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COLONY AND PROTECTORATE OF KENYA

MINING AND GEOLOGICAL DEPARTMENT

GEOLOGICAL SURVEY OF KENYA

GEOLOGY OF THE COUNTRY BETWEEN NANYUKI AND MARALAL

(WITH COLOURED GEOLOGICAL MAP)

by

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CONTENTS

	PAGE
Introduction	1
I—Previous Geological Work	1
II—Physiography	2
III—Summary of the Geological History of the Area	3
IV—Details of Geology (I): The Basement System	5
(1) Nomenclature and General Interpretation	5
(2) Classification, Occurrence and Petrography of the Rocks	6
(3) Metamorphism	21
(4) Structure and Distribution	24
V—Details of Geology (II): The Tertiary and Pleistocene Rocks	27
(1) Sub-volcanic Sediments (Miocene)	27
(2) Tertiary and Pleistocene Volcanic Rocks: Classification—	29
(i) The Samburu Series	29
(ii) The Rumuruti Phonolites	31
(iii) Phonolites of Kapitian type	33
(iv) Losiolo Phonolites	34
(v) Thomson's Falls Phonolites	34
(vi) Mount Kenya Suite	35
(vii) Trachytic Tuffs	38
(viii) The Laikipian Basalts	38
(ix) Quartz Trachyte	39
(3) Pleistocene and Recent Superficial Deposits	40
VI—Physiographic and Structural Evolution of the Area	44
VII—Economic Geology	46
Appendix I—Note on Traverses East of Lake Baringo	53
Appendix II—Note on Traverses near Thomson's Falls	54
References	54

LIST OF ILLUSTRATIONS

	PAGE
Fig. 1—View Westward from the Losiolo Scarp	Frontispiece
Fig. 2—Physiographic Sketch-map of the Maralal Area and Districts to the West	Facing page 2
Fig. 3—Structures in Migmatitic Gneisses	14
Fig. 4—Wavy Foliation in Acid Orthogneiss	16
Fig. 5—Textures in Granitoid Gneiss	17
Fig. 6—Relation of Foliation to *Boudinage* Structure	23
Fig. 7—Map Showing Structures in the Basement System	25
Fig. 8—Geological Cross-sections	Facing page 26
Fig. 9—Parasitic Cones on the North-eastern Slopes of Mt. Kenya	37
Fig. 10—Section of Pleistocene Deposits near Nanyuki	42

PAGE

Fig. 11—Section of Pleistocene Deposits South of the Uaso Nyiro, 11 miles East of Barsalinga Drift 43

Fig. 12—Plan and Section of Krieger's Bentonitic Clay Deposit 48

Fig. 13—Plan and Section of Parminter's Bentonitic Clay Deposit 49

Fig. 14—Sketch-map to Show Geology of the Fault Zone between Laikipia and Lake Baringo as inferred from Traverses .. .. Facing page 54

Plate I. Fig. 1—North Face of Uaraguess: Cliffs of Granitoid Gneiss .. .. Facing page 16

Fig. 2—Typical View of the Eastern Face of the Matthews Range. The cliffs are probably of granitoid gneiss. From Sitin, looking northwards Facing page 16

Plate II. Fig. 1—Cliffs of Phonolitic Lavas (Losiolo Phonolites), near Losiolo .. .. Facing page 17

Fig. 2—View looking East down the Barsaloi River from a point four miles West of its confluence with the Seya. The rocks are garnetiferous paragneisses; they dip steeply eastwards .. .. Facing page 17

Plate III. Fig. 1—View of the South-eastern end of the Karissia Hills (looking south), to show the even summit level which is interpreted as a relic of a Cretaceous or older peneplain .. .. Facing page 44

Fig. 2—The sketch shows the structure of Nolgek which is seen as a distant spur on the photograph .. Facing Page 44

Geological Map of the Area between Nanyuki and Maralal. (In end folder.)

GEOLOGY OF THE COUNTRY BETWEEN NANYUKI AND MARALAL

INTRODUCTION

A geological reconnaissance of the country north of Nanyuki was made primarily to see whether it was likely that any minerals of use during the war could be found there. This report is an account of the geological results of the work.

The area, is limited by the equator, 1° 30′ N, 36° 30′ E, and 37° 30′ E, and is about 6,900 square miles in extent. It includes much of the high plains of Laikipia and Lorogi, the Karissia Hills, the Matthews Range, and Loldaika Hills, the middle and upper Uaso Nyiro basins, and the northern slopes of Mount Kenya. It is referred to here as the Maralal area; Maralal is the administrative post for the northern (Samburu) part of it. This particular area was chosen as being geologically little explored and reasonably accessible from the railheads at Thomson's Falls and Nanyuki and there were vague reports of minerals found in it. Study of the volcanic rocks and water geology were originally excluded, but at a late stage added to the scope of the work, and barely received the attention needed.

The work was done at intervals between December, 1942, and December, 1944. Some 8½ months were spent in field work.

Topographic Maps.—Much of the area, from the equator to 1° N, was surveyed, early in the war, by the Survey Unit of the East Africa Command. This survey had to be done quickly and a few hilly districts were not reached, or were not well covered, among them the forested northern slopes of Mount Kenya, the area between Nyandedu and the main Uaso Nyiro bend and part of the Mukogodo country. Partial sketch revision of the first two of these was done incidentally during the survey. The topography of the north-western section of the area is taken largely from a plane-table sketch map made some years ago by officers of the Survey Department of Kenya, with additional triangulated points and other data added by the Military surveyors. The north-eastern section (Matthews Range) was surveyed during the present work. As this was a quick plane-table survey, done from a traverse route chosen to suit the limitations of camels and to yield geological rather than topographic information, no high degree of accuracy is claimed.

Throughout the work, geological data were plotted from compass and perambulator-wheel or rangefinder traverses. Traverses were tied to previously fixed points, or to points fixed by plane-table resection. The accuracy of the maps was seldom adequate for position to be fixed by reference to details of topography. Field maps were plotted on a scale of 1:125,000 except in the north-west where the 1:250,000 scale was used. Much of the plotting had to be done afterwards from traverse notes.

I—PREVIOUS GEOLOGICAL WORK

There is little published information about the geology of the area. Joseph Thomson, the first European to reach this part of the country, crossed Laikipia in 1883, on his way from Lake Baringo to the Uaso Nyiro. He noticed (Thomson, 1887, pp. 224-221) that the rocks there were lavas. A few years later Teleki and von Höhnel, during their expedition to Lakes Rudolf and [illegible], explored and mapped parts of the area. The rocks they collected were described by Rosiwal (Rosiwal, 1891), but his report is not available in Nairobi. He is said to have described phonolites, trachytes, basalts, and gneisses. In 1893 Gregory, on his return from Baringo to Mount Kenya, crossed Laikipia, but his route lay just beyond the south-west corner of the area. His fascinating book, *The Great Rift Valley* (Gregory, 1896), in which he gives an account of the expedition, contains the first attempt to correlate the volcanic eruptions, the history of the great lakes and the earth movements which formed the Rift Valleys. He divided the whole volcanic period into seven stages, placing the volcanic rocks of Laikipia (ibid., p. 235) within the first four of these, as follows:—

?Miocene	(4) Laikipian	Plateau eruptions of basalt.
Eocene	(3) Nyasan	.....
	(2) Doenyan	Kenya and Settima in eruption.
Cretaceous	(1) Kapitian	First Plateau eruptions.

He gave the name Laikipian to the basalts which "form the main cap of Laikipia, where they lie on eroded surfaces of the older lavas" (ibid., p. 231).

In comparison with the knowledge gained by these explorers of the last century, who had to march from the coast through an unknown country, subsequent advances are insignificant. Only two more geologists appear to have passed through the area. H. B. Maufe in 1906 crossed its south-west corner, recording olivine basalt north of the Suguroi River and phonolite at the Pesi Swamp (Maufe, 1908, p. 39). Parkinson, in 1914 followed the track from Rumuruti to Archer's Post, down the Uaso Nyiro, on one of his journeys into the Northern Frontier Province. He recorded (1920, p. 3) some of the types of metamorphic rocks seen on this traverse, and discussed the geomorphology of the Uaso Nyiro valley.

II—PHYSIOGRAPHY

The physiography of this part of Kenya is varied and interesting. The chief features, which are closely related to the rock formations, are shown diagrammatically in Fig. 2.

The *Loldaika-Mukogodo Hills*, the *Karissia Hills* and the *Matthews Range* are the chief mountainous areas. They form two discontinuous parallel zones trending nearly north-south across the area. The Loldaikas and the Karissia Hills mark the line of the western zone. In the eastern zone the main element is the Matthews Range. This is continued northwards across the Lgerei gap, into the Ndoto Mountains, which are outside the limit of this reconnaissance, and southwards, through Uaraguess and the more isolated Ngurie Hills, to Lengishu, the southern outpost of this line.

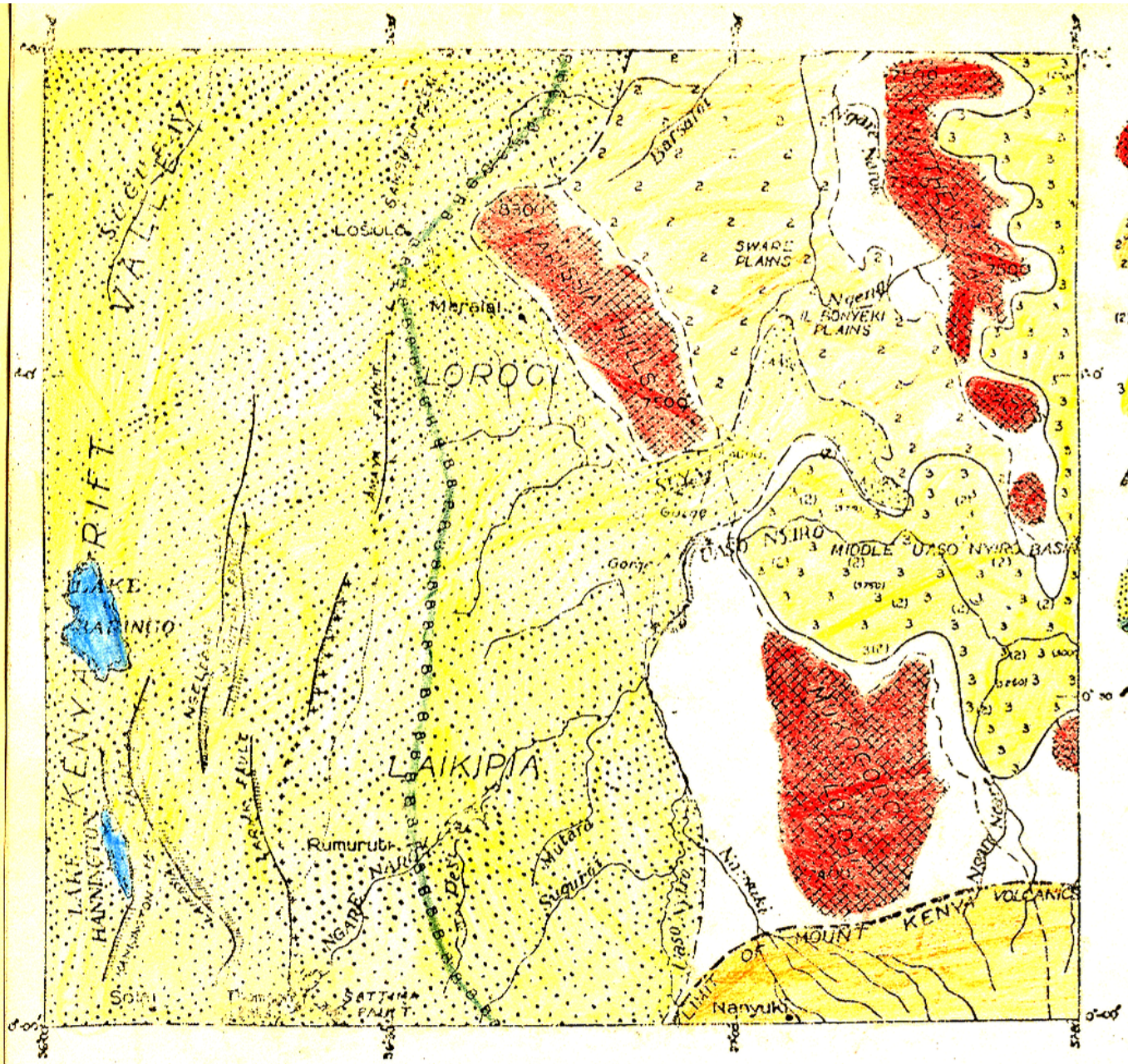
These hills are formed chiefly of gneisses of granitic composition which are among the most resistant of the metamorphic rocks of the Basement System. A conspicuous feature, especially of the Karissia Hills and the Matthews Range, is their even summit-level. This is plainly a relic of an ancient, perhaps Cretaceous, peneplain. The same surface is less distinctly recognizable in the Loldaika-Mukogodo hills. Its present height in the district is between 7,000 and 8,000 feet above sea level. The eastern sides of both the Karissia Hills and the Matthews Range are steep.

Between these ranges the surface has been lowered, mostly by erosion of the less resistant metamorphosed sediments of the Basement System, to plains at various lower levels, such as the *El Barta, Sware, Il Bonyeki* and *Middle Uaso Nyiro* plains. Two distinct peneplained surfaces can be recognized, showing that the uplift, of which the erosion to lower base levels was a consequence, took place in two stages. The Seya and Uaso Nyiro rivers are now cutting down their valleys towards a third, much lower base level of erosion.

West of the Karissia and Loldaika Hills, but still east of the Rift Valley, are the extensive high lava plains of *Laikipia and Lorogi*. These were built up by repeated floods of lava from the Rift Valley region. Some of this lava poured through the gap between the Karissia and Loldaika Hills, and some of it flooded across the country north of the Karissia Hills. In the extreme north-west of the area, this series of lavas is deeply incised by a series of canyons and gorges leading out into the Suguta valley, which drains the Rift Valley south of Lake Rudolf.

The southern part of the district is overshadowed by the denuded volcanic cone of *Mount Kenya*, of which, however, only the lower northern slopes come within the area mapped. Some of the lavas from Mount Kenya, and more especially those from the many late parasitic cones on its slopes, ran out into valleys in the Loldaika Hills and across the lower ground around them.

The drainage pattern of the area has been determined particularly by three factors. First there are the two zones of high ground crossing the district from north to south, and between them, areas where the rocks have the same north-south grain. Secondly there are the various lava sheets, whose surfaces must originally have sloped in the direction in which they flowed, eastwards from the Rift Valley region and radially outwards from Mount Kenya. Consequent streams would follow these slopes, and others would run at the edges of the sheets. Thirdly, the whole area, lying as it does on the eastern flank of the Rift Valley, has the gentle tilt away from the Rift margin, which is nearly everywhere a characteristic part of the Rift Valley structure.



EXPLANATION

Chief mountainous areas of metamorphic rocks. Where the Cretaceous (?) peneplain is recognizable, its approximate height is shown thus 7500.

Areas where the Sub-Miocene peneplain is recognizable. Heights thus 4600.

Areas thought to have been reduced to the Sub-Miocene peneplain but now considerably below it.

Areas of end-Tertiary Peneplanation. Heights thus (3250).

Fault Scarps (faults inferred).

Rift Valley-Indian Ocean watershed.

Approximate eastern limit of Rift Valley faulting.

Supposed original extent of plateau phonolites.

Supposed original eastern limit of Samburu Basalt Series.

Northern limit of the Mt. Kenya Volcanic rocks.

FIG. 2

Physiographic sketch-map of the Maralal area and districts to the west.

[To face page 2

III—SUMMARY OF THE GEOLOGICAL HISTORY OF THE AREA

The sequence of rocks, and the chief events in the history of the region, are summarized in the table below.

SUMMARY OF THE SUCCESSION

Age		Formations	Earth Movements and Climatic and Erosional Phases	Cultural Stages and Faunas
Recent		Black cotton soil and "kunkur" Lateritic ironstone ("murrum") in part.	Re-excavation of valleys and erosion of red earths.	
	U	Gravels in valleys. Lateritic earths.	Gamblian Pluvial Period.	Levallois.
			dry	
Pleistocene	M	Red Lateritic earth.		Kenya Fauresmith. Acheulean.
	L	Uaso Nyiro beds (?). Bentonitic clay.	Kamasian Pluvial Period (?)	
		Parasitic cones.	.....(disturbance)	
		Laikipian basalts. Trachytic tuffs (Suguroi), etc.	.....(disturbance)	
Pliocene			↑ End-tertiary peneplanation.	
		Thomson's Falls//Mt. Kenya. Phonolites //Volcanic Suite.		
Miocene		Losiolo Phonolites. Rumuruti Phonolites. Samburu Basalt Series. Sub-volcanic sediments.	.....(disturbance) ↑ Sub-Miocene peneplanation. ..... (disturbance) ↑ Cretaceous peneplanation.	*Deinotherium hobleyi*.
Archaean		Basement System.		

The rocks of the area fall into two groups, one, geologically very ancient, consisting of gneisses and schists and known as the Basement System, the other, comparatively young, consisting largely of volcanic rocks erupted during the period when the Rift Valleys were being formed. The chief steps in the evolution of the area to its present condition are outlined below.

(1) *Deposition of sediments, and volcanic eruptions, in the Archaean period*

The oldest rocks, those of the *Basement System*, were laid down as a thick series of sediments. Clays, silts, sands, and calcareous oozes were deposited over a very large area. Some layers, now graphitic, contained organic matter; the deposits are, however, much earlier than the oldest known fauna. It is supposed, from their enormous known extent and from the abundance of limestones among them, that they were formed in the sea. Basaltic lavas and tuffs were probably erupted among the sediments

(2) *Metamorphism of the sediments and volcanic rocks of the Basement System*

Later in the Archaean period, this series of rocks must have been involved in some intense deformation of the crust of the earth, by which they were forced down and deeply buried. Under the influence of pressure, heat, deformation and particularly through the activity of alkaline fluids, the rocks were transformed from normal sediments into crystalline gneisses and schists. Clays became aggregates of reddish garnet, silky bluish-white sillimanite, black scaly biotite, quartz, and white and pink felspars. Those rocks that originally contained organic material are spangled with soft shiny black flakes of graphite. The calcareous oozes have become coarsely granular crystalline limestones or marbles, and the sands are now hard white or pink granulites. Many more sediments are altered beyond recognition. The basic lavas are speckled aggregates of greenish-black hornblende and white felspar, with, in a few places, crowds of roundish white spots that are believed to represent vesicles. All these rocks are traversed by innumerable granitic sheets, or merge into intimate mixtures of granitic and sedimentary or volcanic rock. Throughout the whole complex there are thin seams, knobs, lenses and dykes of pegmatite; some composed only of coarse felspar and quartz, others containing also mica, garnet, beryl, iron ore and other minerals.

(3) *Successive stages in the erosion of the Basement System Rocks*

The uplift and erosion needed to expose the regionally metamorphosed rocks of the Basement System at the surface probably followed closely on their metamorphism. In other areas they were already uncovered before some of the later pre-Cambrian formations were laid over them. In this area, however, none of these formations occur and only the last stages in the long cycle of uplift and erosion have left any traces. A long period of stability when the whole area was eroded down to a peneplain presumably not far above sea level, is indicated in the even summit level of the Karissia Hills and the Matthews Range. This stability probably lasted until the Cretaceous period. The Central African region was then again warped upwards. In this area, the uplift amounted to several thousand feet. Active erosion began again and continued, during the following period of stability until once more, much of the region had been lowered to a peneplain. Some areas, such as the Karissia Hills and the Matthews Range formed of the most resistant rocks, were, however, scarcely lowered below the level of the previous peneplain during this cycle of erosion. Many other hills, standing up from the plains as rocky inselbergs, show that the planation was not perfect. None the less, vast areas of Africa were reduced to a plain which, it is thought, was no more than a few hundred feet above the sea even in the middle of the continent. This surface, the Sub-Miocene or Early Tertiary Peneplain, is the most important datum by which to assess the effects of the movements connected with the formation of the Rift Valley.

(4) *Disturbance, erosion, and local sedimentation in the Miocene period*

The early Tertiary peneplanation was interrupted, and a new cycle of erosion started by earth movements about the beginning of the Miocene period. Valleys were eroded, and then in places filled with fluviatile or lacustrine sediments. In some of them Miocene fossils, among them *Deinotherium* and *Mastodon*, have been found. The deposits underlie the phonolitic lavas of Laikipia, though in one place the first phonolite flow is intercalated within the sediments.

(5) *Eruption of Plateau Lavas*

The grasslands of Northern Laikipia and Lorogi are formed of a great series of lava sheets, which flooded out from the Rift Valley Region, towards which the whole series thickens. Two groups of lavas are distinguished, a lower one of basalts with associated red and purple tuffs and an upper one of phonolites. The basalt series is not seen on the plateau, but only some hundreds of feet down the escarpments at its western edge, at the margin of the Rift Valley. The overlying phonolites form the surface of the plateau over most of the area mapped.

(6) *Mount Kenya and the Aberdare Range*

The plateau phonolites are covered in the south-west part of the area by other phonolites of a different type. These dip away from the northern Aberdare Range, which lies south of the limit of the area. Fifty miles east of the Aberdares is Mount Kenya. This too lies mainly outside the area, and only its lower northern slopes were examined. The lavas seen on these slopes are fissile basalts, mugearites, kenytes, and phonolites. Of these, only the kenyte is known to be younger than the plateau phonolites, and it is not known how much earlier the eruptions of Mount Kenya first began.

(7) *The End-Tertiary Peneplanation*

While, in some parts of the area, volcanic eruptions may have continued with little interruption, there is in the Uaso Nyiro basin clear proof that between the time of the plateau phonolite eruptions and the latest floods of basalt, a long period of stability and erosion elapsed. This erosion reduced the surface of a wide area to a peneplain several hundred feet below that over which the plateau phonolites were erupted. In its relation to present river levels and in its general form, it corresponds to the surface that is known in western Kenya and elsewhere as the End-Tertiary Peneplain.

(8) *The Lower Pleistocene Basalt eruptions*

The End-Tertiary Peneplain is partly covered, along the south side of the Uaso Nyiro, by flows of olivine-basalt. The basalts can be traced to denuded vents in the south-eastern part of the area. The lavas flowed into valleys in the Loldaika Hills and the Mukogodo country, over on to the plains below, as well as around the eastern side of the hilly country (beyond the eastern limit of the map). Other similar basalts were erupted from various vents on the northern flank of the Aberdares. Sirrimma Hill is the most conspicuous of these. All these basalts are believed to belong to a single eruptive cycle, which fell largely if not wholly within the Lower Pleistocene Period.

(9) *Middle and Upper Pleistocene erosion and deposition*

Spread over large parts of the area are yellowish, brown and red earthy deposits, mostly unconsolidated. These earths have been formed by the decay of the solid rocks, and the redistribution of the disintegrated products by hillwash and wind. Layers of lateritic ironstone are due to leaching and redeposition of ferric hydroxides. The age of some of these superficial deposits is known from human artefacts which have been found in them. The most primitive are large handaxes of the Acheulean culture. In many places, in the southern part of the district, a slightly younger culture, the Kenya Fauresmith or Nanyukian, has been recognized in the lowest of the superficial deposits. Other still younger cultures, Levalloisean and Neolithic, are widespread.

In some of the valleys, there are quite thick deposits of tuff and gravel. They often contain Levallois type artefacts and largely belong to the Gamblian pluvial period. (Upper Pleistocene.)

5 > p.6

IV—DETAILS OF THE GEOLOGY (I): THE BASEMENT SYSTEM

(1) Nomenclature and General Interpretation

The rocks now to be described are gneisses, granulites and schists belonging to the Basement Complex, as that term has previously been used in Kenya. It covered not only the metamorphosed sediments which were separated many years ago by Parkinson (1913, p. 539) as the Turoka Series, but also the far greater associated mass of rocks, especially biotite gneisses, of which the origin, whether sedimentary, migmatitic, or igneous, remained undetermined. Recently, Stockley (1943, p. 161) has proposed the term Basement System for all these rocks. For the sake of uniformity, it is adopted here.

Nearly all the rocks are regionally metamorphosed to a high degree, besides being gneissose and soaked by granitizing fluids. Under these conditions, discrimination of the igneous, migmatitic and sedimentary components of the complex is difficult, the more so since modern work has shown that rocks of typically igneous aspect can be produced without having reached the condition of magma. In this particular area, rocks such as crystalline limestone, graphitic gneiss and sillimanite gneiss are widespread and are undoubtedly of sedimentary origin. Some of them can be followed many miles across the country as shown on the map. Others are smaller and pieces of calc-silicate granulite the size of a hen's egg have been seen enclosed in biotite gneiss. The outcrops of these sedimentary rocks are thus demonstrably discontinuous. The foliation in the sediments is parallel to the planes of lithological discontinuity and generally almost, if not exactly, coincides with the original stratification. This foliation, when mapped across the country, is found to fall into a single homogeneous pattern, similar to that of a continuous sedimentary structure. The gneisses which form as it were, a matrix for the obvious sediments are quartz-felspar granulites, biotite gneisses and hornblendic gneisses. Biotite gneisses predominate. In this complex, the foliation is still regular, as if the rocks were bedded sediments. None the less, it seems impossible to regard these rocks simply as metamorphosed arkoses, or felspathic sandstones. The occasional occurrence of knobby inclusions of calc-silicate granulite in the middle of the biotite gneisses, the general discontinuous patchy disposition of the undoubted sediments, and the gradual passage, along the strike, from metamorphosed sediments into biotite gneisses, have to be explained. It is inferred that many of the granulites and gneisses must have arisen as a result of profound alterations in the composition of the sediments they replace. It is not, however, believed that they were igneous. They can be distinguished from a series of sheets of granitoid gneiss, which stand out as inselbergs and ridges. In these sheets, the foliation is not usually parallel, but has instead a characteristic waviness (*see* Fig. 4). Elsewhere it is contorted. Lenticular dark streaks and lenses, some sharply and others vaguely defined, can often be seen. Under the microscope, slides of these rocks not uncommonly show a few felspar crystals with straight crystal faces. In a few places the sheets were seen to fork and transgress at a low angle. For these reasons they are believed to have been at least partly, and in many cases wholly, magmatic.

Lastly there are some banded hornblendic gneisses in which the characteristic feature is an intense and irregular contortion. The strike of the contortions is entirely unsystematic and unrelated to the general tectonic pattern. These rocks are interpreted as migmatites that were formed by intimate injection of magma into a crystalline host, to form a composite rock which was then distorted by something approaching viscous flow.

Thus, the general interpretation of the metamorphic rocks of this area is that there is an underlying fabric derived from a series of folded sediments, but that over large areas the composition of the original sediments has been obliterated by mineralogical changes, particularly felspathization, without destroying the continuity of the fabric, which is still shown by the homogeneous structural pattern. Throughout this series there are sheets of granitoid gneiss that are regarded as magmatic.

In constructing the map from reconnaissance traverses, it has been impossible to do more than give a provisional representation of the geology of these rocks. In particular it should be realized that those separated as definitely sedimentary are not necessarily any less altered from their original composition than others, such as those derived from impure sandstones, which, being more difficult to recognize with certainty, were seldom differentiated.

(2) Classification, Occurrence and Petrography of the Rocks

For description, the rocks may be classified into the following groups:—

Sedimentary—

Crystalline limestone Calc-silicate granulite	Calcareous

Sillimanite gneiss		
Graphitic gneiss		Pelitic
Garnetiferous paragneiss		
Garnetiferous para-granulite		
Flaggy biotite-rich gneiss and granulite		(Semi-pelitic)
Psammitic biotite gneiss		
Quartz-felspar para-granulite		
Quartzite		Psammitic
Banded ironstone		
Spessartite granulite		
Volcanic—		
Meta-amygdaloid		
Plagioclase-amphibolite (part)		
Banded hornblendic gneiss (part)		
Migmatitic—		
Hornblendic gneiss		
Biotite gneiss		
Quartz-felspar granulite		
Magmatic—		
Granitoid gneiss		
Garnetiferous ortho-granulite		Acid
Meta-quartz porphyry		
Biotitic foliated dyke rocks		
Meta-dolerite		Basic
Meta-gabbro		
Amphibolite		
Talc rock		Ultrabasic
Peridotite		

Sundry other rocks, among them plagioclase-amphibolites and related pyroxene and epidote-bearing rocks, are discussed afterwards.

Metamorphosed Calcareous Sediments

Two kinds of metamorphic rocks have been formed from calcareous sediments. They are: (*a*) Crystalline limestone: (*b*) Calc-silicate granulite.

(*a*) *Crystalline Limestone.*—Crystalline limestone or marble has been found in many places throughout the area and especially towards the north. Some bands are several hundred feet thick and can be followed for miles across country. The ash-white outcrops are usually visible from far away. The hills which they form are called Oloborsoi, the White Hills, by the Samburu. One persistent zone runs for a long distance nearly parallel with the river Seya. It is said to continue much further north beyond the limit of the country mapped. Another series of bands, or the same one, crosses the Uaso Nyiro near the lower end of the gorge, and can be followed southwards for some 25 miles. Bands elsewhere are less persistent, although by more thorough mapping, their known extent would no doubt be increased.

The limestones frequently overlie a band of graphitic schist or gneiss, and themselves often contain scattered flakes of graphite. Other graphitic bands sometimes outcrop above a limestone. Banded garnetiferous granulites are also associated with the limestones and thin bands of quartzite were seen near them at several places. The general similiarity of the succession at many different places strongly suggests that the same set of rocks is repeated by folding or faulting, but there are probably also several limestone bands at different horizons, which cannot yet be distinguished.

In outcrops the crystalline limestones appear to consist almost entirely of carbonates (chiefly calcite). Layers of dark minerals are seldom noticeable. The colour varies from white to grey or bluish-grey. Banding is distinct, and in places contorted. Slides show calcite and dolomite in coarse sutured aggregates, associated with subordinate silicates. In some the silicate is tremolite, and in others forsterite, with pale serpentine derived from it.

(*b*) *Calc-silicate Granulites* —These rocks do not occur associated with the marbles, but in small separate masses within some of the gneisses. The largest of those seen was only about 20 feet in length and the smallest about an inch.

The commonest and most conspicuous type is heavy and dark with patches of resinous dull pink garnet and dark pyroxene as the chief visible components. In sections the essential constituents are found to be garnet, basic plagioclase and diopside. The garnet has a characteristic salmon pink colour quite unlike the pink of the ordinary almandine garnets of the pelitic gneisses. It has an extraordinary spongy habit,* and is always intergrown with plagioclase, diopside or other minerals. It is isotropic and untwinned.

The felspar is usually bytownite with a composition near Ab_{2}, An_{3}, though in one specimen (36/145)† it is about Ab_{35} An_{5}. It is clear and unaltered, and usually shows albite and pericline twinning. Zoning is rarely seen and then only faintly.

Several varieties of pyroxene were found. The commonest is pale emerald-green, with weak pleochroism and distinct dispersion. Different extinction angles were measured in different slides, but the average value, ZAc, is probably about 40°. It seems to be a diopside related to omphacite, and has poecilobiastic habit. In one slice (35/55) the pyroxene is aegirine in small grains associated with bytownite, the usual garnet, a little quartz, apatite and ore. In another slide (35/71) there is a ferriferous augite with a high extinction angle, and pleochroism: X—pale green; Y—pink; Z—pale green. Slide (35/35) contains hypersthene and a pale green diopside, in about equal amounts. In a few slides there is no pyroxene.

Hornblende, when it occurs, is greenish-brown in colour. Some if not all of it has formed from pyroxene. Epidote is quite common. In some of the rocks it is coarsely granular, in others it is only seen in reaction borders between pyroxene and plagioclase. Other minerals noted are apatite, sphene (characteristically pleochroic from pale brown to pinkish), graphite (36/120), black ore, reddish-brown biotite, quartz, microcline, zoisite, and calcite (36/158).

One unusual rock (35/35) is greenish-black, hornblendic and pyroxenic, with scattered bright pink garnets, and long white crystals radiating in random directions. Some of these crystals are 2 cm. long and 2 to 3 mm. in diameter. Their cross sections are either square or rhombic. In the slides they are seen to be pseudomorphs, made of granular bytownite, enclosing small grains of hornblende, especially near their edges. The pseudomorphs may represent scapolite crystals. The rest of the rock consists of diopside, hypersthene, bytownite, garnet and hornblende, with a little ore and apatite.

The calc-silicate granulites have the habit of xenoliths, not of continuous bands. Several were clearly seen to be enclosed in homogeneous biotite gneiss. Their contacts are sharp and their shapes are irregular and lumpy. It is therefore clear that they are relics that have survived dissolution. Their mineral composition is attributed to reaction between limestone and granitizing fluids, and not to the impurity of the original limestones.

These granulites are sometimes found among hornblendic gneisses and rocks identified in the field as plagioclase amphibolites. In a few cases they appeared to merge into such rocks. It may be that some of the hornblendic rocks represent another stage in the migmatization of calcareous sediments.

Metamorphosed Pelitic Sediments

Rocks supposed to be derived from argillaceous sediments include:—

(*a*) Sillimanite gneiss.
(*b*) Graphitic gneiss.
(*c*) Garnetiferous paragneiss.
(*d*) Garnetiferous para-granulite.

(*a*) *Sillimanite gneiss.*—Sillimanite is one of the characteristic minerals of the metamorphic rocks of the area. It occurs sometimes most unexpectedly in the middle

* A typical example of garnet with this habit was figured by Prior (1902, pl. V, fig. 1), probably from a calc-silicate granulite.

† Numbers in brackets refer to specimens in the Mining and Geological Department, Nairobi.

of an apparently uniform series of biotite gneisses, but usually among rocks obviously derived from sediments. Some of the places where it was seen in the field have been marked on the map. Many of these occurrences have been confirmed microscopically, but usually this is unnecessary as the sillimanite is abundant and coarsely crystallized and can be seen even without breaking the rock. Single crystals are seldom visible, but the prisms are matted into silky bluish-white sheafs that lie parallel on the foliation surfaces and catch the eye.

The sillimanite occurs abundantly in several different kinds of rock. All are believed from their bedded appearance and association with other paragneisses to be derived from sediments, presumably argillaceous. The chief sillimanite-bearing rocks are:—

(1) Sillimanite-garnet-biotite gneiss.
(2) Sillimanitic quartz-felspar granulite.
(3) Biotite gneiss with quartz-sillimanite *faserkiesel*.

It is thought that the first of these is the least altered from its original composition.

The *sillimanite-garnet-biotite gneisses* are thinly foliated dark biotitic rocks, sprinkled with pink garnets, and flecked with parallel sheafs of sillimanite. The sheafs are 1 cm. or so long and lie flat on the foliation with their axes parallel to the lineation. The quartzo-felspathic folia are thin and often wrinkled or wavy.

The few examples sliced (28/16, 35/21, and 28/10) consist of sillimanite, garnet, quartz, felspars, and biotite. The biotite is a reddish-brown kind. In one slide (35/21) most of the felspar is acid plagioclase, in another (28/16) mostly microcline.

There is a little green hercynite spinel in one rock (35/21), and flakes of graphite in another (28/10).

The *sillimanite-quartz-felspar granulites* are characteristically pink or mauve-tinted in outcrops. They resist erosion and tend to form upstanding ribs. One or two bands are remarkably persistent and, although only twenty feet or so thick, have been traced for many miles.

In sections these rocks have less felspar and more quartz than would be thought from their field appearance. The quartz forms a sutured mosaic in which the mats of sillimanite needles are enclosed. Alkali felspar, either untwinned or with microcline "cross-hatching", is subordinate and never encloses sillimanite. Iron-ore, biotite, rutile, epidote and zircon were noticed as occasional scarce accessories.

The *biotite-gneisses* with *faserkiesel* are uncommon, but conspicuous. The *faserkiesel* are ovoid or ellipsoidal quartz-sillimanite bodies, up to 15 cm. in length. Their transverse diameter is about a fifth of their length. These curious bodies lie, with their long axis parallel to the lineation, scattered throughout the rock. Only small isolated exposures were seen. One was near where a band of sillimanitic quartz-felspar granulite was lost among granitoid biotite gneisses, and it is suspected that they represent the last visible stage in the dissolution of the sillimanitic rocks in migmatitic gneiss.

A mass of nearly pure sillimanite rock was seen near the Losigirechi watercourse, on the wall of a shallow gorge. This mass, which was not actually reached, was seen to be several yards thick and lenticular. It occurs, apparently as a segregation, in sillimanitic quartz-felspar granulite. A fallen block, weighing several tons, was extremely tough and homogeneous. A section showed that it consists almost wholly of sillimanite, with a little quartz.

(*b*) *Graphitic Gneiss.*—Graphitic gneisses have been found in many places underlying the crystalline limestones, in a few places overlying them, and seldom elsewhere. No clear sections were seen, but the thickness of the bands is probably no more than twenty feet or so. The graphite flakes are sprinkled in a quartz-felspar matrix, and are ordinarily 1–2 mm. in diameter. Coarser flakes were seen only in small veins, sometimes with quartz. The rocks are soft and often outcrop in watercourses or strike hollows. Although the graphite might have been derived from carbonates during metamorphism, it is thought more probable that it represents original carbonaceous organic material imprisoned in the argillaceous sediment.

(c) *Garnetiferous paragneisses.*—The garnetiferous paragneisses are grey gneisses rich in biotite. The garnets are poorly crystallized and up to 1 cm. in diameter. Very often the foliation is wavy or wrinkled and there are small lenticular quartzose segregations throughout the rock. Such rocks were evidently shales.

Thin sections show the essential minerals to be biotite, garnet, quartz, plagioclase and microcline. The texture is crystalloblastic. The flakes of biotite are aligned and concentrated in folia; they are splayed out against the garnets. In some rocks their colour is reddish brown, in others a duller brown with pleochroism from straw or raw sienna brown to nearly black. The garnets are riddled with quartz blebs and enclose scraps of biotite.

The composition of the plagioclase ranges, in the slides examined, from acid andesine (Ab_{65} An_{35}) to albite, but is typically basic oligoclase. Microcline is nearly always present, although scanty in some rocks. Some slides show microperthitic intergrowths.

Other minerals occasionally seen include hornblende and muscovite. Green spinel was found in one slide (28/4). Small ovoid apatites, grains of ore, and minute zircons are the usual accessories.

A typical rock of this group was estimated to have the following composition by volume:—

	Per cent
Biotite	15
Quartz	30
Plagioclase	25
Microcline	20
Garnet	10

(d) *Garnetiferous para-granulites.*—Garnetiferous acid para-granulites are highly characteristic of this area. They are coarse whitish quartzo-felspathic rocks sprinkled with garnets. Bedding is strongly suggested by concentration of garnets in bands, and by regular coarse slabby jointing. These rocks occur especially in a zone which was mapped for about 60 miles along the strike, from the Barsaloi River in the north, southwards across the Uaso Nyiro. They are associated with limestones and other sedimentary types. This and their regular stratified appearance leaves no doubt of their sedimentary origin. Other rocks with essentially the same appearance, except for the absence of the regular stratification, were however found as transgressive sheets.

In slides the texture is seen to be slightly gneissose; the quartz is segregated in folia, or forms elongated grains. Plagioclase is the chief felspar. It is albite in some slides, oligoclase in others. Microcline is usually seen too, either as small replacive patches, in microperthitic intergrowths, or as separate minutely twinned grains. Biotite is scarce or lacking. Apatite, zircon, rutile, ore, muscovite and sericite were noted in some or other of the slides.

The volume composition of a typical example of these rocks (28/17) was estimated as:—

	Per cent
Albite	60
Quartz	25
Microcline	8
Garnet	5
Ore, apatite, etc.	2

Such a composition does not suggest derivation from a shale; nor would the regular stratification be expected if this were their origin. They are homogeneous and continue apparently unchanged up to their contacts with crystalline limestones, so that a migmatitic origin is difficult to accept. Their mode of origin is left unsettled.

Semipelitic gneisses and granulites

Some flaggy grey biotite-rich granulites and gneisses, which lack visible garnet or sillimanite, but have more biotite than the psammitic granulites, are thought to be derived from semipelitic sediments. They are mostly rather fine-grained. They are

found among other rocks of sedimentary origin. Since no large or continuous occurrences were found, they have not been coloured separately on the map, but are in some places included under the symbol f, and elsewhere in the pelitic gneisses.

In slice, a typical semipelitic granulite (27/73) was seen to consist of well-aligned biotite flakes with a slightly reddish brown colour and about 0.1—0.2 mm. long, in a granulose matrix of quartz, microcline and acid plagioclase (Ab_{88} An_{12}). Proportions of the minerals vary greatly from band to band; the average composition was estimated to be about 30 per cent quartz, 30 per cent plagioclase, 25 per cent microcline and 10 per cent biotite. Another rock (28/21) is more gneissose, and has the following (estimated) composition by volume:—

	Per cent
Quartz	45
Acid oligoclase	40
Microcline	7
Biotite	7

There is also some ore, apatite, a little secondary calcite, and some myrmekite. A little of the plagioclase has grown in ill-formed porphyroblasts. Compared with the previously noticed rock, this one has probably been more altered by granitizing fluids.

Psammitic granulites and gneisses

Metamorphosed sandstones are the most difficult of the sedimentary rocks to recognize, since they differ least from the granitoid gneisses. Pure quartzites are exceptional, and most of the rocks supposed to have been sandstones are quartzo-felspathic granulites, or flaggy biotite gneisses. The only way in which they can usually be distinguished from granitoid and migmatitic gneisses is by their even, parallel foliation and this is not conclusive evidence since some gneisses containing xenoliths and *schlieren* have a similar even foliation. Only the rocks of which the psammitic origin is reasonably certain are mapped as such. The largest mass of such rocks seen was on the eastern side of the Matthews Range.

The three types distinguished are:—

(*a*) Psammitic biotite gneiss.
(*b*) Quartz-felspar para-granulite.
(*c*) Quartzite.

(*a*) *Psammitic biotite gneiss* (included under symbol f on the maps).—These are biotite gneisses with a strong flaggy or slabby parting. The biotite flakes are small, not very abundant, and parallel.

Two rocks (27/54 and 27/44) from north of the Karissia Hills are typical. Both consist of a clean granular mosaic of quartz, acid plagioclase (Ab_{92} An_8 in one, Ab_{91} An_9 in the other) and microcline, with aligned flakes of biotite. The biotite is pleochroic from brownish-black to pale greenish-brown. The ore, which is strongly magnetic, and associated with coronal sphene, is probably titanomagnetite. It is notable that the microcline, untwinned in one rock and faintly twinned in the other, is in simply-shaped grains like the quartz and plagioclase. This habit is different from that seen in the granitoid gneisses.

The estimated volumetric composition of one specimen (27/43) is:—

	Per cent
Quartz	45
Albite	25
Microcline	27
Biotite	1

(*b*) *Quartz felspar para-granulites.*—Rocks which consist almost wholly of quartz and felspars, and which have parallel partings suggestive of bedding are assumed to be derived from sandstones. The spacing of the stratiform partings is not regular but varies, as in a series of bedded sediments. Most of these rocks are pink, at least in the weathered outcrops. A few were found to be white, inside a superficial oxidized crust a few inches thick. Rarely they are white and sugary and then have the appearance

of a quartzite. All, however, are actually highly felspathic. Dark minerals, which are commonly black magnetic ore, or very scanty biotite, are altogether subordinate. Specks of pyrite are not uncommon. In some rocks, flakes of muscovite lie on the stratiform partings.

Such rocks outcrop quite extensively on the eastern flank of the Matthews Range. Sections of typical specimens (28/25, 28/26, 28/27) show that they consist essentially of quartz, microcline and acid plagioclase. Of these, microcline, which forms large clear grains, takes up the largest volume. In one of the rocks it was estimated to be about 40 per cent of the whole.

The microcline has at least partly replaced plagioclase, which not only shows irregularly corroded outlines against microcline, but also faint alkali-edging, and some ingrowth of myrmekite. The plagioclase was determined in two of the specimens as albite, Ab_{91}, An_9, in the other as acid oligoclase. The quartz forms large and irregular lobed grains, and smaller round ones enclosed in the felspars. Other minerals noted in one or other of the slides were: biotite, pleochroic from dark slightly reddish brown to pale brown (in only one rock); a cracked and rounded crystal of yellowish zircon; an irregular patch of pyrite; black ore; rutile? (a granular aggregate); sericite and hematite.

Many other rocks studied are similar, both in texture and in the proportions of the minerals. Felspars are in nearly every case in excess of quartz. In several of the rocks there are microperthitic intergrowths of microcline and plagioclase. A few slides show aligned flakes of muscovite. Blue anatase, rutile, apatite and sphene (pleochroic from brown to greenish) were recorded as rare accessories. Myrmekite, noted above, is exceptional.

(*c*) *Quartzite.*—True quartzites are exceptional in the area. They occur as thin beds associated particularly with the marbles and graphitic schists as, for instance, a few miles south of Wamba on the western flank of Uaraguess mountain. The rocks are white or greyish, and translucent. Slides show a rather coarse sutured quartz mosaic. In one there are flakes of graphite, in another scarce and small shreds of biotite and muscovite, besides a little göthite. The most interesting fact about these rocks is their rarity. It is unlikely that comparatively pure quartz sandstones were originally so uncommon among all these sediments, and it seems more plausible to suppose that most of those that originally existed have been felspathized.

Banded Ironstone

A striped siliceous and ferruginous rock found at one place, suggests a comparison with the banded ironstones in the Nyanzian System of western Kenya. The siliceous bands are cherty and the ferruginous ones black, weathering reddish. The bed is only a few feet thick and was noticed at two points, about half a mile apart, on the same line of strike. The surrounding rocks are acid gneisses, which have no obvious sedimentary features and were mapped as granitoid gneisses.

The slide made of the rock tends to confirm the view that it was originally a banded colloidal deposit like the banded ironstones of the Nyanzian System, with which it was compared in the field. It consists of a fine-grained mosaic of quartz grains 0.05 mm. and less in diameter, with delicate sinuously parallel streaks and films of black dust, which is probably magnetite. These opaque folia swerve apart, and pass round knotty porphyroblasts of albite. One small porphyroblast of microcline was seen, and a subhedral crystal of grey sphene.

It was noticed that the quartz grains, which are somewhat elongated parallel to the foliation, have in a majority of cases their c-axes nearly parallel to the foliation.

Although the magnetite folia are on the whole parallel, some divide into gently diverging streaks or run into irregular patches, which are clearly replacive.

The fineness of grain of the quartz is taken to show that it has crystallized from an even finer-grained or colloidial siliceous material. The oligoclase porphyroblasts, and the preferred orientation of the quartz, prove that the rock is pre-metamorphism, and not a subsequently introduced sheet or vein.

Spessartite-Granulite

Several loose blocks were seen of siliceous granulite with bands of fine-grained spessartite garnet. The garnet bands weather black, and are sharply defined. In one of the specimens, from the Karissia Hills, the bands are intricately contorted on a small scale. Similar rocks have been found elsewhere in the Basement System of Kenya, but their relationships have not been worked out. One specimen from the Lellembe Hills near Kajiado, was collected from below massive quartzite, in a sedimentary complex. It is probable that such spessartite rocks represent manganiferous sediments.

Metamorphic rocks of Volcanic origin

Three kinds of rock are identified, with some hesitation, as of volcanic origin. They are:—

(*a*) Meta-amygdaloid (?);
(*b*) Plagioclase amphibolite (part);
(*c*) Striped hornblendic rocks.

The first two of these are perhaps lavas and the last, tuffs. The supposed *meta-amygdaloids* are hornblendic rocks crowded with ovoid greyish-white spots. The long axes of the ovoids are parallel to the linear fabric of the enclosing rock, and their intermediate axes lie approximately in the plane of the rough foliation. Dimensions vary; the estimated average values for the three axes were 20, 6, and 4 mm. in one rock (36/83). A few of the bodies are indistinctly rhombic in cross-section. In a slide, the spots were seen to consist of ragged interlocked andesine crystals, and a little ilmenite, associated with sphene. Around the spots are hornblende blades, with pleochroism; X—pale yellowish-brown; Y—greenish-brown; Z—dark green. The rest of the rock is a granular aggregate of weakly pleochroic green diopside, plagioclase, a little quartz, sphene and ilmenite. Apatite is accessory. Another rock sliced (35/70) consists largely of hornblende, labradorite (Ab_{33} An_{67}), thin flakes of biotite, and accessory apatite and ore. The spots are filled with a mosaic, finer-grained than the matrix, of plagioclase.

These rocks have only been found in a few places, where they seem to form bands only a few feet thick among the ordinary hornblendic rocks (plagioclase-amphibolites). The most plausible theory of their origin is that they represent the vesicular parts of basic lava flows.

If the spotted rocks are meta-amygdaloids, the associated *plagioclase-amphibolites* are evidently also volcanic. Other plagioclase-amphibolites, occurring among acid and migmatitic gneisses, are supposed to be volcanic because they are homogeneous, unbanded and although in places forming masses hundreds of feet thick, are much finer-grained than, for example, the meta-gabbros of the northern part of the area. In the field their igneous character was not doubted. The best section seen was in a watercourse known as Lendebess. None of these rocks were sliced.

The *striped hornblendic* rocks are uncommon. The best exposures seen were by the Uaso Nyiro near the mouth of the Ngaremat watercourse. The distinctive feature is the delicacy and evenness of the banding. The dark bands are hornblendic, the lighter green ones rich in diopside. There is little gradation from one band to another. Some lighter bands are distinctly coarser in the middle, although they are usually only a few millimeters thick. The bands, although apparently so regular, are in fact not strictly parallel. Pale streaks can sometimes be seen to cross the dark ones at a low angle.

In the slide of a typical example (36/95) the chief minerals are pale green pyroxene, green hornblende, and plagioclase. The hornblende and pyroxene form simply shaped grains, elongated parallel to the other foliation. The plagioclase is a basic andesine. Other minerals are sphene, apatite, calcite and clinozoisite. Nothing in the slide suggests migmatization. The dark and light stripes differ only in the proportions of hornblende and diopside, and of both to plagioclase.

The striped rocks are associated, in the Ngaremat watercourse, with plagioclase-amphibolites and other hornblendic gneisses, but apparently not with metamorphosed sediments. The delicate striping suggests sedimentation and the association with hornblendic rocks, but not with recognized sedimentary gneisses, is in favour of derivation

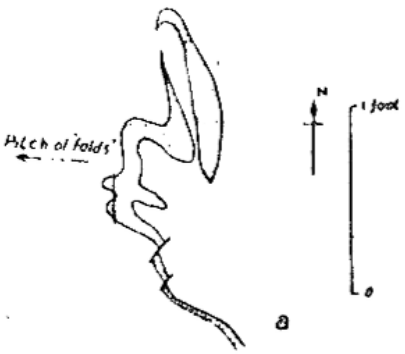
from basic tuff rather than an impure calcareous sediment such as marl. The distinction from banded hornblendic rocks of migmatitic origin is not so definite that a migmatitic origin can be excluded.

Migmatitic Rocks

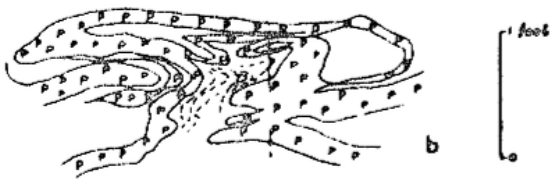
Many of the rocks already described have undoubtedly had their compositions changed by reactions with fluids which permeated them. This permeation did not lead to the formation of magma, and the rocks, although changed, remained homogeneous. Certain other rocks, especially the plagioclase-amphibolites supposed to have been formed from basic volcanic rocks, often enter into complex banded gneisses. In these, the hornblendic host is traversed by innumerable parallel or obliquely anastomosing films and sheets of acid granulitic gneiss. The contacts of the acid and hornblendic components are usually transitional but sometimes sharp. It appears that the acid bands resulted from the injection of magmatic material into the basic host. Intricate contortions which have no evident relation to the regional tectonic pattern, are characteristic (*see* Fig. 3)

FIG. 3

Structures in Migmatitic Gneisses



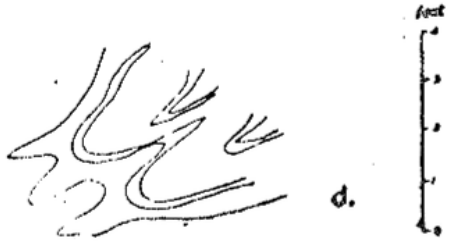
a. Irregularly contorted hornblendic band in magnetite-bearing acid gneiss. Oporoi, Karissia Hills.



b. Pegmatitic veins (P) in hornblendic migmatite. Section on vertical face. One mile W.N.W. of Tupa.



c. Pink granitic bands in intensely folded biotitic migmatitic gneiss. Section on small vertical rock face, as seen looking N.N.W. In gorge about 14 miles N. of Losiolo.



d. Section on vertical rock face, as seen looking N.N.E. The folds trend N. 28 E. Barsaloi River.

These contorted rocks strike irregularly in all directions. The bands swell and thin in a manner suggesting viscous rather than plastic flow. Such rocks are regarded as migmatites. Where the hornblendic bands lose their continuity and become *schlieren*, the rocks pass into hornblendic orthogneisses.

A series of specimens from the Seya River near the drift on the Wamba-Barsoloi road, illustrates the features of these rocks. The hornblendic host (27/92) consists of aligned blades of hornblende, and a granular mosaic of clear untwinned plagioclase, subordinate quartz and some epidote. The hornblende has pleochroism: X—straw; Y—deep green; Z—deep blue-green; ZAC about 16½°. The plagioclase is andesine, about Ab_{63} An_{37}. The rock is faintly banded, and a weak foliation is seen in the slide. A slide of the banded migmatite (27/93) shows acid and hornblendic bands together. The hornblendic band is texturally similar to the host rock just described. Some of the hornblendes have peripheral grains and patches of epidote. The plagioclase is an oligoclase, about Ab_{75} An_{25}, with lamellar twinning. The acid band is a granoblastic mosaic of quartz and clear plagioclase with a few blades of hornblende and elongated grains of sphene. Quartz is less abundant than plagioclase and tends to be segregated in folia. The plagioclase, in which quartz drops are enclosed, is oligoclase, about Ab_{75} An_{25}, and not appreciably different from that in the hornblendic bands, but more acid than in the more homogeneous host rock. The more acid part of the migmatite is a regularly foliated grey and white rock, in which some of the folia are hornblendic. In section it is seen to consist of small blades and shreds of hornblende, the same colour as in the other two slides, in a granulose quartz-plagioclase matrix. The plagioclase, which contains small quartz drops, is oligoclase, about Ab_{75} An_{25}. A little vermicular epidote, irregular grains of sphene and a little ore are associated with the hornblende. The hornblende blades are strung out in ill-defined folia.

Another series represents a hornblendic host rock, a rib of granitoid gneiss and a hornblendic migmatite from between the two. The granitoid gneiss (36/134) is a pink and grey rock with about 5 per cent biotite, no hornblende, some 30 per cent microcline, about the same amount of quartz and slightly more oligoclase. Accessories are zircon, ore and apatite. The migmatitic gneiss (36/135) consists largely of oligoclase (Ab_{78} An_{21}), with subordinate quartz, a little microcline, some biotite and hornblende. The basic host (36/138) is also mostly plagioclase, about Ab_{63} An_{37}, with about 20 per cent of hornblende. Biotite and quartz are scarce. A small lens of biotite-amphibolite was found enclosed in this rock.

Such series show that the acid component of these rocks is by no means an ordinary granitoid gneiss. It has often little or no microcline and the plagioclase is a basic oligoclase, nor does its texture suggest crystallization from magma.

Many other rocks are doubtless also migmatitic, but owing perhaps to the structural properties of their host rocks their nature is less obvious. Many biotite gneisses, and some quartzo-felspathic granulites, are of this kind.

Metamorphosed Intrusive Rocks

(*a*) *Granitoid Gneiss.*—The granitoid gneisses are massive, usually pink, and outcrop conspicuously as tors, bald crags, and inselbergs. In the low country they are often the only rocks exposed, so that one tends to think that they underlie large areas. The inselbergs on which they outcrop are, however, usually aligned parallel to the strike, and have only a backbone of granitoid gneiss. The rocks on either side are often unexposed, but can in some places be seen to be flaggy biotite gneisses. Thin sheets, only 20 or 30 feet in width, form conspicuous rock ribs, some of which are continuous for several miles. The inselbergs are probably developed where the sheets are thickest, or where the gneisses have a larger proportion of microcline. The actual contacts of some of the thinner bands are distinct, and in bare stream section they can be located within a foot or two. There is a rapid transition through banded gneiss, but no chilling.

FIG. 4

Wavy Foliation in acid orthogneiss

The lenticular band (G) is slightly coarser-grained than the surrounding gneiss. Vertical section. Near the Timau–Isiolo road, about one mile W. of the Ngare Ndare.



The foliation in these gneisses has very often a characteristic waviness (*see* Fig. 4), or it may be contorted. A few of the rocks are unfoliated. Dark *schlieren*, either biotitic or hornblendic, are common. In a few cases definite intrusive contacts were seen. The best examples noticed were at the eastern side of the large mass of granitoid gneiss through which the Suiyan has cut a gorge (1° North, 37° East). Here in the sides of the gorge, large masses of evenly foliated biotitic gneisses, evidently altered sediments, are cut off abruptly without relation to the strike, at contacts with granitoid gneiss which was intruded into them. The relationships are comparable to those at many granite contacts in non-metamorphic terrains, but the intrusive rock is apparently the same as the ordinary granitoid gneisses. Another significant contact was studied on the side of a hill of crystalline limestone at 0° 31′ North, 36° 29′ East. The intrusive rock is a pink granulite, with weak gneissose foliation, which encloses large blocks of crystalline limestone similar to that on top of the hill, but slightly coarser. The contacts are sharp and the intrusive pink granulite does not show any sign of contamination, even close to the limestone xenoliths, so far as could be seen in the field. Irregular tongues of the granulite run into the limestones at the same place.

In another place south-east of Olloromade Hill (Lendili), one of the thin ribs of granitoid gneiss forks and the two branches diverge at a low angle. Again, at Murubusi Trigonometrical Point, a ridge of granitoid gneiss curves obliquely across the general strike. From these and other observations it is apparent that the granitoid gneisses are intrusive.

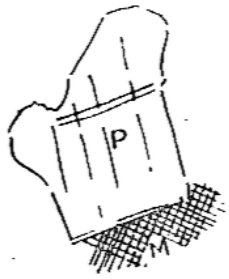
That they attained a semi-magmatic condition is suggested by the wavy foliation and contortion, and also by the fact that unlike most of the metamorphic rocks of the area, they often contain some grains which have plane crystal faces, although no euhedral grains were seen. The *schlieren*, too, have the appearance of semi-plastic lumps drawn out during the flow of the enclosing granitic material. Although none of this evidence is decisive, some difference in condition between these rocks and the surrounding ones is indicated, and since the latter have themselves been altered by reactions with fluids, a further stage in the replacement process, involving production of magma, is inferred for the granitoid gneiss. It must be admitted, however, that in many places the granitoid gneisses of this type could not be definitely discriminated from other rocks.

Thin sections show clearly that replacement has played a large part in producing the textures of these rocks. Replacement of plagioclase by microcline is unmistakably obvious in most slides (*see* Fig. 5).

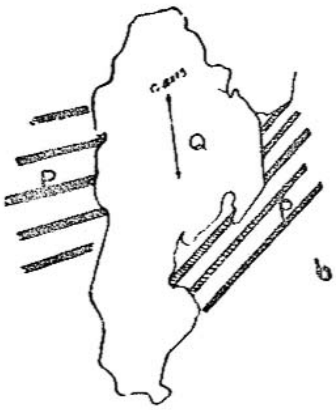
Frayed relics of oligoclase are enclosed in clear plates of microcline. The oligoclase crystals are cloudy, with clear alkali edges against microcline, and myrmekite is common at their contacts with microcline. Replacements of plagioclase by irregular plates of muscovite is frequently seen. Whether quartz has replaced felspars is more doubtful, but in some slides it appears that it has encroached slightly on the microcline. Indications of replacement of plagioclase by quartz are rare.

FIG. 5

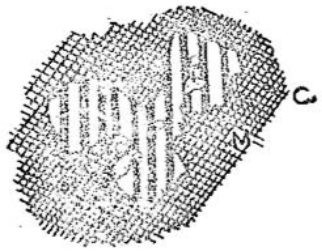
Textures in granitoid gneiss



a. Oligoclase showing crystal face against microcline which crystallized later. (27/6).



b. Quartz showing crystal faces against plagioclase (27/8).



c. Relic of plagioclase, with quartz blebs, enclosed in a large grain of replacive microcline (27/10).

Sketched from thin sections. Each sketch represents about 1 sq. mm. of the section.

Not all the crystal grains have replacement relations however. About half of the slides contain some felspar grains with one or two plane crystal faces. Oligoclase has crystal faces against quartz, microcline, and rarely biotite. In some slides quartz has crystal faces against microcline, though in others the reverse holds. From such relationships it is inferred that some of the minerals crystallized from magma, though igneous textures have largely been obliterated by the replacing microcline.

Gneissose structure is often shown in the field by sub-parallel streaks, wisps or flecks of dark minerals, principally biotite. Quartz is often segregated in lenticular folia. Slides commonly show a rough alignment of biotite flakes. Besides the gneissose structure, there is often a clear lineation, marked especially by parallel streaks of dark minerals. Neither the foliation nor the lineation are regarded as due to deformation after the formation of the rocks, since the fabric seems to be post-deformation. Viscous flow during the deformation, and crystallization after movement had almost ceased, seem best to account for the facts.

The essential mineral components of the granitoid gneisses are quartz, microcline, oligoclase, and biotite. Microcline is the deminant felspar in a majority of the rocks. Microperthitic (often antiperthitic) intergrowths of felspars are not uncommon. The oligoclase varies in composition from Ab_{8_0} An_{2_0} to Ab_{9_0} An_{1_0} in the rocks examined. Quartz forms large lobed grains, small irregular ones, sporadic round blebs in the felspars and vermicules in myrmekite. Strain-polarization is unusual and never intense. The biotite is dull brown or greenish-brown and is occasionally interleaved with muscovite, or transformed to chlorite. Titanomagnetite, sphene, apatite, zircon and muscovite are accessory. Muscovite occurs both as primary well-formed flakes and as replacive ragged patches. Both rounded and euhedral apatites were noticed. In several rocks, the zircons are purplish and internally cracked. Hornblende is not found in typical examples of these rocks. Scarce garnets were seen in two slides.

(*b*) *The Garnetiferous ortho-granulites* are chiefly interesting from their resemblance to other rocks which are known to be sedimentary. At the few places where such rocks were recognized as intrusive they form thin sheets cutting across the foliation of hornblendic rocks at a low angle. The garnets are scattered in a whitish granulitic matrix, and are slightly more concentrated near the contacts of the sheets. The sheets themselves, in at least two cases, have clean contacts and appear to occupy plane fractures.

In thin sections, the rocks are seen to consist largely of quartz, oligoclase, and replacive microcline, with biotite, muscovite (partly replacing biotite in one slide), garnet, ore and zircon. They are distinguished from the superficially similar garnet paragranulites by their field relations, absence of "bedding" and larger proportion of microcline.

(*c*) *Meta-Quartz Porphyry.*—Only one such rock was recognized. It was found east of Lamerok Hill* and in the field was recorded as an aplitic dyke. The thin section shows a very fine-grained quartzo-felspathic aggregate, in which are scattered small flecks of biotite, ragged replacive plates of muscovite, small patches of calcite, a little chlorite secondary after biotite, and a little colourless epidote. The grain size of the quartz-felspar mosaic is rather even, and about 0.05–0.1 mm. In this fine-grained matrix there are a few much larger (0.7 mm.) grains of quartz, with distinctly preserved crystal form, which are clearly phenocrysts. They are not distorted. There are also less well-shaped grains of acid plagioclase, partly converted to sericite and calcite. One has still its original square outline. Microcline replaces the plagioclase in small patches. The biotite flakes, up to 0.2 mm. long are not aligned. The rock is of interest for the light it throws on the metamorphism.

(*d*) *Biotitic foliated dyke rocks.*—Only a few narrow dykes of this type were noticed among the gneisses. Their contacts are sharp and it is clear that they were igneous. They are schistose, owing to the alignment of the minute biotite flakes which are disseminated throughout. The foliation is parallel not to the walls, but to that in the surrounding gneisses. Thin sections show no trace of original structures. One (36/88) has small porphyroblasts of oligoclase (Ab_{7_0} An_{3_0}), aligned plates of biotite, some pale green augite, a little hornblende, quartz, and plagioclase. Apatite and ore are accessory. In another (36/111) there is a porphyroblast of microcline, in a fine-grained base of quartz, microcline, orthoclase (?) acid plagioclase and biotite, with accessory magnetite and apatite. A third rock sliced (36/33a) is more acid. It consists of small aligned greenish-brown flakes of biotite, ragged grains of microcline, round and irregular quartz grains, and grains of apatite, and also a little ore and some myrmekite. Its volume composition was estimated by eye as 25 per cent microcline, 10 per cent biotite and ore, 30 per cent quartz and 35 per cent oligoclase.

* West of the Wamba-Baragoi road, a little beyond the northern limit of the map.

These dykes were probably basic, and their present composition implies considerable reaction with permeating solutions. Pegmatitic films traverse the last mentioned specimen.

(*e*) *Meta-dolerite.*—Several sheets and dykes of an unfoliated dark holo-crystalline rock were seen. They outcrop conspicuously as large spheroidal masses, and some of the intrusions, although narrow, can be traced for several miles. No contacts were seen, although their position was in most cases evident.

The most interesting occurrence is a dyke which cuts across granitoid and migmatitic gneisses nearly at right angles to the strike, in the Mukogodo country. Its width is apparently about fifty yards. A specimen (36/146) of the rock is homogeneous, with plagioclase, pyroxenes (some with bronze schiller) and biotite evident to the eye. Under the microscope the coarse doleritic texture can still be recognized although the original minerals have been replaced. The original ophitic augite is represented by aggregates of schillerized hypersthene, pale-green schillerized monoclinic pyroxene, biotite and a little greenish hornblende. The felspars are unzoned, and are now andesine. They are full of short lines of minute black inclusions, the lines running in all directions without any evident order. Quartz is scarce and interstitial between felspar grains, or among the dark minerals. It encloses minute unoriented rutile prisms. Apatite, as thick prisms, and magnetite or ilmenite, are accessory. Scanty myrmekitic growths of quartz in andesine, and minute specks of microcline (?) and calcite, were also noticed.

Other slides are similar. Four out of five have hypersthene; the one without it (27/20) has hornblende but no pyroxene. The plagioclase was determined as basic oligoclase, oligoclase-andesine (Ab_{70} An_{30}) and andesine (Ab_{57} An_{43}, Ab_{60} An_{40}) in different slides. A rough visual estimate of the composition (by volume) of one rock (36/37) was:—

	Per cent	
Biotite	12	(replaces pyroxene)
Pyroxenes	3	(Hypersthene and diopside)
Quartz	7	
Oligoclase	70	
Ores, apatite	2	
Microcline	1	

This is less mafic than the hand-specimen suggests, but is not typical. The biotite flakes in it are roughly aligned, and the composition suggests reaction with permeating fluids.

(*f*) *Meta-gabbro.*—The best example of a metagabbro was found beyond the northern limit of the area near Baragoi, where basic and ultrabasic rocks are widespread. The rock is coarsely speckled, greenish-black and white. The original large felspars have been replaced by finely granular white aggregates, and the pyroxene by greenish hornblendes. In a section (27/55) the hornblende is seen to enclose opaque dust, rutile prisms, and quartz blebs. Some of the plagioclase is densely clouded, some clear. A clear grain was determined as andesine, about Ab_{60} An_{40}.

Further south, among the metamorphosed sediments east of the Seya, there are large sheets or lens-shaped masses of a distinctive rock with poeciloblastic lozenge- or *augen*-shaped hornblende crystals half an inch or more in length, set in a felspathic base. The rocks are strongly schistose or foliated, unlike the Baragoi metagabbro which is only weakly schistose. The two slides made show poeciloblasts of green hornblende enclosing quartz, plagioclase, and ore, blades of green hornblende free of inclusions, chestnut-brown biotite (in one slide) and plagioclase (basic plagioclase and acid andesine). Quartz, ovoid grains of apatite, and ore, are accessory. These rocks may have been gabbros.

(*g*) *Amphibolite.*—Glistening greenish-black amphibolites are exposed in many of the hills near the northern limit of the area, on either side of the Barsoloi–Baragoi road, as well as further north outside the area. From their associations, field relations, and homogeneity it is obvious that they are metamorphosed igneous rocks, ultrabasic in composition. Rough parallelism of the amphibolite blades gives some of them a weak schistosity.

One rock sliced (27/66) is an aggregate of ragged interlocked prisms and blades of actinolite, in which are enclosed minute prisms and arrow-head or geniculate twins of rutile and minute grains of sphene. In another slide (27/84), actinolite, the major constituent, has clearly replaced crystals of another mineral, probably augite, whose outlines are marked by faint lines of black inclusions. In this slide there is also a little basic plagioclase, with quartz, epidote, and calcite. Such rocks were probably originally pyroxenites. A bright green chlorite schist, consisting of clinochlore with a little actinolite and magnetite, and a green epidosite were seen on Siambu Hill among amphibolites.

(*h*) *Talc-rocks and tremolite rocks.*—Several pod-shaped masses of soft light-coloured talc-rock, tremolite-rock, and mixtures of the two minerals, occur in the same region as the amphibolites just described. Within the area mapped the masses are small and not many yards wide. Further north, towards South Horr, such rocks are said to cover large areas. The tremolite rocks consist of rosettes and fan-shaped clusters of pale buff crystals. The talc rocks are lumpy and brown-weathered. Neither are foliated, but the talc rocks are roughly schistose near their contacts..

In sections, the talc rocks are found to consist of interlocked and unoriented thick plates of talc, with brownish or black dust. There are also scattered small prisms of anthophyllite, and a little serpentine. A tremolite rock (27/60) has matted blades and sheafs of tremolite, and specks of limonitized magnetite. One polygonal dusty shape suggests the form of olivine. These were probably dunites.

(*i*) *Peridotite.*—A low hill, north of the Uaso Nyiro (37° 26′ E., 0° 36′ N.) is formed of a tough, black and heavy peridotite. The rock is fresh and not foliated. The visible minerals are black hornblende, as poecilitic blades up to two inches in length, flakes of bronze biotite, and green granular olivine. The outcrop of the mass is round or oval as if it were a boss. Its contacts with the surrounding acid and hornblendic gneisses were not seen.

A thin section (36/94) shows that the chief constituents are olivine, hornblende, biotite, diallage and hypersthene. Plagioclase is subordinate. Green spinel, magnetite, pyrrhotite and actinolite are accessory.

The olivine, which forms about one-third of the rock, is optically negative with a large optic axial angle. The grains range up to 2 mm. in diameter. Many have kelyphitic borders of hypersthene surrounded by actinolite. Olivines enclosed in hornblende are surrounded by magnetite. Hypersthene, faintly coloured, also occurs as separate compact grains up to 1 mm. in length. Diallage is another original constituent and in parts of the slide is in excess of olivine. It is patchily replaced by greenish-brown hornblende.

The large poecilitic hornblendes are brown, and only weakly pleochroic. They enclose olivine and magnetite. The brown mica also is weakly pleochroic and nearly uniaxial, with $N_m = 1.57$; it is a biotite and not phlogopite.

Plagioclase is interstitial to the dark minerals, and is estimated to amount to less than 5 per cent of the rock. It was determined as labradorite, $Ab_{48}\ An_{52}$.

It is possible that this rock does not belong to the Basement System, but affinity with the meta-dolerites is suggested by the presence of hypersthene, and no intrusions of this kind of any other age have yet been recognized in this part of Kenya.

Rocks of uncertain origin

Of many such rocks only a few deserve mention.

(*a*) *Plagioclase-amphibolite, pyroxene granulite and epidote granulite* – Plagioclase amphibolites are common, especially in the north of the area, and in several places are the prevalent rocks over quite large areas. They are speckled greenish-black and grey with a rough schistosity and faint foliation. In slides the essential minerals are seen to be plagioclase and hornblende, with subordinate quartz. The plagioclase was determined as Ab_{65} An_{35}, Ab_{58} An_{42} and Ab_{67} An_{33} in typical slides. Sphene, biotite, magnetite, apatite, pyrite and chalcopyrite, were noted in one or other of the slides.

Associated with these rocks are others, either granulitic or gneissose, in which the dominant dark mineral is either pyroxene or epidote. A typical pyroxene-bearing granulite (27/7) contains poeciloblastic pale emerald-green pyroxenes, which are weakly pleochroic and have distinct dispersion. They enclose globules of quartz, grains of epidote and small hornblendes. Hornblende, epidote, clear plagioclase (acid andesine) and quartz form a granoblastic mosaic. There is a little sphene and scarce orthoclase. In one rock (36/39) the transformations diopside-hornblende-epidote are clearly shown. In several rocks the sphene is pleochroic from pale brown to pinkish brown. The felspar varies, in different rocks, from oligoclase to labradorite.

These types of rock are conspicuous near Maralal, and on the other side of the Karissia Hills in the Oporoi valley. They may have been derived from basic volcanic rocks.

(*b*) *Aegirine-glaucophane granulite.*—An unusual rock was collected at the top of the western crags of a hill south-east of Uaraguess. The crags are formed of pinkish-weathering granulitic gneisses with a structure suggestive of coarse bedding. The slide (28/36) of what was collected as a representative sample, consists of a granoblastic quartz mosaic, larger grains of microcline, with ragged irregular streaks and patches of dark minerals. Among these, aegirine, in irregular grains, is the chief. It is associated with small compact pleochroic grains of sphene and irregular streaks and clots of magnetite. Along the edges of the aegirine grains and sometimes on the surfaces of other dark minerals, are small flakes and crystals of glaucophane. There is a little acid plagioclase, determined as albite, approximately Ab_{95} An_5. Zircon in very small short rounded and euhedral crystals, is unusually abundant. A mat of rutile needles is associated with some ore. Apatite and scales of hematite were also noted.

(*c*) *Muscovite-quartz-felspar schist.*— Flaky felspathic schists, full of parallel flakes of muscovite, were seen at several places along a zone in the south-eastern part of the area. A section of one of the rocks (36/12) shows aligned cleanly-shaped flakes of muscovite in a granular matrix of quartz, cloudily altered oligoclase, and microcline. Accessories are zircon and rutile. From their persistence along the strike and from their slabby appearance in the field it is thought that these muscovitic schists probably represent a horizon of sandy sediment, altered by permeating fluids. There is, however, little in the slide to suggest such reactions.

(3) Metamorphism

(*a*) *Anatexis*

It has already been remarked that the wide distribution of undoubted metamorphosed sediments, the continuity of certain bands over long distances and the homogeneity of the structural pattern over the whole area, through all kinds of rocks, are taken to mean that the whole complex has been derived from a series of sedimentary and volcanic rocks.

The rocks supposed to be igneous are a small part of the whole. There are no granitic intrusions of batholithic dimensions anywhere in the area nor, so far as is yet

known, anywhere else in the Basement System of East Africa (the Central Granite of Tanganyika, and the granites of the goldfields are considerably younger). There is no direct evidence to connect the metamorphism with any granite mass. The suite as a whole, however, certainly resembles very closely some of the injection complexes described from other parts of the world, for example those of Central Sutherland (Read, 1931). There, addition of material, particularly soda, was proved by analyses. Here, no analyses are available. It appears, however, that in many of these rocks the proportion of soda is higher than it is likely to have been in the original sediments. Whether others of the rocks have lost soda has not been discovered. Were this so, it might well be argued that the metamorphic processes had merely tended to redistribute the constituents, especially alkalies, which were already in the rocks, so as to cause a general convergence towards the composition of granite. The fluids which dissolved and redistributed the alkalies might have been those originally imprisoned in the sediments. Whether or not this interpretation is correct, it is at any rate clear that many of the rocks have been profoundly altered in composition as a consequence of reactions with fluids which permeated them. The penultimate stage of the processes by which the original heterogeneous sedimentary complex is replaced by a more homogeneous biotite gneiss is exemplified by the occasional occurrences of lumps of calc-silicate granulite enclosed in slabby biotite gneisses of sedimentary aspect. Transformations in composition, such as are suggested in the above paragraphs and by evidence contained in the preceding sections, are comprehended in the general term anatexis.

(*b*) *Grade of Metamorphism*

Throughout the area the grade of metamorphism is high. Sillimanite is everywhere the characteristic mineral in the pelitic gneisses, whereas kyanite, which has been found in many other parts of Kenya (Parkinson, 1913, 1941), and in Tanganyika (Temperley, 1938, p. 40) has nowhere been found. Graphite occurs in gneissose rocks and not in fine-grained grey schists as it does in some other places in Kenya. The limestones contain forstertite. Calc-silicate granulites with bytownite, a pale emerald-green pyroxene, and garnet, are found at many places. The high grade, shown particularly by the common occurrence of sillimanite, distinguishes this area from others so far described in Kenya. It seems possible that some broad zoning in the Basement System may be found practicable. If so, it should be of some help in judging where minerals of economic value are likely to occur.

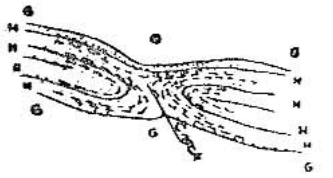
(*c*) *Hydrostatic pressure and shearing stress*

The hydrostatic pressure that prevailed while metamorphism was proceeding does not seem to have been exceptionally high. Among the basic rocks, which are most sensitive to such pressure, the dense eclogite facies has not been discovered. The nearest approach to it is seen in the andesine-green diopside-epidote-garnet assemblages which suggest moderate hydrostatic pressure. No charnockites were found.

The part played by shearing stress in controlling the mineral assemblages and fabrics is judged to be subordinate. The dyke of metadolerite which cuts across the gneisses in the Mukogodo Hills (*see* above p. 19) seems to have the same mineral facies as many other rocks of the area, although it is essentially post-tectonic and is not sheared or foliated. Deformation of original structures in the few rocks where these can be recognized, for instance in the meta-amygdaloids and the meta-quartz porphyry, is not excessive. On the other hand, preferred orientation of many of the minerals is apparent. The mica flakes lie mostly parallel to the foliation, and sillimanite has always grown nearly parallel to the lineation. This orientation of the sillimanite, which has usually grown in a granulose matrix of quartz, cannot be mimetic. The stress must have been applied while the sillimanite was crystallizing, although it does not follow that it was excessive, or involved much deformation. Garnets with spirally arranged inclusions have nowhere been found. The disposition of the foliation in certain hornblendic rocks cannot be interpreted as an effect of plane shearing. (*See* Fig. 6.)

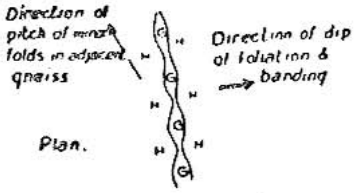
FIG. 6

Relation of foliation to boudinage structure



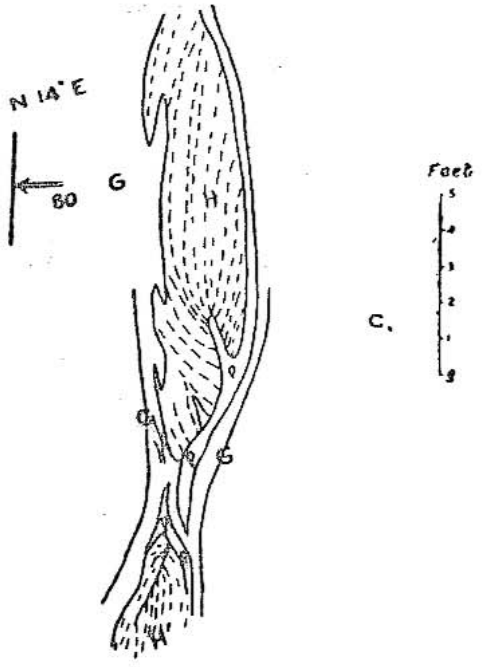
a.

a. Hornblendic gneiss (H), showing *boudinage*-structure and enclosed in acid gneiss (G), the two together forming a migmatitic gneiss. Vertical dip-section. At confluence of Langat and Suiyan water courses.



b.

b. Boudinage structure of an acid gneiss band (G) which is enclosed in fine-grained hornblendic gneiss (H). Plan. In a vertical dip section the width of the gneiss band is constant. S.W. of Wamba.



c.

c. Amphibolite lenses (H) in acid gneiss (G), with white hornblendic-bearing pegmatite veins (P). Exposure on flat surface. Lbagoi water course.

The fabric of the granitoid gneisses seems to be essentially post-tectonic and crystal faces supposed to have formed in magma have not been destroyed or deformed.

This sketch of the factors involved in the metamorphism leads to the conclusion that high temperature and permeating fluids were the essential factors, shearing stress less important, and hydrostatic pressure of little influence. The sheets of granitoid gneiss seem to be one of the products of the regional metamorphism, rather than its cause. No connexion between grade of metamorphism and proximity to such sheets has been traced, although there is some evidence that the effects of alkaline fluids were greatest near them.

(4) Structure and Distribution

The structure of the Basement System in this district is intricate and has not been resolved by this rapid survey. It was hoped that by recording the dip and strike of the foliation, and by using the generally conspicuous limestone bands as markers, the broad structural plan might be discovered, but the data are inconclusive. Most of the structural evidence plotted on the original 1:125,000 maps is reproduced on the 1:250,000 map and only a few aspects of the structure deserve mention here. Some of the structural features are shown in Fig. 7.

Distribution of the metamorphosed sediments

A zone of metamorphosed pelitic and calcareous sediments strikes from north to south through the middle of the area. A less continuous eastern zone trends along the western foothills of the Matthews Range and is continued across the western flanks of Uaraguess and Ngurie. It runs N.N.W.—S.S.E. and so diverges from the central zone, southwards. Between these two principal sedimentary zones there are in the Uaso Nyiro basin, various scattered outcrops of limestone, graphitic gneiss, and pelitic gneiss, but further south in Mukogodo none were seen. Northwest of the Karissia Hills small limestone outcrops were found in two places: limestone was also found, a little north of the limit of the area (see map), near a small basalt outlier south of Lgerei. Limestone and garnetiferous and sillimanite-bearing gneisses form a small hill north of Lengishu. Many of these occurrences show an association of limestone, graphitic gneiss, and pelitic gneiss so similar that it is certain that the same stratigraphical horizons are repeated. There are, however, at least three separate limestone bands south of the Uaso Nyiro and doubtless these are not all.

Structural relations of the sedimentary zones

In the eastern zone the dips are consistently eastwards (or E.N.E.), except northwest of Wamba, where the dips are locally westward. The westward dips appear to be due to subsidiary folds, with wave lengths of one or two miles, a nearly north-south trend and a northward pitch. The gneisses on either side of the eastern zone also dip eastwards. The width of the zone varies from about 2½ miles to nothing. The fingering-out shown on the map is a diagrammatic representation of the manner in which this is thought to occur. The fine section along the Ngeng River shows only one very thin band of sillimanite gneiss in place of the wide outcrops five to ten miles further north. The rapid change cannot plausibly be interpreted as an original variation in facies along the strike and from the dips recorded it can hardly be supposed that the whole sedimentary zone is a complex synclinal infold, nor is faulting indicated. The explanation preferred, in this and similar instances, is that the para-gneisses pass along the strike into migmatitic biotite gneisses by which they have been replaced. It might be argued that if the zones are merely unreplaced relics, the fact that particular associations of metamorphosed sediments are characteristic of them is no indication that such associations were restricted to these zones of the original sedimentary complex. But the persistence along the strike of some bands, notably the limestones, and their rarity elsewhere, is taken to show that the present discontinuous and variable zones do in fact represent the principal horizons of pelitic and calcareous sediments of the original complex.

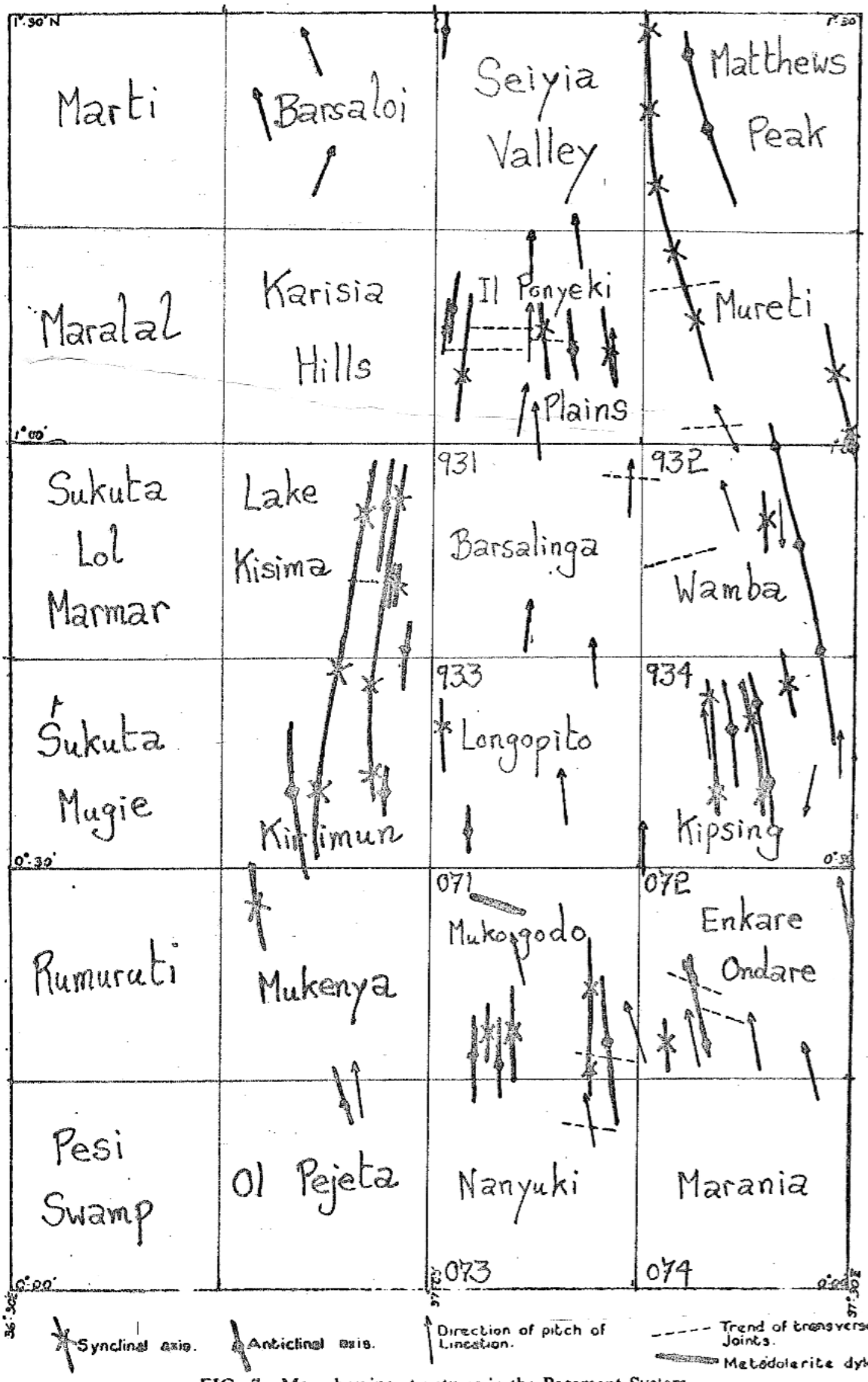


FIG. 7—Map showing structures in the Basement System.

In the central sedimentary zone, the direction of dip is variable (*see* sections, Fig. 8). Towards the south, westerly dips prevail, although contrary dips indicate some tight folding, which is also brought out by the sharp zig-zag of an easily recognized band of sillimanite gneiss west of the Loldaikas. Northwards of the Uaso Nyiro and the Ngare Narok, westerly dips still predominate, but with frequent reversals. Between the Uaso Nyiro and the Seya, easterly dips are most frequent. Still further north, easterly dips are general down the eastern side of the zone and westerly dips down the other side as if it were anticlinal. Overturning and reversed dips occur. It is clear that at least in the north, the central zone of sediments is folded, and the direction of sheet dip is not clear.

Structures in the Basement System outside the main sedimentary zones

Between the two main sedimentary zones, repeated changes in the direction of dip show that there is a series of parallel folds. Beyond the eastern zone, in the Matthews Range, the dips appear to be generally eastwards, with a shallow synclinal roll, perhaps continuing south of Uaraguess, along the axis of the Range, and a complementary anticline further east. West of the central zone, in the low country towards the Karissia Hills, westerly dips prevail. In the Karissia Hills too few dips were recorded from which to generalize, but rather low dips are common, and on the eastern face of the Hills, the low dips appear to be consistently to the west or northwest.

Structural relation of the Granitoid gneisses

Dips and strikes in the granitoid gneisses are in general consistent with those of the surrounding terrain, but small-scale contortions and waviness are widespread. In sheets which are demonstrably transgressive, for example one about 5 miles S.E. of the transverse dolerite dyke of Mukogodo, the foliation also strikes obliquely across the regional foliation. In some places, the strike of the granitoid gneisses conforms to the regional strike, but the dip seems to be slightly different. This needs confirmation.

Structures in the Migmatites

In certain types of banded migmatite, intense unsystematic contortions are a characteristic feature. An indication of their nature is given in Fig. 3. They are interpreted as the result of plastic flow in semi-magmatic material (*see* p. 15).

Faults

Major faulting in the Basement System, other than of Tertiary or later date, has not been proved. Sudden changes of dip suggest that strike faults replace the limbs of some of the tight folds which strike into the eastern face of the southern Karissia Hills. The mapping was generally too hasty to disclose the faults which doubtless exist. Minor faulting is, of course, often seen, but was not found to be systematically related to major structures.

Lineation and Pitch

A linear fabric is common. Whether it is shown by elongation of mineral grains or aggregates, or is the axis of intersection of two or more foliations, its trend and pitch is much the same. Representative measurements are shown on Fig. 7. It will be seen that the lineation generally pitches towards the N.N.W., the angle of pitch being usually between 5° and 10°. Southerly pitch is much less frequent, and in many parts of the area, unknown. Where the pitch of major folds can be discovered, it also is northwards. Pitch of the axes of the small folds in the contorted migmatites is as variable as their trend, and may be any angle from horizontal to vertical.

General Interpretation and Succession

The interpretation tentatively suggested is that the two principal sedimentary zones of paragneisses with limestones, represent the same series on the two limbs of a complex anticline pitching north. If so, the biotite gneisses, granulites, hornblendic gneisses

and granitoid gneisses between the two zones would represent the oldest part of the succession. The limestones, graphitic schists, and pelitic gneisses of the Uaso Nyiro basin, so closely similar to those of the main zones, would be synclinally infolded or infaulted. The granitoid gneisses, biotite gneisses and hornblendic rocks of the Karissia Hills and Matthews Range would overlie the zone of pelitic gneisses and limestones and the psammitic granulites of the eastern flank of the Matthews Range would be the highest visible part of the succession. The northward convergence of the two main sedimentary zones would result from the northerly pitch. Far more detailed mapping would be needed to elucidate the structure adequately. General north-south strike, repetition of similar strata, close folding, and the prevalence of a northerly pitch are established.

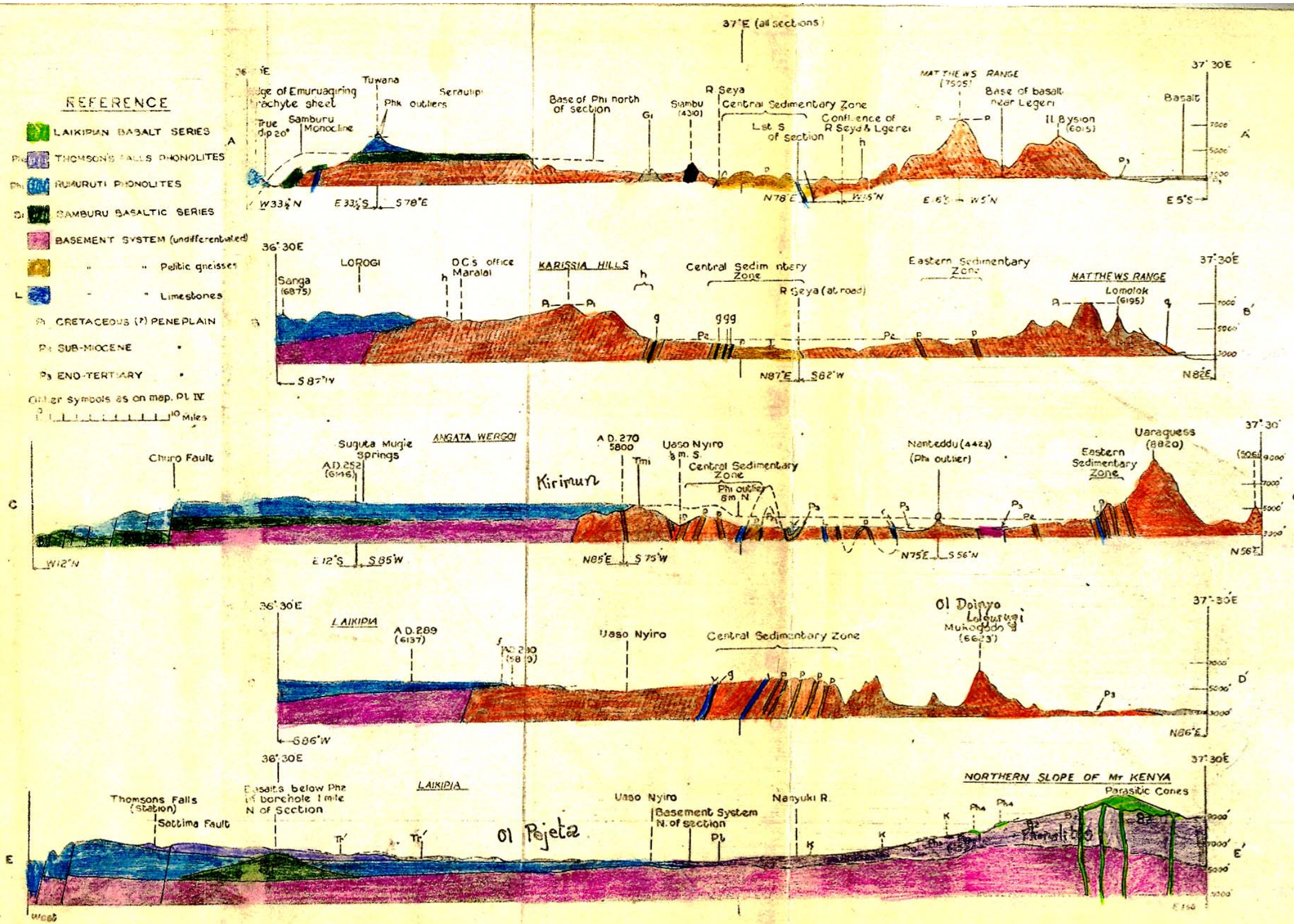


FIG. 8

Geological Cross-sections

p. 27

V—DETAILS OF THE GEOLOGY (II): THE TERTIARY AND PLEISTOCENE ROCKS

Several hundred million years—a large part of geological time—is represented by the unconformity between the Basement System and the overlying rocks which belong, broadly speaking, to the period of formation of the African Rift Valleys. Most of them are lavas, but in a few places, thin deposits of sediments have been found, under the earliest of the lavas, and there is also a cover, seldom more than ten or twenty feet thick except in the valleys, of material accumulated on the volcanic surface after the eruptions ceased. All the rocks of the later periods fall into three groups:—

Pleistocene & Recent	3. Post-volcanic alluvium, gravels, laterite, soils and other superficial deposits
Miocene to Pleistocene	2. Volcanic rocks.
Miocene	1. Sub-volcanic sediments.

(1) Sub-volcanic sediments (Miocene)

Sediments have been discovered underneath the lowest of the volcanic rocks at several places along the eastern fringe of the Laikipia lava plateau, and also beneath a curious narrow and winding outlier of lava east of the Karissia Hills. All these sediments are similar in lithology. The most characteristic is a coarse light-coloured grit with well-rounded pebbles of quartz. There are also whitish shales, soft flaggy siltstone layers, marls with calcareous concretions, greenish-grey clays, and diatomites. They apparently contain no volcanic material but are derived entirely from the underlying metamorphic rocks.

Fossils were found at two places, in the Palagalagi (Palaglan) valley and near Kirimun. There was no time for systematic collecting. The fossils found were submitted to Dr. D. G. McInnes, who identified among them *Deinotherium hobleyi* Andrews, and *Mastodon*, sp. There are also Chelonian scutes, crocodile vertebrae, and other unidentified vertebrate remains.

Details of exposures

The localities where the sub-volcanic sediments have been found are:—

(1) On the northern slope of the Ngare Narok valley, about five miles south-west of the confluence of this river with the Uaso Nyiro.

(2) On the northern side of the Palagalagi valley, about three miles west of the Uaso Nyiro.

(3) Near Kirimun (a few miles south-west of the main bend of the Uaso Nyiro).

(4) Beneath the narrow lava outlier east of the Karissia Hills.

The first of these localities is interesting because it is the only one where the sediments were seen overlying lava; elsewhere they rest directly on metamorphic rocks. A section was seen of about 20 feet of sediments, between a porphyritic phonolite above and a fissile non-porphyritic phonolite below. The latter has only a short outcrop and rests, probably in an old valley, on gneiss. The sediments at

this place are gravelly greenish grits, white impure diatomite (?) and brownish grits, the gravelly beds being at the base. Elsewhere the former presence of the same beds is indicated by well-rounded quartz pebbles strewn over the surface of the non-porphyritic phonolite.

In the Palagalagi valley, the pale outcrops of the sediments are conspicuous below the dark scarp formed by the lowest of the phonolites. The rocks here are quartz grits, gravelly grits, greenish-grey unstratified bentonitic clays, and diatomites. Fossils, amongst them Chelonian scutes, crocodilian vertebrae and other vertebrate remains, are common. The sediments have an outcrop about a mile long but their thickness is probably less than fifty feet.

Kirimun is at the north-eastern corner of the phonolite plateau of Laikipia. The sub-volcanic sediments exposed there are in four separate outcrops. Two, which were not visited, lie a mile or two north-east of the Kirimun spring; the third and principal one is on the western slopes of a small hill capped by a lava outlier east of the spring, and there is a fourth, very small, a quarter of a mile further south. In the largest outcrop, below the lava outlier, the thickness of the sediments may reach a hundred feet. The succession is:—

(6) Porphyritic phonolite.

(5) Flaggy porcellanite layer.

(4) Phonolitic pitchstone.

(3) Pumiceous lapilli tuff (a few feet only).

(2) Sediments, including quartz-grits, silicified arkoses, calcareous grits, marls with calcareous concretions, and greenish bentonitic clays.

(1) Gneiss.

The surface covered by the sediments was uneven, with immature valleys at least a hundred feet deep. Vertebrate remains were found in the clays on the surface. Dr. D. G. McInnes, who examined them, informs me that the fauna includes *Deinotherium hobleyi* Andrews and a species of *Mastodon*. These, in his opinion, suffice to prove the Miocene age of the beds. Further collecting would certainly produce a larger fauna from which more accurate dating should be possible. It seems probable that the beds are approximately synchronous with those of Karungu and other places in western Kenya.

In the Seya valley the sediments occur between the lowest of the phonolites and the underlying gneisses. The surface on which the sediments and lavas rest is even more irregular than at the other places. One very small patch of conglomerate grit underlies the lava, high up on the north side of the valley at an elevation of about 5,800 feet. There is another patch of sediment half way down the same side of the valley and much more extensive outcrops extending up the opposite side from near river level (here about 5,200 feet) to perhaps 200 feet above it. The sediments are being eroded from the slope of gneiss on which they were deposited. The phonolite overlying the sediments flowed into the same valley which for a short distance almost coincides with the present valley of the Seya. The sediments are gravels, gravelly silicified breccias, sands, brown earth, and a rubbly deposit, probably hillwash. A thickness of 150 feet of such beds was measured in a gully south of the Seya.

The sediments also occur east of the Karissia Hills, under outliers of phonolite. At the northernmost of the exposures, on Lowermut Hill, about 70 feet of sediments, chiefly gravels, grits, and laminated flaggy silts, underlie the cap of phonolite. The same series can be seen from a distance under the lava scarps to the south as pale patches, eroded back above a small lower scarp which evidently marks the surface of the gneisses. This part of the outcrop was not reached, but silicified gravels, baked by the overlying lava, were again seen where the lava plateau was crossed about ten miles S.S.W. of Lowermut. The surface of the gneiss under the sediments of this area is remarkably even.

Mode of origin

The generally similar lithology of the sub-volcanic sediments and their stratigraphical position, leaves no doubt that they were all formed under similar conditions at about the same time. In their facies, both lithological and faunal, they resemble the Karungu Miocene beds (Oswald, 1914) which have generally been regarded as lacustrine, although Bayley Willis (Willis, 1936) argued that they are river deposits. In the present area the only evidence in favour of the lacustrine origin is the presence of a thin but rather pure diatomite bed at one place. To explain all of the deposits as lacustrine would mean postulating a lake perhaps 500 feet deep to account for the vertical range in the Seya exposures (a tectonic explanation for the differences in level there can be excluded). A lake of such depth is not suggested by fauna or lithology of the beds at the lower levels. It is possible that the deposits may have been laid down in lakes formed where valleys draining westwards were dammed by lavas flowing into them.

The well-rounded quartz pebbles have evidently travelled far. They recall the similar quartz pebbles also regarded as Miocene, found under the phonolites of the Isuria plateau in S.W. Kenya (Shackleton, 1942).

Comparing these Miocene deposits with those of the post-volcanic period, the absence of laterite and red beds is striking. This and other features suggest that the period was wet.

(2) Tertiary and Pleistocene Volcanic Rocks

Classification

Volcanic rocks cover more than a third of the area. Some of the lava sheets only fifty or a hundred feet thick are yet hundreds of square miles in extent. They are typical plateau lavas. Others, such as those which poured down the slopes of Mount Kenya, congealed in narrower tongues, and are characteristic of the central eruptions. The lavas erupted have a wide range in composition. They are here classified lithologically rather than by age. Their correlation and age relationships are discussed afterwards.

The chief groups distinguished are:—

(i) Samburu Series (basalts and tuffs)	B_1 and B_1'
(ii) Rumuruti Phonolites (Ph_1 part)	Ph_1 (with Ph_k)
(iii) Phonolites of Kapitian type (Ph_k)	Ph_1 (with Ph_k)
(iv) Losiolo Phonolites (Ph_1 part)	Ph_1 (with Ph_k)
(v) Thomson's Falls Phonolites	Ph_2
(vi) Mt. Kenya Suite	
(*a*) Fissile "basalts"	B_2
(*b*) Fissile Phonolite	Ph_3
(*c*) Kenyte and Kenyte agglomerates	K and K′
(*d*) Blocky Phonolite	Ph_4
(*e*) Rocks of the Parasitic Cones	B_3'
(vii) Laikipian basalts	
(*a*) Laikipia	B_3
(*b*) North of Mt. Kenya	B_3
(*c*) Lgerei and north-east of the Matthews Range	B_3
(viii) Quartz Trachyte	Tr
(ix) Trachytic tuffs	Tr′

The symbols are those used on the map.

(i) The Samburu Series

North-west of the Karissia Hills and Lorogi, the country drops steeply, in places even precipitously, from a maximum elevation of 8,104 feet at Losiolo, down to the rocky and barren country dissected by gorges and canyons which lead through the Samburu scarp down into the Suguta valley. The lowest point reached, near the north-west corner of the area, was estimated to be just below 3,000 feet above sea level.

In this dissected country, the great series of rather monotonous phonolites of Laikipia, Lorogi and Losiolo is seen to be underlain by another older series of volcanic rocks, which include red and purple tuffs and porphyritic basalts. This basaltic series is particularly interesting as it helps to connect the volcanic sequence of the Lake Rudolf region with that of the lavas east of the Kenya Rift Valley, and it also throws some light on the early history of the Rift Valley.

The Series consists largely of red and purple tuffs, which are coarsely but regularly stratified. They dip towards the Rift Valley, that is N.N.W., at low to moderate angles. Erosion acting on them has produced a ribbed and linear topography (*see* frontispiece). In this dry area, where vegetation is scanty, individual bands can be followed across the country by eye for many miles. The Series could be seen to extend far to the north beyond the limit of the area towards the hills marked on the military topographic map (E.A.F. No. 1168, Maralal N.W. 1:250,000, 1941) as the Samburu Hills. Place names of any significance are so few on the map of this district that the Series has been called the Samburu Series, after these Hills, although the true Samburu country is further east.

The tuffs are pumice and lapilli tuffs. Their colour suggests that they are basaltic like the associated lavas. The only specimens collected were found to be so decomposed, and impregnated with ferric oxide, that the nature of the lava fragments could not be determined. In one of the slides (27/32) rounded and angular fragments of trachytic pumice, with other volcanic fragments, lie in a ferruginous matrix. The felspars could not be identified. Another slide (27/35) contains fragments of vesicular lava with oblong felspar crystals. In shape, the felspars are like those in one of the associated basalts, but again are so decomposed that they were not even proved to be plagioclase.

One other rock (27/30) from this tuff series was sliced. It is a tuffaceous grit, with angular and sub-angular grains of quartz, microcline, a few flakes of biotite, grains of acid plagioclase, and some larger grains of decomposed lava. The grains are cemented in reddish hematite-dusted quartz. The quartz and felspar grains evidently came from the Basement System rocks not far away.

The stratification of the tuffs is so regular on a large scale as to suggest deposition in water. At a few localities, whitish indistinctly stratified rocks occur in the Series. Those reached were not as was anticipated, diatomites, but whitish tuffs. No definitely lacustrine beds were seen. The coarse stratification is comparable to that of the tuffs which are at least partly lacustrine, of the Kinangop escarpment. Graded bedding was not noticed. The only fossils seen were some silicified tree trunks, evidently weathered out of the tuffs, near a watercourse midway between Losiolo and Tuwana Trigonometrical Points, but the general character of the Series suggests that other fossils might be expected.

Lavas are subordinate to tuffs, but are not rare. Several single basalt flows were seen amongst the tuffs, and in some places basalt was found at the base of the Series, resting directly on gneiss. Basalt with porphyritic plagioclase seems to be the characteristic type. Slides (27/34; 27/39, 27/45, 27/46, 27/104) show phenocrysts of plagioclase, determined as bytownite (Ab_{28} An_{72}) in specimen 27/45, labradorite-bytownite (Ab_{30} An_{70}) in 27/46 and labradorite (Ab_{15} An_{85}) edged with oligoclase in (27/104). The groundmass is basaltic, consisting of plagioclase, pyroxene (either purplish and titaniferous or nearly colourless), small decomposed olivines, ore specks, and various secondary minerals. Biotite shreds in one slide and a kataphorite-like amphibole in another, indicate an alkali tendency.

A porphyritic basalt seen in a gorge at about 36° 32′ E., 1° 25′ N. at the base of the Series, is divided by curved surfaces like those of a pillow lava, but the resemblance may be deceptive.

One non-porphyritic basalt collected (27/31), consists of basic plagioclase laths, slightly purplish pyroxene granules, an amphibole (kataphorite?) pleochroic from very pale reddish-brown to a still paler greenish tinge, granular ore, iddingsite (?) after olivine, and secondary calcite.

In the Langat gorge, east of the Maralal-Baragoi road, the following sequence was seen:—

(5) Porphyritic phonolite (Rumuruti Phonolite Series).

(4) Vesicular basalt, crowded with plagioclase phenocrysts.

(3) Tuffs.

(2) Trachyte, pinkish-buff in colour, streaky, and with glassy felspar phenocrysts.

(1) Gneiss.

The trachyte is unlike any other lava seen in the Samburu Series. A slide shows an aphanitic base with small fluxionally orientated laths of sanidine, a few flakes of greenish-brown biotite, one blade of greenish hornblende and some fragments of microcline. The latter minerals were probably picked up from the surface of the Basement System gneisses, over which the lava flowed. Some enclosed fragments slightly coarser than the matrix show aegirine, felspar, zeolite, and secondary minerals.

In the north-west of the area, the Samburu Series is affected by a strong flexure and broken by a number of small faults, which are well seen in the gorges. Some of the lavas are fractured and secondary minerals, among them fluorite, have been deposited in the fractures. It was at first thought that the Series had been dislocated by early Rift Valley movements before the succeeding phonolites were erupted. But on the steep slope below the trachyte outlier near the north-west corner of the area, the highest of the purple tuffs of the Samburu Series rests on a phonolite essentially the same as those of the Rumuruti Series above, showing that the periods of eruption of the two Series overlapped slightly, and there is no unconformity between them. In the Langat gorge section, 15 miles to the east, nothing was seen to suggest an unconformity, although the phonolites overstep the Samburu Series eastwards. The phonolites are certainly affected by the flexure mentioned and doubtless the reason faults were seen in the Samburu Series but not in the phonolites is merely that the latter were not examined in traverses far enough west.

The preceding description of the Samburu Series concerns the outcrops north-west of the Karissia Hills. About 30 miles further south, basalts are again exposed underneath the phonolites of Lorogi, at the foot of the scarp immediately west of Amaya Trigonometrical Point (6,840 feet). The phonolites are exposed down the scarp to about 6,000 feet, where they are underlain by a series of thin flows of basalt, which are exposed down to the foot of the scarp, estimated to be about 5,700 feet. The base of the series was not seen.

Here again most of the basalts are of the type with plagioclase phenocrysts. Some are highly vesicular, and crowded with fluxionally orientated plagioclase crystals, as in the Kijabe basalt described by Shand. (Shand, 1937.)

Three specimens, 35/78, 35/79, 35/80 represent the Amaya basalts. They are dark grey or purplish-grey rocks, with parallel felspars, which in 35/80 are as much as 1½ inches long. The slides show that they are labradorite. Other minerals seen are decomposed olivine, purplish augite and magnetite. In two of the slides there is a little reddish-brown biotite, and in one, (35/78) some interstitial analcite. As in the basalts from the Samburu Series from further north, the alkali tendency is marked. In view of their comparable stratigraphic position beneath the same plateau phonolites, and their close petrographic similarity there is no doubt that the basalts of the two areas should be correlated. The correlation is supported by the discovery of more basalts below the plateau phonolites, west of Lake Baringo (*see* Appendix I). Tuffs are subordinate to lavas both on the Amaya scarp and near Baringo.

The Samburu Series closely resembles the older basaltic Series of Miocene age of the Lake Rudolf region and the two should almost certainly be correlated.

(ii) *The Rumuruti Phonolites*

The plains of northern Laikipia and Lorogi are underlain by phonolites. As Gregory used the name Laikipian for the basalts of Southern Laikipia the phonolitic

series which actually forms most of Laikipia cannot be called Laikipian and is here called after Rumuruti, which is in the middle of the phonolite area. Although this area is a thousand square miles few separate flows are exposed, as the individual lava sheets each covered a large area, and the general surface of the plains corresponds nearly to the original lava surfaces, not very deeply incised by subsequent erosion. The eastern edge of the phonolite plateau is an erosion scarp, which in plan winds sinuously around the heads of the small valleys draining into the Uaso Nyiro. Outliers, isolated from the main plateau by valleys cut several hundred feet down into the gneisses, show there must have been a very long period of erosion after the eruptions. The comparatively slight erosion of the phonolites on the plateau itself is due not to the shortness of the period of erosion, but to the resistance of the flat hard phonolite sheets. Even on the plateau, the larger streams, especially the Ngare Narok, have cut down through several flows whose eroded scarp edges can be traced far along the sides of the valleys. These scarps are erosion features. They do not indicate the original margins of the sheets.

Only in the escarpments along the eastern side of the Rift Valley are there any clear sections of the phonolite series and most of them are outside the area. The best section within the area is in the scarp west of Amaya Trigonometrical Point, where about 850 feet of phonolites are exposed.

On the plateau, the few flows that are exposed could be mapped easily enough, but in this survey time was too short to do this properly. Such lava scarps as were seen were sketched on the map, which gives a general idea of the disposition of the several sheets.

The lowest flow, seen around Lake Kisima, on outliers south of the Karissia Hills, and near Kirimun, is a dark fissile phonolite, with very scarce phenocrysts. It flowed into hollows in the previous land surface, and consequently outcrops discontinuously. The sheet above has few small biotite flakes, and conspicuous crystals of glassy anorthoclase and greenish nepheline in a fissile greenish base. There are probably several sheets of this type. Above is a flow (or two flows) in which biotite is absent or scarce; in its place there are small black prisms of pyroxene, which are inconspicuous but can usually be seen on the weathered surfaces. This is the highest flow exposed over large areas. Towards the south, it seems to be overlain by another sheet with biotite flakes, but no clear contact was seen. A sheet characterized by anorthoclase phenocrysts up to 1½ inches long, with nephelines and biotite flakes, underlies the one with pyroxenes in a small area at the south-east of the plateau. Such details as were noted are marked on the 1 : 125000 manuscript maps.

Exact correlation of this succession with the Amaya section was not made. It is clear that there are more flows at Amaya than on the plateau, or along its eastern margin. Not all the sheets seen at Amaya flowed far enough east to be exposed again.

In Laikipia borehole records "old land" and sediments are frequently recorded between the phonolites. These were not seen during the present work. This may be partly due to the lack of continuous natural sections. The solid lavas tend to outcrop, while any soft beds between are concealed. The mere presence of the scarps is an indication that there are some more easily eroded horizons between the massive lavas. But it is thought from the available evidence, that the thickness of "old land" and sediments is exaggerated. Some borehole samples were examined and it was found that some of the materials recorded as "old land" are of glassy lava, either fresh or very little weathered. They no doubt represent the surfaces of the flows. In several contact exposures studied, the only indication of the passage from one flow to the next is a few feet of highly vesicular and soft phonolite. At Amaya, no tuffs were seen. Unfortunately many of the borehole samples have been thrown away, and the sampling has in any case often been unreliable. Much information that could have been useful in any systematic boring programme has been lost.

The Rumuruti Phonolites nowhere outcrop east of the Uaso Nyiro after it flows off them north-west of Nanyuki. Probably the course of the river was determined by

the original margin of the phonolites, where their easterly flow was barred by the foothills of the Loldaikas. Much further north, the Karissia Hills also blocked this eastward flood of lavas. Between the Loldaikas and the Karissia Hills, however, the lavas spilled through the gap as is shown by the curiously sinuous outlier between the Uaso Nyiro and the Seya, and by various smaller outliers. All these outliers lie on a surface so regular, that standing on it, for instance at the extreme outliers of Nanteddu or Lowermut, and looking back, one can see no deviation from the evenness of the surface. At Nanteddu, the phonolite rests directly on a planed surface of gneiss. Along the western side of the main outlier, there are up to 70 feet of sediments under the lava.

The sub-volcanic surface now slopes eastwards owing to subsequent tilt; its elevation is about 4,380 feet at Nanteddu, 4,450 feet at Lowermut, and about 4,600 feet on the small hill west of Ngororr (*see* Fig. 2). West of this, the hills rise suddenly, and the lowest lava in the Seya valley, only six miles from the nearest of the outliers of the plains, is at an elevation of about 5,300 feet. The irregular sub-volcanic surface here and the even more irregular surface under the sediments at the Seya and along the eastern edge of Laikipia, are in striking contrast to the peneplained surface beneath the eastern outliers. The drop of the lava base from the upper to the lower level is taken to show that the lava spilled over the lowest part of an old Karissia-Loldaika Range which everywhere rose above the peneplained country to the east. The alternative explanation, that lavas of the two areas are at different levels owing to a fault, is rejected because of the contrasted nature of the sub-volcanic surface, the absence of any regular feature on the ground which could be mapped as a fault, and because further north, at the other end of the Karissia Hills, where the phonolites again overflowed the Loldaika-Karissia barrier, they extend down to an elevation of about 4,500 feet (at the northern edge of the map), and are certainly not faulted.

Petrography.—Microscopically all the Rumuruti Phonolites collected in the area are even more similar than would be supposed in the field. Except in the very fine-grained varieties where the various soda amphiboles and soda-pyroxenes either have not crystallized or are too small to be determined, the mineral composition of the groundmass of the rocks is very regular and such differences as there are in the phenocrysts seem to have little significance. The minerals of the groundmass are aegirine-augite, aegirine, kataphorite, cossyrite, small laths of soda-orthoclase (not specifically determined), abundant minute nephelines, and analcite. The characteristic feature is the abundance of nepheline and analcite. Small crystals in several slides were doubtfully identified as sodalite. There are phenocrysts of anorthoclase and nepheline in nearly all the rocks. In many there are also plates, 1 to 2 mm. in diameter, of biotite, in others there are small phenocrysts of pale green augite, edged with aegirine-augite. Several have small phenocrysts or microphenocrysts of magnetite, often associated with apatite and pyroxene phenocrysts. Some "ghost crystals" made up of magnetite and aegirine seen in one slide appear to represent resorbed biotites. The presence or absence of biotite may thus be of little significance. Olivine was not seen in any of the forty or so slides examined, and blue amphibole was only seen in a single one which, however, may not belong to the Rumuruti Series. Magnetite is rare as a groundmass mineral. Mineralogically as in the field therefore, these phonolites are easily distinguished from the Thomson's Falls Phonolites discussed below. They agree with Campbell Smith's description of the phonolites of Losuguta type (Smith, 1935, pp. 236 and 237).

Losuguta, Type P', Ne & a, small Pl abundant

(iii) *Phonolites of Kapitian type*

Among the phonolites in the north-west of the area, there is one conspicuous sheet which resembles the Kapiti phonolite. It is characterized by anorthoclase phenocrysts several centimeters long and rhombic in cross-section. Some are joined in cruciform twins. Nepheline phenocrysts are inconspicuous or absent. The base is greenish-grey and fissile.

Kapiti Type P, anorthoclase Pl, interstal

Microscopically these rocks correspond to the Kapiti phonolite as described by Sikes (1939, pp. 15 and 16, and Pl. IIIa). In some slides there are small phenocrysts

of pale green augite, and microphenocrysts of olivine, magnetite and apatite. The groundmass, which has the intersertal texture described by Sikes, consists essentially of soda-orthoclase, diopside, aegirine-augite, aegirine, kataphorite, cossyrite, magnetite, nepheline, analcite, apatite (scarce), arfvedsonite (scarce), and olivine.

This type of phonolite was seen at various places from Tuwana Hill to a point about three miles north of Losiolo. The outcrop indicated on the map is continued further south-west, as the flow can be followed by eye along the cliffs there. Precisely similar lava was found on the top of Lamerok Hill, near the Baragoi road, north of the limit of the area.

It is not supposed that the sheet or sheets of Kapiti type phonolites are exactly the same age as the Kapiti phonolite of the type area. There is good reason to believe that they are somewhat younger since they overlie the Samburu Basalt Series, and are at or above the top of the Rumuruti Phonolites, whereas the Kapiti phonolite is at the base of the Nairobi sequence and near Fort Hall underlies basaltic agglomerates which are correlated, through the Nyeri district, with the Samburu Series. It is therefore clear that the Kapiti type of phonolite is not restricted to one horizon.

(iv) *Losiolo Phonolites*

North of Lorogi, the Rumuruti Phonolites are overlain by another series of phonolites. No sharp separation between the two groups was observed, and they were therefore not separated on the map. The upper series is best exposed (*see* Pl. II, Fig. 1 and Frontispiece) on the precipices west of Losiolo after which it is named. The dominant rocks are dark grey fissile phonolites, either non-porphyritic, or with scattered anorthoclase phenocrysts less than 1 mm. long. Neither nepheline nor biotite phenocrysts were seen. In the cliffs west and north of Losiolo a very large number of thin flows are exposed. The tops of the flows are pumiceous, and sometimes weathered to a yellow or reddish earth, but intercalated tuffs were not seen. The whole series recalls the Thomson's Falls Phonolites of the south-west part of the area and may be the same age.

Microscopically, the Losiolo Phonolites correspond to the Kenya type of Campbell Smith (1935, pp. 229–236). In several of the slides there are microphenocrysts of pale green augite. The constituents of the base are aegirine and aegirine-augite, cossyrite, kataphorite (Z/c, 25°), magnetite, soda-orthoclase, minute euhedral nephelines, and interstitial analcite. The felspars are fluxionally arranged. A little reddish-brown biotite was noticed in one slide.

(v) *Thomson's Falls Phonolites*

In the south-west corner of the area, the Rumuruti Phonolites are overlain by another series of phonolite flows of a different type. These are here called after Thomson's Falls, where they outcrop characteristically.

The lavas of this Series are uniform. They are fissile along the flow planes, which are conspicuously twisted and irregular, and resemble the Nairobi Trachyte in this respect. Small anorthoclase phenocrysts can always be seen, and are often stained yellowish or brownish. The only other phenocrysts noticed in the field were very small and scarce yellowish olivines. The colour of the fresh rocks is grey, more like a basalt than a phonolite. Weathering bleaches a thin surface layer and produces a brownish surface film.

There are many flows of this type of lava. Along the Nyeri–Thomson's Falls road, west of the Pesi Bridge, at least seven lava scarps are ascended. At the east side of the Pesi, near the same road, a basalt crowded with plagioclase phenocrysts underlies the lowest of the Thomson's Falls Phonolites. It is similar to the Kijabe type basalts of the northern Aberdares (Shackleton, 1945), and is undoubtedly one of that series. Elsewhere the Thomson's Falls Phonolites overlie the Rumuruti Phonolites. The Thomson's Falls Phonolites are themselves overlain by the Laikipian Basalts, and by some trachytic tuffs.

Petrography.—The microscopic features of these rocks are very constant. The phenocrysts of anorthoclase are tabular parallel to 010, their angles are rounded and they enclose minute specks of other minerals in their outer zones. More than half the slides have small phenocrysts or microphenocrysts of pale green augite and magnetite. Fayalite phenocrysts were noticed in several slides, and small apatite needles are occasionally associated with it.

The base has small plates of orthoclase usually 0.2 mm. and less in length. In most slides they have been oriented during flow. Small euhedral crystals of nepheline (0.7, 0.4, 0.3, 0.2, 0.1 mm. diam. in different slides) are outlined by growths of dark minerals; they enclose felspars and other minerals of the groundmass, but have distinct crystal faces.

The dominant dark mineral is aegirine or aegirine-augite; cossyrite is subordinate. Half the slides contain a little amphibole with pleochroism in greenish-blue, mauvish and pale greenish-straw. Kataphorite also occurs in some of the slides. The majority contain some interstitial analcite, or zeolite derived from it. Specks of magnetite are scattered through nearly all the slides. In two of them, poecilitic fayalite was recorded.

(vi) *Mount Kenya Suite*

Only the northern fringe of the volcanic rocks of Mount Kenya is included in the area, but the chief lava types so far recognized on the mountain are represented, and their mutual relations can be determined, so that the area although small is an important one. As only a few slides were made, and hurriedly examined, the identifications must be regarded as provisional.

The rocks that make up this part of Mount Kenya are:—

(*a*) Fissile phonolites (Ph_3)

(*b*) Blocky phonolite (Ph_1)

(*c*) Kenyte and Kenyte agglomerates (K and K′)

(*d*) Fissile "basalts" (B_2)

(*e*) Rocks of the parasitic cones (B_3')

The symbols are those used on the map.

(*a*) *Fissile Phonolites.*—Greenish-grey and grey fissile lavas, with minute felspars glistening on freshly broken surfaces, and a few small glassy anorthoclase phenocrysts, are the chief rocks of an area between Nanyuki and Timau. There are a large number of thin flows. The half dozen that were sliced are all phonolites. The phenocrysts are anorthoclase, with faint polysynthetic twinning, and have inclusions crowded in an outer zone. Small phenocrysts or microphenocrysts of fayalite were noticed in most of the rocks, and some also of ore. The base consists of trachytic plates of felspar, probably anorthoclase, with cossyrite, kataphorite, aegirine-augite and aegirine with their usual mossy and poecilitic form or in minute formless shreds. Very small euhedral nephelines were found in some of the rocks, and interstitial analcite in all of them. Ore specks and apatite are accessory.

The limit of these lavas to the east was not accurately determined as they were not always distinguished in the field from the fissile "basalts" (B_2), although they are not difficult to recognize. Their distinctive features are the greenish-grey colour, fissility and small anorthoclase phenocrysts. Olivine is often seen. The fissile phonolites underlie the Kenytes and associated blocky phonolite. It was not discovered whether they are older or younger than the fissile "basalts."

(*b*) *Blocky Phonolite.*—South and south-west of Timau there is a blocky greenish phonolite, with phenocrysts of anorthoclase and nepheline. It underlies kenytes and overlies fissile phonolites. In one place a fissile phonolite was seen between two flows of the blocky phonolite.

In slides (only three were made), the phenocrysts are seen to be anorthoclase and nepheline. In one specimen there are also phenocrysts of fayalite, in another, biotite. The groundmass has the usual soda amphiboles and soda pyroxenes of the Kenya phonolites—cossyrite, kataphorite and aegirine, with orthoclase plates and small nephelines. There is probably residual analcite in all three rocks. Apatite and ore were also noticed.

(*c*) *Kenyte and Kenyte Agglomerates.*—The name kenyte was given by Gregory to the rock which forms the outer part of the plug of Mount Kenya (Gregory, 1900, p. 209). He applied the same name to the similar lavas which form much of the higher part of the mountain. Campbell Smith (1931, p. 242) has shown that Gregory's description of the rock was misleading, as it omitted to mention nepheline as one of the chief minerals in the rocks. The type rock contains both anorthoclase and nepheline phenocrysts. It is thus a variety of phonolite. The abundant large anorthoclase crystals, usually with the rhombic habit, are characteristic.

Rocks essentially the same as the type kenyte occur as lavas and agglomerates within the area. The agglomerates are subordinate. Kenyte lava outcrops at various places but the outcrops are probably all at one horizon and may represent only a single flow. Exposures are generally poor and it is often difficult to be sure whether the rocks are *in situ*, because they weather into huge rough round masses, some of which have moved a considerable distance down the slopes from their outcrops. Such masses can be seen for instance in the Nanyuki River below Nanyuki.

The kenyte sheet is discontinuous. Where it is absent, the horizon is in several places marked by agglomerates full of kenyte blocks, as between the Sirimon and Kararu rivers. Kenyte agglomerate also caps a hill about 10 miles N.W. of Nanyuki.

The kenyte in some places (south of Timau) overlies the blocky phonolites (Ph_1) and elsewhere the fissile phonolites (Ph_3). Just across the Liki from Nanyuki the kenyte is itself apparently overlain by a fissile lava which was not sliced but is probably a phonolite.

(*d*) *Fissile "basalts."*—These are dove-grey or neutral grey rocks; they are fissile and minutely glistening like the fissile phonolites, but the only phenocrysts seen were of olivine. The slides show that a range of types are included in the group. The fluxionally arranged felspars are plagioclase, varying from labradorite to oligoclase in different slides. Residual orthoclase was identified or suspected in most slides, and analcite in a few. The augite in some of the slides is greenish, in others purplish and titaniferous. Olivine also is variable. It may be either colourless or distinctly coloured and ferriferous. Magnetite, ilmenite, and serpentinous material were noted.

Magnetite?

These fissile "basalts" are mostly thin flows, ten feet or so thick. They dip nearly parallel with the slope of the ground. Between the flows, layers of reddish earth are sometimes found. One such earth, from a waterfall on the Katuri river 4 miles S.E. of Timau was partially analysed to determine whether it was bauxitic. The analysis showed that it is not; it is essentially a mixture of ferric hydroxide and clay. The analysis showed:—

SiO_2	36.40
Fe_2O_3	15.54
Al_2O_3	26.02

(Analyst, Miss A. F. R. Hitchins, Chemist and Assayer, Mining and Geological Department.)

The source of the fissile basalts was not determined. It is possible that some were erupted from the parasitic cones that are a conspicuous feature of the area where they occur but others appear to underlie the kenyte and blocky phonolites, and if so must be considerably older than the parasitic cones. Until the different types of lava that are included in the group have been separated and mapped, their age and relationships cannot usefully be discussed.

(*e*) *Rocks of the Parasitic Cones.*—Many parasitic cones stand like pimples on the lower slopes of Mount Kenya, in the south-east part of the area, and outside it (*see* Fig. 9).

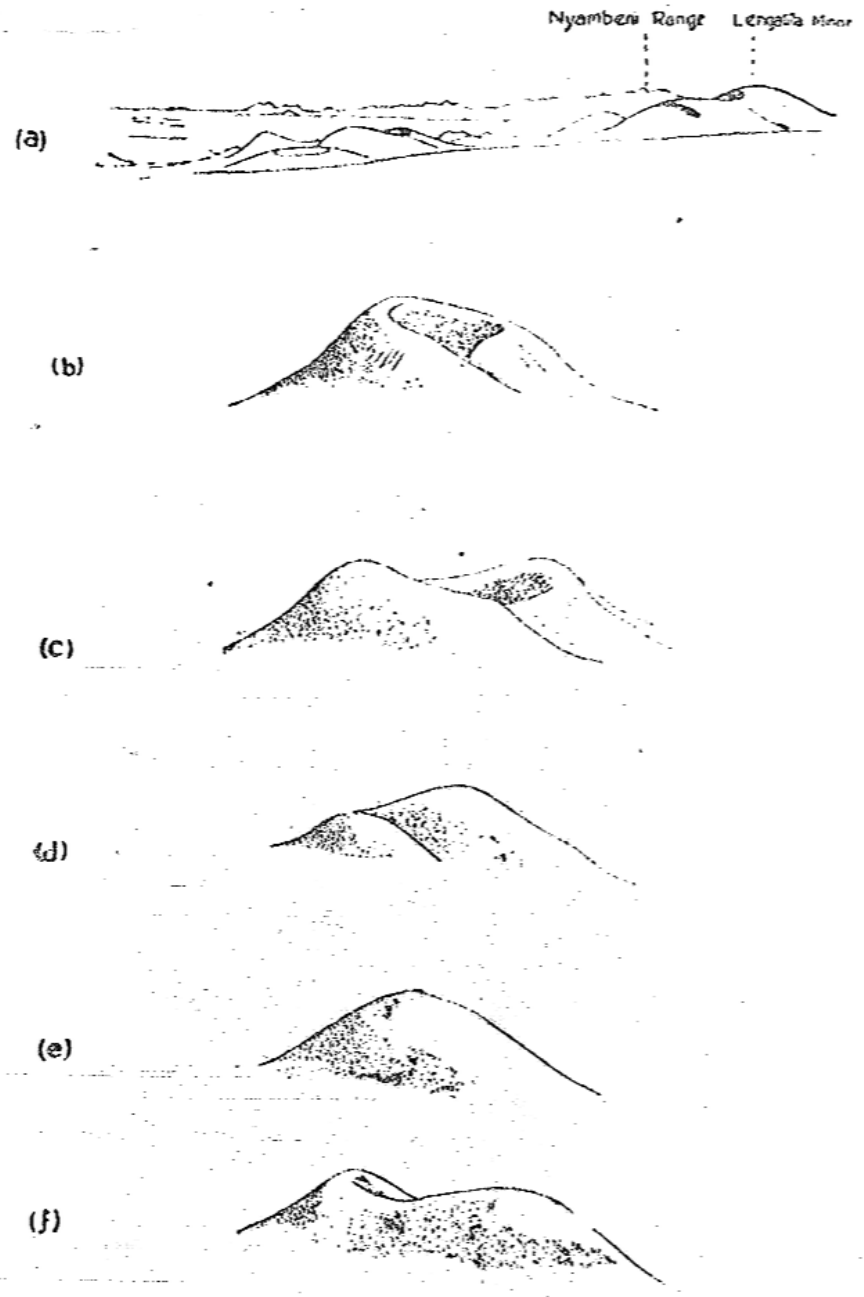


FIG. 9

Parasitic cones on the north-eastern slopes of Mt. Kenya

(*a*) View north-eastwards from Lengalilla Major. Ten cones are shown.

(*b*)–(*f*) Closer views of cones near Lengalilla Major. Their positions in relation to this point, and directions from which they are sketched are: (*a*) 3 miles N., 35° E.; from S.W. (*b*) 1½ miles N.E.; from E. (*c*) 4¾ miles N. 75° E.; from E. (*d*) ¼ mile N.E.; from E.S.E. (*e*) Same hill as (*b*), from S.E.

Most of them still have their craters preserved although erosion has destroyed their sharpness and the inner walls are now usually grassy or rock strewn slopes, seldom very steep. Both tuffs and lavas make up the cones.

Only two of the lavas were sliced. One is an olivine basalt with zoned and slightly sodic titaniferous augite, fresh olivine, and basic plagioclase. The other, a fissile vesicular dove-grey rock collected on a ridge among the groups of cones about 3 miles S.W. of "Lengalilla Major", consists of orthoclase, ore, acmite (?), brown dusty pleochroic apatite, and analcite.

Near the eastern edge of the map between the Raguthu and Morania streams, there is a very recent-looking flow of olivine basalt, with a rough surface, which was traced back to a small cone S.E. of "Lengalilla Minor". Ridges reveal the obstruction to the flow, where it streamed round an older vent.

The reddish earths, which elsewhere contain Kenya Fauresmith and Levalloisean artefacts, sweep up the lower slopes of the parasitic cones, which must therefore be not later than Lower or possibly Middle Pleistocene in age. The preservation of the craters of the cones suggests that they are not much older.

(vii) *Trachytic Tuffs*

Pale trachytic pumice tuffs outcrop at a few places in the south-west part of the area, near the Pesi and Suguroi rivers. The Pesi outcrops are chiefly interesting on account of some diatomite bands intercalated in the tuffs. The diatomites, of which there are several, are only a foot or so thick, but fairly pure. They occur among stratified, and in places current-bedded grey and cream-coloured trachytic tuffs, which rest unconformably on the Thomson's Falls Phonolites. A more massive tuff of the same series is quarried for building stone nearby. The diatomites are evidently lacustrine.

The Suguroi trachytic tuffs are at or near the base of the Laikipian Basalts; one flow of basalt appears to separate them from the underlying phonolites. The tuffs resemble those near the Pesi, but contain no diatomites. They also have been quarried for building stone.

(viii) *The Laikipian Basalts*

In the southern part of Laikipia the Rumuruti and Thomson's Falls Phonolites are overlain by basalts—the Laikipian Basalts of Gregory (1896, p. 231). Other basaltic rocks in other parts of the area are also included in the Series, as although their age cannot be precisely determined, they are similar in character and in their relation to erosion surfaces.

Gregory believed that the Laikipian basalts rest unconformably on the phonolites; the interval was supposed to be represented elsewhere by the "Nyasan Series". The unconformity between the trachytic tuffs near the Pesi River, and the underlying Thomson's Falls Phonolites, implies a long interval, when the Thomson's Fall Phonolites were eroded. There must therefore have been a still longer interval between the eruption of the phonolites and the Laikipian basalts which overlie the trachytic tuffs.

(A) *Southern Laikipia Basalts.*—The Laikipian basalts of the type area, at the southern edge of the area dealt with here, and outside it, are heavy dark basalts which are usually either non-porphyritic or contain small altered olivines. A good section is exposed up the sides of the Suguroi valley near the Nanyuki–Rumuruti road. It shows a number of basaltic flows, vesicular at their surfaces, with little or no interbedded tuff. The depth of the Suguroi and other valleys eroded in these rocks—several hundred feet cut into solid rock—proves that they cannot be younger than Lower Pleistocene in age, and they are probably pre-Pleistocene.

In the basalt area of southern Laikipia there are a number of small isolated hills. They consist of basalts similar to the Laikipian lavas and are old vents. The most conspicuous is Sirrimma Hill on which there are steeply dipping red basaltic pumice and lapilli tuffs as well as basaltic lavas. No crater remains, although an indistinct curved ridge may indicate its position.

rography.—A dozen slides of basalts from southern Laikipia were examined, t[illegible] of them from old vents. In the majority, small olivines can be seen by eye, and in some, augite also. Under the microscope they show a basaltic texture, and are essentially composed of basic plagioclase (labradorite), purplish pyroxene, olivine, and black ore specks. In half of the slides, interstitial analcite was recognized and in two others, zeolite probably derived from it. These rocks are analcite basanites. Several of the others contain minute shreds of biotite, indicating an alkali tendency. Apatite is a scarce accessory. The rocks of the vents are essentially the same as those of the plains. That from Sirrimma Hill has both biotite and analcite. Some of the rocks, among them two from vents, are heavy, contain many augite and olivine phenocrysts, and are picritic basalts.

(B) *Laikipian Basalts between Mount Kenya and the Uaso Nyiro.*—Basaltic rocks probably about the same age as the Laikipian Basalts of southern Laikipia were erupted from vents north of Mount Kenya and in the Mukogodo–Loldaika area. Some of them flowed over the northern edge of those hills and across the plains below. Along part of its course, the Uaso Nyiro runs along their northern edge.

The vents from which these basaltic rocks were erupted, like those of southern Laikipia, are so much eroded that their craters are no longer preserved. In this they differ from the more recent parasitic cones on the lower slopes of Mount Kenya. The two types are separated on the map. The sheets which spread over the plains towards the Uaso Nyiro lie on an even level surface which is estimated from the spot heights on the map to be about 300 feet above the Uaso Nyiro. This surface is continuous with an even surface further west which is tentatively correlated with the End-Tertiary Peneplain of western Kenya. No gravels were found under the basalts which, at the contact exposures seen, rest directly on gneiss. The immense length of time between the eruption of the Rumuruti Phonolites and these basalts is very obvious in this area, where the isolated outliers of the phonolite rest on a peneplain seven or eight hundred feet above the one over which the basalts flowed.

Petrography.—These basalts are very similar to those of southern Laikipia. Most of them have olivine phenocrysts and many have augite also. Residual analcite, or scraps of biotite, indicate their alkalinity. Two specimens contain nepheline in the groundmass. One of them, a nepheline basanite, (36/7) from near the top of Matoni Hill, is a heavy dark lava with phenocrysts of olivine and augite, in a base of purplish augite, magnetite, scarce biotite, a little plagioclase, and residual nepheline and analcite. The other (28/14), from about 2½ miles W.N.W. of Matoni Hill, is similar except that it has no plagioclase, and is thus a nepheline basalt. The only other rock worth mentioning is a mugearite from about 4 miles S.S.W. of Leragai. It consists of flow-oriented oligoclase plates, abundant fayalite grains, greenish pyroxene, magnetite, and a zeolitic residuum.

(C) *Basalts in the north of the area.*—In the extreme north-east of the area, there are outliers of basalt, probably resting on the same erosion surface as those south of the Uaso Nyiro. A specimen from the outlier just north of the 1° 30′ N. latitude line, is an olivine basalt with many small phenocrysts of olivine and a few of pale augite, in a basaltic groundmass. No analcite or alkali felspar was detected.

North of the limit of the map, about two miles west of Baragoi, another outlier of similar basalt was found. This has small phenocrysts of labradorite and micro-phenocrysts of olivine and augite, in a base of plagioclase, yellowish-green pyroxene, olivine, and magnetite. This basalt must be considerably younger than the tilted phonolites which outcrop further west. Its relationships tend to show that it is about the same age as the Laikipian Basalts of the type area.

(ix) *Quartz Trachyte*

In a traverse to a point near the north-western corner of the area, the edge of a nearly flat lava plateau was reached, after climbing up a steep slope formed of the tilted Samburu Series tuffs and the overlying phonolites. The unconformity between

the lava sheet of the plateau, and the tilted rocks beneath, was obvious from far away. In the middle of the plateau, outside the area, there is a low hill, Emuruagiring on the map, which is perhaps the vent from which the lava erupted (*see* Frontispiece). The eastern edge of the plateau is about 1,100 feet above the bottom of the valley to the west. This deep valley has been eroded, largely if not entirely since the lava of the plateau was erupted. The sheet is older than the fault which cuts off these rocks along the eastern side of the Suguta valley.

The lava is a speckly greenish-grey trachyte, in which the only crystals visible in the hand specimen are small flakes of a golden biotite, and small crystals of sanidine. The slide (27/38) shows a groundmass of mosy cossyrite, aegrine, kataphorite grading into a bluish amphibole, laths of sanidine and small poecilitic patches of quartz. The biotite is pleochroic in golden yellows and is probably a titanium-rich variety.

(3) Pleistocene and Recent Superficial Deposits

Throughout the long period of volcanic eruptions, erosion and not deposition prevailed in the region. Time intervals in the volcanic sequence in the area mapped are represented by erosional unconformites, not by any sedimentary formations. Only since the eruptions ceased, a thin cover of earth, laterite, and in the valleys, gravel and silt, has accumulated. These deposits can be broadly classified on lithology, into:—

(*a*) Silts and stratified tuffs containing biotite flakes (Uaso Nyiro beds).

(*b*) Trachytic pumice tuffs.

(*c*) "Bentonitic" clays.

(*d*) Red and buff lateritic earths.

(*e*) Gravels and boulder beds.

(*f*) Reddish sandy soils (covering Basement System rocks).

(*g*) Black cotton soil.

(*h*) Lateritic ironstone (murram).

(*a*) *Silts and Stratified tuffs (Uaso Nyiro Beds)*

Greyish stratified silts, which are evidently waterlain, outcrop along some of the valleys in the southern part of the area. The beds are typically exposed by the Nanyuki-Rumuruti road, near the Uaso Nyiro river after which they are called. The most characteristic feature is the constant presence of small flakes of biotite. It can only be supposed that these were carried by wind from the outcrops of the Basement System rocks to the north. No fossils have been found in the beds except a few unidentified plant impressions, but they are slightly more consolidated than the overlying deposits, which in places contain Acheulean and Kenya Fauresmith artefacts. They may therefore be Lower Pleistocene.

West of Nanyuki, there are in places apparently thicknesses exceeding a hundred feet of these deposits, which are important as a good source of water. Their extent is not shown on the map because they are largely concealed by black soil, or inferred from unchecked borehole logs. Small patches of the same series of deposits were seen in some of the valleys of southern Laikipia. They overlie the Laikipian Basalts unconformably.

Some of the coarser beds in the Uaso Nyiro Series are just hard enough to be used as a building stone.

(*b*) *Trachytic pumice tuffs*

North of the periphery of the Mount Kenya volcanic rocks thin deposits of soft and porous pale yellowish-weathered pumice tuffs occur in some of the valleys. They have been worked in a few places for building stone. Neither their source nor their relations to other Pleistocene deposits was discovered.

(*c*) *"Bentonitic" clays*

Peculiar unstratified greenish-grey and purplish clays, which have absorbent properties and swell to two or three times their volume when wetted, occur at several

places east of Timau. Two typical deposits are described below. The deposits are exposed in eroded areas, usually under black cotton soil and were first noticed as "salt licks." Little petrographic work has been done on these so-called bentonitic clays and their origin is not understood. The deposits are underlain by basalts of the Laikipian Series, but similar deposits elsewhere in Kenya are associated with phonolites. The age of the Timau deposits is post-Laikipian and pre-Acheulean (Middle Pleistocene). They are probably younger than the Uaso Nyiro beds.

One deposit known as Krieger's, which was pitted to test its quality and quantity, is associated with an enormous number of Acheulean artefacts. They are unfortunately not *in situ* and their source was not determined. The section at this locality is shown in Fig. 13. It was shown by the pitting at this locality and more especially at another described later that the bentonitic clay could not have been deposited in water, or covered by water after deposition.

(d) Red and Buff Lateritic earths

These are the earths conspicuously exposed in the eroded areas near Nanyuki and Timau. Erosion once started, quickly removes them and exposes the underlying volcanic rocks. The eroded areas are continuously extended laterally, although large cedars growing on their floors may appear to show that erosion has stopped.

Layers of lateritic ironstone, both massively cellular, and pisolitic, occur at various levels in the earths, but more particularly near the base There are also ashy layers, with much powdery glassy felspar. A sequence could certainly be worked out in these deposits with the help of the artefacts which are found in them. The lowest horizon recognized is a rich red earth, from which at various places between Timau and Nanyuki, artefacts of the Kenya Fauresmith culture have been collected. Higher up in the series Levalloisean types of artefacts are found, especially in a lateritic layer. The series as a whole appears to have been formed in a transitional zone between the forest zone and the plains. This zone was favoured by prehistoric man, and it also seems to have been more sensitive to climatic variations than the forests or plains. The series has been forming at least since the Middle Pleistocene period.

The thickness of these earths is not more than twenty feet and more often ten. They are deposited on a surface essentially the same as the present one, but they thicken towards the smaller valleys which are now being re-excavated.

A typical section of the deposits is exposed beside the Nanyuki-Timau road, immediately east of the Liki River. This section is illustrated in Fig. 10. The grey bentonitic clay (A) at the base, should probably be correlated with the bentonitic clays of the Timau area. The overlying lateritic earths B. C and D merge, towards the Liki, into unstratified earthy clays containing scattered rounded and sub-angular boulders up to a foot in diameter, of a variety of rocks from Mount Kenya. These puzzling boulder clays are strikingly similar to glacial deposits, but are thought to have accumulated by hill-creep or solifluxion.

(e) Gravels and Boulder Beds

Along the principal streams, particularly those rising on Mount Kenya, there are considerable deposits of gravel and boulders. The Sirimon River has deposited a particularly thick mass of such gravels all along its course. It rises on the north face of the 17,000-foot peak of Sendeyo (north of the main peak of Mount Kenya), and the pebbles in the gravels are mostly kenytes from Sendeyo. Along the Liki and Nanyuki rivers similar but thinner gravels are seen. Far down the Uaso Nyiro, the same series of gravels, with similar pebbles derived from Mount Kenya, can be recognized. A section near the middle Uaso Nyiro, eleven miles east of the Barsalinga drift, was measured and is shown in Fig. 11.

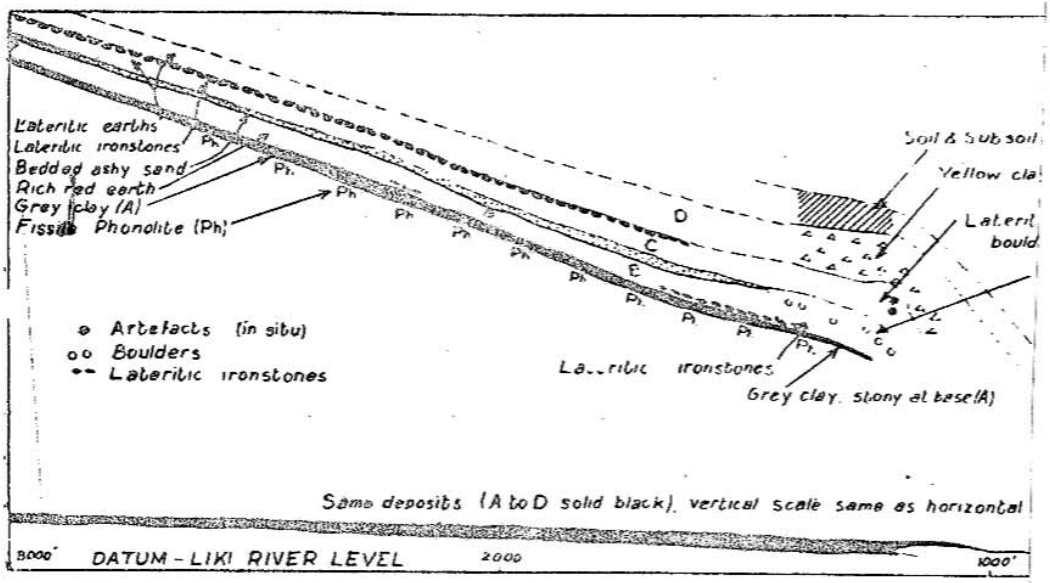


FIG. 10

Section of Pleistocene deposits near Nanyuki (measured near th road, from the Liki River eastwards). The artefacts found in bed Fauresmith type and those in bed C were flakes of Levallois type. The include nepheline syenite from the peak of Mt. Kenya.

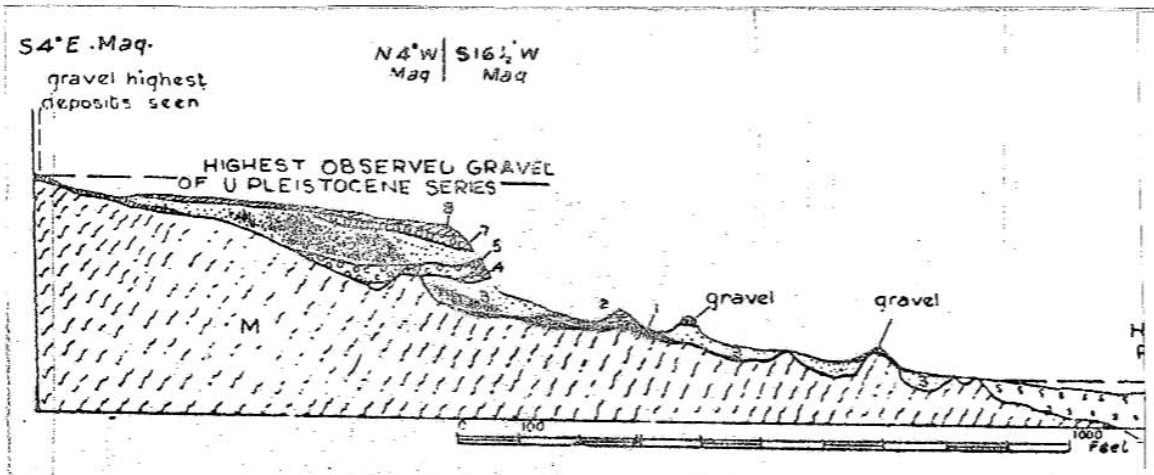


FIG. 11

Section of Pleistocene deposits south of the Uaso Nyiro, 11 miles east of Barsalin

S—Recent Silts.

1–8—Upper Pleistocene (Gamblian Pluvial) deposits:—

(8) Cross-bedded tuff.
(7) Gravel.
(6) Drab-coloured loam.
(5) Gravel.
(4) Laminated and cross-bedded grey tuff.
(3) Drab-coloured loam.
(2) Cross-bedded silts and gravel, with biotite flakes
(1) Brown loam.

M—Basement System Gneiss.

This section is of interest as it yielded many artefacts and vertebrate remains, which according to Dr. L. S. B. Leakey, are typical of the deposits of the Upper Pleistocene Gamblian Pluvial period. The gravels were obviously deposited at a time when the rivers were far bigger than they are now.

(f) Reddish sandy soils (covering Basement System Rocks)

The distribution of these deposits is shown approximately on the map. They are sandy, reddish and yellowish in colour and vary in grade according to their position. Some are fine-grained and stand in miniature vertical cliffs along the sides of gullies eroded through them. This weathering is suggestive of loess but the deposits nearer the hills are coarse and merge into talus. The finer-grained loess-like deposits may have been partly wind-borne. Most of the material has probably been moved, over a very long period of time, by hillcreep and rainwash. The maximum thickness of such deposits is hard to judge; on the plains it is probably nowhere over fifty feet and generally less, but at the foot of steep hillsides, it might be expected to be more.

(g) Black cotton soil

The black soils of this area are similar to those well known in many parts of Kenya. Their distribution is partly indicated on the 1:125000 manuscript maps. They are found covering both basalts and phonolites, but are seldom developed on the Basement System rocks. The chief determinant in their formation is bad drainage.

(h) Lateritic Ironstone (murram)

Except as layers in the red earths (*d* above) ironstone is poorly developed in the area. It was noticed in certain parts of northern Laikipia. None was seen on Basement System rocks.

VI—PHYSIOGRAPHIC AND STRUCTURAL EVOLUTION OF THE AREA

The structures of the Basement System rocks have already been discussed. The structural and physiographic evolution during later periods may be considered under the following heads:—

1. Cretaceous Peneplain.
2. Sub-volcanic surface and the Sub-Miocene Peneplain.
3. Post-Miocene disturbances.
4. End-Tertiary Peneplain.
5. Pleistocene Rift Valley Faulting and Tilt.

The general sequence of events is summarized in the correlation table, p. 3 and Fig. 8, facing page 26.

(1) Cretaceous Peneplain

As in various parts of Kenya, the highest mountains formed of the older rocks rise to an even summit level which is clearly the relic of an old peneplain (*see* Pl. III). In this area, this erosion surface determines the summit level of the Karissia Hills, the Matthews Range, and part of the Loldaikas. It is generaly supposed to date from the Cretaceous period or it may be Jurassic. The even skyline of the *Matthews Range* is best appreciated from the west. It is broken by two deep transverse gaps. Approaching the Range from the west, one encounters a series of hills and parallel ridges, the height of which increases towards the Range. The eastern side of the Range is entirely different. It drops in precipitous rock faces, as much as 4,500 feet in a distance of two miles (*see* Pl. II, fig 2). It does not however form a straight escarpment: the precipices and steep slopes curve irregularly round each of three great embayments, and along the sides of the mountainous ridges which jut out from the main Range between them.

The precipitous faces have been developed by erosion. There is no suggestion of faulting on either side of the Range, and it is clear that neither the Matthews Range peneplain nor the others discussed below could be explained as upfaulted parts of the Miocene peneplain.

The counterpart of the Matthews Range peneplain is seen in the even summit level of the *Karissia Hills*. This is seen most clearly from the east. The eastern side of the Karissia Hills, like the *Matthews Range*, is irregular in plan. Here again the escarpment must be the result of erosion and not faulting.

South of the Karissia Hills, the level of the surface of the Basement System drops sharply, and then south of the Uaso Nyiro, rises again. This rise is gradual and uneven. Not until the southern part of the area, in the *Loldaika Hills*, is there any clear suggestion that the summits approach the old erosion level. There, several parallel ridges reach to about the same height and when seen from a distance, from the west, it is apparent that they are close to the old peneplain level.

Still further south the peneplain has not been recognized until the Mua Hills, whose level skyline is conspicuous in views from near Nairobi.

Present elevation of the Cretaceous Peneplain

The summit level of the Matthews Range is about 7,500 feet. The Karissia Hills rise to about 8,300 in the north-west, nearest the Rift Valley and about 7,500 in the south-east suggesting a tilt, but it is possible that the north-western area remained above the peneplain. In the Loldaikas the summit level is nearly 7,500. These levels must be somewhat below the level of the original surface.

(2) Sub-volcanic Surface and Sub-Miocene Peneplain

The form of the surface on which the volcanic rocks rest is highly uneven and it is still impossible to predict, in more than a very general way, its present elevation beneath any particular point on the volcanic cover.

A datum level is given by the base of the Miocene sediments and phonolites of the outliers east of the Karissia Hills. This surface, as already shown, is remarkably even. The outliers may follow the courses of pre-volcanic rivers, but if so, the rivers flowed across flat country, since the sub-volcanic surface merges into an extensive dissected peneplain further north. This is presumably the Sub-Miocene Peneplain (Shackleton 1942) since it is the lowest erosion surface covered by the Miocene sediments and phonolites.

This peneplain has not been definitely recognized elsewhere in the area; the whole stretch of country from the Karissia Hills to the Loldaikas stood above it. The lavas flooding eastwards from the Rift Valley region, filled up to the level of this barrier and flowed over it north and south of the Karissia Hills, so that the form of the sub-volcanic surface on the western side of the barrier can only be surmised. But the manner in which the Rumuruti Phonolites overstep the older basaltic rocks exposed in the lower parts of the marginal scarps of the Rift Valley, shows that the sub-volcanic surface already sloped downwards towards the area now occupied by the Rift Valley before the eruption of the earliest known volcanic rocks. Whether this slope was merely the descent from the Karissia–Loldaika axis towards another area that had been reduced to the Sub-Miocene Peneplain level, or whether it was a tectonic depression, is unknown.

The Sub-Miocene Peneplain east of the Karissia Hills slopes eastwards. It rises from 4,350 feet at Nanteddu (the south-easternmost phonolite outlier) to about 4,600 feet near the River Seya. The Cretaceous Peneplain is thus about 3,000 feet higher than the Sub-Miocene Peneplain.

At first sight the rather consistent level of the base of the phonolites along the eastern edge of Laikipia might be taken to show that the lavas rest on an even surface, standing now at about 5,700 feet. The reason for this regularity appears however to be that it represents the level which the highest phonolites reached, as they flooded the western slope of the Karissia-Loldaika axis.

(3) Post-Miocene Disturbances

In the northwest of the area, the Samburu basaltic Series and the overlying phonolites are tilted and faulted and are overlain unconformably by a nearly flat sheet of quartz-trachyte, which is itself (outside the area) broken by later faults. The tilting and dislocation of the older rocks cannot be dated but is probably post-Miocene and may be tentatively correlated with the uplift which started a new cycle of erosion, and initiated the base level represented by the End Tertiary Peneplain of the Uaso Nyiro basin (*see* below).

The effects of these post-Miocene disturbances have only been recognized in the north-west part of the area. There the older volcanic rocks have been bent, along a monoclinal flexure (the Samburu Monocline) trending slightly east of north. The older volcanic rocks dip gently W.N.W. just east of the flexure, but as it is crossed, the dips increase suddenly to as much as 25°, and continue at nearly this angle for several miles across the strike to the edge of the area (and considerably beyond).

There is also some minor faulting, near the monoclinal axis. Faults seen in the gorges traversed are nearly vertical, except for one which is a normal fault heading 45° N.E. The throw of these faults is small, perhaps 20 to 50 feet.

(4) End-Tertiary Peneplain

In the Middle Uaso Nyiro Basin, there is a well-marked erosion surface some 300 feet above the level of the Uaso Nyiro. It is most obvious at the base of the basalt sheet which covered it south of the Uaso Nyiro, but the same surface can be traced back towards the Karissia-Loldaika barrier. It may also be represented by the sub-basalt surface in the north-east of the area.

In the Uaso Nyiro basin this erosion surface now slopes eastwards. The drop is about 700 feet in 35 miles, from near the mouth of the Uaso Nyiro gorge, to the lava base at the eastern edge of the area. It is probable that some part of this slope is original since the levels suggest that contours drawn on the surface would now curve in a way which could hardly result from tectonic movements alone. The peneplain probably merged into a gentle slope towards the foot of the curved front of the Karissia-Loldaika barrier.

No gravels were seen on this peneplain. In this respect it differs from the "End-Tertiary Peneplain" of western Kenya (Shackleton 1942) to which, however, it corresponds very closely in its height above present river levels and its relation to the Miocene sediments and volcanics. It is therefore tentatively correlated with the surface mentioned, and attributed to an alteration in base level consequent upon the same major crustal disturbances.

(5) Pleistocene Rift Valley Faulting and Tilt

The main fault scarps of the present-day Rift Valley of Kenya are supposed to be of Pleistocene age. No faults of this age have been distinguished in the area, but much of the regional tilting of the plateau lavas and Sub-Miocene and End-Tertiary Peneplains, probably occurred during this tectonic phase. The tilt of the End-Tertiary Peneplain is about 15 or 20 feet per mile and that of the Sub-Miocene Peneplain is about the same: most of the tilt was therefore presumably Pleistocene.

p.46

VII—ECONOMIC GEOLOGY

The reconnaissance survey has not revealed any mineral deposits of importance, nor are the geological conditions anywhere in the area such that intensive prospecting is thought worth while. The following notes on the occurrence of certain minerals and rocks may, however, be of use. The relation of the geology to water supply problems is also discussed.

(1) Mica

Over most of the area, the only pegmatites are irregular lenticular segregations in which no commercially useful mica can be expected. Only in the northernmost part were crosscutting pegmatites of any size seen. In several of these, books of mica up to about 4 inches in diameter were found but in all of them the mica was crossed by close fractures which rendered it valueless. Similar mica was seen further north around Baragoi.

p.47

(2) Molybdenite

A series of thin quartz veins carrying a little molybdenite and some pyrite were discovered near Kweribe waterhole, north-west of the Karissia Hills. The veins are only a few inches thick, and occur in biotite gneiss. The molybdenite forms flakes up to about 3 or 4 mm. in thickness and 1 cm. or so in diameter but the proportion of molybdenite is so small that the deposit could not be regarded as worth further prospecting, even when molybdenite was in exceptional wartime demand.

(3) Sillimanite

Lenses of almost pure sillimanite rock occur as segregations in the sillimanite gneiss near the Losigirechi watercourse. The quantity of sillimanite available is unlikely to be more than fifty tons and is probably less. Owing to the difficulty of working, prohibitive transport costs, and the small amount available, the deposit is not considered to have any commercial value.

(4) Beryl

Crystals of beryl occur rarely in pegmatites in the Karissia Hills and further north-east. The quantity is negligible. The crystals are not clear and could not be marketed as gems.

(5) Copper

Traces of copper were seen in some of the hornblendic gneisses in the north of the area.

(6) Limestone

Large quantities of crystalline limestone are available at most of the places where this rock is indicated on the map. The percentage of magnesia in them has not been determined but they would doubtless be suitable for burning for agricultural or building lime. The local demand is, however, insufficient to justify erecting a kiln.

(7) Bentonitic Clay

A sample of material from a salt lick some 14 miles N.E. of Timau was sent some years ago to the Scott Agricultural Laboratory, where it was identified as bentonitic and passed on to this Department. Later, when interest was taken in the deposit it was decided to prospect it by pitting. Other deposits in the surrounding area were prospected at the same time.

Two localities showed considerable quantities of the material; one "Parminter's," about 1¼ miles north of Matoni Hill Trigonometrical Point, and the other "Krieger's," 2½ miles W.S.W. of it.

The deposit is similar in each place. It is an unstratified and remarkably homogeneous greenish-grey and chocolate-coloured clay. It feels soapy in the hands, and breaks characteristically on slickensided irregular slip-planes and cracks which traverse it in all directions. Dendritic films of manganese oxide have been deposited in the cracks. When immersed in water, this peculiar rock swells rapidly to two or three times its dry volume, and falls to a flocculent mass of sticky clay.

The geology of "Krieger's" deposit is illustrated in Fig. 12. The locality is a few hundred yards from a stream, which flows down a shallow flattish valley. The clay is exposed in an eroded area where it had been eaten by cattle in a salt lick. Pitting of the deposit showed that its thickness in places exceeds thirty feet and it underlies an area at least a quarter of a mile in diameter.

The clay often rests on olivine basalt or on basalt stones which no doubt rest on the solid lava. In other pits it is underlain by a layer of brownish-grey earth with yellowish mottling, which does not swell appreciably in water and is not very plastic when wet. It contains lava stones. The clay itself is homogeneous except for the differences in colour. The greenish-grey and chocolate types alternate, apparently irregularly. Concretions of "kunkar lime" have formed in the upper ten feet or so of the deposit. In some pits there is an upper layer of redeposited material, which is similar to the clay beneath, but contains lava stones and fragments of other rocks. At the western side of the area, the clay is overlain by a light-coloured tuff containing flakes of biotite.

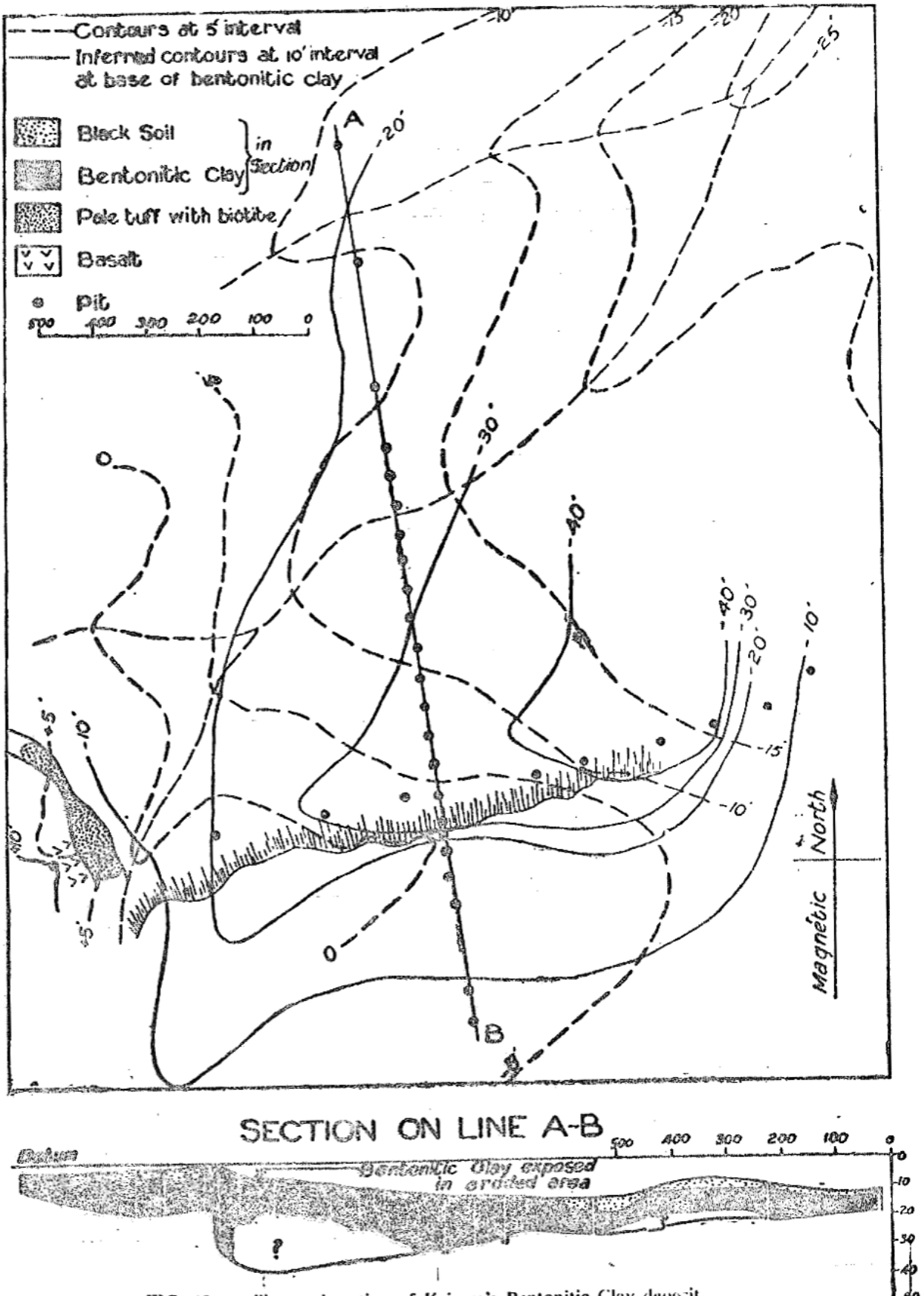


FIG. 12 Plan and section of Krieger's Bentonitic Clay deposit.

On the floor of the eroded area where the deposit was found there are immense numbers of stone artefacts of Acheulean type. Fossilized bones occur with them. The only artefact found *in situ* was in the redeposited top layer of the clay. Had the artefacts been derived from the primary clay deposit, some would surely have been found in it, in the series of over forty pits, which however, only showed a few soft and indeterminable fragments of bone.

The geology of "Parminter's" deposit is similar to Krieger's in that the bentonitic clay overlies olivine basalt (*see* Fig. 13). The locality is, however, on the side of a hill, and it is quite clear that the clay has not been deposited in water.

Investigation into the nature and origin of the material have not been completed. Its composition is shown by two analyses:—

	I	II
SiO_2	51·66	49·31
Al_2O_3	14·97	15·05
TiO_2	0·64	(Not det.)
Fe_2O_3	7·49	7·19
CaO	1·58	2·21
MgO	2·01	2·09
K_2O	1·98	1·15
Na_2O	1·81	3·41
P_2O_5	0·06	(Trace)
CO_2	0·40	1·79
H_2O—	11·88	11·88
H_2O+	5·71	5·45
MnO	0·04	(Not det.)

I.—Sample sent by Mr. A. Douglas, Krieger's Deposit. Anal. Imperial Institute.

II.—Sample 6846, Krieger's Deposit. Anal. Miss A. F. R. Hitchins, Chemist and Assayer, Mining and Geological Department, Nairobi.

The mineralogical composition is under investigation in London. A preliminary report suggests that the clay mineral is an illite type. The high alkali content is notable.

Besides the clay mineral, there are coarser clastic grains. Among these quartz, microcline, albite, orthoclase, zircon, apatite, rutile, epidote, garnet, hornblende (green), biotite, aegirine (?), and magnetite were identified in samples from Krieger's deposit. Evidently these minerals were mostly derived from the Basement System. As no drainage system could plausibly be postulated by which this material could have been brought by streams to the locality, it can only be supposed that it was wind-borne. In a sample from Krieger's deposit the clastic grains amounted to 5½ per cent of the rock.

The origin of the deposit is doubtful.

(8) Building Stone

Stone suitable for building is rather scarce in most parts of the area. Near Timau and Nanyuki the trachytic pumice tuffs (*see* above p. 40) which outcrop in some of the valleys have been used, and trachytic tuff has been quarried along the Suguroi valley. The Uaso Nyiro beds have been used in a few places, for instance near the confluence of the Uaso Nyiro and Burguret Rivers.

(9) Water

The application of the geological results of the survey to water supply problems is considered below. As lithology is in this area a more important controlling factor than structure, the remarks are arranged under the headings of the formations to which they refer.

The Basement System

In the areas of Basement System rocks, the run-off is smaller, and percolation proportionately more than on the volcanic areas, owing to the porosity of the soil and the greater depth of weathering. Surface storage of water by dams is usually difficult except in the steeper valleys where the rock is scoured clean and small dams can profitably be constructed. Borehole statistics for the Basement System in the Colony as a whole show about 70 per cent successes, but in this area the figure is only about

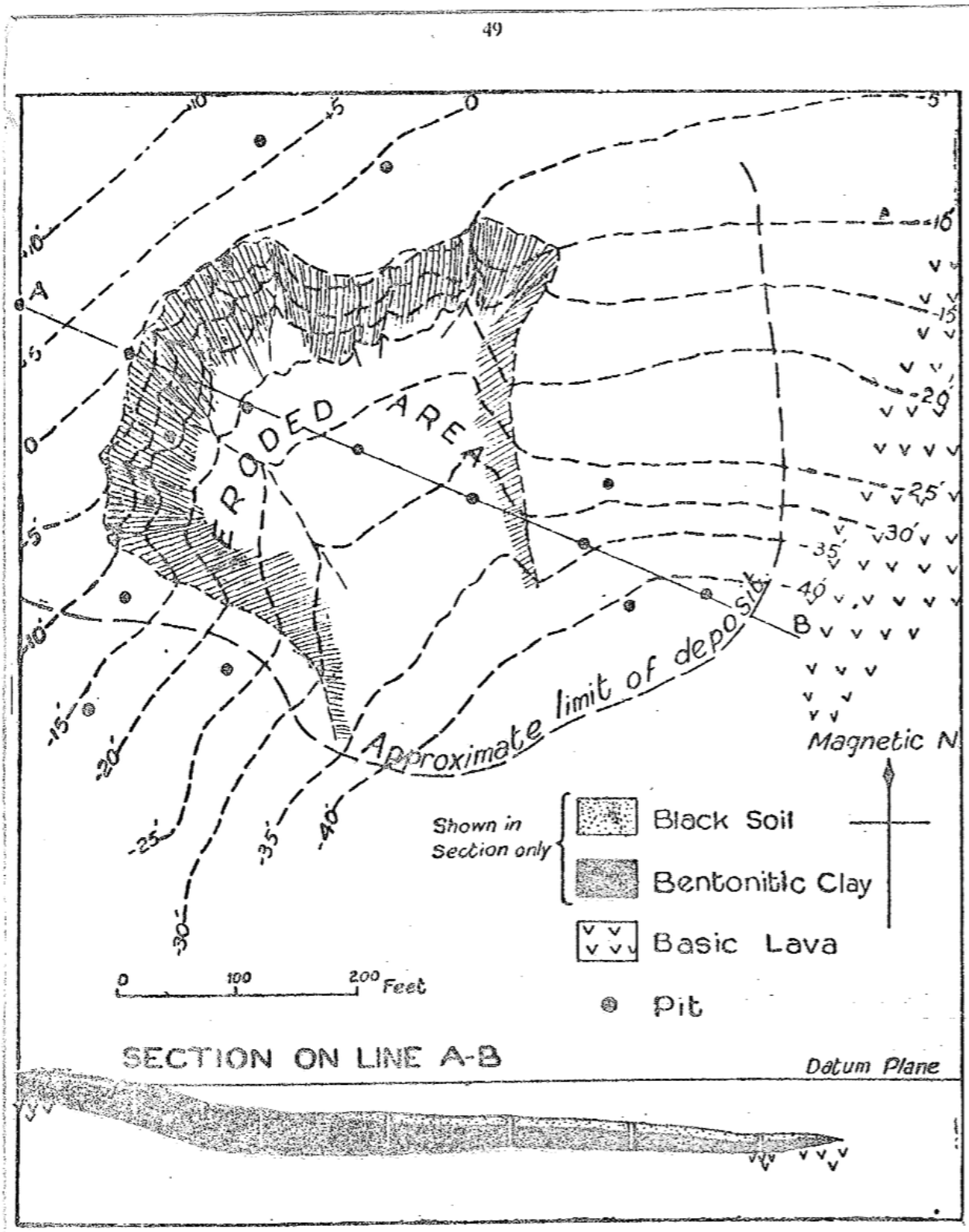


FIG. 13

Plan and section of Parminter's Bentonitic Clay deposit.

50 per cent. This low figure is due to the fact that most of the holes are in the Loldaikas, where conditions are difficult. The prevailing rock there is granitoid gneiss, which is regarded as unfavourable (Sikes, 1934, p. 15). The larger north-south valleys in the Loldaikas are eroded in the softer and more biotitic zones of the gneiss series, and these valleys offer the best hope of success. Topography is perhaps a better guide than the nature of the outcrops, in siting boreholes in these rocks. Places in line with the main ridges should be avoided.

Elsewhere in the area conditions are likely to be better. With the help of the maps, areas can be chosen where the conditions regarded as favourable (*op. cit.* pp. 13–17) are fulfilled, and the most promising sites within such areas can then be found by geophysical methods. Of the sub-divisions indicated on the map, the pelitic gneisses probably offer the best chance of successful boreholes as they are a variable series of easily decomposed rocks, which should yield water readily.

The Miocene Sediments

The surface outcrops of these rocks are small and insignificant. Their extent beneath the plateau lavas of Laikipia is unknown. If they were found to thicken or run into a more continuous formation further west they might well prove an important source of water as they include porous grits and diatomites. In any boreholes that are carried deep enough to approach the bottom of the plateau phonolites of Laikipia, these sediments should be sought. If a hole in the phonolites fails to yield water, and is thought to have reached nearly to their base, it is probably worth deepening it, in the hope of getting water either from the Miocene sediments or the weathered surface of gneiss.

The Samburu Series (Basalts and Tuffs)

These rocks underlie the phonolites along the western side of Laikipia. They are more permeable than the phonolites, and if, as is thought, they dip gently eastwards to their eastern feather-edge somewhere under Laikipia, it might be anticipated that they would yield water under a considerable hydrostatic head. Their catchment is, however, small and the depth to be drilled in order to reach them from the surface of Laikipia would be considerable. East of Amaya, where they are nearest to the surface, they must still be about eight hundred feet down. Further south their depth is probably much more. It is not therefore likely that water will be obtained from them anywhere in Laikipia. The area north-west of the Karissia Hills, where the Series outcrops extensively, is too barren for boreholes to be worth considering.

The Rumuruti Phonolite Series

Phonolites of this Series form most of Laikipia and Lorogi, both areas where more water is needed. Its collection at the surface in reservoirs is favoured by the imperviousness of the phonolites, and several successful dams have been constructed, particularly close to the edge of lava scarps. The capacity of reservoirs in such positions may not be great, but the loss by percolation is small, as bare phonolite is exposed in the watercourses. In parts of the plateau, there is a cover of black soil through which there would be some loss, but as a general rule this phonolite area is suitable for dams.

The prospects of boreholes in the Series have in the past been considered unfavourable. Of the holes known to have been drilled into it, however, twelve out of sixteen (or 75 per cent) were successful and the average yield of the eleven successful holes for which records are available here, was a little over 24,000 gallons per day. These holes are all in the southern third of the area of Rumuruti Phonolites, but there does not appear to be any material difference in the lithology of the Series between the northern and southern parts of the area.

Considerable springs emerge from the Rumuruti Phonolite Series at Suguta Marmar, Suguta Mugie, Lake Kelele, Kirimon and elsewhere in northern Laikipia, showing that there are permeable horizons saturated with water within the Series. The waters at some of these springs are weakly saline, and boreholes might give similar water, but it is unlikely that it would be unusable for stock on this account.

The depth of the water table in Northern Laikipia is unknown; it is possible that the various large springs emerge at perched water tables, in which case the true water table might still be far below surface. In southern Laikipia, however, the rest levels in the boreholes are consistent enough to show that in general they coincide with the true

water table. This rest level is nowhere known to be more than 200 feet from surface, and the boreholes where it is more than 150 feet down are those on the flat ridges. Even in these situations, the depth to the water table is little more than the fall to the main valleys on either side. From this it appears that the water table in southern Laikipia is not far below the level of the main valleys and the same is probably true of northern Laikipia.

The conclusion therefore from this survey is that the probability of getting water from properly sited boreholes in northern Laikipia is good.

An area geologically distinct from the plateau of Laikipia is the fault zone shown in Fig. 14. Here the drainage pattern and scarps indicate a system of parallel faults comparable to those west of Nairobi. In that area, boreholes sited as close as possible to the faults have generally been successful, and it is likely that the same would be true of the faulted area at the margin of Laikipia.

One other area of the Rumuruti Phonolites which should be mentioned is the plateau north of the Karissia Hills. On this plateau, which extends northwards beyond the limit of the area shown on the map, there is said to be grazing that cannot at present be used owing to lack of water. The surface slopes steeply down from both eastern and western edges of the plateau. The permeable horizons between the lavas are thus likely to be drained, and as there is only a narrow connexion between the lavas of the plateau and those extending further up to the wetter heights of the Karissia Hills, the water table probably sinks rapidly deeper, away from the hills. The boring prospects are therefore not considered favourable.

The Losiolo Phonolites

These are thin flows with vesicular surfaces which would evidently be permeable, and the Series would no doubt yield water, but surface supplies are adequate and boreholes would not be justified.

The Thomson's Falls Phonolites

The phonolites of this group yield so little water in boreholes that boring into them is best avoided unless the intention is to go deep enough to reach more favourable formations below. None of the boreholes situated on the Series, within the area of the map, were actually visited but it is thought that the following were begun in the Series:—

No.	134,	depth	66	feet,	yield	per	24	hours	7,200 gallons.
,,	136,	,,	410	,,	,,	,,	,,	,,	240 ,,
,,	145,	,,	112	,,	,,	,,	,,	,,	240 ,,
,,	C64,	,,	348	,,	,,	,,	,,	,,	2,000 ,,
,,	C65,	,,	392	,,	,,	,,	,,	,,	3,000 ,,
,,	C66,	,,	158	,,	,,	,,	,,	,,	20,000 ,,
,,	C118,	,,	436	,,	,,	,,	,,	,,	1,600 ,,
,,	C157,	,,	247	,,	,,	,,	,,	,,	2,640 ,,
,,	C226,	,,	257	,,	,,	,,	,,	,,	21,120 ,,

NOTE.—The numbers are those used by the Public Works Department.

Of these, C118 and C226 are known to have penetrated through the Thomson's Falls Phonolites into underlying formations. In C118, the samples from above 196 feet are of phonolite, but those from below are all of basalt—presumably the series which can be seen under the Thomson's Falls Phonolites further south (outside the area) along the face of the Sattima Scarp. C226 is in a deep valley, at an estimated elevation of 6,600 feet. It was not visited but is within the area shown on the map as consisting of Thomson's Falls Phonolites. A first glance at the powdered samples, under the microscope, showed that they are probably all of the Rumuruti Phonolites.

Biotite flakes were seen in samples from 230—240 feet, and both phenocrysts and minute euhedra of nepheline in one from 170—215 feet. Some if not all of the water in this borehole is therefore derived from the Rumuruti Phonolites. Disregarding these two holes which enter underlying formations, only 2 out of 7 holes were successful in the Thomson's Falls Series. (Holes yielding less than 3,600 gallons per 24 hours are classified as unsuccessful.)

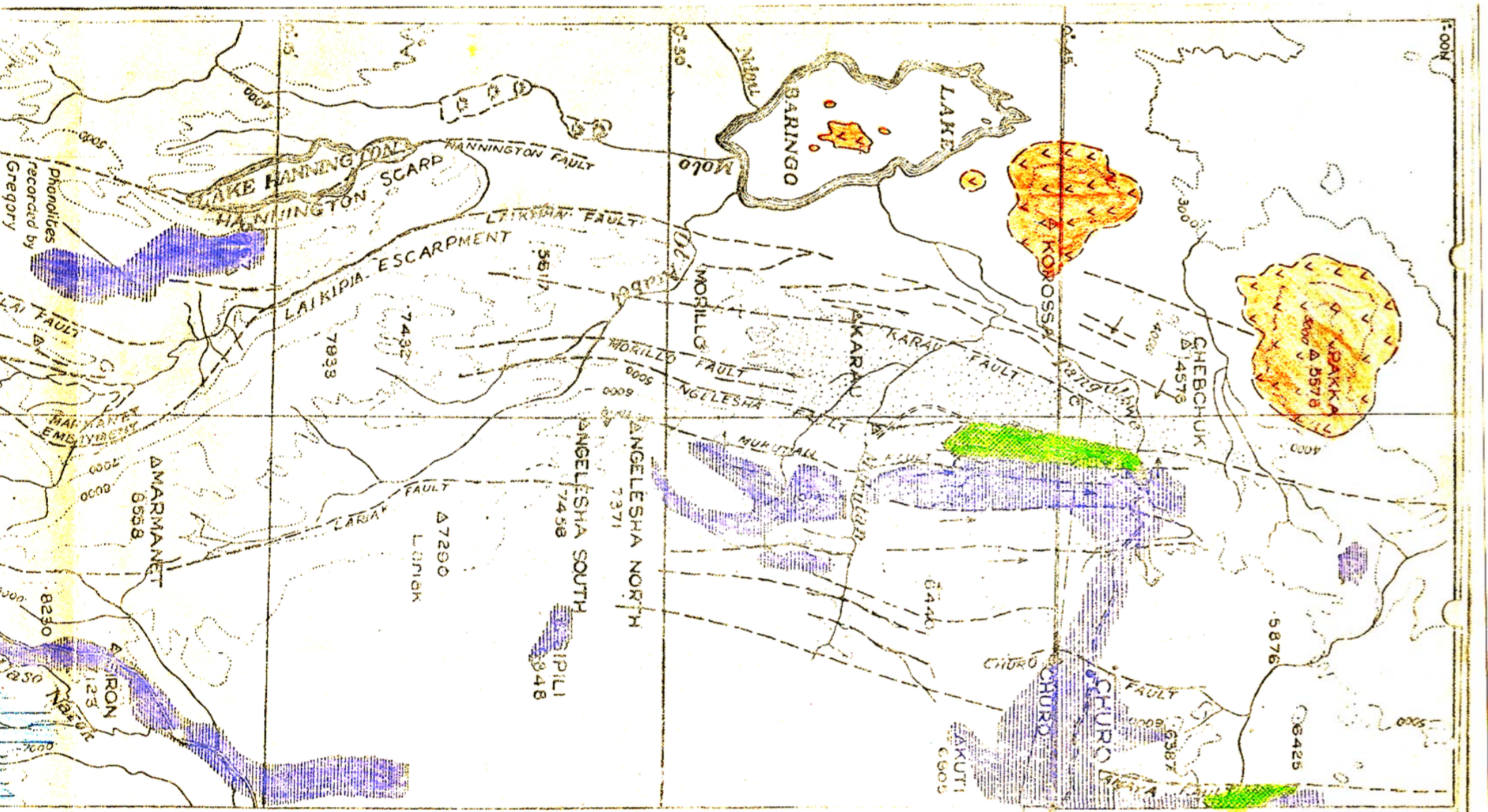


FIG. 14

Sketch-map to show geology of the fault zone between Laikipia and Lake Baringo as inferred from traverses.

[To face page 58]

While the Series is therefore unfavourable for boring, it will hold water well in reservoirs. The soil cover is thin and the rock itself is very little weathered even immediately under the soil.

The Laikipian Series of Basalts

Many of these basalt flows are divided into vertical columns by joints, which opened owing to contraction as the lava crystallized. Moreover, the flows have vesicular surfaces and porous tuffs occur between them, especially near the vents. It is therefore reasonable to expect good results from boreholes, but so few have been drilled in these basalts, within the part of Laikipia included on the map, that no conclusions can be drawn from the results.

Similar basalts have flowed into some of the valleys in the Loldaikas and they cover a large area east of the N'gare Ndare, extending northwards almost to the Uaso Nyiro. Several boreholes near the Loldaikas have struck water in tuffs or sandy detritus immediately below the basalts; consideration of the form of the surface buried under the lavas is important here. In the more extensive lava sheets, such as that south of the Uaso Nyiro, good borehole results might be anticipated.

The outliers on the north-eastern part of this area are too small to be of much significance.

The Mount Kenya Volcanic Suite

More detailed work would be needed before reliable generalizations could be made as to the prospects of boreholes in this complex series of rocks.

Pleistocene Tuffs, Silts and Gravels

Thick deposits of fluviatile gravels and silts, with subordinate tuff, underlie much of the black soil area west of Nanyuki, towards the Uaso Nyiro. Boreholes into these deposits yield water at shallow depths. The conditions in this area were discussed at length by Sikes (*op. cit.* pp. 30-32).

Red Sandy Earths covering the Basement System Rocks

The talus, hillwash, sandy soil, and loess-like materials included in this group are all so porous that percolating water must drain rapidly downwards to the water table, which lies usually within the underlying metamorphic rocks. It is unlikely that shallow boreholes would be successful in these earths, except perhaps where they merge into alluvial cones at the mouth of some of the valleys which drain the higher hills. Nor are reservoirs likely to hold water except where the sandy earths are covered, as they are in some flat valleys, by black soil.

APPENDIX

p53

I—Note on Traverses East of Lake Baringo

A hurried traverse along the road from Suguta Mugie westwards to Churo and Tangulbwe, and thence to Mukutan and Karau, was made to determine from the exposures on the escarpments, what rocks are likely to be reached in boreholes in western Laikipia. Fig. 14 is a sketch of the geology of the area seen on this traverse and others around Thomson's Falls.

From the point of view of the main area, two conclusions are important. The first is that at Tangulbwe, and from there southwards, the Rumuruti Phonolites are underlain by a series of basaltic rocks. These are correlated with the Samburu Series and with the basalts at the base of the Amaya Scarp. Secondly, the level of the contact between the basalts and the phonolites is at about 6,000 feet below Amaya, compared with only about 4,100 feet near Tangulbwe, which is only 15 miles further W.S.W. The observed dips between these two points are very low, and the difference in height is evidently due to a series of faults, which in the aggregate have a throw of well over a thousand feet. This is exclusive of the throw of the main fault west of Tangulbwe.

The positions of some of the faults was evident from the north-south valleys and straight westward-facing scarps. It is clear that the Rift Valley fault zone reaches very close to the edge of the main area, west of Suguta Mugie. Experience in the comparable fault zone west of Nairobi shows that the elucidation of such a fault zone can do much to increase the chance of success in boring for water.

II—Note on Traverses near Thomson's Falls

The Uaso Narok at Thomson's Falls drops over a phonolite of the Thomson's Falls Series. Further down, in the bottom of the gorge, the underlying Rumuruti Phonolites outcrop.

A road west of Thomson's Falls was traversed, as far as the foot of the Laikipia escarpment, to compare the section with that seen in the Baringo traverses. The section is included in Fig. 8. The scarp exposes specially phonolites with few phenocrysts, similar to some of those in the Rumuruti Phonolite Series east of Baringo. No basalts were seen. Data from other traverses near Thomson's Falls are included in Fig. 14.

REFERENCES

Note: Dates shown in brackets refer to reports as yet unpublished, and indicate the time of completion of the scripts.

Gregory, J. W., 1896.—*The Great Rift Valley*, London.

——— 1900.—"Contributions to the Geology of British East Africa, Pt. II. The Geology of Mt. Kenya," *Quart. Jour. Geol. Soc.*, London, LVI, pp. 205-222.

Maufe (Muff), H. B., 1908.—"Report relating to the Geology of the East Africa Protectorate." Col. Rept. Misc. No. 45 (Cd. 3828), London.

Oswald, F., 1914.—"The Miocene Beds of the Victoria Nyanza and the Geology of the Country between the Lake and the Kisii Highlands." *Quart. Jour. Geol. Soc.*, London, LXX, pp. 128-198.

Parkinson, J., 1913.—"On a group of Metamorphosed Sediments situated between Machakos and Lake Magadi in British East Africa," *Quart. Jour. Geol. Soc.*, London, LXIX, pp. 534-539.

——— 1920.—"Report on the Geology and Geography of the northern part of the East Africa Protectorate with a note on the Gneisses and Schists of the District." Col. Rept. Misc. No. 91 E.A.P. (Cd. 729).

——— (1941).—"Outlines of the Geology of the Mtito Andei-Tsavo Area: Report No. 13, Mining and Geological Department, Kenya.

*Rosiwal, A., 1891.—"Uber Gesteine aus dem Gebiete Zwischen Usambara und dem Stefanie-See, nebst einem Anhange: Uber Gesteine aus Schoa und Assab." *Denk. Akad. Wiss. Wien*, LVIII, pp. 465-550.

Read, H. H., 1931.—"The Geology of Central Sutherland." *Mem. Geol. Surv.*, Scotland.

Shackleton, R. M. (1942).—"The Geology of the Migori Area, South Kavirondo." Report No. 10, Mining and Geological Department, Kenya.

——— 1945.—"The Geology of the Nyeri District." Report No. 12. Mining and Geological Department, Kenya.

Shand, S. J., 1937.—"The Rocks of the Kedong Scarp, Kenya Rift Valley." *Geol. Mag.*, LXXIX, pp. 262-271.

Sikes, H. L., 1934.—*The Underground Water Resources of Kenya Colony*," Crown Agents, London.

Smith, W. Campbell, 1931.—"A classification of some Rhyolites, Trachytes, and Phonolites from Part of Kenya Colony, with a note on some of the associated Basaltic Rocks." *Quart. Jour. Geol. Soc.*, London, LXXXVIII, pp. 212-258.

Stockley, G.M., 1934.—"The Pre-Karroo Stratigraphy of Tanganyika. *Geol. Mag.*, LXXX, No. 5, pp. 161-170.

*Thomson, J., 1887.—*Through Masai Land; a journey of Exploration among the snow-clad volcanic Mountains and strange Tribes of Eastern Equatorial Africa*, London.

Temperley, B. N., 1938.—"The Geology of the Country around Mpwapwa." Short Paper No. 19, Department, Lands and Mines, Geol. Division, Dar es Salaam.

Willis, B., 1936.—*East African Plateaus and Rift Valleys*, Carnegie Inst. of Washington.

*References not consulted.


MARALAL
LORGOI
KAMAYA ROAD
ANGATA
WERGOI
RUMURUTI
LONGORA
BlackGirl
KAN YUK
GEOLOGICAL SYMBOLS
1/250,000
RECENT
PLEISTOCENE
MIOCENE TO PLEISTOCENE
BASEMENT SYSTEM
TOPOGRAPHY
Based on a 1:250,000 map Laikipia Plateau & the country to the South Lands & Survey Dept.
Plane table sketch made by the Geologists
Based on surveys made by the East Africa Survey Group in 1940
Springs
Waterholes
Boreholes
The usual conventional representation of minor topographic features.
Form line interval 250'
Map drawn for reproduction by M.A'Zal Draughtsmen
Geologically surveyed by
Robert M Shackleton B.Sc. (Hon) F.G.S. Geologist