REPORT No. 67



GOVERNMENT OF KENYA

MINISTRY OF NATURAL RESOURCES
GEOLOGICAL SURVEY OF KENYA

GEOLOGY OF THE KIJABE AREA

DEGREE SHEET 43, S.E. QUARTER
(with coloured geological map)

by

A. O. THOMPSON, M.Sc.
Geologist

Fifteen Shillings - 1964

FOREWORD

This geological report on the Kijabe quarter degree sheet describes an area of volcanic rocks and sediments on either side of the southern half of the Aberdare Range. On the higher forested ground, which rises to almost 13,000 feet east of the Rift Valley, rock exposures are not common, and to the west on the lower ground where outcrops are more abundant, the geology is complicated by faulting, at times associated with spectacular topographical features, but frequently tending to have been obliterated by ash showers. Stratigraphical correlation has not been easy therefore, although it is considered that the purpose of these regional geological reports, which is to record the boundaries between and the extent and age of the main groups of rock, has been accomplished.

In well-populated parts of the area, the water supply question is important and has received much attention; a section of the report incorporates records obtained during drilling. The results of some of the drilling for water has furnished useful information concerning the presence of natural gas and unusually hot and cold water. The discovery that gas in the "soda" spring at Kerita is predominantly carbon dioxide, led, after a period of prospecting by drilling, to the establishment of a factory to produce bottled gas and dry ice for commercial use. The possibility of discovering further carbon dioxide wells and exploration for hot water possibly associated with steam, such as is known near the major rift valley faulting in this area, warrant further investigation.

Dr. E. P. Saggerson undertook the initial editing of the report, the final editing being carried out by the Chief Geologist and approved by Dr. W. Pulfrey, Commissioner (Mines and Geology).

N. J. GUEST,
Chief Geologist.

26th June 1962.

CONTENTS

	Page
Abstract	
I—Introduction	1
II—Previous Geological Work	4
III—Physiography	7
IV—Summary of Geology	10
V—Details of Geology	15
1. Simbara Series	15
2. Sattima Series and Laikipian Lavas	17
(1) Rift Valley Trachytes and Phonolites	18
(2) Pyroclastic rocks	20
(3) Laikipian basalts and allied rocks	22
3. The Kijabe-type Basalts	23
4. Trachytic rocks of the younger Aberdare vents	23
5. Pleistocene and Holocene sediments	24
VI—Structure	26
VII—Mineral Deposits	28
1. Clays	28
2. Building-stone and sand	29
3. Pumice	30
4. Limestone	30
5. Pigments	32
6. Road-metal and ballast	32
7. Natural gas	33
8. Water Supplies	36
VIII—References	50

LIST OF ILLUSTRATIONS

Fig. 1.—Isohyetals for the Kijabe Area	2
Fig. 2.—Drainage areas of the Kijabe Area	8
Fig. 3.—Structural map of the Kijabe Area	27
Fig. 4.—The Maru Ngishu limestone deposit	31
Fig. 5.—Carbon dioxide bore-holes and springs, Kerita Forest	34
Fig. 6.—The location of the Sasumua dam	37
Fig. 7.—Plan of the Sasumua dam	38
Fig. 8.—Bore-hole sites and water rest-level contour-lines of part of the Kijabe area	40

MAP

Geological Map of the Kijabe Area (Degree sheet 43, S.E. Quarter), Scale 1:125,000 at end

ABSTRACT

The report deals with an area of approximately 1,200 squares miles, bounded by latitudes 0° 30′ and 1° 00′ S. and by longitudes 36° 30′ and 37° 00′ E. Physiographically the area may be divided into four units: (1) the Rift Valley, (2) the Kinangop platform, (3) the Aberdare range, (4) the Kikuyu and forest reserve highlands. The area is composed almost entirely of volcanic rocks comprising lavas and pyroclastics which, particularly west of the Aberdare range, are considerably faulted. Although the oldest rocks cannot be dated accurately it is believed they are probably Tertiary in age.

Faulting in connexion with the formation of the Gregory Rift Valley has dissected the terrain and is responsible for some spectacular scenery. In the extreme south-western part of the area intense faulting has produced many platforms along the eastern wall of the Rift Valley.

An account is given of the petrology of the rocks, and the structures of the area are described. Economically the area is poor in minerals, though water-supplies are important and some of the volcanic products are useful as building materials. There is at least one occurrence of natural gas in the area which has proved economically interesting.

GEOLOGY OF THE KIJABE AREA

I—INTRODUCTION

The Kijabe area is covered by the south-east quarter of degree sheet 43 (Kenya) and is bounded by latitudes 0° 30′ and 1° 00′ S. and by longitudes 36° 30′ and 37° 00′ E. (Directorate of Overseas Surveys Sheet No. 134). Most of the geological reconnaissance was carried out between the months of November 1956 and March 1957.

Approximately equal proportions of the area are covered by farmlands, forest reserve together with part of the Aberdare National Park, and a part of the Kikuyu special area. The forest, National Park and part of the Kikuyu special area that lie in the Kijabe area are administered by the Provincial Commissioner of Central Province with headquarters at Nyeri, through District Commissioners at Nyeri and Fort Hall. The remainder of the area which lies in the Rift Valley Province and is administered from Naivasha with Provincial headquarters at Nakuru, is farmed mostly by Europeans. A certain amount of timber milling is done in the forest reserves and extensive programmes of re-afforestation are being undertaken by the Forest Department. Near the Kerita Forest Station a natural gas and "soda spring" occurs.

Extensive evapo-transpiration and other experiments, relating to surface and ground waters in the afforested areas near the Fort Essex (Kimakia) Forest Station, are being undertaken by the East African Agriculture and Forestry Research Organization in conjunction with other Government departments, chiefly the Ministry of Works. Some of the results of this work have been published in the Annual Reports of E.A.A.F.R.O. for 1955, 1958 and 1960.

Maps.—Four maps of the preliminary plot series on the scale of 1:50,000 were used, viz. the G.S.G.S. 4786 Fifth Edition sheets SA37/A-IV NW (134/I), SA37/A-IV NE (134/II), SA37/A-IV SW (134/III), and SA37/A-IV SE (134/IV). Mapping was also done using aerial photographs, although small gaps in the photographic cover exists on both sides of Niandarawa on the Aberdare range. Reference was also made to the map G.S.G.S. No. 1764 "Nakuru-Nyeri" and to the military map "Nairobi and the Aberdares", E.A.F. No. 1633, both on the scale of 1:250,000.

Communications.—The railway line between Kenya and Uganda as well as the tarmacadamized road between Nairobi and Nakuru pass across the south-western corner of the area. In the Kikuyu special area earth roads are largely confined to interfluves and are frequently impassable in the wet season, though they dry quickly after rain. The forest reserve tracks are also frequently rendered impassable through rain and also through the depredations of elephants. In the early 1950s, during the Emergency, several tracks and roads were constructed in the forest reserves, but these are rapidly becoming overgrown through lack of maintenance.

The railway line which skirts the fault-scarps near Kijabe is part of a realignment, the previous alignment having run along the north-east edge of Kijabe township. A still earlier alignment was situated just beyond the extreme southern edge of the area, where coaches and trucks were hoisted up and down the escarpment by winch and cable.

Climate.—The area as a whole receives good annual rainfall (Fig. 1). The Kedong valley in the south-western corner receives the least precipitation, whereas the Kikuyu special area receives the highest rainfall (*see* Table I). Although the Kinangop rainfall stations record the greatest number of rainy days, the amount of rain received is not as high as some of the stations in the Kikuyu reserve where the falls of rain are spasmodic but generally heavier. In the Kikuyu reserve the soils are almost invariably bright red in colour whereas soils on the Kinangop, where evaporation is less, are grey.

In the neighbourhood of the Rift Valley there is a marked decrease in precipitation as altitude decreases. For example, the average rainfall at the Kerita Forest Station situated on the top of the east wall of the Rift Valley at about 8,000 feet is 51.56 inches, but it is only 26.89 inches on the Mount Margaret Estate in the Rift Valley at about 6,200 feet and about four miles distant.

Maximum and minimum temperatures recorded during the period of the survey show an approximate average daily difference of 30° F., and the highest temperature recorded on the Kinangop was 88° F., in December 1956. Unfortunately no temperature recordings were made on Niandarawa and other high altitudes over 12,000 feet.

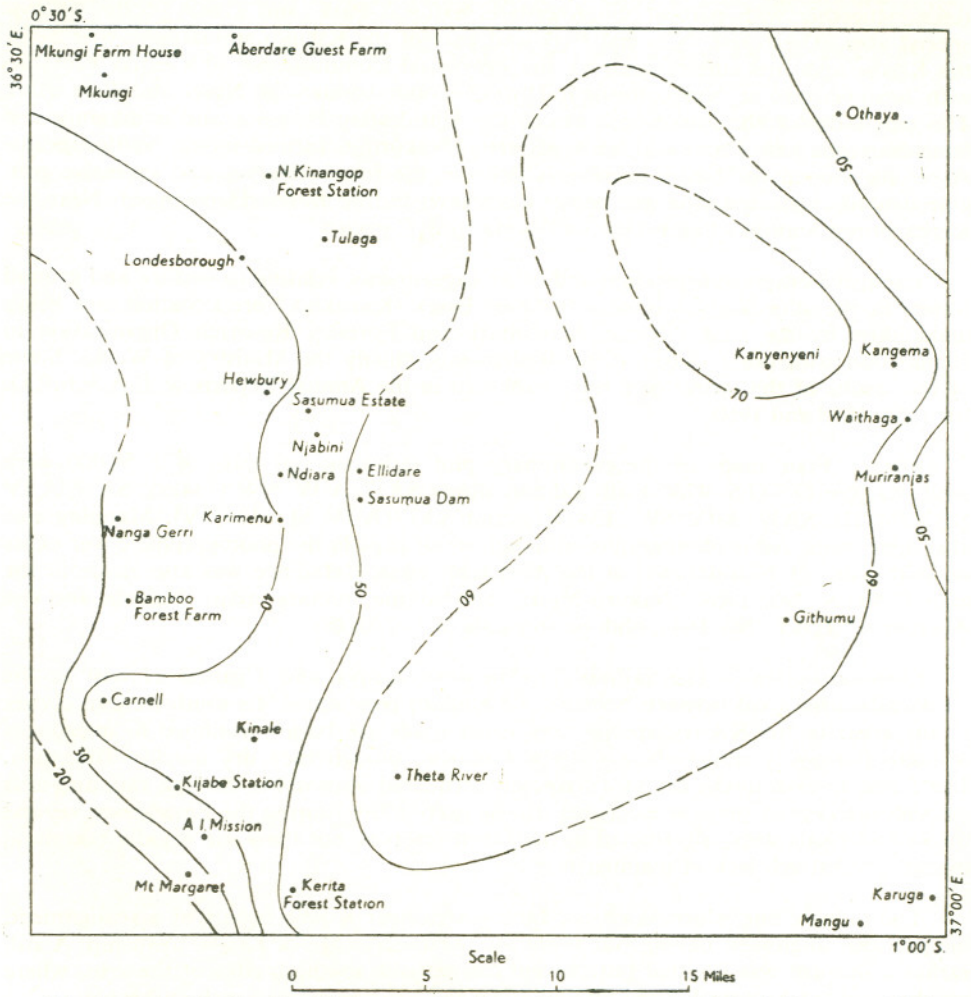


Fig. 1—Isohyetals for the Kijabe area, based on the average rainfall in inches as at 1957

TABLE I

RAINFALL STATISTICS FOR THE KIJABE AREA

(From the Records of the Meteorological Department)

Station	Altitude in feet (approx.)	No. of Years Recorded	Total Rainfall (inches)		Average Yearly Rainfall (inches)	Number of Rainy Days	
			1956	1957	1957	1956	1957
Kijabe Railway Station ..	7,227	7	29·61	36·67	39·91	86	106
Kijabe Africa Inland Mission	7,500	32	30·13	N.A.*	35·29	122	N.A.
Matathia Mt. Margaret Estate	6,200	34	25·14	33·99	26·89	72	100
Naivasha, Mkungi Farm House	8,000	14	45·52	44·01	45·04	233	184
Naivasha, Mkungi Estate ..	8,000	21	49·73	49·66	46·54	N.A.	226
Naivasha, Nanga Gerri ..	8,000	28	34·34	35·13	31·93	122	121
North Kinangop Aberdare Guest Farm	8,275	7	54·53	43·94	45·13	221	190
North Kinangop Forest Station	8,630	38	40·84	45·97	44·40	117	169
Tulaga, J. N. Nimmo ..	8,500	9	52·02	41·30	45·57	N.A.	N.A.
North Kinangop, Londesborough Farm	8,300	7	42·57	40·79	40·17	157	N.A.
South Kinangop, Howbury ..	8,500	21	47·12	43·76	38·23	146	147
South Kinangop, Sasumua Estate	8,500	10	48·63	53·77	45·24	215	207
South Kinangop, Njambini ..	8,500	5	46·95	58·01	45·29	112	135
South Kinangop, Ndiara ..	8,350	23	50·44	53·75	44·48	192	163
South Kinangop, Ellidare ..	8,100	10	55·80	61·05	53·01	176	184
South Kinangop, Sasumua Dam	8,140	7	54·86	64·51	52·75	191	192
South Kinangop, Karimenu..	8,600	7	42·72	47·99	40·38	160	132
Kijabe—Bamboo Forest Farm	8,600	7	34·15	34·51	34·49	128	88
Longonot, Carnell	8,000	27	44·09	49·31	42·53	174	168
Matathia, Kinale	8,500	11	45·97	52·54	43·95	175	172
Matathia, Kerita Forest Station	8,000	26	53·58	61·77	51·56	165	163
Matathia, Theta River ..	8,000	7	59·23	78·21	64·66	179	180
Thika, Karuga Farm.. ..	5,100	3	50·46	71·16	50·45	123	109
Nyeri, Othaya	6,000	13	45·71	59·18	48·46	139	155
Fort Hall, Kanyenyeni ..	6,600	17	81·76	91·97	76·32	140	138
Fort Hall, Kangema	5,800	7	44·20		67·38	77	N.A.
Fort Hall, Waithaga C.M.S. Mission	5,800	12	70·38		60·31	104	
Fort Hall, Muriranja's Hospital	5,600	18	70·98		53·30	79	
Thika, Githumu A.I. Mission	6,400	16	69·25	85·77	63·68	144	145
Mangu, St. Francis' Girls' School	5,300	1	N.A.	57·27	N.A.	N.A.	131

*N.A.—Not available.

The rainfall stations are grouped in their respective drainage areas.

Cultivation and Vegetation.—In the European farmlands on the Kinangop plateau and along the eastern side of the Rift Valley, the main cultivated crops are wheat and pyrethrum. Other cereals and root crops are also farmed extensively.

In African farmlands of the Kikuyu special areas, where land consolidation has been implemented in the last few years, a great variety of foodstuff is grown. Maize, the staple food of the Kikuyu, and millet form the main cereal crops; pineapples are extensively cultivated in the Thika district and in the Othaya location of the Nyeri district: tea and coffee are also being established. Bananas and citrus fruits are cultivated, as well as numerous root-crops such as potatoes, sweet potatoes, yams, and various other vegetables. Wattle trees are used both as a source of fuel and for the bark, which is sent to tanneries located outside the African area. The most flourishing wattle plantations generally occur above 6,000 feet and up to the forest edge at an altitude of about 7,000 feet. Charcoal is prepared and largely exported from the area to nearby towns of Thika and Nairobi.

Much of the Kikuyu cultivation has been accomplished at the expense of the forest. Towards the end of last century Hobley (1894, p. 110)* noted that the Kikuyu villages were never found above an altitude of 6,000 feet, then the altitude of the forest edge: nowadays their villages are seen at elevations above 7,000 feet. In a later publication Hobley (1914, p. 474) considered that in the higher parts of East Africa, particularly in Kikuyuland, some 3,000 square miles of forest had been artificially decreased in historic times. He thought this might account for a decrease in rainfall in a certain portion of the Rift Valley during that period. The Forest Department with its reafforestation schemes is replacing bamboo mainly with coniferous trees.

ACKNOWLEDGEMENTS

The writer wishes to express his thanks to the officers of the Provincial Administration and to the Kenya Police during the survey, in particular the latter who supplied escorts when work had to be carried out in prohibited and forested areas. Thanks are also due to the farmers on the Kinangop and at Kijabe for their help and hospitality.

II—PREVIOUS GEOLOGICAL WORK

Many of the early explorers and geologists en route to Uganda and the northern parts of the Rift Valley probably passed through or near to the Kijabe area. In their descriptions these travellers paid particular attention to physiography, being attracted by the Rift Valley, its flanking mountains and plains, the volcanoes and the scarps that abound in the area. Few, however, gave any rock or geological descriptions.

Thomson (1887) named the Aberdare mountains and fixed their position on a map. He was, however, criticized by Von Höhnel (1891, p. 7) and Gregory (1894, p. 421) over the positioning and nomenclature of the peaks and rivers.

Admiral Von Höhnel (1890), a member of the Teleki expedition, travelled through the Kijabe area in 1887 and noted the volcanic origin of the rocks and ashes there and in other parts of the Rift Valley. He passed through the Kiambu, Fort Hall and Nyeri districts en route to Mount Kenya and Lake Rudolf, and then in the following year on his return from Lake Rudolf crossed the western part of the area. He was mainly concerned with orography (op. cit., pp. 6-7) and described the peaks in the Aberdare range. Von Höhnel noted that no well-defined craters existed there, but believed that the area and range were built up by floods of lava and ashes.

F. Toula (1891, p. 552) mentioned that quartz trachytes with decomposed sanidine phenocrysts and prominent basalts rich in zeolites were found by the Von Höhnel expedition in Kikuyuland on the southern flank of the Aberdares and A. Rosiwal (1891, pp. 490-1) described basalts and a trachyte collected by the expedition. The trachyte described by Rosiwal, judging from its position on Von Höhnel's map, was possibly collected in the vicinity of Kanjuku in the Kiambu district.

Walcot Gibson (1893, pp. 561-563) described the geology of East Africa in general terms, and believed the lavas and pyroclastics flanking the Rift Valley were erupted from a north-south fissure whose position is now marked by the Rift Valley lakes. He stated that the lavas of Lykipia (Laikipia) were mainly acidic types.

In 1893, whilst on his way to Lake Baringo, Gregory noted that the Kikuyu escarpment, which is about 800 feet in height, is broken by a terrace 300 feet from the base (Gregory, 1894, p. 305). He believed the main slope of the Kikuyu uplands was determined by subsidence of the district now covered by the Kapte (Kapiti) plains, and the lava plains of the upper Tana Valley. As Laikipia resisted this movement it gave the whole of the Kikuyu uplands a south-eastern slope. The more imposing fault-scarp on the eastern side of the Kinangop platform he described as part of the great "Laikipia fault-scarp". As a result of this first journey to Kenya he postulated his "keystone theory" for the origin of the Rift Valley (Gregory, 1896, p. 231). Gregory believed that

* References are quoted on pp. 50 and 51.

Kipipiri and Isanga, the former just beyond the northern limit of the Kijabe area, were volcanic hills built up around vents on the marginal faults of the Rift Valley. Further south from the Kinangop he noted (op. cit., 1896) that the steps (fault-blocks) became narrower until the eastern wall of the Rift Valley above the Kedong basin becomes one wall, broken near Kijabe by only a single narrow platform.

Specimen 182, collected by Gregory in 1893 from the Kedong scarp, was described by Prior (1903, p. 242) as a phonolitic quartz trachyte.

Lt.-Col. W. H. Broun passed through the area in 1904 after visiting the Lorian Swamp. He crossed the moorlands and the Kinangop between Nyeri and Naivasha in 13 days (Broun, 1906, p. 50). His paper dealt more with geographical than geological aspects.

H. B. Maufe (Muff, 1908) described some of the faults, rocks and soils in the Rift Valley, and agreed with Gregory's theory for the origin of the Rift Valley by faulting. Muff (op. cit., p. 40) also believed that Kijabe hill was an old volcano "which burst out . . . after the subsidences of the Rift Valley had taken place". He (op. cit., p. 29) also referred to a mofette or stink-hole in the Kedong valley, which he had heard emitted a poisonous gas. During the course of the present survey the alleged site of the mofette was visited, but no hole was observed. Local inhabitants maintained, however, that wild animals whilst consuming grass in the vicinity of the mofette were overcome by gas (presumably carbon dioxide) and died, though no bones are now visible. The reported position of the mofette is shown on the map that accompanies this report.

In 1908, P. F. Perlo published an account of his ascent of the Kinangop mountains (Niandarawa) from the eastern side. He set off from a mission at Tuso, but although recognizing the volcanic origin of the rocks, only described the topography and geography of the mountain region.

E. Krenkel (1911, pp. 243-267) visited the Rift Valley in 1908 and made various observations. He supported Gregory's "keystone" hypothesis for the formation of the Rift Valley and noted that where up-arching of the Basement had taken place rifting occurred. He believed (op. cit., p. 259) that with the collapse of the rift floor the shoulders of Basement were raised at the same time.

During 1910 G. L. Collie (1912) visited the Rift Valley and reached the conclusion that the valley was a vast graben or tectonic trough. He added that there is little direct proof of faulting, and believed the lava flows came mainly from fissures which in many cases possibly became the fault-planes of the great rift (op. cit., pp. 312 and 313).

After his second visit to Kenya and the Rift Valley in 1919, Gregory (1920) described the faults and fault-scarps near Kijabe and Naivasha, noticing that the "two main steps are those up to a steep scarp on to the plain of Kinangop . . . and thence up the Settima (Sattima) scarp on to the eastern plateau". In dealing with the history and age of the Rift Valley, he quoted a succession of lavas, the base of which consisted of phonolites including the Kapiti Phonolite. There followed, he believed (op. cit., p. 36), "a series of basaltic eruptions which produced the basaltic agglomerates of northern Kikuyu . . . and the porphyritic basalts of Kijabe and the Settima range. These basaltic eruptions were probably synchronous or followed shortly after the first of the Rift Valley faults, and they were succeeded by a long stage of rest and denudation until renewed volcanic disturbances discharged the rhyolites and trachytes which are especially well developed in the Kikuyu country". In a later publication Gregory (1921) gave a more comprehensive account of the Rift Valley and its formation.

H. L. Sikes (1926, pp. 385-402) published a paper dealing with the structure of the eastern flank of the Rift Valley, and tabulated in chronological order the rocks of this and neighbouring areas. Sikes supported the hypothesis of tension as the cause of the structural movements that formed the Rift Valley. The conditions under which water is

likely to be encountered both in the Rift Valley and on the Kinangop have also been discussed by Sikes (1934), who dealt with the rocks in these areas in relation to their water-bearing propensities. Sikes believed (op. cit., p. 18) that the porosity of the comparatively recent Rift Valley volcanic rocks, even though a great distance from the vents of the volcanoes from which they were derived, accounted for some of the bore-holes being dry, for example BH 53 (*see* Fig. 8).

During 1929-30, under the auspices of the Carnegie Institution of Washington, Bailey Willis travelled widely throughout East Africa, studying its plateaux and rift valleys. The faults within the present area are, he believed (Willis, 1936, p. 267), "structural effects of the uparching of the broad flat arch which constitutes the high plateau of southern Kenya".

In 1931 W. Campbell Smith published a paper describing several types of volcanic rocks collected by various geologists who had visited Kenya, and included a number of chemical analyses of selected specimens. Some rocks from the Kikuyu or Kedong scarp in the vicinity of Kijabe township, previously referred to as "kenytes" and "porphyritic phonolitic quartz-trachytes", he renamed soda-trachytes (Gibélé type) (op. cit., pp. 220-221); others he called "katophorite trachyte" (op. cit., 224-229). He also dealt with basalts, including some from the Kijabe area.

R. E. Moreau (1933, p. 424), in his paper dealing with Pleistocene climatic changes and their relation to the distribution of life, particularly with respect to birds, stated that the immense tectonic activity in East Africa has manifested itself in "three great shatter-belts . . . the effects of which are apparent today as three lines of eastward-looking scarps", of which he considered the Aberdares forms one.

During May 1933, R. Murray-Hughes (1934, p. 19) made a short reconnaissance in search of bentonite from Naivasha to Lereko without locating any deposit.

In 1936, after a visit to the Rift Valley of Kenya, Shand described the Kijabe region in which he recorded the presence of syenite-porphyry on the western edge of the Kijabe terrace (op. cit., p. 310). He stated that the Rift Valley was formed by the prolongation and perpetuation of a fissure, and believed that neither regional compression nor regional tension was a necessary condition for its formation. He referred to the faulted nature of the area near Kijabe but believed the Kijabe terrace owed its origin to erosion. In a later paper Shand (1937, pp. 262-271) dealt with the rocks in the Kedong scarp; the analysis and norm for a trachyte was quoted (op. cit., p. 265). He believed that the Kijabe hill basalts and the Ngong "augitites" were derived from the same magma.

H. G. Busk (1939, p. 232), in an explanatory note to a block diagram of the Rift Valley between Lake Magadi and Nakuru, described the Melawa river, tributaries of which rise in the Kijabe area, as a consequent on the Kinangop platform which he considered to be tilted northwards. He believed physical features in the area to be tectonic, erosion playing only a secondary part. In his diagram the Sattima fault-scarp is shown but not Fey's Peak and Tulaga.

In 1945 R. M. Shackleton carried out a geological survey of the Nyeri area, and extended his observations into the Kijabe area. His terminology has been largely adopted in the compilation of the present report. Shackleton published a paper on the Pleistocene faulting in the Rift Valley, and localities within the Kijabe area were discussed (Shackleton, 1955). He concluded that while there was strong faulting at the end of the Middle Pleistocene period, the main faulting was earlier, probably late Pliocene or earliest Pleistocene (op. cit., p. 257).

Several geologists of the Mines and Geological Department have visited places within the Kijabe area and written departmental reports. Dr. W. Pulfrey visited a proposed brick-field near Kijabe in 1945, and in May 1948 investigated clay deposits which he considered to be of lacustrine origin, on J. W. Etherington's farm on the Kinangop. He suggested a pitting programme and test methods for the various clays.

He also wrote a report in 1949 on the limestone deposit on Glenleedle farm, and in 1957 reported on the kaolin deposits and the bore-hole for carbon dioxide at Kerita. Up to the end of 1961 Dr. Pulfrey had visited this locality several times and advised on the development of carbon dioxide there.

III—PHYSIOGRAPHY

Four physiographic units defined either by predominant volcanic rock types or the results of tectonic movement can be recognized in the Kijabe area. They are (*a*) the Rift Valley, (*b*) the Kinangop platform, (*c*) Niandarawa and Elephant mountains of the Aberdare Range, and (*d*) the Kikuyu and forest reserve highlands.

Two major drainage areas can be recognized, that feeding the internal drainage of the Rift Valley and the second with rivers flowing towards the Indian Ocean (Fig. 2). Near Kijabe, the Lake Naivasha and Kedong drainage systems together comprise the drainage into the Rift Valley. Rivers flowing eastwards from the Aberdares are tributaries of the Tana and Athi rivers which drain into the Indian Ocean. The Tana river system can be subdivided into a larger Maragua-Sagana portion and a smaller Thika-Chania portion.

1. The Rift Valley

The Rift Valley physiographic unit includes the scarps and fault-blocks between the Rift floor and the Kinangop plain. Although minor faults have produced topographic features on the Kinangop, they are small in comparison with the major Rift Valley fault. Shand mentioned (1936, p. 308) that "the depth of the African rifts, although impressive when stated in feet, is quite insignificant in relation to their width", and on p. 307, while he disagreed with early writers, referred to some who claimed that several scarps were impossible to climb. Nevertheless, the height and abruptness of the scarps, particularly in accessible regions, about Kijabe for instance, are spectacular when compared with the flatter parts of Kenya, and it was these features which vividly impressed the early explorers to Kenya.

Between Kijabe and the southern boundary of the area down-thrown blocks have been tilted at many different angles. Subsequent eruptions of pyroclastics have tended to reduce the topographic relief, but the tectonic complexity of the region is still discernible. Numerous faults, often of only short lateral length, cut the flank of the Rift Valley in this region. Further north earth-movements appear to have been on a grander scale, for the scarps sometimes extend for many miles, some joining with those in the Naivasha area.

The lowest part of this unit is about 5,800 feet above sea-level, but the Rift floor rises to a maximum elevation of about 8,800 feet at the edge of the Kinangop, east of Kijabe hill. Kijabe hill, which rises to just over 8,600 feet, forms a prominent feature standing above the floor of the Rift Valley and bears a similar relationship to the Kijabe scarp as Kipipiri does to the Sattima scarp in the Nyeri area (Shackleton, 1945, p. 8). In both instances a volcano has been built up, not on the major fault-line as might have been expected but a short distance west of the fault. Rivers rising within the Rift Valley, or on the Kinangop and flowing into the Rift Valley, extend for only short distances.

2. The Kinangop

Though commonly referred to as a plateau, the Kinangop is really a step on the side of the Rift Valley, a plain rising from about 8,200 feet in the north to 8,800 feet near Kijabe. This plain is deeply dissected by the Makungi, Kitiri, Turasha and other rivers, all tributaries of the Melawa, which ultimately discharges into Lake Naivasha. On its southern and south-eastern fringe, the Kinangop is the catchment area for tributaries to the Athi and Tana rivers, which discharge into the Indian Ocean.

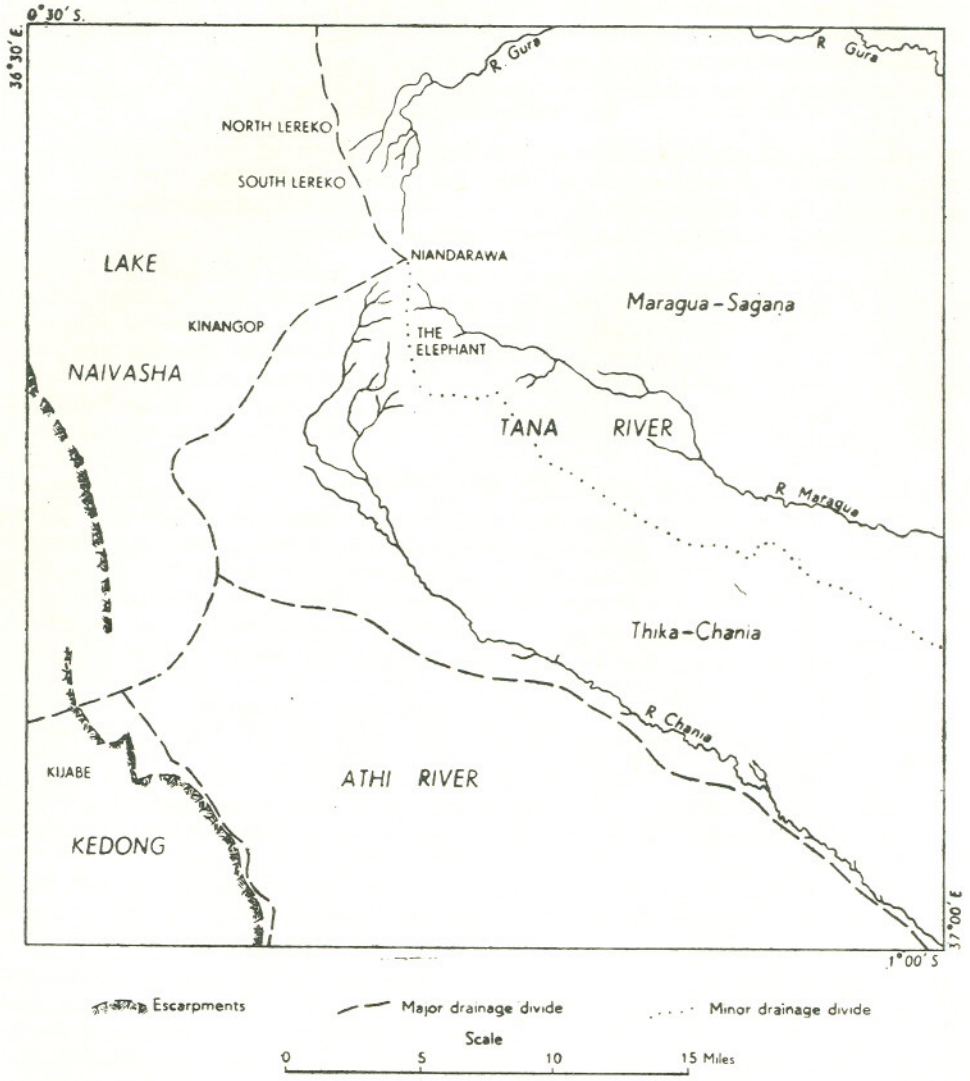


Fig. 2—Drainage areas in the Kijabe area

The Kinangop plain is continuous with the Ol Bolossat plain at the foot of the Sattima scarp, north of the present area near Ol Kalou and Ol Joro Orok. Most of the Kinangop is farmland, though a portion particularly in the south is covered by forest. Some drainage channels in the forest region have been impounded by slight earth movements, but swamps, such as that at Kinari, have recently been drained. Headward erosion of the south-easterly flowing Gatamayu river is rapidly extending westwards to the Kinangop plain, a knick-point at a small waterfall near Kinari marking the present limit of erosional progress. Several other waterfalls on rivers draining the Kinangop indicate temporary halts in the grading of the river-courses on the pyroclastic rocks. These water-falls, seldom more than 50 feet high, are often caused by slightly harder bands of pyroclastic rocks or welded tuffs.

3. The Aberdare Range

This mountain range, comprising in the area mapped Niandarawa (12,816 feet) and the Elephant (11,900 feet), forms the highest feature in the Kijabe area. Moorland, which generally occurs above 11,000 feet though scattered trees occur on slopes above this altitude, is commoner on Niandarawa than on the Elephant. The lower slopes of Niandarawa and the Elephant are forested with trees and bamboo, the latter seldom growing on steep slopes or above 10,000 feet. At lower altitudes, particularly along water-courses, dense bush includes numerous, sometimes giant varieties, of stinging-nettles. North Lereko (Mutubiu) and South Kereko (Kantuere), two smaller mountains north of Niandarawa, are also covered by dense vegetation concealing the underlying rocks, which are believed to be basaltic agglomerates.

The mountains have a radial drainage, but once the rivers reach the Kinangop, mastery of the streams is disputed between the headwaters of the north-westerly flowing Melawa and south-easterly flowing Chania system rivers. On Polhill's farm the divide between tributaries of these two rivers is very gentle and river-captures can be anticipated (*see* Fig. 2). Niandarawa is the source of the Chania and Maragua rivers, the divide between them being very small, while the Gura river rises in the east-facing slopes of Lereko further north.

The Elephant, composed of basaltic agglomerates, has prominent cliffs up to 500 feet in height on its western side. Numerous basaltic dykes radiate from Niandarawa, though a pronounced east-west concentration is seen on the moorland. Similar dykes on the Elephant and in the forested parts of the mountains are not so easily observed owing to the thick cover of soil and vegetation.

The overall dip of the lavas on Niandarawa, the relic of a stratiform volcano, is 2° to the north-west. Although Niandarawa is also faulted on the eastern side (between Niandarawa and the Twelve Apostles), no sign of the volcano throat was seen.

4. The Kikuyu and Forest Reserve Range

The generally eastward sloping country east of the Aberdare mountains and the Kinangop comprises the Kikuyu and Forest reserves. These highlands descend from about 8,500 feet to less than 5,000 feet in the south-eastern corner of the area. This part of the Kijabe region is deeply dissected by numerous streams, a feature that is most pronounced in the Kiambu district where scarcely a single ridge is wider than half a mile, with rivers incised several hundreds of feet.

In that part of the Kiambu district which falls within the Kijabe area, consequent streams are closely spaced, contrasting slightly with the Fort Hall and Nyeri districts. The rivers of the Maragua-Sagana portion of the Tana river drainage have a general easterly direction, whereas rivers in the Thika-Chania portion have a marked south-easterly trend. Throughout the greater part of the Maragua-Sagana region, basalts with associated agglomerates and autobreccias are being incised, whereas in the Thika-Chania and Athi river drainage systems pyroclastic rocks are being dissected. The blanket of pyroclastics probably laid down over the whole region in Pleistocene times was probably thinner around Fort Hall and Nyeri than around Kiambu and has been largely stripped away. Streams have had more opportunity therefore to erode their channels laterally in the first named area, so that valleys and interfluves are wider and gradients more gentle. The tendency for some streams to flow in a north-easterly direction in part of the Maragua-Sagana drainage system is probably due to river-capture by tributaries of the deeply incised Sagana river; the Gakira river is a typical example. In the Athi river drainage region the streams flow in a more southerly direction; the presence of faults as the Kedong drainage system is approached probably influences the flow direction. Basalts from volcanic vents have built up small rounded hills in places, Karima hill in the Othaya location being a good example; other vents also occur in the forest reserve.

IV—SUMMARY OF GEOLOGY

The principal rocks distinguished in the Kijabe area are basalts, basaltic agglomerates (autobreccias), trachytes, phonolites, pyroclastic rocks and lacustrine deposits.

The sequence in which these rocks were laid down is tabulated in some detail in Table II. Although a general attempt has been made to establish the stratigraphy in certain areas, there is still some uncertainty between the exact correlation of neighbouring sections, both of rock types and their ages, which can only be resolved by more detailed mapping beyond the scope of the present report. The succession, largely following Shackleton (1945), can be summarized as follows: —

	Thickness (feet)
3. Younger Pleistocene volcanic rocks and Holocene sediments	<100
2. Pliocene ? to Middle Pleistocene Sattima Series and Laikipian Lavas with associated pyroclastics	<3,000
1. Miocene ? Simbara Series	>3,000

TABLE II

GEOLOGICAL SUCCESSION IN THE KIJABE AREA

Age	Localities and Rock Types			Remarks	Archaeological Stages	Climatic Stages (after Cole, 1954)	Kenya Artifact Cultures
	Aberdares, Kinangop, Kikuyuland	Kijabe Hill	Southern boundary				
	Red and grey soils	Ashes (Longonot) (Qvf)		Minor faulting	Neolithic	Recent	Wilton and Gumban
Holocene						Nakuran	,,
			Trachytes (Longonot) (Plh_4)		Mesolithic	Dry	,,
						Makalian	Wilton and Elmenteitan
						Dry	Magosian Upper Capsian
Upper Pleistocene			Lacustrine deposits (Q1)	Lacustrine deposits in Rift floor (Kedong valley)	Upper Palaeolithic	Gamblian III II I	Stillbay Capsian Lower Capsian
				Erosion and minor faulting	Middle Palaeolithic	3rd Interpluvial	Fauresmith
Upper	Lateritized soils Pyroclastic deposits ($P1t_3$)					Kanjeran	Psuedo-Stillbay Acheulian
Middle Pleistocene	Trachytic rocks of the Younger Aberdare Vents. ($P1h_2$)			Old land surfaces, erosion		2nd Interpluvial	Acheulian

TABLE II—(*Contd.*)

GEOLOGICAL SUCCESSION IN THE KIJABE AREA

Age	Localities and Rock Types			Remarks	Archaeological Stages	Climatic Stages (after Cols, 1954)	Kenya Artifact Cultures
	Aberdares, Kinangop, Kikuyuland	Kijabe Hill	Southern boundary				
Middle Pleistocene	Welded tuffs (P1tf)	Kijabe basalt ($P1b_2$) Pyroclastic rocks ($P1t_3$)		Intense faulting (Sattima and Rift faults)			
Lower	Sattima Series and Laikipian Lavas Pyroclastic rocks ($P1t_2$) Laikipian basalts ($P1b_1$)	Pyroclastic rocks ($P1t_2$) Trachytes ($P1h_1$)	Trachytes ($P1h_1$)	Erosion	Lower Palaeolithic	Kamasian	Chellean
	Pyroclastic rocks ($P1t_1$)	($P1t_1$) Pyroclastic rocks and intercalated phonolites and non-porphyritic trachytes ($P1h_1$)	Porphyritic Trachytes ($P1h_1$)			1st Interpluvial	
Lower Pleistocene	Pyroclastic rocks ($P1t_1$)			Lava and pyroclastic eruptions		Kageran	(not represented)
Pliocene (?)		?	?	Erosion			
Miocene (?)	Simbara Series (Tvb_1)	Basalts and agglomerates					

Wavy line indicates an unconformity.

1. Simbara Series

The oldest rocks in the area are the basalts of the Simbara Series exposed on Niandarawa. These porphyritic rocks are overlain by basaltic agglomerates and autobreccias; all are grouped together as representing the Simbara Series and are believed to be of Miocene age. The series has a probable minimum thickness of about 3,000 feet, but the base was not seen. Closely associated with this period of vulcanicity are dyke-like intrusions of basaltic composition which outcrop on Niandarawa and the Elephant.

2. Sattima Series and Laikipia Lavas

During the period of erosion that followed the extrusion of the Simbara Series, the landscape composed of these rocks was highly dissected so that subsequent volcanic deposits, mostly non-porphyritic lavas and pyroclastic rocks of the Sattima Series and the Laikipian group, were laid on a very uneven surface. The unconformable contact between the two series is seen in the south Nyeri district, east of Othayo. No dykes were observed cutting any of these rocks.

In his report on the Nyeri area Shackleton (1945, p. 2) described separately the Sattima Series and the Laikipian Basalts, but combined them on the geological map accompanying his report.

In the report on the Kijabe area they are combined for general descriptive purposes, although several units within this group of rocks are shown separately on the geological map. Descriptions of rock types similar to those described by Shackleton (op. cit., p. 2 and 3) are recorded later (p. 17).

The older rocks of the Sattima Series are phonolites and trachytes and the younger non-porphyritic basalts are the Laikipian representatives. It is possible that some of the pyroclastic rocks associated with rocks of the Sattima Series may be older than the Kamasian, perhaps even Pliocene, as considered by Shackleton (1945, p. 6) for the Kinangop trachytic tuffs.

To avoid possible confusion due to the recurrence of the word Laikipian, the equivalents of Shackleton's "rocks of the Laikipian vents" (op. cit., p. 4) are called rocks of the Younger Aberdare Vents in the present report and are described later (p. 23).

Shackleton (1945, p. 2) recognized a porphyritic trachyte, which he called the "Dragon Teeth Trachyte", in the Sattima Series on Sattima in the Nyeri area. No similar porphyritic trachyte was seen on Niandarawa, although a markedly porphyritic trachyte found west and south of Kijabe township is believed by the writer to be correlatable. Successive flows of trachyte become less porphyritic, and the uppermost of this particular suite were probably referred to previously as the Limuru Trachyte by Sikes (1934, p. 20).

Flows of phonolite and trachyte (Plh_1) within the pyroclastic rocks (Plt_1 and Plt_2) east and north of Kijabe station were contemporaneous with the later of the trachytes. The southern extensions of these flows interdigitate with the Limuru Trachyte, representatives of which were found along the southern boundary of the area near the old Escarpment railway station and Matathia. The earlier lavas were probably partly erupted in Pliocene times; younger flows intercalated in pyroclastics being of Pleistocene age.

Laikipian basalts succeed the Sattima Series, and representatives are found mainly in the Kikuyu special area and east of the Aberdare range. Essentially, they are fine-grained, dark basaltic rocks, and one lava flow found intercalated in the pyroclastics (Plt_2) was traced over a considerable distance through the Kikuyu special area, chiefly in the Kiambu and Fort Hall districts. In the Othaya location essentially fine-grained basalts cover a fairly large area.

The age of the pyroclastic rocks in which the basalt flow occurs extensively east of the escarpment is Kamasian, lower Middle Pleistocene, and the top of the Sattima Series and Laikipian Group is considered to be the uppermost member of the pyroclastic suite (Plt_2).

The non-porphyritic lavas of the Sattima Series and Laikipian Group probably do not exceed 2,000 feet in thickness. The pyroclastic rocks and intercalated trachytes, phonolites and basalts are considered to be between 500 and 1,000 feet thick, while in the scarps near Kijabe the trachytes and phonolites found in these pyroclastic rocks are never more than 300 feet thick.

3. Younger Pleistocene Volcanic Rocks and Holocene Sediments

The eruption of trachytes and phonolites after the Simbara Series was followed by the deposition of pyroclastic rocks, which continued until upper Middle Pleistocene times. The upper Middle Pleistocene pyroclastic rocks (Plt_3), including a welded tuff (Pltf), are considered to be younger than rocks, including pyroclastics, of the Simbara Series and Laikipian Lavas. Some of these pyroclastic rocks were deposited around the base of the Aberdare range, lapping around the southern slopes of the Elephant and extending into the Kiambu, Fort Hall and Nyeri districts, where they, like the Sattima Series and Laikipian basalts and associated rocks, were deposited unconformably on the eroded surfaces of the Simbara Series. The pyroclastic rocks produced an even surface sloping gently away from the mountainous regions.

The pyroclastic rocks appear to have been locally eroded before the deposition of succeeding rocks. This can be observed near Githuya in the Kiambu district, where in a valley cut in the pyroclastic rocks a basalt flowed over a felspar-rich sand.

Pyroclastic rocks (Plt_2) which form the Kinangop scarps are probably partly of Kamasian age (lower Middle Pleistocene) (*see* Thompson and Dodson, 1963, p. 14). They are overlain by other pyroclastic rocks (Plt_3) which on archaeological evidence are considered to be of Kanjeran age (upper Middle Pleistocene). Rift faulting became intense towards the end of the earlier phase of the pyroclastic eruptions, but the Kanjeran deposits are of local extent, comparatively thin, and post-date the phase of rift faulting.

In Kanjeran times, in the upper Middle Pleistocene, the deposition of these fragmental rocks had almost ceased, and the topography took on its present outline. Deposits of Kanjeran age can be seen on Durie's farm resting unconformably on the older deposits, and artifacts of pseudo-Stillbay culture have been found on the Kinangop in the vicinity of Kijabe. Along the eastern flank of the Rift Valley intense erosion formed deep valleys in the pyroclastic rocks and lavas, which because of later earth-movements and possibly climatic changes became infilled with talus. Such features can be seen clearly in the railway cuttings south of Kijabe station. Deposits of pyroclastic rocks were laid down concealing the fault-scarps in the region of Durie's farm.

Near the end of the intense Middle Pleistocene rift faulting, a further basaltic eruption took place and Kijabe hill was formed, its basalt (Plb_2) spreading over the porphyritic trachyte and pyroclastic rocks (Plt_2) near Kijabe township. The flows were not thick and do not appear to have piled up to any appreciable extent against the Kijabe scarp.

Trachytic and allied rocks from the Younger Aberdare Vents are believed to have been extruded in the Middle and Upper Pleistocene.

In the lower Upper Pleistocene, earth movements on the Rift Valley floor produced small scarps in the down-faulted pyroclastic sediments. Younger sediments, probably of Gamblian age, were deposited in hollows formed by later erosion. Penecontemporaneously, an upper Pleistocene lake in the Kedong valley was infilled with sediments, essentially ashes. In the Kijabe area these deposits were not very thick and it is difficult to differentiate them from later ashes derived from Longonot.

Probably during the latest Upper Pleistocene or even during the Holocene, the trachyte eruptions of Longonot took place and one flow reached the south-western part of the area. Contemporaneous with and post-dating these eruptions, outpourings of pumiceous ash covered much of the area near Kijabe and Longonot station.

At this time a large fault on Kijabe hill dropped down the western side of one of the trachytic craters. This portion of the crater is now probably concealed beneath younger ashes, which have also banked up against the eroded scarp and Kijabe hill.

Red soils are prevalent in the Kikuyu special area and, together with the grey soils that characterize swampy ground, are probably entirely Holocene in age. Fragments of obsidian and some artifacts were found in these soils.

Deposits of Pleistocene and Recent age are very variable in thickness. The sub-aqueous sediments rarely, if ever, exceed 100 feet in thickness, while the ashes and occasional lavas of both Pleistocene and Holocene age, although fairly widespread, are not thick, except where the ashes in particular accumulated locally.

V—DETAILS OF GEOLOGY

For descriptive purposes the following divisions have been made:—

	Thickness (feet)
5. Pleistocene and Holocene sediments	<100
4. Trachytic rocks of the Younger Aberdare Vents	?
3. The Kijabe-type Basalts	?
2. Pliocene ? to Middle Pleistocene Sattima Series and Laikipian Lavas:	
(3) Laikipian basalts and allied rocks	<2,000
(2) Pyroclastic rocks	Between 500 and 1,000
(1) Rift Valley Trachytes and Phonolites	<300
1. Miocene ? —Simbara Series	>3,000

1. The Simbara Series

The Simbara Series, consisting of basalts and basaltic agglomerates, was first described by Shackleton (1945) from around Nyeri, where representatives compose the high peaks of the Aberdare Range. The equivalents in the Kijabe area are believed to be the oldest rocks present and form the mountainous region including Niandarawa and Elephant, as well as the lower forested slopes of the Aberdares, the Fort Hall district, and part of the Nyeri district of the Kikuyu reserve; these rocks are probably Miocene in age. Although frequent references are made to the basaltic agglomerates of the Simbara Series, this rock group includes flow-brecciated lavas termed "autobreccias", similar to those described from Kilimanjaro, whose structure according to Wilcockson (1956, p. 225) results from the disruption of gassy lavas in *aa* flows. These autobreccias, as Wilcockson also observed on Kilimanjaro, are accompanied by subordinate quantities of solid lava, true agglomerates and tuffs, though the latter are rare in the Kijabe area.

Both lavas and particularly the agglomerates were subsequently deeply dissected, so that later lava flows and Rift Valley pyroclastic rocks were deposited on a very uneven surface.

The rocks of the Simbara Series are generally melanocratic when fresh, becoming lighter-coloured as the felspar content increases, when the basalts appear also to be more vesicular. Another characteristic feature is that black augite crystals often stand out on weathered surfaces, or can be easily seen on fractured surfaces. In specimen 43/585* from Niandarawa, the felspar crystals are sometimes arranged concentrically around vesicles. The lower basalts on Niandarawa are rich in ferromagnesian constituents and phenocrysts of felspar are rare. Near the peak, however, the rocks contain more felspar, and the felspar insets give an appearance of "chopped straw" to the rock. In

* Number 43/585, etc., refer to specimens in the regional collection of the Geological Survey, Nairobi.

specimen 43/579 from Fey's peak (Kiamweri), although the felspar insets are visible in hand-specimen they are smaller (about 2 mm. in length) than in the Niandarawa rocks. This rock is light grey in colour, with minute vesicles. Bronze-coloured olivine crystals partly altered to iddingsite are seen on fractured surfaces of specimen 43/600, from about 1½ miles south-east of the Aberdare Guest Farm. Some augite crystals in this specimen measure 1.5 cm. in length and 1 cm. across, but the altered olivine crystals rarely exceed 0.5 cm. in width.

Shackleton (1945, p. 2) compared the Simbara lavas with those of Kijabe hill. Both contain platy plagioclase crystals, rarely more than 2 mm. in length in the case of the Simbara basalts, but he distinguished (op. cit., p. 9) in the Simbara Series later basalts containing phenocrysts of augite and olivine only.

During work in the Nyeri area Shackleton (op. cit., p. 9) found boulders of a plutonic rock, an essexitic (?) gabbro (specimen 43/65), in the Turasha river near Tulaga. A plutonic outcrop was not located during the present survey, but the source of the boulders possibly represents the oldest rock in the area, and most likely formed in the throat of the volcano responsible for the eruption of the porphyritic Simbara basalts.

The Simbara basalts consist essentially of phenocrysts of augite, olivine and plagioclase in a groundmass of the same minerals. The felspars are frequently intergrown, as in specimen 43/578 collected from Fey's Peak, while intergrowths between felspar phenocrysts and augite as well as with iron ores were occasionally seen, as in specimen 43/582 from the south-western slopes of Niandarawa. The plagioclase is usually labradorite but andesine and bytownite were also recognized. Zoning of a large felspar phenocryst can be seen in specimen 43/590, collected from two miles east of Ray's house.

Olivine is invariably altered to iddingsite and sometimes possibly bowlingite, while serpentinous alteration products occur along cracks. Banded olivines were observed on rare occasions as in specimen 43/580, a piece of float collected on the western slopes of the Elephant. Hamilton (1957, p. 138) stated that banding of olivines in certain basalts in Scotland may be due to deformation by local shear during the closing stages of emplacement, and it is possible that this mode of origin may apply to the banding in the olivines of the Simbara basalts.

Poikilitic textures are common in the Simbara basalts, such as the inclusions of olivine within felspar in specimen 43/590, from the southern slopes of the Isanga Ridge.

The Simbara lavas are generally holocrystalline with interlocking felspar prisms, pyroxene grains and opaque iron ores constituting the bulk of the groundmass. Occasionally, interstitial glass can be seen in some of the rocks, but analcite was not identified. Titanaugite was sometimes seen in the groundmass, as in specimens 43/577 and 43/548, both collected from Fey's Peak, and as phenocrysts in specimens 43/579, also from Fey's Peak, and 43/593 mentioned below. Basaltic hornblende (lamprobolite) was seen in specimen 43/659 from near Kagongo village.

The opaque iron ore so liberally distributed throughout the groundmass in these lavas is either in subhedral crystals, as in specimen 43/586 from the south-western slopes of Niandarawa, or in needles as in specimen 43/581 from the same general locality and 43/584 from the western edge of the Twelve Apostles. Both types are rarely seen in the same rock, but specimens 43/582 and 43/593 are examples where both forms were recognized. The former was collected from about 1½ miles south of Niandarawa summit and the latter some three miles slightly north of west from the summit.

An analysis of a sample of Simbara basalt, 43/586A collected from the western slopes of Niandarawa, is given below. Phenocrysts of augite and olivine are seen in the hand-specimen.

Analysis of Olivine Basalt, Niandarawa

	%		*Norm*
SiO_2	46·58	or	7·78
Al_2O_3	13·67	ab	21·48
Fe_2O_3	6·15	an	21·96
FeO	6·37	di	24·94
MgO	7·66	hy	2·76
CaO	11·20	ol	6·13
Na_2O	2·55	mt	8·82
K_2O	1·30	il	5·02
H_2O+	1·70	ap	0·67
H_2O-	0·46		
TiO_2	2·66		
P_2O_5	0·25		
MnO	trace		
TOTAL ..	100·55		

Analyst: J. Furst.

This analysis indicates a composition similar to an alkali basalt, quoted by Campbell Smith (1931, p. 252), and described by Miss Neilson (in Gregory 1921, p. 404) as a basanite. It was collected by Professor J. W. Gregory in 1921 as an olivine basalt (Gregory, 1921, p. 139) and probably is a member of the Simbara basalts. It came from the Nyeri-Naivasha track at 10,500 feet, at the top of the pass over the Aberdare Range.

Basaltic dykes that have invaded rocks of the Simbara Series are represented by specimens 43/582, 43/590, 43/592 and 43/596. Specimen 43/590 was collected from almost two miles south-west of Tulaga, and 43/592 from about one mile south-west of the same locality. Specimen 43/582 was collected about 1¼ miles south of Niandarawa, and 43/596 came from the south side of North Lereko. The dykes, rarely more than 4 feet wide, are strongly jointed with closely-spaced joints striking north-south. The basalt dykes contain olivine, pyroxene and abundant laths of labradorite, with about 5 per cent of iron ores. They are normally characterized by felspar phenocrysts, though occasionally augite and more rarely olivine form smaller phenocrysts. These phenocrysts are set in a plexus of the same minerals.

One probable dyke consists of large bouldery rocks situated about a quarter of a mile south of Nyakianga. The outcrop is about 30 feet wide, striking at 110°, and is composed of porphyritic basalt (43/654). Joint directions in this outcrop are 50° and 330° In thin section the rock is seen to have the composition mentioned in the previous paragraph. A wall of rock about 15 feet high on the southern slopes of the Isanga ridge on Tulaga, which strikes east-north-east over a distance of about 30 feet, is also believed to be a dyke. Specimen 43/589 from Isanga ridge is vesicular and less porphyritic than basalts of the Simbara Series. A notable feature is the grouping of felspar prisms around felspar phenocrysts imparting a glomero-porphyritic texture to the rock.

Dykes on the high ground of Niandarawa and the Elephant are grouped in a swarm striking generally east-west. Features interpreted as dykes commonly appear on aerial photographs both on the eastern and western slopes of Niandarawa, though in the field the majority of such dyke features were rarely recognized because of the thick cover of moorland grass.

2. The Sattima Series and Laikipian Lavas

Overlying the Simbara basalts on and around Simbara in the Nyeri area Shackleton (1945, p. 2) recognized phonolites, olivine alkali trachytes, mugearites and fissile basalts, which comprised his Sattima Series. He believed that these lavas, particularly the fissile varieties, dip more steeply than the fall of the ground east of Sattima peak and pass beneath the Laikipian basalts which form the lower ground below the forests (op. cit.,

p. 3), though on his map he did not separate rocks of the Sattima Series from the Laikipian Lavas. Shackleton followed Gregory's definition of the Laikipian Lavas (Gregory 1921, p. 105), but restricted the use of the term to basalts which are essentially non-porphyritic though occasionally display small specks of olivine, and which are younger than the Simbara and Sattima Series. He also stated that the Laikipian basalts show a characteristic hackly fracture, and in thin section are mainly olivine alkali basalts and analcite basanites (op. cit., p. 3).

During the present survey a group of rocks unconformably overlying the porphyritic rocks of the Simbara Series was mapped as the Sattima Series and Laikipian Lavas combined. The variety of rock types comprising this group as recognized by Shackleton at Simabara was not observed in the vicinity of Niandarawa and the Elephant, although the non-porphyritic nature of the lavas overlying the Simbara Series there is diagnostic. It might have been preferable to have defined all the lavas only which overlie the Simbara Series in the Kijabe area as Laikipian, as they have greater affinities with the Laikipian basalts described by Shackleton from the Nyeri area. For the time being, however, grouping of the Sattima Series and the Laikipian Lavas is retained, as future geological investigations may discover rocks east of Niandarawa and the Elephant relatable to those included by Shackleton in the Sattima Series.

On the eastern flank of the Rift Valley trachytes and phonolites intercalated in pyroclastics are exposed. These lavas are considered to be older than a non-porphyritic basalt found within pyroclastics of the Laikipian Lavas in the Kikuyu special area and the Laikipian basalt in the north-east of the area. For want of further evidence these trachytes and phonolites and accompanying pyroclastics are all provisionally regarded as the equivalent of Shackleton's Sattima Series within the grouping of the Sattima Series and the Laikipian Lavas.

The essential feature of rocks of the Sattima Series and Laikipian group is their non-porphyritic texture.

(1) Rift Valley Trachytes and Phonolites

The rocks belonging to this group are best exposed in the scarps near Kijabe hill and township, and extend southwards to the boundary of the area. A trachyte seen in a scarp on the western border of the area 11 miles north-north-west of Kijabe hill is also included. The continuation of this trachyte in the Naivasha area has been assigned a Middle Pleistocene age (Thomson and Dodson, 1963, p. 17).

An outcrop of dyke-like appearance of highly porphyritic trachyte (Plh_1) occurring about half a mile south-west of Kijabe township was described by Shand (1936, p. 310) as a syenite-porphyry. The rock probably represents magma near the point of eruption or a deep-seated dyke along a fissure from which the lava was erupted. The outcrop forms the northern part of a fault-scarp extending southwards to the southern boundary of the Kijabe area, and is offset westwards by faulting near Kijabe. Also in the neighbourhood of Kijabe, near the Narok-Kijabe road, the scarp is about 150 feet high and covered by coarse, pale yellow tuff. A specimen of the trachyte, 43/679, from one mile west-south-west of Kijabe township, is highly porphyritic, mottled and slightly vesicular. The felspar phenocrysts vary from about 2 mm. to 3 cm. in length, and measure up to 2 cm. in width and thickness. The groundmass in the hand-specimen is a purplish grey colour. In thin section an abundance of phenocrysts of anorthoclase commonly about 0.8 mm. in length is seen, with fewer phenocrysts of slightly smaller plagioclase, augite and opaque iron ores. A feature of the large felspars are their rounded corners and some crystals have cavities infilled with groundmass. The fine-grained groundmass is light brown and liberally scattered with needle-like crystals, probably pyroxene, and microlites of felspars which sometimes have a radial pattern. Augite phenocrysts and smaller grains in the groundmass have a slight green to yellowish colour, and show no

pleochroism. A few twinned felspars present are probably oligoclase. A smaller amount of interstitial clear, isotropic material with a low refractive index is believed to be analcite. In a second thin section (43/679a), a corroded crystal of kataphorite was identified.

Two specimens of the same rock collected from the scarps near the Italian Memorial Church, 43/550 and 43/561, are of similar composition, though the felspar phenocrysts are smaller than in 43/679, and contain clusters of green pyroxene.

The majority of trachytes from other parts of the Kijabe area contain soda-rich felspars and pyroxenes. The felspars recognized are sanidine, anorthoclase and plagioclase, ranging in composition from albite to andesine, oligoclase being the most common. Cossyrite was identified in several specimens, two examples being 43/565 and 43/543 collected from one mile south-west, and three-quarters of a mile west, of Kijabe beacon respectively, while white-brown isotropic glass is frequently present, as in specimens 43/543 and 43/555, the latter from one mile north-east of Kijabe.

Both magnetite and ilmenite are present in these trachytes, magnetite having been recognized in specimens 43/555 and 43/545 from one mile north of Kijabe beacon, and ilmenite with leucoxene in specimen 43/558. The latter trachyte was collected in the second railway cutting north of the railway hut on the south-western slopes of Kijabe hill.

The trachyte occurring on the southern boundary of the area near the old Escarpment railway station is believed to be the Limuru Trachyte described by Sikes (1934, p. 20). A specimen (43/560) collected from a small quarry just beyond the bounds of the present area near the old Escarpment railway station has a mineral assemblage typical of most trachytes found in the Kijabe area. Sanidine is present as phenocrysts up to 3 mm. in length, while sanidine and aegirine-augite are the main groundmass constituents. Quartz was not recognized in the thin section of specimen 43/560, though Sikes (1939, p. 23), in describing the Limuru Trachytes, mentioned patches of poikilitic quartz. Similarly, Baker observed (1958, p. 19) that the Plateau Trachyte in the Magadi area, which is also the equivalent of the Limuru Trachyte, sometimes contains quartz. Microphenocrysts of pale yellow-green olivine surrounded by dense alteration products were also seen in specimen 43/650 described above.

Rather unusual examples of trachytes are represented by specimens 43/549 and 43/572, collected respectively from scarps on the farms belonging to Higgins and Durie. Both outcrops are quarried for building-stone, the former at 2½ miles north-west of Kijabe hill and the latter three-quarters of a mile south-west of Durie's house. Both examples are highly vesicular, light grey rocks, the vesicles being encrusted with a light yellow mineral, believed to be scolecite. In specimen 43/572 the vesicles are compressed and elongated, measuring up to 4 cm. in length. In thin section, felspar phenocrysts are seen to be set in a finely crystalline radiating plexus of potash felspars, aegirine-augite, riebeckite and cossyrite, with opaque ores including white leucoxene.

The trachytes in the vicinity of Kijabe are intercalated with phonolites and pyroclastic rocks, fine-grained types sometimes being difficult to differentiate in the field. No phonolites were recognized amongst rocks from the scarp north of Kijabe hill, although a phonolite, represented by specimen 43/680, was mapped near Kijabe township. A light grey, well-laminated lava found in the Tongitongi gorge, just above the railway-line and near to bore-hole C2138, is also a phonolite. Specimen 43/682, from near the intake of Kijabe's water-supply pipe-line further up the same gorge, is also a phonolite containing a little interstitial nepheline.

Specimen 43/680, from beside the old railway-line about one mile west of Kijabe township, contains between 10 and 15 per cent of altered nepheline, partly replaced by aegirine needles which form a green fringe around small nepheline phenocrysts.

Abundant cossyrite, strongly pleochoic from brown to almost black, is present in the groundmass and is associated with the pyroxene fringing the nepheline. The felspars forming the bulk of the groundmass are soda-orthoclase, occasionally showing poikilitic intergrowth with the dark minerals.

(2) Pyroclastic Rocks

Pyroclastic rocks in the neighbouring Naivasha area (Thompson and Dodson, 1963, p. 17, Plt_1 and Plt_2) are believed to be Kamasian in age.

In the Kijabe area, however, some of the pyroclastic rocks designated Plt_1 may possibly be older than the Kamasian where they occur with rocks of the Sattima Series, but this has not been definitely established. Further, Shackleton (1945, p. 6) considered the Kinangop trachytic tuffs to be Pliocene. Some of the younger pyroclastic rocks which are now described petrographically are not members of the Sattima Series and Laikipian, the division between them and the younger pyroclastic units was stated on p. 13.

In the vicinty of Kijabe township, where trachytes and phonolites are intercalated in pyroclastic rocks, these have been grouped as a single unit (Plh_1), and elsewhere another pyroclastic suite (Plt_2) includes a basalt flow.

Soft, light-coloured tuffs are the most common pyroclastic rocks. They frequently form thick deposits particularly on the Kinangop, and on scarps on the flank of the Rift Valley, as well as in the Kiambu district. They occur in the Fort Hall and Nyeri districts, and often fill hollows in the eroded basaltic agglomerates of the Simbara Series. The tuffs vary in composition. Shackleton (1945, p. 3) described the tuffs of his Kinangop Tuff Series as trachytic pumice tuffs, the matrix consisting of comminuted pumice, but in both the Kijabe and Naivasha areas many varieties containing fragments of pumice are also present. Such pumice tuffs are generally uncemented. Some tuffs, mainly in the vicinity of Kijabe, are of sub-aqueous origin, but the majority are believed to have been derived from Longonot, 10 miles west of Kijabe. Owing to the localized occurrences of the various tuffs and agglomerates it was not possible during this regional survey to work out a comprehensive stratigraphical succession, or establish reliable thicknesses, but, in both the Kiambu district and that part of the forest reserve in the vicinity of the Gikohi saw-mills, the approximate succession is as follows:—

Rock Type	*Locality*
Top	
Buff-coloured agglomerates	Gikohi
Yellow agglomerate	Makohokoho
Light greenish-grey, soft tuff	Nduriri
Grey yellow weathering agglomerate	Gacharage
Dark grey, pumiceous agglomerate with numerous obsidian fragments (specimen 43/618)	Gacharage
Grey agglomerate containing lava fragments (specimen 43/625)	Karatina
Grey agglomerate (specimen 43/621)	Kanyoni
Mauve-grey agglomerate (specimen 43/613)	Gathaite
Bottom	
Mauve-grey agglomerate, sometimes scoriaceous (specimen 43/626)	Kiarie
Light grey, coarse agglomerate	Githuya

Below the light grey coarse agglomerate, the following section containing water-lain sediments was measured on the road near Githuya village on the southern boundary of the area.

	Thickness (feet)
Light grey, coarse agglomerate	?
Obsidian-rich agglomerate	3
Buff-coloured coarse, felspar sand with lava fragments	6
Drab to buff-coloured, ashy sediment	1
Red clayey soil	2
Black welded tuff, weathering grey (specimen 43/610)	15
Vesicular basalt (specimen 43/611)	20
Drab-coloured felspar sand with water-worn pebbles (two inches in diameter) and yellow tuff	30
Grey agglomerate	15
Yellow pumiceous agglomerate which weathers grey (base not seen)	30

It is difficult to estimate accurately an average thickness for the generalized section of the pyroclastic rocks because of the localized development of the beds. The occurrences cannot be traced far laterally, nor is it possible to calculate reliably all their thicknesses because of variable dip readings. An indication of the variability is provided by the values and directions of dip estimated from outcrops of three "bands" within the succession quoted:—

	Dip (feet per mile)	*Direction of Dip (magnetic)*
Dark grey pumiceous agglomerate with numerous obsidian fragments	152	115°
Grey agglomerate	105	90°
Mauve-grey agglomerate	72	130°

A further complication liable to upset calculation of thickness is that the pyroclastic rocks were deposited upon an eroded surface of the Simbara Series. Assuming that the approximate slope of the surface on which the pyroclastic rocks rest was 1° in a south-easterly direction, their thickness along a line from a corner of the forest boundary on the Kinangop near Nightingale's farm-house, through a point between Makohokoho and Wanugu, to Githuya on the southern border of the area, could be 1,000 feet. The difference in height between the two boundary points is about 3,200 feet and the distance between them some 25 miles. As there is the possibility of a steepening of the floor of Basement System rocks towards the Rift Valley, and a similar steepening of the Simbara Series that rests on it and underlies the pyroclastic rocks, 1,000 feet might be an over-estimate. Deep bore-holes have not yet penetrated the pyroclastic rocks to the underlying rocks, nor is it certain that the pyroclastic rocks exposed in the scarps flanking the Rift Valley represent the full sequence erupted. The local nature of some of the tuffs and agglomerates seen, and the possibility of several centres of eruption, suggests that the total amount of pyroclastic rocks deposited in the Kijabe area may not be so much as a summation based on outcrop at diverse localities indicates, and the writer considers that the thickness is probably between 500 and 1,000 feet.

Intercalated in the pyroclastics within the Kikuyu reserve and part of the forest reserve is a basalt mentioned previously, which is believed to belong to the Sattima and Laikipian Series. Also intercalated in places in the pyroclastics between Plt_2 and Plt_3 are welded tuffs, weathering to a light grey colour. Specimen 43/610, collected from near Githuya, is typical, the unweathered glassy-looking rock being black with white mottling, but on the weathered surface having the appearance of a grey agglomerate.

In thin sections the welded tuffs were seen to contain abundant angular crystal and rock fragments, distributed through a glassy base, as in specimen 43/610. In some cases silicification of the matrix has occurred, as in specimen 43/624 from half a mile north-east of Kathirika.

Both the welded tuff and the pyroclastic suite (Plt_3) are thought to be younger than the Sattima Series and Laikipian Lavas.

(3) Laikipian Basalts and Allied Rocks

Rarely are phenocrysts seen in these rocks, but in most thin sections microphenocrysts of olivine, pyroxene and felspar are found, though microphenocrysts are sometimes absent or rare, as in specimens 43/617 from half a mile south of Kamunyaka, and 43/638 from half a mile south-east of Kigori village. The groundmass usually consists of a plexus of pyroxene and olivine grains, iron ores and felspar laths with occasional interstitial glass. There are a greater variety of textures than in the Simbara Series rocks; flow and glomeroporphyritic structures are particularly common.

Thin sections reveal microphenocrysts of pyroxene and olivine with a liberal sprinkling of opaque iron ores situated in a holocrystalline matrix in specimens 43/623 and 43/651, from a mile west-north-west of Gakoe village, and from the forest edge along the Kimakia river respectively.

Specimen 43/662 contains a few bytownite insets, and in a thin section of specimen 43/663 small cubes of iron ore tend to occur in glomeroporphyritic groups. Specimen 43/662 was collected half a mile south of Githambo, and specimen 43/663 half a mile west of Kihome. In the lava fragments of an agglomerate 43/665, collected half a mile south-east of Iriaini school, numerous felspar laths are grouped around rare olivine microphenocrysts.

The most common rock type forming part of the Sattima Series and the Laikipian Lavas is olivine basalt. Typical examples are specimens 43/633, from near Narugutu market and 43/651 mentioned above. The olivine basalts are non-porphyritic and rarely vesicular. They consist of olivine showing alteration to iddingsite and bowlingite, with pyroxene, felspar prisms, and opaque iron ores. Pyroxenes and olivines, in almost equal proportions, comprise the bulk of the microphenocrysts. The pyroxenes are usually augite but rare titanaugite and pigeonite were recognized in specimens 43/617, 43/651 and 43/665. Labradorite is common in most specimens though both andesine and bytownite are sometimes present. The groundmass is composed largely of olivine and pyroxene grains with abundant iron ore cubes. Interstitial alteration products were recognized, including pseudo-isotropic or isotropic brownish palagonite, and an olive-green, greenish brown antigorite were identified in specimens 43/642 and 43/672. Specimen 43/642, was collected half a mile north-west of Makomboki and specimen 43/672, a similar distance south of Kairuthi.

A single specimen, 43/649 from two miles WNW of Gotakaini, is classified as a mugearite. Shackelton's (1945, p. 14) description of mugearites from the Nyeri area applies equally well to this rock from the Kijabe area. In the hand-specimen the rock is slightly fissile and dark grey to black, with a characteristic light grey weathered zone about 5 mms. thick beneath a brown iron-rich skin. In a thin section, rare phenocrysts up to 6 mms. in length of a sodic plagioclase, some of which is oligoclase, and orthoclase are to be seen. The mugearite is characterized by the presence of sodic plagioclase, orthoclase, and by its trachytic texture. Fragments of pyroxene, chlorite and iron ore are also present.

In specimen 43/663, a trachy-andesite, locality already mentioned above, the olivines and pyroxenes are difficult to distinguish owing to alteration products, including iddingsite and serpentine.

A basalt specimen 43/664, collected from a bomb-crater 1½ miles NNE of Mazuri caused during a bombing raid on Mau Mau terrorists, contains analcite and is considered as an analcite basalt. Specimen 43/665, from Thunguri, also contains some analcite in the groundmass.

In the Kijabe area, the upper boundary of the Sattima Series and Laikipian Lavas group is considered to be either the top of the building stone trachyte (Plh_1) or the top of the pyroclastic formation (Plt_2) with intercalated basalt, which in the west of the area is overlain in places by a welded tuff (Pltf). This welded tuff separates the two pyroclastic rock horizons (Plt_2 and Plt_3).

3. The Kijabe-type Basalts

These were described by Shand (1937, pp. 265-267), and later Shackleton (1945, p. 16) found similar rocks in the Nyeri area. It is now believed that the Kijabe basalt is not contemporaneous with the Simbara basalts as Shackelton (1945, p. 2) thought, nor with the Mahindu river basalt in the Naivasha area as Thompson and Dodson (1963, p. 24) considered. Thompson and Dodson assigned a probable Lower Pleistocene age to the Mahindu basalt, found beneath a series of pyroclastic rocks and subaqueous sediments, the youngest of which is of Middle Pleistocene age. During the present survey the basalts of Kijabe hill were found overlying trachytes intercalated in this same series of pyroclastics and sediments. It is considered, therefore, that the Kijabe basalt is younger than the Mahindu basalt and post-dates the faulting in this part of the Kijabe area. No basalts were found associated with pyroclastic rocks on the scarps of Higgins' farm five miles north of Kijabe township, nor were they seen overlying sediments bearing pseudo-Stillbay artifacts on the Kinangop. The presence of a now ill-defined crater at the summit of Kijabe hill also suggests that the Kijabe basalts are younger than the Simbara or Mahindu basalts.

Three specimens of basalt 43/542 collected from the summit of Kijabe hill, 43/554 and 43/569—show a high degree of vesicularity. The vesicles, particularly in specimen 43/554 from a cutting on the old railway line about one mile WNW of Kijabe township, contain zeolitic minerals. Purplish brown titanaugite is the common pyroxene in the groundmass, while radiating clusters of felspar and pyroxenes are abundant in specimen 43/569, which was collected from the south-western slopes of Kijabe hill about a mile from the beacon.

An analysis of Kijabe basalt given by Shand (1937, p. 266) is quoted below:—

Analysis of Kijabe basalt

	%		*Norm*
SiO_2	46·74		
Al_2O_3	18·88		
Fe_2O_3	3·11	or	10·01
FeO	7·15	ab	28·82
MgO	3·16	an	27·52
CaO	9·30	ne	3·69
Na_2O	4·17	di	7·58
K_2O	1·67	ol	8·08
H_2O+	0·63	mt	4·41
H_2O-	1·07	il	4·56
CO_2	0·16	ap	3·25
TiO_2	2·44	$CaCO_3$	3·30
P_2O_5	1·29		
F	0·11		
MnO	0·18		
Less O for F	0·05		
TOTAL ..	100·01		

Analyst: S. J. Shand.

4. Trachytic rocks of the Younger Aberdare Vents

Two small eroded volcanic vents, forming rounded hills at Fort Warwick in the forest reserve, and at Karima hill in the Nyeri district, appear to be composed of trachyte and mugearite. In a thin section of specimen 43/655 (from Fort Warwick), the

felspars exhibit fluxion structure and are mostly oligoclase and sanidine. Small clusters and shreds of green, sometimes slightly pleochroic aegirine-augite, rarely greater than 0.2 mm. in length, are associated with the felspars in the groundmass. Sphene is quite common and there are many small olivine grains some of which are considerably altered to iddingsite. Opaque iron ore minerals are fairly common, several occur as microphenocrysts, and there is some chlorite. This rock is classified as a mugearite.

A thin section of 43/677 (from Karima) reveals only rare olivine, but contains epidote, sphene and less iron ore. The fresh felspars, mostly sanidine with albite and oligioclase, exhibit good trachytic texture and the rock is classified as a trachyte.

A rock collected from a small hill at Fort Lancaster, probably another remnant volcanic vent, is an olivine basalt (specimen 43/650).

Two more rock samples from old volcanic vents on the Kinangop are represented by specimens 43/603 and 43/607. The first specimen was collected on Reynard's farm on the northern boundary, and the second from just south of the Kitiri river. These rocks, which are weathered, appear to be trachytes, specimen 43/607 probably representing very pumiceous lava. There is much opaque material in thin sections, and the microphenocrysts include strongly pleochroic orange-brown biotite. The weathered felspars, probably sanidine, are fluxionally arranged, and the vesicularity of the rock has not altered the texture. There is a small amount of possible analcite in both thin sections, and in specimen 43/607, a brown isotropic mineral is probably palagonite.

5. Pleistocene and Holocene sediments

Thompson and Dodson (1963, p. 39) considered, partly on archaeological grounds, that certain sediments intercalated in pyroclastics below a prominent band of welded tuff in the Naivasha area, were deposited in lower Middle Pleistocene (Kamasian Pluvial) times. These sediments, composed mainly of pyroclastic material though some were deposited subaqueously, are exposed both in the scarps on the eastern flank of the Rift Valley and in the Njorowa gorge. Comparable sediments were not observed in the scarps forming the western edge of the Kinangop platform in the Kijabe area, but soft agglomerates and ashy beds seen in the scarps near the Kerr and Knight farm-houses may be the equivalent.

Coarse pumice and rubble beds in a railway cutting about one mile west of Kijabe station are probably also representative of Kamasian deposits.

Small faults in the Rift Valley floor on Mt. Margaret Estate, have exposed light-coloured lacustrine sediments which resemble certain Kamasian rocks exposed in the Njorowa gorge, and are accordingly believed to be of Kamasian age. The lake-beds on this Estate are exposed in a scarp about 15 feet high, and the agglomeratic material of which they are composed is fairly well compacted and remarkably uniform. Overlying these beds unconformably are lacustrine sediments about 10 feet thick and composed of grey pumiceous material deposited in erosion hollows, probably formed during the Gamblian pluvial period. Sediments probably deposited during the interpluvial between the Kanjeran and Gamblian pluvial periods, are represented by a thin bed of red heterogeneous, clay-like pumiceous material below the grey lake beds. The sequence is:—

Sediments	*Proposed Climatic stage*	*Approximate thickness (in feet)*
Grey pumice lake-beds	Gamblian	10
Red clayey pumiceous beds ..	Interpluvial	3
Unconformity ?	Kanjeran ?	
Yellow compact agglomeratic beds	Kamasian	15

More extensive lacustrine beds including thick diatomites at Kichero (Gicheru) on the east side of Kedong Valley, illustrated by Sikes (1926, between pp. 396 and 397) occur south of the present area.

Sediments in which pseudo-Stillbay artifacts have been found accumulated locally during the Kanjeran pluvial on the Kinangop. Such sediments, which are light coloured and mainly composed of pyroclastic material, can be seen to have been deposited on a greenish grey welded tuff at several exposures along the edge of the Kinangop platform. The welded tuff is believed to mark the close of the Kamasian pluvial period.

At Durie's site, Shackleton (1955, p. 261) noted that laterites "pass smoothly, on a 5° slope, over the edge (of the Kinangop), overstepping successive beds of the trachytic tuff beneath". During the present survey, the following succession was noted in this vicinity:—

		Approximate thickness (in feet)
Light grey silty soil, probably a recent ash	Holocene	2–4
Drab, pumiceous silty beds with laterite pebbles.. ..	Kanjeran	2
Nodular laterite with calcrete nodules	Kanjeran	up to 4
Light brown to drab agglomerate	Kamasian	5–10
Greenish-grey trachyte, highly vesicular	Kamasian	10–15
Buff agglomerate (base not exposed)	Kamasian (?)	15±

The nodular laterite, which varies from a few inches to about four feet in thickness, overlaps the vesicular trachyte onto the underlying buff agglomerate. Pseudo-Stillbay artifacts like those found in lateritic deposits at several archaeological sites elsewhere on the Kinangop, are also found in the nodular laterite at Durie's site. In the writer's opinion these deposits represent an old laterized soil, which rested unconformably on the trachyte, welded tuff, Kamasian sediments and pyroclastic rocks on the Kinangop. At Wetherall's site, where the Naivasha-Njabini road reaches the Kinangop platform, similar deposits have yielded pseudo-Stillbay artifacts. Cole (1954, p. 161) states that Fauresmith artifacts have also been found in the same horizon on the Kinangop though not at Wetherall's site, the pseudo-Stillbay and Fauresmith cultures being penecontemporaneous in late Kanjeran times. Shackleton (1945, p. 5) noted that artifacts of the Fauresmith culture (which was developed between the upper Middle Pleistocene and early Upper Pleistocene) were found in red and pale lateritic earths in the Nyeri area. Artifacts and numerous fragments of obsidian are still being found in the red soils in Kikuyuland in the Kijabe area.

Undifferentiated grey to buff ashes and pumice beds in the south-western part of the Kijabe area are considered to be Upper Pleistocene to Holocene in age.

The larger of the pumice beds about Kijabe hill, some of which are quarried for building material, are probably of Holocene age, and are composed of ejectamenta from Longonot. A typical section of the pumice beds exposed in an old quarry beside the road leading to the Kinangop is recorded below. This road leaves the main tarmac road about two miles north of Longonot station.

Description	*Approximate thickness (in feet and inches)*
Reddish-brown scoriaceous and pumiceous ashes, (individual fragments up to 4 inches across)	5·0
Light grye fine pumice ash	9
Drab pumiceous ashes, calcareous in parts	4·0
Grey fine pumice ash	1·6
Grey coarse pumice showing graded bedding	6
Yellow ochreous pumice with lava fragments	8
Grey pumice with many lava fragments (trachyte), some up to 1 foot at base of exposure	12·0

The pumiceous beds in this section dip eastwards at 6°.

The powdery light grey pumiceous ash found over much of the wheatlands of the Kinangop, was deposited in post-Kanjeran times, possibly in the Holocene, and may be equivalent in age with the pumice eruptions derived from Longonot. It has not been differentiated on the map. At Sisiun on the edge of the Kinangop, coarse pumice fragments up to half an inch across are common in the soil. These ash eruptions do not appear to have extended far into the Kikuyu special area or to have been deposited there and subsequently removed by erosion, because typical red soils are found in the greater part of the reserve.

Travertine has been deposited from springs issuing at the foot of the scarp on the western edge of the Kinangop plain, and on the Mara Ngishu estate a travertine deposit was found to be about 60 feet thick (Baker, 1959). These travertine occurrences, which are probably of upper Pleistocene age are dealt with in more detail later in this report.

Black soils, including black-cotton types occur in regions of poor drainages and swamps, a typical example occurring south of Gachichi. Along the rivers, particularly in the Nyeri and Fort Hall districts where the rivers flow in wide valleys, black soils are frequently encountered.

VI—STRUCTURE

Faults.—The Sattima fault is the major fault in the Kijabe area (*see* Fig. 3) and represents a continuation of the Rift fault mapped by Shackleton in the Nyeri area. Its total length in this region is about 70 miles, 25 miles in the Kijabe area and 45 miles in the Nyeri area: it forms one of the eastern boundary faults of the Gregory Rift Valley. The maximum displacement along the Sattima fault in the Kijabe area is in the region of 3,000 feet. The majority of faults connected with and situated nearer the Rift Valley are shorter in length than the Sattima fault, and quickly die out in either direction.

The southern continuation of the Sattima fault described by Shackleton (1945, p. 19), forms the scarp to the east of the North Kinangop and cleaves the mountainous region. Fey's Peak (Kiamweri), and the Isanga ridge (Tulaga), represent the downthrow western side of the fault, whereas Niandarawa and the Elephant occur on the upthrow side. Branching of the Sattima fault in the Nyeri area and the attitude of the rocks between the branches suggested to Shackleton (op. cit., p. 8) that the fault is inclined westwards, indicating that it is normal and tensional. Although it was not established that the branch of the Sattima fault continues into the Kijabe area, some features were observed which may support Shackleton's conclusion on the nature of the fault.

Shackleton (op. cit., p. 21), showed that it is untenable that the age of the Sattima fault belongs " to an earlier phase (of faulting) than the Kinangop faults". As the intense phase of faulting along the western edge of the Kinangop is now considered to be pre-Kanjeran, probably during the second inter-pluvial, the Sattima fault must be ascribed to a Middle Pleistocene age.

Another fault on the eastern slopes of Niandarawa separating it from the Twelve Apostles, has downthrown the Simbara agglomerates to the east; thus the Niandarawa peak is a horst. It is judged that the dip of the fault is about 70° east.

In the south-western part of the area grid faulting is intense, e.g. near Sisiun. Grid faulting occurs when two parallel intersecting faults produce rectangular or near-rectangular fault-blocks resembling railway station platforms. The faults on the Kinangop do not represent great movements whereas those flanking the Rift Valley, although not of the same magnitude as the Sattima fault, are nevertheless spectacular, probably on account of the narrowness of the resulting fault-blocks.

In the vicinity of Sisiun the young pumice eruptions have covered over the fault-scarps, particularly in the vicinity of the Longonot-Kinangop road, so they now form less spectacular features.

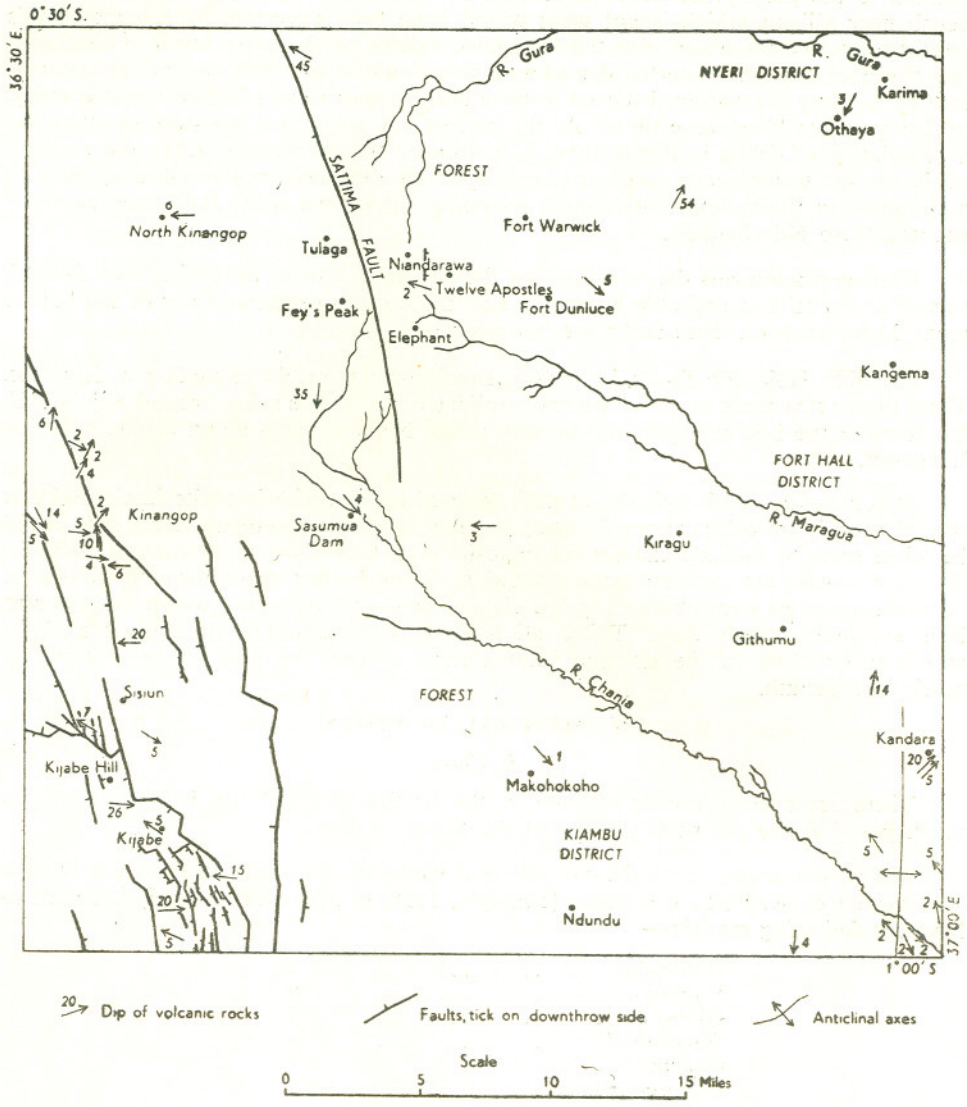


Fig. 3—Structural map of the Kijabe area

The general trend of the faults in the Kijabe area particularly those flanking the Rift Valley is NNW-SSE, although several diverge notably from that direction. In the vicinity of Kijabe township the trend of the closely spaced faults is more north-west—south-east, although numerous cross-faults, generally with small throws, are also present.

The general NNW-SSE fault-trend occurs in the oldest rocks exposed in this section of the Rift Valley and affects the porphyritic trachytes at the bases of the Rift Valley scarps. NNW-SSE-trending faults are perhaps the oldest that have affected this part of

the Rift Valley. Younger faults affecting the trachytes along the southern boundary of the Kijabe area, have an almost north-south trend. It is believed the north-south faults have had the effect of dropping down the finer-grained trachytes and phonolites in relation to the porphyritic trachyte, so that the porphyritic trachyte forms the lowest bench near Kijabe, which is not what would have been expected. Movement of this type is supported by evidence of the talus-filled valleys on the scarp above the railway-line south of Kijabe. Ill-sorted deposits of lava boulders and soil can be observed in railway cuttings in what are believed to have been former valleys incised into the scarp, probably in late Pleistocene times. As the present day scarps are too steep to allow the accumulation of debris in this fashion, it is deduced that previously, when the gradient of the ancient watercourses was less steep, deposition exceeded erosion allowing talus to accumulate in the valleys. Subsequent movement along the same fault-lines has now exposed these old channels.

Kinangop sediments deposited during the Kanjeran pluvial have also been faulted, as well as deposits of probable Kamasian age in the south-western corner of the Kijabe area. Movements on these faults rarely exceeded 20 feet.

Probable Holocene faults have very small throws, rarely exceeding a few feet. These minor structures occur in the unconsolidated pumiceous ashes around Kijabe hill, but some of the best examples can be seen in the Naivasha area about a mile north of Longonot.

Minor Folds.—Although the overall slope of the pyroclastic rocks in the Kikuyu special area is probably about 2° east, the few localities where measurements could be taken seem to indicate exactly the opposite dip. Exposures of pyroclastic rocks in the river courses are rare and confined mainly to the harder bands forming waterfalls. Most dip readings were obtained in the vicinity of the Chania river where the different beds are more clearly seen. Taken all together dip measurements suggest a slight anticlinal structure in the extreme south-eastern corner, the axis probably trending nearly north-south.

VII—MINERAL DEPOSITS

1. Clays

There are a great variety of clays in the Kijabe area but few have been put to much practical use except at the site of the Sasumua dam.

The Sasumua clay from the dam-site and flanks of the Sasumua river nearby was investigated by R. H. S. Robertson (Terzaghi, 1958, p. 376) and on analysis found to have the following modal:—

Halloysite	58·9
Kaolinite	3·9
Gibbsite	9·1
"Geothite"	15·9
Quartz	6·4
Other constituents	5·8

The halloysite crystals consist of tubes with a length of about 0.5μ and an external diameter of about 0.08μ. The "goethite" (iron hydroxide) particles were said to be too small to be measured. Though only three representative samples of Sasumua clay have been investigated, the data given by Terzaghi makes it fairly certain that a large portion of the clay consists of halloysite and a considerable portion hydrated iron oxide.

Terzaghi (op. cit., p. 369) stated "the major portion of the dam consists of the products of tropical weathering of basaltic lavas, tuffs and breccias. The clay content of these residual soils and their plastic limits are abnormally high, and the dry density at optimum moisture content is abnormally low. The unusual properties of the soils

gave rise to doubts as to whether the soils could be used safely as a constructional material for the bulk of an earth dam". The results of the mineralogical and physical investigations, however, showed that the abnormal properties were assets and that the material could be safely used for dam construction.

Coloured clays are common in the area but most are of very local extent. Weathering of the basalts and basaltic agglomerates, chiefly those belonging to the Simbara Series, frequently produces blue, red and cream-coloured clays, the pyroclastic rocks weathering into a variety of coloured clays.

In 1945 Dr. W. Pulfrey paid several visits to a portion of the Kikuyu forest reserve north of Kijabe station and township, on which P. E. Anderson proposed to burn bricks. The clays from this area were found to be suitable for the manufacture of bricks and tiles, but of a quality inferior to the generally accepted standard in Britain and elsewhere. Certain bands of the clays were found to be alkaline and unsuitable, but Pulfrey (1945) estimated that some 1,500,000 short tons of usable clay were present in the concession area.

Brick-clays on J. W. Etherington's farm on the Kinangop were also investigated by Pulfrey, in 1948. He considered that these clays were derived from lacustrine deposits, and suggested an intensive pitting and sampling programme.

In an unpublished departmental report Pulfrey (1957) stated that chippings from a bore-hole drilled at the Kerita spring, at depths of between 10 and 20 feet were much kaolinized but in a road cutting about 100 yards south of the bore-hole little whitening by kaolinization was evident. Pulfrey believed that the tonnage of kaolin is likely to be small, as this clay probably only occurs in the immediate vicinity of the spring.

2. Building-stone and Sand

Ample quantities of building-stone exist in most parts of the Kijabe area except in parts of the Fort Hall and Nyeri districts. Indurated tuffs and agglomerates form the main source of supply, although two quarries were seen where scoriaceous and vesicular lava were worked; one on Rex Higgins' farm and the other on Durie's farm on the Kinangop. Specimens of these lavas, 43/549 and 43/572 have already been described (p. 19).

Quarries in the trachytic tuffs within the Kikuyu special area are rarely worked economically, the rock faces becoming smothered with rock waste as a result of trimming the extracted stone. Weathering has frequently produced a thick overburden of red soil, or a cream-coloured sometimes yellowish decomposed material, which when more than about six feet thick generally renders the extraction of good building-stone uneconomical. Hard stone and stone liable to efflorescence of sodic salts are not favoured by buyers. The limited outcrops of pyroclastic rocks in the Nyeri district have made it necessary to quarry building-stone where the overburden is often thick. On the southern banks of the Gura river along the extreme northern edge of the area, a quarry in tuffs is situated about a mile north-east of Kagere, where a quarry face exposes rock 30 feet thick beneath an overburden of about 44 feet. The section exposed is:—

	Approximate thickness (in feet)
Brown and red soil	c.10
Bluish, purple and drab-coloured weathered basalt and soil ..	15
Blocks of basalt	c. 4
Yellowish brown soil	15
Grey mottled yellow coarse tuff	30

Just south of the Kijabe area near the old escarpment railway station, a quarry in trachyte correlated with the Limuru Trachyte is being worked for building-stone. Other outcrops of this trachyte within the Kijabe area could be worked if necessary.

In Appendix 4 of the Development Committee Report in 1946, it was stated (p. 55) with regard to sand that "there is little likelihood that any district (in Kenya) will experience a shortage" but in the vicinity of Kijabe sand was considered to be available only in limited quantities (p. 64). Reference was also made to building-stone of inferior quality also available near Kijabe, and it was estimated that sufficient quantities exist for the present-day and foreseeable future needs. Dealing with recommendations for increasing the supply and improving the quality of local building materials, the Development Committee suggested that efforts were required to increase the number of skilled stone-dressers by (*a*) improved quarry conditions and, (*b*) improved training of stone-dressers.

Where specifications are not exacting, sands for building purposes are available in valleys throughout most of the Kijabe area. Tests carried out in 1946 on typical non-quartzose volcanic sands collected by A. Huddleston from S. J. O. Armstrong's farm, Naivasha, revealed that cement mixtures containing these sands did not have the tensile strengths required by the British Standard Specification. Near Kijabe hill volcanic ashes are plentiful which could serve in a limited way as building sand while, in the Kikuyu special area, river sands although not plentiful, are probably sufficient for present-day needs. No extensive deposits of quartz sands occur within this area.

3. Pumice

Pumice is widespread throughout the western part of the Kijabe area particularly north of and near to Kijabe hill. J. Walsh (1957 and 1958) in unpublished departmental reports, estimated at least 80,000 cubic yards of pumice in a quarry covering some 50 acres, situated almost on the western boundary of the Kijabe area about a mile north of Longonot station. Similar deposits are located near the Longonot-Njabini road between Longonot station and the edge of the Kinangop plateau, but because of overburden detailed investigation is required on the quality of pumice available and the possibility of its economic extraction. On the north-western and western flanks of Kijabe hill pumice was observed but it is doubtful if the quality is good. Other occurrences were seen on the Rift Valley floor between Kijabe hill and near the Kijabe-Narok road, but the pumice is contaminated with fine volcanic dust and ash.

4. Limestone

In 1949, Dr. W. Pulfrey investigated a deposit of tufa limestone on Marshall's farm "Glenleedle", at the foot of the Kinangop scarp, and concluded that it was formed by precipitation from a spring, probably in (Upper) Pleistocene times. This limestone is now being removed by a stream from a spring that emerges east of the limestone occurrence. The limestone deposit extends about 50 yards, thins rapidly towards the edges and appears to be thickest nearest the scarp where a maximum thickness of about nine feet has been reported.

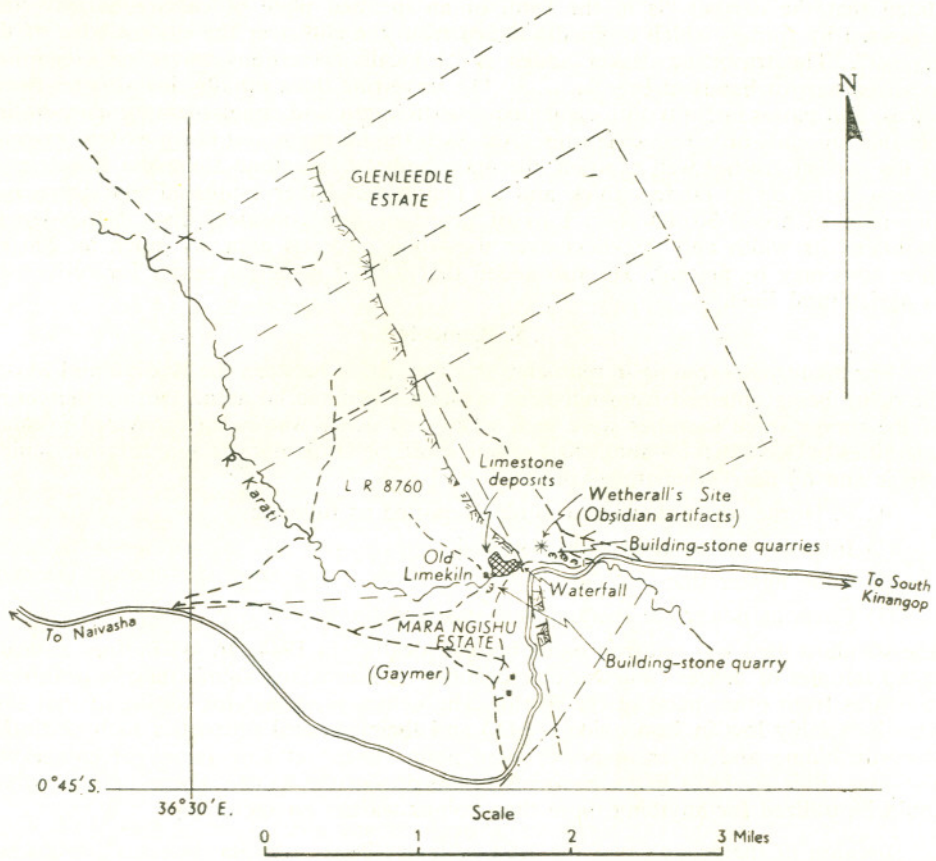
An analysis of the limestone made in 1949 follows:—

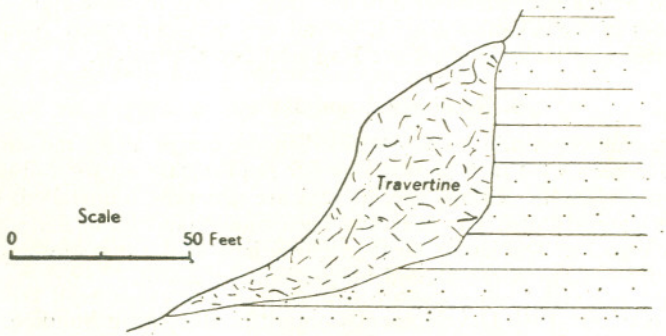
SiO_2	2·39
Al_2O_3	1·52
Fe_2O_3	1·19
MgO	0·08
CaO	50·90
H_2O	0·81
TiO_2	0·12
Loss on Ignition	42·40
TOTAL	99·41

Analyst: East African Industrial Research Board.

Pulfrey stated that the only commercial value of the deposit would be as limestone (for grinding for agricultural purposes) or by burning for lime for agricultural and building purposes, but limited reserves prevents exploitations on a large scale.

THE MARA NGISHU LIMESTONE DEPOSIT





Diagrammatic section in the Karati River

After B. H. Baker

Fig. 4—The Mara Ngishu Limestone Deposit

Another travertine deposit on the Mara Ngishu estate was reported on in 1959 by by B. H. Baker. This deposit occurs on the north bank of the Karati river at the base of the scarp on the western edge of the Kinangop plain. It is exposed in a cliff above the river, the bottom of the deposit being a few feet above the river-bed (Fig. 4). Baker stated that the deposit "is in the form of an inclined plate of calcareous travertine deposited by springs which originally issued from the cliff near the eastern edge of the deposit". The travertine, Baker added is "a locally cavernous travertine containing localized narrow bands of breccia. . . ." The travertine thins rapidly downstream (westwards) and passes laterally into cemented limestone grit and conglomerate incorporating variable amounts of volcanic detritus. Although the northern and north-eastern margins of the deposit are not well exposed, the main body of limestone along the Karati river is seen to be up to 60 feet thick and 50 feet wide. Baker estimated that there is a minimum of about 30,000 short tons of limestone and considers that, if the deposit maintains its width and thickness over the whole exposed area, as much as 200,000 short tons may be present. He also added that it is of sufficient purity for conversion to agricultural lime.

5. Pigments

For many years trading in red ochre was carried on between the Kikuyu and Masai, the ochre being obtained from hill-sides in the Kikuyu special area. During the course of the survey three localities were seen where red ochre was being excavated in small quantities by Kikuyu: (*a*) about half-a-mile south of Githambo village, (*b*) near Ichichi village and (*c*) near Mucharage village.

W. P. Horne who examined a sample reported as follows:—

(1) Intensity not so good as in standard.

(2) Tone lighter than standard.

(3) Covering power not so good as in standard.

The standard used was red iron oxide bought locally. In 1944 Dr. W. Pulfrey critically tested samples of ochres from various localities in Kenya and found they were inferior to ochres from other parts of the world. The ochres produced for testing at that time were invariably low in iron oxide (Fe_2O_3) and their physical properties such as tinting strength, hiding and covering power were poor. Their oil absorption percentage was also low. It is doubtful if the pigments found during the course of the present survey could be utilized for anything more than colour washes on buildings.

Because of the grouping of the Kikuyu into villages and the resultant competition between them in decorating their huts, several clays and pigments have been used to colour the mud walls of their houses; brown, cream, blue and purplish blue colours have been obtained by the application of different clays. Some of these clays came from the pyroclastic rocks in the Kiambu district, but all the red ochres were obtained from basaltic agglomerates and lavas in the Fort Hall and Nyeri districts.

6. Road-metal and Ballast

The trachytes, phonolites and basalts exposed in the scarps along the east flank of the Rift Valley have been used in a limited way for road-metal and for railway ballast. Roads in the forest and in the Kikuyu special area are generally unmetalled, but where metalling has been carried out it has generally been undertaken using material derived from the pyroclastic rocks. The basalt flows in the Kijabe area are a source of suitable road-metal; stone from Karima hill should be particularly useful.

In Appendix 4 of the 1946 Development Committee Report on building materials, it was stated (p. 55), that the resources of hard rock suitable for ballast are extensive and usually situated within practical distance of the consuming localities. Near Kijabe the committee stated that hard stone suitable for ballast is available within five miles of Kijabe. Quarries opened up since 1946 have exploited rock both for ballast and

building-stone. A ballast and road-metal quarry about one mile north of Longonot station just beyond the limit of the Kijabe area, has been worked for several years, and about a mile eastwards there are several smaller building-stone quarries.

7. Natural Gas

The presence of a "soda" spring about 2½ miles north of the Kerita Forest station (Fig. 5) had been known for some time, but it was not until 1957 that serious investigation into its nature began after carbon dioxide was detected in a small sample of gas collected by A. G. Richardson of the Richardson Drilling Company, who brought the sample to the Mines and Geological Department. A larger sample of gas collected by the author in August 1957 was analysed by the East African Industrial Research Organization, Nairobi, with the following result:—

Carbon dioxide (CO_2)	98·00
Combustibles (CH_4?)	1·00
Inert gases	1·00
TOTAL	100·00

Analyst: F. E. Dean.

Richardson working in partnership with W. L. K. Morson, sank a bore-hole to 234 feet near the spring later in the year and non-precious minerals lode location 3/1 was pegged around the bore-hole on the 16th February 1958. Richardson reported that a gusher of carbon dioxide was struck at 230 feet in lavas, the gas blowing-off to a height of about 30 feet. An analysis of a sample of this gas sent to the Government Chemist, London, showed:—

Carbon dioxide	97·8
Oxygen	0·2
Hydrocarbons, as methane ..	1·1
Helium	*
Argon and other inert gases ..	0·07
Nitrogen (by difference) ..	0·80
TOTAL	99·99

* Not detected—probably less than 0.2.

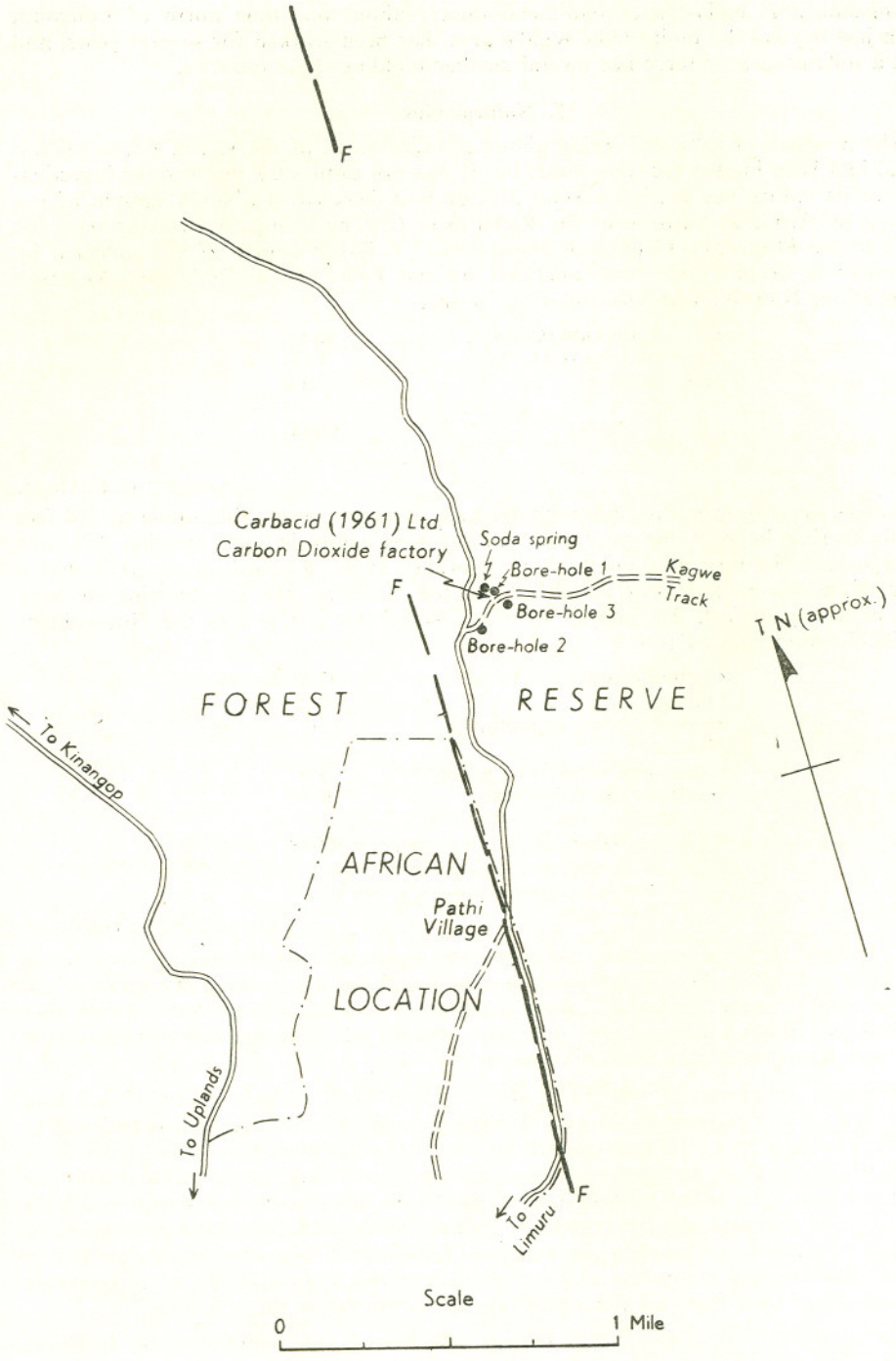
Analyst: R. C. Hardwick

Dr. W. Pulfrey (1957) who visited the bore-hole, suggested that the gas at lower levels passes up a fault-plane "but is deflected by clay gouge before reaching the surface into the lavas struck in the bore-hole". Such a deflection would account for the fact that the spring lies about a quarter of a mile east of the fault which passes to the west of Kerita and Karaini hills and downthrows to the west.

Although outcrops near the fault are rare and only a thick cover of soil and decomposed rock is exposed in the nearby road cuttings, the country rock is believed to be tuffs. The first 50 to 70 feet of rock struck in the gas bore-hole were pyroclastic, beneath which trachytic and vesicular lavas were present. The fault associated with the soda spring was intersected by bore-hole C 2421*, in which cold water and probably carbon dioxide gas were also encountered. Pulfrey believed that the high proportion of silica and phosphates revealed in the analysis of the water from the spring (see p. ?) suggests "that the gas is juvenile and is perhaps derived from alkaline or carbonatitic intrusions rather than from the baking of limestones buried by the volcanics".

The additional information that follows has been compiled by Dr. N. J. Guest from Departmental records up to the end of March, 1962. Prospecting work and a certain amount of drilling continued after 1957, and in March and April 1960 a third

* Bore-hole localities are shown on the geological map.



Adapted from a diagram by W. Pulfrey

Fig. 5—Carbon dioxide bore-holes and spring, Kerita Forest

bore-hole was drilled to 310 feet. In the driller's log it was recorded that "a little water was blown up by gas which eventually petered out". Dr. W. Pulfrey reported on another visit on the 26th October 1960 when the original bore-hole No. 1 and bore-hole No. 3, were capped, both recording a gas pressure of 25 lb./sq. inch. The drilling rig had then returned to bore-hole 2 which was blowing off gas at an unknown pressure. Difficulties in maintaining gas pressure were still being experienced and the position at that time was summarized by Dr. Pulfrey thus:—

> "The original pressure in bore-hole 1 was about 40 lb./sq. in. and for some months the gas was used to run an engine. When bore-hole 2 was sunk it did not affect the pressure at bore-hole 1 but it could not itself be controlled owing to lateral leaks, and when an attempt was made to plug it lateral leakage increased considerably and caused cratering around the hole. Bore-hole 3 was then begun and gas obtained, apparently at about 40 lb./sq. in. though the emission of gas was pulsating. When an attempt was made to re-open bore-hole 2 the pressure at bore-hole 1 and 3 dropped to about 10 lb./sq. in. and has only built up to 25 lb./sq. in. slowly over a few weeks. It is also reported that the emission of gas bubbles from the spring has considerably diminished."

Dr. Pulfrey recommended that bore-hole 2 should be re-drilled and cased almost to the gas horizon, and further advice was given on several occasions as drilling progressed.

Subsequent drilling work in all bore-holes which involved reaming, deepening, and casing, resulted in an increased volume of gas, particularly from No. 1 hole, so that at the 31st December 1960 the state of the three bore-holes was:—

	Bore-hole 1 (*feet*)	*Bore-hole* 2 (*feet*)	*Bore-hole* 3 (*feet*)
Collar height (a.s.l.)	8,335	8,410	8,307½
Depth of bore-hole	325	300	310
Depth at which gas appears	230	300	290
Gas pressure, lb./sq. in.	22	44	20

After gas pressure had built up again, the bottling of gas commenced in May 1961 from bore-hole 1 and dry ice was produced experimentally. In the following months additional machinery was installed in order to bring the factory into full production.

The non-precious minerals lode location 3/1 was transferred to Kagwe Ltd., on the 6th October 1959, and subsequently, on the 20th November 1961, was transferred to Carbacid (1961) Ltd.

Mr. P. A. Wortley was granted Exclusive Prospecting Licence 142 on 1st October 1959, covering five sq. miles. Location 3/1 was situated within this Exclusive Prospecting Licence but was excluded from the effect of the licence. On the 19th March 1960, Exclusive Prospecting Licence 142 was transferred to Kagwe Ltd., and renewed for a year from the 1st October 1960, and for a further year from 1st October 1961. Resulting from prospecting work so far undertaken on Exclusive Prospecting Licence 142, it has been planned to drill a further six holes in this licence area up to the end of 1964.

Kagwe Ltd., was granted Exclusive Prospecting Licence 144 covering 2.5 sq. miles, lying west of but contiguous with Exclusive Prospecting Licence 142, from the 1st July 1960, and a first extension of one year was granted from 1st July 1961. Prospecting work in this area had revealed the presence of carbon dioxide and a drilling programme was being planned.

On the 15th November 1961 one non-precious minerals lode location (No. 12/1-2) was pegged by Kagwe Ltd., covering an area around bore-holes 2 and 3. The location was transferred to Carbacid (1961) Ltd., on the 30th December 1961.

Production figures to date are:—

1961	*lb.*
May to July, Kagwe Ltd.	81,895
August to December, Carbacid (1961) Ltd. ..	132,923
	214,818
1962	
January to March, Carbacid (1961) Ltd.	105,341

Estimated value at 50 cts. per lb, are, 1961—£5,370 and 1962—£2,633.

8. Water Supplies

Although there is a good annual rainfall throughout the greater part of the Kijabe area, and the Kikuyu special area and the forest reserve have abundant supplies of surface water in the form of perennial streams and some springs, the Kinangop and Rift Valley must rely to a large extent for their water-supplies on groundwater.

The headwaters of the larger rivers in the Kijabe area, the Chania, Thika and Maragua, rise in the Aberdare Range, generally near Niandarawa. The catchments of these rivers although relatively small, provide good surface water supplies for those areas through which the rivers flow.

At the base of the Kinangop scarp south of Kijabe station, a group of hot springs in pyroclastic rocks which overlie a trachyte flow, are believed to be associated with a concealed fault.

The following details describe how the ample water supplies of the Chania and Sasumua rivers have been impounded for use by the City of Nairobi.

(1) The Chania-Sasumua Scheme

The Chania-Sasumua scheme, conceived in 1945, has resulted in water from the Sasumua river augmented by water led from the Chania river by means of a tunnel, being impounded in a reservoir formed by the construction of an earth dam on the Sasumua river (*see* Figs. 6 and 7). The dam, situated at an elevation of approximately 8,060 feet above sea-level, lies just within the forest reserve about 2½ miles south-east of Njabini. The dam wall is about 100 feet high and has an overflow altitude of 8,164.25 feet above sea-level. It impounds 2,000 million gallons of water, and the reservoir has been designed to maintain a supply of four million gallons per day to Nairobi. The water flows by gravity through a 38-mile steel pipe-line from the treatment works, situated about half-a-mile downstream of the dam, to Kabete on the outskirts of Nairobi, nearly 2,000 feet below dam level. Use of the water began in 1956 when the reservoir filled to capacity.

The following conditions were laid down by the water Apportionment Board and the Fisheries section of Game Department for the abstraction of water from the Chania river:—

(1) No water may be taken when the flow in the river is less than 5 cusecs (i.e. about 2,700,000 gallons per day).

(2) Water in excess of 5 cusecs and up to 290 cusecs may be diverted.

(3) Water in excess of 290 cusecs must be returned to the Chania river.

(4) Migrating fish (mainly brown trout) must be able to pass freely up and down the Chania river, but must not swim down the aqueduct and on to the reservoir

Prior to the construction of the dam, 34 bore-holes were sunk as part of a geological investigation undertaken by Dr. E. Parsons who prepared a report on a number of proposed dam-sites. The depth of most of the bore-holes ranged between 40 and 80 feet, the deepest being 106 feet. Some of the cores were referred to Dr. W. Pulfrey, Chief Geologist of the Mines and Geological Department, Nairobi, for examination.

Terzaghi (1958, p. 371), stated that Parsons distinguished the following principal zones encountered in the drilling operations:—

"A_w An upper series of decomposed clayey lavas with red clays indicating Old Land Surfaces, these often being associated with tuffs.

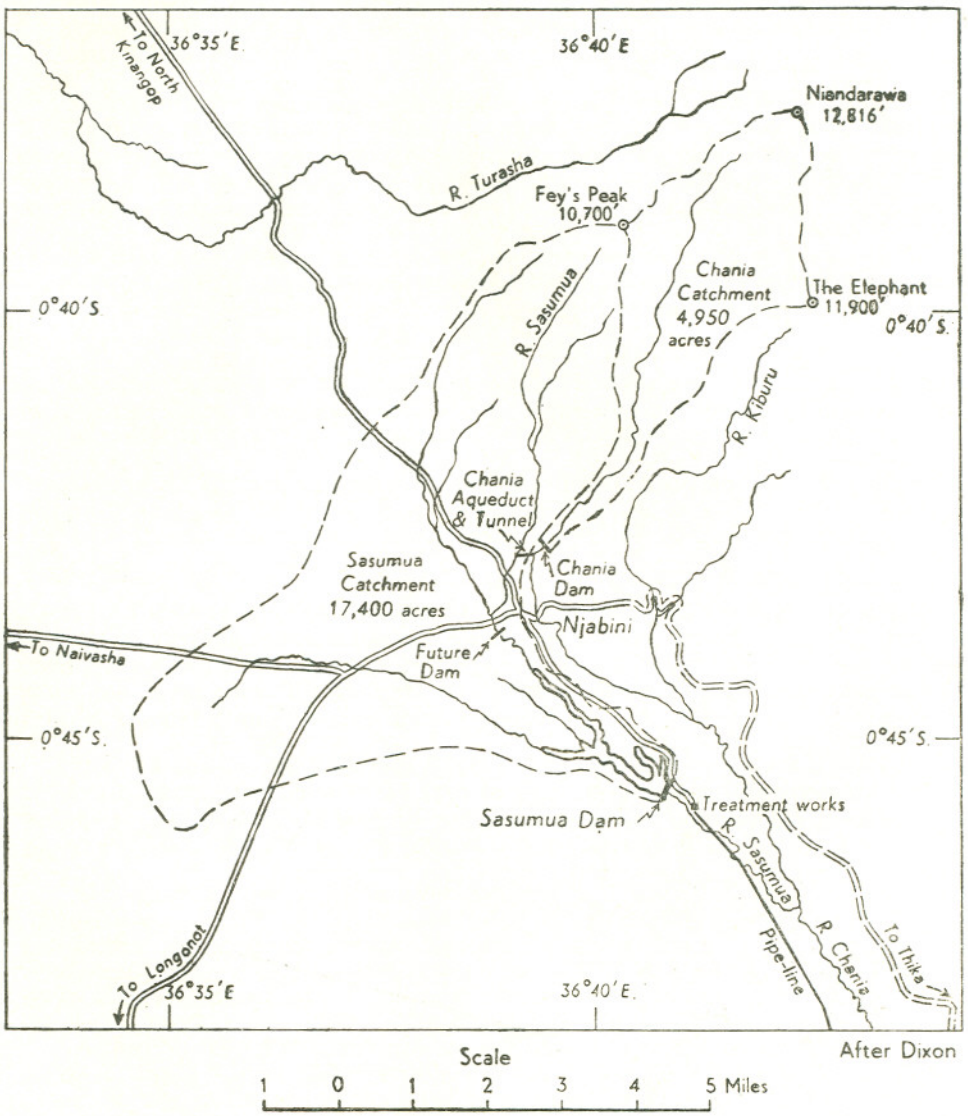


Fig. 6—The location of the Sasumua Dam

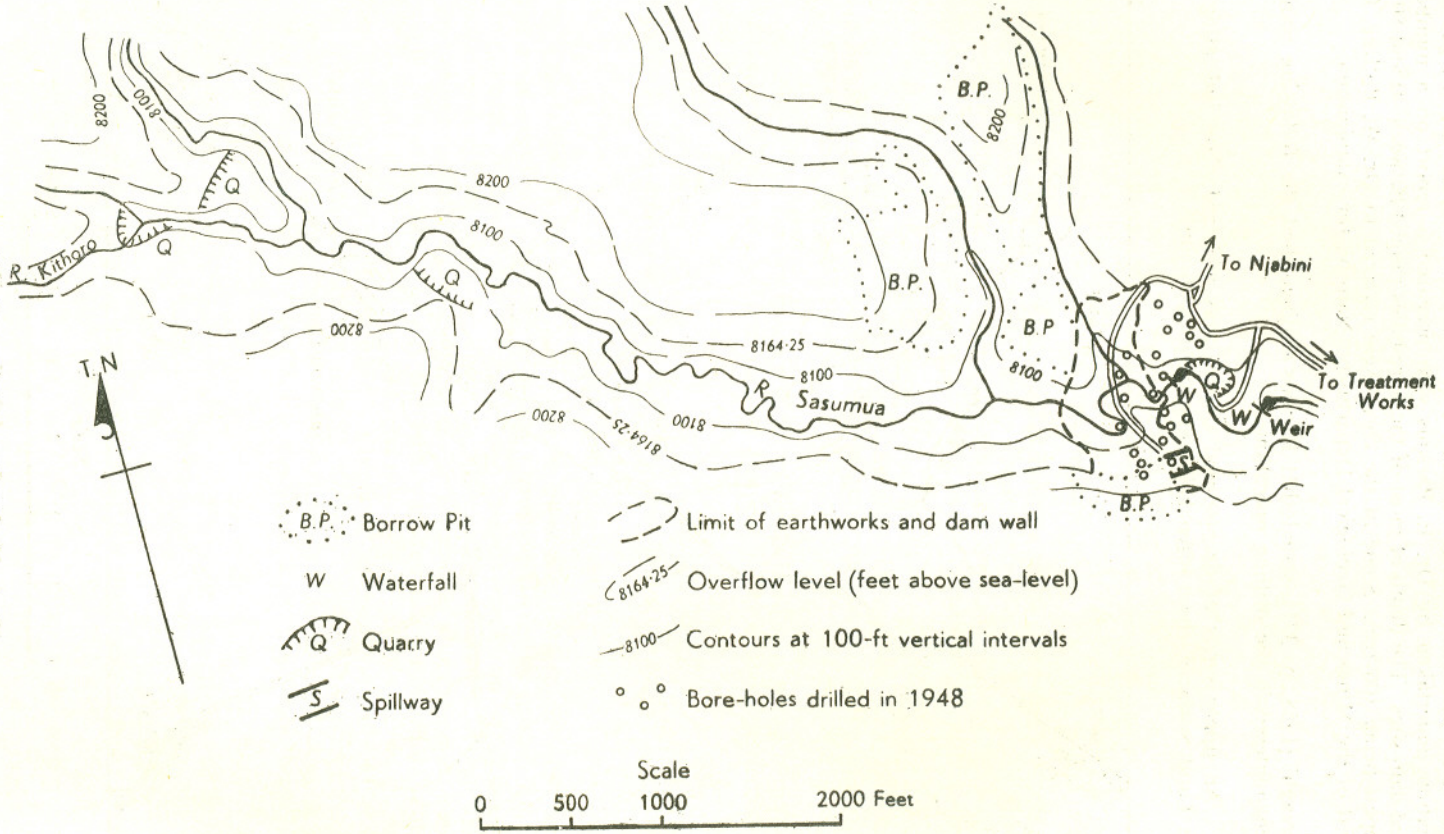


Fig. 7—Plan of the Sasumua Dam

A_s An intermediate series of massive lavas characterized by numerous inclusions and often well-jointed.

B_w A lower series of decomposed clayey lavas identical with the uppermost beds.

The zones A_w and A_s appear to represent a unit composed of lava sheets which were laid down in relatively rapid succession. . . . Each unit is composed of relatively thin sheets of lava with more or less different petrographic characteristics. . . . The resulting rock profile is lenticular and very intricate. In volcanic regions profiles of this kind are very common. . . . In some places, scattered at random over the explored area, the uppermost portion of the weathered part of the older lava beds (zone B_w) consists of highly weathered lava with numerous inclusions of glass, pumice, and pyroclastic material. During the process of drilling this material disintegrated completely. Therefore in the boring records it appears under the name of 'sand'."

Bore-hole cores reported on in a letter to the City Engineer, Nairobi, by Dr. W. Pulfrey, were identified as "tuffs", composed largely of volcanic glass with some pumice, together with fragments of felspar, pyroxene and garnet, etc., and occasional lava grains. Pulfrey stated that the glass and pumice were deposited while in a state of considerable heat, as a marked amount of welding together of the grains had occurred.

There is no doubt that Parsons confused these welded tuffs with lavas, for lavas were not recognized in the immediate vicinity of the Sasumua dam during the course of survey, nor in the bore-hole cores (which have been retained by the Mines and Geological Department).

Parsons (Terzaghi, op. cit., p. 370), believed "the lava sheets located within a depth of a hundred feet below the ground surface originated during two periods of intense volcanic activity each of which was followed by a long period of inactivity.

During the periods of quiescence the lavas which had been deposited during the preceding period of volcanic activity were subject to intense surface weathering which converted the uppermost tens of feet of the strata to residual clay or partly decomposed rock."

In the absence of good dam-sites for the impounding of water in a large reservoir on the Chania river, the Sasumua site was chosen. Water is diverted by an ingeniously constructed weir on the Chania river, through an aqueduct and tunnel into the Sasumua, about four miles above the Sasumua dam. The aqueduct is open for most of its 1,300-foot length, and is only covered where necessary.

Dixon, Edington and Fitzgerald (1958, p. 352), state that the aqueduct was excavated chiefly in firm weathered rock, although in places residual clay was encountered. The vertical sides stood well and no timbering was needed; they interpret this as an indication of the high shear strength of the material, a fact also mentioned by Terzaghi.

Through the ridge separating the Sasumua and Chania rivers, the water passes through a tunnel 1,200 feet long. It was cut "through reddish weathered rock for about 600 feet at the upstream end, and for the remainder through dark coloured friable crystalline lava or tuff" (Dixon et al., op. cit., p. 353). The crystalline lava referred to is no doubt the welded tuff.

A reservoir of 1,500 million gallons capacity, with a dam wall having a maximum height of about 75 feet, is likely to be built in the future about one mile downstream from the exit to the tunnel. This is Site G investigated during the Chania-Sasumua scheme. The head of the reservoir formed by the Sasumua dam which is $2\frac{1}{2}$ miles long, is about half-a-mile downstream from the G site.

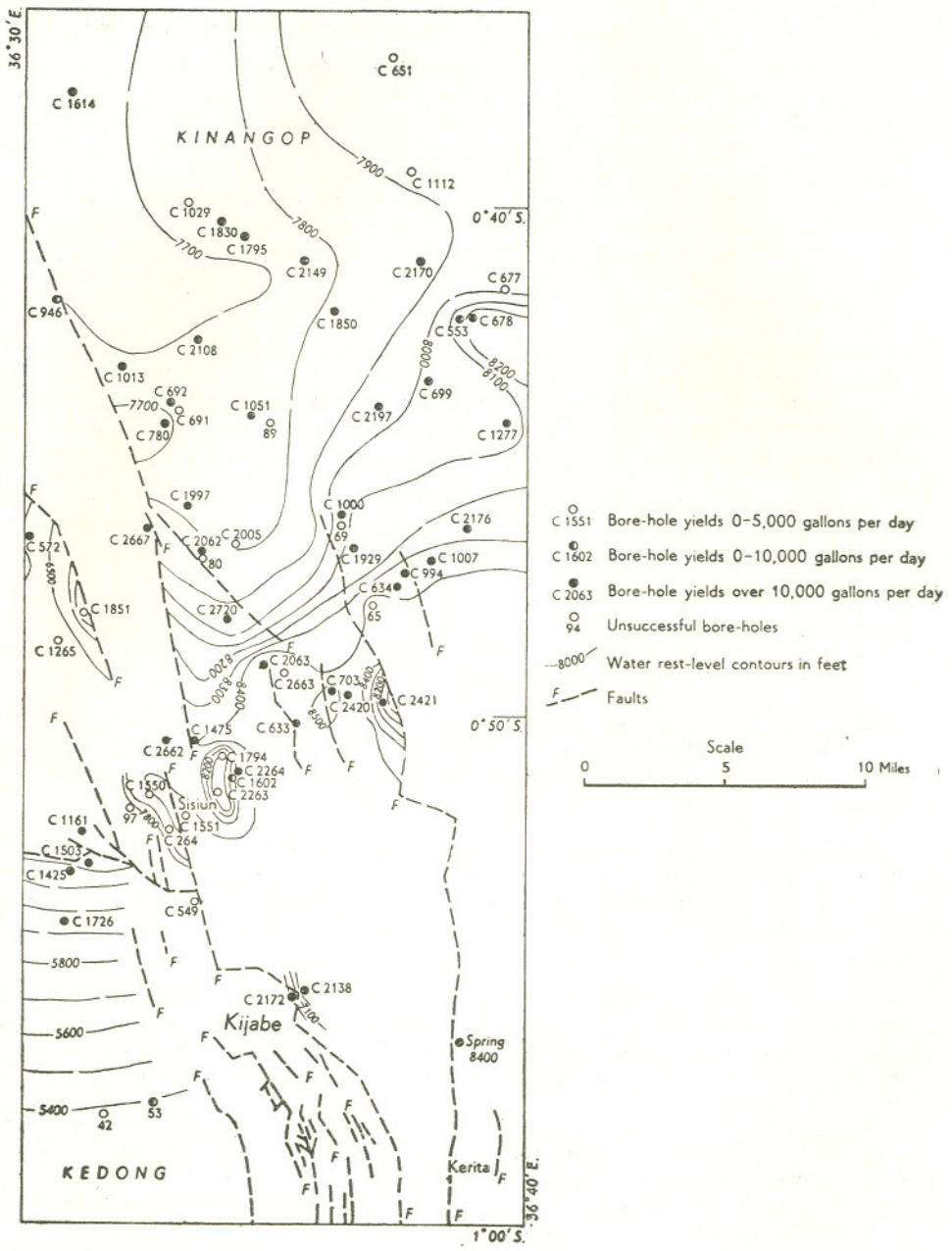


Fig. 8—Bore-hole sites and water rest-level contour-lines of part of the Kijabe area

The catchment area above the Chania diversion dam is only 7¾ square miles in thick forest, whereas the Sasumua dam catchment area is 27¼ square miles and embraces part of the Kinangop which is cultivated farmland. Stream gaugings have shown (Dixon *et al.*, op. cit., p. 347) that on the average the flow diverted from the Chania river will account for three-quarters of the yield, and the Sasumua catchment area the remainder.

(2) Bore-holes

A total of 69 bore-holes had been drilled in the Kijabe area up to the middle of 1958 (*see* Table III). They are distributed as follows:—

Locality	*Number*
Rift Valley	17
Kinangop	48
Kikuyu special area	4

All the bore-holes in the area, except those in the Kikuyu special area, are shown on Fig. 8. The line of division between the Kinangop and Rift Valley has been fixed arbitrarily by the faults immediately to the east of bore-holes C 946, C 2662, C 549 and C 2172. Borehole C 2138 is included in the Kinangop group although in many aspects it may be considered with bore-holes in the Rift Valley.

TABLE III

BORE-HOLES IN THE KIJABE AREA

Borehole Number	Name of Owner and Farm (at time of drilling)	Approximate Height of Borehole above sea-level	Total Depth (in feet)	Datum at which water struck	Approximate Datum of Rest Level	Yield in Gallons per day	Remarks
	RIFT VALLEY						
42	Mt. Margaret Estate	6,050	543	—	—	Nil	
53	Mt. Margaret Estate	6,100	751	5,373	5,400	7,200	Water Warm
97	H. J. Mitchell	8,200	404	—	—	Nil	
C264 ..	M. I. Mitchell	8,400	600	7,910	7,930	1,920	
C549 ..	Rex Higgins	8,000	521	—	—	Nil	
C572 ..	S. J. O. Armstrong	7,150	750	6,403	6,459	>18,000	
C946 ..	A. C. Pritchard	7,500	805	6,704	6,720	>5,000	
C1161 ..	Tom Brown	7,500	709	6,841	6,859	13,200	
C1265 ..	J. G. van Deventer	7,400	842	—	—	Nil	
C1425 ..	Rex Higgins	7,050	930	6,120	6,185	6,000?	
C1503 ..	Rex Higgins	7,100	940	6,240	6,240	12,000	Water hot
C1550 ..	Tom Brown	8,800	810	—	—	Nil	
C1726 ..	P. E. Andersen	6,800	930	5,940	5,950	21,600	
C1851 ..	C. J. Muller	7,650	1,005	6,697	6,708	960	
C2172 ..	E.A.R. & H., Kijabe	7,200	468	6,915	7,062	13,200	Temp. 110°F.
C2662 ..	Mrs. N. Johanson	8,400	840	7,680	7,740	26,800	
C2667 ..	Mrs. D. E. Ker	8,100	675	7,480	7,592	26,800	
	KINANGOP						
65	H. C. Nightingale	8,620	330	8,325	8,420	11,520	
69	H. C. Nightingale	8,450	403	—	—	Nil	
80	F. G. Taylor	8,600	425	—	—	Nil	
89	Dr. M. C. Wetherall	8,450	138	—	—	Nil	
C553 ..	G. Hearne	8,400	350	8,110	8,110	15,600	
C633 ..	M. G. Mitchell	8,850	600	8,259	8,492	21,120	
C634 ..	C. Campbell	8,500	340	8,200	8,371	36,000	
C651 ..	M. S. Ray	8,600	530	—	—	Nil	
C677 ..	G. Parsons	8,600	600	—	—	Nil	
C678 ..	G. S. Parsons	8,400	200	8,234	8,292	24,000	
C691 ..	M. W. Firth	8,300	360	—	—	Nil	
C692 ..	M. W. Firth	8,250	630	7,640	7,730	14,400	
C699 ..	R. H. Bramwell	8,300	300	8,000	8,050	10,800	
C703 ..	Tom Brown	8,800	310	8,520	8,520	72,000	
C780 ..	G. S. Garratt	8,250	690	7,587	7,654	21,600	
C994 ..	H. B. Frazer	8,500	332	8,200	8,360	34,560	
C100 ..	E. M. Kidner	8,500	487	8,035	8,090	20,400	

TABLE III—(*Contd.*)

BORE-HOLES IN THE KIJABE AREA

Borehole Number	Name of Owner and Farm (at time of drilling)	Approximate Height of Borehole above sea-level	Total Depth (in feet)	Datum at which water struck	Approximate Datum of Rest Level	Yield in Gallons per day	Remarks
	KINANGOP—(*Contd.*)						
C1007 ..	L. B. L. Hughes	8,400	200	8,251	8,325	60,000	
C1013 ..	M. W. Firth	8,250	662½	7,660	7,707	13,200	
C1029 ..	J. G. van Deventer	8,180	450	—	—	Nil	
C1051 ..	M. W. Firth	8,300	637	7,750	7,775	14,400	
C1112 ..	J. G. Thynne	8,700	500	—	—	Nil	
C1277 ..	Lennox Brown	8,300	373	7,927	8,075	55,200	
C1475 ..	M. Johanson	8,600	350	8,272	8,400	10,800	
C1551 ..	Tom Brown	8,800	450	8,380	8,457	4,320	
C1602 ..	P. E. Andersen	8,850	565	8,300	8,357	8,160	
C1614 ..	J. M. Benn	8,010	620	7,419	7,622	43,200	
C1794–D ..	G. V. Vignau	8,850	775	8,107	8,198	4,800	
C1795 ..	G. M. Steenkamp	8,210	534	7,712	7,778	40,800	
C1830 ..	J. G. van Deventer	8,200	559	7,690	7,779	14,400	
C1850 ..	J. Semini	8,300	630	7,675	7,842	28,800	
C1929 ..	R. P. Prentice	8,500	447	8,091	8,171	15,840	
C1997 ..	Mrs. Weaver	8,450	733	7,730	7,795	16,800	
C2005 ..	J. D. Durie	8,500	837	7,682	7,708	3,792	
C2062 ..	J. D. Durie	8,600	856	7,749	7,852	10,800	
C2063 ..	J. von Lansberg	8,750	424	8,360	8,425	28,800	
C2108 ..	E. R. K. Hunt	8,250	616	7,634	7,704	31,200	
C2138 ..	E.A.R. & H., Kijabe	7,350	407	7,185	7,236	72,000	Temp. 117°F.
C2149 ..	J. M. Nightingale	8,220	650	7,580	7,747	25,320	
C2170 ..	S. F. Polhill	8,500	740	7,820	7,888	16,200	
C2176 ..	J. W. Etherington	8,300	252	8,060	8,246	51,840	
C2197 ..	D. J. de Wet	8,300	600	7,710	7,928	28,800	
C2263 ..	P. E. Andersen	8,900	900	—	—	Nil	
C2264 ..	P. E. Andersen	8,850	800	8,130	8,360	21,600	
C2420 ..	P. Grimwood	8,700	407	8,314	8,476	>103,200	
C2421 ..	P. Grimwood	8,650	635	8,015	8,030	>50,880 (?)	CO_2
C2663 ..	Catholic Mission	8,750	450	8,390	8,430	60,000	
C2720 ..	Alse Ltd.	8,650	925	7,745	7,940	12,000	
	KIKUYU SPECIAL AREA						
C1685 ..	Holy Ghost Mission, Mangu	5,300	412	4,903	5,140	43,200	
C1985 ..	Kangema Police Post	5,780	503	5,284	—	17,280	
C2008 ..	Kigumo Police Post	5,850	707	5,797	5,797	5,760	
C2392 ..	M. O. W. Kangema	5,650	600	—	—	Nil	

Fifteen of the sixty-nine bore-holes drilled were unsuccessful although several others, for example C 1851 and C 264, have low yields by comparison with the rest. The yield from bore-holes in the Rift Valley is notably variable. Two bore-holes drilled near the railway south of Kijabe station yield warm water; the water in bore-hole C 2138 has a temperature of 117° F. while in C 2172 the temperature is 110° F. Hot water encountered in one of Mr. Rex Higgins' bore-holes, C 1503, can barely be touched, and the writer understands that water struck in bore-hole 53 was also warm, although the temperature was not recorded. Of interest too is the report that gas issues from bore-hole C 2421, the water being noticeably colder than air-temperature. This bore-hole was sited close to a fault whose southerly continuation, as mentioned above, passes close to the "soda" spring north of Kerita Forest station where water and carbon dioxide have been recorded.

It is doubtful if there is a general water-table for the Rift Valley within the Kijabe area; it is believed that separate water-tables of limited extent do exist, and are related to the faults associated with particular fault-blocks. Although many faults can be recognized by surface features, it is considered that particularly in the Rift Valley, faults are present that have no surface expression. The recent pumice deposits around Sisiun have concealed many structural features, and an unrevealed complexity of structure may account for some of the anomalies of depth of water table indicated by bore-hole data.

Contour-lines have been drawn on Fig. 8 in the parts where a certain amount of bore-hole data is available and it is believed a water-table may exist. Contour-lines could not be drawn between bore-holes C 2662, C 2667 and C 946 for want of information. The results obtained in the two bore-holes C 2662 and C 2667 indicate, however, that water in fair quantities may be encountered at an altitude of about 7.600 feet $\pm$ 150 feet above sea-level between these two bore-holes.

The proximity of a bore-hole to a fault apparently has an extremely variable effect on the volume of water yielded. Bore-hole C 946 has a low yield in comparison with bore-holes C 2662 and C 2667. On the Kinangop, however, bore-hole C 2421 produces water in excess of 50,000 gallons per day which, although a high yield, is not the greatest recorded in the Kijabe area.

On the Kinangop near Sisiun and north-east of this locality, several bore-holes in fairly close proximity have extremely variable yields. In general, production from the bore-holes near Sisiun are low; C 2263 was a failure, although bore-hole C 2264 about half-a-mile north-east yielded 21,600 gallons per day. Further north-east, the apparent Kinangop water-table occurs at its highest elevation of about 8,500 feet above sea-level. The water-table slopes NNW from 8,500 feet south of Nightingale's farm, down to about 7,650 feet in the vicinity of bore-hole C 1614, and east of the high point appears to drop rapidly from the highest levels revealed by bore-hole C 703 to the lowest levels indicated by C 2421, where the water-table lies at 8,030 feet above sea-level. The greatest yields in this part of the area are encountered in the three bore-holes C 703, C 2420 and C 2421.

The major cause of failure to find water in bore-holes on the Kinangop, appears to be that they were not drilled sufficiently deep. Although the water-table is almost always depressed, it can be seen from Fig. 8 that bore-holes such as C 1029, 80 and 69 were not taken deep enough and so failed to reach the water-table.

Only three bore-holes have been drilled in the Kikuyu special area, and these pass mainly through the basalts and basaltic agglomerates of the Sattima and Simbara Series. They do not have good yields; in fact, one bore-hole C 2392 was a failure while bore-hole C 2008 has a low yield. A fourth bore-hole C 1685 with a yield of over 40,000 gallons per day, although not drilled within the special area is considered with the other three. The driller's log for this bore-hole records ashes and tuffs throughout. From

these meagre data the outlook for successful water bore-holes in this part of the Kijabe area is poor. It is doubtful whether deeper drilling, within the limits of present-day economic pumping depths, would enhance the prospects.

Thirty-two analyses of water from the Kijabe area are shown in Table IV. As expected, the surface waters have on the whole lower alkalinity (bicarbonate), silica, fluoride, total hardness and total solids values, than the groundwaters. The spring waters appear to be intermediate between these two. The analyses for the Sasumua river indicate that its waters are generally slightly acidic, whereas the Chania waters are slightly alkaline. Both rivers have a low fluorine content in contrast to the Tongi-tongi river with a fluorine content in excess of one part per million. This high fluorine content is possibly due to contamination of river water by hot-springs which contain 3 p.p.m. fluorine on the southern flank of the river below the railway-line. The analysis of the water from the Sasumua dam is, as expected, almost the same as that of the Sasumua river. Durie's well water is alkaline and high in fluorine content.

The majority of analyses of water from the bore-holes indicate high fluorine content, while pH values indicate both acid and alkaline waters. There appears to be some correspondence between alkalinity and fluorine content.

TABLE IV

ANALYSES OF WATER FROM THE KIJABE AREA

(Parts per 100,000 except the fluorides which are parts per million)

Name	Lab. No. and Year	Alkalinity (as $CaCO_3$)		Ammonia		Chlorides (as Cl)	Sulphates (as So_4)	Nitrites (as NO_2)	Nitrates (as NO_3)	Calcium (as Ca)	Magnesium (as Mg)
		Carbonate	Bi-carbonate	Saline	Albumin-oid						
SASAMUA RIVER—											
City Council of Nairobi	1439/1947	Nil	2·6	trace	0·008	0·6	Nil	Nil	present		
City Council of Nairobi	1570/1947	Nil	2·1	trace	0·007	0·5	trace	Nil	present		
City Council of Nairobi	1897/1947	Nil	2·2	0·003	0·010	0·5	Nil	Nil	present		
City Council of Nairobi	301/1948	Nil	3·8	0·01	0·03	0·8	Nil	Nil	Nil		
Equator Roads Ltd.	382/1951	Nil	2·2	0·004	0·009	0·5	Nil	Nil	present		
Howard Humphreys Ltd. ..	652/1951	Nil	1·6			1·0	trace	Nil	present		
CHANIA RIVER—											
City Council of Nairobi	1440/1947	Nil	3·8	trace	0·004	0·5	Nil	Nil	present		
City Council of Nairobi	1571/1947	Nil	2·4	0·005	0·006	0·2	trace	Nil	present		
City Council of Nairobi	1896/1947	Nil	2·3	0·002	0·005	0·3	Nil	present	present		
City Council of Nairobi	300/1948	0·4	4·0	0·008	0·015	0·8	Nil	Nil	Nil		
Ministry of Works (P.W.D.) ..	436/1950	Nil	3·9	trace	0·002	0·4	trace	Nil	Nil		
Equator Roads Ltd.	383/1951	Nil	3·1	trace	0·007	0·2	Nil	Nil	present		
TONGITONGI—											
Ministry of Works (P.W.D.) ..	117/1945	2·7	16·1			0·7	Nil				
Naivasha County Council ..	5561/1953	Nil	15·7	trace	0·004	2·0	1·6	present	Nil		
SASUMUA DAM—											
Equator Roads Ltd.	895/1952	Nil	1·0	trace	0·004	0·5	trace	Nil	Nil		
SPRINGS—											
Dr. J. H. Propst, A.I.M., Kijabe..	4413/1953	Nil	7·3	trace	trace	1·2	trace	Nil	Nil		
Hot Springs, Tongitongi, Naivasha County Council	5562/1953	6·2	10·7	trace	trace	0·8	trace	Nil	Nil		
Kerita "Soda" Spring*	2238/1957	Nil	1·0	0·005	0·002	0·2	trace	present	Nil		
WELL—											
J. A. Durie	1283/1951	Nil	37·2	0·10	0·025	1·8	trace	Nil	trace		

*Phosphates 0·65 Manganese trace

(*Continued below*)

TABLE IV—(*Contd.*)

ANALYSES OF WATER FROM THE KIJABE AREA

(Parts per 100,000 except the fluorides which are parts per million)

Name	Lab. No. and Year	Alkalinity (as $CaCO_3$)		Ammonia		Chlorides (as Cl)	Sulphates (as So_4)	Nitrites (as NO_2)	Nitrates (as NO_3)	Calcium (as Ca)	Magnesium (as Mg)
		Carbonate	Bi-carbonate	Saline	Albumin-oid						
BORE-HOLES—											
C572	539/1949	Nil	26·4	0·018	trace	1·7	trace	Nil	Nil		
S. J. O. Armstrong C572	5029/1953	Nil	26·4	0·018	trace	1·7	trace	Nil	Nil		
M. V. Colpoys C699	588/1949	Nil	5·2	trace	0·005	1·6	trace	Nil	Nil		
T. Brown C703	654/1950	Nil	58·2			3·5	4·5	Nil	Nil	4·0	1·1
M. W. Firth	1564/1950	4·8	19·1	trace	0·012	1·2	trace	trace	present		
V. F. Kent	1513/1951	Nil	3·4	trace	0·004	0·4	trace	Nil	trace		
Rex Higgins C1425	1518/1951	Nil	71·4	0·006	0·044	3·6	4·8	Nil	Nil	3·4	2·5
Rex Higgins C1503	2077/1951	Nil	81·0	trace	trace	3·3	3·1	Nil	Nil	4·5	2·8
P. E. Andersen C2264	2255/1951	Nil	12·6	trace	0·008	1·0	0·8	trace	trace		
J. Benn C1614	46/1952	Nil	19·8	0·004	0·014	1·5	1·6	Nil	trace		
Kijabe Station E.A.R. & H. C2172	6084/1953	Nil	8·7			0·8	trace	Nil	Nil	1·1	0·65
Kijabe E.A.R. & H. C2138 ..	6108/1953	4·2	13·1	trace	0·006	1·1	trace	Nil	Nil		
C2420	2631/1955	Nil	9·7	trace	trace	0·6	trace	Nil	Nil		
P. Grimwood C2421	3356/1955	Nil	9·2	trace	trace	1·4	trace	present	Nil		

(*Continued below*)

TABLE IV—(*Contd.*)

Name	Lab. No. and Year	Iron (as Fe)	Silica (as SiO_2)	Hardness			Free CO_2	Total Solids	Oxygen Absorbed 4 hrs. at 80° F.	Fluorides (as F) p.p.m.	pH
				Total	Permanent	Temporary					
SASUMUA RIVER—											
City Council of Nairobi	1439/1947			1·5				5·6	0·122		7·1
City Council of Nairobi	1570/1947			1·5				4·6	0·084		7·0
City Council of Nairobi	1897/1947			1·5				5·5	0·113		7·0
City Council of Nairobi	301/1948			2·8				5·2	0·124		6·8
Equator Roads Ltd.	382/1951	0·045	0·6	2·0			present	5·0 soluble	0·13	0·2	6·85
Howard Humphreys Ltd. ..	652/1951	0·09	1·4	0·5			present	12·5			6·3
CHANIA RIVER—											
City Council of Nairobi	1440/1947			2·5				7·0	0·142		7·4
City Council of Nairobi	1571/1947			2·5				4·7	0·130		7·1
City Council of Nairobi	1896/1947			2·0				4·8	0·137		7·1
City Council of Nairobi	300/1948			3·0				6·4	0·089		7·6
Ministry of Works (P.W.D.) ..	436/1950	0·12	1·3	4·0				7·2	0·08	0·18	7·4
Equator Roads Ltd.	383/1951	0·18	1·3	3·0			present	6·0	0·15	0·12	6·9
TONGITONGI—											
Ministry of Works (P.W.D.) ..	117/1945							24·0			7·8
Naivasha County Council ..	5561/1953	0·14	1·8	1·5				25·5		2·4	7·3
SASUMUA DAM—											
Equator Roads Ltd.	895/1952	0·014	0·65	0·0			present	3·0	trace	trace	6·5
SPRINGS—											
Dr. J. H. Propst, A.I.M., Kijabe..	4413/1953	0·13	4·0	4·0			present	19·0	Nil	0·1	6·7
Hot Springs, Tongitongi, Naivasha County Council	5562/1953	0·16	2·5	1·0				28·0		3·0	8·7
Kerita "Soda" Spring	2238/1957	0·06	0·8	1·0			present	4·5		1·1	5·2
WELL—											
J. A. Durie	1283/1951	trace	5·0	15·5				48·2		3·1	7·7

TABLE IV—(*Contd.*)

Name	Lab. No. and Year	Iron (as Fe)	Silica (as SiO_2)	Hardness			Free CO_2	Total Solids	Oxygen Absorbed 4 hrs. at 80° F.	Fluorides (as F) p.p.m.	pH
				Total	Permanent	Temporary					
BORE-HOLES—											
C572	539/1949	0·04	4·0	3·0				42·0		9·3	7·5
S. J. O. Armstrong C572 ..	5029/1953	0·04	4·0	3·0				42·0		9·3	7·5
M. V. Colpoys C699	588/1949	0·01	3·4	5·0			present	15·25	0·028		6·6
T. Brown C703	654/1950	—	5·6	14·5				91·0		2·7	7·7
M. W. Firth	1564/1950	0·06	5·0	5·5				37·7	0·08	5·3	8·5
V. F. Kent	1513/1951	0·92	2·7	2·0			present	8·0	trace	0·1	5·9
Rex Higgins C1425	1518/1951	0·32		18·8	Nil	18·8		100·0	0·36	2·6	7·1
Rex Higgins C1503	2077/1951	0·2	8·6	22·8	Nil	22·8	present	103·0	trace	2·7	6·95
P. E. Andersen C2264	2255/1951	0·14	8·4	2·5			present	28·5	0·06	2·4	6·9
J. Benn C1614	46/1952	0·08	5·8	6·0				32·0	0·18	2·9	7·1
Kijabe Station E.A.R. & H. C2172	6084/1953	0·07	2·8	5·2			4·4 p.p.m.	17·0			7·5
Kijabe E.A.R. & H. C2138 ..	6108/1953	0·56	0·75	1·0				44·5		2·7	9·1
C2420	2631/1955	0·17	6·0	5·0			present	21·0		1·0	6·4
P. Grimwood C2421	3356/1955	0·07	5·2	2·0			present	17·5		1·8	6·7

Analyst: Government Chemist, Kenya.

VIII—REFERENCES

Anonymous, 1946.—Report of the Development Committee, Vol. II. Govt. Printer, Nairobi.

Baker, B. H., 1958.—"The Geology of the Magadi Area". Report No. 42, Geol. Surv. Kenya.

———— 1959.—"The Mara Ngishu Limestone Deposit". Mines and Geological Department report. (Unpublished.)

Broun, W. H., 1906.—"A journey to the Lorian Swamp, British East Africa". *Geog. Jour.*, Vol. 27, pp. 36-51.

Busk, H. G., 1939.—"Block diagram in isometric projection of the Great Rift Valley from Nakuru to Lake Magadi, with explanatory note". *Quart. Jour. Geol. Soc.*, Vol. XCV, pp. 231-233.

Cole, S., 1954.—"The Pre-history of East Africa".

Collie, G. L., 1912.—"Plateaux of British East Africa". *Bull. Geol. Soc. Amer.*, Vol. 23, pp. 297-316.

Cooke, H. B. S., 1957.—"Observations relating to Quaternary environments in East and Southern Africa". *Geol. Soc. S. Africa*, Annexure to Vol. LX.

Dixon, H. H., Edington, G. A., and Fitzgerald, E. P., 1958.—"The Chania-Sasumua Water Supply for Nairobi". *Proc. Inst. Civil Engrs.*, Vol. 9, pp. 345-368.

Fontainas, M. P., 1937.—"Considerations sur la genese des crevasses de l'Afrique orientale". *Bull. Inst. Roy. Colon. Belge.*, Vol. 8, Fasc. 2, pp. 606-619.

Gibson, W., 1893.—"Geological sketch of Central East Africa". *Geol. Mag.*, Vol. X, pp. 561-563.

Gregory, J. W., 1894.—"Contributions to the Physical Geography of British East Africa". *Geog. Jour.*, Vol. IV, pp. 289-315 and 408-424.

———— 1896.—"The Great Rift Valley".

———— 1920.—"The African Rift Valleys". *Geog. Jour.*, Vol. 56, pp. 13-17.

———— 1921.—"The Rift Valleys and Geology of East Africa".

———— 1923.—"The Structure of the Great Rift Valley". *Nature*, Vol. 12, pp. 514-6.

Hamilton, J., 1957.—"Banded olivines in some Scottish Carboniferous olivine-basalt". *Geol. Mag.*, Vol. XCIV, pp. 135-139.

Hobley, C. W., 1894.—"Peoples, places and prospects in British East Africa". *Geog. Jour.*, Vol. IV, pp. 97-123.

———— 1905.—"Mr. C. W. Hobley's recent journey in East Africa". *Geog. Jour.*, Vol. 25, pp. 292-5.

———— 1914.—"The alleged desiccation of East Africa". *Geog. Jour.*, Vol. 44, pp. 467-477.

Krenkel, E., 1911.—"Geologische Beobachtungen in Britisch-Ostafrika". *N. Jahrb. Min. Geol. Pal.*, 31, pp. 243-267.

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

Moreau, R. E., 1933.—"Pleistocene climatic changes and the distribution of life in East Africa". *Jour. Ecol.*, Vol. 21, pp. 415-425.

Murray Hughes, R., 1934.—Annual Report for 1933, Mines Dept., Nairobi.

Perlo, P. F., 1908.—"Un ascensione sul Kinangop nell'Africa-Equatoriale". *Bull. Soc. Geog. Ital.*, Vol. 45, pp. 653-672 and 746-765.

Prior, G. T., 1903.—"Contributions to the Petrology of British East Africa". *Mineral. Mag.*, Vol. XIII, pp. 228-263.

Pulfrey, W., 1945.—"Proposed brick field at Kijabe". Mines and Geological Department. (Unpublished.)

———— 1949.—"Limestone Deposit, Glenleedle Farm, near Naivasha". Mines and Geological Department, Nairobi. (Unpublished.)

———— 1957.—"Kaolin deposits at Kerita Soda Spring". Mines and Geological Department. (Unpublished.)

———— 1957.—"The Kerita Forest carbon dioxide bore-hole". Mines and Geological Department, Nairobi. (Unpublished.)

Rosiwal, A., 1891.—"Beiträge zur geologischen Kenntniss des östlichen Afrika. Theil II. Uber gesteine aus dem Gebiete zwischen Usambara und dem Stefanie-See". *Denkschr. K. Akad. Wiss. Wien, Math. Nat.* K1. LVIII, pp. 465-550.

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

———— 1955.—"Pleistocene movements in the Gregory Rift Valley". *Geol. Runds.* Bd. 43, Heft 1, pp. 257-263.

Shand, S. J., 1936.—"Rift Valley Impressions". *Geol. Mag.*, Vol. LXXIII, pp. 307-312.

———— 1937.—"The rocks of the Kedong scarp, Kenya Rift Valley". *Geol. Mag.*, Vol. LXXIV, pp. 262-271.

Sikes, H. L., 1926.—"The structure of the eastern flank of the Rift Valley near Nairobi". *Geog. Jour.*, Vol. LXVII, pp. 385-402.

———— 1934.—"The underground water resources of Kenya Colony".

———— 1939.—"Notes on the Geology of the Area surrounding Nairobi". Geol. Surv. Kenya.

Smith, W. Campbell, 1931.—"A classification of some rhyolites, trachytes and phonolites from part of Kenya Colony, with a note on some associated basaltic rocks". *Quart. Jour. Geol. Soc.*, Vol. LXXXVII, pp. 212-258.

Terzaghi, K., 1958.—"Design and Performance of the Sasumua Dam". *Proc. Inst. Civil Engrs.*, Vol. 9, pp. 369-376.

*Thomson, J., 1887.—"Through Masailand".

Thompson, A. O., and Dodson, R. G., 1963.—"The Geology of the Naivasha Area". Report No. 55, Geol. Surv. Kenya.

Toula, F., 1891.—"Geologische Ubersichtskarte der Gebiete Zwischen Usambara und dem Rudolf-See, und Begleitworte zu derselben. *Denk k. Acad. Wiss.* Wien, Vol. LVIII, pp. 551-554.

Von. Höhnel, L. R., 1890.—"Ostaquatorial-Afrika zwischen Pangani und dem neuentdecken Rudolf-See. *Pett. Mitt.* 99, pp. 1-44.

*———— 1891.—"Orographische-hydrographische Skizze des Forschungsgebietes des graf Samuel Teleki-schen Expedition 1887-88. *Denk. Akad. Wiss.* Wien, Bd. 58, pp. 447-464.

* Not consulted in original.

Wilcockson, W. H., 1956.—"Preliminary Notes on the Geology of Kilimanjaro". *Geol. Mag.*, Vol. 93, pp. 218-228.

Willis, Bailey, 1936.—"East African Plateaux and Rift Valleys". Carnegie Institution, Washington.

Wilson, G., 1952.—"Ground water conditions on the east flank of the Rift Valley of Kenya Colony between Lake Naivasha and the Aberdare Range". Ministry of Works, Hydraulic Branch. (Unpublished.)

G.P.K. 1666—1m—6/62