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GEOLOGY OF THE NYERI AREA

(with colored geological map)

by

R.M. Shackleton, B.Sc. Ph.D., F.G.S. Geologist

First print 1945
Reprint 2007

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I—INTRODUCTION

A rapid geological survey of the district around Nyeri was carried out early in 1945, partly in order to determine whether the geological structure between Mt. Kenya and the Aberdare Range was such that artesian water was likely to occur there. This report deals with the geology of the Nyeri quarter-degree sheet, which was surveyed in more detail than the surrounding areas. The limits of the sheet are the equator, 0° 30′ S., 36° 30′ E., and 37° 30′ E.; it has an area of a little less than 1,200 square miles. Eleven weeks were spent in field work in this area; reconnaissance traverses were also made of surrounding areas to obtain a general idea of the structure of the areas where it had been hoped to find artesian water.

Maps.—The 1 : 125,000 Nyeri Sheet (Africa South A-37/A II), published in 1909 by the Geographical Section of the General Staff, was used as the topographic basis of the map of the Nyeri District. A large part of the area, covered by the Aberdare forests, is represented so inaccurately on the topographic map that no scruple was felt in altering lines to give a closer approximation to reality. No systematic topographic surveying was carried out, but a plane-table sketch map was made of the parts of the northern Aberdares above the forests. In the settled areas, geological data were usually plotted on the 1 : 62,500 cadastral sheets published by the Lands and Survey Department. A few heights have been re-determined by officers of the Survey Unit, East Africa Command; the new values have been incorporated in the map. The most important is Sattima, the elevation of which, at a point a few feet from the summit, was determined as 13,104 feet.

Acknowledgment is gratefully made for hospitality and assistance received from many people in the area. Particular thanks are due to Mr. Raymond Hook of Nanyuki, who organized mule transport on the Aberdare Range and Mt. Kenya, and gave me much useful information.

II—PREVIOUS GEOLOGICAL WORK

Gregory crossed southern Laikipia on his 1893 expedition. He was forced to hurry, but was able to see that the phonolites which he had traversed on his way from Lake Baringo passed beneath basalt sheets beyond the Ngobit River. He continued over these basalts to the foot of "a high down-like hill, Songari", which, he wrote "consists of a coarse phonolite with large crystals of anorthoclase and nepheline and rare olivine; this rock belongs to the Kapitian phonolites of the Kapiti Plains, but is a more basic variety". (Gregory, 1921, p. 136.)

Other rapid traverses were made by Gregory in 1919, from Naivasha to Songari Hill, and from Nyeri along the old Meru road. From the combined observations of these traverses the following Laikipian succession was deduced (*ibid.*, p. 143):—

Naivashan	.. Phonolitoid kenyte of Nyeri, etc.
Laikipian	.. Quartz trachyte and rhyolite. Phonolitic trachytes. Basalts and basanites and lower phonolitoid kenyte.
Nyasan ..	.. Unconformity.
Doinyan	.. Kenya type of phonolite and kenyte intrusions (Domo Arabel). Losaguta type of phonolite.
Kapitian	.. Coarse prophyritic phonolite.

Maufe also recorded details of a traverse across the area from Nyeri to Rumuruti. Besides basalts, the only rocks mentioned were a tuff quarried at Nyeri for building, and a coarse agglomerate in the bottom of the Amboni valley, beneath the basalts. (Maufe, 1908, p. 39.)

The rocks collected by Gregory were classified by Miss Neilson (Gregory, 1921, Appendix IV). The classification of these and some other rocks was revised, with the support of more analyses, by Campbell Smith (1931). A rock from the Amboni valley near Songari Hill was analysed and described as representing Neilson's "phonolite of

Kapitian type", but as it was recognized that this rock was petrographically identical with some of the rocks of Mount Kenya described as kenytes by Gregory, his distinction between kenytes and the phonolites of Kapiti type seemed to have no petrographic basis and to rest only on field evidence. A phonolite from a stream south of the Guaso Lashau (Suguroi River) was shown to be typical of the Mount Höhnel (or Kenya) type. The basaltic rocks were found to include fayalite-bearing phonolite (Nyeri Hill), fayalite-bearing alkali-trachyte (Guru Bridge on the Nyeri–Naivasha track), nepheline-basanite (south of the Ngobit River) and trachybasalts (Suta River south of Nyeri, and east of the Amboni River on the old Nyeri–Meru road).

III—SUMMARY OF THE GEOLOGICAL SUCCESSION

The principal groups of rocks distinguished in the area are:—

(1) Simbara Series.
(2) Sattima Series.
(3) Thomson's Falls phonolites.
(4) Kinangop trachytic tuffs and Nyeri tuff.
(5) Laikipian basalts.
(6) Rocks of the Laikipia vents.
(7) Mt. Kenya Volcanic Suite.
(8) Pleistocene and Recent superficial deposits.

A summary of their general features is given below. A more detailed description of their occurrence and character in different parts of the area is given in Section V and their age and correlation are discussed and tabulated in Section IV of the report.

(1) *The Simbara Series*

In the northern Aberdares, on Kipipiri and in valleys near the south-eastern edge of the area, the oldest exposed volcanic rocks are basaltic lavas and agglomerates of a distinctive type. They are here referred to as the Simbara Series after the area where they are best exposed. The principal centres of eruption of these basalts were near Sattima, and Kipipiri. Closely similar basalts were erupted, probably during the same volcanic phase, at Niandarawa and Kijabe Hill. Denudation has long ago removed any trace of the craters of these volcanoes and other lavas have been erupted on and around them.

Most of the lavas are of the Kijabe type basalt (*see* p. 16) with abundant parallel plagioclase phenocrysts. Some melanocratic basalts associated with the Kijabe type basalts have not been included in the Simbara Series on the map because their limits were not defined and similar lavas occur at other horizons. In Simbara, innumerable dykes of Kijabe type basalt, quartz trachyte and phonolite, cut the Simbara Series. Radial dykes converge towards a point a little south of Sattima and the lavas dip outwards from this focus.

Away from the eruptive centre, agglomerates predominate over lava flows. The blocks in these agglomerates are of Kijabe type basalt and melanocratic basalt with olivine and augite crystals, and scarcer basalts of other types. These agglomeratic rocks are exposed by the Amboni and Chania rivers, and have been seen also further south as far as Sabasaba and Makindi. (*See* Fig. 1.)

(2) *The Sattima Series*

The Simbara basalts are overlain, on and around Simbara, by fissile pale-weathering lavas, identified as phonolites, olivine alkali-trachytes, mugearites, and fissile basalts. A sheet of porphyritic quartz trachyte, the "Dragon's Teeth Trachyte", is closely associated with the lavas of the Sattima Series but it is at least partly intrusive.

There was probably an interval between the eruptions of the Simbara basalts and the lavas of the Sattima Series, as the contact between the two is everywhere sharp, and not one of the many dykes traversing the Simbara Series was seen to enter the Sattima Series. Nevertheless some of the dyke rocks closely resemble the Sattima Series lavas, and may represent their feeders.

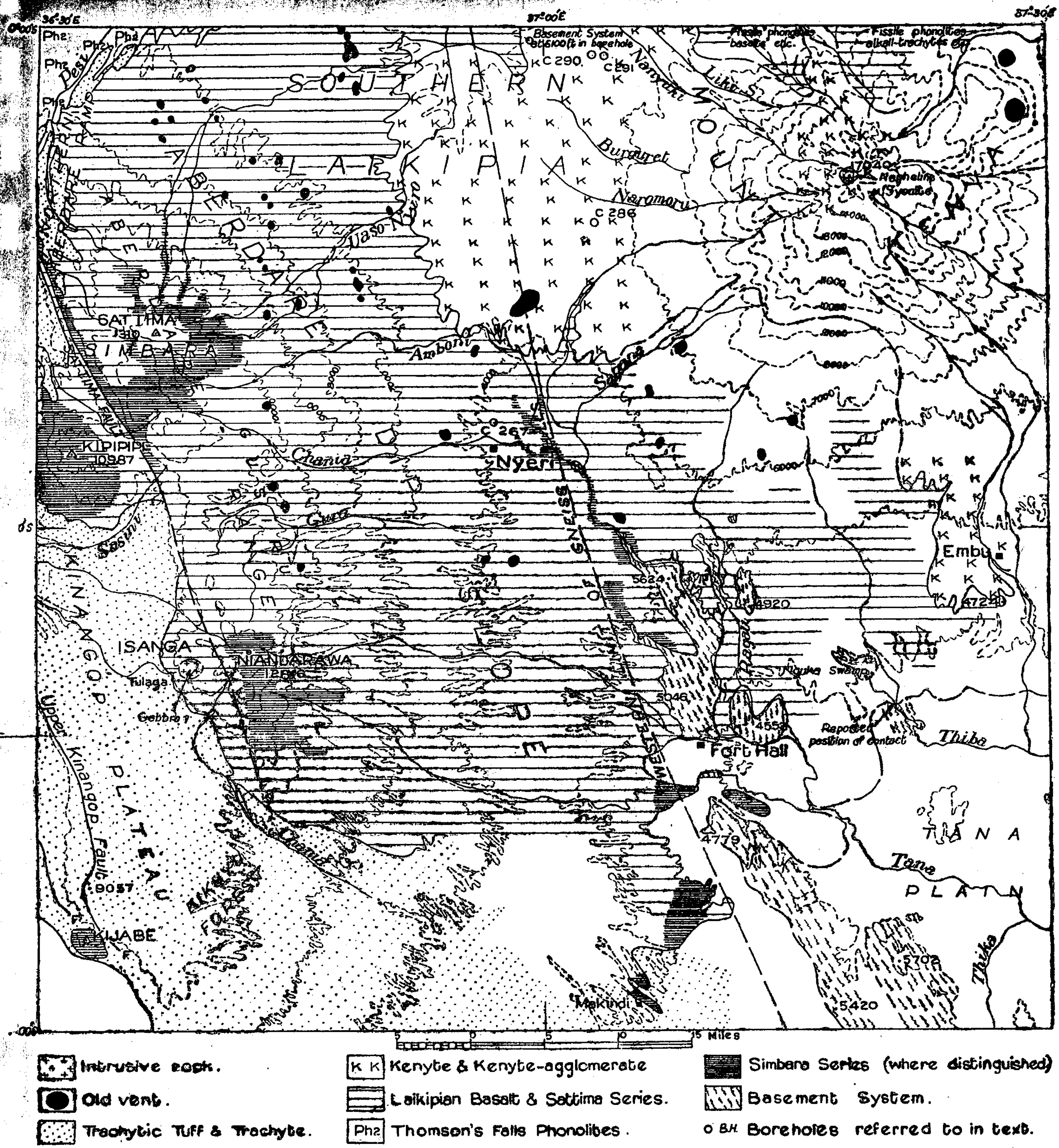


FIG. 1

Geological Sketch-map showing Mount Kenya and the Aberdare Range

[To face p. 2

The Sattima Series has not been recognized except in Simbara. Looking from above into the valleys that lead down through the Aberdare forests it appears as though the fissile lavas dip more steeply than the fall of the ground and therefore disappear beneath the Laikipian basalts of which most of the country below the forests is formed.

(3) *The Thomson's Falls Series*

In the north-western part of the area, a distinct and rather uniform series of phonolitic lavas overlies the Simbara basalts. These phonolites have a twisted flow-structure which gives their outcrops a distinctive irregular appearance. Closer examination shows small anorthoclase crystals, and often characteristic knobbly inclusions of phonolite slightly different in texture and colour from the matrix. Where freshly broken the rocks are grey and glisten from minute parallel plates of felspar. Microscopically they are found to be phonolites of the Kenya type.

They appear to have been erupted from the Rift Valley region.

(4) *The Kinangop Tuff Series and the Nyeri Tuff*

These are light-coloured trachytic pumice tuffs. The main development of the Kinangop tuffs is outside the area. The sections on the Kinangop scarps east of Naivasha show hundreds of feet of trachytic tuffs, and water-lain stratified tuffs, as well as some trachytes. In the area of this report, no such thicknesses are exposed. Along the rivers flowing towards the Kinangop from the Sattima scarp and Kipipiri, rough grey-weathered unstratified tuffs are exposed. Fragments of obsidian, speckled trachyte resembling the Nairobi Trachyte, and other lavas, project on the weathered surfaces from the softer buff-coloured matrix of comminuted pumice. In the slides this pumice is seen to have a warm brown or purplish-brown tint. It is fibrous or minutely frothy. In the more crystalline trachytic fragments in the tuff, small poecilitic patches of quartz can be distinguished. The tuffs are probably pantelleritic.

The Kinangop tuffs underlie the Kinangop and Ol Bolossat plains and towards the north they are underlain by the Thomson's Falls phonolites. Precisely similar tuffs are again exposed at the top of the northern part of the Sattima fault scarp and on the northern Aberdare ramp, where again they rest on the Thomson's Falls phonolites. They appear to thin to a feather edge against the flank of the older volcanic pile composed of the Simbara basalts and the Sattima Series. Further north-east, by the Pesi River, the same series of trachytic tuffs, diminished to about 70 feet in thickness, underlies one of the Laikipian basalts; still further north-east, the tuff is exposed in the Suguroi valley, where it is quarried. There again it rests on the Thomson's Falls phonolites, and is overlain by Laikipian basalts. In the floor of the Ngobit valley similar trachytic tuff appears from beneath the Laikipian basalts for a short distance. There is then a twenty-five mile gap, without exposures of any such tuffs, until the Nyeri country is reached. There a trachytic tuff, petrographically similar to the Kinangop tuffs, is again found. It lies between the Simbara Series below and the Laikipian basalts above. It is correlated, with some hesitation, with the Kinangop tuff Series.

(5) *The Laikipian Basalts*

Gregory gave the name Laikipian to the Series of basalts which he observed overlying the phonolites in southern Laikipia. The term has been retained here (although it cannot at present be accurately defined), because the basalts which Gregory called Laikipian are mostly of one type and rocks of this type have a wide distribution in the area. It is clear that Gregory's term should not be used to include the Simbara Series, since it was intended for the basalts which overlie the phonolites, whereas the Simbara basalts underlie them. It is not so clear whether the Laikipian should include also the Sattima Series into which the typical Laikipian basalts seem to pass by alternation, but as the Sattima Series includes phonolites, and is probably itself mainly older than the Thomson's Falls Series, it seems that it should be excluded from the Laikipian. Thus restricted, the Laikipian includes in the type area a series of basalts, most of which are either non-porphyritic or contain very small specks of olivine. Many of them show a characteristic hackly fracture and in the majority of flows there is a widely spaced columnar jointing. Examination under the microscope shows that olivine alkali-basalts and analçite-basanites are the commonest types.

Most of the waterfalls in the district occur where columnar Laikipian basalts have been undercut. Examples are those on the Chania just above Nyeri, and others in the Aberdare Forest; the Amboni Falls just below the Nyeri–Nanyuki road; and several falls on the Zuka Zuka and Moyo rivers above their confluence.

The Laikipian basalts probably erupted from numerous small volcanoes, the stumps of which are a conspicuous feature of southern Laikipia. Similar basalts, referred to the same Series, occur high up on Simbara, especially on the western flank.

The Laikipian basalts are mainly developed east of the Sattima fault, but there is also a thick series of columnar non-porphyritic basalts of Laikipian type, exposed in the Wainjohi gorge north-east of Kipipiri, and similar basalts occur in the intermediate fault strip between the two branches of the Sattima fault.

Typical Laikipian basalts are seen to overlie the Kinangop tuff Series near the Pesi River, near the Mutara, and along the Suguroi. Their distribution suggests that they were there erupted on to a surface which was tilted towards the east with the result that they did not spread over the surface of the Kinangop tuffs of the Ol Bolossat plains.

The main mass of the Laikipian basalts is believed, for reasons stated below, to overlie the kenyte agglomerates of the Mount Kenya Suite, but the earliest of them are clearly seen to pass beneath the kenyte agglomerates in the Amboni valley. The kenytes were therefore erupted early in Gregory's Laikipian stage. As the Mount Kenya rocks were the chief representative of his Doinyan Series, supposed to be earlier than the Laikipian, it is obvious that this part of his classification is confused. Furthermore, the kenyte of the Amboni valley was identified by Gregory as Kapiti phonolite and so referred to his Kapitian stage.

(6) *Rocks of the Laikipian Vents*

Many small isolated hills rise abruptly from the otherwise smoothly undulating surface of southern Laikipia. These represent old volcanic vents. Few, if any, retain any trace of their original craters. Erosion acting on the scoriaceous lavas and pumiceous tuffs of which they are chiefly built has destroyed their original form and only the stumps remain.

The rocks of most of these vents are basaltic. Some are hackly basalts, either non-porphyritic or with small brown altered olivines. Others are highly porphyritic with abundant olivines and augites. Reddish basaltic tuffs usually occur on and around the vents.

Nyeri Hill and Songari consist of trachytic rocks. The Nyeri Hill rock was identified by Campbell Smith (1931) as a fayalite-bearing phonolite. On the northern slopes of Songari there are grey, fissile fine-grained trachytes, but near the triangulation point there is a very small outcrop of kenyte. The higher southern summit was not traversed during this survey, but Gregory who states that Songari Hill is kenyte, probably refers to the southern summit.

Rarely fragments of gneiss have been blown out of the vents, and a piece of Kijabe type basalt, indicating the presence of the Simbara Series below, was collected from a tuff at the side of Ol Doinyo Narasha.

The date of the last eruption of one of the Laikipian vents may be known when some fossils discovered in a basaltic tuff near the Moyo River have been identified (*see* p. 12). In the opinion of Dr. Leakey, they may be either Lower or Middle Pleistocene, but probably the former.

(7) *The Mount Kenya Suite*

The north-eastern part of the area is a gently rolling plain, traversed by shallow rather featureless valleys, along the sides of a few of which there are discontinuous exposures of agglomerates with blocks of kenyte and green fissile phonolite. Near the Amboni and one of its tributaries, kenyte lava is exposed. Fissile phonolites were seen by a stream about five miles north by west of Nyeri Station, and in a single outcrop on the slope north of the Naromoru river. From such scattered outcrops, the extent of the area underlain by these various rocks can be approximately determined. The only place where their contact with the Laikipian basalts was actually seen was on the north side of the Amboni valley, where kenyte agglomerates and lava overlie a basalt of Laikipian type. The whole of the western boundary shown on the map is conjectural. It is drawn on the assumption that the Laikipian basalts which outcrop along a low scarp, overlie the kenyte agglomerates of the low ground east of it.

The kenyte agglomerates and lavas, and the phonolitic lavas mentioned, are part of a continuous field of such rocks which can be followed up the lower slopes of Mount Kenya, so that there is no doubt that they were erupted from the former Mount Kenya volcano. Pieces of nepheline syenite like that of the central plug of Mount Kenya are sometimes found in the agglomerate.

The kenyte agglomerates by the Amboni River near the Nyeri–Rumuruti road, rest directly on agglomerates of the Simbara Series. Further down the Amboni, on the other hand, there are a series of basalt flows of Laikipian type between the Nyeri tuff below and the kenyte agglomerates above.

(8) *Pleistocene and Recent Superficial Deposits*

These are thin unconsolidated or semi-consolidated deposits which have accumulated since the volcanic eruptions ceased. There is little evidence by which they can be dated. The deposits are classified into the following types:—

(*a*) Naromoru ash.
(*b*) Moraines.
(*c*) Solifluxion deposits.
(*d*) Red soils.
(*e*) Red and pale lateritic earths.
(*f*) Black soils.
(*g*) Alluvium.

(*a*) *The Naromoru Ash*.—This is a thin deposit of greenish-grey tuffaceous material occurring in many parts of southern Laikipia, notably near Naromoru. Its most characteristic feature is the constant presence of small flakes of biotite. It is uncertain whether the deposit is pyroclastic.

In this area it is usually unstratified, but in the valleys, similar material (or the same, re-deposited), is distinctly stratified and contains small gritty fragments of kenyte and other rocks derived from Mount Kenya. These stratified deposits are termed the Uaso Nyiro Beds in the Nanyuki area (Shackleton: Maralal Report).

The Naromoru ash is younger than a Lower or Middle Pleistocene basaltic tuff (*see* p. 12) and older than the Late Middle Pleistocene Kenya Fauresmith horizon (*see* paragraph (*e*) below). It is exposed beneath black soil in many roadside pits. "Kunkar" concretions commonly occur both in the ash and in the lower part of the black soil.

(*b*) *Moraines*.—These are confined to the highest valleys on Simbara. They are believed to be of the same age as those on Mount Kenya referred to the Upper Pleistocene Gamblian Pluvial Period (*see* p. 11).

(*c*) *Solifluxion Deposits*.—Material believed to have accumulated as a result of solifluxion occurs on Simbara (*see* p. 10).

The fact that the Honi has cut a channel 20 feet deep through one of the deposits suggests that its age is Pleistocene and not Recent.

(*d*) *Red Soils*.—These are typically developed in the Nyeri area where they are often ten or twenty feet thick. They are unstratified and homogeneous, and appear to result from rock decomposition under forest cover during a long period of time. They have not yielded artefacts and it seems likely that the forests under which they formed were uninhabited by prehistoric man.

(*e*) *Red and Pale Lateritic Earths*.—At many places east of the limit of the area, erosion has exposed a series of red and pale lateritic earths. In the lowest of these, a rich red earth, artefacts of the Kenya Fauresmith (Nanyukian) culture have been found. At Leakey's type locality for this culture (Leakey, 1931) by the road to the Nanyuki Forest Station, red earths in which the artefacts occur, rest unconformably on the biotite-bearing Naromoru ash. Within the area of the map, artefacts of the Kenya Fauresmith culture have only been found at a few places near the Pesi River. These localities were discovered and shown to me by Mr. T. P. O'Brien. They are in eroded patches and the sections show a foot or two of lateritic earths at or near the base, overlain by yellowish, brown to grey soils with "kunkar" concretions. There are artefacts, mostly unrolled, of Kenya Fauresmith, Levallois and other types. Some with adhering laterite are obviously derived from the basal lateritic horizon, but none were seen *in situ*.

(*f*) *Black Soils*.—These cover most of the flatter ground. With them are included some brown soils into which they pass on slightly more sloping ground. Both the black and brown types have concretions of "kunkar lime" at their base.

The distribution of the red and black soils depends on slope, which controls drainage and consequently oxygenation, rather than on the nature of the bedrock. Both red soils and black soils are typically developed on basalts, phonolites and trachytic tuffs in this area.

(*g*) *Alluvium*.—Alluvium has been deposited during the silting up of some of the flatter valleys such as the Moyo. Gravels are surprisingly scarce and insignificant.

IV—CORRELATION WITH OTHER AREAS

A provisional correlation of the principal volcanic rocks and superficial deposits is given in the table. Some of the evidence on which the table is based is discussed below.

(1) *Correlation of the Older Basaltic Rocks*

The Samburu Series, the Simbara Series and the Ngong basalts are thought to be approximately of the same age, principally on account of their petrographic similarities. Basalts of Kijabe type are characteristic of the Samburu Series and the Simbara Series. Melanocratic basalts with olivine and augite phenocrysts occur in the Samburu Series east of Baringo, in the Simbara Series in Simbara, and in the Ngong basalts. Basaltic rocks are known to occur low in the volcanic succession in western Kenya (Kent, 1944, pp. 16–18), and in the Lake Rudolf Basin (Arambourg, 1935; Fuchs, 1939, pp. 230–246); the description of the Miocene basalts and tuffs of the Losidok Hills west of Lake Rudolph (*ibid.*, p. 231) indicates that they are very similar to the Samburu Series of the north-western part of the Maralal area. In the Tambach–Kabarnet area at the western side of the Kenya Rift Valley, Mr. J. Scott of the Public Works Department determined (personal communication) the following succession:—

6. Kabarnet Trachytes.
5. Stratified tuffs, etc. (? Kamasian).
4. Uasin Gishu Phonolite.
3. Basalt.
2. Conglomerates, grits and green tuff (? Miocene).
1. Gneiss (Basement System).

Thus here also basalt occurs at the base of the volcanic series.

The presence of a flow of Kijabe type basalt between the Thomson's Falls Phonolites and the Rumuruti Phonolites, near the Pesi River (Shackleton, Maralal Report) suggests that the last of the basalts of the Simbara Series were erupted later than the Rumuruti Phonolites.

(2) *Correlation of the Kinangop Tuffs, Nyeri Tuff and Sattima Series*

The Nyeri tuff is correlated with the Kinangop tuff on account of its similar lithology, and because it lies in the same relation to the Laikipian basalts as the trachyte tuffs of Ngobit, Suguroi and Mutara, which undoubtedly belong to the Kinangop tuffs.

The Nyeri tuff contains cognate fragments of a quartz-trachyte which resembles the porphyritic quartz-trachyte of the Sattima Series, but their correlation is questionable.

(3) *Relative Age of the Trachytic Tuffs and the Mount Kenya Volcanic Suite*

In view of the occurrence of trachytic tuffs at many horizons in the Nairobi sequence, the suggested correlation of the Kerichwa valley tuff with the Nyeri and Kinangop tuffs is open to doubt. It is possible that the Kinangop tuffs and the Kerichwa valley tuffs are in part younger than the Mount Kenya Volcanic Suite.

V—PHYSICAL AND GENERAL GEOLOGY

The area is one where the form of the ground clearly reflects the main geological features. Most people familiar with the district are aware of differences in terrain, soil, rocks and drainage, between for example, the Kinangop plateau, the Aberdare farms, and the coffee growing areas around Nyeri. These depend on differences in the rocks and their structure.

The chief physiographic units (*see* Fig. 1) are:—

(1) The Kinangop Plateau.
(2) The Ol Bolossat Plain.
(3) Kipipiri.
(4) The Sattima Fault Scarp.
(5) The Northern Aberdare Ramp (northern part of the Aberdare Range).
(6) Simbara (the mountains) (northern part of the Aberdare Range).
(7) Gusiru (the moorland) (northern part of the Aberdare Range).
(8) The Aberdare Dip-slope.
(9) Southern Laikipia.

(1) *The Kinangop Plateau*

This is a platform about ten miles wide, with an elevation of 8,000 to 9,000 feet. It extends westwards from the foot of the Aberdares to the upper Kinangop fault scarp. Only a small part of it, south and south-east of Kipipiri, is included in the area dealt with in this report.

The margin of the Kinangop plateau is a distinct topographic feature which corresponds, within perhaps half a mile, with the geological boundary between the trachytic tuffs of the plateau and the basalts of Kipipiri and the Aberdares. It follows an irregular course round Kipipiri and southwards along the foot of the Aberdares, marking the unconformable contact between the Kinangop tuffs and the underlying basalts.

The surface of the Kinangop is conspicuously smooth. It is the marginal strip of a plain of accumulation which formerly extended from the foot of the Aberdares and Kipipiri across the Rift Valley region, and probably also eastwards across the northern end of the Aberdares.

The trachytic tuffs of which the Kinangop is built are well exposed along the Sasin river.

(2) *Ol Bolossat Plain* (Angata Pus)

Geologically, this is a continuation of the Kinangop. It is formed of the same trachytic tuffs, built up to a similar even surface. The marsh of Ol Bolossat is the dwindling relic of a former lake. Its existence at the foot of the Sattima fault scarp indicates that when the faulting occurred, the rocks of the Ol Bolossat plain were tilted eastwards, and a lake thus formed by the water impounded against the scarp. Its disappearance is doubtless due to silting up, as well as to the progressive desiccation of the country since the Upper Pleistocene (Gamblian) Pluvial phase.

(3) *Kipipiri*

This enormous mound rises some 3,000 feet above the surrounding plains to 10,987 feet. Its sides are furrowed by radial valleys and covered with dense bush and forest. It stands apart from the main Aberdare Range, from which it is separated by a saddle deeply trenched by the streams draining either side.

The profile of Kipipiri is similar from each side and except for a spur extending northwards, it is nearly round in plan, with a diameter of about seven miles. Its symmetrical form suggests that it is an old volcano and outward dips in the lavas of which it is formed confirm this. From the 1 : 125,000 map one might indeed suppose that traces of the original crater perhaps still exist, but from the summit it is obvious that this is not the case. Several of the higher points are connected by a curved ridge, with a flat area between them, but there are others nowhere near this ridge, which has been formed by erosion. Moreover the profile of the mountain is no longer that of a simple cone. It is clear that it has been lowered by erosion hundreds of feet below its original height.

Three groups of rocks were seen on Kipipiri. There is a core of basalts of the Kijabe type; many thin flows are exposed in dark cliffs at the sides and head of the radial valleys, and similar rocks were seen in valleys along the western side of the mountain. This series of basalts is overlain by trachytes which form the pale slabby outcrops of most of the highest points, and extend down the north ridge and no doubt also down some of the other unexplored ridges. On the northern spur, and in the saddle between Kipipiri and the Aberdares, there are flows of columnar non-porphyritic basalt. A small hill near the end of the northern spur may mark one of the vents from which these basalts erupted.

The volcanic succession on Kipipiri is so similar to that of the Aberdares that their correlation is not in doubt. The Simbara Series is represented by the older basalts of Kipipiri, the Sattima Series by the trachytes, and the Laikipian Series by the columnar basalts of the saddle.

Kipipiri is thus as old as the Aberdares. It is not, as has generally been supposed, a younger volcano located on the Sattima fault.

(4) *The Sattima Fault Scarp*

The Sattima scarp is a long straight and steep rock face (*see* Pl. I (*a*)). It bounds the northern Aberdare ramp, and the high part of the range itself, from Thomson's Falls to north Kinangop, a distance of about 40 miles. The height of the scarp increases gradually from Thomson's Falls southwards, and then again declines still further south. Although the fault face is incised by some deep and precipitous-sided valleys, notably those of the several branches of the Melawa and the Wainjohi, the scarp between these incisions is little affected by erosion. It has the appearance of a geologically young feature.

Along one 7-mile stretch the fault is split, and as explained in more detail later, the geometry of the outcrops of the outer (eastern) branch suggests that it is inclined westwards. If so, the fault would be normal, that is tensional. As it is one of the principal boundary faults of the Rift Valley, proof that it is tensional would be hard to reconcile with any theory of the compressional origin of this Rift Valley.

Another point of interest is that the Sattima faulting appears to have taken place after the deposition of the Kinangop tuffs; the continuation of the tuffs of the Ol Bolossat plain is found at the top of the scarp.

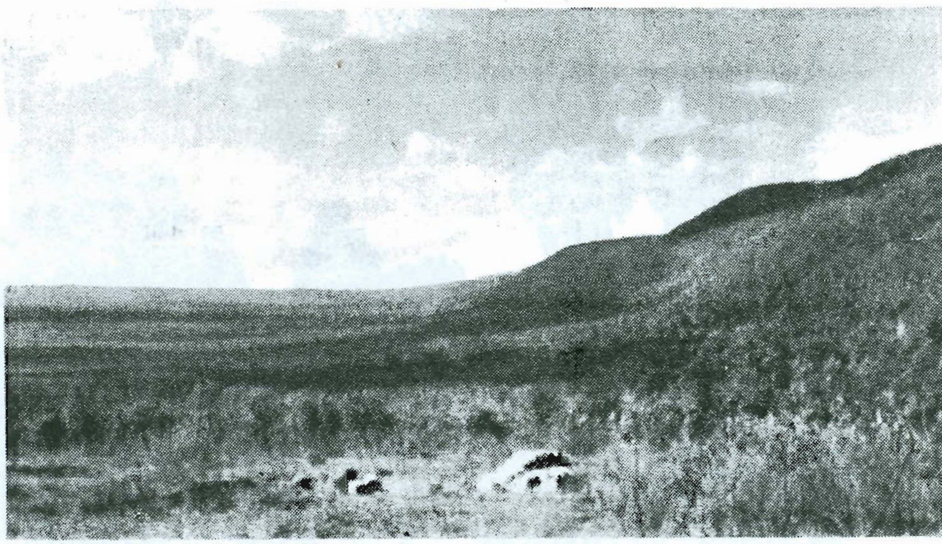
(5) *The Northern Aberdare Ramp*

In most parts of the Aberdare range the present slope of the ground has been determined both by the original slope of the volcanic rocks, away from their centre of eruption, and by subsequent tectonic tilt. There is, however, an area at the northern end of the range where the original volcanic surface was nearly flat, and the present slope is almost entirely the result of tilting. This area is described here as the northern Aberdare ramp. To the north and north-east it merges into the flatter plains and flatter structures of Laikipia.

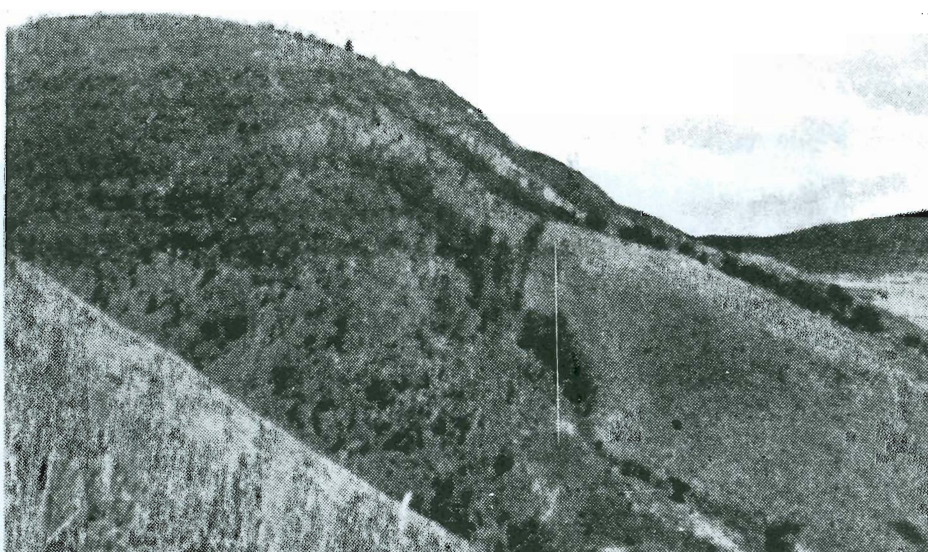
The rocks of the ramp are the Thomson's Falls Phonolites and the Kinangop trachytic tuffs. They are exposed in section on the Sattima fault face. There it is seen that the phonolites thin southwards to a feather edge on the Simbara basalts. Resting on the phonolites and extending to the very edge of the fault scarp are the Kinangop trachytic tuffs.

The river system of the ramp is interesting. The streams flow onto it from the old Simbara cone where they have a radial pattern, but as they run out over the ramp, instead of continuing in their previous courses, they swerve to the right, away from the edge of the Sattima scarp towards Laikipia, and the Sattima scarp drains only a small area of the edge of the ramp. The courses of these rivers across the ramp is proof that the Aberdare Block, as it was uplifted, was gently tilted towards the east. There is no sign of any pre-tilt drainage pattern, from which it appears that the faulting and movements followed very soon after the eruptions had ceased.

PLATE I



(*a*) View northwards along the Sattima Fault Scarp, from a point two miles N.E. of Kipipiri. This part of the scarp consists of basalts of the Simbara Series. The gentle slope in the middle is formed of talus. At the left is the Ol Bolossat Plain, formed of trachytic tuffs.



(*b*) Part of the Sattima scarp, showing the feature due to the eastern fault. The bush-covered slopes to the left of the fault feature are formed of nearly horizontal basalts of the Simbara Series. The smooth slopes below are formed by basalts of the Laikipian Series, covered with talus. The eastern edge of Kipipiri is seen across the end of the Ol Bolossat Plain, at the right. The view is taken looking south-eastwards.

Photo. R.M.S.

[*To face p.* 8

PLATE II

(*a*) Crags of porphyritic quartz-trachyte ("Dragon's Teeth Trachyte") of the Sattima Series, two miles north of Sattima.

(*b*) View northwards up the Honi Valley to Sattima, showing supposed solifluxion deposit, ending in a rock-stream slope along the right bank of the Honi.

To face p. 9

Photo. R.M.S.

(6) *Simbara*

Simbara is the name applied by the Kikuyu to the high mountainous part of the northern Aberdares. The name Sattima, given to the highest point on the maps, is seldom familiar to them. Sattima is not an isolated peak, but the inconspicuous culmination of a considerable area of high ground. Simbara is uninhabited; most of the hills are unnamed and the streams have only the names of the rivers into which they flow. Existing maps are misleading and inaccurate. Simbara in the sense used by the natives corresponds roughly to the area occupied by the two older divisions of the local volcanic rocks. These are the Simbara Series below, and the Sattima Series above; together they form the old volcanic core of the northern Aberdares.

The rocks of the *Simbara Series*, as shown on the map, are exposed in the valleys of Simbara and on some of the ridges. Some deeply incised valleys show over a thousand feet of basaltic lavas and the base of the series is nowhere seen. The lava flows are thin, vesicular and mostly of porphyritic basalt of the Kijabe type. They are readily weathered and often underlie grassy slopes with few outcrops. Steeper and rockier slopes show dark parallel outcrops of a great number of thin flows.

The Simbara basalts dip outwards from the central part of Simbara. They are traversed by dozens of dykes, mostly of porphyritic basalt similar to the lavas. Some are of pale fissile trachyte and a few of phonolite and non-porphyritic basalt. As shown on the map, many of the dykes belong to a radial system evidently centred on the main eruptive focus, which is less closely defined by the dip of the lavas outwards from it. Besides the radial dykes, there is a linear swarm (inadequately shown on the map) along the axis of the range, parallel to the Sattima fault. Most of the dykes of this swarm, are nearly vertical.

Other dykes have no obvious regularity. Their direction often changes abruptly, and some are branched. Few of the dykes are more than ten feet thick and many are a foot or less. In the other areas where the Simbara Series is exposed, along the Sattima scarp, in the Amboni valley, by the Chania below Nyeri, and elsewhere, no dykes were seen and there certainly cannot be many, although an occasional one may have been overlooked. The dykes are apparently confined to the Simbara Series; none were seen in the overlying rocks.

Although it is evident that the Simbara basalts were erupted from a centre a mile or two south of Sattima, no plug or vent was discovered, nor any topographic feature to suggest one. Several small rock knobs were found to stand out where the basaltic lavas were reinforced by dykes. Nor were any blocks or boulders of plutonic rocks found anywhere in the northern Aberdares.*

It is presumed therefore that the dykes, of which there are many more than could be shown on the map, mark the fissures from which the lavas were erupted.

The dominant lavas of the Simbara Series are Kijabe type basalts crowded with porphyritic felspar crystals. On the northern and southern flanks of Simbara, however, the prevailing type is a basalt with many visible crystals of olivine and augite. In various places they can be seen to overlie the other type of basalts; they are themselves traversed by dykes, and overlain in at least one place by a trachyte of the Sattima Series. They form the subordinate upper division of the Simbara Series.

The Sattima Series includes pale-weathering slabby and fissile rocks which, on the summits of Simbara and on Kipipiri, overlie the Simbara basalts. They include porphyritic quartz-trachytes, fayalite alkali-trachytes, alkali-trachytes, and phonolites. Of these, the porphyritic quartz trachytes are at least partly intrusive, as dykes and a sheet, but the others appear to be lavas. They occur chiefly as isolated outliers.

The porphyritic quartz trachyte is the most striking and conspicuous rock in the whole district. (Plate II (*a*).) Down the western slope of Simbara it forms bizarre outcrops, comb-like outliers on the ridges, vertically fluted and serrated crags, and fields of pronged and knobby rocks. In the field the rock was named the Dragon's Teeth Trachyte.

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* In the foothills and on Laikipia, stones of nepheline syenite the size of a tennis ball or less are sometimes found, but these are from Mount Kenya and were carried, and often shaped by prehistoric men for throwing-stones or bolas balls. The only plutonic rock yet known in the Aberdares is a gabbro (? essexitic), of which many blocks were found in the Turasha River near Tulaga, west of Niandarawa. (Spec. 43/65.)

At first this formation was taken for a lava sheet. In most of its exposures it directly overlies the Simbara basalts, but near the Melawa tributary four miles south-west of Sattima the sheet is overlain by other Simbara Series basalts, similar to those below it. In some of the valleys which cut into the Sattima scarp the same quartz trachyte sheet could be seen from below to cut transgressively through the great series of Simbara basalts. The sheet dips across the nearly flat lavas at angles up to 15°, and is here clearly intrusive. Near Sattima a similar rock which overlies a non-porphyritic alkali-trachyte of the Sattima Series may be a lava. Its connexion with the other fissile lavas is in any case certainly close. There are many dykes of similar rock.

The other rocks of the Sattima Series are apparently lavas.

In Simbara, which is probably the centre from which they were erupted, the Sattima Series is distinct, but on Gusiru, similar lavas are interdigitated with basalts of the Laikipian Series, and it has not been found possible to show the limit of the Sattima Series on the map. Low down on the western slope of Simbara, however, non-porphyritic basalts of Laikipian type were mapped, clearly overlying the porphyritic trachyte and the Simbara basalts.

Glaciation of Simbara.—It has been known for some time that there were at one time glaciers on the Aberdares (Nilsson, 1940, p. 4). The most convincing evidence of this glaciation is to be seen at the heads of the two main branches of the Melawa Ndogo River. In each of these, typical lateral moraines slant down the side of the valley to the lower end of an alluvial flat which evidently covers a small rock basin, now silted up. The heads of the valleys, above these old lake basins, have the scooped-out appearance and U-shaped cross-section typical of glaciated valleys, while immediately below the lips of the basins the valleys drop steeply and have the V-shaped cross-sections typical of river erosion. In the northern Melawa valley there is another small moraine above the old lake bed. The glaciers in these valleys reached down to about 12,000 feet.

At the head of the Wainjohi there is also an area whose form suggests glaciation. No moraines or old lake beds were seen there, but there is a distinct lip where the supposed glaciated part gives place to the V-shaped valley below, and this lip lies at about the same elevation as those in the Melawa valleys. In the Ngobit, moraine ridges converge towards the lower end of a flat-floored area that was evidently glaciated; below this the valley is deeply cut.

The small glaciers in these valleys lay round the western and northern side of the highest ridge of Simbara. The eastern side of this ridge drains into the Honi, around the head of which the highest summits are grouped. Yet no evidence of glaciation was seen at the head of the Honi streams, which run, on the contrary, in deep V-shaped valleys. Further down the narrow headstream valleys join and the valley becomes more open. There, for about a mile along the right bank of the Honi (Plate II, fig. 2, opp. p. 9) there is a deposit of large and small blocks of the rocks from the ridges above, in an earth matrix. The deposit ends in a steep slope along the right bank of the Honi. There is no corresponding slope on the other side of the stream. The slope must be an original feature and not the result of a stream erosion.

Away from the stream, the surface of the deposit slopes smoothly up and merges above into the stony earth which covers the hillside as far as the rock outcrops near the ridge. This cover, which is seen on most of the less steep hillsides of Simbara, is intricately and closely furrowed by a reticular pattern of alleys, some of them several feet deep, running transversely to the slope of the ground. The whole of this furrowed cover is believed to move by solifluxion, the embankment-like lower edge marking the limit of its flow. The downstream limit of this deposit is indefinite. Three successive smooth terraces which were at first interpreted as drift, were found to be lava scarps partly buried by detritus and soil.

Still further down, below these terraces, the stream, flowing east, plunges suddenly into a mass of loose rocks and earth, through which it has cut a narrow channel, about twenty feet deep. The deposit here is similar to the one upstream. It lies across the middle of the valley, merges imperceptibly into the slopes on either side, and no noticeable feature marks its lower limit, which is at an elevation of approximately 10,700 feet. A similar deposit was seen in the Chania valley at about the same elevation.

These deposits, and the glaciation of Simbara, deserve more study than was possible during hurried traverses. It is plausible to correlate the glaciation down to about 12,000 feet with the glaciation down to about the same level on Mount Kenya. This has been regarded (Nilsson, 1940, p. 70) as marking the maximum of the Gamblian Pluvial Period. It might be suggested that the deposits here attributed to solifluxion are denuded moraines of an earlier and greater glaciation, but the form of the deposits and of the valleys above them would then be difficult to understand.

(7) *Gusiru*

Quite distinct from Simbara is the plateau to the south, known to the Kikuyu as Gusiru, the moorland. A long but inconspicuous spur from Simbara extends along its western side; it drains eastwards. Its eastern edge, coincident with the upper limit of the bamboo forest, is sharply defined, the ground falling away there in a steep and sudden slope.

Some of the rocks of Gusiru are basalts, non-porphyritic dark blue-black rocks with columnar jointing. Others are fissile rocks, paler weathered, bluish-grey within and glistening on broken surfaces with minute felspar plates. These fissile rocks are provisionally identified as mugearites and fayalite alkali-trachytes. Some of them seem to be identical with some of the lavas of the Sattima Series both to the eye and microscopically, nor could any distinction be drawn in the field. It is quite clear in the stream sections on Gusiru, such as those along the Gura and Chania rivers, that the columnar basalts and the fissile lavas alternate and were being erupted at the same time. The northern part of Gusiru seemed, so far as could be seen from the few exposures noticed on two traverses, to consist entirely of the fissile lavas.

The flatness of the plateau is in striking contrast to the steep slope down through the forest. The gentle slope is little greater than the gentle eastward dip of the sheets of lava which build the plateau. Several low sinuously embayed lava scarps, facing east, mark the edges of successive sheets. Near the eastern margin, there are several isolated hills which are obviously old vents. The Nyeri–Naivasha track traverses the flank of one of these a mile east of the Gura bridge. Purplish basaltic tuffs, agglomerates, and rubbly lavas confirm the proximity to a vent. The arrangement of these vents near its edge may have protected the plateau from erosion while increasing the steepness of the slope to the east. The eastward dip of the lavas in the forest is probably steeper than it is on the plateau and this would favour faster and deeper erosion. Possibly too, the plateau was protected by the relatively hard sheets of the fissile lavas. There is nothing to suggest faulting at its edge.

The several ponds, meres and marshes on Gusiru are said to be shallow. They may be due to the unequal accumulation of silt trapped by rushes and other vegetation. Those seen were in flat peaty areas, on the broad shelves formed by the gently dipping lava sheets.

(8) *The Aberdare Dip-slope*

Between Gusiru, Simbara and the ramp to the west, and Laikipia to the north-east, is the Aberdare dip-slope. This, although deeply furrowed by valleys, slopes evenly with an average gradient of about 1 in 15. Most of it is covered by the Aberdare forests, through which few traverses were made. Photographs of some waterfalls on the Chania show columnar lavas, presumably basalts, and the pebbles in the streams are mostly of basalt and fissile lava. Below the forest boundary the deep valleys of the Gura and Chania expose both columnar and fissile lavas, dipping at about the same angle as the general slope of the surrounding country. It appears that the dip-slope is largely formed of lavas of the Laikipian Series, but whether some of the fissile lavas should be included in the Sattima Series is uncertain.

At the eastern foot of the dip-slope, around Nyeri, other rocks emerge in the valleys, from beneath the Laikipian basalts, as shown on the map. The oldest lavas and agglomerates of the Simbara Series, are well exposed in the cuttings along the Nyeri–Nairobi road on both sides of the Amboni valley. Agglomerates alternate with lavas. Other good exposures of the Simbara Series can be seen on the steep slopes above the confluence of the Chania and Amboni. Flows of melanocratic basalt with augite and olivine phenocrysts occur here among agglomerates in which most of the blocks are of Kijabe type basalt.

The Simbara Series is overlain in this part of the area by the Nyeri tuff, a bed of columnar trachytic tuff usually about 30 feet thick. This tuff is used as a building stone and is well-exposed in numerous quarries and natural exposures. By the Chania east of Nyeri, feebly stratified tuffs were seen below the massive building stone. The contact of the Nyeri tuff with the underlying Simbara Series was nowhere seen.

The surface of the Aberdare dip-slope is in general deeply weathered to a rich red soil, and rock exposures are seldom seen except in the valleys with running streams.

(9) *Southern Laikipia*

The southern part of the extensive grass-covered plateau of Laikipia is included in the area dealt with in this report. Its limit is taken to be where the black soil of the plains gives way to the red soil of the Aberdare dip-slope. This corresponds to the former boundary between grassland and forest. The areas covered by black soil are distinguished by stippling on the map. The change in soil depends chiefly on drainage and slope, and is very little influenced by the nature of the underlying rock.

Much of southern Laikipia is formed of basaltic lavas of Gregory's Laikipian Series. These are well exposed in the Ngobit valley near the Nyeri-Rumuruti road, and in many other places.

Small hills rising above the plains are the stumps of the many small volcanoes from which the surrounding Laikipian basalts were erupted. Reddish basaltic tuffs are commonly found on and near the vents. Some of these tuffs have been used for building stone and in one of the trial holes on a farm north of the Moyo River some fossil bones were discovered by the owner, Colonel Elliot. The tuff in which they were found lies on a gently sloping ridge. Other exposures on the side of the same ridge show similar but less weathered tuffs, reddish in colour and typical of the lapilli tuffs discharged from many of the Laikipian vents. These tuffs overlie Laikipian basalts. The bones are unrolled and apparently articulated in their original position. It is supposed that they are the remains of animals buried in a sudden shower of "ash" and lapilli; if so, further finds are not very probable. The fossils have not been finally identified, but Dr. L. S. B. Leakey, to whom they were sent, informs me that the fauna includes a baboon not so far identified with any known species, but having affinities with a Lower Pleistocene form from South Africa. He is of the opinion that the fauna is not younger than Middle Pleistocene and is more probably Lower Pleistocene in age.

In the pit where the fossils were found, the basaltic tuff containing them is overlain by a layer, less than a foot thick, of pale brownish ash with biotite flakes. This is thought to represent the Naromoru Ash. The eastern part of southern Laikipia is underlain by the rocks of the Mount Kenya Volcanic Suite, but over most of this part of the area, black soil conceals the underlying rocks, which are seldom exposed except along the sides of the principal valleys.

In many parts of Laikipia the black soil of the plains is underlain by the Naromoru ash.

VI—PETROGRAPHY

A preliminary examination of about two hundred thin sections made from the rocks collected shows that similar types occur in various parts of the sequence, although some are locally restricted to a particular horizon or series. It appears from this first study of the slides that a continuous series can be traced from olivine basalts to phonolites and trachytes, and that any member of this series is liable to occur almost anywhere in the sequence. To avoid repetition, a sketch of the petrography of the chief types is given below without regard to their order or place of eruption. It should be realized that the classification is tentative since no analyses are available for most of the types, and hurried microscopic identification, especially of the potash-bearing plagioclase felspars and the occult felspathoids, is uncertain.

The principal rock types distinguished are:—

Olivine basalt	B_3	2·84	(56)
Olivine alkali-basalt			
Analcite basanite			
Olivine trachybasalt			
Mugearitic basalt	^{f}B	2·80	(9)
Mugearite		2·75	(9)
Olivine alkali-trachyte	^{f}Tr	2·70	(12)
Alkali-trachyte		2·74	(4)
Quartz trachyte	Tr	2·65	
Phonolite, non-prophyritic, fissile	^{f}Ph and ^{k}Ph	2·67	(11)
Phonolite	Ph_2	2·60	(4)
Kenyte	K	2·54	(2)
Basalt, Kijabe type	B_1	2·83	(8)
Basalt with olivine and augite phenocrysts	B_p	3·08	(3)

The symbols are those used on the map. Figures on the right are mean specific gravities, the figures in brackets showing the number of specimens measured.

Other types of extrusive rocks noticed are picritic basalt and nepheline basanite (?); trachytic and basaltic tuffs occur; a few other rocks are found as ejected blocks in some of the tuffs.

Olivine Basalt

These rocks are generally non-porphyritic, and have basaltic texture. They are seldom vesicular. They consist essentially of olivine, augite, labradorite, and opaque ores. There is no obvious alkali tendency. Residual potash-felspar, analcite, and reaction-biotite are absent or insignificant. The pyroxene is augite, usually only faintly purplish, and non-pleochroic. Olivine is colourless in section, and optically positive. Apatite was very rarely noticed. Secondary minerals such as göthite, iddingsite (?) and serpentine, derived from olivine, are not uncommon.

Rocks of this type mostly with columnar jointing, were found south of Nyeri, on the Aberdares, near the Ngobit River, on Il Pejeta, north of Nyeri Station, west of Ndaragwa, by the Zuka Zuka River, and at many other places.

Olivine Alkali-basalt

The basaltic rocks classified under this head are those which contain sufficient biotite to indicate a definite alkali tendency, but which are without appreciable amounts of potash-felspar or analcite. The biotite is the variety usual in such rocks, pleochroic from pale golden brown to foxy brown. It forms ragged poecilitic plates, or small flecks. It has seldom grown on ore grains and seems to have crystallized directly from a potassic residuum rather than as a result of reaction between such a fluid and previously crystallized ores. Apart from the presence of biotite, these rocks are similar to the olivine basalts. Some contain small phenocrysts of olivine. No feature was noticed by which they could be recognized in the field.

Rocks of this type were collected from the Gura Falls, a little way north of the Nyeri–Naivasha track; from the west side of Simbara where they overlie the quartz-trachyte sheet; from the Sattima scarp, above Kijabe type basalts and from the upper Pesi, Suguroi, and Segara river valleys in each of which they overlie trachytic tuffs. One specimen (43/157) from a 6 ft. dyke in Simbara is of this type.

Analcite Basanite

In 19 of the slides of basaltic rocks, a colourless isotropic mineral with a low refractive index, was determined as analcite. It is interstitial and residual but apparently primary. The rocks are otherwise normal basalts with faintly purplish augite, colourless olivine in many cases partly or wholly altered to an iddingsite-like mineral, specks and minute crystals of ore (often identified by its form as magnetite), and plagioclase laths.

The plagioclase is generally labradorite, though occasionally it appears to be less basic. The texture is usually basaltic. In one thin section the pyroxene is sub-ophitic, and in another, the plates of labradorite are fluxionally arranged. Many of the rocks have phenocrysts or microphenocrysts of olivine.

About half of the specimens were of columnar basalts, all but one of which belong to the Laikipian Series. The exception (43/224), collected near the Uaso Nyiro close to the Aberdare forest boundary, is a basalt with phenocrysts of olivine and augite. It probably belongs to the upper division of the Simbara Series. Another rock with olivine and augite phenocrysts, also from the Simbara Series, has interstitial zeolitic material which may represent decomposed analcite.

Olivine Trachybasalt

Five rocks to which this name was doubtfully given have basic plagioclase as the chief felspar, but with it, a little alkali felspar which seems to be orthoclase. In other respects the five rocks differ; they are not a natural group. One (43/249) has trachytically arranged felspar plates, the larger of which (about 0.5 mm. in length) are labradorite, Ab_{45} An_{55}, and the smaller, oligoclase-andesine and orthoclase. There are granules of faintly yellowish ferriferous olivine, and pale greenish augite. Another rock (43/170) consists of fluxionally arranged labradorite laths, clear olivine grains, pale greenish pyroxene, serpentine, and alkali felspar. Specimen 43/269 is a fissile lava with labradorite, faintly purplish augite in poecilitic patches, and magnetite; some orthoclase forms fringes on the plagioclase and some is interstitial. These three rocks are fissile. A non-fissile basalt (43/289) which may belong here consists of labradorite (Ab_{45} An_{55}), olivine altering to iddingsite, greyish interstitial pyroxene, ore and scanty untwinned alkali felspar presumed to be orthoclase.

Mugearitic Basalt

These are fissile lavas which, like the mugearites and alkali trachytes, consist of trachytically arranged felspar plates, with ferriferous olivine grains, and subordinate greenish pyroxene, but with andesine instead of oligoclase or anorthoclase. The olivine, when fresh, is yellowish in section. In some of the rocks it is replaced by iddingsite (?).

In several of the sections, scraps of biotite were noticed and in a few small apatite prisms with minute inclusions. There are the usual ore specks.

Mugearite

About a dozen of the specimens are classified as mugearites. They are bluish-grey fissile non-porphyritic rocks, in which minute glistening felspars are visible. In slides the trachytically arranged felspars are seen to be mostly oligoclase but probably there is usually also some anorthoclase. The felspars have refractive indices below that of canada balsam, even those whose extinction angles would be taken to indicate andesine. Probably they all contain a notable proportion of potash. Zoning and lamellar twinning are generally faint but distinct.

Olivine is plentiful, occurring in minute granules, which are identified by their yellowish colour and optically negative character as fayalite. Pyroxene, subordinate to olivine, is greenish diopside or aegirine-augite. Small prisms of apatite, dusted with inclusions, were seen in several slides. Ore specks are scattered much less thickly than in the basalts. Late primary biotite is rare. Secondary iddingsite and serpentine are common.

Olivine Alkali-Trachyte

In texture and general appearance both to the eye and microscopically, these rocks are very much like the mugearites, but their felspar is mostly anorthoclase. Olivine, as in the mugearites, is a yellowish, optically negative fayalite. Pyroxene, of which there is normally less than olivine, is often an aegirine-augite with distinct pleochroism. It sometimes forms small pleochroic patches. Apatite with minute inclusions was noticed not infrequently and kataphorite is an occasional minor constituent. Magnetite, as minute specks and crystals, is thinly scattered in all the rocks.

The principal rock types distinguished are:—

Olivine basalt	B3	2·84	(56)
Olivine alkali-basalt			
Analcite basanite			
Olivine trachybasalt			
Mugearitic basalt	fB	2·80	(9)
Mugearite		2·75	(9)
Olivine alkali-trachyte	fTr	2·70	(12)
Alkali-trachyte		2·74	(4)
Quartz trachyte	Tr	2·65	
Phonolite, non-prophyritic, fissile ..	fPh and kPh	2·67	(11)
Phonolite	Ph2	2·60	(4)
Kenyte	K	2·54	(2)
Basalt, Kijabe type	B1	2·83	(8)
Basalt with olivine and augite phenocrysts	Bp	3·08	(3)

The symbols are those used on the map. Figures on the right are mean specific gravities, the figures in brackets showing the number of specimens measured.

Other types of extrusive rocks noticed are picritic basalt and nepheline basanite (?); trachytic and basaltic tuffs occur; a few other rocks are found as ejected blocks in some of the tuffs.

Olivine Basalt

These rocks are generally non-porphyritic, and have basaltic texture. They are seldom vesicular. They consist essentially of olivine, augite, labradorite, and opaque ores. There is no obvious alkali tendency. Residual potash-felspar, analcite, and reaction-biotite are absent or insignificant. The pyroxene is augite, usually only faintly purplish, and non-pleochroic. Olivine is colourless in section, and optically positive. Apatite was very rarely noticed. Secondary minerals such as göthite, iddingsite (?) and serpentine, derived from olivine, are not uncommon.

Rocks of this type mostly with columnar jointing, were found south of Nyeri, on the Aberdares, near the Ngobit River, on Il Pejeta, north of Nyeri Station, west of Ndaragwa, by the Zuka Zuka River, and at many other places.

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Rocks of this type were collected from the Gura Falls, a little way north of the Nyeri–Naivasha track; from the west side of Simbara where they overlie the quartz-trachyte sheet; from the Sattima scarp, above Kijabe type basalts and from the upper Pesi, Suguroi, and Segara river valleys in each of which they overlie trachytic tuffs. One specimen (43/157) from a 6 ft. dyke in Simbara is of this type.

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In 19 of the slides of basaltic rocks, a colourless isotropic mineral with a low refractive index, was determined as analcite. It is interstitial and residual but apparently primary. The rocks are otherwise normal basalts with faintly purplish augite, colourless olivine in many cases partly or wholly altered to an iddingsite-like mineral, specks and minute crystals of ore (often identified by its form as magnetite), and plagioclase laths.

Alkali-Trachyte

A few slides are of trachytic rocks, consisting chiefly of anorthoclase plates and sodic pyroxene, with, so far as could be seen, neither olivine, felspathoid nor quartz. Re-examination has shown that some rocks had been misplaced here, as they contain olivine or felspathoid or both of these minerals. Closer scrutiny or microchemical tests might show their presence in other rocks still retained in the group.

A rock from Sattima summit (43/179) has phenocrysts of a felspar that is thought to be potash-oligoclase and a few smaller phenocrysts of greenish pyroxene. The matrix, which varies in coarseness, consists of laths of anorthoclase and interstitial yellowish-green material.

Another rock (43/208) from the north summit of Songari Hill, is a fine-grained grey fissile lava. The slide shows thin flow-aligned plates of anorthoclase, small grains and microphenocrysts of ore (magnetite?), apatite crystals full of black dust, and yellowish ferruginous alteration products which have perhaps formed from interstitial sodic pyroxene.

Phonolite (fissile, non-porphyritic type)

Phonolites closely related to the olivine-alkali trachytes occur in the Sattima Series. They are fissile greenish-grey rocks, pale and slabby in outcrops. In slides, the minerals usually seen are anorthoclase, aegirine-augite, fayalite, magnetite and nepheline or analcite or both. Anorthoclase occurs in trachytically arranged plates, which in some rocks range in seriate gradation from 1 mm. in diameter down to very small ones. In others, they are thin and minute, and form a feathery mesh. Aegirine-augite forms prismatic tufts or irregular interstitial specks. In some specimens there is perhaps a little aegirine. The fayalite has a distinct yellowish-brown colour. It forms either subhedral minute grains, or poecilitic patches enclosing anorthoclase. Magnetite specks are evenly scattered in all the slides.

The felspathoids are generally inconspicuous. Euhedral crystals of nepheline, about 0.2 mm. in diameter, and outlined by aegirine-augite growths, are evident in 43/192 and interstitial clear analcite is plentiful in 43/151. In several of the other rocks close search is needed to see either of these minerals.

Ore-saturated green "ghosts" in two slides are relics of resorbed phenocrysts. Anorthoclase phenocrysts were seen in one rock (43/182) which was regarded as a phonolite only on account of its similarity to another (43/183) in which analcite was doubtfully identified. Cossyrite and kataphorite (?) were noticed in 43/192. One of the fissile phonolites (43/166) is a dyke rock from Simbara. It contains small euhedral nephelines surrounded by mossy aegirine, with cossyrite, pale kataphorite, and slender felted alkali-felspar plates.

Other fissile non-porphyritic phonolites, petrographically like those of the Sattima Series, occur in the Mount Kenya Volcanic Suite. They are greener in colour than the Sattima rocks. A flow of this kind is exposed along the side of a ravine about a mile west of the railway, and five miles north of Nyeri station. Large blocks of similar lava are common in the agglomerates, where they seem to be indiscriminately mixed with blocks of kenyte. Microscope study shows that the fissile phonolites of the Mount Kenya Suite vary in texture and mineral composition. The lava mentioned above has microphenocrysts of anorthoclase in a dark base of mossy aegirine and cossyrite, clearer areas of alkali felspar, minute nephelines, and analcite. A block (43/207) from an agglomerate has ragged patches and subhedral granules of fayalite as well as the usual aegirine, cossyrite, anorthoclase, and nepheline. Another block (43/210) contains trachytic anorthoclase, flecks of arfvedsonite, some kataphorite and probably fayalite, aegirine, aegirine-augite and cossyrite. Some vaguely defined shapes seem to represent altered nephelines.

One fissile lava belonging to the Mount Kenya Suite is similar in appearance to the phonolites but seems to be a fayalite alkali-trachyte or possibly a mugearite. It outcrops on the north slope of the Naromoru valley about two and a half miles east of the Uaso Nyiro. It contains phenocrysts probably potash-oligoclase and microphenocrysts of fayalite in a trachytic base with interstitial aegirine.

Phonolite (Kenya type)

The phonolites of the Thomson's Falls Series are petrographically uniform and agree with Campbell Smith's description of the Kenya type of phonolite (Smith, 1931, pp. 229–236). They are fissile dark grey lavas, almost always with small phenocrysts of anorthoclase.

Thin sections show anorthoclase phenocrysts with marginal inclusions in a base of anorthoclase, aegirine and aegirine-augite, cossyrite, usually a little kataphorite, a little bluish arfvedsonite-like amphibole, and specks of magnetite.

Nepheline, usually cloudily altered, is conspicuous, as small euhedra about 0.1 mm. in diameter. Olivine is seen in some slides, but is never plentiful.

"Kenyte"

Gregory (1900, page 209), gave the name kenyte to the rocks which surround the nepheline syenite in the plug of Mount Kenya. Unfortunately, as Campbell Smith (1935, pp. 242–250) found when he re-examined the type rocks, Gregory did not notice the nepheline crystals in his kenytes, and so his definition of them does not apply to the rocks for which it was intended. Further confusion has arisen because Gregory also mistook some rocks near Songari Hill for the Kapitian phonolite and Campbell Smith described one of them as an example of the Kapiti type of phonolite. As he found it to be essentially identical with Gregory's kenyte, he doubted whether there was any significant difference between the kenytes and the Kapiti type of phonolite. Actually, this supposed Kapiti phonolite is a kenyte of the Mount Kenya Suite and has no connexion with the Kapiti phonolites which are stratigraphically and petrographically distinct from the kenytes.

The term kenyte is here used for rocks corresponding to Smith's re-description of Gregory's types. The similarity between these and the kenytes of the present area is so close that further re-description is superfluous.

The kenytes are distinguished in the field by their very abundant large anorthoclase crystals, usually of the rhombic habit, and fewer greenish nephelines, in a dark grey non-fissile base. Weathering to very large rough masses, round rather than angular, is highly characteristic (and entirely different from the slabby outcrops of the fissile Kapiti phonolite, or any other of the plateau phonolites). There are often small irregularly shaped vesicles lined with zeolites.

Olivine Basalt, Kijabe type

The characteristic basalts of the Simbara Series are similar to the Kijabe basalts described by Shand (1937, pp. 265–267). His lucid description of the Kijabe rock applies equally well to most of the rocks of Simbara, except that in the very much greater mass of lavas exposed there, there is naturally a greater range of variation, which is, however, only in non-essential particulars. As the type is now known to have a wide distribution in Kenya, it is convenient to have a local name for it, and the name Kijabe type is proposed. The type rock is the one from Kijabe Hill described and analysed by Shand. The type should include similar olivine basalts characterized by abundant plagioclase phenocrysts—the limiting proportion cannot be decided without quantitative analysis of the rocks to be included—and an alkali residuum of either zeolite, analcite or orthoclase.

The plagioclase phenocrysts in most of the slides examined, are labradorite, though in two they are bytownite. There are usually some smaller phenocrysts of olivine, and sometimes augite also.

The groundmass consists of granular purplish augite, small laths of labradorite, olivine granules, and ore, together with prisms of apatite, and various interstitial minerals. The ore is in rough plates and skeletal crystals, or parallel rods with knobby growths and pagoda-like forms. These forms suggest ilmenite. Interstitial zeolite, analcite, orthoclase and dirty serpentinous material were seen. No nepheline was identified in any slide; a little biotite was seen in a few.

A number of the specimens sliced were from dykes. Both microscopically and megascopically they are essentially the same as the lavas. The thickest dyke seen, about 30 feet, is more coarsely crystallized than the other rocks.

The Kijabe type basalts are generally more vesicular than other basic lavas of the area, although some thick flows are non-vesicular. No correlation was found between the proportion of plagioclase phenocrysts and the vesicularity (cf. Shand, *ibid.*, pp. 269 and 270). In two dykes the phenocrysts were seen to be much smaller at the chilled margins than in the middle. These phenocrysts must have crystallized in the rocks where they now are: they were not concentrated there by gas-flotation. Moreover, they lie parallel to the walls of the dykes, without any bubbles underneath them. If the concentration of plagioclase crystals is attributed to gas flotation, then it must be supposed that in this case the crystals first collected were dissolved in the magma, and that others later crystallized from it.

It is, moreover, clear that in this area the crystals were not concentrated in the lavas after eruption. As the pressure would inhibit the separation of a gas phase in depth, the gas flotation mechanism suggested by Shand could only happen in a body of magma relatively near the surface. Such conditions are hardly likely to have been fulfilled persistently enough to produce the enormous volume of these lavas seen in the northern and southern Aberdares, and further north. As a general explanation of the abundance of plagioclase phenocrysts in the Kijabe type basalts, the gas flotation theory is perhaps inadequate. That it must have happened in some places is, however, shown by a specimen from Kijabe. In this, crowds of small bubbles are collected under each of the thin plagioclase plates, which must obviously have been buoyed up.

Basalt with olivine and augite phenocrysts

Heavy melanocratic basalts, studded with many olivine and augite crystals are a distinct type, easily recognized in the field. Of the eight such collected and sliced, five were classified as melanocratic basalts, two as picritic basalts, and one as picrite.

The *melanocratic basalts* have phenocrysts of augite and olivine in a base of pyroxene, basic plagioclase, olivine and ore, with either flecks of biotite, or interstitial analcite, or zeolite. The large augite crystals are very pale or colourless in section; the augite granules and prisms in the base are usually purplish. Olivine is mostly fresh, but sometimes altered peripherally or wholly to an iddingsite-like mineral. The ore has the octahedral form of magnetite. Felspar, often subordinate, is a basic plagioclase determined in several of the rocks as labradorite.

The pyroxene phenocrysts in one slide (43/217) enclose small irregular patches of plagioclase, ore and biotite, resembling the same minerals in the groundmass. It is unlikely that the magma from which these inclusions crystallized, was enclosed in the crystals at depth, and it is, therefore, supposed that phenocrysts crystallized from the magma during its eruption.

The two *picritic basalts* (43/238 and 43/293) are closely allied to the rocks described above, but plagioclase is scarcer. The large augite crystals in slide 43/293 are weakly pleochroic from very pale dirty green to a faintly purplish green. They are zoned, and contain inclusions of felspar, serpentine and ore similar to the groundmass minerals. In the other rock (43/238), instead of augite phenocrysts, there are large ragged poecilitic crystals of an amphibole of the kataphorite series, with pleochroism.

X—very pale brown.

Y—purplish.

Z—raw-sienna brown.

There is possibly some interstitial analcite.

The picrite (43/240) has many large and small euhedral phenocrysts of olivine and augite in a dense black base. The olivine is colourless in section, and the pyroxene faintly green with a narrow feebly pleochroic titaniferous rim. The base consists of closely packed granules and prisms of purplish augite, grains of ore, altered granules of olivine and a small proportion of basic plagioclase. Small irregular clear pools are apparently of zeolite.

No distinction was made in the field between the above three types. All are included on the map under the symbol B_p. The picrite was collected from the bed of the Nairutia River west of Tanyai Hill: one of the picritic basalts (43/238) is from a hill south of Il Pejeta and the other from the Sattima scarp east of Kipipiri. Rocks of these three types occur at various horizons from the Simbara Series upwards. Some of the lavas erupted from the Laikipian vents were of this type.

Other Rocks

A few rocks collected fall within none of the above groups. Those of interest are—

Tephrite? (43/168) specific gravity 2.87.

Nepheline basanite (43/237) specific gravity 2.97.

Tinguaite? (43/227, 43/295) specific gravity of 43/227, 2.75.

Nepheline Syenite (43/214).

Tephrite? (43/168).—The slide shows microphenocrysts of ore (magnetite?), and greenish-purple titaniferous augite. The dark base has a slaggy appearance owing to the segregation in streaks and lenticles of colourless minerals, apparently both felspar and nepheline. The dark part of the base consists of yellowish-green pyroxene, ore, and an undetermined brown pleochroic mineral. There are some apatite prisms full of black dust.

Nepheline Basanite (43/237).—This was collected on a spur of Il Pejeta. The slides show a few small and corroded microphenocrysts of greenish-brown barkevikitic amphibole, and many small crystals of olivine, ore, and pyroxene in a dense blackish base. The olivine has been replaced by a brown iddingsite-like mineral. The pyroxenes are pale dirty greenish within, and purplish at the edges. There is a little biotite.

Felsic constituents are scanty. They are in small clear pockets, sharply defined from the rest of the rock. Both plagioclase and nepheline were doubtfully identified.

The above two rocks are interesting as the only basaltic lavas in the area in which nepheline was found.

Tinguaite? (43/227, 43/295).—The first of these rocks was collected near the south bank of the Ngobit River, east-south-east of Il Pejeta. It was taken for a basaltic lava. In the slide, there are microphenocrysts of a sodic titanaugite with peculiar pleochroism in purplish and brownish greens, and a high extinction angle. There are also some small microphenocrysts of ore. The base consists of matted prisms of dirty green pyroxene, small plates and larger poecilitic patches of anorthoclase (?), grains of ore, and decomposed nepheline crystals. A few apatite prisms full of inclusions, and a little zeolite, were also seen. The texture is coarser than the lavas of the district and it is quite likely the rock is intrusive. It differs from the ordinary Laikipian basalts, though it has affinities with the previously described rock (43/237) from the same area.

The other rock, 43/295, is part of a boulder from a stream at the foot of the Sattima scarp east of Kipipiri. There were many more boulders of the same type there. It is a striking rock, with black crystals of hornblende and pyroxene, and crystals of nepheline, in a grey base. The slide shows that the amphibole is barkevikite, in crystals prominently edged with black dust. The augite of the phenocrysts is a pleochroic titaniferous and slightly sodic variety. There are also some sharply euhedral microphenocrysts of grey sphene. The nepheline crystals in the slide are microphenocrysts, but others in the rocks can be seen by eye. The groundmass is fine-grained, and consists of simply twinned "orthoclase", pale greenish augite, and ore specks. Apatite is accessory.

This rock is unlike any of the lavas of the district and is probably intrusive, although its base is fine-grained.

Nepheline Syenite (43/214).—A piece of nepheline syenite of the Mount Kenya type was collected from the kenyte agglomerate near the Amboni River. The slide shows anorthoclase, nepheline, kataphorite, diopside, aegirine, cossyrite, apatite and ore. Nepheline and anorthoclase are the major constituents and both crystallized early.

VII—STRUCTURE

(1) *The Sattima fault and related displacements*

The Sattima fault is the most important structural feature of the area. It is one of the main eastern boundary faults of the Kenya Rift Valley. Near Thomson's Falls, north-west of the limit of the map, it forms an inconspicuous wooded scarp with a north-west to south-east trend. Traced southwards, the fault scarp curves slightly and continues, in a south-south-easterly direction, as a long, straight and steep scarp, increasing gradually in height, until opposite Kipipiri its face is over 2,000 feet in height. (*See* Pl. I (*a*).) Still further south it declines and seems to disappear as a topographic feature, short of the North Kinangop Forest Station. Some features suggest that it may continue, across the western side of the peak of Niandarawa, and along the western side of the southern spur of the Aberdare range, almost as far as the Chania River. (*See* Fig. 1.) This possible southern extension of the fault has not, however, been proved. The known length of the fault from Thomson's Falls, to a little north of the Kinangop Forest Station, is about 45 miles.

The increase in height of the fault face southwards from Thomson's Falls is due to the increasing displacement towards the south. At Thomson's Falls, the ground on both sides of the fault is underlain by phonolites of the Thomson's Falls Series. Southwards, on the downthrown side these phonolites soon pitch below the surface and are overlain by trachytic tuffs of the Kinangop Series, which underlie the plain below the scarp probably as far as the Wainjohi valley. While the rocks on the downthrown side pitch gently towards the south, those on the upthrown pitch in the opposite direction. Consequently the Thomson's Falls Phonolite Series is seen gradually rising southwards up the face of the scarp. About 15 miles south of Thomson's Falls, the underlying basalts appear at the foot of the scarp and four miles further, the phonolites wedge out near the top of the scarp, about a thousand feet above the surface of the plains below. Beyond this, the lines of the basaltic lava flows can be followed by eye, still rising gradually southwards. The culmination of pitch on the upthrown block seems to be about opposite Kipipiri, but the dips and structure south of this are obscured by forest. The greatest displacement on the Sattima fault may exceed 3,000 feet.

Only the middle section of the Sattima fault is included in the map (though more was examined). In the section included, for about seven miles, there are two parallel faults, about half a mile apart. The eastern is the main fault. It has produced a sharply defined rock face, cleanly cut through the series of basalt flows. Against this rocky fault face lies the intermediate strip, in which the outcropping rocks are another series of basalts, correlated with those at the top of the main scarp. These basalts weather much more smoothly than those on the adjacent fault face. (*See* Pl. I (*b*).) To some extent the smoother surface of the fault strip is due to a cover of talus fallen from above, and actual rock outcrops were not seen on the fault strip very close to the main fault. None the less, the difference in the form of the ground on the two sides of the line is so distinct, and so regular, that a line can be drawn which, it is believed, accurately marks the position of the fault.

The fault scarp is furrowed by deep valleys. The line of outcrop of the fault plunges up and down across these valleys. Just above it, for several miles, runs a surveyed and cut line marking the forest reserve boundary. This line, straight in plan, runs across the valleys in the same way as the outcrop of a vertical plane of the same strike. The outcrop of the fault, just above this line, swings alternately towards it and away, as it plunges into the deep valleys and climbs the intervening ridges. Therefore, the fault must be a surface dipping westwards, and since the downthrow is to the west, a normal fault. The inclination was judged, at a point north of the Melawa Ndogo, to be slightly over 80°. Further south it appears to be less.

Along the seven-mile stretch where there are two fault scarps the upper one is straight and continuous. The western one is also straight, but weaker and less continuously exposed than the one above. It is impossible to regard either fault as due to a landslide or to secondary superficial faulting developed on an earlier fault scarp. At the base of the lower fault is a flat plain, continuous from near Thomson's Falls to the Kinangop. Nothing that could be attributed to local landsliding breaks its surface. The intermediate fault strip shows basalts which are correlated with others

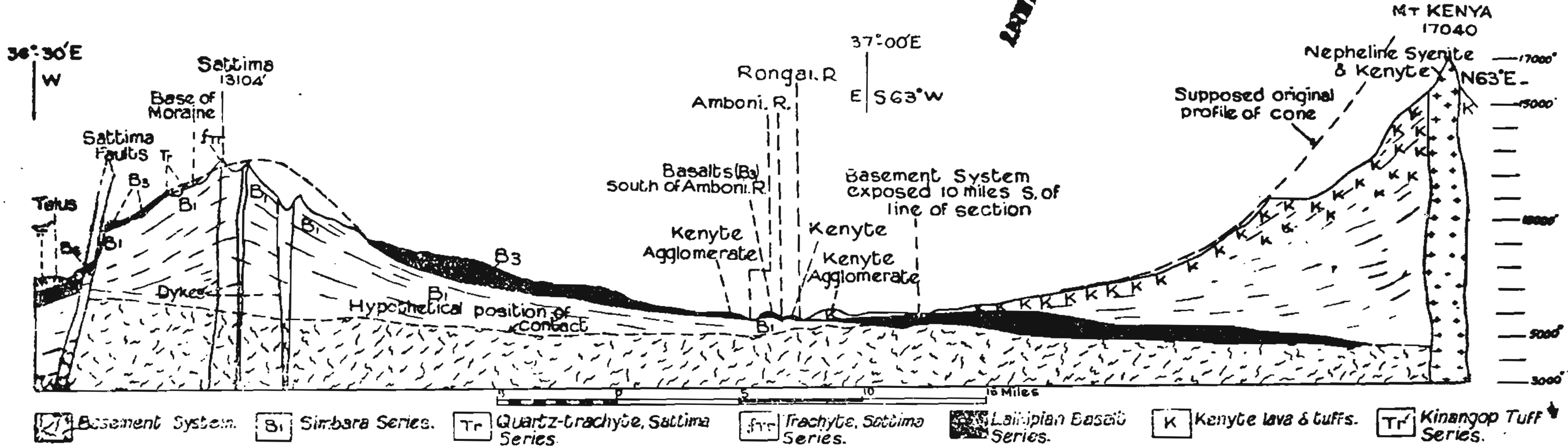

FIG. 2

Geological Section from Sattima to Mount Kenya

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at the top of the main scarp. It is clear that the base of this intermediate slice, were it a landslide, could not be less than a thousand feet or so *below* the level of the adjacent plain. It could only have reached such a position before the rocks forming the plain were in existence. But further north, above the main fault, the rocks capping the scarp are the same series of trachytic tuffs which underlie the Kinangop platform. They outcrop along the top of the fault face, and again at its foot. No lithological change is noticed as they are traced westwards across the plateau towards the scarp edge, nor could any difference be seen between the tuffs at the top and those at the foot of the scarp. Those at the base are free from admixed talus. It cannot be doubted, therefore, that, like the rest of the rocks exposed on the fault face, these tuffs were actually displaced by the fault. Their situation cannot be explained by supposing that they were erupted on to a pre-existing fault scarp. These trachytic tuffs were, however, almost the last beds to be deposited before the Kinangop faulting. It is clear, therefore, that the common belief that the Sattima fault belongs to an earlier phase than the Kinangop faults is untenable. Nor does the form of the Sattima scarp suggest any greater age; it is still very steep, clean and straight. The western margin of the Aberdare range, further south beyond the limit of the map, is indeed an irregular line, but this is in my opinion due, not to prolonged erosion of an earlier fault scarp, but to the absence there of any faulting whatever. Along the margin of the southern Aberdares the trachytic tuffs can be proved, at various exposures from Tulaga in the north to the Chania in the south, to rest directly and unconformably on the Aberdare basalts. Whether the regular westwards slope of the basalt ridges there corresponds to the original dip of the lava flows, or whether it indicates the presence of a monoclinal flexure, is uncertain.

The dislocation and movement of which the Sattima fault is the most obvious effect in the area, also resulted in tilting and warping of the crustal blocks on either side of the fault. The western block was tilted south-eastwards. Its southward pitch is shown by the disappearance of the Thomson's Falls Phonolites beneath the Kinangop tuffs south of Thomson's Falls, and its easterly tilt by the presence of the Ol Bolossat and other marshes at the foot of the scarp.

The vertical movements in the block east of the Sattima fault—that is in most of the area—must have been differential. Superimposed on the general eastwards slope towards the Indian Ocean, which affects all the country east of the Rift Valley, there are local tilts correlated with the movements at the Sattima fault. They can be regarded as due to differential upward displacements of the Aberdare–Nyeri block. The amount of this displacement increases westwards to a maximum against the fault, while at the same time it increased along the fault from zero north of Thomson's Falls to a maximum, opposite Kipipiri or thereabouts, of about 3,000 feet.

The tilt of the crustal block east of the Sattima fault is difficult to evaluate. If the correlation of the Nyeri tuff with the Kinangop tuffs is correct, and if the surface of these tuffs was originally nearly level from the Ol Bolossat area and the Aberdare ramp to Nyeri, it can be used as a datum. Its present elevation north-east of Sattima is nearly 10,000 feet and at Nyeri about 5,700 feet, giving a difference of over 4,000 feet between points about 30 miles apart. This would imply a tilt of about 1 in 30 at right angles to the fault. Consideration of the probable form and elevation of the surface of the Basement System suggests, however, that such a tilt would bring the Basement System surface to a minimum elevation of about 7,000 feet under the Sattima Scarp. This allows for an original drop of 2,000 feet from the old gneiss hill now exposed at 5,700 feet, six and a half miles east of Nyeri, to the base-level elsewhere known as the Sub-Miocene Peneplain (Shackleton, Maralal Report). As it seems doubtful whether the Basement System is actually so close beneath the surface under the Sattima scarp, it is thought that the estimated value of the tilt may be slightly too high.

(2) *The Simbara Dykes*

The majority of dykes mapped on Simbara fall into a radial pattern, but there are also many others, under-emphasized on the map, which together form a swarm parallel to the Sattima fault. These are evidently injected along fractures of tectonic origin. The quartz-trachytes north of Sattima are traversed by a close system of shear-joints in the same direction. So far as could be seen, most of the linear dykes, and the shearing, are very nearly vertical, though two persistent dykes were seen to be inclined steeply westwards.

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(3) *Laikipian Vents*

The arrangement of the vents of southern Laikipia appears from the map to be haphazard. Certain features suggest, however, that north-north-west to south-south-east fractures parallel to the Sattima fault, may, to some extent have controlled the position of the vents. Dykes on Il Pejeta and on a hill ten miles north of Sattima trend between north-west to south-east and north to south. A north-north-west to south-south-east alignment of adjacent vents of similar character, at Ol Doinyo Narasha, is apparent in the field where the form of the individual hills can be appreciated, and a similar alignment can be seen in the Il Pejeta group.

(4) *Relation between the trend of the Rift Valley faults and strikes in the Basement System*

Along the eastern side of the Rift Valley, both in this area (*see* Fig. 1) and further north (Shackleton, Maralal Report), the trend of the Rift Valley faults corresponds to the strike in the Basement System.

VIII—ECONOMIC GEOLOGY

(1) *Building Stone*

The most useful building stone in the area is the Nyeri tuff. The main quarries now being worked are those near Nyeri Station, but local demand at Nyeri would probably justify working the outcrops nearer the township. Some of the houses in Nyeri that are built of the Nyeri tuff are cracked, but this is the result of poor foundations, and not faulty stone. It is possible that this is a rock which would be better laid with the original bedding flat. Some reaction between alkalies extracted from the rock by rain water, and cement used in pointing, would be expected, but it is unlikely to be appreciably harmful in practice.

Trachytic tuff was formerly quarried in the Ngobit valley. The rock exposed there is soft and crumbly but apparently the stone was not unsatisfactory for building. Harder trachytic tuff, with columnar jointing, is quarried near the Suguroi, and is a good building stone. Trachytic tuffs also outcrop on the northern Aberdare ramp. Their quality varies from one bed to another, but good stone should be obtainable over most of the mapped outcrop, except in the flatter areas.

On the slopes of many of the Laikipian vents, there are reddish basaltic lapilli tuffs, and in various places attempts have been made to quarry them. Although they are much more intractable than the trachytic tuffs, they yield a durable building stone and the difficulty of quarrying and dressing is probably worth meeting, if competent stone-masons can be found.

(2) *Road Metal*

Plenty of rocks suitable for road metal are available in most parts of the area, except on the Naromoru plains. The basalts are usually easiest to work as under red soils weathering often penetrates to a depth of ten feet and the weathered rock can easily be quarried. The Thomson's Falls phonolites are seldom weathered so deeply and when fresh are tough and difficult to work. They should be avoided where possible. Most of the tuffs are too soft to be of use. The kenyte agglomerate is worked in a large quarry by the railway, some distance north of Nyeri Station.

(3) *Diatomite*

A thin deposit of diatomite occurs near a tributary watercourse of the Ngobit, three miles west-north-west of Tanyai Hill. Although apparently of good quality, the deposit is too small to be of any commercial value. The thickness at the place where the bed is exposed is less than ten feet. No other outcrops are known, and it is unlikely that a thicker deposit could be found in the vicinity, and in any case transport costs would be prohibitive, except in the unlikely event of a local demand arising.

(4) *Brick Earths*

Bricks have been made on several farms in the district, with various results, but there is no doubt that suitable subsoils or alluvial silts exist in many places. There has perhaps been a tendency to use earths that are too plastic.

IX—WATER SUPPLY GEOLOGY OF THE AREA BETWEEN MT. KENYA AND THE ABERDARE RANGE

It has been suggested that there might be a possibility of artesian conditions in the area between Mount Kenya and the Aberdares. The argument, briefly, is that both Mount Kenya and the Aberdares were built up by volcanic eruptions and consist of lavas and tuffs which dip outwards from the volcanic centres. It is assumed that some of the lavas are impermeable while others, and probably most of the tuffs, are permeable. Water entering the permeable beds might be confined between impermeable ones, under a considerable head owing to the great height at which it enters the rocks. If not completely confined, it might still be under pressure if the resistance to its passage through the rocks were sufficient. It is further argued that the underlying floor of relatively impermeable gneisses of the Basement System, sloping southwards from about 6,000 feet near Nanyuki to under 4,000 feet at the margin of the Tana plains, would prevent the subsurface water from escaping northwards to the Uaso Nyiro catchment, and thus increase the resistance to be overcome before the water escaped at the surface.

The geological aspect of this problem is discussed below and illustrated in Fig. 1 and Fig. 2.

(1) *The Basement System Floor*

The sub-volcanic floor, formed of gneisses of the Basement System, is a highly irregular surface. This irregularity is the result of erosion acting on a diversity of rocks, and not to the faulting or folding of a previously peneplained surface. The elevation of the surface is difficult to predict, as no peneplains have been recognized in this area, although the surface beneath the Kapiti phonolite of the Tana plain may be part of the sub-Miocene Peneplain. West of the Tana there is an almost continuous barrier of gneiss hills, which disappears under the volcanic rocks near Tumu-tumu, reappears as an inlier in the Chania east of Nyeri, and is doubtless represented by the gneiss penetrated by a borehole near Nanyuki (Sikes, 1934, Pl. X, Fig. 4). Still further north, this zone of gneiss hills merges into an elevated region which extends from the Loldaikas to the Karissia Hills. It is evident that on the pre-volcanic land surface, no rivers flowed eastwards from the Rift Valley region across this barrier to the Indian Ocean anywhere between 1° S. and 1° 30′ N. The drainage west of the barrier may have been towards a depression in the area of the present Rift Valley. It is in any case clear that so far as the Basement System floor influences the subsurface flow, its effect would be to turn the water in the rocks beneath Mount Kenya towards the south or south-east, and that beneath Laikipia, the Nyeri area, and the Aberdares, towards the west or south-west. The Basement System floor appears from beneath the volcanic rocks south of Mount Kenya and water diverted in that direction should emerge there as springs. Springs are in fact reported at this surface, near the Nguka swamp, and others were noticed during this survey south of Karatina on the side of the Sagana valley. West of the zone of gneiss hills the Basement System is not again exposed east of the Rift Valley.

It should perhaps be emphasized that subsurface water flows in the direction of the slope of its surface (the water-table), which may have no relation to the slope of any subsurface floor.

(2) *The Aberdare Range*

The structure and rock succession of the northern part of the Aberdare range have been discussed in the report above. The southern part of the range is known to be formed of similar rocks, and the structure is doubtless also similar. A concentration of dykes near Niandarawa shows that this mountain is near to a main focus of eruption comparable to the one near Sattima. As regards artesian water, the significant features of the Aberdare structure are—

(*a*) the oldest rocks are exposed around Sattima and Niandarawa in the highest parts of the range;

(*b*) the same series of rocks emerge, much thinner and in an agglomeratic facies, at the eastern edge of the basalt field, as near Nyeri in the Sagana and Maragua valleys, and near Saba-saba and Makindi;

(*c*) the eastern slope is essentially a dissected dip slope;

(*d*) all the rocks are basaltic;

(*e*) the Laikipian basalts which cover the middle and lower slopes are trenched, in places to their base, by deep valleys.

As the oldest rocks emerge again at the foot of the dip slope, water permeating through them can escape freely. Furthermore, the cover of Laikipian basalts, in which columnar jointing is a conspicuous feature, are likely to behave as aquifers. It is believed, therefore, that the subsurface water of the Aberdare dip-slopes will in general be found to behave as a single system, the hydrostatic pressure at any point depending on its depth below the water table. The slope of the water table will tend to reflect the general slope of the ground and will determine the flow of the subsurface water.

(3) *Mount Kenya*

Only the north-western sector of Mount Kenya between Nanyuki and the peak, and its periphery from Nanyuki to Embu, were hurriedly examined during this survey. Gregory recorded details of his route up the south-western side of the mountain, (Gregory, 1900, pp. 215 and 216).

In the deep valleys radiating from the central peak, the rocks exposed are kenyte lavas and tuffs. Two thousand feet of these rocks are seen on Sendeyo, and their full thickness must be very great. They dip outwards at angles diminishing from 20° near the plug to less than 10° five miles away, and still less further down the slope. In profile, the lower slopes show the upward steepening curve characteristic of a volcano such as Fujiyama, but the upper slopes lie below the imaginary continuation of this line. It is evident that the upper part of the volcano has been lowered by erosion at least 3,000 feet below its original height, while the lower slopes still reflect its original form. It follows from this interpretation that the lavas and tuffs exposed around the core plunge beneath those of the lower slopes, and water can readily enter the permeable strata, through which it will sink beneath the intermediate slopes of the mountain.

At the periphery of the Mount Kenya volcanic area, however, the base of the kenyte series is exposed. The Series rests, around the western and southern sides of the mountain, on basaltic lavas. Therefore the immense thickness of kenyte lavas and tuffs of the main cone diminishes to a feather edge, which is freely exposed at the periphery of the mountain. The water which enters the permeable parts of the Series high on the mountain must either escape at the surface, or sink downwards through the underlying rocks to the water table and thereafter flow, according to the pressure gradient, within the ground-water system of the region.

Borehole Data

Few boreholes have been drilled in the area that is being considered. Some in the Nanyuki area were discussed by Sikes (1934, pp. 30–32).

Samples from other more recent ones have been examined in connexion with the present work. The localities are shown on Fig. 2. Material from the samples was merely mounted in oil and inspected under the microscope, and the logs are to be regarded as provisional. Those of interest are given:—

(*a*) *Borehole* C. 267 (*Muringato Estate, Nyeri*).—

Depth From ft.		To ft.	
0	..	30	Red soil.
30	..	55	Gritty clay.
55	..	186	Olivine basalts (Laikipian Series).
186	..	306(?)	Gravel and trachytic tuff (Nyeri tuff).
306	..	345	Gravel; stones are Kijabe type basalt (Simbara Series).
345	..	440	Kijabe type basalt (Simbara Series).

Main water from the lowest basalts, below 386 ft. (37,032 gal./24 hrs). Rest level 347 ft. Perched water table at about 148 ft.

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(*b*) *Borehole C.* 286 (*Farm* 5175, *Naromoru*).—

Depth From ft.	To ft.	
0 ..	19	Grey soil, etc.
19 ..	244	Kenyte lavas; tuff or weathered kenyte at two horizons?

Main water at 225 ft. (20,400 gal./24 hrs.). Rest level 173 ft.

(*c*) *Borehole C* 290 (*Farm L.R.* 2830/4, *Nanyuki*).—

Depth From ft.	To ft.	
0 ..	28	Soil, etc.
28 ..	80	(Gravel and boulders, according to drillers log.) Fragments of phonolite.
80 ..	100	Tuffaceous earth?
100 ..	110	Gravel (phonolite fragments).
110 ..	125	Light-brownish clay.
125 ..	150	Polygenetic gravel. A fragment of nepheline-syenite.
150 ..	275	Kenyte?
275 ..	419	Kenyte.

Water at 148 ft., 200 ft., 293 ft., 415 ft. (21,600 gal./24 hrs.). Rest level 123 ft.

(*d*) *Borehole C* 291 (*Farm* 1232. *Nanyuki*).—

Depth From ft.	To ft.	
0 ..	44	Black soil, murram, etc.
44 ..	110	Gravel (fragments of kenyte, nepheline syenite, etc.).
110 ..	195	Kenyte.
195 ..	208	Clay (bentonitic?).
208 ..	320	(?)Kenyte.
320 ..	354	Gravel and clay.
354 ..	365	Kenyte.

Water at 105 ft., 180 ft., and 290 ft. downwards (17,280 gal./24 hrs.). Rest level 78 ft.

The first of these boreholes (C 267) penetrated about 100 feet into the Simbara Series, from which a good supply was obtained, but there is no indication of artesian conditions.

The other three (C 286, C 290, C 291) all enter the Mount Kenya Volcanic Series. In these too, good supplies were obtained, but the water does not rise above the expected level of the water table.

Conclusions

In view of the evidence outlined above the chance of striking artesian water is thought to be poor. Both the Simbara Basalt Series and the Kenyte Series of Mount Kenya outcrop so extensively at the periphery of their respective volcanic fields that the water which enters them on the higher areas can easily escape at their base. Boreholes into both series have failed to show any artesian pressure and there appears to be no reason why conditions deeper below the surface should in this respect differ from conditions in similar lavas and tuffs of the same series at less depth. Over much of the area, deep boreholes—1,000 feet has been mentioned—would in fact pass through these series either into the Basement System, or into other volcanic rocks unlikely to yield artesian water. It is possible that artesian conditions may prevail over small areas, but it is doubtful whether, if so, they could be discovered by intensive geological or geophysical surveys.

Although the chance of artesian water is thus thought to be poor, the district appears to be a favourable one for boreholes to normal depths. In particular, on the plains west of Naromoru, underlain by rocks of the Mount Kenya Volcanic Suite, the chances of getting water appear to be good. The water table in this area is unlikely to be far below the level of the principal watercourses, and as the relief is low, depth to water should not be excessive in boreholes on the ridges. On the slopes formed by the Laikipian basalts the water table may be slightly deeper, since these rocks are open-jointed, and the gradient of the water table from the plains mentioned above, towards the Aberdares, is thus likely to be low. In the Ngobit gorge, which is cut deeply into the Laikipian Basalt Series there are apparently no springs whatever. The water table must therefore be at or below the level of the Ngobit river, and boreholes in that area which stop short of this level can only obtain water from perched water tables.

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