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**MINISTRY OF ENVIRONMENT AND NATURAL RESOURCES
MINES AND GEOLOGICAL DEPARTMENT**

GEOLOGY OF THE SUSWA AREA

**DEGREE SHEET 51, NW QUARTER
(with coloured geological map)**

by

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and

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Geologists

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MAP

Geological map of the Suswa area; Degree Sheet 51, NW Quarter. (Scale 1:125,000)	at end
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PREFACE

This report is another in a series of quarter degree geological sheet descriptions that, regrettably, have been awaiting publication for several years. Field work was completed in 1964 and the geological map published soon afterwards.

The task of preparing the report for publication has been part of a UK-funded project under which geologists of the British Geological Survey have worked alongside Kenyan counterparts of the Editorial Section of the Mines and Geological Department. A major aim of this project is to reduce publication delays in the future so as to ensure the rapid application of geological data to the search for, and controlled development of, Kenya's mineral, groundwater and energy resources.

A significant part of the report is a detailed description of a sequence of Cainozoic volcanic rocks. Special attention is given to the Suswa strato-volcano which, because of its youth and well preserved form, has attracted the attention of several generations of volcanologists.

At least two magma chambers are known to lie at depth below the Suswa cone, making geothermal energy the most promising resource of the area.

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March 1991

EDITORS' NOTE

With the exception of Suswa mountain, the mapping of the Suswa area (Degree sheet 51, north-west quarter) was essentially of a reconnaissance nature, involving only one month of fieldwork following a photogeological exercise. The rapid fieldwork, the lack of age dates, and problems of correlating lithologically-similar volcanic units in such a complex and strongly faulted area, have unfortunately meant that there are several stratigraphic anomalies present in the report. Where such anomalies have been reconciled by subsequent work, footnotes and appropriate references have been provided.

Since this report was written (c. 1965) much additional information has become available in both published and unpublished works, giving a more precise chronology of the volcanicity and tectonism in this part of the Rift. It is impossible to summarise the more recent findings here, but important papers are listed below and have been incorporated into the reference list. Users of this report would be well advised to consult Baker *et al.* 1988 for a broad stratigraphic and chronological framework, and Torfason 1987 for a geological overview of the area covered by the present report. Other important references are: Baker *et al.* 1971, 1988; Baker & Mitchell 1976; Clarke *et al.* 1990; Crossley 1976, 1979; Crossley & Knight 1981; Fairhead *et al.* 1972; Hay *et al.* 1979; Henage 1977; Johnson 1966a, 1966b, 1969; Knight 1976; Scott 1977, 1980, 1982; Scott & Bailey 1986; Torfason 1987; Williams 1970, 1978; and Williams *et al.* 1983.

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MAP

Geological map of the Suswa area; Degree Sheet 51, NW quarter of 51

Scale 1:25,000

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ABSTRACT

This report describes an area of approximately 3,175 km² lying between longitudes 36°00' E and 36°30' E, and latitudes 1°00' S and 1°30' S in the Gregory Rift Valley. The area is dominated by Suswa mountain, a volcano of Quaternary age which is composed of phonolites and pyroclastics; its geology is the subject of a separate chapter in this report. The remainder of the area is composed of basalts, alkali trachytes and pyroclastics of Upper Tertiary and Quaternary age. Locally, sediments are also present.

The petrography of the rocks is described; and the structure, which includes the low western wall of the Rift Valley and the grid faulting on the floor of the Valley, is discussed.

by N.V. Bhatt, Trainee Geologist, between October and November 1964. Dr R.W. Johnson spent two field seasons, each of several months' duration, mapping Suswa mountain.

Climate and vegetation. With the exception of the north-western portion of the area, the climate is generally dry and hot. The only rainfall figures available were from Murrumbidgee in the north-west, where an average of 448 mm was recorded over nine years up to 1961. Orlongville, a few kilometres south of the area, averaged 615 mm over eight years, and Mount Margaret Estate, just outside the north-east corner of the area, averaged 712 mm over 44 years. The low rainfall, which occurs over most of the area, combined with the heat which forms the backdrop, produces a semi-arid landscape. The vegetation is generally composed of scattered thorn bushes (including the whistling thorn, *Acacia drepanolobium*) and patches of grass, but river and stream beds are often marked by lines of trees and seasonal rivers such as the Lami River, the Seyani and the Kibonyi have thick vegetation along their banks. The drainage from fault blocks and from Suswa does not extend for any great distance, but rapidly infiltrates the thick cover of soil and alluvium.

On the central island block and in the volcanic trench of Suswa, vegetation consists of more extensive vegetation with denser stands of *Euphorbia*, locally mixed with *Acacia* and, along the rocky walls, *Pinus*, *Peperomia* and *Sesuvium* spp. In and around the low hummocks (which are more fully described later), a different type of vegetation is found of *E. glabra*, *pinus*, *Acacia*. Within the collapsed holes are often large and conspicuous *Pinus* spp. and also a palm-like plant, *Dracaena* spp. which forms localised thickets on the sides of sinkholes or on the rubble inside them. Occasionally the white-*Pinus* spp. grow on the edge of a collapsed hole. Commonly, two types of creepers are found *Chenopodium* and *Ipomoea* with polyanthus *Ipomoea* and *Chenopodium* spp. with a *Crucifera* like *Crucifera*. At the base of holes, particularly in shaded areas, *Bracken* (fern) *Polypodium* and other ferns together with several other ferns.

The main escarpment is thickly covered with grass and trees, including *Bambusa*, although on the western slopes on some of the lower levels there are grassy patches.

* Imperial measures have been converted to metric (1964).

I. INTRODUCTION

The 'Suswa' map sheet comprises the north-west quadrant of degree sheet 51 (Kenya) and corresponds to sheet 147 of the Directorate of Overseas Surveys. In area approximately 3,175 km², it is bounded by latitudes 1°00' S and 1°30' S and longitudes 36° 00' E and 36° 30' E. The bulk of the area falls in the Rift Valley Province of Kenya with its administrative headquarters at Nakuru. Three Districts of this Province occur in the area, and are administered by District Commissioners at Narok, Nakuru and Kajiado. A small part of the eastern side falls within the Kiambu District of Central Province.

Following a photogeological exercise, fieldwork was carried out by the senior author assisted by N.V. Bhatt, Trainee Geologist, between October and November 1964. Dr R.W. Johnson spent two field seasons, each of several months' duration, mapping Suswa mountain.

Climate and vegetation With the exception of the north-western portion of the area, the climate is generally dry and hot. The only rainfall figures available were from Nairage Ngare in the north-west, where an average of 348 mm was recorded over nine years up to 1961. Olorgesailie, a few kilometres south of the area, averaged 608 mm over eight years, and Mount Margaret Estate, just outside the north-east corner of the area, averaged 712 mm over 44 years. The low rainfall, which occurs over most of the area, combined with the lavas which form the bedrock, produce a semi-arid landscape. The vegetation is generally composed of stunted thorn bushes (including the whistling thorn, *Acacia drepanolobium*) and patches of grass, but river and stream beds are often marked by lines of trees and seasonal rivers such as the Uaso Ngiro, the Seyabei and the Kedong have thicker vegetation along their banks. The drainage from fault blocks and from Suswa does not extend for any great distance but rapidly infiltrates the thick cover of soil and alluvium.

On the central island block and in the annular trench of Suswa, vegetation consists of more evergreen vegetation with dense candelabrum *Euphorbia*, locally mixed with *Acacia* and, along the rocky walls, *Ficus*, *Velozia* and *Sansevieria* spp. In and around the lava tunnels (which are more fully described later), a different type of vegetation is found (P.E. Glover, pers. comm.). Within the collapsed holes are often large and conspicuous wild fig trees (*Ficus* sp.) and also a palm-like plant, *Dracaena* sp., which forms local communities on the sides of sinkholes or on the rubble inside them. Occasionally the wild olive, *Olea africana*, grows on the edge of a collapsed hole. Commonly, two types of creeper are found: *Phytolacca dodecandra* with poisonous leaves and *Coccinea* sp. with a cucumber-like fruit. At the base of holes, particularly in shaded areas, bracken (*Pteridium aquilinum*) occurs together with several other ferns.

The Mau escarpment is thickly covered with upland forest, including belts of bamboo, although on the western slopes on some of the interfluvies there are grassy patches.

* Imperial measures have been converted to metric (Eds).

Communications The main Nairobi-Narok road runs across the northern part of the area. A road from Nairage Ngare joins the Narok road at Nangaru. The road to Mosiro was being realigned and widened when the fieldwork was under way and its position as shown on the map is approximate. Other roads in the northern part of the area, such as the one to Ndulele and that from Nairage Ngare to Mau Narok, can be used only with extreme difficulty by four-wheel-drive vehicles. In the north-eastern part of the area there are a number of ranch and estate tracks, several of which, south of the Narok road, converge and continue to the Uaso Kedong trading centre, which is just outside the eastern boundary of the area, and from there to Ngong and Kikuyu. It is possible to drive up Suswa mountain as far as the foot of the outer caldera wall, although four-wheel-drive vehicles are necessary.

In the south-eastern quarter of the area it is possible to drive between the fault blocks and to the west and south of Mosiro the flat plain makes movement in a vehicle easy.

Maps Four Preliminary Plot maps on the scale of 1:50,000 cover the area and were used in this survey. These are the GSGS 4786 Second Edition Sheets 147/I-IV. These maps were based on air photographs taken by the RAF between 1948 and 1952. A newer set of RAF photographs (on contract to the Survey of Kenya) were taken between 1960 and 1961 and were used routinely during this survey with their principle points marked on the map. None of the GSGS sheets at the scale of 1:50,000 are contoured, but the 1:250,000 Y503-Nairobi sheet has form lines for the whole area, and those produced on the map with this report are a combination of those form lines and spot heights taken during the survey with an aneroid barometer, and should be regarded as approximate only.

Geological information was plotted in the field, directly onto the air photographs and was later transferred to the 1:50,000 maps.

In the report, the names 'Suswa' or 'Suswa mountain/volcano' are generally used. 'Ol Doinyo Nyukie', ('the red mountain') refers to the remnants of the highest point of Suswa, a separate cone on the south-west side of the inner caldera.

Population Most of the people are Maasai with the remainder Kikuyu, and some Somali who often own shops. The Maasai are nomadic people whose movements are controlled by the presence of water for their cattle. Lack of water in the south-east results in that region being practically deserted, both by man and animals. Trading centres have been established at Mosiro, Joroi and Nairage Ngare where there is also a Police Post. There are Government dispensaries at Nairage Ngare and Mosiro.

Wildlife Wildlife is plentiful in the area, particularly on the plains around Suswa. Many varieties of antelope were seen, as well as lion, rhinoceros, elephant, giraffe and zebra.

II. PREVIOUS GEOLOGICAL WORK

The first European explorer known to have passed through the area was Fischer in May 1883 on his journey northwards to Naivasha (Fischer 1885). His expedition took him through the south-east part of the present map sheet by Mosiro and Sosian (pp. 200-202), and on his return journey he noted that Suswa and Longonot volcanoes were composed of volcanic tuffs and breccias, and andesites (p. 205). He collected various rock samples which were described by Mugge (1885). Fischer was followed a few months later by Thomson (1887; and see Loftus 1951); and the Teleki expedition on its return from Lake Turkana (Rudolf) passed through the north-east corner of the area (von Höhnelt 1890). Gorges (1900), another early traveller between Lake Naivasha and Lake Victoria, passed through the north-west corner of the present map sheet.

Gibson (1893) believed that the lavas, tuffs and ashes on the high central plateau of the Mau, Kamasia and Laikipia had issued from a N-S fissure and that the site of this fissure was now occupied by a chain of lakes from Lake Naivasha in the south to Lake Baringo in the north.

In 1893 Gregory first visited the Rift Valley. In the Kedong valley he noted the presence of terraces of a former lake which he called 'Lake Suess' (Gregory 1896). From a viewpoint on the eastern escarpment he saw Suswa crater and considered the central plateau inside the 'moat' to be a new cone. The rocks collected during this expedition were described by Prior (1903), who noted that the majority were rich in alkalis and of phonolitic type. Gregory revisited East Africa in 1919 and in his second book (1921), in which he combined the results of his two expeditions, he revised some of his earlier ideas, particularly with regard to Suswa. By this time, McGregor Ross had climbed the mountain and discovered that what Gregory had taken to be a new cone inside the 'moat' was in fact a block of old lava; he named this portion of the mountain the 'Lost Land' owing to its inaccessibility. Gregory also noted that the northern and western slopes of Suswa were composed of phonolitic tuff, and that lava was more abundant on the southern and eastern slopes. Soit Amut, the small volcano south-south-east of the summit of Suswa, was described as being of phonolitic trachyte, with a breached crater to the south-east and a very denuded rim (1921, p. 175). From Soit Amut he traversed across the eastern part of the sheet and described some of the trachytes encountered (p. 176). Some of the rocks collected on this expedition were described by Miss Neilson (Gregory 1921: Appendix). Later, Smith (1931) described rocks collected during both Gregory's expeditions, and others collected by Lacroix and Maufe. He mentioned, in particular, trachytes from the southern end of the Kedong basin.

In a report on the geology of the East African Protectorate, Maufe (1908) noted that at the south end of the Kedong basin there was a tract of faulted ground projecting into the Rift Valley; and correctly inferred that the eruption of Suswa, together with that of Longonot

and probably Kijabe hill, had occurred after the subsidence of the Rift Valley.

Collie travelled through the Rift Valley in 1910. In a paper (Collie 1912) mainly on the geomorphology of East Africa, he noted that many of the Rift Valley fault scarps were curved. He also pointed out that the lavas of the volcanoes of Suswa and Longonot belonged to two distinct periods and that the last phase of volcanic activity in the Valley was explosive in type.

In a paper on the structure of the eastern flank of the Rift Valley, Sikes (1926) regarded the parallel valleys of the grid faulting 'as having been initiated and given direction by gravity faulting and jointing in a region of E-W tension and as having been widened by erosion'. He gave evidence for four or possibly five major earth movements followed by periods of volcanicity, and noted that the movements along the major cross faults showed no evidence of N-S compression. In further work, Sikes (1934) presented the results of drilling for water in the Rift Valley and noted that one of the boreholes drilled south of Suswa had been abandoned due to steam being struck; while in a later geological report (1939) he described much of the eastern boundary of the Suswa map sheet, including the Kedong basin.

Willis conducted a study of East African plateaux and rift valleys in 1929 to 1930 (Willis 1936). He traversed and worked in the Suswa area, particularly in the Kedong basin and in the area of grid faulting. He made observations on structures, but (p. 271) was unable to identify any shore features of the former 'Lake Suess' postulated by Gregory.

Work on the soils of the northern half of the area was published by Milne (1936).

Shand (1937) described the rocks of the Kedong scarp close to the eastern boundary of the map sheet. Bowen (1937) described a quartz trachyte from the same area, and also noted (1938) that the rocks of the Eastern Rift Valley usually contained an excess of alkalis over alumina. He showed that there was a lack of any convincing relationship between lava chemistry and tectonics in rift valleys.

In an explanatory note to a block diagram of the Rift Valley between the equator and Lake Magadi, Busk (1939) expressed the opinion that nearly all the physical features shown on the diagram were tectonic and that erosion had played only a secondary part.

Dixey (1946), in a paper on the erosional tectonics of the East African Rift system, suggested that the Rift system had developed mainly from an ancient series of fractures and that it was only due in part to post-Tertiary fracturing.

Temperley (1955) described pressure structures in the Orthophyre Trachytes in the southern part of the area and around Magadi.

Spink visited Suswa volcano in 1943 (Spink 1945) and described the main physical features

of the caldera. He noted the presence of several fumaroles along the rim of the central Suswa plateau, and saw sodium sulphate and a sprinkling of sulphur among the fumaroles, which registered temperatures of 80-90°C. Spink later made a trip from Lake Magadi to Suswa in 1945 (Spink and Stevens 1946) and noticed about 25 steam vents on the south side of Soit Amut. These were situated in two N-S-aligned fissures; and on looking southwards toward Lake Magadi he noted that the floor of the Rift Valley was composed of several successive lake beds divided from each other by scarps, and progressively falling in altitude to the south. Richard (Richard and Van Padang 1957), describing the active volcanoes of East Africa, classified Suswa as a caldera in a stratovolcano.

Interest in Suswa mountain continued, leading to the publication of several papers in the 1960s. Williams (1963) described the lava tunnels on Suswa and Glover (Glover *et al.* 1964) gave further details of these caves, listing the flora and fauna found in them. McCall and Bristow (1965) outlined the main features of Suswa volcano and gave a brief petrographic description of some of the rocks present.

In recent years the areas adjacent to Suswa have been mapped by staff of the Geological Survey of Kenya: to the north, the Naivasha area, by Thompson and Dodson (1963); to the south, the Magadi area, by Baker (1958); to the west, the Nairobi area, by Saggerson (in press), and to the west, the Narok area, by Wright (1967).

* More recent work has been noted in footnotes to the text (Eds).

III. PHYSIOGRAPHY

The area mapped covers the greater part of the width of the Rift Valley and includes the western wall. As Shand (1936) pointed out, if a true scale section were drawn from the coast to Lake Victoria across the deepest part of the Rift Valley, it would appear insignificant; nevertheless there are in this area strikingly impressive features formed by faulted and eroded scarps, small ash cones and by Suswa itself.

Drainage in the Suswa area is largely internal and rarely extends for any great distance. The Uaso Ngiro, the only perennial river in the area, is fed by drainage from the Mau escarpment in the north-west of the area and drains southwards to Lake Natron in Tanzania. The Kedong river contains water for most of the year over part of its course but north of Sakureti the river bed is dry.

For descriptive purposes, the area can be divided into three parts: the Mau escarpment; the Enguasero Nanyukie plateau at the northern end of the Nguruman escarpment; and the Rift Valley floor.

The Mau escarpment This physiographic unit cuts across the north-west corner of the map sheet and is composed mainly of volcanic ashes and tuffs, with very rare outcrops of lava. It rises to over 2,350 m in the present area and still higher near Naivasha to the north (Thompson and Dodson 1963).

The Mau escarpment consists of a series of approximately N-S-trending steep-sided ridges which separate the drainage of the various rivers to the Seyabei and Uaso Ngiro. Due to the soft nature of the rocks forming the escarpment, erosion is rapid and the rivers are muddy as they carry high quantities of silt. On the eastern side of the escarpment, particularly east of Nairage Ngare, overgrazing by cattle is exposing many areas to gully erosion.

Forest cover is dense on the higher slopes of the Mau escarpment, but on lower ground forest growth is generally confined to river valleys.

The result of rifting has been to produce faults which downthrow to the east, but it is difficult to determine the actual sites of the fault lines as they are masked by material which has been eroded off the escarpment and by showers of ash which emanated from the volcanoes of Suswa and Longonot to the east.

The Enguasero Nanyukie plateau This forms the northern portion of the Nguruman escarpment, and extends northwards to Olioti and Urikyuu, north of which the Uaso Ngiro river has cut into the escarpment to form a gorge which in places is over 60 m deep. The Uaso Ngiro is the principal river in the area and contains water throughout the year. During rainy seasons it carries a large volume of water due to its large catchment area in the region

to the west, and it is also served by tributaries descending the Mau escarpment in the north-west corner of the map. Tributaries entering the Uaso Ngiro from the Enguasero Nanyukie plateau and from Oloiti and Urikyuu carry water only in the rainy seasons.

The plateau drops steeply on its faulted eastern side to the floor of the Rift Valley. Further north-east of Sosian, there is another steep drop to the Rift floor.

The Rift Valley floor The Rift floor shows a steady decrease in altitude from north to south. It is dominated by Suswa mountain, the summit of which (Ol Doinyo Nyukie) rises to 2,357 m. North of Suswa there are several ash and cinder cones and hills rising above the gentle slopes of the Akira plains. South of Suswa the southern half of the area displays close grid faulting (0.5-3 km spacing). This faulting has broken the valley floor into a series of N-S fault blocks separated by troughs which are wider than the width of the blocks. The surfaces of the fault blocks and troughs are generally featureless, with a local, thin, scrubby vegetation. Erosion has had little effect beyond the cutting of impersistent drainage channels. The sides of the fault blocks are often covered by scree.

Rivers on the floor of the Rift Valley are mainly seasonal, and flow into basins of internal drainage. In the case of the perennial Uaso Ngiro in the south-west, drainage is into the closed basin of Lake Natron in Tanzania.

The topography of the southern half of the area consists of a series of small hills, isolated plateaux and groups of tors. The relief of the ground in this part of the area is low and none of these features rise to more than 30 or 60 m above the surrounding country. Some of the hills have definite defiles running across them, several with two defiles meeting and crossing, which were named 'hot cross bun' structures by Temperley in an unpublished report on the Magadi area (1951). The plateaux are up to several kilometres wide, but the 'hot cross buns' are never more than a few hundred metres across.

There are several features that distinguish these lavas (Orthophyre Trachytes) from others in the area: (1) the lavas crop out only on the plateaux, tors and 'hot cross bun' structures; (2) the areas between the outcrops are filled with a thick soil cover; (3) the ground around the soil exposures contains numerous fragments of broken rock, feldspar and ferromagnesian minerals; and (4) in outcrop these porphyritic lavas occur as sub-rounded boulders.

These trachytic lavas are easily recognisable from air photographs, and also from the ground, as they support a fairly dense, stunted thorn bush vegetation which is in sharp contrast to the alkali trachyte which generally is bereft of any vegetation apart from grass and occasional thorn bushes.

Suswa mountain in the north-east part of the area rises to 2,357 m at its southern summit, Ol Doinyo Nyukie. It consists of a caldera approximately 11 km across, the walls of which

are preserved on the north, west and north-west sides. A well-developed ring graben up to 210 m deep, 130-260 m wide, and 1.8 km in outside diameter, is situated practically in the centre of the caldera. The graben forms an annular trench to a tilted block which slopes down to the north.

On the eastern side of Suswa, tunnels within the lava (first reported by Hobden, Government Prospector, in 1962) taken together extend for several kilometres and have been described in more detail by Williams (1963) and Glover *et al.* (1964). They are very similar to lava tubes or tunnels observed in Hawaii (Wentworth and MacDonald 1953) and may be entered at points where the roofs have collapsed. They are generally semi-circular in cross-section and about 10 m high at the entrances. They are not confined to one level: cracks and collapses of the floor often reveal tunnels below, and minor passages also enter the tunnels at points above floor level. The floors of the tunnels near the entrances are often covered by soil which has been washed in, but further inside the soil cover lessens. The tunnel walls in many places show a type of lava stalactite structure which indicates some mobility of the lava during and after formation of the tunnels.

IV. SUMMARY OF GEOLOGY*

Most of the rocks mapped are volcanic in origin. The inferred oldest rocks exposed are pyroclastics which locally show current bedding. These are overlain by the Kirikiti Basalts, which reach their maximum development in the Magadi area to the south (Baker 1958).

Sediments derived from pyroclastics which locally, as in the Seyabei gorge, are intercalated with alkali basalts, are thought to have been deposited next in the sequence. Sediments cropping out in the Uaso Ngiro gorge may be of the same age. The alkali basalts and the sediments were succeeded by welded tuffs.

Voluminous lavas (alkali trachytes) were probably erupted from fissures, and these were followed by the distinctive Orthophyre Trachyte. Ash and scoriaceous lava cones mark the end of this activity. The volcanicity of Suswa is much younger, as early lavas from the volcano are found resting on the alkali trachytes, and have been cut by grid faulting.

The volcanic ashes which make up the Mau escarpment were deposited in the Middle Pleistocene, and more lavas were erupted from Suswa in the same period. It is probable that the sediments in the Kedong valley were deposited at the same time.

The Suswa activity continued in the Upper Pleistocene,** and small ash and cinder cones and hills were formed north of the Narok road. The trachyte which crops out in the extreme north-east corner of the area and which emanated from the south-east flanks of Longonot was also erupted in the Upper Pleistocene.

The youngest lavas on Suswa were produced in Recent times, and minor activity continues to the present day in the form of steam vents. Superficial soils occur in the fault troughs of the grid-faulted portion of the map sheet.

A proposed succession for the Suswa area is given in Table 1. ***

* Some of the age relationships of the succession proposed below have been superseded by later work., cited in the summary of stratigraphy on p. 10 and in footnotes in the section entitled 'Details of geology' (Eds).

** This refers to a flow which has a 'Recent' radiometric date: see 2nd footnote p 19 (Eds).

***Added to this is a revised succession (after Baker *et al.* 1988) which highlights the stratigraphic anomalies in this earlier work (Eds).

Table 1 Contrasting views on the Cainozoic volcanic succession in the Suswa area

Classification as in this report		Classification after Baker <i>et al.</i> 1988	Age (BP), Ma
Recent	Superficial deposits	Suswa Phonolites	(< 5 K)
	Phonolites of Suswa	Longonot Trachyte	(> 3.2 < 5 K)
Upper Pleistocene	Ash and cinder cones and hills	Kedong valley flood deposits	0.1
	Phonolites of Suswa	Suswa Volcanics	0-0.4
	Longonot Trachyte	Mau Ashes	
Middle Pleistocene	Sediments of the Kedong valley	Tandamara Formation (basalts and scoria cones)	> 0.15 < 0.24
	Mau Pyroclastics (ashes)	Lower sequence of Longonot Volcanics	0.9-?
	Phonolites, pumice and ash of Suswa	Legemunge Beds	0.43
Lower Pleistocene	Phonolites of Suswa	Barajai Trachytes	0.4-1.37
	Ash and scoriaceous lava vents	Magadi Trachytes	
	Orthophyre Trachyte	Plateau Trachytes	0.8-1.4
Plio- Pleistocene	Alkali trachytes	Ol Tepesi Basalts	1.4-1.6
	Lengitoto Trachyte	Seyabei Pyroclastics	
		Gesumiti Trachytes	1.9-2.1
Pliocene (?)	Welded tuffs	Limuru Trachytes	1.8-2.0
	Alkali basalts	Mosiro Trachytes	1.9-2.3
	Pyroclastic sediments	Olorgesailie Volcanics	2.2-2.8
Miocene	Kirikiti Basalts	Kirikiti Basalts	2.5-3.1
	Pyroclastics	Kinangop Tuffs/Mau Tuffs	3.4-3.7
		Ol Esayeti Volcanics	?
		Melanephelinites	4.2-5.0
		Lengitoto Trachyte	5.0-6.9
		Kishalduga Nephelinite	11.0

V. CAINOZOIC AND ASSOCIATED VOLCANIC ROCKS

1. Pyroclastic sediments underlying the Kirikiti Basalts

These sediments are exposed along the edge of the Enguasero Nanyukie plateau. Further south in the Magadi area (Baker 1958), sediments including mudstones and fossiliferous limestones were found in the Oloibortoto river which, although not mentioned by Baker in his report, were noted by Saggerson (1966, p. 30) in the Loita hills area report. It is possible that the pyroclastic material exposed in the present area is a different facies from that to the south.

In the Suswa area exposures of these pyroclastics are generally good towards the top of the escarpment, but the lower slopes tend to be obscured by scree of basaltic boulders. They are predominantly white or grey, with local, brown variations. Generally the stratification of the pyroclastics is regular and near-horizontal but locally, small flexures were encountered with the bedding dipping 12° SE. Evidence that these pyroclastics may have been water-deposited is found in the presence of current bedding and occasional graded bedding. Bands of pale grey ash are intercalated with the whitish-coloured material in places. The pyroclastic material is very friable and generally unconsolidated and where cattle tracks cross it the paths have a layer of dust several centimetres thick.

Where the pyroclastics are seen directly underlying basalt, contact metamorphism has taken place with the result that the pyroclastic material adjacent to the basaltic flow has been baked to a brick-red colour. Streaked through the metamorphosed part of the pyroclastics are black impregnations of basaltic material.

Locally there are hard bands scattered through the pyroclastics but these are very rare. One such specimen was collected from a point at the northern edge of the Enguasero Nanyukie plateau. This specimen, 51/1243, is pale grey and is readily scratched by a knife. In thin section isolated crystals of anorthoclase feldspar can be seen, together with fragments of aegirine, cossyrite and kataphorite.

2. Kirikiti Basalts

These occur in the south-west of the area on the Enguasero Nanyukie plateau. They also extend southwards into the Magadi area (Baker 1958, p. 16) where they attain their maximum development, and where they rest against the lower part of a pre-existing fault scarp of 'Basement System' rocks.* Further faulting along new fault lines, north of the Oloibortoto

* Crossley and Knight (1981) give well-constrained dates for the Kirikiti Basalts ranging from 3.1-2.5 Ma and emphasise their relationship to a major period of faulting just prior to their eruption (Eds).

river and along a pre-existing fault line south of the river, then took place, leaving a ledge of basalts on the lower part of the Nguruman escarpment and downfaulting the remainder of the series.

In the Magadi area the Kirikiti Basalts consist of a number of lava flows locally interbedded with conglomerate and sand lenses. These are absent in the Suswa area and where basalt is exposed on the top of the Enguasero Nanyukie plateau only a single flow is believed to be present. It is probable, therefore, that these lavas thin northwards from the Magadi area. The top of the Enguasero Nanyukie plateau is relatively level, and although mainly consisting of a thick soil cover, occasional exposures indicate that they are underlain by basalt. In places low ridges are present which have been formed by faulting. A marked feature of the Kirikiti Basalts is their spheroidal weathering which is well seen on some exposures along the edges of the plateau.

Specimen 51/1326 from 1.5 km south of the Uaso Ngiri river is typical of these basalts. In hand specimen it is a melanocratic, vesicular and non-porphyrific rock, some of the vesicles having a secondary infilling. Thin section examination reveals that it is composed of abundant augite and olivine with labradorite feldspar. Iron ores in the form of magnetite and haematite are also present. Many of the olivines have alteration rims of iddingsite.

Another specimen, 51/1326, collected from the edge of the Enguasero Nanyukie escarpment shows slight differences from the one described above. In hand specimen it is melanocratic, non-vesicular and contains small feldspar phenocrysts. Both the phenocrysts and the ground-mass feldspars are labradorite. Augite is abundant, but olivine occurs only as sparse crystals, and magnetite is also present.

3. Alkali basalts

In the present area these crop out in the region of the Seyabei river, and have only a limited extent. They are more extensively developed in the Narok area to the west (Wright 1967). They are underlain at Ngwiriroi by pyroclastics, and in the walls of the Seyabei gorge they are both underlain and overlain by the same material. The lava flow which caps the Seyabei gorge is an Orthophyre Trachyte, considered to be of Pleistocene age, and for this reason these older alkali basalts have been placed in the Pliocene.

A typical example of this lava is specimen 51/1249 from Ngwiriroi. In hand specimen it is a melanocratic, non-porphyrific, vesicular rock, some of the vesicles having a secondary infilling. In this section, subhedral crystals of augite are seen, together with olivine, most of the latter having undergone alteration to iddingsite. The feldspars fall mainly in the oligoclase-andesine range, but a few are of andesine-labradorite composition. Magnetite is a prominent constituent of the groundmass. Specimen 51/1251 from the upper part of the Seyabei gorge is similar in hand specimen to the one described above except that it is

non-vesicular. In thin section it is seen to be very fine grained, with abundant magnetite in the groundmass. Augite and olivine are present, although the latter is not so plentiful as in 51/1249. The feldspars are in the oligoclase-andesine range.

4. Pyroclastic sediments of the Seyabei and Uaso Ngiri valleys

In the gorges of the Seyabei and Uaso Ngiri pyroclastic sediments occur. At the latter locality they are interbedded with alkali basalts, and are capped on the north side of the gorge by Orthophyre Trachytes. The sediments present in the Uaso Ngiri gorge are not capped by lava. Wright (1967, p. 27) considered that these sediments, which are more extensive in the Narok area to the west, were deposited in large bodies of shallow standing water, thought to have been formed by the damming of the Uaso Ngiri and other rivers farther east, which were supplied with fine pyroclastic material either aerially or from rivers flowing into the lakes. Wright considered the sediments in the Uaso Ngiri and Seyabei gorges to be of approximately the same age. In the present area there is no evidence whereby the two sets of sediments can be correlated. The sediments in the Seyabei have, as has been noted, intercalated alkali basalt flows which are considered to be of Pliocene age, and hence the sediments underlying these basalts are older. It is possible that the Seyabei sediments range from Pliocene to Pleistocene in age. In the Uaso Ngiri sediments there is no marker horizon, and the age of these sediments is conjectural. It is possible that they could be correlated with the pyroclastics underlying the Kirikiti Basalts, in which case they would be Pliocene in age, but it is more likely that they are younger, probably Pleistocene. The fact that these sediments, particularly those in the Uaso Ngiri, have been waterlain is seen from the presence of current and graded bedding which locally occurs. They are uniform, being white or pale grey, but there are also brown colours in places. The thickness of the sediments is variable up to a maximum of 60 m.

5. Welded tuffs

Welded tuffs** were mapped in the Ladare and Ngare Ngossor rivers where they are apparently continuous with similar tuffs to the west. In the Mau area to the north-west (Williams, 1991) welded tuffs were found to be extensively developed at the bottoms of river valleys.

The Ladare river has cut through the welded tuffs and agglomerates to form a gorge. The

* The Seyabei Pyroclastics do not have good direct radiometric age dates. It is most likely that they span the Plio-Pleistocene boundary, i.e. 2.0-1.7 Ma, at least in part (Crossley and Knight 1981) (Eds).

** Baker *et al.* 1988 consider these Mau Tuffs on the western escarpment to be the equivalent of the Kinangop Tuffs on the eastern escarpment of the Rift. The 'Kinangop Tuffs eruptive episode' spans the period 6-2.5 Ma, with a well-constrained age of 3.7-3.4 Ma for the Kinangop Tuffs in the Naivasha area (Eds).

grey to black welded tuff is over 4.5 m thick in this locality and is grey to black. It often contains lenticular, flattened pumice fragments, clear colourless feldspar crystals and occasional lithic fragments. Specimen 51/1300 is typical with fragments of quartz, feldspar and relict pyroxene set in a semi-opaque iron-stained matrix. Specimen 51/1305, also from the Ladare river, does not show quartz grains but is similar in other respects to 51/1300.

Underlying the welded tuff locally is a zone of agglomerate composed of pumice, feldspar crystals and rock fragments. Specimen 51/1301 shows in thin section an iron-stained semi-opaque groundmass with microphenocrysts of labradorite and quartz.

6. Lengitoto Trachyte

The Lengitoto Trachyte crops out on the Enguasero Nanyukie and Urikyuu plateaux in the south-west portion of the area. This trachyte extends southwards into the Magadi area where it rests on approximately 30 m of tuffaceous silts, which in turn rest on the Kirikiti Basalts. In the Suswa area, the Lengitoto Trachyte rests on the Kirikiti Basalts with no intervening sediments. These trachytes are poorly exposed, being obscured by soil cover, and crop out generally in fault scarps. In hand specimen they vary from pale grey to dark grey, some varieties being slightly porphyritic. Specimen 51/1237 from the Urikyuu plateau is pale grey, non-vesicular, and contains slender laths of feldspar phenocrysts which are randomly distributed. In thin section it is seen to contain phenocrysts of anorthoclase feldspar, together with aegirine, cossyrite pleochroic from dark brown to opaque, and kataphorite. Specimen 51/1246 from the centre of the Enguasero Nanyukie plateau is dark grey with feldspar phenocrysts, and contains the same mineral assemblage as 51/1237 with the addition of aegirine-augite. The mineral assemblage of these trachytes is the same as that of the alkali trachytes which are described in the following section. It is thought that the Lengitoto Trachyte represents an early phase of the alkali trachytes.

7. Alkali trachytes **

These are common throughout the area, and since they are cut by grid faulting are well exposed in the fault escarpments. When these escarpments are viewed from a distance it is often possible to trace individual lava flows for many kilometres. The similarity in hand specimen of all the samples collected during the fieldwork, and also the similarity of all the

* The Lengitoto Trachyte *sensu stricto* from the type area to the south is older (6.9-5.0 Ma) than the Kirikiti Basalts (2.5-3.1 Ma: Crossley and Knight 1981; Baker *et al.* 1988). Therefore, this trachyte is more likely to be the equivalent of the Limuru Trachytes *sensu lato* (including the Ewaso Ngiro and Mosiro Trachytes) of which this, the western extension, has only recently been demonstrated (Eds).

** These may be correlated with the Plateau Trachytes (0.8-1.4 Ma) of more recent workers in the area, and include the slightly younger Magadi Trachytes which range in age from 1.4 to 0.8 Ma (Eds).

flows in vertical sections, makes it likely that these lavas had their origin in a common source which was emitting the same type of lava over a period of time. This similarity throughout the flows is probably due to the fact that they were produced by fissure eruption, which is indicated by the absence of any central vents from which they could have been produced. Locally up to eight individual flows can be seen in vertical sections.

The relationship of the alkali trachytes to the previously-mentioned lavas and pyroclastics is nowhere to be seen, though it is fairly certain that they are younger than the Kirikiti Basalts.

As already noted, these lavas crop out on fault blocks of the grid-faulted portion of the area. The surface of these fault blocks is composed of rubble, soil and bare rock. The soil is light brown and occurs only in depressions protected from the wind. The vegetation is generally poor, consisting of stunted, scattered thorn bushes and occasional patches of poor-quality grass. The sides of the fault blocks are often marked by scree material. In many of the escarpments the uppermost flow is locally brecciated and in hand specimen is seen to be highly vesicular, but this gives way a few metres below to a massive rock which contains both vertical and horizontal jointing, the former being more widely spaced than the latter. Lineations due to the alignment of vesicles are sometimes seen. The outer surfaces of the rocks are weathered generally to a dark brown or black colour and through this weathered zone feldspar phenocrysts protrude, giving a rough surface.

On a clean surface, however, these trachytes are pale to medium-grey, fine grained, with scattered pale brownish, glassy feldspar phenocrysts up to 5.0 mm in length.

Examination of the rocks in hand specimen and thin section reveals the presence of three generations of feldspars: phenocrysts, microphenocrysts and groundmass feldspars. The phenocrysts are not very common in this section as they are randomly distributed through the rock, but where they do occur they have been determined as anorthoclase. The microphenocrysts and the feldspars of the groundmass are also anorthoclase. Twinning on the feldspars, where it is present, is according to the Carlsbad law. The microphenocrysts have undulose extinction in some examples, and near the margins of the crystals there is a dusty zone of inclusions of aegirine which Baker (1958, p. 18) considered to be diagnostic of these alkali trachytes. These inclusions, although common in the rocks of this series, do not occur in all the microphenocrysts.

The groundmass is composed of anorthoclase feldspar together with aegirine, which occurs as an intersertal mineral. The aegirine crystals are generally associated with cossyrite, which has a dark brown to opaque pleochroism, and kataphorite. In some thin sections augite occurs as microphenocrysts and in others it occurs in the groundmass. Barkevikite and arfvedsonite were seen in several specimens, e.g. 51/1348 and 51/1350, from 11.5 km north-east of Lorgunono respectively. Riebeckite was found in one specimen, 51/1357, from 9.5 km

west of Uprikeli, and quartz was found in one rock, 51/1355, 13 km south-west of Uprikeli. Quartz also occurs in some of the alkali trachytes of the Magadi area to the south (Baker 1958, p. 19). There is a general petrographic similarity between these rocks and the Limuru quartz trachytes near Nairobi (Sikes 1939, p. 22) but recent palaeomagnetic work (Mussett *et al.* 1964) has shown that the magnetic field of the Limuru quartz trachyte is reversed with respect to that of the alkali trachytes. Iron ores are also present in most specimens, generally in the form of magnetite. Sericitization has taken place along cracks in some of the feldspar phenocrysts.

Analyses of alkali trachytes from the vicinity of Lake Magadi are given by Baker (1958, p. 20).

8. Orthophyre Trachytes

These are very distinctive lavas which conformably overlie the alkali trachytes.* They are common in the south-west quarter of the area, and also occur in the south-east quarter. Evidence that these lavas are conformable on the alkali trachytes is present at Lolwa where the two are seen in contact. The topography produced by these lavas is very characteristic and is easily recognisable from air photographs and from the ground. As already mentioned, these lavas give rise to tor-type of topography, and to 'hot cross bun' and plateau structures. The surface of these lavas is much more uneven than that of the alkali trachytes and there is a thick and extensive soil cover through which boulders of the lava protrude. The vegetation on these lavas is also characteristic, consisting of a thick growth of stunted thorn trees, whereas the alkali trachytes have little or no vegetation. Weathering on boulders of the Orthophyre Trachytes is deep, and it is sometimes difficult to obtain fresh specimens. There is a similarity of appearance of these lavas throughout their outcrop. On weathered surfaces the colour of the rocks is dark brown or black, with numerous feldspar phenocrysts which protrude above the surface. On freshly-broken surfaces the colour varies from light to medium-grey. The feldspar phenocrysts are not very prominent in fresh specimens as they have a colour similar to that of the groundmass. The thick soil cover surrounding outcrops of these lavas is reddish-brown and contains numerous fragments of feldspar phenocrysts.

In thin section the feldspar phenocrysts are seen to be anorthoclase up to 10 mm in length. As in the alkali trachytes, microphenocrysts are present which frequently contain dusty inclusions and are traversed by cracks, some of which have an iron or sericite infilling. Twinning, particularly in the phenocrysts, is generally rare, but where it occurs is according to the Carlsbad law. The groundmass is composed mainly of anorthoclase. Pale green anhedral

* Crossley (1979) states: 'areas previously mapped as Orthophyre trachytes are now known to include at least two flows of quite different ages: the Ewaso Ng'iro trachyte and the North Kordjia trachyte'. These have ages of c 2.1 and c 1.8 Ma, respectively.

augite is common, some of which is in the form of microphenocrysts. Aegirine and cossyrite, the latter pleochroic from red-brown to opaque, are present in nearly all specimens, and kataphorite occurs in some thin sections. Iron ores in the form of magnetite or haematite are ubiquitous. Apatite is present as an accessory mineral in one rock, 51/1227 from Koloo, and calcite occurs as a secondary infilling in the same specimen. Other examples typical of these lavas are 51/1229 from Lolwa, 51/1233 from 6.5 km south-east of Mosiro and 51/1240 from 1.5 km south-east of Sosian.

Orthophyre Trachyte also occurs at the edge and at the foot of the Enguasero Nanyukie plateau and forms a distinct topographic feature in the form of a ridge along the edge of the escarpment. This lava differs in its macroscopic features from Orthophyre Trachytes seen elsewhere in the area. In hand specimens 51/1248, 51/1331 and 51/1332 it is seen to be highly porphyritic, with feldspar phenocrysts up to 20 mm in length. Thin section examination reveals that the constituent minerals of these specimens are the same as have already been described. This Orthophyre Trachyte, where it crops out on top of the scarp, rests on Kirikiti Basalts.

9. Ash and scoriaceous lava vents

On the Narok road, about 2.5 km east of Nangaru, there is a small conical hill of trachyte lava which is down-faulted on its western side. In hand specimen (51/1222) it is medium-grey with glassy feldspar phenocrysts. Thin section examination shows that these phenocrysts are anorthoclase, and this mineral also makes up the bulk of the groundmass where it occurs as small needles. Other minerals present are augite and aegirine, and small grains of cossyrite and magnetite also occur.

Another small cone occurs close to the southern border of the map. Again, the lava there is a trachyte, fine-grained and very closely jointed. It differs from the normal alkali trachytes in that it is non-porphyritic.

These cones rest on alkali trachytes and are probably older than the grid faulting. Similar cones and vents occur in the Magadi area (Baker 1958, p. 25) where it was thought that they represent the closing phase of alkali trachyte volcanicity, and it is considered that those in the present area can be correlated with those of the Magadi area.

10. Mau Ashes

The pyroclastics which occur on the Mau escarpment in the north-west quarter of the area are dominantly brownish or grey and are composed of material of ash size. On the higher parts of the escarpment, towards the northern part of the area, the high rainfall has altered these pyroclastics and converted them to a clayey ash. Exposures on the Mau are generally

poor and the ashes are seen only in section in road cuttings and in erosion gullies near the crests of interfluvies, or in some of the cattle tracks.

Siliceous and calcareous nodules occur in places embedded in the ashes, and are up to 80 mm in length. In good exposures, the bedded nature of the pyroclastics can be seen. One such section, at a locality about 3.2 km east of Nairage Ngare shows the following succession:

	Thickness (m)
6. Pale buff-coloured ashes	2.4
5. Banded brown and grey ashes	0.9
4. Grey ashes	0.3
3. Grey pumice band	0.15
2. Brown ashes	0.15
1. Grey ashes	0.6
Total	4.5

Small faults occur in the banded brown and grey ashes but the movements are only of the order of some 100 mm. Angular obsidian fragments, together with grains of quartz and feldspar, are commonly found embedded in the ashes.

It is probable that the majority of the ashes were deposited sub-aerially. It was noted during the survey that the valleys cutting through the pyroclastics are not symmetrical, the eastern sides of the valleys being steeper than the western sides. This fact was also noted in the Mau area to the north-west (Williams, 1991) where it was concluded that a gentle eastward tilting was responsible.

Obsidian artefacts in thin soils overlying these pyroclastics in the Mau area (Williams, 1991) have been dated provisionally as late Upper Pleistocene, and it is inferred from this that the bulk of the ashes are older than late Upper Pleistocene, and they have therefore been assigned to the Middle Pleistocene.

* The Mau Ashes are generally considered now to be distal pyroclastic deposits predominantly from Longonot and Suswa volcanoes. They are therefore younger than about 0.24 Ma (Baker *et al.* 1988) (Eds).

11. Longonot Trachyte*

This lava crops out in the extreme north-east corner of the area, where it forms a distinct topographic feature rising about 30 m above the level of the plain. This flow is of the *aa* type and originated in the Naivasha area to the north, probably from a small vent or fissure on the south-east side of Longonot mountain. In hand specimen 51/1259 the lava is medium-grey, vesicular, and rather frothy in appearance. No visible phenocrysts are present. In thin section it is very fine grained, but needles of anorthoclase feldspar are present, together with cossyrite and probably other sodic pyroxenes.

12. Basalt cinder cones and hills**

North of the Narok road there are several hills and cones. The latter are approximately circular in shape, each with a flat top which has a slight depression towards the centre. The depressions have been infilled by windborne material but it is considered that they mark the original sites of the vents. The small hills on the other hand are irregular in shape and size, with no definite site for the vent. The sides of the cones are composed of highly-vesicular basaltic cinders which are very light in weight.

Specimen 51/1340 was collected from the hill 5.6 km north of the site of the abandoned Suswa Police Post. In hand specimen it is a melanocratic rock, locally with black phenocrysts. In thin section it is seen to contain labradorite feldspar, augite, olivine and magnetite.

Another specimen is 51/1261, from an upstanding block 4.8 km west-south-west of Akira Ranch. This rock is mesocratic, holocrystalline, non-porphyritic and slightly vesicular. In thin section it has the same composition as 51/1340.

13. Sediments of the Kedong valley

To the east of the Kedong river, a thick series of sediments, poorly exposed, extends to the eastern scarp of the Rift Valley. They also crop out at the southern end of the Kedong valley. The eastern limit of these sediments is marked by the diatomite deposit at Munyu wa Gicheru, which lies east of the map sheet boundary. This, it is thought, is the site of 'Lake Suess' which was postulated by Gregory (1896). A section in these sediments at the southern end of the Kedong valley revealed the following succession:

* The Longonot Trachyte is younger than 9,150 BP on the evidence of radiocarbon dating (probably younger than 5,000 BP) and older than 3,280 BP (Clarke *et al.* 1990) (Eds).

** These are described as the Tandamara Formation by Torfason (1987) and predate the collapse of Suswa caldera. In age they are therefore probably between 0.15 and 0.24 Ma but may be as young as 0.1 Ma (Eds).

	Thickness (m)
5. Fine grey sand	3.4
4. Coarse sand	0.3
3. Red-brown clays	4.6
2. Conglomerate	0.9
1. Red-brown clays	3.0
Total	12.2

There is little grading in these sediments and it is probable that they resulted from rapid deposition. Immediately to the west of this point, the Kedong river abruptly changes direction from a dominantly N-S trend to E-W, and the river has carved out a vertical-sided gorge.* It is possible that this represents the original overflow channel of 'Lake Suess', and that over the years the river has gradually cut down through the lava which formed the dam wall, the erosion possibly being assisted by the presence of jointing. Shackleton (1955, p. 259) thought that the lake deposits which are well exposed at Munyu wa Gicheru were probably of Middle Pleistocene age. Gregory (1896) originally thought that these deposits were Pliocene but later re-assigned them to the Lower Pleistocene (Gregory 1921, p. 199).

It is possible that small lake deposits exist in between the fault blocks in the grid-faulted portion of the area, but at present none are exposed, and the surface cover consists of loessic soil.

14. Superficial deposits

These deposits are generally confined to the troughs between faulted lava blocks. The fault blocks themselves have a very poor soil cover when present, but more often it is absent except where it has been preserved in pockets protected from wind erosion. The soils in the troughs are light brown and dusty, and have been derived by wind erosion from the fault blocks and from hillwash. The Orthophyre Trachytes on the other hand have a thick, dark red soil cover and support a dense vegetation of stunted thorn bushes which protect the soil from erosion.

Soils occur on the floors of some of the Suswa lava tunnels, generally near the entrances. Samples have been collected and analysed with the following results (Glover *et al.* 1964, p. 64) which are shown in Table 2.

* Dates from Suswa lavas establish the approximate age of this Kedong flood at about 100,000 BP (Baker *et al.* 1988). The flood drained not just water dammed in the Kedong valley but also part of the Naivasha-Elmenteita lake basin (Eds).

Table 2 Soil analyses (Suswa lava tunnels)

	unit	I	II
Depth	feet	0.25	5.00
Colour		Brown	Brown
Texture		Loamy fine sand	
pH		(4.4)	(4.2)
Na	me %	(1.8)	0.5
K	me %	0.4	0.2
Ca	me %	0.6	0.2
Mg	me %	0.1	0.0
Mn	me %	0.2	0.2
P	ppm	112	62
N	%	0.35	0.05
C	%	3.24	0.93
Hp	me %	(5.5)	(3.5)

Anal. E. Bellis, Scott Agricultural Laboratories, Nairobi

me = milli-equivalent; toxicities are bracketed; deficiencies are in *italics*

Bellis (reported in Glover *et al.* 1964, p. 63) described this soil as: 'decidedly odd ... an extremely acid, intensely-leached, loamy fine sand derived from volcanic ash. Its surface has a high organic content and has been influenced probably by sodium-enriched water. The profile is notable for its high phosphorus status; it also contains toxic amounts of aluminium (Hp. me %)... The high carbon content ... would appear to be the result of the accumulation of dead plant material such as leaves, branches and dead grass washed into the cave from the vegetation in and around its entrance.'

VI. GEOLOGY OF MOUNT SUSWA*

1. Introduction

Mount Suswa is one of the largest, and probably the most complex, of several Quaternary, central-type volcanoes in the eastern Rift Valley of Kenya. It rises as an asymmetric, shield-shaped cone from the south-sloping floor of the Rift, at 1525 to 1615 m above sea level, to a maximum altitude of 2,357 m at Ol Doinyo Nyukie trigonometric point. The volcano covers about 270 km² but many of its lava flows, and much of the pyroclastic material, extend beyond the base of the cone. Altogether the products of Mount Suswa probably cover an area of the order of 1,035 km².

The lavas of Mount Suswa are nepheline-bearing, sodalite phonolites. They contrast with the underlying flood lavas of the Rift floor (the Plateau Trachytes), none of which contain feldspathoids, but some of which contain quartz. In hand specimens, however, both lava types are greenish-grey and fine grained, containing a few feldspar phenocrysts, and they cannot be distinguished from one another in the field.

South of Mount Suswa, closely-spaced N-S fault scarps cut the volcanic plateau into horst and trough structures. The faults do not truncate the bulk of the lavas making up Mount Suswa; instead they converge and quickly die out when traced towards the volcano. However, early flows of Mount Suswa are known to have been erupted during faulting because a few of them flowed over fault scarps and were affected by later fault movements. Since Shackleton (1955) and Baker (1958) both consider that most of the block faulting ended before Upper Pleistocene times, the beginning of Mount Suswa volcanic activity can also be dated as pre-Upper Pleistocene.

The history of the volcano may be divided into three major eruptive episodes. During the first episode a primitive shield volcano was built (unit 1 lavas). The second was marked by formation of a caldera and eruption of abundant pumice and thick lava flows of restricted lateral extent, most of which issued from a ring fracture zone outside and concentric with the caldera escarpment (unit 2 lavas). During the third episode lavas partly infilled the caldera and later built Ol Doinyo Nyukie volcano (unit 3 lavas). A later, smaller, collapse feature, in the form of a ring graben, is present within the older caldera on the north flank of Ol Doinyo Nyukie. An idealised cross-section of Mount Suswa, showing the various lava units, is given in Fig. 1.

* This chapter was compiled by R. W. Johnson (Authors).

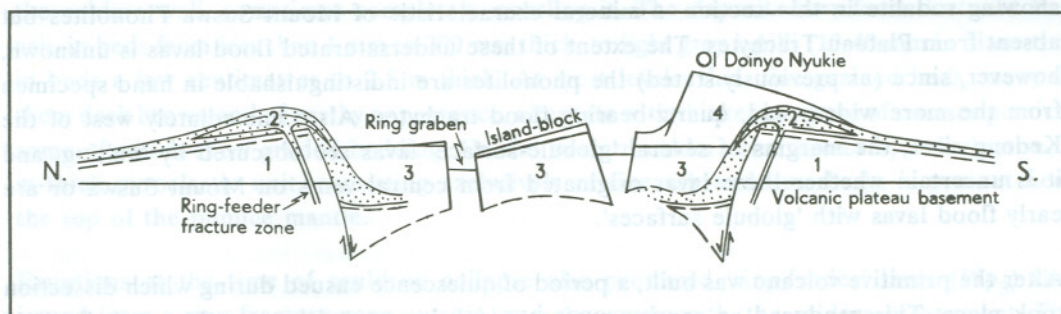


Figure 1 Idealised north-south cross-section of Mount Suswa showing volcanic plateau basement and the four stratigraphic lava units:
 1. Primitive shield lavas; 2. Ring-feeder lavas; 3. Early post-caldera lavas;
 4. Late post-caldera lavas (Ol Doinyo Nyukie lavas)

2. Primitive shield (unit 1) lavas

The phonolite lavas of the primitive, shield-shaped volcano are easily recognised on aerial photographs by their radial arrangement around the mountain summit. The earliest of these lavas were more voluminous and extensive than later ones.*

A characteristic feature of primitive shield lavas is an unusual rock found on surfaces of the later flows ('globule-surface' lavas, Plp₂ on the coloured map). In hand specimen this rock is inhomogeneous, well compacted, and dull grey to dark buff. It is easily indented by a blow from a hammer, and shows columnar jointing with polygonal cross-sections that range in diameter from 40 or 50 mm to about 500 mm. Especially characteristic are cellular, sub-rounded or lenticular, vesicular patches of material which range from microscopic dimensions up to about 50 mm in length. In thin section the rock is seen to consist principally of globules, mainly 0.05-3.00 mm in diameter, with open spaces between them. Each globule has a highly vesicular, crystalline core of alkali feldspar laths, with some interstitial ferro-magnesian minerals and glass, and an enclosing rim of dark brown glass containing numerous opaque grains. The cellular patches of material visible in hand specimens are the cores of larger globules. 'Globule rock' also constitutes the entire volume of a few uniform sheets, 0.5 m to 1 m in thickness, which are exposed in steep-sided gorges on the north flank of Mount Suswa. This rock appears to have formed by vesiculation of the upper parts of the flows. A fuller description and discussion on the origin is contained in Johnson (1968).

Distinction in the field between Mount Suswa Phonolites and Plateau Trachytes is not always clear. For example, several flood lavas immediately south of the volcano are undersaturated,

* These lavas have been further subdivided into two formations by Torfason (1987), with the older formation being affected by grid faulting (Eds).

** See also Hay *et al.* 1979; and Torfason (1987) who describes these as 'agglutinate flows' (Eds).

showing sodalite in thin section, a mineral characteristic of Mount Suswa Phonolites but absent from Plateau Trachytes. The extent of these undersaturated flood lavas is unknown, however, since (as previously stated) the phonolites are indistinguishable in hand specimen from the more widespread, quartz-bearing flood trachytes. Also, immediately west of the Kedong river, the margins of several 'globule-surface' lavas are obscured by faulting, and it is uncertain whether these lavas originated from central vents on Mount Suswa or are early flood lavas with 'globule surfaces'.

After the primitive volcano was built, a period of quiescence ensued during which dissection took place. This produced an erosion surface which is exposed low on the north flank of the volcano.

3. Eruptions at the time of cauldron subsidence (unit 2 lavas)

After the period of quiescence, a caldera was formed and large quantities of pumice were erupted. The caldera is bounded by a steep, inward-dipping escarpment, and occupies a roughly oval area of about 8.3 km². Its E-N-E axis is about 12 km long and lies parallel to the longitudinal axis of the primitive cone; the shorter axis is about 8 km long. The height of the escarpment above the caldera floor ranges from 0-198 m, but is mostly between 110 and 160 m. The floor of the caldera consists entirely of post-caldera lavas; nowhere inside the depression can collapsed remnants of the primitive volcano be identified.

The earliest eruptions at the time of cauldron subsidence produced a distinctive layer of pyroclastic rocks (Plt₂) which is exposed, in outcrops up to 2 m thick, on the northern, eastern and southern outer flanks of Mount Suswa. The layer consists of pumice fragments (less than 20 mm in diameter) with local concentrations of tabular alkali feldspar crystals and small black glass flakes, set in a fine-grained, yellow- to buff-coloured, semi-consolidated and carbonate-rich matrix. The coherent nature of the material, and the absence of lateral or vertical grading and sorting, suggests that the mode of deposition was probably from debris flows, probably *lahars*. At the Kedong river the *lahars* overlie a thick sequence of sedimentary rocks (Pl) that occupies the southern part of a depositional basin which Gregory (1896) called 'Lake Suess'. The *lahars* are also well exposed on the northern flank of the volcano, but when traced to the north-eastern wall of the caldera, they change from unbedded deposits to well-laminated, sub-horizontal beds consisting of accretionary lapilli (2.5-10 mm in diameter), and vesicular, black ash fragments (rarely greater than 15 mm in diameter).

In contrast to the *lahars*, later deposits of pumice (Plt₃) are much thicker, and well bedded and sorted. On the western flank these form a continuous pyroclastic mantle which, at the caldera rim, reaches a maximum thickness of about 60 m. Numerous closely-spaced, steep-sided gullies cut deeply into the mantle producing a characteristic 'badlands' drainage pattern. The mantle thins on the northern and southern flanks of the volcano and disappears entirely on the eastern flank. In the western part of the caldera, pumice beds are inclined against

the caldera wall, sometimes completely mantling it. The deposits vary from dust and fine ash, in beds from less than 1 mm to 300 mm thick, to light grey lapilli (10-40 mm in diameter) in beds a few centimetres to 2.5 m thick. At most levels, thin, fine-grained beds, many of them dark brown and of earthy appearance, alternate with thicker horizons of coarser pumice, some of which show graded bedding. On the western caldera rim, however, a distinctive, 7 m-thick pyroclastic unit, consisting exclusively of fine ash and dust beds, is present near the top of the pumice mantle.

Eruptions at the time of cauldron collapse also produced 'ring-feeder' lavas (Plp₃) that issued from a ring fracture zone outside, and concentric with, the caldera escarpment. The position of this zone is marked by a prominent camber formed by surfaces of the thick, sometimes bulbous, fissure, ring-feeder flows. The camber is absent in the western part of the caldera where a later, small collapse feature has produced a scalloped embayment extending beyond the line of the ring fracture zone.

The ring-feeder lavas flowed mainly on to the upper part of the outer flanks, but at the caldera wall they also dip into the caldera and, locally, cover the escarpment completely. Elsewhere the flows are irregularly truncated, a feature caused by collapse of lava when viscous flows moved over the steep caldera escarpment. Lavas of a similar type to ring-feeder flows were also erupted from N-S fissures on the north flank, marked by well-defined lines of cumulodomes. Spatter beds of ring-feeder lava, 1.0-1.5 m in thickness, are also present, many of which intercalate with pumice beds inclines against the caldera escarpment.

Cross-sections through most ring-feeder flows reveal textures that indicate the viscous nature of the flows at the time of extrusion. A prominent but crude banding, resulting from myriads of small, irregularly-shaped vesicles, lies sub-parallel to flow surfaces. Locally, intense flow convolutions are developed, many of which show rotation of included fragments. In other places distension of lava during flow has formed drawn-out spicules that extend into dilation cavities. Bubbly scoriaceous lenses and layers also show jagged druses between highly irregular clots of vesicular lava that range from microscopic sizes to several centimeters in diameter.

4. Post-caldera eruptions (units 3 and 4 lavas)

The final eruptive episode on Mount Suswa produced lavas that originated mainly within the caldera. These lavas partly filled the caldera, overflowed the lowest part of the rim, and extended down the outer, southern and eastern slopes as long, narrow flows which contrast in form with the more tabular and thicker lavas of the earlier episodes. The post-caldera lavas also show *pahoehoe* surface features which are absent on the earlier flows. Towards the end of the post-caldera period a prominent pit crater and ring graben formed inside the older caldera.

The post-caldera succession may be divided into two parts: (1) unit 3, older non-porphyrific

lavas (Plp₄) and lavas in which sparse tabular, soda-sanidine phenocrysts are present (Plp₅); (2) unit 4, later, Ol Doinyo Nyukie lavas containing abundant, rhombic anorthoclase phenocrysts (Plp₆). The earlier flows are exposed within the caldera and on the south-east, outer flanks of Mount Suswa. The oldest exposed flow inside the caldera is a congealed lava lake which, in the walls of the ring graben, shows a thickness of at least 60 m; the upper surface constitutes the flat floor of the caldera, but the base is not exposed. Later flows were erupted from vents on a linear fissure in the north-eastern part of the caldera floor, marked by a row of lava cones. The first of these lavas were thin and became ponded against the north-eastern caldera escarpment, but later lavas overflowed the eastern caldera wall and extended down the outer flanks to the Kedong basin in a series of voluminous, overlapping lobes. An extensive network of collapse holes and anastomosing lava tubes is developed in the later flows immediately east of the caldera rim; these structures have been described in detail by Williams (1963) and Glover *et al.* (1964). The age of the early post-caldera lavas on the south-eastern outer flank, relative to those within the caldera, is unknown since later Ol Doinyo Nyukie lavas have concealed any possible overlap. These same Ol Doinyo Nyukie lavas have also covered the sources of the early post-caldera lavas on the outer flanks.

The last period of volcanicity on Mount Suswa was marked by eruptions of porphyritic Ol Doinyo Nyukie lavas. Most of the flows issued from a single central vent in the south-western part of the caldera, giving rise to Ol Doinyo Nyukie volcano, a cone rising more than 485 m above the caldera floor. Several satellite eruptions later broke through the flank of Ol Doinyo Nyukie, and the main summit vent was widened to form a pit crater.

Ol Doinyo Nyukie volcano is roughly elliptical in plan, its long, N-W axis running tangential to the later ring graben. The base of Ol Doinyo Nyukie in the north-western wall of the ring graben overlies a prominent pyroclastic horizon consisting of finely-bedded, light brown to black ash fragments (less than 5 mm in diameter) and angular fragments of alkali feldspar. The horizon is about 30 m in maximum thickness, but it thins rapidly eastwards and is missing along the northern, outer wall of the ring graben.

Satellite-vents on the flanks of Ol Doinyo Nyukie have produced two prominent lava flows, each consisting of several flow units, and a number of small lava cones. The flow exposed low on the north-western flank of Ol Doinyo Nyukie originated from a vent just west of the north-western edge of the ring graben and flowed northwards and westwards on to the caldera floor. The age of the ring graben collapse, relative to the time of eruption of the flow, therefore remains uncertain since the flow is not cut by the ring fault. The second flow was erupted from a fissure, at least 1.5 km long, which trends towards the summit of Ol Doinyo Nyukie and is cut off by the outer fault of the ring graben. The line of this fissure is marked by a row of about 30 lava cones. The feldspar phenocrysts of both satellite-vent flows are generally smaller and more tabular than those of lavas making up the main cone.

A third satellite-vent flow is probably present on the inaccessible 'island-block' inside the ring graben.

The most recent flows on Mount Suswa, although younger than the ring graben, are similar to Ol Doinyo Nyukie lavas in containing abundant phenocrysts of anorthoclase. The sporadic cover of vegetation and the freshness of the lava suggest that these flows are probably only one or two centuries old. One lava crops out in the base of the ring graben and has a crescentic plan due to flow in two opposite directions from a hidden vent on the floor of the ring graben. The other lava crops out on the southern outer flank of Mount Suswa and was erupted from a N-S fissure.

After eruption of the last flow from the summit of Ol Doinyo Nyukie, the main vent was enlarged to form a prominent pit crater. This enlargement may have been caused by peripheral collapses into the vent, or by cylindrical subsidence along a ring fault of small diameter. The pit crater is approximately 460 m deep and is truncated on its north-eastern side by the later graben. The remnant features of the crater indicate that it was originally elliptical in plan, its longest axis tangential to the later ring graben.

5. Ring graben

The second major collapse on Mount Suswa took place entirely within the older caldera and produced an annular trench or 'ring graben' which lies slightly toward the south-eastern rim of the caldera. In contrast to the earlier cauldron collapse, formation of the ring graben was not accompanied by eruption of lava flows or pyroclastic material (McCall 1963).

The ring graben consists of two more or less concentric fault scarps bounding a steep-sided, annular zone of subsidence. It cuts deeply into the post-caldera lavas of the outer caldera floor, truncates the pit crater, and isolates an oval, flat-topped, steep-sided 'island-block' (McCall and Bristow 1965), with a circumference of 10.5 km, a maximum diameter of 3.7 km and a minimum diameter of 2.4 km. The block is tilted a few degrees to the north-west, and its south-eastern and north-western edges are slightly upwarped. Most of the island-block surface lies below the level of the surrounding inward-facing fault scarp rim. Step faults and slumped segments of Ol Doinyo Nyukie lavas are preserved along its northern edge. Thick vegetation makes the block extremely difficult to reach and traverse on foot and only the northern rim has been mapped by the writer.

The width of the ring graben varies from about 490 m in the north to 1,830 m in the south-east. In the northern part the height of the outer fault scarp ranges from about 90 to 215 m, and at the precipice beneath Ol Doinyo Nyukie summit it reaches a maximum of about 520 m. These variations in height are caused by the variable topography of the graben floor and the gradual rise of the outer escarpment rim towards the summit of Ol Doinyo Nyukie. Due to partial filling by the crescentic, post-ring-graben flow (Rvp₂), the southern part of the

graben floor is flat. The surface of the flow decreases in altitude and width to the north-western and north-eastern tips of the crescent between which, in the north, the topography is irregular and rugged. There high ridges are found covered by extensive talus deposits consisting of boulders up to about 4 m in diameter.

Although the surface of the island-block and the rim of the outer ring graben wall both consist of Ol Doinyo Nyukie lavas, no individual flow on the central block has been correlated with a counterpart across the ring graben. Moreover, as emphasised by McCall and Bristow (1965) there is no remnant of the steeper parts of the main cone of Ol Doinyo Nyukie on the opposite rim of the island-block. McCall and Bristow explained this feature by considering that flows from Ol Doinyo Nyukie terminated close to the vent on the north side so that they failed to reach the area enclosed in the island-block. Therefore, although it is possible that the surface of the island-block is the direct continuation of the outer caldera floor across the ring graben, evidence to support this has not been found.

The northern flanks of two *en échelon* ridges in the north-eastern part of the ring graben show rare outcrops of non-vesicular, dense, crystalline phonolite (Rvp₁) characterised by a lamination that dips northward at 20° to 50°. In thin section the lamination is seen to be due to parallelism of groundmass feldspar laths, accentuated by hydrothermal alteration, which gives a coarse banding composed of alternating dark and light streaks and irregular lamellae. Tabular alkali feldspar phenocrysts are frequent; and rounded, non-laminated patches (less than 10 mm and up to 100 mm in diameter) of material identical in mineral content to the enclosing matrix are occasionally found which allow gradational contacts with the fissile matrix. Because of its distinctive appearance and slightly different mineral content compared to lavas in the opposite wall of the ring graben, it is believed that this rock may be intrusive and that the ridges which it constitutes are inclined blocks of a ring intrusion that was emplaced before collapse of the ring graben.

A coarse agglomerate (Rvf) consisting of sub-rounded boulders, up to about 3 m in diameter, set in a dull grey to brown, earthy, pulverulent matrix is restricted entirely to the walls of the ring graben. The boulders consist of Ol Doinyo Nyukie lavas, lavas of the earlier post-caldera period, and laminated 'ring-intrusion' rocks. The agglomerate appears to have been formed by explosions which took place along the ring fractures, comminuting the wall rocks and causing detached blocks to become rounded. Subsequent collapse along the same fractures left fault scarps coated with agglomerate.

6. Geothermal activity

Geothermal activity still continues on Mount Suswa. Small amounts of steam emerge at low pressure from hot soil patches and cracks on lava flow crusts and are clearly visible at times of high humidity. The location of other hot patches is also indicated by characteristic 'bald' spots which favour the growth of a particular type of plant, *Fimbristylis exilis*. Although the

water vapour usually issues as small drifting columns of steam, violent phreatic rushes have also been observed (Glover 1965, pers. comm.). Between 4 and 5 pm on 29th February 1964, after a period of heavy rainfall, two steam jets were observed to blow vertically from the east-central part of the island-block, and from the pit crater wall. Each blast lasted about two minutes and rose more than 150 m, but as far as the observer could see, neither was accompanied by the ejection of any debris.

Fumaroles coincide with the major ring fractures in the area of the caldera. They are particularly well developed along the northern part of the ring graben, where hot soil patches are associated with small hydrothermal mineral deposits of kaolinite, alum, goethite, silica and sulphur. Ash beds at the base of the Ol Doiyo Nyukie sequence are also a prominent horizon at which rising hydrothermal vapours are arrested.

7. Petrology*

The lavas of Mount Suswa are nepheline-bearing, sodalite phonolites. Their undersaturated nature is indicated in Table 3 by the CIPW norms of ten analysed samples all of which show normative nepheline. This contrasts with analyses of Plateau Trachytes which show normative quartz (Baker 1958, p. 20). There is little variation in the mineral content of the Mount Suswa lavas throughout the succession. Variable proportions of phenocrysts include, in order of abundance, soda-rich alkali feldspar, augite, fayalitic olivine, titanomagnetite, and to some extent sodalite and nepheline. The matrices of the lavas vary from glass containing alkali feldspar laths, opaque grains, and sparse nepheline crystals to a completely crystalline groundmass in which sodalite, augite, aenigmatite and soda-amphibole are present as additional constituents. Many of the glassy rocks are heterogeneous with patches, lenses and lamellae of more crystalline, and generally more vesicular material in a darker, glassy matrix. These rocks are similar to some described by McCall (1965) from the controversial 'froth-flows' found in various parts of the Rift Valley.

In describing the slight variations in mineralogy and chemistry of the Mount Suswa sequence it is convenient to consider the following four stratigraphic units: (1) primitive volcano lavas; (2) ring-feeder lavas; (3) early post-caldera lavas; and 4) Ol Doiyo Nyukie lavas (Fig. 1).

Two types of feldspar phenocryst are found in the Mount Suswa lavas, both of which, from optical examination, appear unzoned and non-perthitic. One type is distributed erratically throughout units 1, 2 and 3. These feldspars are tabular and up to 15 mm in length. They commonly show Carlsbad twins but twinning on triclinic laws is usually absent.

* This account of the petrology is condensed from a more complete account by Nash *et al.* 1969 (Author).

Table 3 Chemical analyses of Mount Suswa lavas

	Plateau Trachyte	Unit 1	Unit 2	Unit 3			Unit 4			
	W300	W120	W100	W47	W118	W134	W160	W158	W109	W52
SiO ₂	61.09	57.63	59.10	56.14	56.13	57.73	56.95	56.87	57.58	56.74
TiO ₂	0.91	0.59	0.65	1.05	1.07	1.18	1.36	1.31	1.02	0.69
ZrO ₂	-	0.24	-	0.13	0.14	0.07	0.09	0.09	0.10	0.13
Al ₂ O ₃	16.64	15.29	15.12	16.34	16.13	17.05	16.80	16.63	16.83	17.87
Fe ₂ O ₃	3.37	4.92	5.32	4.43	4.00	2.55	2.65	2.35	3.25	1.92
FeO	2.40	3.13	2.49	3.92	4.57	4.35	5.14	5.16	4.39	5.00
MnO	0.18	0.40	0.37	0.36	0.35	0.28	0.31	0.31	0.33	0.30
MgO	0.59	0.51	0.49	0.75	1.59	1.11	0.99	1.04	0.74	0.66
CaO	1.52	1.52	1.66	2.43	2.43	3.10	2.87	3.13	2.19	2.11
Na ₂ O	6.49	7.07	7.17	6.71	7.24	6.81	6.89	6.63	7.86	8.92
K ₂ O	5.89	5.29	5.12	5.18	4.99	4.27	4.43	4.36	4.95	4.95
P ₂ O ₅	0.13	0.14	0.07	0.19	0.20	0.34	0.34	0.31	0.25	0.16
H ₂ O +	0.68	1.40	1.19	0.84	0.86	0.64	0.64	1.11	0.21	0.19
H ₂ O -	0.28	1.38	0.66	1.24	0.35	0.39	0.34	0.43	0.13	0.13
Cl	0.08	0.45	0.22	0.20	0.20	0.09	0.11	0.09	0.16	0.20
CO ₂	-	-	-	-	-	-	0.19	-	0.13	-
- O eqv	0.02	0.10	0.05	0.04	0.04	0.02	0.02	0.02	0.04	0.04
Total	100.23	99.86	99.58	99.87	100.21	99.94	100.08	99.80	100.08	99.93

W300 Sodalite-bearing flood lava from plateau basement; centre of flow at base of sthn. flank of Mt. Suswa

W120 Primitive shield volcano lava; centre of 25 m-thick flow in north-east wall

W100 'Ring-feeder' lava; 2 m from base of 27 m-thick flow in western caldera wall

W47 One metre from base of 4 m-thick flow in north-eastern wall of ring graben

W118 Surface of flow close to eastern caldera wall

W134 Two metres from base of 10 m-thick flow in north-western graben wall

W160 Surface of flow 1 km south-east of Ol Doinyo Nyukie summit

W158 Surface of flow at Ol Doinyo Nyukie summit

W109 Surface of north-west satellite-vent flow at its western margin

W52 Surface of flow on floor of ring graben at north-east tip of crescent.

Table 3 (continued) CIPW norms of Mount Suswa lavas

	Plateau Trachyte	Unit 1	Unit 2	Unit 3			Unit 4			
	W300	W120	W100	W47	W118	W134	W160	W158	W109	W52
z	-	0.36	-	0.19	0.21	0.10	0.13	0.13	0.15	0.19
or	34.81	31.26	30.26	30.61	29.49	25.23	26.18	25.76	29.25	29.25
ab	50.29	42.28	44.38	41.40	35.74	47.57	45.88	44.95	38.31	31.01
an	-	-	-	-	-	3.70	2.26	3.09	-	-
ne	1.36	3.75	2.65	7.48	10.53	5.09	6.29	5.68	11.22	18.06
hl	0.13	0.74	0.36	0.33	0.33	0.15	0.18	0.15	0.26	0.33
ac	1.34	6.43	8.61	0.08	4.05	-	-	-	5.56	5.55
ns	-	-	-	-	-	-	-	-	-	0.78
wo	2.80	2.77	3.25	4.52	4.49	3.95	3.57	4.35	3.51	3.93
en	1.47	0.80	1.17	1.87	1.95	1.53	1.13	1.37	0.88	0.68
fs	0.84	2.08	2.15	2.50	2.53	2.47	2.57	3.14	2.83	3.57
fo	-	0.33	0.04	-	1.41	0.86	0.93	0.86	0.67	0.67
fa	-	0.93	0.08	-	2.01	1.53	2.33	2.17	2.37	3.88
mt	4.21	3.91	3.40	6.38	3.77	3.70	3.84	3.41	1.92	-
il	1.73	1.12	1.23	1.99	2.03	2.24	2.58	2.49	1.94	1.31
ap	0.31	0.33	0.17	0.45	0.47	0.81	0.81	0.73	0.59	0.38
cc	-	-	-	-	-	-	0.43	-	0.30	-
H ₂ O +	0.68	1.40	1.19	0.84	0.86	0.64	0.64	1.11	0.21	0.19
H ₂ O -	0.28	1.38	0.66	1.24	0.35	0.39	0.34	0.43	0.13	0.13
Total	100.24	99.87	99.59	99.88	100.22	99.96	100.10	99.82	100.1	99.94

X-ray diffraction analyses* of feldspars from nine rocks show compositions varying from Or₃₀ to Or₃₉, placing most of the feldspar in the soda-sanidine range. The second type of feldspar phenocryst is abundant in the distinctive Ol Doiyo Nyukie lavas (unit 4). In general, these are larger than the earlier types, some reaching 30 mm in length. Many are rhombic and most show cross-hatched ('anorthoclase') twinning. X-ray diffraction analyses of feldspars from eight Ol Doiyo Nyukie lavas gave compositions from Or₁₇ to Or₃₀, placing them in the anorthoclase range.

* Determinations were made using the $\bar{2}01$ method of Bowen and Tuttle (1950) on a Philips powder diffractometer with KBrO₄ as internal standard (Orville 1957) (Author).

Mafic phenocrysts are usually less numerous, and all are much smaller than the accompanying feldspars. Phenocrysts and glomeroporphyritic aggregates of mafic minerals are particularly abundant in the Ol Doinyo Nyukie lavas (unit 4). Augite (2V of about 60°) showing a pale green to pale brown pleochroism, is present as euhedral crystals up to 0.4 mm in diameter. Fayalite (2V of about 50°) is found as pale honey-yellow, anhedral to subhedral grains, up to 0.4 mm in diameter, in any one rock tending to be smaller and less abundant than the pyroxenes. Euhedral grains of titanomagnetite, up to 0.2 mm in diameter, are common and frequently enclosed in the more abundant silicate phenocrysts.

Sodalite and nepheline are both present in the Mount Suswa lavas. Their relative proportions differ, however, depending upon the crystallinity of the groundmass of the lavas. Sodalite is absent in glassy rocks but common in completely crystalline types. In contrast, nepheline may be found in both glassy and crystalline lavas. The sodalite is clear, colourless, isotropic ($n = 1.484 \pm 0.002$) and is usually found as dodecahedral grains. Single crystals rarely exceed 3 mm but simple aggregates, consisting of two to four anhedral grains, intergrown with augite, reach a maximum diameter of about 0.4 mm. Typically, groundmass ferromagnesian minerals surround sodalite microphenocrysts in irregular patchy zones. Nepheline (uniaxial, sometimes with a small 2V, optically negative) is present as erratically-distributed grains, dominantly rectangular in outline, a few of which show hexagonal cross-sections. Crystals are usually less than 0.1 mm in length and frequently contain opaque grains which are sometimes arranged in ring-like zones.

The groundmass of samples from centres of flows thicker than about 4 m are usually completely crystalline. They show abundant alkali feldspar laths and a variety of interstitial ferromagnesian minerals including dull, pale green to brownish-green, weakly-pleochroic, augite; strongly pleochroic, russet-red to opaque aenigmatite; and soda-amphibole with a strong, pale or bright green to brownish-green pleochroism suggestive of an arfvedsonitic composition. The pleochroism of the groundmass amphibole in the phonolite believed to be a ring intrusion (Rvp1) is characterised by a prominent blue which probably indicates a composition closer to riebeckite. Faint tinges of blue are sometimes shown by the amphibole lavas.

A glassy groundmass is found in all parts of flows less than about 4 m thick; in thicker lavas it is restricted to the tops and bottoms of flows. In lavas of unit 2, glassy rocks are common and only in the centres of flows thicker than about 15 m is interstitial glass totally absent. The glassy rocks contain alkali feldspar laths, some nepheline and numerous opaque grains. Titanomagnetite in grains less than three microns in diameter, peppers the glassy rocks of all four units, but decreases in amount where interstitial ferromagnesian minerals are present. Ilmenite is also common in glassy rocks of units 3 and 4, and is easily recognised by the numerous vein-like apophyses that extend from central grains in complex anastomosing patterns. Ulvospinel, a rare opaque mineral usually found in intrusive rocks, is present in the 'ring intrusion' phonolite, but has not been identified in lavas.

The commonest amygdale-minerals are calcite and chalcedony. Amygdaloidal zeolites are rare although many small vesicles in massive crystalline lavas are filled with fibrous aggregates that may be natrolite.

VII. STRUCTURE

The earliest systematic studies of Rift faulting (Baker 1958, 1963) demonstrated a probable total of three distinct periods of faulting. The first movement cut through 'Basement System' rocks and marked the western Rift margin with a downthrow to the east. Baker considered this fault to be of Middle or Lower Tertiary age. This movement was followed by the eruption of the Kirikiti Basalts which themselves were downthrown to the east by a younger fault which gave rise to the Kirikiti platform. This younger fault was thought to be end-Tertiary or Early Pleistocene in age (p. 63). The third movement was postulated on evidence found in the area south of Magadi (Baker 1963) and this is considered to be of post-Lower Pleistocene age. Shackleton (1955, p. 262) considered that the main faulting had taken place prior to the Lower Pleistocene, and Kent (1944, p. 24) thought that the earliest rifting had taken place in the Upper Miocene. McCall (1967, pp. 11-12) considered that major faulting had taken place on three occasions, in the late Miocene or early Pliocene, in the late Pliocene and in the Middle Pleistocene.

Faulting in the Suswa area is very clear both on air photographs and on the ground. This is due to the freshness of the fault scarps, which have suffered little erosion. Three types of faulting are recognised: rift faulting, grid faulting and minor faulting. Fig. 2 shows the distribution of faults in the Suswa area.

With regard to the Rift faulting, the last movement took place in post-Lower Pleistocene times as the Orthophyre Trachyte, which occurs at the edge of the Enguasero Nanyukie plateau and as down-faulted blocks at the bottom of the escarpment, is of assumed Lower Pleistocene age. This trachyte also occurs around Sosian, east of which it is downthrown to the east. It is possible that there has been an earlier movement in the same region, and if this is the case the following suggestion is put forward as to the sequence of events.

The first lavas to be erupted were the Kirikiti Basalts and these were followed by the eruption of the alkali trachytes. Faulting then occurred, downthrowing the Kirikiti Basalts and the early trachyte flows to the east. This was followed by the eruption of more alkali trachytes further to the east, and these in turn were succeeded by the Orthophyre Trachytes which in the area around Sosian flowed up, and locally over, the existing fault scarp onto the Kirikiti Basalts and older trachytes. A further movement then occurred downfaulting the Orthophyre Trachytes to the east followed by a rejuvenation of the original fault, producing the scarp seen at the present time. On the Enguasero Nanyukie plateau there was no eruption of alkali trachytes and the Orthophyre Trachyte rests on the Kirikiti Basalts.

The grid faulting which occurs over much of the southern half of the area has been provisionally dated as lower Middle Pleistocene in age (Baker 1958, p. 63) as the Olorgesailie Lake Beds which are of upper Middle Pleistocene age, and which occur in the north-eastern part of the Magadi area, are known in places to overlies scree at the base of fault escarpments (p. 35). The general trend of these grid faults is a few degrees E of N and is very constant, although there are local deviations from this direction, some of which are quite marked. The throw of the faults is variable and they tend to die out quickly, being replaced by others

which continue the movement in an *en échelon* block. The topography produced by this kind of faulting is of the step, table and trough type. The fault blocks are often tilted in a southerly direction, but some have a northerly tilt. Around Suswa these grid faults take on a different trend and exhibit a concentric arrangement around and particularly to the south of the volcano.

Minor faulting took place at a later date, possibly in Upper Pleistocene times, and affected the Mau pyroclastics, but movements along these faults are small and displacements are generally of only a few centimetres.

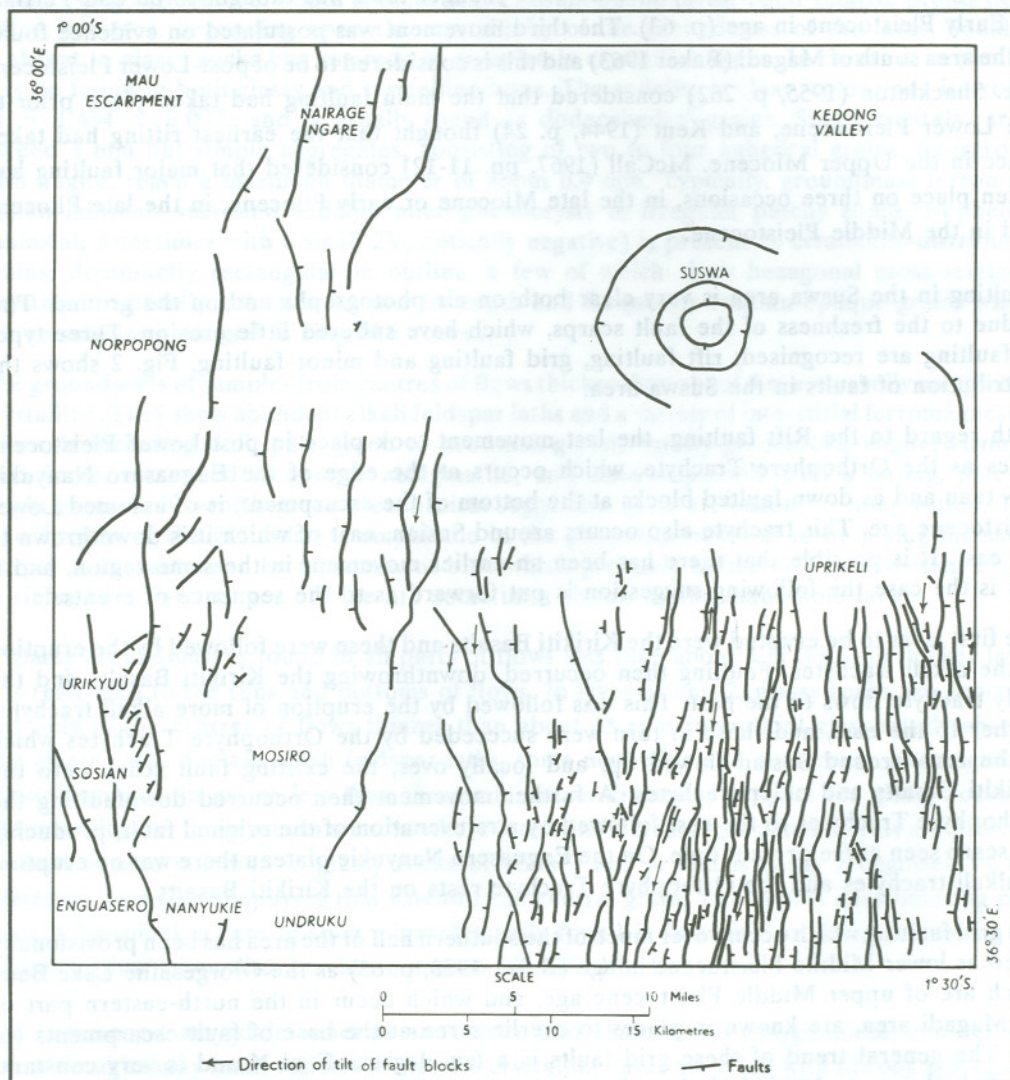


Figure 2 Fault patterns in the Suswa area

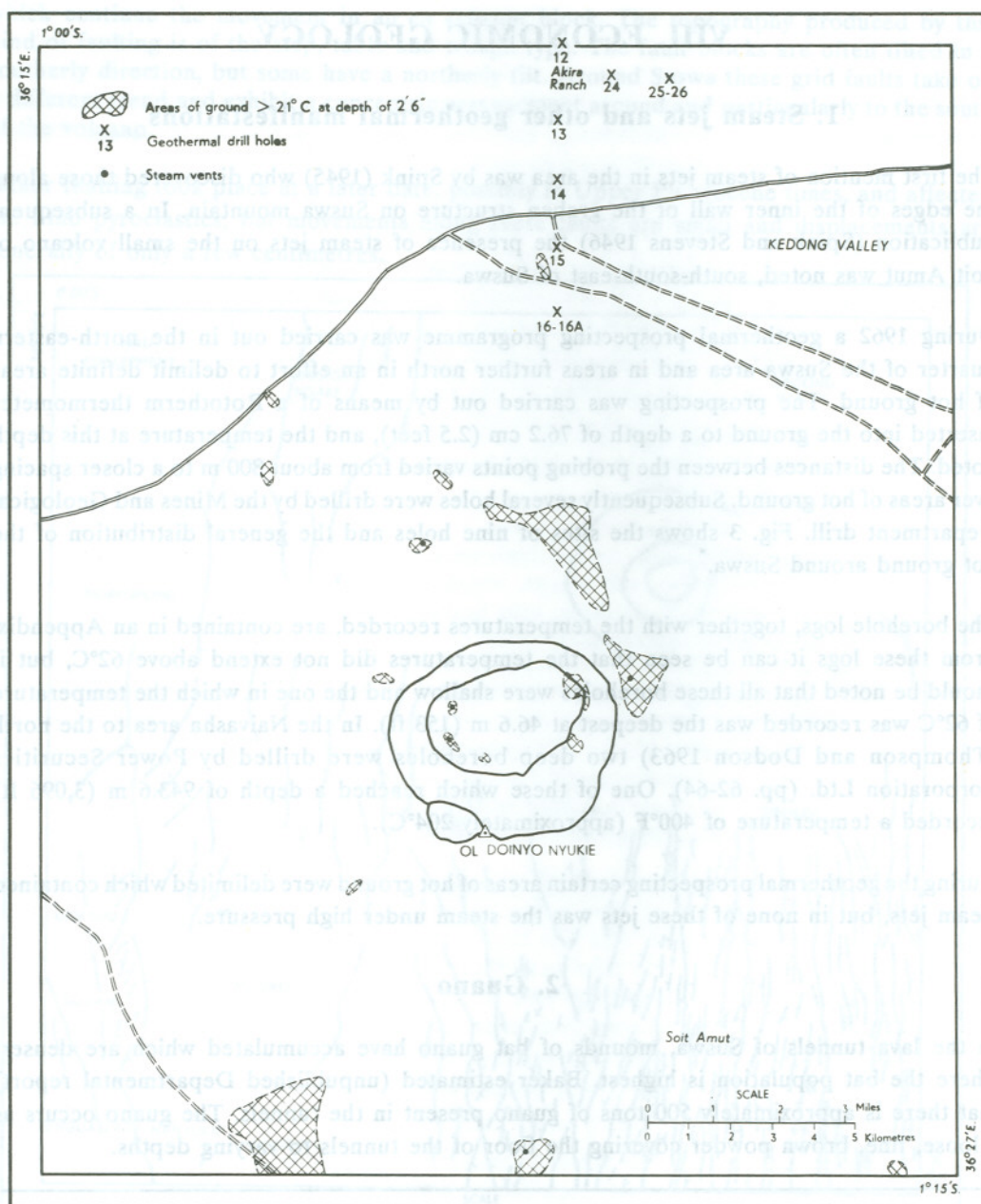


Figure 3 Areas of hot ground around Mount Suswa

Analyses of various samples of guano have been carried out and the results are given in Table 4. The location of the caves from which these samples were taken is unknown.

Table 4 Analysis of bat guano samples (per cent)

	SU/1	SU/2	SU/3	SU/4
Moisture	39.55	15.57	18.57	17.83
Dry sample:				
Total P_2O_5	12.07	12.75	7.01	13.34
Citric-acid-soluble P_2O_5	10.27	8.61	6.59	10.97
Loss on ignition	80.12	77.70	39.56	77.22
N	12.51	10.57	7.01*	10.74

Anal. C H Jani, Mines and Geological Department, Nairobi

* Insufficient sample for complete analysis, hence taken dry and nitrogen calculated

3. Water supplies

In the north-western part of the area water is relatively abundant, as rivers flowing off the Mau escarpment generally contain water throughout the year. In the south-west of the area the Uaso Ngiro river provides a perennial water supply, and cattle are brought to the river from miles around. The Kedong river in the north-west has water over part of its length but this is liable to disappear in the dry season. The south-east portion of the map area is very poorly supplied with water and as a result most of it is practically uninhabited by man or by wildlife. The trading centre of Joroi has wells close by, but the water is somewhat saline. With regard to the other trading centres, Nairage Ngare has a piped supply to a tap in the centre of the town, but Mosiro in the south-west has no fixed supply and has to rely on water carried from the Uaso Ngiro about 11.3 km away. This is not a satisfactory arrangement, particularly as there is a dispensary there, but it would appear that the only solution would be to provide a pipeline and pump water from the river. The river water is always muddy but it was found that boiling and filtering made it clear and potable.

To date a total of seven boreholes, varying in depth from 21.3-85.3 m (70-280 ft) have been drilled in the area, all in the northern half, but none have produced water and it is unlikely that further boreholes will be sunk in the foreseeable future. One place, however, where it is possible that water might be obtained by drilling is at the foot of the Ol Esakut hills which rise to nearly 2,105 m just outside the eastern boundary in the extreme south-east of the area, but there is the possibility that the water might be saline, as are the wells at Joroi.

In places where steam jets are known, i.e. on and around Suswa, it should be possible to erect simple condenser plants which would alleviate the water shortage to a certain degree, but even for this a certain amount of drilling would be necessary. The construction of small earth dams has been carried out here and there, particularly in the south-east quarter, but these have not been very successful due to the general lack of rain in that region.

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