-track north-east of Baragoi the metagabbros contain complex structures; a zone several feet wide of completely transposed foliation is seen (*see* p. 55) and locally strong shearing affects the rocks giving rise to narrow bands of friable hornblende-biotite schist. Mesotype biotite gneiss dykes are numerous and are frequently slip-folded by movement in the shear-zones of the host-rocks.

(*f*) *Intermediate Intrusives.*—Dykes and sills of soft, friable, easily weathered intrusive rocks occur in the sections exposed in the Kolowaton, Lebanyuki, Lamerok and Baragoi rivers. They are generally only two or three feet wide and are always involved to a greater or lesser degree in the same deformation as has affected the

country rocks. Exposures are generally poor, and few are shown on the map since it is difficult to measure the orientation of the dykes. Many of the dykes are slip-folded and they do not occur as swarms with a constant orientation as do the younger post-tectonic aplite dykes.

A group of four or five narrow dykes occur in the col immediately north-west of Lamerok hill. These were originally mapped as metadolerites on account of their dark homogeneous appearance, their moderate grain size and the apparent lack of foliation. In thin section, however, a specimen (27/194) of these rocks is seen to be composed of ragged green hornblende prisms associated with brown biotite and epidote granules in a matrix consisting of large interlocking intermediate plagioclase grains and scattered small, often irregular, quartz grains. The plagioclase is untwinned and contains abundant small inclusions of hornblende, biotite and minute rods of zoisite. The texture of the rock is metamorphic but there is no trace of a directional fabric. The rock is comparable to epidiorite.

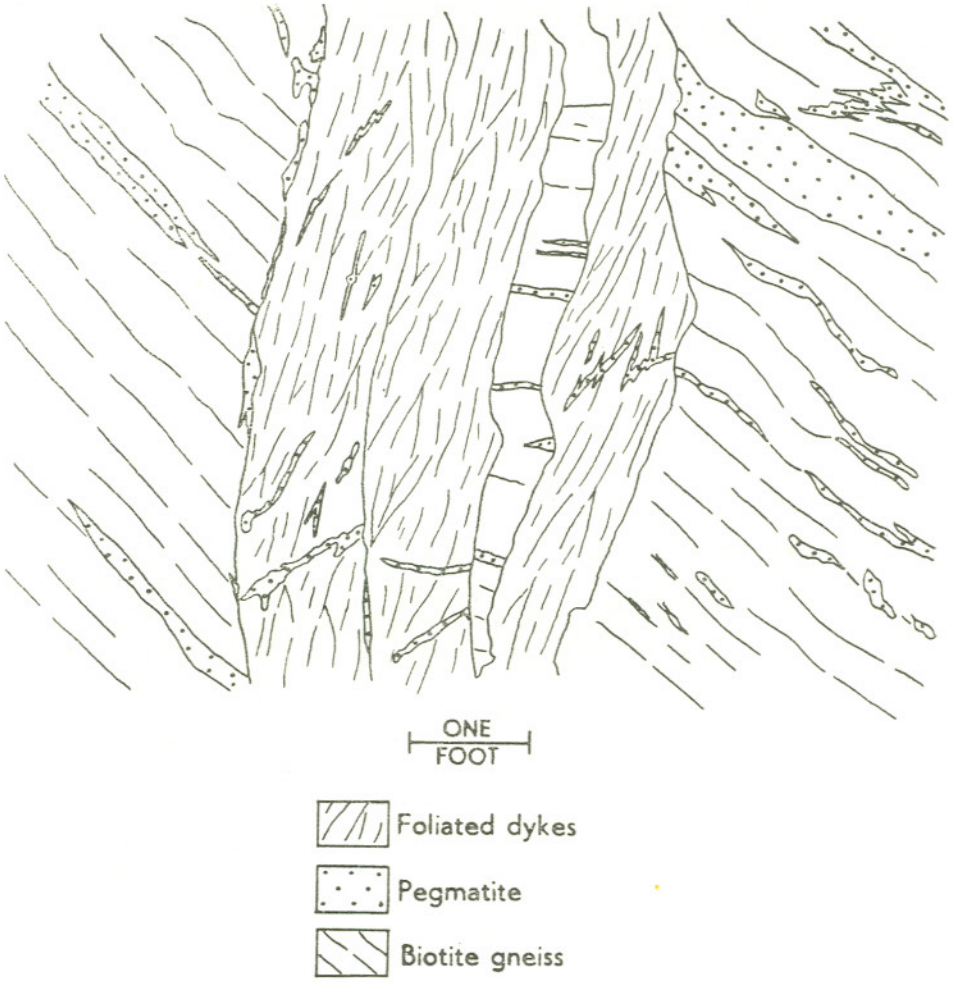


Fig. 5—Dykes with independent foliation cut by pegmatites

The main class of deformed dykes consists of numerous foliated biotitic, rather light-coloured dykes that occur exposed in the Lamerok, Baragoi, Lebanyuki and Kolowaton rivers. These rocks form a distinctive group—they are usually well foliated medium-grained rocks, carrying conspicuous biotite flakes up to one inch in diameter in addition to numerous small biotite flakes. These give the rocks a characteristic spotted appearance when a foliation surface is seen. The dykes are frequently slip-folded by movement on the foliation of the host-rocks—examples are excellently exposed in the Baragoi river immediately north of Baragoi township. In a few localities comparatively unfoliated forms of the dykes were observed, e.g. on the plains four miles north of Tipaku, in a left bank tributary of the Lebanyuki river two and a half miles north-east of Soitoniron hill, and among the swarm of dykes at the north end of Koitokol hill. In each case the poorly foliated rock was proved to be continuous with the commoner schistose variety. Two specimens of the poorly foliated rocks, specimens 27/214 and 27/225 from the Lebanyuki river and the north end of Koitokol respectively, are grey faintly foliated rocks characterised by the presence of small felspar augen three or four millimetres in diameter, which stand out in relief on weathered surfaces. The thin section of specimen 27/225 shows xenomorphic inequigranular texture—the slice consists mainly of microcline grains of differing sizes. Intergranular spaces are occupied by deep green pleochroic hornblende grains, which are sometimes poecilitic,

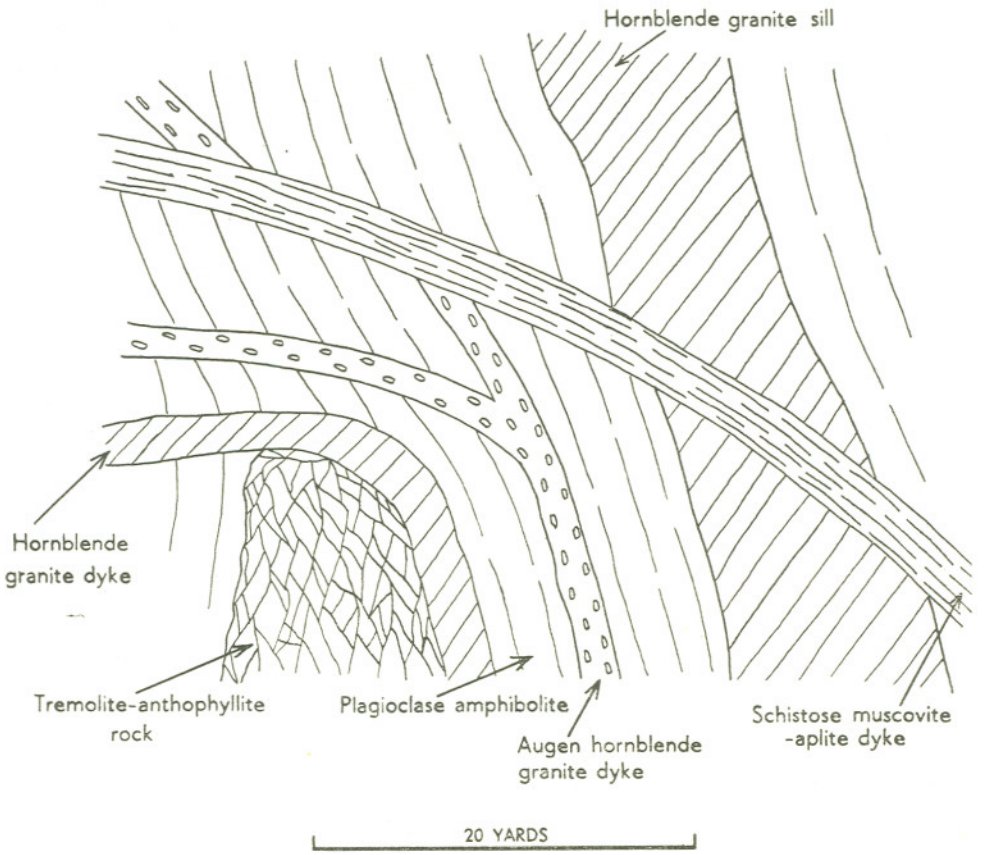


Fig. 6—Dykes and sills on the Lolenyok ridge

containing quartz inclusions. Quartz is minor in amount, occurring in small aggregates at the margins of the microcline crystals and often intergrown with the hornblende. A few minute plagioclase grains occur with the microcline and idiomorphic sphene is plentiful, usually in association with the hornblende.

Specimen 27/214 is somewhat weathered and the minerals scarcely recognizable in consequence. The texture appears to be porphyritic—large turbid felspar prisms occur in a fine-grained matrix containing biotite and muscovite, plagioclase and quartz.

In the Baragoi river approximately three miles south-west of Nachola several dykes were found that did not appear to be deformed. They occupy plane fractures and have no foliation. They differ slightly from each other but are all fine-grained greenish leucocratic rocks with small hornblende phenocrysts set in fine-grained matrices (specimens 27/231 and 27/232). In specimen 27/231, a few hornblende phenocrysts reach one centimetre in diameter and the matrix contains biotite as well as hornblende. In the thin section of specimen 27/232 the texture is seen to be porphyritic. Pale green hornblende prisms are orientated at random in an equigranular fine-grained matrix consisting of untwinned alkali felspar and quartz grains. All the minerals contain minute epidote prisms. These rocks are characterised by the lack of textures indicative of strain, but this may be a local phenomenon. It is probable that under the appropriate conditions of metamorphism and deformation they could give rise to schistose biotitic derivatives similar to the dykes described above.

All the foregoing dykes are penetrated by irregular pegmatitic veins with sharp boundaries (Fig. 5), and are sometimes invaded by parallel-sided aplite veins. Their position in the sequence of intrusions is somewhat obscure, and it is possible that they are of differing ages. They appear to be older than the granitic and aplitic intrusives described below, for they were never seen invading them, and on the Lolenyok ridge aplites were seen invading foliated dyke-rocks and granitic dykes alike (*see* Fig. 6).

(5) Intrusives due to Granitization of the Metamorphic Rocks

The intrusives described below are all granitic in composition, generally only slightly foliated or unfoliated, and in the case of the granites at least, show evidence of having been formed by granitization. Since the age of the granitization is unknown these intrusives are not here included in the Basement System.

The granites form a perplexing group showing a wide variety of relationships with the country rocks. They occur as small circumscribed stocks, as clearly intrusive sills and dykes, and as elongated tabular bodies or lenses surrounded by migmatitic partly granitized country rocks. An important feature of some of the bodies, the Sartim and Luwamara granites in particular, is the displacement and "swelling" of the foliation about them. Many of the granites described below are indistinguishable as rocks from the granitoid gneisses of metasedimentary origin. Two features of the granitoid gneisses, however, stand out as characteristic—the fact that they frequently form marked topographic features such as the Kowop hills and the Musei range, of which Gurika and Leroi mountains are a part, and their typical pale yellowish brown colour which is distinctive from the greyish tones of the migmatitic granites.

(*a*) *Small Granite Stocks.*—Some of the small granite bodies occur as isolated stocks with rounded outcrop plans. In most cases exposures were too poor to allow the nature of the contact of the granite with the country-rock to be determined, but their apparently random distribution and their coarse granitic nature indicates that they are intrusives.

The largest of these granites is only two to three hundred yards across and outcrops as a bald crag close to the north end of the Koitokol ridge. The granite is coarse-grained and homogeneous, without any trace of foliation, and is traversed by narrow

parallel-sided pegmatite veins. In hand-specimen (27/224) the rock is inequigranular, with tabular felspars reaching one inch in length. In thin section the texture is seen to be strongly inequigranular—aggregates of large fractured quartz grains are surrounded by an aggregate of smaller grains of oligoclase, crystals of biotite and small amounts of replacive microcline. Cracks in the quartz and felspars are filled with flakes of white mica. None of the large felspars visible in hand-specimen appear in the thin section, but the examination of grain mounts shows that they are microcline.

Two further granite stocks of similar appearance occur by the roadside, one two miles south of Baragoi, the other at Nagiss. Both outcrops are of pinkish grey even-grained granite without foliation, but with a tendency to a slabby parting trending more or less north-south. A specimen of the Nagiss granite (27/176) is of medium to coarse grain, pinkish in colour and without any ferromagnesian minerals. In thin section the texture is seen to be complex inequigranular—irregular large quartz grains with lobate margins occur in a matrix of anhedral albite (An_7) and muscovite crystals and flakes. Microcline is absent. The rock is an albite granite.

The two small stock-like granites west of Kangura are similar to the Nagiss granite.

(*b*) *Luwamara Granite.*—The Luwamara granite is one and a half miles wide and about two miles long. The foliation of the country rocks "swells" around the body suggesting its intrusive nature. It forms a distinctive hill with two summits and outcrops are excellent, particularly on the western side. The rocks of the central part of the mass have a well marked foliation trending north-north-west and with steep dip. This foliation is oblique to that of the surrounding gneisses. The marginal parts of the mass have an ill-defined foliation parallel to the margins and locally off-shoots of the granite invade the hornblendic migmatites along its western margin. Much of the western margin of the granite is a tectonic contact, however, and the original contact phenomena are generally obscured. Dykes of a similar granite occur among partly granitized plagioclase amphibolites and amphibolites two miles east of the granite.

The granite is a moderately homogeneous body, containing only a few small quartz veins and one or two large tabular pegmatites. It is well foliated and frequently augen gneisses have developed, and variations in texture occur which are due to differing degrees of deformation. In specimen 27/198 the augen are seen to be porphyroclastic felspars, probably microcline, and the matrix consists of xenomorphic-granular plagioclase and subordinate quartz. A few small replacive microcline grains occur. Scattered small dark green hornblende crystals occur, but brown biotite is more frequent and occurs in larger crystals.

The intrusive nature of this granite can hardly be questioned, but about its relationship to the narrow zone of migmatites in which it occurs there may be some doubt. The margin of the granite is well exposed at the ford over the motor-track at the Masegeta river. Apophyses of the granite penetrate the strongly migmatitic envelope, and have sharp transcurrent contacts.

The evidence suggests that the intrusion followed the migmatization, a fact which was found to be true of all the granites where they are in contact with migmatites. The granites in such cases are therefore not the cause of the migmatization but are more likely to be the effect of migmatization or the end-product. It seems probable in this case, as in all cases described below, that the granite is not far travelled, in that it occupies a part of the migmatite zone in which it was itself formed by granitization (*see* p. 50). The Luwamara granite probably illustrates a late stage in the granitization sequence—migmatization, partial mobilization, intrusion—the early stages of which are described below.

(*c*) *Migmatitic Granites.*—The granites now to be described are called migmatitic because they are considered to be composed of two components—granitic gneisses which have formed by granitization *in situ,* and autochthonous granite, mobilized and intrusive, but probably derived from the same migmatite zone.

The best example of this type is on Sartim hill, where there is an elongated granite body of lenticular form, around which the foliation swells, suggesting a largely intrusive rather than a replacive origin. The granite appears to be a conformable body margined by a narrow but well marked zone of migmatites. The south-western foot of the hill is composed of interbanded gneissose granite and felspathized, streaky hornblende-biotite gneisses. Part way up this side of the hill the rocks are mesotype biotite-hornblende gneisses with irregular diffuse granitic streaks. Above, the rocks become homogeneous gneissose granites with xenolithic dark hornblende gneiss bodies of random shape and sharp contacts. Locally these xenoliths are so numerous as to present the appearance of a bed of dark hornblende gneiss reticulated by granite veins. In other exposures the dark inclusions are lenticular and orientated parallel to the foliation. The whole of the upper part of the hill is composed of homogeneous gneissose biotite granite which is exposed in large exfoliation surfaces.

At the southern extremity of the granite, along the south foot of the hill, the rocks are mainly gneissose hornblende-biotite granites containing lenticular and tabular inclusions of amphibolite and partly granitized hornblende gneisses. Towards the eastern margin of the body pale-coloured granular unfoliated granites are crudely interbanded with lensing rather coarse plagioclase amphibolites.

Below the north face of Sartim hill the rocks are more or less uniform, pale, medium-grained gneissose granites. In several places a very light-coloured, rather fine-grained granite was seen to be intrusive into the normal types, and occurs as veins and broad zones containing xenoliths of the older granite gneiss. Locally the gneissose granites have a strong fibrous fabric which plunges at low angles to the north.

Parallel-sided aplite veins are common among the rocks at the margins of the Sartim granite, particularly along its eastern contact. Small pegmatite veins occur on the hill itself, mainly among the homogeneous granites.

Among the specimens collected are three that illustrate the textures of these granites particularly well—they are specimen 27/273 from the foot of the south-west face of the hill, 27/346 from the summit ridge 200 yards east of the summit, and 27/348 from the south-east end of the summit ridge. Thin sections of these rocks show that the textures are inequigranular; irregular lobed quartz grains up to 3 millimetres in diameter are characteristic. Oligoclase (about An_{20}) occurs as xenomorphic aggregates of small grains but in specimen 27/348 occasionally displays a semblance of prismatic form. Microcline occurs in all the specimens and is plentiful, occurring as small intergranular crystals, and as larger replacive grains. In specimen 27/346 it is extensively developed as large crystals so full of inclusions of partly resorbed plagioclase and quartz grains that the enveloping microcline often occurs as networks in optical continuity. Biotite occurs as isolated unorientated flakes in all the specimens and sphene is common as an accessory mineral. Several small clusters of epidote grains occur in specimen 27/346.

The development of microcline among the other grains and the way in which it digests the quartz and plagioclase is particularly well shown in specimen 27/346. It is an excellent example of the process of alkali felspathization by replacement, a process which is seen in all the granitized rocks and migmatites. This type of occurrence of microcline is discussed by Marmo (1955, p. 432), who also gives some of the leading features of "synkinematic granites" similar to the Sartim, Luwamara, and Nakefenda granites (*see* also discussion on granitization, p. 50).

It is difficult to distinguish between mobilized intrusive granite and granite developed *in situ* in the Sartim mass. The occurrences of xenoliths in the granite of the western face of the hill suggests that the central granite at least is intrusive. The mass probably represents a granitization centre in parts of which mobilization of the granite took place.

The two Nakefenda granites are elongated tabular bodies concordant with the foliation of the surrounding migmatites, the relationship of which to the migmatites has already been described (p. 16).

The easterly of the granites is a coarse-grained augen gneiss with much biotite, and is homogeneous but moderately well foliated. On the western side the granite grades into darker massive hornblende-biotite migmatites with oligoclase augen. No clear-cut intrusive contacts were seen at the margins of this granite, but the abundance of granitic and aplitic veins and patches in the adjacent migmatites suggest that it reached a stage of fluidity.

The westerly and larger of the Nakefenda granites is more homogeneous—only parts of it are foliated, and it weathers into large rounded blocks. It is generally similar to the eastern mass, but locally contains hornblende as well as biotite. Parts contain angular dark xenoliths and there are screens of partly granitized gneisses orientated parallel to the local foliation. The granite can be seen to be intrusive into porphyroblastic hornblende migmatites, but at other places the contacts often indicate no displacement of the migmatites and in these cases the granite appears to have assimilated the migmatite.

Of the two granites the smaller eastern one is the "less intrusive" of the two, since it is characterized by gradational contacts. Both granites occur in a zone of variable granitization and like the Sartim granite they are clearly palingenetic in part, but in each case the mobile granite has not moved beyond the migmatite zone in which it was formed.

(*d*) *Granite Dykes and Sills.*—The granite dykes occur mainly in the Kolowaton river four or five miles north-west of Ngoriche hill. Scattered sill-like granites occur elsewhere among migmatites, such as in the Baragoi river valley two miles south-west of Nachola. Larger irregular dyke-like sheets of granite occur south-east of Lawun, in the south-east corner of the area.

The granites of the Kolowaton river are of two types—hornblende granite sills that are frequently irregular in shape but concordant with the foliation, and biotite granites, that cut across the foliation but also form interfingering bodies. The host-rocks to these granites are strongly granitized migmatitic gneisses, frequently full of felspathic streaks and showing a tendency to develop augen texture. An example of the hornblende granites is specimen 27/211, from the Kolowaton river two and a half miles north-west of Ngoriche, a faintly foliated medium to coarse-grained granular rock. In thin section it is found to consist almost entirely of microcline grains about two millimetres across, sometimes having marginal inclusions of vermiform quartz. Interstitially there are small sodic plagioclase grains and some quartz grains, and scattered deep green hornblende crystals occur together with sphene. A few biotite crystals are also present. One small cluster of small pale green epidote grains was seen, similar to the epidote occurring in the eastern Nakefenda and Sartim granites (*see* also Marmo, 1955, p. 434).

One of the biotite granite intrusives occurs a few hundred yards east of the above locality. The granite is of the interfingering variety, and varies greatly in thickness. It shows a tendency to invade the host-rocks *lit-par-lit*, as is illustrated in Plate III, fig. 1. The rock is granular and faintly foliated, with sub-idiomorphic felspar phenocrysts. The matrix contains small clots of biotite flakes which are locally associated with hornblende.

The hornblende granites frequently grade rapidly into leucocratic hornblendic migmatites and rarely occupy plane fractures. For this reason it is probable that they are of local origin. The biotite granites on the other hand have sharp contacts and their origin is probably more remote. It is likely that they are derived from the palingenetic hornblende granites, for wherever hornblende and biotite granite occur together the biotite granites are the younger.

It is possible that the area of biotite gneiss mapped north-west of Ngoriche is, in fact, a swarm of gneissose biotite granite sills. The exposures are poor and it was not possible to see the relationships to the adjacent rocks. One cross-cutting dyke of a similar gneiss was seen nearby at a point four miles due west of Soit Olbayen rocks.

The elongated granites south-west of Lawun were passed over quickly and little was recorded of them, but a cursory examination indicated that they consist of pinkish, homogeneous, faintly gneissose muscovite-biotite granite, generally similar to that of the bosses west of Kangura.

A considerable number of small outcrops of biotite gneiss was found among the ubiquitous plagioclase amphibolites of the area, particularly in a zone immediately north-east of the Lamerok river. These exposures, which are of well foliated leucocratic biotite gneisses, are too poor and scattered to be plotted on the map, but may be the outcrops of deformed biotite granite sills. Some of the more deformed biotite granites are so like metasedimentary biotite gneisses that this confusion could easily arise. Moreover, in river sections of good exposure, such biotite gneisses as are seen are frequently identifiable as deformed granitic or granodioritic intrusives.

(*e*) *Pegmatites.*—Pegmatites are numerous throughout the area, but tend to be concentrated into zones in which one type greatly predominates over the others. The three main types that can be distinguished in the area are:—

1. Segregation pegmatites.
2. Permeation pegmatites.
3. Intrusion pegmatites.

Segregation pegmatites.—The segregation pegmatites are found most commonly among the migmatites, but occur also throughout the metamorphic complex. They take the form of small flat lenses, stringers, patches and ramifying streaks in the foliation of the host-rocks. Their form is characteristically irregular and they generally have diffuse contacts, and are rarely more than a few inches in width. They are composed mainly of intermediate to sodic plagioclase, with little quartz, and often contain scattered rather large ferromagnesian grains similar to, but larger than those of the host-rocks. Thus, garnetiferous micro-pegmatite is commonplace in garnet-bearing rocks. The grain-size is variable but frequently of the same order as that of the host-rocks. On occasion parts of the pegmatites contain large rounded augen of alkali felspar, but this is rare.

The segregation pegmatites characteristically occupy areas of high stress in the host-rocks. They are found along the margins of lenticular competent rocks such as amphibolites and as patches and veins apparently healing fractures in such rocks. Similar phenomena were observed in the Machakos area (Baker, 1954, pp. 9-11, 18-19). In rocks where oblique slip-planes are developed the pegmatite streaks often occupy the slip-planes rather than the original foliation. This phenomenon is excellently seen in the Lebanyuki river.

The rocks in which the segregation pegmatites occur are essentially similar to the "veined gneisses" described by Searle (1954, pp. 16-19) from the Sultan Hamud area.

Frequently the pegmatitic streaks do not off-set the banding of the host-rocks, and in these cases must be replacive (Turner and Verhoogen, 1951, p. 329). In other cases concordant lenses of pegmatite occur around which the foliation "swells". Such structures can be explained either by the growth of the pegmatite *in situ,* or by assuming that the lenticles are parts of originally continuous sheets that developed boudinage structures as a result of deformation. In cases where the pegmatite lenses have sharp boundaries and occur aligned in a single foliation plane their form is certainly due to boudinage structure. In the case of diffuse irregular disconnected lenticles it must be assumed that the pegmatites originated by growth *in situ.*

All the segregation pegmatites are deformed to a greater or lesser extent, but they rarely show this by the development of gneissose structures for they are frequently more incompetent than the host-rocks in which they occur. A lineation is frequently observed on the surfaces of the pegmatite lenses, and the pegmatites have been involved in the same folding as has affected the rest of the rocks.

The segregation pegmatites of the Baragoi area are regarded as having formed by the growth of quartzo-felspathic material in foliation planes, fractures and zones of shear in the host-rocks. There is no evidence that they formed by crystallization from a liquid or gas phase, although such phases may have assisted in the transport of the necessary elements through the rock fabric. The material of which the pegmatites are composed must have been at least partly derived from the adjacent rocks, to account for minerals characteristic of the host-rocks occurring in the pegmatite, but extraneous quartzo-felspathic material is also involved. This extraneous material must be similar to that responsible for alkali metasomatism in the migmatitic zones, where segregation pegmatites are most commonly seen.

Permeation pegmatites.—The permeation pegmatites are of restricted occurrence, and are found almost excusively in meta-sedimentary granitoid gneisses at Lesirikan, near Soit Nyiro hill and between these localities, where they occur in zones up to 20 yards across. They are associated with augen gneisses and are characterised by diffuse margins, complete lack of regular shape, and the absence of ferromagnesian minerals. These pegmatites grade imperceptibly into faintly foliated leucocratic augen gneisses, and consist largely of microcline and a little quartz. They are never zoned in any way and do not show the effects of deformation. It is supposed that the permeation pegmatites developed at the time of the felspathization of the adjacent augen gneisses.

Intrusion pegmatites.—Intrusive pegmatites occur in well marked zones in the area as concordant and cross-cutting sheets and veins varying from a few inches to over one hundred feet in width, and up to one and a half miles long. One of the best-marked pegmatite zones extends from the western part of the Atagirion hills past Nachola hill and along the Kisima ridge towards Nagiss. A further zone occurs stratigraphically above the biotite gneisses of the Butabut anticline, west of Koitokol. These zones contain the larger, generally concordant pegmatites, but smaller veins, both concordant and cross-cutting, are found throughout the area.

The intrusion pegmatites are characterised by their sheet-like form, with parallel walls and sharp contacts, and a marked coarseness of grain. They are distinguished from the segregation pegmatites by their regular form and greater grain size, and are seen to cut across the older segregation pegmatites in numerous exposures.

The smaller cross-cutting pegmatites are frequently deformed and it seems likely that they are syntectonic. The larger pegmatites are only rarely deformed, and are largely post-tectonic, but there is no evidence to suggest the length of the interval between the intrusion of the deformed and undeformed pegmatites. The small pegmatite veins are frequently slip-folded, or have been sheared or crushed by the formation of simultaneous slip-planes with different orientations (Plate III, fig. 2, figs. 3 and 10B). Pegmatitic breccias are formed locally and are gradational into

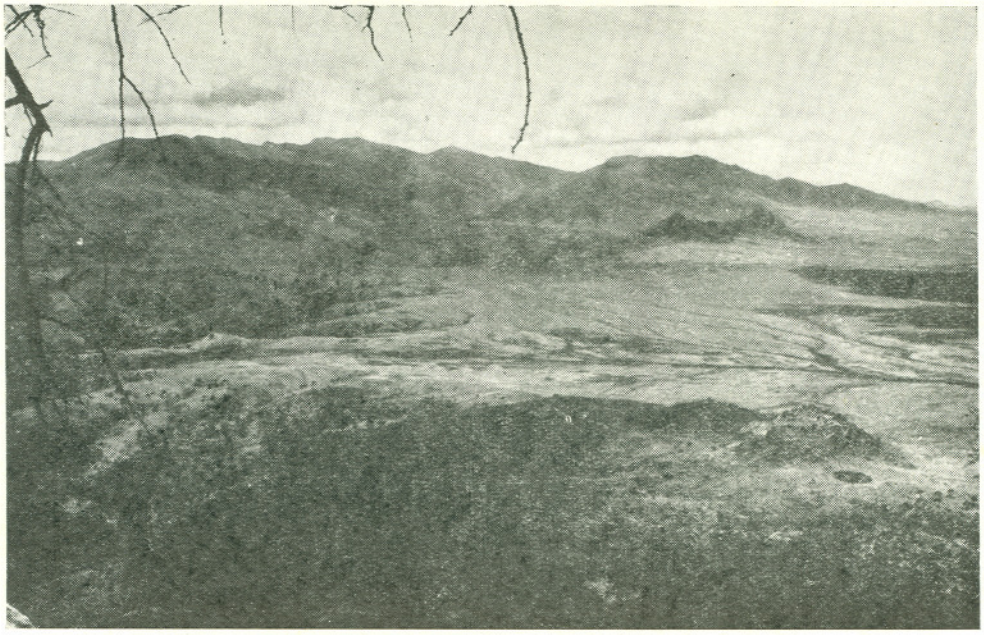


Fig. 1—The Northern El Barta plains and Musei range seen from Sartim

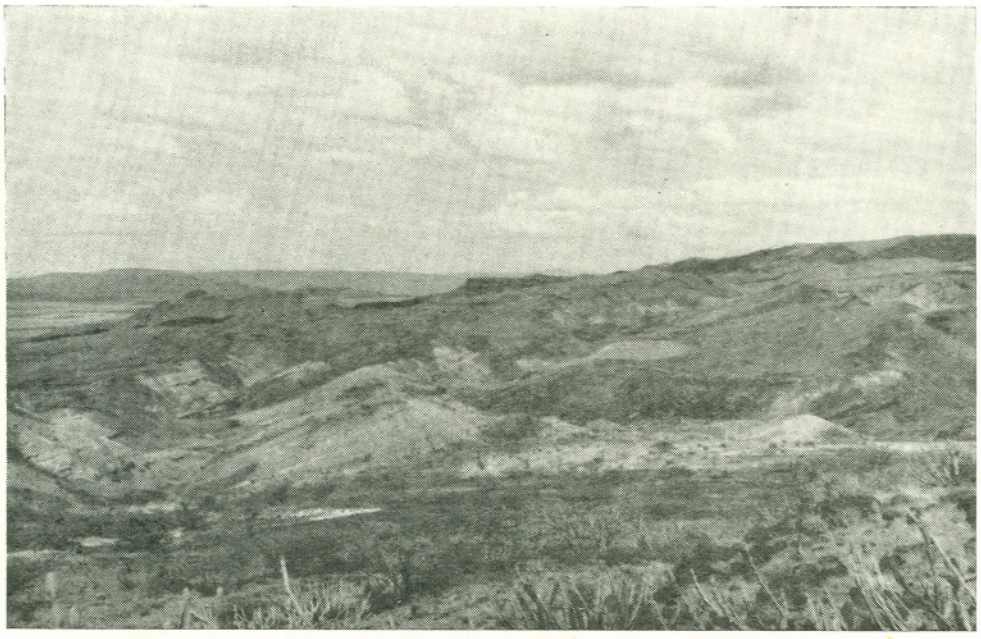


Fig. 2—Dipping lake beds among volcanics north of Waitiakwell hill



Fig. 1—Vertical grooving in fault-breccia near Logobuk Springs



Fig. 2—Horizontal columnar jointing in augite basalt stock in the Kangetet river

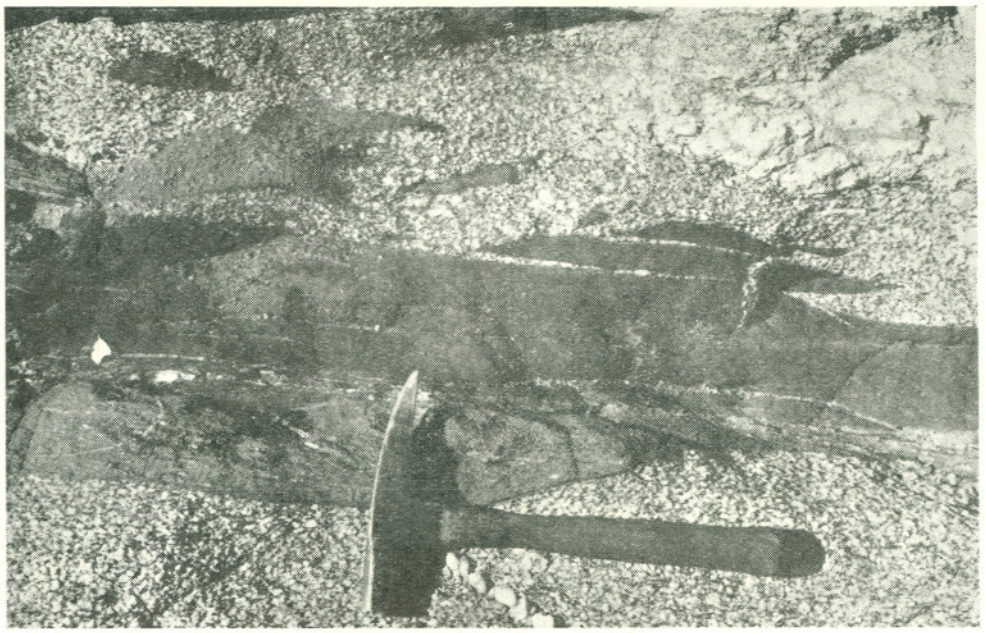


Fig. 1—Granite dyke in the Kolowaton river



Fig. 2—Deformed pegmatite with fibrous structure

Plate IV

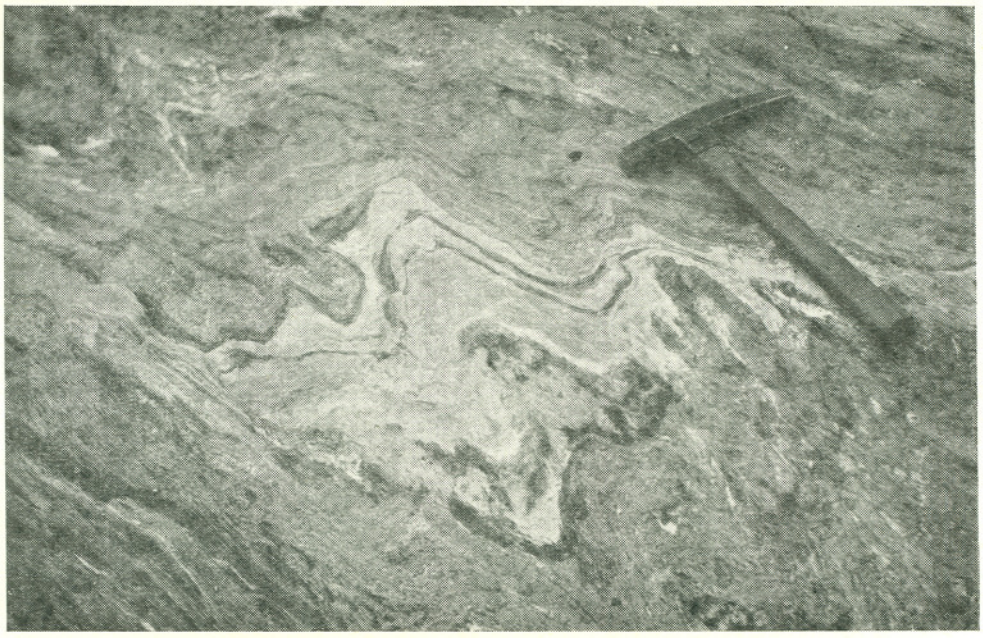


Fig. 1—Profile of minor folds



Fig. 2—Profile of minor fold

porphyroclastic augen schists, as is seen on the Ngoriche ridge, in the Baragoi river three miles south-east of Ngoriche and on the El Barta plains five miles south-east of Baragoi, where a sheared pegmatite four feet wide is cut across by a slightly deformed pegmatite vein. Two specimens from this locality, 27/189 and 27/188, of the sheared pegmatite and of the slightly deformed vein respectively, illustrate the degree of deformation that affects these rocks in certain localities. The earlier more deformed pegmatite (specimen 27/189) has been converted to a pale grey well-foliated augen gneiss, composed of granular felspar augen up to one centimetre long, set in a fine-grained matrix of quartz, felspar and minute muscovite and biotite flakes. The presence of muscovite and biotite in considerable quantities in sheared pegmatites which are normally devoid of them was repeatedly observed. The comparatively slightly deformed pegmatite vein (specimen 27/188) is a coarse rock with cataclastic texture. It consists of rather angular, roughly lens-like alkali felspar fragments up to one inch long separated by irregular fractures and aggregates of quartz grains. Minute garnet granules occur in the alkali felspar fragments.

In the Baragoi river three miles east-south-east of Ngoriche a narrow concordant pegmatite has been sheared to muscovite schist (specimen 27/172). In thin section this rock exhibits a number of interesting cataclastic features. The texture is highly irregular, grains being sometimes intricately intergrown and often with sutured margins. A marked lamination is apparent due to zones of differing grain size and the occurrence of greatly elongated lenses of "granulitic" quartz. Within these lenses and among the trains of quartz grains along the same planes in the fabric there is an easily visible preferred planar orientation of c-axes. Muscovite flakes occur orientated in the laminae and as frequently in planes oblique to the main foliation. Between the quartzose layers are sodic plagioclase grains of xenomorphic-inequigranular texture.

In several localities pegmatite veins were observed to have invaded transcurrent shear-zones, and along the margins of earlier deformed dykes. An example of the former case is illustrated in Fig. 7.

The larger mainly concordant, intrusive pegmatites occur on the Nachola-Kisima ridge, where some of them have been exploited by prospectors for mica. Many of the larger pegmatites are zoned and are several hundred yards long and up to 50 or 60 feet wide. Many of these were examined by L. M. Bear (Annual Report for 1954, Mines and Geological Department, pp. 9-10), and much of the following account is based on his work. Among the zoned pegmatites the core generally consists of glassy or milky massive quartz in the form of an elongated lens or a series of disconnected bodies of irregular outline. The innermost intermediate zones are usually of coarse-grained pink blocky microcline or white albite, but in some cases quartz, small garnets and mica occur also. The wall-zones consist of either of the following: — fine-grained felspar, subordinate quartz and mica books up to two inches in diameter; fine-grained felspar, quartz and garnet with or without subordinate mica. The few contacts of the pegmatites observed showed a narrow aplitic border zone composed of either felspar-quartz-garnet, or felspar-quartz-mica, the mica being rare. Where books of mica of economic size and quality were seen they were generally developed near the outer margin of the quartz core.

Several radio-active minerals have been identified in the pegmatites, including euxenite, samarskite and monazite. These minerals occur as very scattered individual crystals or in small clusters in the pegmatites. A thorough search of many of the Nachola pegmatites with a Geiger-Müller counter did not reveal any occurrences of these minerals in present-day exposures, and it seems likely that specimens obtained in the past came from the primitive mica workings which are now collapsed and overgrown.

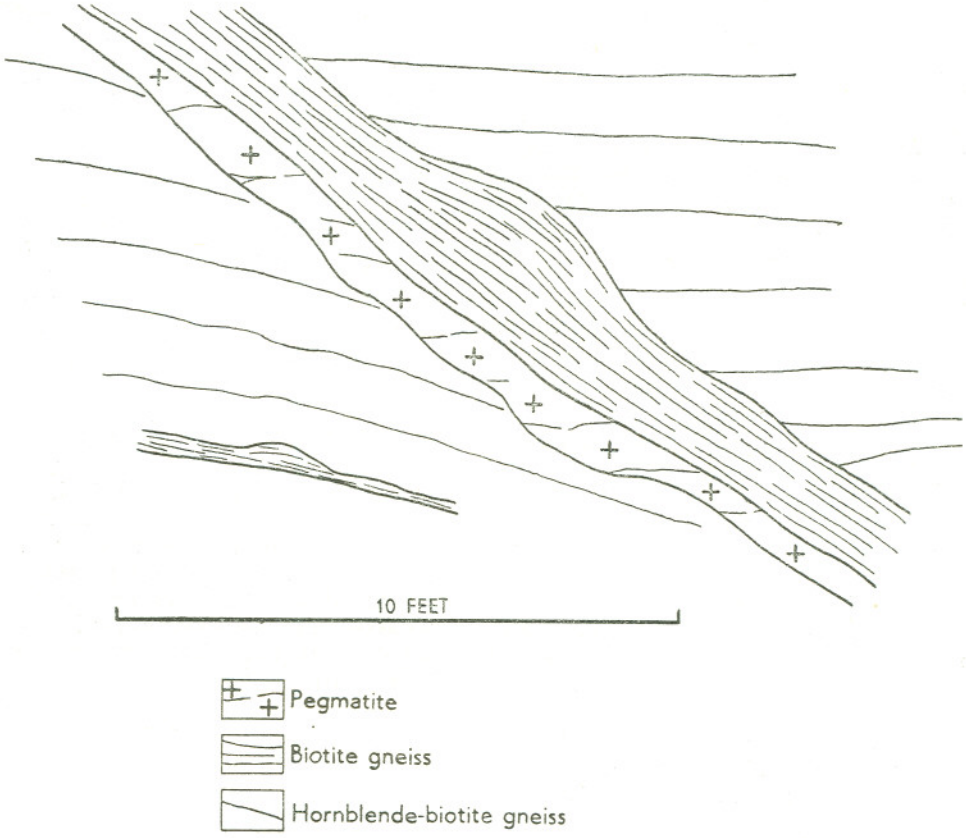


Fig. 7—Pegmatite vein intrusive into transcurrent shear-zone in Baragoi R., three miles ESE. of Ngoriche

Pegmatites of a distinctive type occur about seven miles south-east of Lawun, in the south-east corner of the area. Here a swarm of granite, aplite and pegmatite dykes occurs trending north-west-south-east and cutting across plagioclase amphibolites and hornblende migmatites. The dykes are constant in composition but variable in texture; those north of the Masegeta river are frequently pegmatitic in one place and granitic in another. Patches of pegmatite occur in granite and *vice versa* and occasional aplitic facies are also seen. A specimen of the granitic types has already been described (p. 33). The pegmatitic dykes are sometimes branching and send off-shoots into the host-rocks; the off-shoots are frequently granitic.

(*f*) *Aplites.*—Aplites are especially common in the area, and are found for example east and north of Lamerok and Kangura, in the upper reaches of the Kolowaton river; at the north end of the Koitokol ridge and on the Lolenyok ridge. They are easily recognized rocks, fine-grained and of white to dirty buff colour. They are characteristically mottled by minute specks of opaque minerals and almost invariably contain muscovite. The majority of the aplites are narrow cross-cutting sheets, frequently faintly foliated parallel to their length. They are resistant to weathering and outcrop on the El Barta plains as lines of isolated outcrops. They are found cross-cutting all other rock types and are therefore regarded as the youngest of the intrusives of the area.

The aplites are homogeneous in composition and texture, the essential minerals being quartz, albite-oligoclase, muscovite and minor amounts of microcline. In one case a few flakes of biotite were also found. Quartz is present to the extent of 50 per cent by volume. The grain size is small, of the order of 0.1 millimetre and the texture granular to moderately inequigranular. In the thin section of an aplite dyke (specimen 27/235), from a few hundred yards north of Ol Doinyo Luwarak, there is a single optically strained phenocryst of quartz two millimetres in length. In the other thin sections examined quartz tends to occur as larger grains than the felspars. The quartz grains also tend to be round and to occur as inclusions in a matrix of sodic plagioclase. This is strongly reminiscent of the replacive textures seen in the migmatites, and its significance is discussed in a later page. Some of the aplites are poorly foliated, and show a faint directional texture in thin section.

A chemical analysis of an aplite vein (specimen 27/235), from a few hundred yards north of Ol Doinyo Luwarak, is given below, and indicates that the aplite has a composition intermediate between the kali-granites and the soda-aplite class as defined by Johanssen (1960, vol. II, p. 103, p. 376). The sodium-potassium ratio is higher than in the normal granite aplites.

	%
SiO_2	73·38
Al_2O_3	15·52
Fe_2O_3	0·34
FeO	0·40
MgO	0·07
CaO	1·73
Na_2O	6·13
K_2O	2·22
H_2O+	0·47
H_2O-	0·09
TiO_2	0·04
P_2O_5	0·06
MnO	nil
	100·45

Norm	%
Q	73·20
or	3·89
ab	16·74
an	5·24
hy	0·68
mt	0·34
	100·09

Analyst—J. Furst, 4–9–56.

One aplite specimen, 27/193, from three miles west-north-west of Nagiss, is strongly sheared, and is a pale brown flaggy rock with closely-spaced shear surfaces giving it a schistose appearance.

In the majority of cases the aplite dykes are steeply dipping and occur in swarms that have a good degree of regularity of trend. The dykes between Kisima and Kangura trend towards the south-south-west, and another cross-cutting swarm occurs at the

north end of Koitokol. Elsewhere the aplites are narrow concordant bodies. The orientation of the aplite dykes is probably controlled by the structure of the area—they appear to occur in plane fractures close to the *ac* plane of the megascropic fabric. The *ac* plane is normally a direction in which tensional fracturing takes place (cf. Turner and Verhoogen, 1951, pp. 535-536), and *ac* jointing is commonplace in the area.

(*g*) *Quartz Veins.*—Quartz veins are exceedingly rare in the area and in places where vein quartz outcrops on the plains it is not always possible to decide whether it represents a quartz vein or the core of a zoned pegmatite. Such vein quartz outcrops as were seen south-east and north of Lamerok hill consist of milky quartz with small flakes of hematite and limonite. They are commonly orientated in the same fashion as the aplite dykes and are considered to be of the same age. They do not contain economic minerals.

2. Tertiary Volcanic Rocks and Associated Sediments

The Tertiary volcanic rocks and associated sediments occurring in the western part of the area are tabulated in order of succession:—

(7) Olivine basalts.
(6) Tirr Tirr Series—basalts and trachytes.
(5) Olivine and augite basalts (Laikipian Basalts?).
(4) Lake beds and interbedded volcanics.
(3) Rumuruti Phonolites and tuffs.
(2) Porphyritic basalts and tuffs (Samburu Series).
(1) Sub-volcanic sediments.

Owing to the inaccessibility of much of the volcanic area, lack of time, and unforeseen structural complexities, the succession of the volcanic rocks is not so firmly established as might be desired. It is proposed therefore to describe the inter-relationships of the lava types, and the evidence for the present succession, so as to facilitate any future re-appraisal of the volcanic geology of the area in the light of additional information.

In the area west and north-west of Nachola the lower part of the succession is formed of interbedded quartz gravels, pebble beds, tuffs and a flow of porphyritic basalt. These are overlain by phonolites. This succession is repeated south-west of Nachola and further downstream in the Baragoi river section. North of latitude 1° 50′ no phonolites are observed in the succession—augite basalts rest directly on the Basement System and are themselves overlain with angular unconformity by the lavas of the Tirr Tirr. West of Nachola, on the southern part of the Napung ridge, the augite basalts are seen to overlie the most northerly of the phonolites. There is thus good evidence of the occurrence of two basaltic formations that differ in character, one below and the other above the Rumuruti Phonolites.

In the southern part of the area, west of Nagoriagwen, there occurs a thick sequence of welded tuffs, which rest directly on the Basement System and which are grouped with the Rumuruti Phonolites. These tuffs form the prominent Naramarsiro-Emuru-Abenyo escarpment and appear to extend to the Akangoramiriek plateau. In deep canyons eroded in the tuffs phonolites are exposed both above and below, yet do not appear in the face of the escarpment a short distance to the east. In the south-eastern face of the Akalodak plateau the tuffs appear to pass beneath the phonolites and to be continuous with the agglomeratic tuffs that form the base of the volcanic sequence in the Ayena Etuthuru gorge west of Nagippi. At the highest point on the Akangoramiriek plateau, however, the tuffs and agglomerates are overlain by a distinctive reddish brown

phonolite, and a similar lava also occurs at the base of the tuff sequence. A reddish brown phonolite is seen repeatedly nearby, in the escarpments to the north of the Baragoi river, and this lava rests on a comparatively thin tuff bed at the top of the phonolite sequence. Tuffs occur therefore intercalated in the phonolite sequence. It seems that the phonolites beneath the Naramarsiro plateau must wedge out eastwards, the tuffs overstepping them.

(1) Sub-volcanic Sediments

Lacustrine sedimentary rocks occur at intervals at the base of the Tertiary volcanics, but they vary considerably from place to place and do not make up a well defined formation.

At the foot of the phonolite escarpment west of Segera there are approximately 200 feet of conglomeratic grit, containing rounded quartz pebbles up to three quarters of an inch in diameter. At the base a conglomerate 10 feet thick is exposed containing pebbles of quartzite, pegmatite and biotite gneiss ranging from half an inch to 6 inches long. Resting on the grits is a thin vesicular phonolite, forming the base of the Rumuruti Phonolites, and above it approximately 30 feet of brick-red tuff overlain by 20 feet of light grey tuff. The tuffs are overlain by the phonolite that forms the plateau. Similar tuffs occur at the descent of the Maralal-Baragoi road from the Lopet plateau, but there are no non-pyroclastic sediments. Lake sediments occur again in the broad valleys between two and six miles north of Logorgor. Much of the flat ground shown as covered by sediments on the geological map, is blanketed by quartz pebble sheets resting on the original sub-volcanic surface. On the lower slopes of the escarpments, and on small hillocks on the valley floor, are exposed clean quartz sands and grey-green volcanic soils with calcified layers, capped by reddish grey tuff. Unconsolidated quartz pebble beds occur at the base of this sequence, which is at least 120 feet thick.

Immediately north of the Baragoi river at the edge of the volcanic outcrop, and continuing northwards at least as far as the escarpment east of Emuru Etuku in the north of the area, are quartz pebble sheets, some clearly redeposited one or more times. West of Nachola the Basement System surface is irregular and hollows are filled with quartz pebbles overlain by calcareous grit and thin basalt lava, with more quartz pebbles above.

North of the Baragoi river the sediments are generally not more than 20 feet thick and dip westwards at angles between 2 and 7 degrees. The sediments are characterised by their poor bedding, small degree of sorting and their arenaceous character. They are probably torrential sediments and swept into hollows in the sub-Miocene peneplain.

These sediments are closely comparable to those described by Shackleton (1946, pp. 27-29) from the Nanyuki-Maralal area. No fossils were found in the present area, but Shackleton (*op. cit.*, p. 28) found *Deinotherium hobleyi* Andrews in sediments beneath the Rumuruti Phonolites near Kirimun, and concluded that the sediments are of Miocene age.

Similar deposits, the Turkana grits, though generally thicker and more extensive are widespread in Turkana, and have been described by Fuchs (1939, pp. 228-231), Arambourg ((1943, pp. 161-171), who called the grits the Lubur Serier), and by Mason and Gibson (1957, pp. 17-23).

There can be little doubt that the Turkana Grits are Miocene in age, and it is probable that the sub-volcanic sediments of the Baragoi area and of the sub-volcanic sediments Nanyuki-Maralal area are the equivalents of the Turkana Grits on the east side of the Rift Valley. Mason and Gibson (1957, p. 23) correlated their Tiati Grits

with the Miocene sub-volcanic sediments described by Shackleton, and tentatively regard the Turkana Grits of the Kolossia-Tiati area as pre-Miocene. This view is probably mistaken, for the sub-volcanic sediments of the Samburu area are composed exclusively of material derived from the Basement System, whereas the Tiati Grits Series is composed of volcanic material.

(2) Porphyritic Basalts and Tuffs (Samburu Series)

These volcanics rest directly on the sub-volcanic sediments between two and 14 miles north of Logorgor and are overlain by the Rumuruti Phonolites which extend southwards to form the Lopet plateau. They thin towards the north, and at a point three miles north-north-east of Napung hill augite basalts of the later basalt formation rest directly on only a thin porphyritic basalt. Further north, in the Kangetet valley and on Emuru Etuku hill no porphyritic basalts are found—the stratigraphically higher olivine and augite basalts rest directly on the Basement System.

The main outcrop of the prophyritic basalts and tuff is in the Naori river basin, an area of comparatively low-lying ground between phonolite plateaux. They develop their greatest observed thickness here, a thickness not exceeding 400 feet of exposed lavas and tuffs, and because of their low dip it is likely that the unexposed part of the succession is not in excess of 200 to 300 feet. They thin rapidly eastwards, and where they reappear beneath the phonolites east of Lodopal they are scarcely 100 feet thick and must rapidly taper out north of Logorgor.

The basalts and tuffs on and south-east of Morilem hill and the sediments on which they rest have the following succession:—

		feet
Basalt and tuff formation	10. Grey basalt	c.40
	9. Vesicular purple basalt	c.50
	8. Cherty limestone with silicified tree trunks	6–8
	7. Dark grey basalt	c.15
	6. Coarse sands	3–4
	5. Dark green tuff	10
	4. Black porphyritic basalt	c.30
Sub-volcanic sediments	3. Fine white sands	c. 8
	2. Friable olive-grey clay	c. 2
	1. Conglomeratic grit	3
	(Basement System)	

The succession is approximately 150 feet thick and the sediments interbedded with the volcanic rocks were found to extend some five or six miles southwards, but are very variable from place to place. Resting on the black porphyritic basalt at various localities are reddish brown ash beds, buff and green clays with thin green chert beds, quartz pebble sheets and in one locality, immediately below the overlying phonolites are 90 ft. of buff fine-grained sands.

In the Baragoi valley north of Logorgor water-laid sediments are absent and the sequence consists of thin brick-red tuffs, purplish grey agglomerates with rounded pumice fragments and pale grey and reddish grey porphyritic basalts. One of the basalts (specimen 27/333), from the bank of the Baragoi seven miles north of Logorgor, is composed of straw-coloured basic plagioclase phenocrysts up to one centimetre long in a matrix containing small plagioclase microphenocrysts, augite granules and lath-like plagioclase. Limonite staining accounts for the reddish colour of the rock.

At the confluence of the Naori and Baragoi rivers the upper part of the basalt-tuff sequence is well exposed in tilted fault-blocks. High up in the cliff overlooking the river confluence is a distinctive brick-red ash, which is repeatedly seen near the top of the formation. Below this ash is a number of basaltic lavas and tuffs, and at river-level the lavas are seen to be purplish grey rocks with many vesicles containing coarse calcite crystals. In the Nagiss river a little way to the south, the sequence is mainly of deep reddish brown tuffs, grey agglomerates and thin grey compact basalts without phenocrysts.

In the Naori river section itself the sequence is seen to be composed largely of tuffs. Reddish tuffs occur immediately beneath the phonolites at the western end of the section and are seen at intervals forming the tops of the hills on either side of the valley. Beneath the tuffs are several thin basalts which overlie a thick grey agglomerate with more thin basalts beneath. The lowest of these lavas are brownish grey and highly fractured, with yellowish calcite veins in the fractures.

There is a considerable similarity between the basalts—they are mostly rather pale brownish grey, leached and altered rocks with much calcite in vesicles and veins. Specimens 27/319B, from the Naori-Baragoi river confluence, 27/259 from the Naori valley three miles east of the confluence, and specimen 27/329 from beneath the phonolites six miles east of the confluence contain numerous frequently corroded plagioclase phenocrysts up to three millimetres in length in matrices of plagioclase laths and pyroxene pseudomorphs. Limonite occurs throughout and masks the ferromagnesian mineral. Vesicles are lined with limonite and chalcedony and have cores of calcite. Minute replacive patches with a spherulitic green chloritic mineral are common. In a slice of specimen 27/319B small amounts of analcite occur in the matrix.

The porphyritic basalts and tuffs strongly resemble the Samburu Series which Shackleton found in the Nanyuki-Maralal area south of the Baragoi area. Both formations underlie the phonolites, have a few porphyritic basalts and are composed largely of tuff (Shackleton, 1946, pp. 29-31). Shackleton's name for his series is somewhat misleading, as he himself pointed out, for it does not outcrop in Samburu country but in the western parts of the administrative Samburu area which is occupied by Turkana, and in any case the greater part of the "Samburu" hills to which Shackleton referred (the Napung ridge) are composed of basalts which are distinctly younger than the Samburu Series and its supposed equivalents in the Baragoi area.

(3) The Rumuruti Phonolites and Tuffs

Phonolites form the upstanding Lopet, Nagippi and Logorgor plateaux and occur on dipping fault-blocks along the course of the Baragoi river and in the Nganyamonyen valley. They thin northwards and eastwards, and are not present north of latitude 1° 50′ N.

The lowest part of the phonolite sequence is composed of tuffs, which are variable in thickness and character. In the Baragoi river north of Logorgor they consist of a lower reddish brown agglomeratic tuff and an upper green-grey tuff, the whole being at least 200 ft. thick. These tuffs are present in the lower part of the phonolite escarpment from the vicinity of Logorgor round to the building-stone quarries by the roadside west of Tipaku. The reddish tuffs are absent from the quarries and only reappear in one place in the escarpment south of Tipaku.

At the north-eastern end of the Kalamudang plateau the sequence below the phonolite is as follows:—

		feet
	(Phonolite)	
(4)	Pale yellow-brown tuffs with pumice and gneiss fragments	30
(3)	Greyish-brown tuff with phonolite fragments	35
(2)	Localized bright green tuff	6
(1)	Quartz pebbles (sub-volcanic sediments)	4
	(Basement System)	

The tuffs exposed on the south face of the Nagippi plateau are up to 150 ft. thick, and are mainly pale yellow-brown in colour, with occasional agglomeratic bands. They can be followed round the escarpment and appear to be continuous with the Emuru Abenyo tuffs and the Naramarsiro tuffs. At Emuru Abenyo the tuffs are about 100 ft. thick; the junction of the tuffs with the Basement System slopes north-westwards from this point and southwards towards the Lakwarsignen river, for the altitude of the base of the tuffs is 4,738 ft. on Emuru Abenyo, and 3,808 ft. in the Lakwarsignen river. South of the Lakwarsignen the junction again rises to 4,616 ft. on the north-east face of Naramarsiro. The reason for this rapid variation in the altitude of the contact is not apparent, but is probably bound up with the occurrence of altered phonolites at the base of the tuff in the Lakwarsignen gorge and in the Nangormirie gorge, and may be due to deposition on an uneven surface.

The sequence in the Lakwarsignen river and in the sides of its gorge is as follows:—

(6) Porphyritic phonolites.
(5) Brown tuff.
(4) Reddish brown altered phonolite.
(3) Massive pale grey or reddish brown pumice tuff.
(2) Grey agglomerate with thin phonolites.
(1) Pale green grey phonolite.

(Basement System)

The thickness from the base of the porphyritic phonolites to the base of the lowest phonolite is approximately 160 ft., yet five miles to the south-south-east the succession consists of two massive beds of tuff which are over 1,000 ft. thick with two or three thin phonolites at the base. These thick tuffs on Naramarsiro are similar to the pale grey or reddish brown tuff of the Lakwarsignen section and the tuff on Emuru Abenyo hill.

The tuffs of Naramarsiro and Emuru Abenyo ridge are represented by specimens 27/339 and 27/344 respectively, the first being a pale reddish brown patchy tuff, hard, compact, poorly bedded with pale yellowish brown irregular bodies that in this section are seen to be composed of a mineral in spherulitic aggregates. The groundmass in both specimens is microcrystalline to glassy, with felspar prisms which have been reduced to microcrystalline aggregates. Minute angular to rounded felspar inclusions occur. Specimen 27/344 in particular shows a marked parallel texture, with alkali felspars recrystallized as aggregates. Both specimens are probably welded tuffs of phonolitic composition.

On the plateau surfaces the phonolites weather into rounded boulders with a light brown skin, but the commonest type of phonolite is a hard dark greenish grey rock with a tendency to flaggy or fissile outcrop. The most widespread variety has few anorthoclase phenocrysts up to one centimetre in diameter, and no nepheline is visible in hand-specimens. The other phonolites are glomero-porphyritic, the individual phenocrysts reaching two to three centimetres in length. Such phonolites occur in the hills above Logobuk springs, on the plateau west and north-west of Logorgor, and six miles east of Logorgor overlying the normal poorly porphyritic variety.

Microscopically the phonolites are all much alike. The groundmasses have a characteristically mottled appearance due to the occurrence of scattered interstitial green aegirine and dark brown pleochroic cossyrite. Stout prisms, or more rarely, lath-like crystals of soda-orthoclase are abundant, the interspaces being filled by the ferro-magnesian minerals and localized patches of isotropic analcite. Microphenocrysts of nepheline are abundant in some slices, for instance specimen 27/334 from the isolated phonolite plateau three and three-quarter miles south-west of Nachola. The nepheline occurs as euhedral turbid crystals, frequently crowded with minute orthoclase prisms. Microphenocrysts of euhedral green augite occur sparingly in most of the thin sections. Reddish brown crossyrite is typical and is developed in most of the rocks.

Near the top of the phonolite sequence in the gorge of the lower Baragoi river in the vicinity of Akangaurak, there is a distinctive reddish phonolite lava that was mapped in several localities. It invariably overlies a bright brick-red tuff and usually forms a resistant feature. The tuff and lava occur in the long precipitous Lolgurio escarpment through which both the Baragoi and Nanganyamonyen rivers flow in deep gorges at the western edge of the area. West of Akangaurak the lava is overlain by augite basalts of the succeeding formation, but locally one or two thin phonolite flows intervene between the reddish lava and the overlying augite basalts. An identical lava occurs at the base and at the top of the thick series of reddish brown and brown tuffs and agglomerates which form the pediment of the Akangoramiriek plateau. The reddish lavas vary from reddish grey to pale reddish brown in colour, and contain small felspar phenocrysts Microscopically they are all alike, having a fine-grained matrix of stout orthoclase laths and prisms between which is abundant analcite. Limonitic films and patches appear to have replaced the ferromagnesian minerals and give the rocks their colour. Representatives of this type of phonolite are specimen 27/321, from the Baragoi river at Akangaurak, and specimen 27/326, from the north-east side of the Akangoramiriek plateau.

The Akangoramiriek red tuffs and phonolites form a sequence about 700 ft. thick at the northern end of the plateau. No tuff-agglomerate beds of similar thickness occur in the Baragoi river immediately to the north, and, in the absence of conclusive evidence, these tuffs are equated with the Naramarsiro-Emuru Abenyo tuffs, and placed in the middle of the phonolite sequence of the south-western part of the area.

(4) Lake Beds and Interbedded Volcanics

In the narrow valley two and a half miles north-west of Akangaurak are exposures of bedded sediments. Similar sediments are extensively developed on Waitiakwel hill and in the vicinity (*see* Plate I, fig. 2). The beds extend northwards and southwards over a considerable distance—southwards as far as the south-west corner of the area, but northwards they seem to disappear before reaching the Kongia-Echua Etom area.

The relationship between the sediments in the valley two and a half miles north-west of Akangaurak and the adjacent lavas is complicated by faulting. The sediments dip at 35 degrees to the north-east, whereas the lavas dip at approximately 10 degrees to the west. The sediments consist almost exclusively of reworked volcanic material, with one interbedded basalt. The succession is as follows:—

	feet
(6) Brick-red gravels, buff sands, white silts	80
(5) Yellow-brown volcanic sands with pumice fragments	40
(4) Lava conglomerate with gravel beds	25
(3) Grey-brown ashes with diatomaceous bands	60
(2) Grey porphyritic basalt	20
(1) Purplish grey gravels and silts	25
Total	250

On Waitiakwel hill there is a thickness of approximately 350 ft. of sediments, ashes and tuffs resting on basalt. The sediments here include buff porcellaneous clays and olive-green, pale grey-green and brown silty clays with narrow bands of water-worn pumice pebbles. These are interbedded with brick-red agglomerates and tuffs. Above the sediments are two basalt flows, one with felspar phenocrysts and the other with olivine and augite phenocrysts.

The sediments of the Lolgurio area and the Nanganyamonyen valley were not examined but their continuity with the beds in the vicinity of Waitiakwel is obvious from the aerial photographs. In the upper Nanganyamonyen valley they are drawn as if directly overlying the phonolites, but this relationship was not proved in the field and the situation may easily be complicated by faulting. Nevertheless the lake beds are provisionally placed at or near the base of the porphyritic olivine and augite basalts.

The presence within the sediments of water-worn gravels, graded sands and finely bedded clays proves that they are sub-aqueous deposits, in part at least. The beds probably accumulated in shallow basins on the volcanic surface, the deposition being lacustrine and fluviatile in different places.

It is tempting to suggest a correlation between these lake beds and the Kamasian lake beds of the Baringo basin (Fuchs, 1950). The Kamasian lake beds occur at the base of the Laikipian basalts and overlie a phonolitic series (Gregory, 1921, pp. 107-109)—a moderately good parallel with the present area. The greatest difficulty facing this correlation is the fact that if the lake beds of the Waitiakwel-Lolgurio area are regarded as Kamasian and middle Pleistocene in age, then the superposed basalts and the Tirr Tirr Series must be regarded as middle and upper Pleistocene and the post Tirr Tirr Series faults become very young. Since the fluviatile and lacustrine beds in the Suguta valley are possibly late Pleistocene, and are clearly very much younger than the volcanic rocks, the bulk of the evidence suggests that the lake beds of the Waitiakwel-Lolgurio area cannot be younger than the lower Pleistocene, and it follows that they are not of Kamasian age, in spite of the close parallel with the Baringo Kamasian.

(5) Porphyritic Olivine and Augite Basalts (Laikipian Basalts?)

The olivine and augitė basalts that occupy a considerable part of the north-western section of the area form the thickest sequence within the Tertiary volcanics. They overstep the Rumuruti Phonolites and the Samburu Basalts going to the north, where they rest directly on the Basement System. The formation appears to thin rapidly southwards, and was not identified by Shackleton (1946) in the northern part of his area. In the north-western part of the area the basalts dip at angles up to 15 degrees to the west-north-west, and pass beneath the sub-horizontal lavas of the Tirr Tirr Series, which overlie it with unconformity.

The sequence is repeated by normal faults, but the lavas are so much alike that it is impossible to establish any detailed succession. The lowest lavas, however, are invariably dark grey hard basalts with abundant augite phenocrysts, hackly fracture and bouldery outcrop, such as are excellently exposed on the Napung ridge. The dipping lava sheets do not form flat-topped plateaux as do the phonolites, but build chains of irregular hills covered with *Euphorbia candalabra.*

Tuffs are absent from the lower part of the formation but between Morilem, Napung and Aka Aiteputh a number of thin basalts devoid of phenocrysts separate the porphyritic basalts.

West of the head-streams of the Ayena Aturkan river the nature of the lavas changes—they become thinner and tuffs occur. Basalts with olivine phenocrysts become common and are interbedded with augite basalts. Occasionally a basalt with both olivine and augite phenocrysts is seen. Crystal tuffs occur as thin beds among the lavas and south of Echua Etom dykes and sills of columnar basalt invade the lavas and tuffs as inclined sheets. The dykes are emplaced along planes normal to the surfaces of the lavas i.e. they dip steeply eastwards, suggesting that they were vertical when the lavas were horizontal. Many of the basalts are strongly vesicular, even scoriaceous, and

contain many narrow veins and spots of coarse white calcite. At one place near the Echua Etom springs a basalt breccia of six- to nine-inch fragments in a coarse crystalline calcite matrix was found, and together with local reversals of dip suggest the presence of a fault.

In the vicinity of the Kongia wells and springs the basalts contain felspar phenocrysts and are somewhat more massive and lighter in colour than those further to the east.

On the cliffs around the alluvial fan of the Nitelejo river and also near Kanganya the base of the Tirr Tirr Series is exposed. The basalts beneath the Tirr Tirr Series dip at angles up to 18 degrees, and are of the variety with felspar phenocrysts. Between kanganya and Lowoi, along the base of the escarpment at the western margin of Tirr Tirr, the basalts outcrop sporadically in fault-blocks capped by a fissile trachyte lava of the Tirr Tirr Series. The basalts here are mostly dark blocky rocks with augite phenocrysts, olivine phenocrysts or both. North of Lowoi it seems as if the Tirr Tirr Series extends down to the level of the Suguta valley—no basalts appear in the escarpments.

The base of the basalts formation can be clearly seen along the east face of the Emuru Etuku hills. The exposed thickness of basalts here is not more than 400 ft., and the lavas are interbedded porphyritic augite basalts and basalts without phenocrysts. Similar basalts also outcrop at the south-west extremity of the Emuru Akirim plateau, where they occur as a thin wedge beneath the horizontal Tirr Tirr Series basalt which caps the plateau (*see* Fig. 8).

Stocks of augite basalt were found in two places, one in the upper Kangetet river valley six miles north of Napung, and another in the Lopurr river at Sibukwe. The former has excellent horizontal columnar jointing (Plate II, fig. 2).

Petrographically the basalts are all much alike except for variations in the nature and amount of phenocrysts. Basic plagioclase and small anhedral augite microphenocrysts occur in a typically basaltic groundmass consisting of plagioclase, augite granules and iron ore grains. Some also contain olivine phenocrysts which attain one centimetre in diameter, and a small amount of olivine as minute granules is frequently found in the matrix. Among the more weathered reddish coloured basalts, such as those east of the Echua Etom springs, the smaller olivine granules are altered to iddingsite. In a few of the basalts there is an isotropic mineral of low refractive index between the plagioclase prisms of the groundmass. This may be analcite, and is indicative of an alkali tendency among some of the basalts.

There is a marked similarity between these basalts and the Laikipian Basalts of the Nyeri, Nanyuki and Mukogodo-Loldaika areas. The Laikipian Basalts are also dense dark rocks with hackly fracture, containing olivine and augite phenocrysts and with a tendency to columnar structure (Shackleton, 1945, pp. 3-4; 1946, pp. 38-39). Both formations rest on the Rumuruti Phonolites.

(6) Tirr Tirr Series

The Tirr Tirr Series is composed of basalts and trachytes. The series, which is at least 1,000 ft. thick as exposed in the escarpments overlooking the Suguta valley, thins to approximately 100 ft. on the Emuru Akirim plateau, where only a single flow, a basalt, is exposed. The upper surface of the Tirr Tirr plateau is composed of trachyte, which outcrops as rounded boulders, but below this in the western and northern parts, are several other flows, the nature of which is not known. Along the eastern margin of the plateau the series consists only of a trachyte overlying two basalts, the lower of which is similar to the basalt on Emuru Akirim. At Lowoi, on the west, basic trachyte occur as numbers of thin flows with intervening tuffs, and are frequently capped by a massive olivine basalt that forms the surface of the fault-blocks.

The lavas forming the Tirr Tirr plateau can be seen to rest with marked unconformity on the dipping basalts beneath. Viewing the plateau from the east this relationship is not obvious, but on traversing the valleys on the east side of the plateau the unconformity is easily seen high on the face of the escarpment (fig. 8). The unconformity is also readily visible among the fault-blocks at the western edge of the plateau, in the escarpments overlooking the Suguta valley.

Petrographically the basalts of Emuru Akirim, the east Tirr Tirr scarp and the basal flows near Lowoi are very similar. They are medium grey, paler than the olivine and augite basalts of the preceeding formations, and with a tendency to irregular fracture. Altered reddish brown olivine phenocrysts are common but felspar phenocrysts are rare and only reach five to six millimetres in length. Under the microscope the matrix is seen to be typically basaltic—small basic plagioclase prisms, purplish augite granules and abundant iron ore grains occur. Augite micro-phenocrysts are common, and olivine occurs as patchily distributed, locally abundant small granules partly or completely altered to iddingsite. Examples of these rocks are specimen 27/313, from the edge of the Tirr Tirr plateau opposite Emuru Etuku, and specimen 27/314, from the south-western extremity of the Emuru Akirim plateau.

The trachytes closely resemble the basalts in the field being greenish in tone and only slightly lighter in colour, and having a tendency to form fissile outcrops. In thin section (specimens 27/300 and 27/301, from Lowoi and four miles south-east of Lowoi respectively) they are distinctive rocks with light green aegirine micro-phenocrysts, scattered alkali felspar phenocrysts, and groundmasses of oligoclase prisms showing a fluidal texture. Small elongated purplish augites occur in the felspathic matrix together with iron ore dust in the intergranular spaces. Both the rocks mentioned are rather basic alkali trachytes.

The Tirr Tirr Series is faulted by a system of closely-spaced parallel faults of moderate throw, downthrowing eastwards over the greater part of the plateau, but westwards along its western edge. The series dips at angles up to three degrees west-north-westwards over much of the plateau, but is nearly horizontal along its eastern edge. The Emuru Akirim plateau is practically horizontal and is affected by only a few faults of minor throw. The difference in height between the base of the series on the west face of the Emuru Akirim plateau and the east face of the Tirr Tirr plateau is due to the tilting and consequent depression of the Tirr Tirr plateau relative to the Emuru Akirim plateau.

The Tirr Tirr Series was erupted after the greater part of the westward tilting that affected the older volcanic rocks had taken place and before the faulting. It is possible that the Emuruagiring quartz trachyte referred to by Shackleton (1946, pp. 39-40) is of the same age as the Tirr Tirr Series, for it forms a flat faulted plateau resting with obvious unconformity on dipping phonolites and basalts. The Tirr Tirr plateau extends northwards towards the eastern end of the Barrier range at the south end of Lake Rudolf, a range composed of phonolites and phonolitic trachytes much older than the very recent volcanics that occur about the Teleki and Likaiyu volcanoes (Champion, 1937, pp. 169-172). The lavas of the Barrier are extensively faulted in a fashion similar to the Tirr Tirr Series, and are shown on a map by Fuchs (1939, Plate 32*) as lower and middle Pleistocene basalts and trachytes.

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* On Fuchs' map the area immediately west and south-west of Mount Nyiro is incorrectly shown as composed of Basement System rocks. It is in fact formed by a plateau of Tirr Tirr lavas dipping gently northwards.

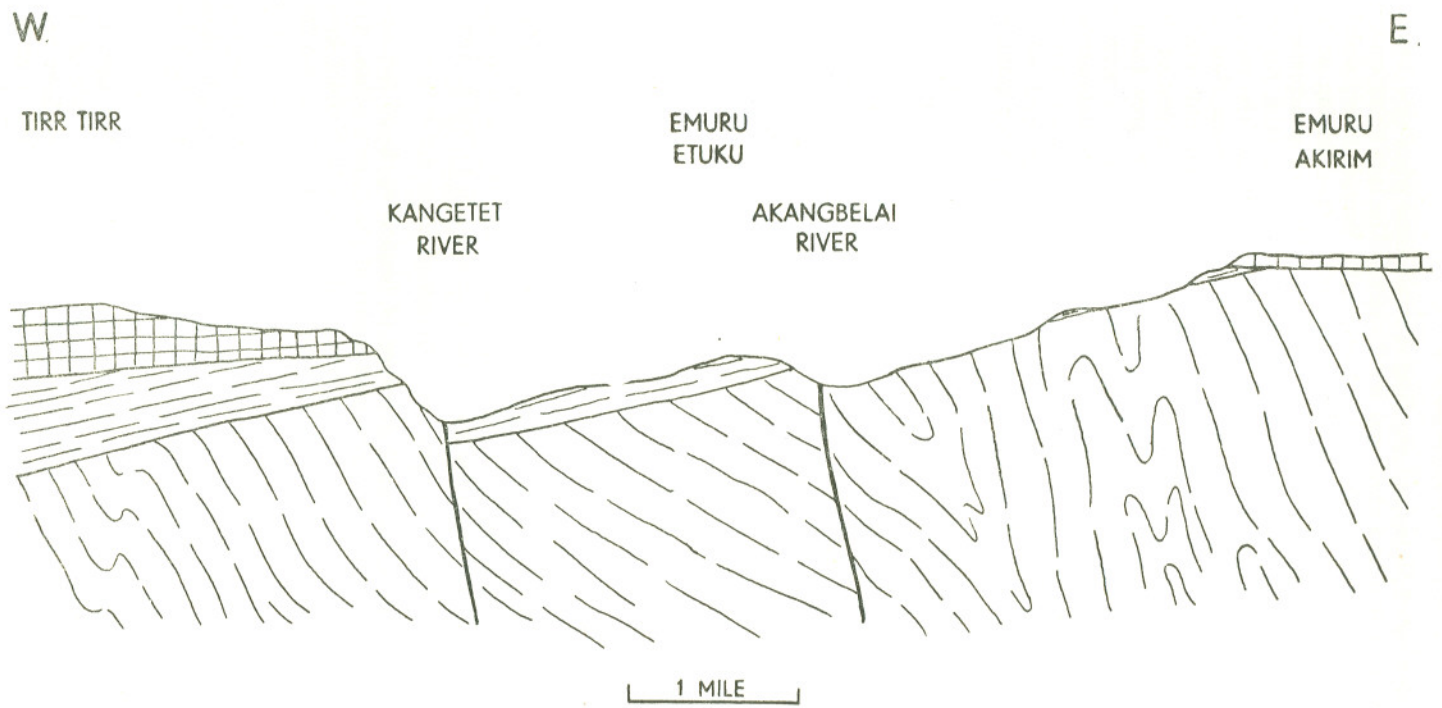


Fig. 8—The unconformity below the Tirr Tirr Series. Diagrammatic, vertical scale exaggerated

(7) Olivine Basalts

East, north and north-west of Soitoniron are several small areas of olivine basalt, in the form of a discontinuous thin lava sheet and small stocks. The lava sheet occurs at an altitude of 4,200 ft., 250 ft. above the bed of the nearby Baragoi river, and is thin, probably no thicker than 15 ft., and rests on a uniform surface sloping gently westwards. This surface is at much the same level as the sub-Miocene peneplain in this vicinity, but this can not be taken as indicative of the age of the basalts, for the sub-Miocene surface has been protected from erosion by the Tertiary lavas. The basalts occur in the form of rounded boulders and large blocks split by curved joints. Locally they contain minute felspar phenocrysts but commonly the phenocrysts are only visible under the microscope. Specimen 27/228, from the southern edge of the largest of the basalt outcrops north-west of Soitoniron, is a compact dark brownish grey faintly mottled rock with scattered vesicles filled with calcite. In thin section it is seen to contain small glomero-porphyritic groups composed of basic plagioclase (labradorite An_{60}) and poorly formed augite grains. The augite grains seem to adhere to the margins of the plagioclase grains. The groundmass contains purplish augite and olivine micro-phenocrysts in a matrix of plagioclase microlites with augite and iron ore granules.

Two small stocks occur in the lower part of the Lanana river in the south-east part of the area. They were not visited, but are believed to be formed of similar basalts.

The basalt near Soitoniron was referred to by Shackleton (1946, p. 39) and has already been mentioned on p. 6 of this report. As there stated the writer hesitates to correlate this basalt with the Laikipian basalts as described by Gregory (1921, pp. 204-205; see also Shackleton, 1946, p. 38), as was suggested by Shackleton (*op. cit.*, p. 39). It is probably a much younger rock, perhaps middle or upper Pleistocene, and of the same age as the basalts which occur on the end-Tertiary peneplain east of the Musei mountains (cf. Dixey, 1948, pp. 7-8).

(8) Fluviatile and Lacustrine Sediments

These beds include a number of isolated occurrences of fluviatile and lacustrine deposits formed at the time when the Suguta valley was occupied by a lake of considerable size. Immediately west of Kongia springs there are fluviatile terraces composed of silts, gravels and boulder beds of volcanic material up to 75 ft. in thickness, the upper surface of the terrace being at approximately 1,800 ft., 400 ft. above the floor of the Suguta valley one and a half miles to the west. These deposits must have been formed at a time when the Suguta valley was occupied by a lake reaching 250 to 300 ft. above the present valley floor.

Immediately north of Kanganya, a small exposure of bedded brick-red volcanic gravel appears to be a relic of lake beds that occupied a part of the Suguta valley. On the side of the entrance to the Nitelejo gorge also laminated clays with boulder beds are banked against a slope of lava boulders at a height of about 150 ft. above the valley floor.

Extensive river terraces occur in the Nanganyamonyen valley in the south-western part of the area. These were not visited during the survey but aerial photographs show at least three well marked terraces reaching a height of several hundred feet above the floor of the valley on its western side.

The occurrence of these terraces and remnants of lake beds, together with the flight of beach terraces which was observed in the distance on the western side of the Suguta valley, prove that the valley was occupied by a lake. This lake must have been connected, directly or indirectly, with lake Rudolf. The beds are, therefore, regarded as ranging from middle Pleistocene to Recent age (cf. Fuchs, 1939, pp. 247-254).

(9) Basalt (?), Suguta Valley

During compilation of the geological map after the field survey was completed it was found that a small part of a very recent lava flow occurs in the north-western extremity of the area. The Suguta river could not be crossed at the time of the survey due to floods and the lava was not examined. The flow originates from a small breached cone on the west side of the valley and flows eastwards, covering an area of five or six square miles. Concentric structures on its surface, the lack of vegetation, and its fresh appearance suggest that it is a very recent lava, possibly of the same age as the flows from Teleki and Likaiyu volcanoes at the south end of Lake Rudolf (Champion, 1937, pp. 164-169).

3. Superficial Deposits

The soils of the El Barta plains are reddish brown and sandy and with occasional layers of quartz pebbles. In some streams the lower part of the soil is seen to be full of small kunkar nodules. In the more eroded areas the soils are essentially fine sand on the surface, the finer soil fraction having been washed into the shallow valleys where the soils are brown to grey and clay-like.

In the north-east corner of the area, on the end-Tertiary erosion surface, the surface material is unconsolidated sand of considerable depth.

The volcanic plateaux are covered by lava rubble and thin dusty reddish brown soil with dark clay patches in hollows and other places of poor drainage. In the more dissected parts of the volcanic area soil is scarce, and superficial material is largely lava fragments of various sizes with little fine material.

The superficial deposits of the Suguta valley are gravels and boulder beds forming the outwash fans of the rivers. The central part of the valley consists of very fine pale reddish brown clay that exhibits large drying cracks.

V—METAMORPHISM AND GRANITIZATION

The physio-chemical conditions governing the formation of the metamorphic complex of the Baragoi area differ only in detail from those postulated for other areas. The rocks of the present area are regarded as having been derived from a crudely layered sequence of basic igneous rocks intercalated with sediments such as limestones, shales and sandstones. These became depressed deep into the earth's crust and were subjected to regional metamorphism, folding and granitization. These three processes occurred in the order written, but overlapped considerably in time.

The regional metamorphism, which was syntectonic with the earlier stages of deformation, gave rise to a banded crystalline rock mass of medium grade of metamorphism. The co-existence of calcite and quartz in certain limestones sets an upper limit to the pressure-temperature conditions reached, which were appropriate to the staurolite-kyanite sub-facies of the amphibolite facies (Turner, 1948, pp. 81-85). The absence of sillimanite and rarity of pyroxenes suggests that temperatures were moderate. Shear inhibited the formation of the typical "contact" or anti-stress minerals such as andalusite and cordierite, and was responsible for the formation of zoisite from calcic plagioclase, actinolite from hornblende and other strictly retrogressive effects such as the formation of chlorite-magnetite schists in response to falling temperature.

The parageneses among the derivatives of the basic igneous rocks are essentially retrogressive (cf. Wiseman, 1934) and were "triggered" by shear. The adjustment of these rocks to amphibolite facies conditions is usually complete; assemblages not in equilibrium are rare and relic minerals scarce. Whereas the above transformations of a retrogressive nature took place at the height of regional metamorphism, the other

retrogressive effects such as the formation of chlorite schists took place during the period of declining temperature, and both these must be distinguished from hydrothermal alterations such as resulted in the formation of talc, serpentine and calcite in the metamorphosed ultra-basic rocks.

No significant variations in the grade of metamorphism are noticeable in the area, not even in the migmatite zones or in the proximity to intrusive granites. This suggests that granitization and granitic intrusion contributed little or none of the heat required for regional metamorphism (Turner, 1948, pp. 291-293).

It is a common observation that granitization zones are also zones of complex structure, and it is also clear that structure largely controlled the position of granitization centres such as the Morilem hornblende migmatite area in the core of the Morilem syncline, the migmatites in the Atagirion anticline, and in the complex area west of Ngoriche hill. It follows that granitization was most easily effected in the most deformed rocks and that the main folds in the area were in being before the granitization reached its maximum. The form of minor structures within the granitized areas, however, is also complex and often distinctive, and it follows that these are due to inherent structural peculiarities of the migmatites, and were formed at the height of granitization. The migmatites behaved as *b*-tectonites throughout their formation, and it is only where they exhibit definite intrusive features that they appear to have deformed by viscous as opposed to plastic flow.

The process of granitization is envisaged as taking place by the following sequence of events:—

(1) Formation of segregation pegmatites; much of the material required for the process being derived from the adjacent metamorphic rocks.

(2) Soda metasomatism; permeation of the rocks by alkaline water-rich fluids resulting in oligoclase porphyroblast gneisses locally.

(3) Potash metasomatism supersedes the soda metasomatism; growth of microcline in intergranular spaces; transformations such as hornblende + basic plagioclase → biotite + epidote + oligoclase + microcline + quartz are characteristic. In semi-pelitic rocks the process is one of simple felspathization.

(4) Formation of hornblende and biotite granitoid gneisses and granites, some of which become mobilized and intrusive.

(5) Injection of aplite and pegmatite dykes.

In the scheme outlined above granitization is seen as the process leading to the formation of intrusive granites rather than the reverse process, which is that intrusion of granite is responsible for the granitization. The close textural and compositional similarity of the more intensely granitized rocks to the mobilized granites, a similarity noted also by Schoeman (1951, p. 17), is confirmation of this view. This similarity extends even to the aplites, which are remarkable in retaining the replacement textures characteristic of the migmatites. These textures are referred to by Marmo (1955, p. 432) as characteristic of syntectonic granites, in which microcline develops in intergranular spaces as small vermicular bodies in process of enlarging themselves by replacing plagioclase and quartz. A common stage, which is seen in the aplites and fine-grained granites, is when the microcline forms a "mesh" enclosing individual grains and aggregates of grains of plagioclase and quartz. A further stage is seen in the Baragoi granites and granitoid gneisses. The microcline "mesh" locally replaces the included grains completely and amalgamates to form porphyroblastic crystals crowded with inclusions.

Whereas the migmatites are definitely syntectonic, the intrusives derived from them show comparatively little evidence of deformation. Among the rocks produced by granitization there is an easily detectable sequence in which deformative effects decrease markedly, as follows:—

(1) Migmatites (always strongly deformed).
(2) Rheomorphic granitoid migmatites.
(3) Granite dykes and bosses.
(4) Aplites.
(5) Pegmatites (rarely deformed).

The aplites are frequently faintly foliated; the pegmatites very rarely so, and it appears that deformation decreased steadily during the intrusive phase.

VI—STRUCTURE

1. Structures in the Precambrian Rocks

Because of good exposure over most of the area and the comparative simplicity of the larger structures, it proved possible to determine the nature of the megascopic structures in the field, and to confirm them by means of geometrical analysis of foliation and lineation. A high degree of similarity was observed between macroscopic and megascopic tectonic style throughout the area, but it was also found that, whereas the megascopic structure viewed on the scale of the area as a whole is simple, the macroscopic structure observed on single exposures was locally complex. There is, therefore, contrary to the general rule, an increase of structural homogeneity with increase in scale.

Definition of some of the structural terms used in the following discussion is desirable to avoid confusion. The term *foliation* is employed throughout in its broadest non-genetic sense, is synonymous with schistosity, and is used to ". . . cover all those megascopically conspicuous parallel fabrics of metamorphic origin which impart a definite fissibility to the rocks in which they occur . . ." (Turner, 1948, p. 275). Foliation can conveniently be symbolized by S, S_1 and S_2, to denote the order of formation of foliations in rocks containing several foliations. S_1 or S_2 may not have the same tectonic significance in adjacent exposures, however, and such distinctions are valid only for the field described, usually a single exposure.

Lineation is defined as any linear element in the fabric of a metamorphic rock, and it follows that it is generally formed on foliation surfaces in rocks that have suffered penetrative deformation and is usually of three main types, which are described and discussed by Turner and Verhoogen (1951, pp. 533-534).

(1) Megascopic Structures

The megascopic structure of the area is dominated by the Morilem syncline, a large fold of comparatively simple character near its closure in the south-east of the area, and which becomes locally overturned in the vicinity of Nagiss and Gelai. The syncline plunges towards the north-north-west at an angle between 20 and 30 degrees near the nose of the fold, but north of a line joining Uass Aibarr mountain in the east to Tipaku in the south-centre of the area, the plunge is reversed and is to the south-south-east. Towards the northern part of the area the syncline passes into a series of folds plunging at shallow angles generally southwards. From west to east the folds of this northern part of the area are (Fig. 16, at end):—

(1) The Atagirion complex anticline; broad and complex fold with steep western limb and dimpled crest.

(2) The Kowop folds; characterised by compressed steep limbs—the folds are of "concertina" style.

(3) The shallow Soit Olbayen syncline.

(4) The Butabut anticline.

(5) The Koitokol syncline, which is characterised by two reversals of plunge, Koitokol having a "canoe shaped" structure.

Among the relatively minor north-north-westerly plunging structures in the limbs of the Morilem syncline are the small folds east of Kangura, and the Gurika and Kileshwa folds north-east of Lesirikan. These are "drag-folds" in the limbs of the Morilem syncline.

The axial planes of the folds are generally vertical or dip steeply. The folds are broadly cylindroidal, with locally a tendency to isoclinal style. No thrust faults were recognized in the area but localized zones of shearing were mapped west and south of Ngoriche, along the western margin of the Soit Nyiro-Gurika granitoid gneiss zone and in the migmatite zone of the Lamerok river.

(2) Macroscopic Structures

With the exception of some of the plagioclase amphibolites, amphibolites, pegmatites and aplites, most of the metamorphic rocks are foliated to some degree. The micaceous gneisses are often flaggy with the compositional banding paralleled by prominent partings, the banding being emphasized by the preferred orientation of micaceous and prismatic minerals, the latter frequently parallel to the margins of the larger rock-bodies of undoubted metasedimentary origin such as marbles and some quartzites, and it appears likely that the principal foliation of the area as a whole parallels the bedding of the metasedimentary rocks. Numerous cases were observed, however, where a second foliation had been formed transverse to the regional foliation, and it is likely that in many localities a secondary foliation occurs where there is no evidence to identify it as such.

Folds on the macroscopic scale are plentiful throughout the area, especially in the micaceous rocks and in the migmatites. They are of two main types: flexural-slip folds and slip-folds (Turner, 1948, p. 165, p. 173); some of the former are illustrated in Plate IV, figures 1 and 2 and in Figure 9.

The flexural-slip folds are characterized by variability of wave-length, simple cylindroidal pattern, and by the presence in them of only one foliation which is paralleled by the planar and linear fabric elements. These folds are the small-scale counterparts of the megascopic folds, and frequently have minutely corrugated limbs giving the rocks a fibrous appearance, and yielding a strong lineation. These lineations, and others due to the stretching out of augen, preferred orientation of amphibole prisms, and trains of mica flakes on foliation surfaces are invariably parallel to the axes of these folds on all scales.

The slip-folds are almost excusively confined to areas of migmatization, and differ markedly in form from the simple flexural-slip folds (*see* Fig. 10). They have a wave-length rarely exceeding three feet, and seem to have no replica on the megascopic scale. The foliation defined by the orientation of micas is invariably transverse to the compositional banding which defines an older foliation. The folding of the composition (S_1) layers is acute, but the micaceous foliation (S_2) is invariably parallel to the axial planes of the folds. Comparable folds appear to be widespread among the Moine rocks of Central Scotland, and King and Rast (1956, fig. 2c, 4a, pp. 246, 250) have figured identical folds which they attribute to shearing. Folds of this style are formed by the development of parallel penetrative slip-planes transecting the original foliation of the rocks. Non-affine slip on these planes gives rise to slip-folds of complex form. Such folds are frequently rootless and can occasionally only be recognized by the presence of small arcuate bodies of distinctive appearance in laminated uniform rocks. A faint lineation is generally observed on the foliation surfaces of slip-folded rocks, and is

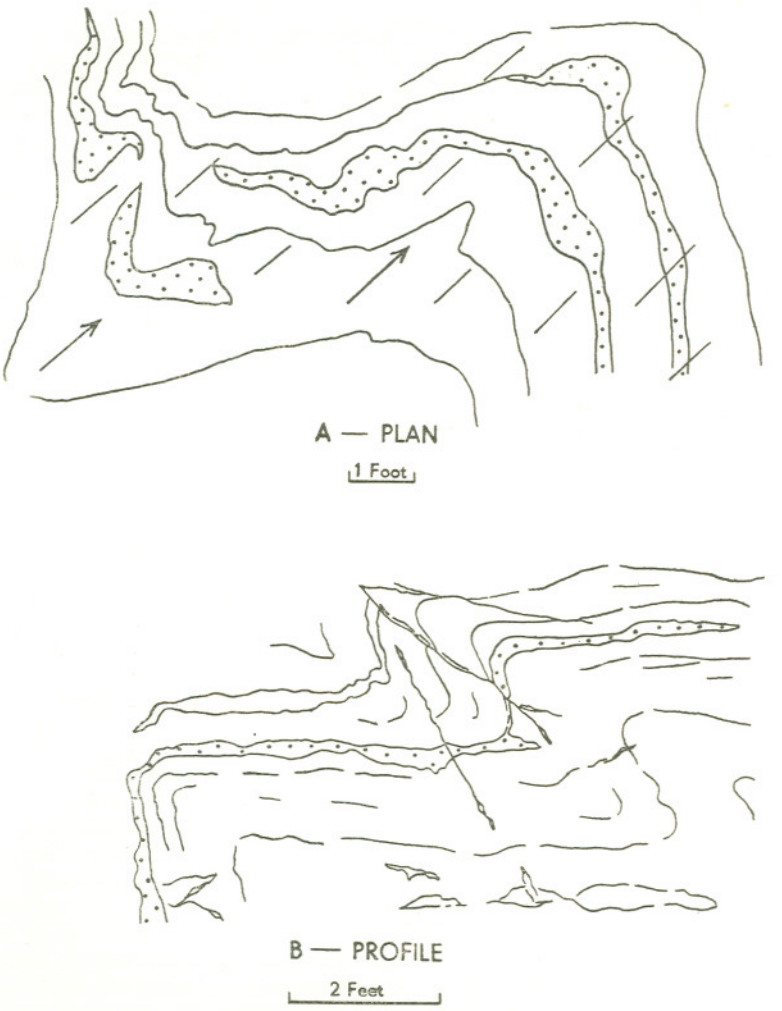
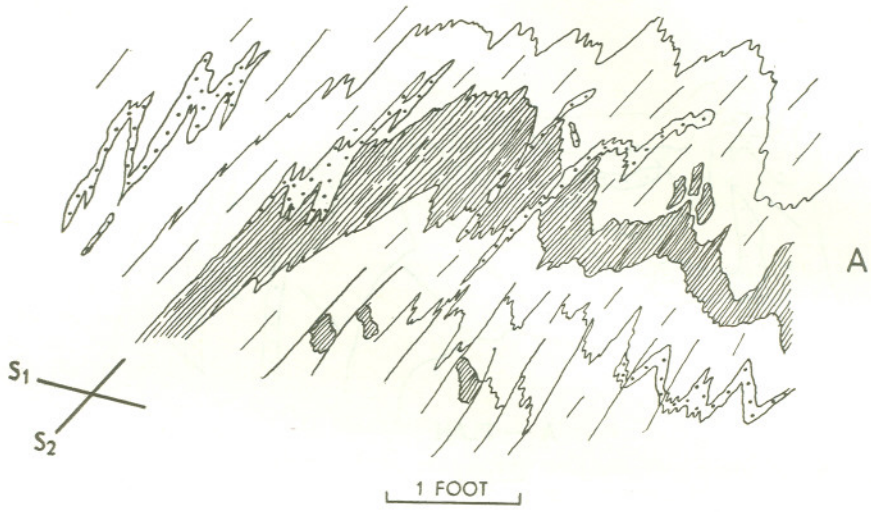
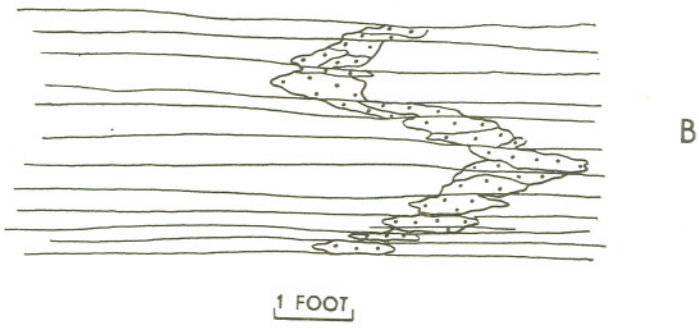


Fig. 9—Diagrams of flexural-slip folds

invariably parallel to the axes of the slip-folds, being formed by the intersection of the compositional layering (S_1) and the slip-planes (S_2). The fold-axes and the lineation are not usually parallel to the regional flexural-slip fold-axes on any scale, for the geometry of the slip-folds is determined solely by the orientation of the planes S_1 and S_2, which may be fortuitous. This is demonstrated in cross-cutting pegmatites and dykes. In these cases the transcurrent pegmatites and dykes which one may assume were originally planar, have become slip-folded as a result of non-affine slip on the foliation of the host-rocks. These structures, which are prevalent in migmatitic zones (*see* Fig. 9), are very similar to some figured by Shackleton (1946, p. 14), and which he describes as having no evident relation to the regional tectonic pattern, and as being "unsystematic contortions". Statistical analysis of such structures in the Baragoi area reveals that locally the slip-folds may be broadly co-axial over a limited area, and that the unsystematic appearance of the folding is due to the presence of diverse flexural-slip and slip-folds in the same exposures.





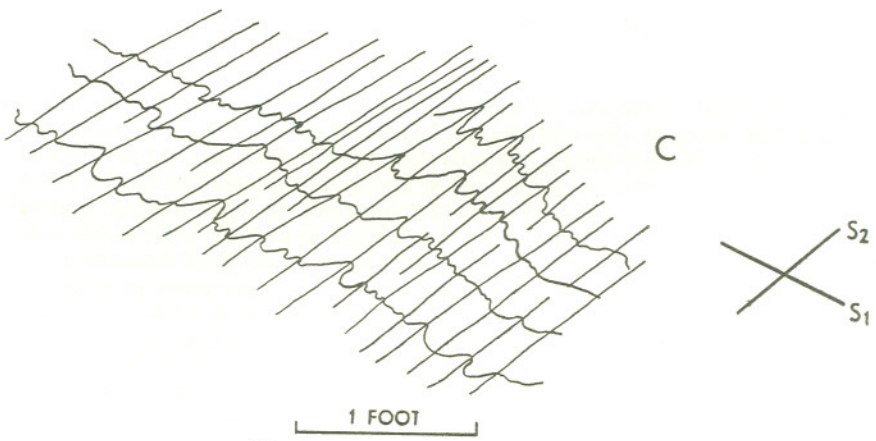


Fig. 10—Profiles of slip-folds

Additional complexity is often introduced in migmatite zones and in some other rocks with a well marked micaceous foliation by deformation by "flattening" (Turner, 1948, pp. 166-172), and Ramberg (1956, pp. 192-193) has convincingly demonstrated that ptygmatic structures may develop by flattening movements. The structures in the Lanana river migmatite (fig. 3) may well have developed by slip and flattening operating in small overlapping phases. Where such structures are observed monoclinic symmetry is lost and fold forms are orthorhombic or unsystematic. There is thus every gradation of fold forms of ptygmatic style to those of simple slip or shear.

In areas where slip-folding is prevalent it is commonplace to observe that the composition layering and foliation are parallel over considerable areas, and that S_1 and S_2 can only be differentiated locally. This raises two possibilities:—

(1) Slip on S_2 has completely reorientated S_1—S_1 is recognizable only where the culminations of small slip-folds remain.

(2) that no S_2 planes developed except in a few zones of complex structure and that the slip-folds are often modified flexural slip-folds.

If the first possibility is accepted, one has to assume that the foliation over large areas bears little relation to the original bedding foliation. This concept would introduce considerable complexity into the structure of the area as a whole, a complexity that does not, in fact, exist, for analysis of the compositional foliation shows that it conforms to the same tectonic style as folded metasedimentary beds. It is far more likely that the slip-folds are developments of flexural-slip folds, and that the S_2 foliation is only locally distinct from S_1. The development of slip-folds in this manner was noted in the Baragoi area, and has also been observed in Scotland by King and Rast (1956, p. 194) who suggested that the "shear" folds of south-eastern Cowal developed from simple flexural folds.

In zones of migmatites, where the development of mica in plagioclase amphibolites occurs early in the history of granitization, flexural-slip folds are the first to form in response to deformation. Continued folding takes place in this style until the folds are more or less isoclinal, with closely compressed sub-parallel limbs and squeezed out cores. Continued deformation under the effect of the same forces can then only take place by flattening (Turner, 1948, pp. 166-172), or by shear along the now almost uniformly flat foliation (S). Transport by such shear will result in the elongation of the limbs of the folds and give rise to a second foliation (S_2) in the noses of the folds. At this stage S_2 coincides with S_1 everywhere except in the nose of the fold. Transport on S_2 may then attenuate the remnants of S_1 in the nose of the fold and transpose S_1 into S_2. At this stage all recognizable trace of the flexual-slip fold has disappeared. What can be detected in the field are the intermediate stages in the destruction of the flexural-slip folds. Non-affine slip on S_2 can complicate the form of the original fold at its closure with the production of a number of smaller carinate folds of a distinctive complex style. The limbs of such folds merge into the adjacent planar foliation and they appear to be root-less folds, "floating" in the foliation. Such structures have been explained as due to "plastic" deformation and writers have frequently assumed that the rocks in which they occur acquired a mobility approaching that of magma.

A few cases were observed in the Baragoi and Lebanyuki rivers north and north-west of Baragoi where transverse slip-planes (S_2) are developed that are totally unrelated to any pre-existing foliation. In the Baragoi river near the road crossing north-east of Baragoi, transposition of S_1 into S_2 is complete over a zone up to five feet wide and the margin of the slip-zone contains slip-folds indicating the sense of the slip (*see* Fig. 11). In the Lebanyuki river section, around the granitoid gneiss mass west of Ngoriche, the development of secondary foliation by slip is excellently shown in numerous exposures. Shallow-dipping slip-zones traverse the rocks and are expressed as narrow simple shear-zones, broader zones in which micas are re-orientated into the

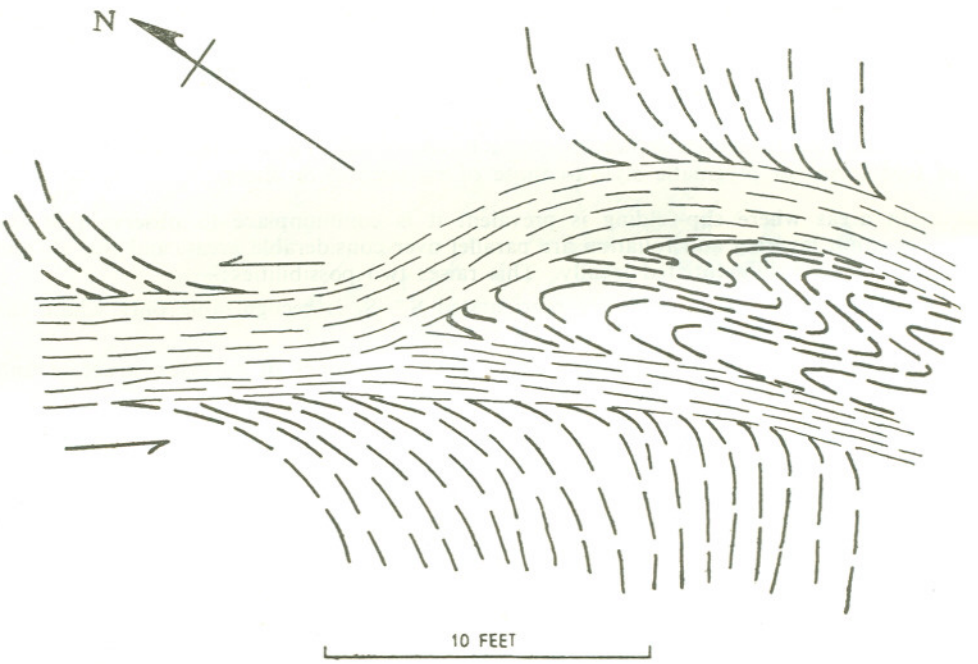


Fig. 11—Transposition of foliation by slip, Baragoi R., one mile north-east of Baragoi

plane of slip, and zones of partial transposition and slip-folding in which the original foliation of the rocks is largely destroyed. Narrow micropegmatite streaks frequently occupy slip-planes and small-scale slip-folding of the older foliation is commonplace. The majority of lineations conform to the local *B*-axis, which plunges gently to the south-south-east, but other lineations are given in Fig. 12, which illustrates that the anomalous lineations plunging into the north-east and south-west quadrants are due to the intersection of the original foliation S_1 and the penetrative slip-planes S_2. The axes of the slip-folds are broadly co-axial with the lineation L_2, but show a tendency to swing towards the regional *B*-axis.

The different varieties of slip-folds can be summarized as follows:—

(*a*) Slip-folds developed from flexural-slip folds.

(*b*) Slip-folds formed by non-affine slip on a plane, causing folding of the original foliation.

(*c*) Slip-folds in cross-cutting dykes and pegmatites due to non-affine slip on the foliation of the country rock.

Slip on intersecting plane surfaces.—Only two good examples of this type of deformation were seen and it is significant that in both cases the rocks concerned are pegmatites. The better of the two exposures occurs two miles west-north-west of Barenyiro hill where a large exfoliation pavement of pegmatite shows closely-spaced plane fractures dipping steeply westwards and intersecting at an angle of approximately 50 degrees. The fabric of the rock is fibrous, the felspars being up to one inch wide

and nine inches long. Muscovite is distributed as minute flakes on the fracture planes, and quartz appears to have become granulated. Such a fabric must have developed as a result of simultaneous slip on the two intersecting surfaces, with extension of the fabric in the direction defined by the intersection of the two planes (Turner, 1948, pp. 166-169).

Some steeply plunging lineations observed near the western contact of the augen granitoid gneiss south-west of Soit Nyiro may be due to a similar process, but the intersecting planes were not seen at this locality.

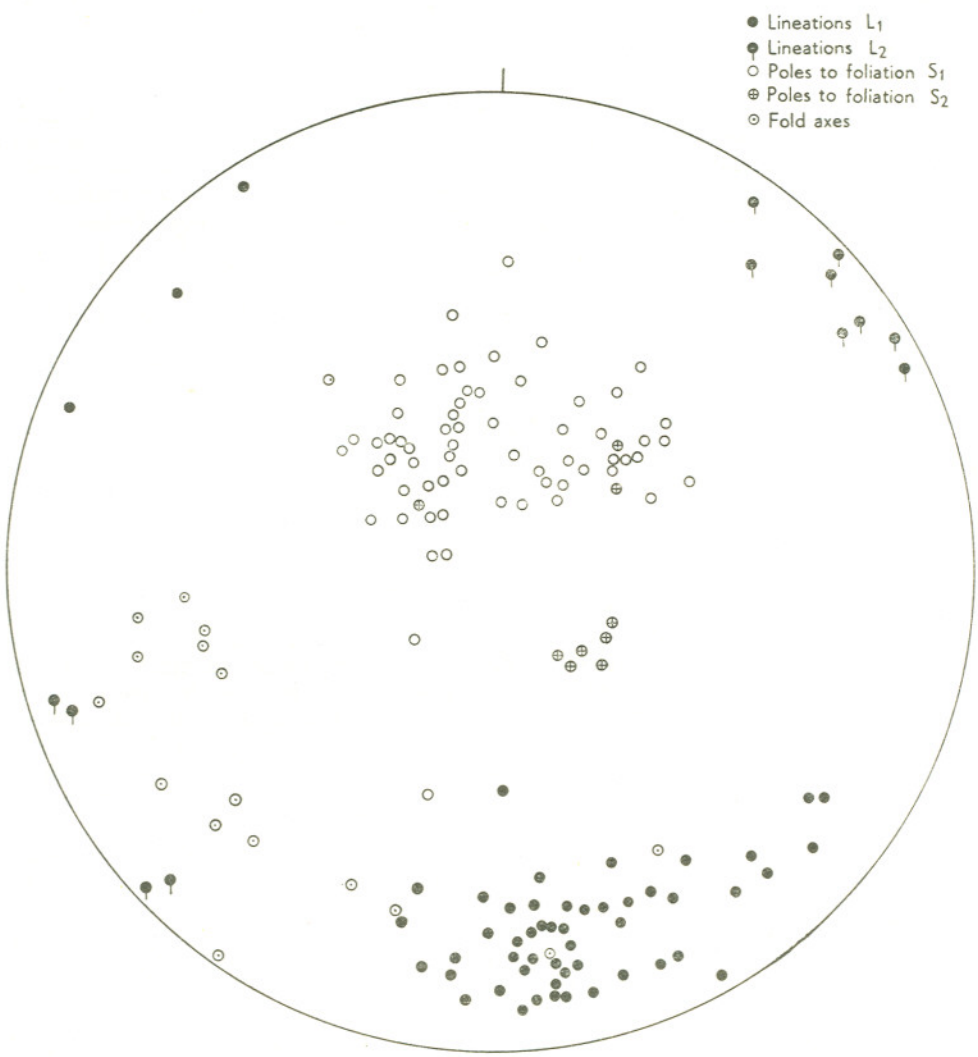


Fig. 12—Stereographic projection of structural data from the Lebanyuki river, four miles south-west of Ngoriche

Many of the epidiorite dykes cutting the Basement System are foliated parallel to the walls rather than parallel to the foliation of the host-rock. This condition exists where the dykes are sub-normal to the foliation of the host-rock. Where they are orientated sub-parallel to the foliation they are commonly slip-folded with slip-planes parallel to the local foliation. Many of the aplite dykes are poorly foliated parallel to their length, and show localized schistosity and textural changes due to deformation.

Most of the features described above i.e. flexural-slip and slip-folding, transverse slip-zones, deformation of plane dykes etc. are well exposed in the Lebanyuki river north-west of Baragoi. The exposures form part of a zone of structural complexity passing north-north-westwards from Baragoi towards Kowop South. In the northern part of the zone, three miles west of Ngoriche, a stream section exposes a *mélange,* of hornblendic rocks containing tectonic lenticles of granite. Locally granite dykes cut across the *mélange,* however, indicating that most of the deformation preceded the intrusion of the dykes.

A *mélange* zone occurs also in the core of the Kileshwa syncline, where the rocks are graphitic schists and marbles, and marble lenses and fragments are found as tectonic inclusions in the contorted and broken graphitic schists. A further zone of complex structure extends approximately along the lower Lamerok river. Here the hornblendic rocks have no regular foliation and are cut by numerous small post-crystallization fractures.

In two places small folds that differ markedly from those already described were observed. In both cases the folds are small, with a wave-length of about one foot, and are about sub-vertical axes. A single lineation visible in these folds was observed on foliation surfaces to be folded about the vertical axes. No lineation parallel to the fold axes was seen. These folds must be later than the main folding and of only local significance. They may be due to local penetrative deformation.

(3) Synthesis of Basement System Structures

To assist in the structural interpretation several hundred observations of the orientation and nature of foliations, schistosities and lineations were made, and the data plotted for comparatively small fields of investigation on equal area stereographic projections. It became apparent that the degree of structural homogeneity was moderate to low on all scales in some areas and very low to non-existent in others. The low degree of homogeneity is apparent in fig. 13 *a* and *b*, which show that there is considerable variation in both lineation and foliation in the area as a whole. Nevertheless plots of individual folds often show a moderate degree of monoclinic symmetry, sufficient to enable the fold axis (B) to be determined statistically, and to show that in almost every case the statistical maxima of lineations in such homogeneous areas are *b*-lineations by definition (Turner, 1948, p. 198) and together define the regional B-axis for the area as a whole. The attitude of *b* (B) varies through an angle of approximately 50 degrees in the horizontal and vertical planes. Although the symmetry of the structures on the intermediate scale is often monoclinic the symmetry of the whole area is slightly triclinic, and is probably due to restriction applied to the deforming rock pile from north or south or both, giving rise to the gentle undulation and curvature of the B-axis.

The style of folding in a part of the area that has good homogeneity and monoclinic symmetry, i.e. the south-eastern part of the area, which includes the nose of the broad north-westerly plunging Morilem syncline, is illustrated by a profile in Fig. 15.

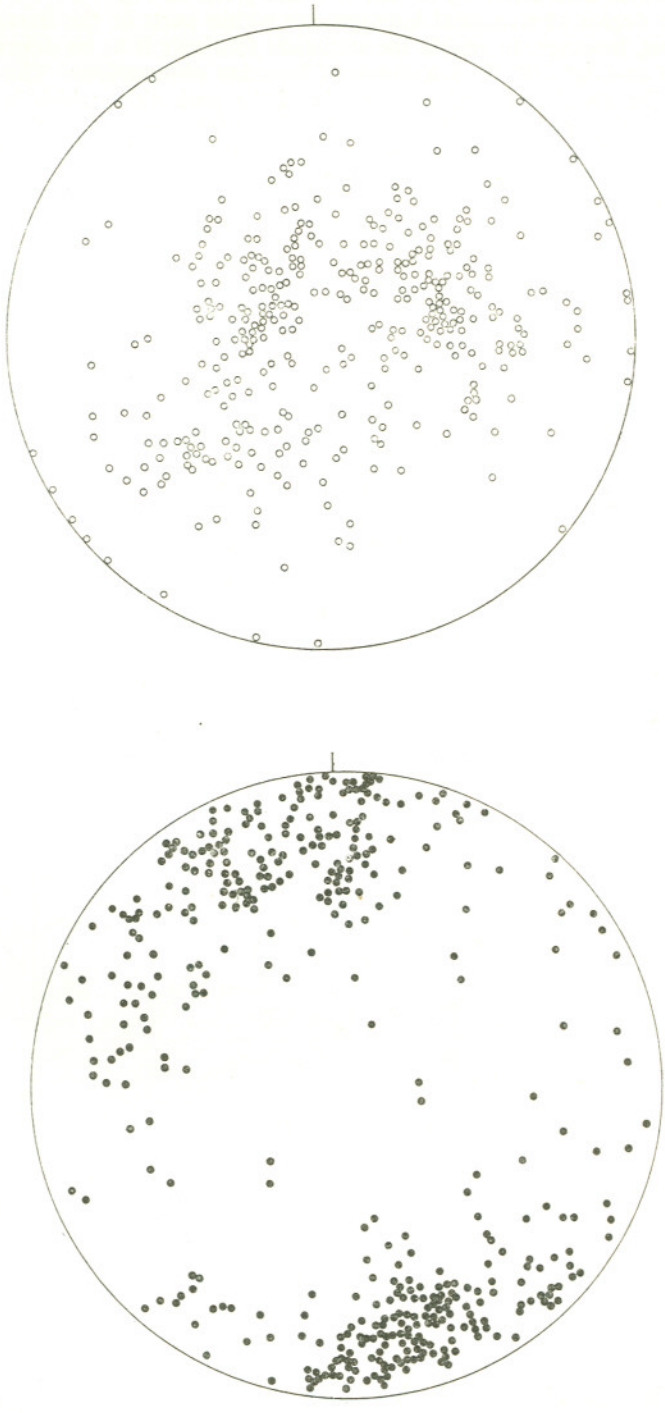


Fig. 13—Stereographic equal area plots on the lower hemisphere of all lineations and foliations observed in the Baragoi area. (a) 338 poles to foliation. (b) 415 lineations

The structural data referring to this area are given in Fig. 14, which indicates the only moderate degree of structural homogeneity within parts of the Baragoi area. The diagram suffices, however, to enable the statistical fold axis B to be determined, and to show that it is co-axial with the maximum of lineation observations. The scatter of the poles to foliation about the ideal great circle of the projection, which is marked by a dashed line in the figure, is regarded as partly due to inhomogeneity of structure, partly to lenticularity of beds, and partly to complications of structure such as the swell of the foliation about the Luwamara granite.

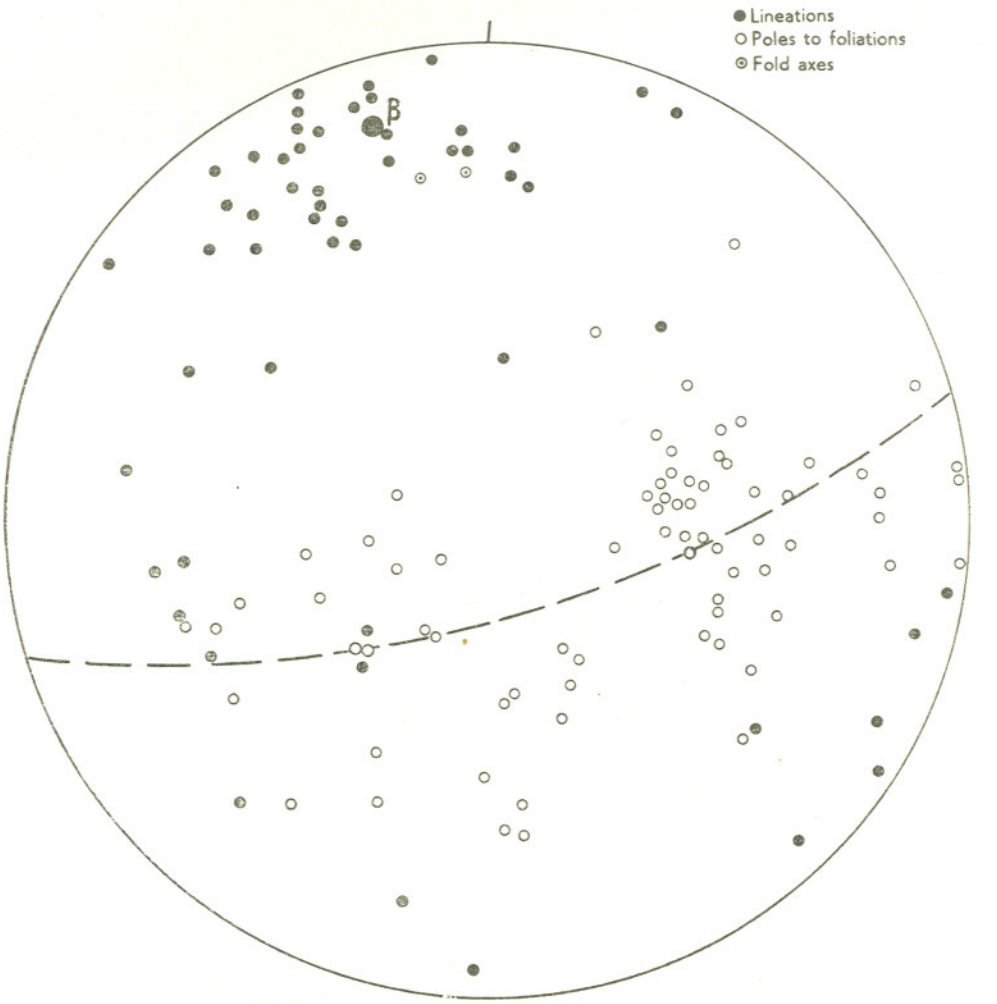


Fig. 14—Stereographic projection of poles to foliation, and lineation, in the south-eastern part of the Baragoi area

The profile (Fig. 15), is a projection of the south-east corner of the map on a plane normal to the B-axis. It gives a qualitative representation of tectonic style, and is illustrative of the degree of lenticularity of the beds.

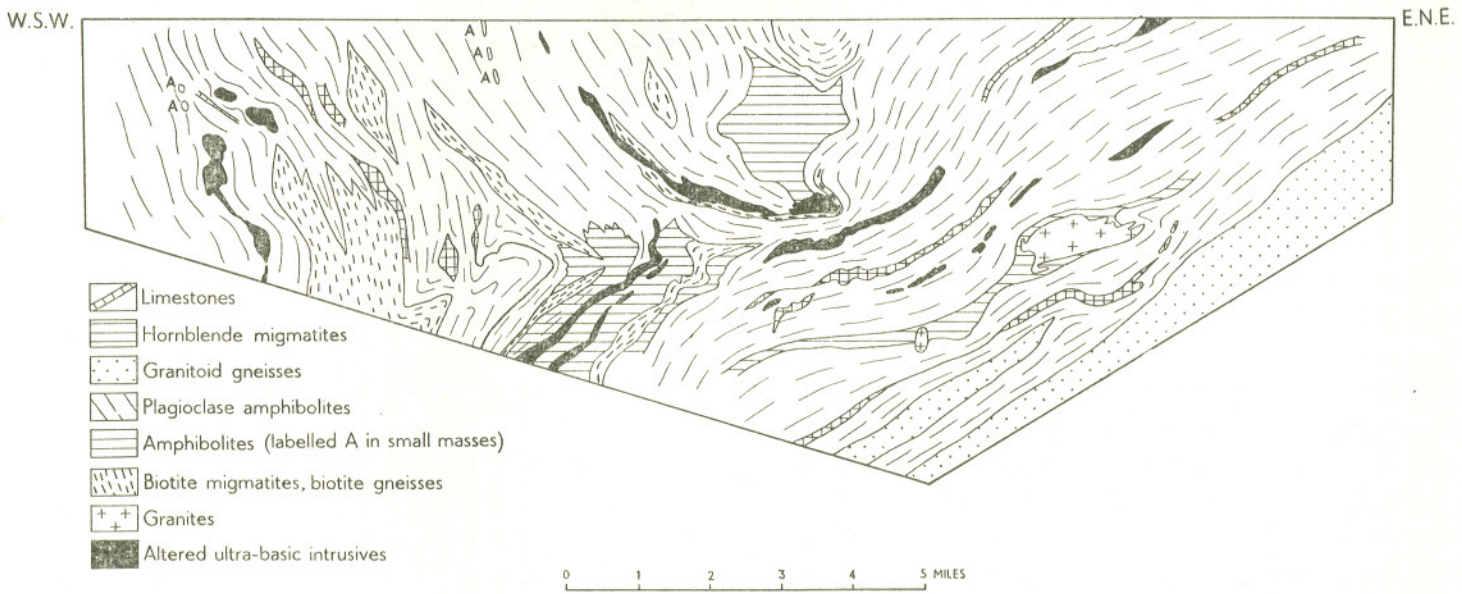


Fig. 15—Profile of the Morilem syncline

Complications of structure are invariably introduced wherever slip has taken place on surfaces oblique to the principal foliation. Such slip-planes have caused slip-folding about axes differing from the local B-axis. Zones of transposition of foliation have been observed that have destroyed the local simple symmetry of the folding, as in the region west and north-west of Ngoriche. The several factors that assist in modifying the monoclinic symmetry of the folding may be summarized as follows:—

(*a*) The presence of independent oblique slip surfaces, which are probably due to local variations in direction of movement during deformation.

(*b*) The lenticularity of the lithological units.

(*c*) Granitization, which facilitates the formation of oblique slip-planes, boudinage structure and shearing parallel to the foliation.

(*d*) The variation in trend and plunge of the regional B-axis, which is caused by factors mentioned above.

The axial planes of the megascopic folds are either vertical or dip steeply towards the west-south-west, west and west-north-west. On the assumption that the forces producing the folding acted along lines approximately normal to the axial planes of the folds, those forces must have acted on east-west lines. This generalized conclusion accords with the stress picture deduced by Shackleton (1946, pp. 26-27) for the Nanyuki-Maralal area to the south.

2. Tertiary and Quaternary Structures

The structures to be described were formed during the later Tertiary and Pleistocene periods and were associated with the movements that formed the Gregory Rift Valley, of which the Suguta valley is a part.

The volcanic rocks of the western part of the area have been folded into a gentle monocline which was recognized by Shackleton (1946, p. 46), who called it the Samburu flexure. West of longitude 36° 40′ E. the volcanic rocks dip at shallow angles to the west. The dip increases till at the western margin of the area it varies from 25 to 30 degrees to the west-north-west.

Cutting across the volcanic rocks are numbers of normal faults the majority of which downthrow to the east (*see* fig. 16, at end), that is, away from the Rift Valley. The fault pattern is reminiscent of Sikes' grid (Sikes, 1939, pp. 11-14; Baker, 1958, pp. 61-63), which is commonplace in the floor of the Rift Valley between Magadi and the Kedong valley and elsewhere. The faults are particularly easily mapped on the gently sloping Tirr Tirr plateau, where they form escarpments. The number of faults appear to decrease southwards and comparatively few were recognized by Shackleton (1946), in the area north-west of the Karissia hills.

At the eastern margin of the Suguta valley there are a number of faults downthrowing to the west—the "rift" faults of the Suguta trough (Plate II, fig. 1). These appear to be of the same age as the faults downthrowing to the east, but the amount of throw is much greater. The broader zone of faults downthrowing to the east has a different significance. The throw of the faults in the zone is small, of the order of 50 to 100 ft., and all the faults trend a few degrees east of north, and are locally parallel to the strike of the Basement System rocks. Elsewhere, however, they bear no relationship to the Basement System structures; the post-Miocene faults follow the Basement System strike where it is favourably orientated, but otherwise they cut across the older structures. No pre-Tertiary fractures that might have exerted a structural control over the post-Miocene faulting were observed anywhere in the area.

The sequence of post-Miocene tectonic events may be summarized as follows: following the eruption of the porphyritic basalts of the Samburu Series, the Rumuruti Phonolites and the olivine and augite basalts, westerly tilting affected the volcanic area west of the line Nanganyamonyen valley—Nachola-Kowop. After a short period of erosion, which was probably contemporaneous with the tilting, the Tirr Tirr Series was erupted in the north. Slight north-westerly tilting followed and was accompanied by the faulting. This phase of faulting is correlated with the faulting of the Lake Rudolf area, which was regarded as middle-Pleistocene in age by Fuchs (1939, p. 249).

The tectonic events of this section of the Rift Valley differ from those in areas further to the south. Several periods of faulting, some of them pre-middle Pleistocene, have been recognized in the Gregory Rift Valley in the Magadi and Naivasha areas, but these did not occur in the Suguta trough. The Suguta rift faulting appears to be of the same age as the final major period of faulting that affected the Rift Valley as a whole, i.e. the pre-Kamasian (middle Pleistocene) faulting. The late Tertiary and lower Pleistocene history of the Suguta trough is, however, one of vulcanicity followed by downwarping, whereas in the south it is of vulcanicity accompanied by faulting.

Several writers have perpetuated the misconception of von Höhnel (quoted in Willis, 1936, pp. 286-287), that the Rift Valley disappears a little to the north of Lake Baringo (see also Mason and Gibson, 1957, p. 32). Champion (1937, pp. 171-172) makes it clear, however, that he regards the Suguta trough as a part of the Rift Valley, and Fuchs (1939, pp. 264-267) shows that middle-Pleistocene faulting is important in defining the form of the Rudolf basin at least as far north as latitude 3° N.

VII—MINERAL DEPOSITS

1. History of Prospecting

Prospecting was carried out in the area by private individuals between late 1950 and mid-1954. No more than four or five prospectors were operative, and most of them pegged claims in the Nachola area and attempted small-scale mining of the mica pegmatites there without much success.

The chief factors that created difficulties for the prospectors were labour shortages, the great distance to the nearest rail-head (160 miles) and the poor condition of the few roads. The Samburu of the area are not anxious to undertake manual labour, and the number of Turkana who are prepared to engage in mining is very limited. The Administration is most reluctant to allow alien Turkana to enter the area, for they do their utmost to stay in the Samburu area where grazing conditions are better than in Turkana. The only alternative, the importation of labour from Nyanza or elsewhere, requires the provision of transport, housing and food on a much more lavish scale than would be necessary were local people employed.

Prospectors proposing to work in the Baragoi area require the consent of the Provincial Commissioner, Rift Valley Province, to prospect or mine in the Samburu District, and a permit to enter an "outlying district" from the District Commissioner, Maralal, in addition to the normal Prospecting Licence issued by the Commissioner of Mines and Geology, Nairobi.

The following table summarizes the prospecting activity in the area up to the end of August, 1956.

MINING LOCATIONS, BARAGOI AREA

Reg. Nos. of Claims	Name of Holder	Location	Date Registered	Date of Expiry	Minerals Discovered	Details of Production
15/1–3	P. J. Visser	Nachola ..	8–3–52	30–12–52	mica	Total mica produced together with mica from a claim near Arsim—1,750 lbs, value Sh. 8,600.
21/1–3	P. J. Visser	Nachola ..	25–6–52	30–12–52	mica	
22/1–4	P. J. Visser	Nachola	1–7–52	30–12–52	mica	
39/1–6	N. H. Visser	Nachola ..	28–10–53	5–4–54 (abandoned)	mica ..	No recorded production.
16/1	G. W. van der Merwe	S. Kowop	12–5–52	12–5–53	asbestos	No production.
17/1	G. W. van der Merwe	S. Kowop	12–5–52	12–5–53	asbestos	
20/1	G. W. van der Merwe	Nachola	20–6–52	20–6–54	mica	
19/1–4	G. W. van der Merwe	Nachola ..	19–6–52	20–6–54	mica	
3/1	W. A. Tooley ..	Nachola ..	16–7–50	16–7–51	mica ..	Approximately 60 lbs.
18/1	W. A. Tooley ..	Nachola ..	16–5–52	16–5–53	mica ..	No recorded production.

Some slight impetus was given to prospecting when metallic ores obtained from some of the Nachola pegmatites proved to be samarskite (a uranium mineral) and radio-active columbite. Beryl and chromite at Kangura were discovered at the same time, but interest flagged when it was realized that the pegmatitic ores are uneconomic.

2. Economic Minerals

(1) Mica

Mica is the only mineral recorded as having been mined in the area, and the claims were all pegged in a comparatively small area bounded by a line through Soitoniron and Nachola hill, and the Baragoi river. The workings are generally small, and numerous small prospect pits on pegmatites were found during the survey. The mica-bearing pegmatites are generally the largest of the concordant zoned pegmatites so abundant in the Nachola-Kisima zone (p. 35). Little can be said of the nature of the mica in these rocks. The old workings are largely overgrown and the faces have been stripped of mica and other minerals.

According to a departmental report made during the activity at Nachola the mica produced was mainly green or clear spotted block mica of average size four by four inches. Judging from the size of the splittings around the old workings this was the maximum size of mica found. Much of the mica appears to have been fractured, and this may well have been the main difficulty in producing worth-while mica, in addition to difficulties of transport and lack of skill on the part of the miners and cutters.

No estimate of the possible reserves of mica are possible owing to lack of data on the mica content of the rock mined and the percentage of sheet mica recovered from the crude material. No systematic pitting or trenching was carried out to prove the distribution of workable mica. The mica deposits of the Nachola area are sporadic in occurrence, few of the many pegmatites are zoned and, in the writer's opinion, it is unlikely that exploitation will ever be economically profitable. The deposits are not so good as those of the Machakos area, where circumstances are more favourable.

An occurrence of mica that might possibly repay investigation was found in the group of pegmatites forming a low hill three and a half miles north-west of Koitokol hill. Here a number of branching pegmatites is well exposed containing books of clear muscovite up to two inches in diameter and muscovite float is plentiful.

The pegmatites forming Soit Olbayen hill are affected by deformation and any mica occurring in them will be of poor quality.

Precise figures for the total mica production from the area are not obtainable, but are likely to be of the order of 3,500-3,750 lb.

(2) Asbestos

Two claims on an asbestos deposit about three to four miles west of Ngoriche hill were pegged by G. W. van der Merwe during 1952. This location was not found during the survey and nothing is known of its nature. No asbestos production is recorded from the claims.

Three other asbestos occurrences were found in the area, two by L. M. Bear (formerly a Government Geologist), and one by the writer. One deposit is situated half a mile south of Soitoniron hill in an altered ultra-basic sill composed largely of tremolite-anthophyllite rocks. The anthophyllite asbestos vein is exposed in a trench ten feet long and two feet deep, and varies in width from 14 to $2\frac{1}{2}$ in. The asbestos is pale pink to milky white in colour, of the cross-fibre variety and of a short fibre length. Impurities in the asbestos consist of powdery carbonates and would reduce its value. The deposit is too small to be of economic significance.

There is a further small occurrence in the Baragoi river about one mile west of Baragoi, where the asbestos occurs as a narrow vein up to one and a half inches wide in tremolite-anthophyllite rocks. The vein is composed mainly of cross-fibre asbestos with locally a median parting containing slip fibre. It grades laterally into mono-mineralic actinolite rocks.

Asbestos occurs in two forms, as veins and pods, in a small ultra-basic intrusive four miles north-east of Uass Aibarr hill, in the Kileshwa valley. The main vein is of brittle long fibre anthophyllite and is up to 18 in. long and can be followed for 20 yd. along the strike. Occurring near the main vein are several pod-shaped bodies of soft white short-fibre asbestos with small amounts of tremolite as impurity. The pods reach a size of 4 × 6 ft. on the surface and occur in brown fine-grained tremolite-anthophyllite rocks. The asbestos of the main vein is too brittle to yield a satisfactory product and the mass-fibre asbestos of the pods, although of fine white silky quality, is of short fibre length. The deposit is not easily accessible and on present evidence the reserves appear likely to be small.

The asbestos deposits are disappointing in view of the favourable geological conditions in the area. It might have been expected that some bodies of chrysotile would have been formed in one or other of the altered ultra-basic masses as a result of hydro-thermal alteration, in particular in the larger occurrences which are composed largely of serpentine, but although asbestiform serpentine is common on the microscopic scale no veins of economic size were seen during the survey.

(3) Magnesite

Magnesite veins occur in all the larger serpentine bodies—at Kangura, Lawun, Morilem, Nakwawi and Barenyiro. Their association with serpentine is notable, no magnesite being found in the tremolite-anthophyllite rocks associated with the serpentine bodies.

In the largest of the Kangura intrusives the magnesite veins are confined to its northern half. The majority of the veins are less than half an inch wide, and are impersistent as regards length, width and orientation. The magnesite is of hard porcellaneous variety and often contains relics of unreplaced serpentine. Much of it is pale brown in colour, and reacts with cold hydrochloric acid, indicating a high lime content.

The eastern end of Morilem hill contains magnesite veins up to six inches wide, orientated north-west—south-east, and spaced approximately 10 to 15 yd. apart. The magnesite is discoloured and contains many inclusions.

On Nakwawi and Barenyiro the magnesite is very scattered and occurs locally among the serpentines as narrow impersistent veins, often associated with tremolite or talc. A few magnesite veins up to one inch wide were found near the southern margin of the serpentine three miles south-east of Nderentei.

Neither the width of the veins, nor the vein density among the best of the magnesite deposits are sufficient to provide workable quantities. The most promising of the occurrences is that on Morilem hill, but even were the deposit much better it is certain that the ore could not be economically transported to rail-head 160 miles away. The price of magnesite in the raw unground state is variable, but ground material low in silica, lime and sesquioxides would realize approximately Sh. 400, and calcined magnesite approximately Sh. 550 to Sh. 600 in the United Kingdom.

(4) Chromite

Chromite has been found in the Kangura serpentine and also in the serpentine three miles south-east of Kangura. In the former locality it occurs as narrow small veins near the western margin of the body. The veins vary in width from a few inches to a maximum of four feet, and the largest outcrops for only 20 ft. The total amount of chromite is estimated as no more than 200 tons. Samples from the largest vein have been assayed with the following results:—

	1 %	2 %	3 %
Cr	34·94	33·55	30·99
Fe	14·18	11·44	17·22
Cr/Fe ratio	2·45:1	2·92:1	1·80:1
(Cr_2O_3)	(50·66)	(51·60)	(45·00)

1. }
2. } From the main chromite vein, Kangura.
3. From block of chromite, 3 miles S.E. of Kangura.

Analyst—J. Furst, 17–5–56.

The second occurrence is three miles south-east of Kangura, where a rounded block of approximately 2 tons weight was found near the eastern edge of the serpentine.

For metallurgical grade chromite, consumers demand a minimum Cr_2O_3 content of 48 per cent and a chromium-iron ratio of at least 3:1. None of the samples analysed satisfies this specification, although such material might be suitable for use as a refractory or in the chemical industry. The tonnage of ore in sight is, however, too small to justify working the deposits, and even if high-grade material were produced it would be unprofitable to transport it to rail-head.

(5) Talc

A further mineral occurring in association with the altered ultra-basic intrusive rocks is talc. Many of the hydro-thermally altered tremolite-actinolite-anthophyllite rocks carry minor quantities of talc, but rocks rich in talc occur only on the northern end of the Lolenyok ridge, one and a half miles south-east of the point where the south Horr road crosses the northern boundary of the area. The rocks are composed of talc and tremolite, the latter being asbestiform and occurring as large columnar and radiating aggregates. Pure talc rocks occur only as small pockets and lenses a few inches across.

Talc also occurs in talc-tremolite veins on Nakwawi hill and in the abundant talc-chlorite slips of the southern part of the Kangura intrusive. In these occurrences the talc is too scattered and impure to be of economic value.

(6) Copper

A small copper occurrence was found by L. M. Bear (former Government Geologist) in the vicinity of Nachola. No further copper occurrences were observed by the writer during the survey except the occurrence of malachite staining in the calcite fillings of vesicles in porphyritic basalt in the Baragoi river six miles north of Logorgor.

The Nachola copper prospect occurs five and a half miles due west of Baragoi about a quarter of a mile south of the Nachola motor-track, and is exposed in two trenches dug ten feet apart to a depth of six feet. The trenches reveal a negligible amount of malachite staining associated with a thin vein of limonite. The hornblende gneisses of the trench walls are patchily impregnated with malachite.

A float block of hornblende gneiss veined with limonite and malachite was found one and a half miles south-east of Baragoi.

The survey has revealed no copper mineralization of note in the area, and the occurrences described above are localized and of a type common in the Basement System elsewhere. They are not economic and are not usually indicative of the possibility of concealed copper bodies.

(7) Building-stone and Sand

A quarry for building-stone is being worked by the Consolata Mission at Baragoi by the roadside at the descent from the Lopet plateau three miles north-west of Tipaku. The stone is a pale greenish grey tuff with small lava and pumice fragments in a fine-grained compact pyroclastic matrix. The bed in which the stone occurs rests directly on the Basement System and occurs at the base of the Rumuruti Phonolites. It is approximately 16 ft. thick, unbedded and with widely spaced polygonal joints in the centre and more closely spaced joints at the upper surface, which forms an erosional platform up to 100 yd. wide. The upper two or three feet of the tuff are too weathered and rotten to be of any use and at a depth of five feet the rock is rather massive and too hard to work easily. It is the tuff between two and five feet below the upper surface of the bed that is generally used. This tuff extends along the north front of the phonolite plateau and, although it becomes locally reddened and agglomeratic, there is an abundance of stone to satisfy the needs of the area for a long time. Tests indicate that the tuff is slightly radio-active, probably owing to the presence of monazite.

The serpentine three miles south-east of Nderentei occurs as a massive outcrop of homogeneous pale grey rock of attractive appearance. It is perhaps a little more difficult to trim than the tuff, but would probably provide a building-stone of pleasant appearance and great strength.

Sand for building purposes is available in abundance in the many rivers of the area.

Limestone for lime-burning is obtainable from the white marble outcrops one and a half miles south-east of Baragoi.

(8) Graphite

Limestones, quartzites and graphite schists occur together in the nose of the Gurika anticline north of Adawacheke and in the Kileshwa valley. Quartz-graphite schists occur between two marble beds and are associated with quartz schists, hornblende-biotite schists and fine-grained quartzo-felspathic rocks. The graphite schists are interlaminated with these rock types, but the succession cannot be precisely determined owing to the effects of shear and poor exposure. It was estimated that the lower, eastern part of the schist sequence contains a total thickness of approximately 50 ft. of graphitic beds in an overall thickness of 300 ft. The structure of the schists in the Kileshwa valley is exceedingly complex; hornblendic and biotite schists with tectonic inclusions of marble occur and the core of the small syncline is, in effect, a zone of *mélange*.

The quartz-graphite schists are of fine grain—the graphite flakes are generally no larger than one millimetre and are interleaved with muscovite. The gauge minerals are quartz, opal and muscovite. The proportion of graphite is high, as indicated by the following percentages obtained by ignition of the rocks:—

Specimen number	*Loss on ignition* %
27/265	16.08
27/266	22.54

Anal: J. Furst, 10.5.56.

The small size of the graphite flake reduces its value, and the remoteness of the deposit and the difficulty of obtaining an adequate supply of water for treatment probably render this deposit uneconomic, in spite of its size and high graphite content.

It is of interest to note that this graphite occurrence is on the same line of strike as others mapped further south by Shackleton (1946). There is reason to suppose that other graphite occurrences will be found in this zone mapped as "pelitic gneisses and schists" by Shackleton, and which appears to be the same as the Gurika-Luwa Lakairap granitoid gneiss and associated migmatites.

(9) Radio-active Minerals

Since the beginning of prospecting in the Nachola area in 1950 small samples of radio-active minerals have been produced from pegmatites. These have been identified as samarskite, low-grade pitchblende, radio-active columbite, euxenite (8 per cent eU_3O_8), and monazite (a thorium mineral). Some of these, probably samarskite, were analysed and showed the following percentages of uranium oxide (U_3O_8)—0.26, 13.20 and 11.53.

These minerals occur sporadically in the pegmatites in various part of the Basement System, and, so far as is known to the writer no economic occurrence of these minerals in pegmatites has been found anywhere in the world. A small production of uraninite is obtained, however, from mica pegmatites in the Uluguru mountains of Tanganyika

The writer conducted a rapid search with a Geiger-Müller counter to try to find additional radio-active occurrences, without success. Several localities said to be radio-active were visited without obtaining any significant anomaly, and it must be concluded that the radio-active minerals occur mainly as isolated crystals or groups of crystals in pegmatites, and were obtained mostly during the period of mica mining in the area. Such occurrences are not economic and are no indication of an area of valuable uranium mineralization. It would be unwise to rule out the possibility of an economic uraniferous deposit being found in the area, but the occurrence of such a deposit seems highly improbable to the writer.

(10) Beryl

A small amount of beryl has been recovered from the pegmatites at Nachola, and it is recorded that one ton valued at £50 was sold in 1952 (Annual Report for 1952, Mines and Geological Department, p. 5). It is reputed that, in fact, some five tons was produced and sold in East Africa. The beryl is a blue variety and of attractive appearance.

3. Water-supply

(1) Bore-holes

Two bore-holes have been drilled in the area, and a third is also mentioned here as it is close to the southern boundary of the area. The three bore-holes are:—C 1613—by the side of the Lopurr river about 6 miles north-north-west of Kowop; C 1553—

half a mile west of the road on the Lopet plateau; and C 1639—by the road on the Lopet plateau about half a mile south of the southern boundary of the area. Information supplied by the Hydraulic Branch of the Ministry of Works relating to the bore-holes is tabulated below:—

	C 1613	*C 1553*	*C 1639*
Depth (feet)	395	445	335
Water struck at	225	230	227
Water rest-level	214	195	198
Yield (gallons/24 hrs.)	16,800	3,600	22,800
Date of completion	24.11.51	10.10.51	11.1.52

There appears to be no reason why the yield of the two bore-holes drilled through the Lopet phonolites should be so different. Both probably tap aquifers in the gritty or tuffaceous sub-volcanic sediments.

Analyses of water from two of the bore-holes are:—

	C 1613 parts per 100,000	C 1553 parts per 100,000
ALKALINITY ($CaC0_3$)		
Carbonate	44·8	23·5
Bicarbonate	nil	nil
AMMONIA		
Saline	0·048	0·005
Albumen	trace	trace
Cl	27	23·1
SO_4	95	119·4
NO_2..	present	trace
NO_3..	present	trace
Ca	35·2	43·8
Mg	5·2	5·2
Fe	0·025	0·014
Total hardness	2·8	2·8
Total solids	245·0	257·5
F(p.p.m.)	4·0	2·7

Analyst—Government Chemist.

It is seen that the waters contain a small concentration of sulphates in solution, and moderate amounts of fluorine.

All three bore-holes are equipped with reciprocating pumps, reservoir tanks and cattle-troughs and provide the only absolutely reliable supply of water in the area.

(2) DAMS

Simple earth dams have been constructed in several places on the El Barta plains. These, roughly in order of size and storage capacity, are called Lamerok, Barenyiro, Gelai, Tangar and Segera. The dam walls are usually about 15 ft. high or a little less, the spillway being approximately three feet below the tops of the walls. The most successful dams are Lamerok and Barenyiro, both of which usually contain water for at least one month after the long rains, and, in exceptional years, may not dry up for several months. All the dams suffer from silting up owing to the rapid run-off from their catchment areas and most could now be deepened with advantage.

(3) Natural Pans, Wells and Springs

Natural pans occur at Lokongori, Nderentei, three miles north-west of Gelai, Ildebessare, three miles south-west of Baragoi, and one and a half miles north-west of Baragoi. All these have been enlarged, and low walls built around the lower margins so as to increase storage capacity. Other small natural pans occur in areas of impermeable soil. Several occur on the Lopet plateau and elsewhere on the phonolite outcrop, and there is one at Noyarot on the Tirr Tirr plateau. The water is short-lived due to the small capacity of pans, which do not contribute significantly to the water-supply of the area as a whole.

The principal sources of water in the area are wells, seepages and springs in the sandy beds of rivers. The Turkana in particular are skilful at locating water in the beds of sand-rivers, and frequently dig to depths of up to 15 ft. to obtain it. The principal source of water in this respect is the Baragoi river, the bed of which contains water downstream from Baragoi. The main well sites are near Baragoi, north-west of Nachola and sporadically further downstream. Seepages are common in the lower reaches of the river wherever hard impervious rocks floor the river-bed. There is an important deep well at Lokuto in the Lopurr river, at a point where a granite dyke crosses the river. Further downstream seepages occur in the bed of the Akangbelai river west of the Emuru Akirim plateau, and wells dug here supply the Turkana who graze their cattle on the east side of Tirr Tirr and on the west of Emuru Akirim.

Owing to the fractured nature of the olivine basalts of the Ayena Aturkan drainage water points on them are few. The only perennial seepages and wells are at Echua Etom and Kongia, on the important cattle and camel track linking the Baragoi area with the Suguta valley. This track is the only route regularly used by the Turkana in bringing stock from Suguta or beyond, most other routes being too rough for camels. Further south seepages occur in the Nanganyamonyen river and along a fault on one of its right bank tributaries, the Logobuk. In the Lakwarsignen valley, north of Naramarsiro, one group of wells supplies the Turkana who graze their stock on the Naramarsiro plateau, in Nagoriagwen, and on the Emuru Asarit hills.

At the base of the escarpment on the east side of the Suguta valley are a number of slightly saline seepages, such as those at Kanganya. Further north there is a hot saline spring at Elboitong, but it is reported to be too hot and saline to be of use. The Suguta river itself is reported to be too saline for use during the dry season, but the Turkana use it when it is more potable during the rains.

On the Basement System outcrop in the eastern part of the area water is difficult to find in the sand-rivers except in those draining the western slopes of the Musei range. An excellent watering point occurs at Lesirikan, where the river is partly dammed by a resistant pegmatitic gneiss. Wells dug into the bouldery gravels behind the barrier yield abundant water of good quality. At Lare Odo in the Kileshwa river there are wells and seepages, but they are often filled with black oily stagnant water. In the lower reaches of the Kileshwa and Satchati rivers no water is obtainable and the low ground in the north-east part of the area is rarely used for grazing for this reason.

In the south-east of the area water is obtainable in the Masegeta river at the contact of the Luwamara granite. Some wells are dug in the lower Lanana river but are liable to be dry in seasons of poor rainfall. The water-supply situation in this district is poor except about the Lgerei gap between the Matthews range and the southern end of the Musei mountains, a region outside the present area.

(4) General Considerations

The water-supply situation of the area as a whole is one of difficulty, but not more so than in other outlying parts of Kenya with a semi-arid climate. The position must be viewed in relation to the grazing requirements of the Turkana and Samburu, and is intimately connected with grazing control, the de-stocking policy of the District

VIII—REFERENCES

Arambourg, C., 1943.—"Mission Scientifique de L'Omo." Vol. I, fasc. II, Mus. Nat. d'Hist. Nat., Paris.

Baker, B. H., 1958.—"Geology of the Magadi area." Rept. No. 42, Geol. Surv., Kenya.

Bear, L. M., 1952.—"A geological reconnaissance of the area south-east of Embu." Rept. No. 23, Geol. Surv., Kenya.

Cavendish, H. S. H., 1898.—"Through Somaliland and south of Lake Rudolf." *Geogr. Journ.,* Vol. XI, pp. 372-396.

Champion, A. M., 1937.—"The volcanic region around the southern end of Lake Rudolf, Kenya Colony." *Zeitschrift. für Vulkanologie,* Band XVII, pp. 163-172.

Dixey, F., 1948.—"Geology of Northern Kenya." Rept. No. 15, Geol. Surv., Kenya.

Fuchs, V. E., 1939.—"The Geological History of the Lake Rudolf Basin, Kenya Colony." *Phil. Trans. Roy. Soc.,* London, Ser. B, No. 560, Vol. CCXXIX, pp. 219-274.

————, 1950.—"Pleistocene Events in the Baringo Basin, Kenya Colony." *Geol. Mag.,* Vol. LXXXVII, pp. 149-174.

Gregory, J. W., 1921.—"Rift Valleys and Geology of East Africa."

Holmes, A., and L. Cahen, 1956.—"African Geochronology." *Col. Geol. Min. Res.,* Vol. V, No. 1, pp. 3-38.

Johannsen, A., 1937.—"A descriptive petrography of the igneous rocks." Vol. III.

King, B. C., and N. Rast, 1956.—"Tectonic styles in the Dalradians and Moines of parts of the Central Highlands of Scotland." Proc. Geol. Assoc., Vol. LXVI, pt. 3, pp. 243-269.

————, 1956.—"The small-scale Structures of South-eastern Cowal, Argyllshire." *Geol. Mag.,* Vol. XCIII, pp. 185-195.

Marmo, V., 1955.—"On the classification of the Precambrian granites." *Col. Geol. and Min. Res.,* Vol. V, No. 4, pp. 429-437.

Mason, P., 1955.—"Geology of the Meru-Isiolo area." Rept. No. 31, Geol. Surv., Kenya.

————, and Gibson, A. B., 1957.—"Geology of the Kolossia-Tiati area." Rept. No. 41, Geol. Surv., Kenya.

Mines and Geological Department, 1955.—"Annual Report, 1954."

Ramberg, H., 1956.—"Pegmatites in West Greenland." *Bull. Geol. Soc. Am.,* Vol. LXVII, No. 2, pp. 185-214.

Rosiwal, A., 1891.—"Uber gesteine aus dem Gebiete zwischen Usambara and dem Stefanie-See." Denkschr. K. Akad. Wiss. Wien, Math. Nat., LVIII, pp. 465-550.

Sabine, P. A., 1953.—"The Petrography and geological significance of the post-Cambrian minor intrusions of Assynt and the adjoining districts of North-west Scotland." *Quart. Journ. Geol. Soc.,* Vol. CIX, pp. 137-171.

Sanders, L. D., 1954.—"Geology of the Kitui area." Rept. No. 30, Geol. Surv., Kenya.

Schoeman, J. J., 1951.—"A geological reconnaissance of the country between Embu and Meru." Rept. No. 17, Geol. Surv., Kenya.

Searle, D. L., 1952.—"Geology of the area north-west of Kitale township (Trans Nzoia, Elgon and West Suk)." Rept. No. 19, Geol. Surv., Kenya.

————————, 1954.—"Geology of the Sultan Hamud area." Rept. No. 29, Geol. Surv., Kenya.

Shackleton, R. M., 1945.—"Geology of the Nyeri area." Rept. No. 12, Geol. Surv., Kenya.

————————, 1946.—"Geology of the country between Nanyuki and Maralal." Rept. No. 11, Geol. Surv., Kenya.

Sikes, H. L., 1939.—"Notes on the Geology of the country surrounding Nairobi." Geol. Surv., Kenya.

Turner, F. J., 1948.—"Mineralogical and Structural Evolution of the Metamorphic Rocks." Mem. 30, Geol. Soc. Amer.

Turner, F. J., and J. Verhoogen, 1951.—"Igneous and Metamorphic Petrology."

Von Höhnel, L., 1938.—"The Lake Rudolf Region." *Journ. Royal African Soc.,* Vol. XXXVII, pp. 21-44, 206-226.

Willis, B., 1936.—"East African Plateaus and Rift Valleys." Carnegie Institute of Washington.

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