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Report No. 63



GOVERNMENT OF KENYA

MINISTRY OF NATURAL RESOURCES
GEOLOGICAL SURVEY OF KENYA

GEOLOGY OF THE KAPSABET–PLATEAU AREA

DEGREE SHEET 34, S.W. QUARTER
(with coloured geological map)

by

D. J. JENNINGS, B.Sc.
Geologist

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FOREWORD

The report on the Kapsabet-Plateau area continues to the north work already published in a report on the Kericho area (F. W. Binge, 1962) and to the east work made available in a report on the Kakamega area (A. Huddleston, 1954). It covers part of the Nyando escarpment, which forms the northern wall of the Kavirondo gulf graben, the northern part of the large volcano Tinderet, part of the phonolite-covered Uasin Gishu plateau and, on the west, an area of ancient rocks, including granites.

The southern part of the area is important as it contains Miocene lake deposits, including limestones, which are seen on both the downthrown and upthrown sides of the Nyando escarpment faults and give a measure of the displacement of the surface on which the sediments were laid down. Other water-lain sediments are exposed at places along the edge of the phonolites of the Uasin Gishu, but have not yet yielded sufficient fossil evidence to be accurately dated.

The lavas of Tinderet are of considerable interest as they include nephelinites and melilite-bearing types. Boulders of carbonatite are reported from fragmental volcanic rocks on the south side of the mountain, and it is reasonable to infer that the volcano superstructure overlies a carbonatite centre.

In the western part of the area there are exposures of old lavas of the Nyanzian System, such as further south, in the Kibigori area, contain gold-bearing quartz veins. A small amount of gold has been recovered from such veins in the south-western part of the area. One of the veins has also yielded the calcium tungstate, scheelite, but it was in only a small part of the vein that there was any notable concentration.

The Tinderet volcanic rocks are notably carbonated and water emerging from them is mineralized. One spring, at Keben, where there is a Vichy-type water, was for a time used as a spa. The area as a whole is well-watered, and water-supply presents little problem.

Nairobi,
28th March, 1961.

WILLIAM PULFREY,
Commissioner (Mines and Geology).

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ABSTRACT

The report describes the area immediately to the south of Eldoret. It comprises some 1,200 square miles, bounded by the equator and latitude 0° 30′ N. and by longitudes 35° 00′ and 35° 30′ E. Physiographically the area can be divided into a broad band of undulating hills of Basement System rocks in the west, the Uasin Gishu lava plateau to the north-east, and the wooded highlands of the Tinderet volcanic mass to the south-east.

The rocks of the Basement System are highly granitized gneisses and migmatites. They have been invaded by dolerite dykes and two small bodies of granodiorite and, in the south-west, by the main Maragoli granite. Patches of altered volcanic rocks preserved near the margin of the granite as fault-blocks are assumed to be Nyanzian age.

Miocene lake-beds occur in the south, overlain by agglomerates of Tinderet, which are in turn overlain by the plateau phonolites extending from the north-east. The last are succeeded by the remainder of the volcanic sequence at Tinderet, including a variety of under-saturated basic lava types.

Gold and scheelite deposits are described.

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GEOLOGY OF THE KAPSABET—PLATEAU AREA

I—INTRODUCTION AND GENERAL INFORMATION

A geological reconnaissance of the south-west quarter of degree sheet 34 (Kenya Colony, corresponding with sheet 103 of the Directorate of Colonial Surveys) was carried out during the period November, 1956, to July, 1957. The area is bounded by the equator and latitude 0° 30′ N. and longitudes 35° 00′ and 35° 30′ E. and comprises some 1,200 square miles. It includes parts of the Nandi District, Uasin Gishu District and Nakuru District, all within the Rift Valley Province, and part of the Kericho District of the Nyanza Province.

In the field information was plotted directly on air photographs, at the scale of approximately 1 : 30,000, produced by the Royal Air Force in the early part of 1952. The information was then transferred to four preliminary plots, North A.36/X III N.E., N.W., S.E. and S.W., at a scale of 1 : 50,000. Form-lines were taken from War Office sheet North A.36/X (Uasin Gishu) at the scale of 1 : 25,000, being modified where necessary for greater accuracy. Final reduction to a scale suitable for printing was carried out photographically.

About one-third of the area lies within the Nandi Special Area, and is administered from Kapsabet; approximately half is occupied by European farmland, wattle and tea plantations, while the remaining sixth is reserved forest land. Of the latter the North and South Nandi Forests are mainly confined to ground below 6,500 feet and form a marked contrast to the Northern Tinderet, Timboroa, Nabkoi and Kaptagat Forests which extend from 7,500 feet to over 9,000 feet. The South Nandi Forest Reserve is a natural forest composed of mixed indigenous hardwoods, the most common species being *Croton megalocarpus* which forms some 65 per cent of the forest. There is limited demand for timber of this variety and the forest is almost untouched, supporting a single saw-mill within the area. A small amount of reafforestation is being carried out north of the Kapsabet-Kakamega road. The Northern Tinderet Forest on the other hand is extensively exploited for timber, mainly podo, and five major saw-milling companies operate within the area. Extensive reafforestation schemes are in progress.

The Nandi Special Area occupies a broad tract of land along the western margin of the area and includes most of the outcrop of Basement System rocks within it. In the north these rocks are well exposed in the hills of Sorora and Sangalo as granite-like tors, but further south they are masked by a considerable thickness of red soil, usually covered with ant-hills. Outcrops are also limited, and traversing difficult in the Nandi Forest area, but the well-dissected scarp bordering the area to the south again provides good exposure.

The Nandi, related to the Masai and similar in appearance, have lost the nomadic habits of the latter, and are being encouraged to extend the arable side of their farming, at the same time improving the quality and reducing the numbers in their flocks. A livestock improvement centre has been maintained at Baraton for many years and benefits both European and African farmers.

Rainfall is adequate and perennial springs exist throughout the reserve. Soil erosion is locally severe in regions of regular grass burning and persistent overgrazing.

The European farms covering the northern foothills of Tinderet, and the plateau land in the north-east produce wheat and maize, and cattle are reared for milk and beef. There are extensive wattle plantations, especially in the north-central region, the bark being processed at the Plateau Wattle Company's factory on the railway at Eldoret. This town forms the main centre for the European community and is situated on the northern boundary of the area. A small amount of flax is grown near Kaptagat. On the top of the Nyando escarpment, near the western margin of the North Tinderet Forest, conditions are ideal for growing tea, and large estates are expanding rapidly. Further west, and at a lower level, coffee is produced while at the foot of the scarp south of Soyet the major crop is sisal.

The following table, taken from records of the East African Meteorological Department, illustrates the rainfall variation across the area:—

Station	Region	1956 Total (inches)	1957 Total (inches)	Average Annual rainfall (inches)	No. of years recorded
Kaptagat (Forest Station) ..	North-east	47·96	45·71	48·78	29
Plateau (Letonyok)	North-east	42·55	35·87	38·55	8
Ainabkoi (Nabkoi Forest Station).	South-east	41·51	42·11	42·36	11
Eldoret (Meteorological Station)*.	North-central	46·10	37·99	40·60	11
Lessos (Lessos Farm) ..	Central	48·88	48·14	48·80	8
Siret (Siret Tea Co.)	South-central	55·98	58·65	59·31	14
Kabiyet (Dispensary) ..	North-west	53·85	52·18	56·58	4
Baraton (Veterinary Station). .	West-central	59·02	57·05	58·12	20
Kapsabet (District Office) ..	West-central	60·25	51·25	60·84	52
Savani (Savani Estates) ..	South-west	50·04	55·57	57·74	28

* A little north of the area.

Communications within the area are good, but even the major roads become temporarily impassable after heavy rain, the worst stretches being where the roads cross outcrops of agglomerate and tuff. The major routes crossing the area, all of metal or murram construction, are the Timboroa-Eldoret stretch of the main Nairobi-Uganda road, the route from Eldoret to Kapsabet and on to Kakamega, and the road to Kapsabet via Lessos and Nandi Hills.

The railway to Uganda crosses the plateau in the north-east of the area from Kipkabus to Eldoret, with stations at Kipkabus, Kaptagat and Plateau.

The electric power-line, feeding Nairobi from the Owen Falls hydro-electric scheme, traverses the area, entering near Sangalo and leaving south of Nabkoi.

II—PREVIOUS GEOLOGICAL WORK

Little geological work was carried out in the area before the present survey. The north-west corner was crossed by E. E. Walker, a Government geologist, who, after travelling from Elgeyo to Mumias in 1903,* mentioned "the typical granite knolls of Sangalo" (Walker, 1903, p. 7). G. T. Prior described "a more ordinary type of phonolite with abundant sphene and no soda-amphiboles . . . from the Nandi District" from among specimens collected by officers of the then Uganda Protectorate (Prior, 1903, p. 239), but the specimen locality, the Sigowet Hills, is unknown to the writer. The rock described by Prior more closely resembles the phonolitic nephelinites of this report, rather than the plateau phonolites.

As a member of the 1947 British-Kenya Expedition, R. M. Shackleton investigated the extent and disposition of the Miocene sediments in the region of Songhor with particular reference to the Koru limestone, in order to elucidate the extent of post-Miocene faulting (Shackleton, 1951, p. 363). The most northerly exposures described fall just within the southern margin of the area now under consideration. The map accompanying Shackleton's report indicates the approximate limits of the Miocene sediments, the volcanic rocks of Tinderet and the plateau phonolites, and suggests positions for both the Nandi and Nyando major faults.

The vicinity of the mineral spring at Keben, south of Lessos, was examined in 1944 for the Mines and Geological Department by W. D. Harverson and subsequently in 1947 by W. Pulfrey. In their reports both doubted the possibility of economic exploitation of the small limestone deposits present. Subsequent visits to the area by Government geologists were made in 1951 when A. Huddleston investigated the nature and extent of a clay deposit on the property of Eastern Produce and Estates Limited and in 1952 when L. D. Sanders investigated a scheelite occurrence at Koyo in the extreme south-west of the area. The latter deposit proved of negligible extent. In July, 1954, E. P. Saggerson visited the scarp north of Songhor and produced a provisional map of the Songhor-Kapsabet road up the Nyando escarpment.

The area to the south, mainly in the Kericho District, was mapped by F. W. Binge in 1949. The equator forms the boundary between that area and the present area, and in the west runs along the line of the Nyando escarpment. Here the ground is extremely rugged and the outcrops, while locally well exposed, are often scree-covered, especially on the lower slopes. In the proximity of the escarpment, both above and below the scarp, there has been complex faulting and large- and small-scale intrusion and, although the same rock types have been recognized by Binge and by the writer, considerable discrepancy in detail of outcrop is apparent on the maps, as is inevitable in reconnaissance surveys.

Along the eastern part of the common boundary Binge has mapped a succession of analcime basanite flows, overlain by phonolitic nephelinite, followed by welded and trachytic tuffs. The erosion of the Mtetei river has exposed nephelinite agglomerates flooring the valley and ten miles east of the Nandi Hills-Songhor road the highly irregular surface over which the analcime basanite lavas flowed is well demonstrated. Further east the basanite flows, composing much of the upper slopes of Tinderet in the Kericho area do not extend into the present area, nor were the phonolitic nephelinite lavas which overlie the basanites recognized north of the equator.

In the heavily wooded south-east corner of the area on the southern slope of the Mtetei valley unrelieved pyroclastic rocks apparently outcrop to a height of 8,800 feet. North of the equator these have been included in their entirety with agglomerates of melanephelinite and phonolitic nephelinite composition. The lower part of this succession can be correlated with Binge's lower agglomeratic tuff, the upper part with his upper welded and trachytic tuffs.

* References are given on p. 43.

III—PHYSIOGRAPHY

(1) Topography and Drainage

The area can be divided into five distinct physiographical regions composed of three major units and two less extensive sub-units (Fig. 1):—

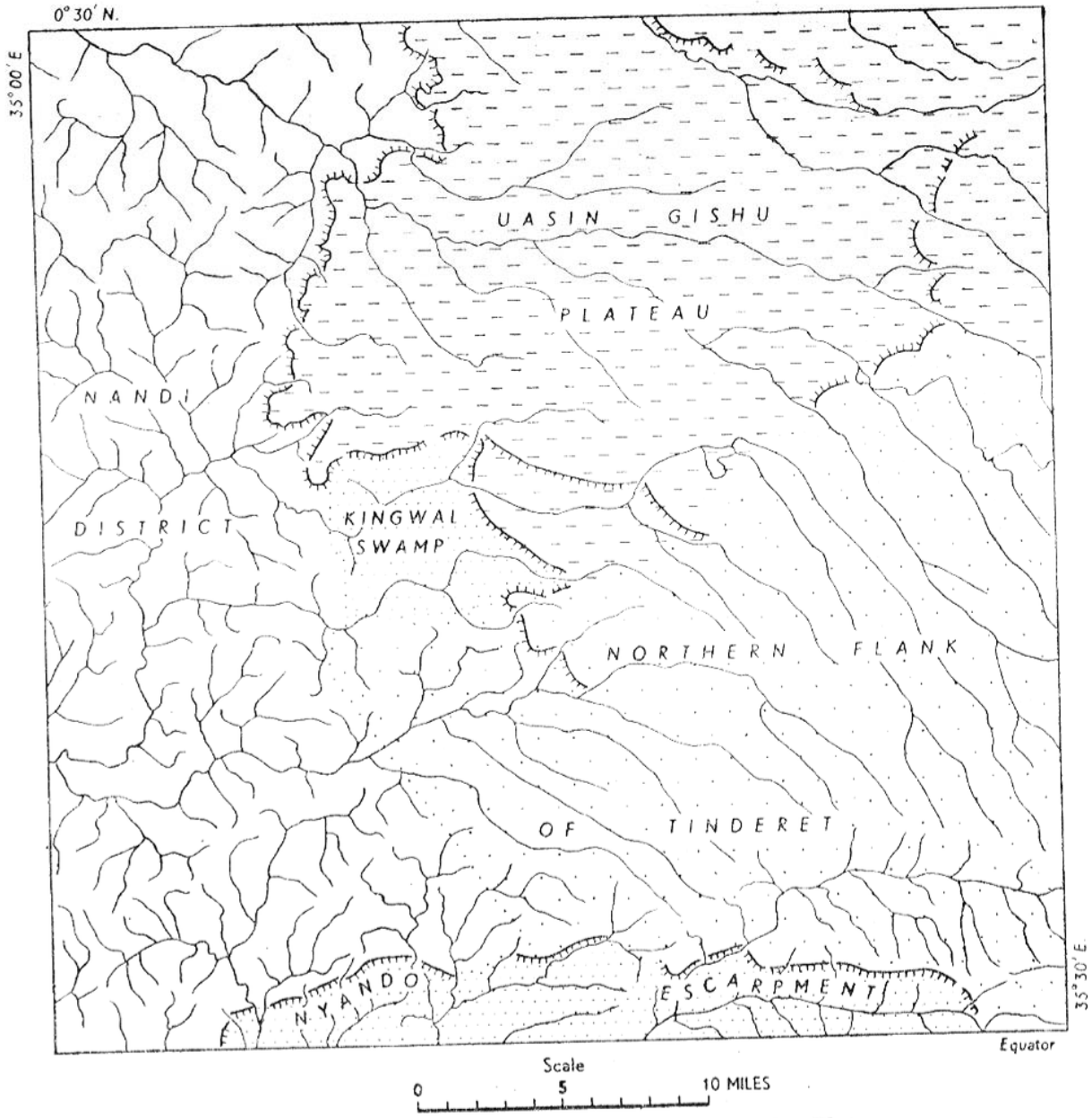


Fig. 1—Drainage and physiographic units of the Kapsabet-Plateau area

(1) The undulating hills of the Nandi Special Area, to the west.

(2) The Uasin Gishu plateau in the north-east.

(3) The foothills and wooded highlands of the northern flank of the Tinderet volcanic mass to the south-east,

with the minor units:—

(4) The Kingwal swamp in the centre of the area.

(5) The highly dissected Nyando escarpment along the southern boundary.

The first unit is composed of low rolling hills of more or less granitized gneisses of the Basement System. In the main these are flat-topped ridges with uniform summit heights and are apparently the dissected remains of a mature plainland, above which rise occasional remnants of a previous peneplain bevel. The drainage in the Nandi

Special Area is of arborescent pattern. The middle reaches of the rivers are mature and typically clogged with extensive reed-beds, but the main Mokong-Kimonde river system displays more youthful characteristics everywhere downstream of the Baraton Veterinary Station.

The second physiographic unit, the Uasin Gishu phonolite plateau, is an extensive lava plain rising steadily to the east, the monotony being broken only where the upper of the two major flows that are present forms a distinct scarp feature rising above the lower. Along the eastern boundary, north of Kipkabus, erosion has produced a more undulating surface on the phonolite lavas lying nearer the shoulder of the Rift Valley. The rivers running over the plateau form a sub-parallel consequent drainage system incised on the lava surface, their course, slightly north of west, indicating the general dip of the flows (Fig. 1).

The Tinderet highland area is part of a dissected volcanic pile of lavas alternating with agglomerates and tuffs, the rivers forming the north-west quadrant of a radial drainage pattern (Fig. 1). The slope of the river-beds is at an angle rather greater than the dip of the volcanic rocks, so that progressively older rocks are exposed to the north and west. There are two exceptions to the radial drainage pattern—the major rivers, the Mtetei and Kipkurere, in the extreme south. Both have deeply incised valleys and flow south of west. Their courses follow faults parallel to the main Nyando fault direction or zones of weakness where the fault itself has become indistinct, branching and swinging north-east.

The Kingwal and Kipterges rivers and their tributaries drain a large section of the north-western flank of Tinderet. In the centre of the area these rivers produce substantial waterfalls, dropping from the top of the lower phonolite to the level of the extensive swamp which foots the scarp. The Kingwal swamp has an area of some sixty square miles, and lies at a height of just over 6,400 feet. This swamp region is considered to be the site of a hollow in the undulating pre-Tertiary surface, and is probably floored in places by waterlain tuffs or agglomerates from Tinderet. The nearest Basement System rocks outcropping at swamp level are seen north of Cheptet. Drainage now being prevented to the north and east by phonolite, and to the south by agglomerates of Tinderet, the rivers escape to the west over a series of rapids composed of hard bands in the Basement System gneisses.

The fifth physiographic unit is formed by the Nyando escarpment, running sub-parallel to the equator along the southern boundary of the area. The character of the scarp varies with the nature of the rocks of which it is composed. The watershed dividing the rivers descending the scarp face from the Kimonde-Mokong river system runs only some six or seven miles north of the top of the scarp (Fig. 1) and hence the drainage area of the scarp rivers is small and the volume of water carried highly variable and dependent on fluctuations in rainfall. Often, however, the volume of water flowing is large and many of the rivers descend impressive rapids. Hills along the shoulder of the scarp approach a height of 7,000 feet while to the south the plain lies at below 4,400 feet.

(2) Erosion Bevels

(*a*) *The "High Peneplain" (End-Cretaceous?)*

North of the Nyando escarpment hills of granite, Nyanzian volcanic rocks and Basement System gneisses have summit heights approaching 7,000 feet. Just outside the area to the west, along the Nandi fault a ridge of hills has summits again approaching 7,000 feet. These, together with Algabbyet and the hills to the north-west of Sangalo are residuals of an early bevel and are included by Shackleton (1951, p. 379 and map) among remnants of a "high peneplain" possibly of Jurassic age but which may be of end-Cretaceous age.

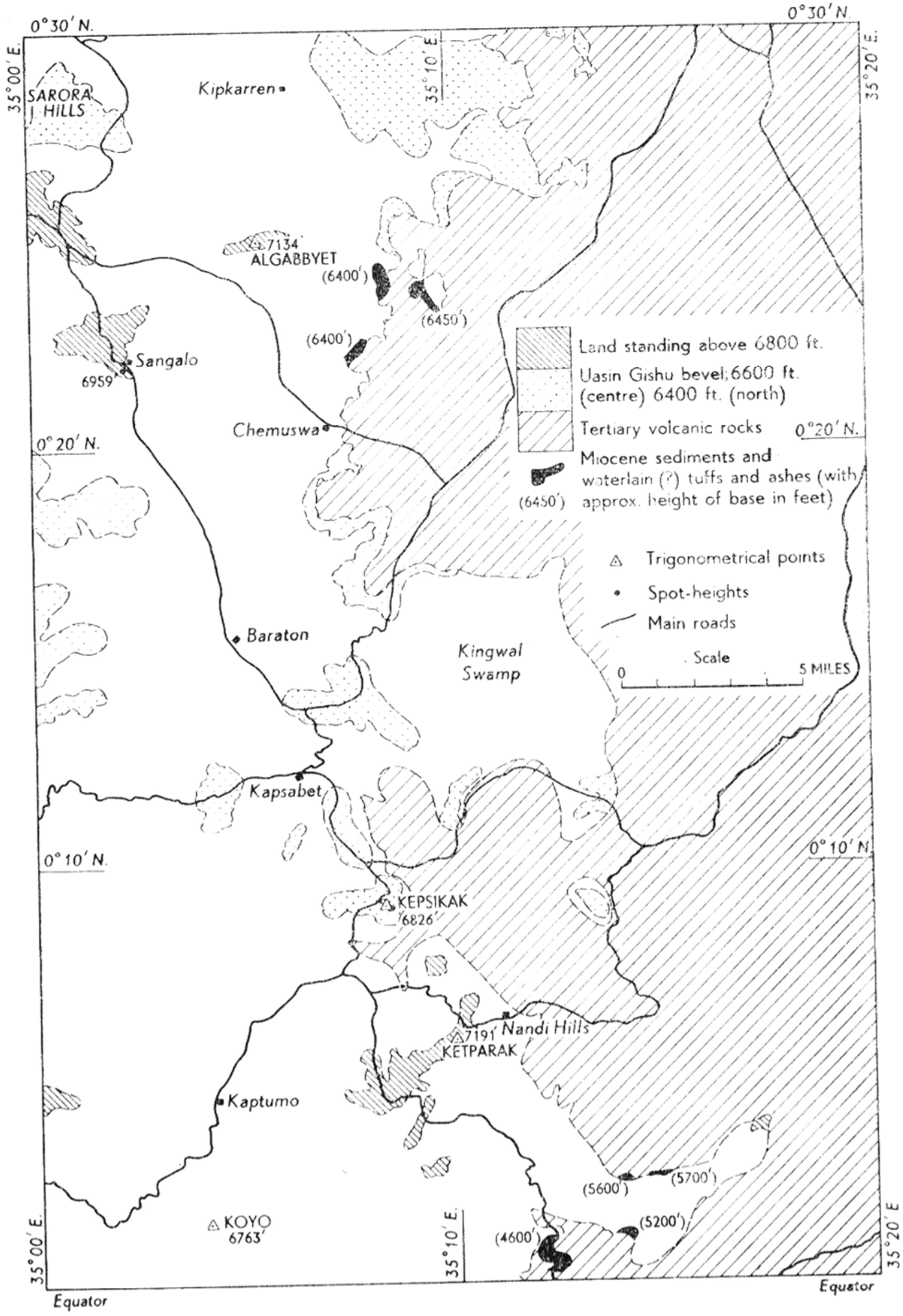


Fig. 2—Sketch map of the relationship of erosion bevels, Miocene sediments and Tertiary volcanic rocks in the Kapsabet-Plateau area

(*b*) *The Uasin Gishu Surface*

The plainland, the dissected remains of which form a conspicuous bevel in the area around Kapsabet at a height of approximately 6,600 feet, is concealed by Tertiary volcanic rocks to the east and north-east. Inspection of the height of the base of the plateau phonolites shows that the surface over which the lavas flowed slopes gently northward from over 6,600 feet at Kosirai to 6,600 feet at Chemuswa and to 6,400 feet west of Eldoret. Local irregularities occur and waterlain tuffs, mudstones, and green agglomerates rich in fossil wood are preserved in hollows in the peneplain surface, while locally the flows of phonolite were diverted by upstanding residuals. Algabbyet, standing some 600 feet above the surrounding plain is presumed to have been such a residual, though there is no present evidence that it was surrounded by lavas. The interfluves forming ridges to the south and west of Algabbyet are demonstrably higher than the base of the lavas at this latitude. It is likely that phonolite flows passed almost to the western boundary of the area, flowing north of Algabbyet towards the Sorora hills and south across the area now occupied by the Kingwal swamp.

It is clear that the extensive interfluves south and west of Algabbyet, lying at 6,600 feet were never eroded down to the level of the Uasin Gishu plateau surface, and should not therefore be correlated with comparable summit heights in the Kapsabet area; rather these ridges should be considered, with Algabbyet and the hills north-west of Sangalo as residuals upon the Uasin Gishu surface (Fig. 2).

The lava flows, emanating from the shoulder of the Rift Valley extend as far north as Hoey's Bridge. The nature of the surface on which they lie has been investigated in detail north of Eldoret (Sanders, 1964) where it is clear that the extension of the Uasin Gishu surface to the north is coincident with the Kitale plain (Dixey, 1946, p. 244; Shackleton, 1951, p. 379; Pulfrey, 1960, p. 7).

The lava base at Hoey's Bridge lies at 6,200 feet and rises to 6,400 feet west of Eldoret. This slope is maintained in the present area, south of Eldoret, where the lava base-level reaches 6,600 feet at Chemuswa.

There is no widespread agreement on the status of the Kitale plain with relation to the sub-Miocene bevel. In discussing the peneplains of western Kenya Dixey called the bevel now referred to the sub-Miocene, the "Uganda' or "main" peneplain. Dealing with the peneplains north of the Kavirondo Gulf rift (Dixey, 1946, p. 244) he described the dissected upland surrounding the Kisumu scarp as residual on the "main" peneplain and correlatable with the 6,500-foot plateau (that of the Uasin Gishu) and the Elgon-Kitale plain. Dixey re-stated his distinction between the latter and the sub-Miocene bevel in his report on the geology of Northern Kenya (1948, p. 26) where he claimed that the "Kitale (6,200-foot) Plateau" is clearly a residual on the Uganda peneplain. Gibson (1954, p. 9) maintained the distinction between the sub-Miocene and Kitale surfaces and Pulfrey (1960, p. 7) accepted this.

Shackleton (1951, p. 379 and map) correlated the Bugishu Beds and sub-Elgon surface with the Kitale plain and the Uasin Gishu plateau and asserted that they are all one and the same, and sub-Miocene in age. Contour lines drawn by Shackleton on a map of the projected extension of the sub-Miocene plain from Kitale to Eldoret and south to the Nyando escarpment, however, indicate a marked south-westerly slope (from 6,000 feet along the edge of the phonolite outcrop to 5,500 feet in the south-west corner of the area). Sanders measured a distinct northerly component of slope (from 6,200 feet at Hoey's Bridge to 6,400 feet west of Eldoret) and evidence from the Kapsabet area confirms the extension of the bevel to the south with similar slope.

A critical piece of evidence in Shackleton's construction of contour lines on his map of the sub-Miocene plain in western Kenya is the presence in the Nyando escarpment north of Songhor or an outcrop of lacustrine limestone at 5,700 feet (Fig. 2). This is extremely similar to outcrops of early Miocene limestone at a lower level outside the area to the south, which can be demonstrated to lie on the sub-Miocene surface

in the floor of the Kavirondo Gulf rift valley. Shackleton (1951, p. 366) assumes a fault with a throw of over 1,000 feet between these exposures of limestone, and accepts the height of the most northerly outcrop as an indication of the height of the sub-Miocene surface in the southern part of the area. Insufficient detailed work was done by the writer in this part of the area to confirm or disprove this suggestion.

The only peneplain bevel clearly recognized within the Kapsabet area is the southern extension of the surface underlying the western lavas of the Uasin Gishu plateau, which is the extension of the Kitale plain.

IV—SUMMARY OF THE GEOLOGY AND GEOLOGICAL HISTORY OF THE AREA

The oldest rocks of the area are Precambrian in age and are represented by gneisses of the Basement System, highly metamorphosed lavas of the Nyanzian System, and intrusives of inferred post-Kavirondian age. They occupy approximately one third of the area, in the west. A consistent banding of different gneisses, which could be related to differences in an original sedimentary succession, was not detected in the rocks of the Basement Sysem. Well-foliated biotite gneisses of the central region about Kapsabet give way both to north and to south to more highly granitized and leucocratic varieties, with a high proportion of microcline, negligible foliation and a granitoid texture.

The outcrops of Nyanzian rocks in the area are small and usually poorly exposed. They are preserved on the Nyando scarp as fault-blocks in the complex structure at the intersection of the Nyando and Nandi fault systems. They consist of sheared and altered lavas, mainly of basaltic composition, highly injected with quartz veins. It proved impossible to demonstrate conclusively the age relations between the Nyanzian and the Basement System rocks.

The granite in the south-west corner of the area is widely variable in composition and texture, and owing to the thickly forested nature of the terrain its contacts with the surrounding rocks are not easily determined. It encloses a number of patches of Nyanzian lavas, apparently as roof pendants, indicating that it is at least post-Nyanzian in age. It is, however, continuous with granites further west that invade Kavirondian rocks and is, therefore, dated as post-Kavirondian.

The eastern two-thirds of the area is covered by volcanic rocks of Tertiary age. In the north, two major phonolite flows can be distinguished. Small exposures of tuff and agglomerate indicate that a pyroclastic phase preceeded the original phonolite outpouring, and a similar phase occurred between the flows. In the Burnt Forest area it can be demonstrated that the upper volcanic rocks of Tinderet overlie the plateau phonolites, while further south near Lessos, it can be shown that the phonolites succeeded the eruption of the major Tinderet nephelinite agglomerate (Shackleton, 1951, p. 368). In the extreme south the latter is seen resting on a thin sedimentary series which, near Songhor, has been proved to be of Miocene age. The succession in the Tertiary rocks can be summarized as follows:—

TERTIARY ROCKS OF THE KAPSABET AREA

Formation	Rock Types	Source of Origin	Map Symbol
5. Tinderet phonolites ..	Lavas predominate	Tinderet	Tvp_4
4. Upper volcanic rocks of Tinderet.	Lavas predominate	Tinderet	Tvp_3 Tvpn
3. Uasin Gishu phonolites ..	Lavas	Elgeyo scarp direction ?.	Tvp_1 Tvp_2
2. "Nephelinitic" agglomerates	Pyroclastic rocks predominate.	Tinderet	Tv
1. Miocene lake-beds	Limestone and waterlain tuffs.		Tm Tmf

Recent deposits of gravels and alluvium are not extensive but a thick red soil cover overlies gneisses of the Basement System in the area north of Baraton, and a deep mantle of red soil also covers much of the plateau. Black-cotton soil has developed locally in regions of poor drainage, the largest expanse bounding the swamps on the Kipterges and Kingwal rivers.

Summary of the Geological History of the Area

The geological history of the area can be summarized as follows:—

Early Precambrian

1. Geosynclinal deposition of a fairly uniform succession of semi-pelitic sediments of the Basement System.
2. Emplacement of dykes.
3. Orogenesis, in which the results of several metamorphic processes can be recognized, which may have proceeded separately, intermittently or contemporaneously.
   (*a*) Regional Metamorphism, with production mainly of biotite gneisses.
   (*b*) Limited mobilization locally, and alkali metasomatism to form migmatites, granitoid gneisses and granites.
4. Injection of quartz and pegmatite veins.

Later Precambrian

5. Extrusive phase, with outpourings of Nyanzian lavas, mainly basaltic in composition.
6. Orogenesis, intense folding and faulting.
7. Minor intrusive phase, with emplacement of epidiorites (age relative to granites uncertain).
8. Major plutonic phase, with emplacement of the post-Kavirondian granites.
9. Minor intrusive phase, with emplacement of dolerites and giant quartz veins.
10. Faulting, affecting Nyanzian rocks of Koyo hill.

Late Precambrian and post-Precambrian

11. Quiescent period, a great lapse of time that has left no record in the rocks of the area, and terminating in the formation of the "high" peneplain (end-Cretaceous?).

Tertiary

12. Uplift, followed by the formation of the sub-Miocene peneplain.
13. Minor sedimentary phase, with formation of the Miocene lake-beds.
14. Major extrusive phase, with eruptions from central-type cones like Tinderet and from fissures, as with the plateau phonolites.

Upper Tertiary-Pleistocene (?)

15. Tectonic upheaval, with formation of the Kavirondo Gulf Rift Valley and rejuventation of the Nandi escarpment, and with local dynamic metamorphism of the adjacent rocks.
16. Extrusive phase, with eruption of the uppermost Tinderet volcanic rocks.

Tertiary to Present Day

17. Erosion, to form present land surface.

V—DETAILS OF GEOLOGY

1. Basement System

The rocks of the Basement System in the area lack the regional banding characteristics of the system in many other parts of Kenya. There are no crystalline limestones, quartzites or other distinctive metamorphosed sediments. The prevailing rock type was probably derived from a fairly uniform series of semi-pelitic sediments, which give rise on metamorphism to various banded and homogeneous biotite and hornblende-biotite gneisses. These have been subjected to injection, disruption and regional metasomatism. Locally, metasomatism has been intense, when the rocks assume a granitoid appearance and lose the last indications of their sedimentary origin. In the better foliated exposures the general strike of the foliation varies between north-south and northwest-southeast, and lineation is generally steep to the south-east.

For the purposes of description the Basement System rocks of the area and rocks derived from them can be divided into the following groups:—

Basement System Rocks

(1) *Pelitic and semi-pelitic gneisses.* Biotite gneisses and banded hornblende and biotite gneisses.

(2) *Migmatites.* Biotite migmatites

Hornblende migmatites.

(3) *Granitoid gneisses.*

Derived Rocks

(1) *Migmatitic Granites*

The total thickness of the rocks of the Basement System in the area is difficult to assess and any estimate must be considered highly speculative. The section on the map runs approximately at right-angles to the strike of the foliation and between the Kaptumo-Kapsabet and Lessos-Nandi Hills roads nearly vertical gneisses outcrop sporadically over a distance of twelve miles. If the degree of folding illustrated in the section is accepted, i.e. the amount of repetition of beds due to isoclinal folding is as suggested, a total thickness of some 25,000 feet of biotite and granitoid gneisses must be involved.

The rocks in the north of the area have suffered more extreme metamorphism and metasomatism and display all the characteristics of migmatites. The persistent high plunge values of southerly lineation throughout the area, indicating steeply plunging fold axes, suggest that the southern extension of these northern rocks underlies the biotite gneisses in the south. A northeast-southwest section through Pire cuts nearly 16 miles of rocks of the Basement System, involving a succession of at least 20,000 feet of biotite and hornblende-biotite migmatites.

(1) Pelitic and Semi-pelitic Gneisses

Biotite gneisses and banded biotite and hornblende gneisses occupy a large area around Kapsabet. Their separation on the map may not be justified, as the areas marked as occupied by banded gneisses are where exposures are best developed, for example in the region of the Songhor road-cutting, where erosion is sufficiently rapid to display

a good section of the more readily weathered, and therefore normally less frequently exposed units. The gneisses are not well exposed along the major streams as valleys have reached a mature state, and their beds are typically clogged with reeds. The gneisses are best displayed towards the heads of the minor tributaries; on the interfluves there is usually a substantial soil cover and exposures are few.

The types of gneisses encountered are common in the Basement System of Kenya and have been described in a number of previous reports. In this area they are rarely homogeneous over great distances, varying in grain size, proportion of mafic minerals and degree of foliation. The last two factors are interrelated. The higher the proportion of mafic minerals, usually biotite, the more pronounced the foliation, while the more leucocratic the rock, the more homogeneous and the more resistant to weathering. The gneisses are everywhere highly injected and disrupted, and approaching the south the foliation becomes less pronounced and the rocks more highly felspathized. There is no evidence to suggest that this is a consequence of the action of fluids derived from the granite that invades them in that part of the area.

Specimen 34/68* collected from two miles north of Cheptet Mission is a type of fine-grained biotite gneiss of wide distribution. It tends to weather uniformly, creating platform-like exposures, on which numerous injected quartz and pegmatite veins form small upstanding ridges. A thin section of the rock shows that biotite is the only ferromagnesian mineral present, constituting some 15 per cent of the total volume, and being of a variety pleochroic from dark olive-green to buff. A small amount of plagioclase within the oligoclase range of composition is present, but the mass of the rock is composed of quartz and alkali felspar. The accessory minerals include epidote, apatite and sphene.

Specimen 34/109, from an outcrop displaying tombstone-type of weathering some two and a half miles south of Kapsabet, is a well-foliated, medium-grained biotite gneiss, characterized by its bright pink felspar. In thin section this rock is seen to be much changed from what it must have been originally, as a result of crushing, metasomatism and recrystallization. It is now rich in microcline. The original dark mineral, biotite, has been largely replaced by muscovite and epidote, while quartz occurs in elongated patches with mosaic structure, and grains exhibiting shadowy extinction. A similar type was found at Mugondi, five miles south of Kapsabet, though it is slightly paler and more fine-grained. In thin section (specimen 34/60) a rather larger proportion of muscovite mica is seen to accompany the epidote and biotite. A coarse-grained, coarsely foliated biotite gneiss (34/57) from Koyo, one and a half miles south of Kaptumo, again has biotite as the only ferromagnesian mineral. It is present as small crystals and is disposed interstitially, or wrapped as aggregates round the larger felspar crystals. The felspar is usually untwinned and slightly sericitized, though some plagioclase and microcline are also present, while the subordinate quartz has shadowy extinction and rows of inclusions.

Specimen 34/65 from the Kimonde River bridge, west of Kapsabet, is from a very leucocratic band. It is extremely fine-grained and has a granulitic texture with a faintly marked foliation. A thin section shows that the rock consists of a granular quartz-felspar base with scattered biotite flecks, in which are set irregular felspar crystals up to 1 mm. diameter, variably untwinned or showing carlsbad, multiple and microcline twinning. A similar fine-grained granular leucocratic gneiss, this time faintly banded, occurs one and a half miles south of Kaptumo (specimen 34/59). Here the granular base consists of untwinned potash felspar with subordinate quartz, sparse biotite flakes filling the interstices. Occasional subhedral iron ore grains are present.

* Numbers prefixed by 34/ refer to specimens in the regional collections of the Geological Survey of Kenya.

Exposures near the pumping station, a mile and a half north-east of Kapsabet, reveal members of the banded gneiss sequence, and indicate the complexity of the instrusion history of the area prior to metamorphism. Here the host-rocks consist of mafic biotite gneisses with alternating more felsic layers, both being typically in bands of more than a foot thickness. A subsidiary member of the sequence (34/70) is a finely layered rock, with narrow leucocratic bands of 2 mm. or less alternating with broader bands containing much hornblende. In thin section it is seen that green orientated hornblende constitutes rather more than half of such bands, the remainder being composed of quartz, plagioclase (oligoclase) and orthoclase, with sphene the most common accessory.

The rocks already mentioned were invaded by felspathic veins along the strike, and then cut by two dykes of intermediate composition. The first cut the banding of the host-rocks at about 45°, and the second was emplaced at right-angles to the first. The minerals of both dyke rocks are now arranged so that the dykes have the same orientation of foliation as the host-rocks, the earlier dyke (34/71) now being a hornblende-biotite-epidote gneiss and the later dyke a more leucocratic biotite gneiss (34/66). Subsequent to metamorphism the whole complex was injected with anastomosing pegmatite veins.

(2) Migmatites

In the north-western part of the area the Basement System rocks exposed have been highly metasomatized. In hand-specimen many would pass for granites, as they are medium- or coarse-grained, with granular texture and often no foliation. In exposures, however, the variation in composition, the existence of schlieren of contrasting rock type, and the presence of highly contorted felspathic segregations and veins show that the rocks are mixed on a macroscopic scale. They were mapped as migmatites, a rough distinction being made between those containing hornblende among the ferromagnesian minerals, and those exclusively biotitic, though the junction between the two types is gradational. Some of these rocks apparently became sufficiently plastic to flow locally, producing a characteristically swirled and irregular incipient secondary foliation. These flow structures are often emphasized by elongated blebs and relic disintegrating bands of felsic material, and lines of schlieren or remnants of the less readily mobilized members of the original sequence.

(a) Biotite Migmatites

A typical specimen of the host-rock of the biotite migmatites (34/150) was collected from the tors one mile north-west of Sangalo. The rock is compact and grey, medium-grained, and without visible foliation in the hand-specimen or in thin section. It is estimated that it contains 15 per cent of irregularly disposed green-brown biotite as small ragged crystals. The biotite appears in patches associated with grains of quartz and potash felspar and accessory epidote and sphene, and also occurs in concentrations outlining the larger felspars. The main leucrocratic minerals are quartz and untwinned or multiple-twinned felspar, and a little plagioclase. Specimen 34/172, from one mile south-east of Pire market, displays large subparallel segregations of pink felspar in a biotitic host. In thin section it can be seen that biotite constitutes only some 3 per cent or 4 per cent of the rock and is of a variety diochroic from buff to almost black. It occurs interstitially associated with muscovite, irregular grains of magnetite and occasional apatite. The large felspars are mainly untwinned or display very shadowy twinning and have sutured margins. They include multiple-twinned plagioclase within the oligoclase range of composition. Again the smaller crystals consist of biotite; interlocking mosaics of quartz, with shadowy extinction; microcline and sodic plagioclase.

A more homogeneous rock (34/193) poorly foliated and medium-grained, forms the host-rock in the biotite migmatite tors south of the Sorora hills, 1½ miles north of Pire market. Biotite is the only dark mineral, occurring in aggregates that wrap round

the larger felspars, and as a component of the fine-grained groundmass in which the latter lie. The large felspars show no twinning, or shadowy multiple twinning, while the fine-grained material is as in the previous example. Specimen 34/192, from the same exposure was, from consideration of its field relationship, assumed to be part of a pre-metamorphism dyke intrusion. In hand-specimen it appears fine-grained and dark grey, with local concentrations of pink felspar. In thin section it is seen to consist of the same mineral assemblage as the host-rock but to contain a notably higher proportion of biotite. In addition small concentrations of iron ore occur associated with accessory sphene.

(*b*) *Hornblende migmatites*

In the region of Kabiyet and immediately to the north, the migmatite host-rock is seen to contain hornblende, usually as distinctive large crystals, though the rock is light in colour and the proportion of hornblende rarely exceeds that of biotite. In this area, too, the concentration of amphibole-rich segregations, disrupted bands and part digested remnants of the original rock is far higher than among the biotite migmatites.

Specimen 34/210 from one and a half miles south of Kipkarren market is coarse-grained, with no foliation, possessing veins and segregations of leucocratic minerals, in particular pink felspar, and isolated black amphibole crystals. The dark minerals are associated in clots, and consist of biotite, diochroic from straw-yellow to dark brown; hornblende, pleochroic from pale yellow-green to dark green; magnetite and garnet. Biotite also occurs as trains of crystals surrounding some of the larger felsic crystals. The main light-coloured mineral is potash felspar, either completely untwinned or showing shadowy microcline twinning. The fine-grained material consists of quartz, biotite and plagioclase of composition An_{30}.

Specimen 34/189 from three and a half miles east of Kabiyet is a similar, though darker coarse-grained hornblende-bearing rock. In thin section it appears sheared, with streamed-out quartz mosaics and patches of biotite plates and deformed microcline crystals.

(3) Granitoid Gneisses

In the region of Soyet, and along the southern boundary of the area west of the Kamaasae river, much of the rock exposed is quartz-felspathic gneiss with a granitoid texture and has been mapped as granitoid gneiss. It is not uniform over wide areas, showing a variable degree of foliation and relic banded structures, and containing patches richer in dark minerals. It grades progressively into more normal banded and biotite gneisses to the east and north. The large central core of this outcrop, south of Soyet, is sufficiently homogeneous and sufficiently faintly foliated to justify the field classification of "leucogranite", though the junction with the surrounding rocks is everywhere gradational and there is no indication of an intrusive origin.

The granitoid gneisses weather typically to form large boulders that exfoliate with the production of copious coarse-grained, quartz-rich rubble which supports little vegetation. The gneiss outcrops are cut only occasionally by quartz and pegmatite veins, in the most homogeneous sections of the outcrop, but to the north the pegmatites become massive, frequently yielding the only exposures, and providing heavy float deposits.

Specimens 34/308 and 34/316 from the top and bottom of the scarp south-east of Soyet, both contain some 30 per cent of quartz and minor amounts of mafic minerals in the form of biotite, part-altered to muscovite and epidote. The greater part of the rocks is felspar, showing perthitic intergrowth and multiple or microcline twinning.

2. Rocks Derived from the Basement System

(1) Migmatitic Granites

Several small areas in the north-west were mapped as migmatitic granites. The justification for demarcating them from the surrounding rock types is slight, and smaller exposures of identical rocks occur sporadically throughout the migmatites. They represent the nearest approach to true granites developed *in situ* within the northern part of the area. They represent metasomatic centres and the proportion of added granitic material is highest here, and the foliation most irregular and least distinct. Inclusions of amphibole-rich material are still common. The granites are compact felspathic rocks that weather slowly, and exposures form large upstanding masses, of which the Sarora hills is one. A microcline-porphyroblastic facies is developed locally with the felspar crystals up to 2 cms. long.

3. Nyanzian System

Rocks of Precambrian age assumed to be later than the Basement System are confined to the south-west part of the area. They consist of metamorphosed and sheared volcanic rocks, mainly of original basaltic composition, and by analogy with rocks of neighbouring areas on the south and west are referred to as members of the Nyanzian System.

These Precambrian lavas produce a number of small outcrops but, except where they occur in the well dissected Nyando scarp, exposure is poor and the junctions with the surrounding rocks are not displayed. In the region of the scarp it can be seen that the Nyanzian rocks are preserved as blocks down-faulted by the Nandi and Nyando fault-systems into the Basement System gneisses and against the post-Kavirondian granites, though it seems unlikely that the faulting was confined to post-Miocene times, when the activity on the Nyando fault took place. As all boundaries between Nyanzian rocks and Basement System gneisses observed are faulted, in the absence of other evidence the remaining lines between rocks of these types should also be tentatively considered as faults.

Traverses in the South Nandi Forest revealed streams crossing country composed mainly of coarse-grained granite, with locally, however, float with a high percentage of Nyanzian rock types. Invariably exposures were so sparse as to render delineation of the outcrop boundaries impossible. It is considered probable that such blocks of Nyanzian rocks exist in the granite as xenolithic rafts or roof pendants.

The degree of metamorphism of the lavas increases progressively to the north-west, the rocks in the south retaining unmistakable basaltic characteristic while those in the north resemble more closely plagioclase amphibolites, petrologically comparable with those in the Basement System.

Some of the Nyanzian rocks still display a compact, fine-grained basaltic appearance in hand-specimen. Specimens 34/52 and 34/54 from the north-eastern slopes of Koyo hill and 34/396 and 34/398, from one mile west and three miles north-west of Kaptumo respectively, are of this type. The first two, though now composed mainly of hornblende preserve a relic igneous feature in the lath-shaped patches of recrystallized felspar visible in thin section and in 34/54 crystals of the original igneous plagioclase remain. Specimen 34/396 has recrystallized to a plagioclase amphibolite with 50 per cent hornblende, approaching euhedral in shape, and clear quartz and felspar, the latter showing multiple twinning. More coarsely crystalline veins composed mainly of quartz and epidote cut the rock, the latter mineral also occurring in association with hornblende and poikilitic plates of diopsidic pyroxene. Specimen 34/398 shows in thin section a well preserved igneous texture. The original pyroxene is largely altered to hornblende, and occasional biotite, but there are remnants of felspar prisims up to $\frac{1}{2}$ mm. in length.

Many of the Nyanzian rocks are highly sheared and the minerals display complete recrystallization and a pronounced preferred orientation. The rocks are often banded and frequently injected with quartz or granitic material, and iron pyrite is common along fracture planes. Specimen 34/342, from one and a half miles south-west of Kaptumo, is variably injected with granitic material, locally epidotized and rich in pyrite.

Specimen 34/403 from the most northerly outcrop of Nyanzian volcanic rocks, one and a half miles north of Chemogonja, is another fractured banded rock. In thin section it is found to be well foliated with bands of hornblende and plagioclase grading into bands consisting of abundant granules of diopside set in large poikilitic plates of clinozoisite. Small grains of sphene are present and the iron ore is pyrite. Half a mile further south the rock exposed is again a banded plagioclase amphibolite. Specimen 34/135 from this locality shows occasional leucocratic and amphibolitic bands, the rock as a whole consisting of 60 per cent hornblende, pleochroic from buff to dark green, plagioclase of composition An_{54}, scattered crystals and concentrations of grains of diopside, and occasional quartz lenses. Granules of sphene are abundant and some magnetite is present. The rock is cut by chlorite veinlets at right-angles to the foliation.

Occurring among more typical Nyanzian float in several of the South Nandi Forest streams are highly sheared and fractured siliceous rocks. Thin sections provide little evidence as to their origin as they show only a variety of cataclastic textures, involving leucocratic minerals, more or less disguised by the introduction of secondary silica. Such rocks may be produced from highly sheared Basement System rocks along the fault-zones bounding the Nyanzian outcrops, or may represent siliceous members of the Nyanzian volcanic suite. Other material originating from fault-zones appears to consist almost entirely of highly mylonitized quartz, often of more than one generation and rich in iron pyrite. An iron ore concentration (34/341) associated with the Nyanzian rocks two miles north of Kaptumo consists of a high proportion of limonite. The texture of included fragments suggests that the rock was originally a breccia of granular fine-grained material, consisting of strained plagioclase and quartz, the fragments being rounded and resorbed at the time of replacement by secondary limonite.

4. Intrusions into the Precambrian Rocks

(1) Major Silica-Rich Intrusions

(a) The Maragoli granite

In the extreme south-west part of the area the country rock is of granite, and a variety of similar coarse-grained rock types have been mapped as a single unit, though they probably represent the results of more than one intrusive phase. No contacts between dissimilar types were recognized in the field, but a uniform and distinctive pink porphyritic facies exists everywhere west and south of the Koyo hill Nyanzian outcrop along the top of the Nyando scarp. This granite is considered to be the marginal zone of that mapped over wide areas to the west, where Pulfrey (1946, p. 21) recognized the possibility of more than one intrusion forming the granite in the Maragoli area.

The granitic rocks of this part of Kenya exhibit wide variations in appearance and composition. In the area south of the present area leucocratic granites have been mapped (Binge, 1962), and granite, porphyritic granite and syenite to the south-west (Saggerson, 1952, p. 64) while of the granites immediately to the west Huddleston (1954, p. 16) remarked " . . . relatively large masses of hybrid syenites, diorites and syeno-diorites have been produced, possibly by the extreme alteration of roof pendants of earlier intrusive or wall-rocks".

Owing to the nature of the terrain in the Kapsabet area, the high degree of granitization of the Basement System and the development of a distinct foliation in the granites in the region of their contact, the delineation of their boundary is difficult and must be considered approximate only.

The granite south of Ndurio weathers along prominent joints and is typically exposed as tors and massive monolithic blocks of a bright pink colour. In specimen 34/394 from this part, pink felspar phenocrysts display prominent carlsbad twinning and stand out from the weathered surfaces, and quartz and biotite can be recognized in a yellowish felspathic groundmass. In thin section large microclines are seen to be associated with oligoclase, of which they also include small crystals. Plagioclase crystals form about a third of the rock, with quartz occurring as large anhedral plates and small mosaic patches. The only dark minerals present are biotite and small amounts of epidote.

A similar rock (34/399) from five miles south-west of Kapsabet contains smaller pink carlsbad-twinned felspars, and considerable epidote and pyrite. Ragged plates of highly pleochroic biotite constitute some 5 per cent of the rock, while patches of clear interlocking crystals of quartz account for a further 15 per cent. The remainder of the rock is composed of felspar, the plagioclase being highly sericitised and displaying shadowy twinning suggesting a composition of An_{30}.

An extremely leucocratic facies (34/395) from within the forest consists of 40 per cent quartz, the rest being mainly felspar. Accessory quantities of epidote, muscovite and chlorite almost replace the rare biotite flakes. The felspar is mainly slightly altered plagioclase, so the rock is classified as a leucocratic granodiorite.

The granite in the region of Chemogonja (34/64) has a distinct foliated appearance, with large pink phenocrysts wrapped in a fine-grained matrix rich in ferromagnesian minerals. In thin slice it proves to be highly sheared with clusters of mafic minerals, composed of biotite, epidote, sphene and occasional chlorite, streamed-out around fractured felspars and strained quartz.

Crossing the otherwise uniform granite exposures south of Ndurio is a broad tract rich in xenoliths. The host-rock is the typical highly porphyritic granite of the region, while the included fragments, often so abundant as to form two-thirds of the rock mass, are highly altered, and may originally have been of leucocratic-gneissic composition. The trend of the contaminated tract is about 40°, and the fragments are elongated in that direction.

(*b*) *Northern granodiorite*

South-west of Chemnowet market a coarse-grained rock of igneous appearance occurs, contrasting markedly with the surrounding rocks. The rock is without pronounced foliation, and the ferromagnesian minerals occur in clusters. It weathers readily and exposures are confined to the streams. The rock was mapped as a hornblende-biotite granodiorite, intrusive into the Basement System.

Crystal size varies within the outcrop, specimen 34/194 being a relatively fine-grained sample. In thin section it is seen to consist of some 8 per cent dark minerals with a preponderance of subhedral hornblende over more fine-grained biotite. The former is pleochroic from light yellow-green to dark green, the latter dichroic from straw-yellow to dark brown. Quartz, constituting some 20 per cent of the rock, occurs in large clear patches, often cracked and occasionally showing lines of dusty inclusions and shadowy extinction. The larger felspars consist of orthoclase, often rounded and resorbed, and plagioclase of oligoclase composition. The finer-grained material consists largely of similar plagioclase felspar, and accessories noted included zircon and calcite.

(c) *Southern granodiorite*

In the south of the area and well exposed along the Savani road down the escarpment to Muhuroni, there is an intrusion like that of the northern granodiorite into the Precambrian granites and gneisses of that part of the area. Specimen 34/305 is a coarse-grained, black and white rock, of igneous appearance, without pronounced foliation, and carrying biotite and hornblende crystals up to 1 cm. in length.

The hornblende, pleochroic from dark to light green occurs in equal amount with biotite, dichroic from yellow to dark green-brown. Sphene occurs associated with iron ore and hornblende, and is also present in large euhedral crystals. Quartz constitutes some 15 per cent of the rock as irregular patches of interlocking grains, and small areas of quartz-felspar intergrowth are present. Some of the felspar is slightly sericitized, most of the rock being composed of plagioclase, some with subhedral form and faint zoning. The extinction angles measured on the multiple twins in the better preserved crystals indicate a composition within the oligoclase range. Microcline occurs interstitially and replacing plagioclase.

(2) Basic Intrusions

(a) *Highly metamorphosed basic intrusive rocks Plagioclase Amphibolites*

Plagioclase amphibolites are not common in the area, but occur among the migmatites in the north-west, where they form a contrast with the surrounding leucocratic rocks. Where the regional strike can be detected they do not necessarily conform. They have been less affectd by granitization processes than the rocks around them, though there is a marked increase in the concentration of amphibolitic inclusions in the migmatites approaching their boundaries, and felspathic veins inject them, especially along foliation planes where they are present. It is thought that these rocks originated from cross-cutting, pre-metamorphism, basic sheet intrusives into the Basement System. Being originally composed of a mineral assemblage stable at high temperatures they have been less drastically altered than their hosts by regional metamorphism and metasomatism. When much of the surrounding rock was being profoundly changed and in part mobilized, these major mafic units remained as competent rafts, often distorted and occasionally pulled apart, but essentially unaffected apart from recrystallization and retrogressive metamorphism from a near-dolerite constitution to that of plagioclase amphibolites.

The major outcrop of plagioclase amphibolite in the area forms the ridge of the hill at Algabbyet. Good exposures of hornblendic migmatite with a high proportion of amphibolitic schlieren surround the hill, overlying and underlying the amphibolite, which occurs as a steeply inclined sheet with a generally southerly dip. The sheet has been extensively faulted at its eastern end.

The plagioclase amphibolite is fine-grained and fairly uniform, locally distinctly foliated in outcrop, but only faintly so in hand-specimen. Garnetiferous layers occur sporadically.

Specimen 34/208, from the eastern end of Algabbyet, displays both garnet and pyrite in hand-specimen. In thin section it is seen to consist of 50 per cent of light green hornblende, the remainder being mainly plagioclase with subordinate quartz and pinkish garnet, the latter enclosing grains of sphene, quartz and iron ore. Accessory minerals include clinozoisite, sphene, zircon, apatite and pyrite. Specimen 34/170 from the peak of the same hill shows some 65 per cent of hornblende and quartz is more prominent than in the previous example. A fracture-zone crossing the north-western part of the amphibolite exposure, has been infilled with iron ore and now consists largely of limonite bands and nodules with patches of strained quartz mosaic (34/171).

The eastern end of the exposure is cut by several quartz veins. These are distinctive in appearance, being sheared and possessing a cellular structure. The quartz is granular and stained along the shear-planes by secondary iron ores, presumably derived from iron oxides or pyrite that originally filled the cavities that now give the veins their porous structure.

Two and a half miles south-east of Kipkarren market another plagioclase amphibolite band is exposed in the valley, and cut off to the north by a N.E.-S.W. fault. It is variable in hand-specimen (34/405) showing leucocratic segregations surrounded by greenish pyroxene-rich patches. The rock is composed of hornblende, pale diopsidic pyroxene, garnet, quartz as mosaic patches and plagioclase of the composition of basic andesine An_{46}. Accessory minerals include clinozoisite, sphene, pyrite and calcite.

An outcrop of a similar rock (34/199) is cut by the Kipkarren river one and a half miles north of Chemnowet market. The rock contains some 40 per cent hornblende, 20 per cent garnet, 30 per cent plagioclase, subordinate quartz, epidote, diopside and accessory magnetite and sphene.

(b) Dolerites, meta-dolerites and norites

Rocks of this group occur occasionally as dykes over the whole extent of the Basement System within the area, and were seen cutting the granite of the south-west, though not the Nyanzian volcanic rocks. Outcrops are small and irregular in shape and the dykes show little regional trend. The example traversing the eastern slope of Algabbyet follows a proved fault-line.

A division of the specimens sectioned into two types is possible; those with olivine, and those with quartz. Examples without olivine occur in which garnet is present, probably indicating that the intrusion of those particular dykes came before the completion of metamorphism.

Specimen 34/88 from half a mile north-east of Kapsabet is typical of the quartz dolerites. In hand-specimen a medium-grained black rock, it is seen in thin section to consist of roughly equal proportions of interlocking plagioclase prisms up to 1.5 mm. in length in poikilitic relation to clusters of augite crystals. The plagioclase has the composition An_{44}. The augite is often twinned, and displays colourless cores with mauve (titaniferous?) outer zones dusted with minute inclusions. Green amphibole forms a narrow impersistent fringe around the fresh pyroxene crystals, and a rather better developed reaction rim of the same amphibole surrounds iron ore crystals of skeletal habit. A very small amount of quartz occurs interstitially. Rocks of similar composition include 34/102 from east of the road, one and a half miles north of Mugundoi, 34/119 from half a mile north of Tilolwa, and 34/174 from half a mile south-west of Chemuswa. In 34/200 from one and a half miles north of Chemnowet market most of the pyroxene has been replaced by red-brown biotite, skeletal iron ores and euhedral garnet surrounded by, or associated with green amphibole and chlorite. The remainder of the rock consists of well-twinned fresh plagioclase in prisms up to 2 mm. in length, and neither quartz nor olivine was seen. Specimen 34/231 from half a mile south-west of Kilibwoni is somewhat similar, though much more coarse-grained. In addition it retains much of its original pyroxene and has no garnet.

Specimen 34/185 from eastern Algabbyet carries a high proportion of ferromagnesian minerals and is typical of the olivine dolerites. In this rock the olivines are large fresh euhedra with cracks accentuated by granules of black iron ore. Subhedral enstatite crystals are abundant. Primary iron ore is not common and is associated with red-brown biotite, and progressively outward-decreasing extinction indicates that the labradorite crystals are zoned, with increasing soda content outwards. The nature of the pyroxene indicates that the rock could be considered as a micro-norite.

A similar mineral assemblage, but with a rather lower proportion of ferromagnesian minerals is displayed by 34/104, a specimen obtained from the most southerly of three dykes west of the Kapsabet-Nandi Hills road, one mile north of the Mokong river bridge. The coarse-grained nature of this rock justifies inclusion within the gabbro group, and on the nature of the predominant pyroxene it can be classified as an olivine norite. This coarse-grained rock has felspars up to 4 mm. across and contains clear euhedral pyroxene and clouded labradorite (An_{62}) in equal proportions. The pyroxene is faintly pleochroic enstatite. The olivine is subordinate and is in rounded grains, altered to iron ore and in part pseudomorphosed by iddingsite and serpentine minerals. It has developed narrow amphibolitic reaction rims where enclosed in plagioclase. The association of iron ore and biotite is again present.

A rock representing a much altered igneous intrusion of near-dolerite composition is 34/173 from one mile west of Chemuswa market. It is medium-grained, speckled black and white, and unfoliated. In thin section it is seen to consist of 40 per cent hornblende, partly as large crystals with patterns of lines of clusters of iron ore inclusions (almost certainly thrown out on conversion of pyroxene to hornblende) and partly as smaller clear grains in a mosaic with quartz. Biotite occurs inter-grown with the hornblende and as thin independent plates, while almost colourless garnet crystals and aggregates are scattered rather sparsely through the rock. The light minerals are quartz and felspar.

Another altered, but not metamorphosed, medium-grained dolerite invades and is faulted against the granite in the south-west, south of Ndurio. Inspection suggests that the rock (34/290) originally possessed an approximate mode of pyroxene 40 per cent, iron ore (ilmenite) 5 per cent and plagioclase 55 per cent. Little of the pyroxene now remains, the majority of the crystals being altered to amphibole and the greater part of the ilmenite now occurs as leucoxene. The plagioclase is highly saussuritized, but the original twinning is still visible. Micrographic quartz-felspar intergrowths occur interstitially.

(c) *Amphibole Rocks*

(i) *Hornblende Epidiorites*

The name hornblende epidiorite is here used to describe rocks considered to be of igneous origin, but now altered and consisting mainly of hornblende. Rocks of this type are recognized in several small, poorly exposed outcrops west and north-east of Kapsabet, and against the boundary of the Nyanzian rocks one mile east of Kaptumo.

Specimen 34/83 from two miles west of Kapsabet is a highly altered, friable rock, green in colour but flecked with white. On microscope inspection the rock is seen to consist of an irregular mosaic of hornblende crystals forming some 80 per cent of the rock, together with granular epidote, accessory plagioclase and quartz carrying concentrations of hair-like inclusions. Specimen 34/93 from a mile further east is a similar rock. On inspection the hornblende mosaic, which again constitutes some 80 per cent of the rock, is seen to be more regular and to consist of larger ragged plates. Quartz and plagioclase occur interstitially and locally form aggregates of crystals associated with small quantities of epidote.

The rock forming a small outcrop one mile east of Kaptumo (34/297) is closely related to the previous examples. Hornblende, pleochroic from pale bottle-green to yellowish green forms a loose association of subhedral plates and mosaic patches. Quartz, plagioclase and muscovite occupy interstitial spaces, together with subsidiary epidote. The amphibole constitutes some 70 per cent of the rock.

(ii) *Actinolite Epidiorites*

This rock-type is also considered to represent the alteration product of original intrusive igneous rocks, which occur in two masses in the Nyanzian volcanic rocks one and a half miles south-west of Koyo hill.

In hand-specimen (34/294) it is a highly fractured, coarse-grained, basic rock composed mainly of lustrous black amphibole crystals, and with much secondary pyrite on fracture planes. In thin section the amphibole proves to be actinolite and constitutes some 70 per cent of the rock, while the remainder is composed mainly of variably clear and saussuritized labradorite and subordinate iron ore.

(3) Pegmatites and Giant Quartz Veins

Pegmatites are of widespread occurrence in the Basement System, being conspicuously developed both in the migmatite zone and around the granite and granitoid gneiss in the south. Often it is apparent that they have been developed *in situ* as segregations, but elsewhere veins of pegmatitic material have invaded the country rock. For convenience they are considered together here. Pegmatites occur as isolated blebs and swirls in the northern migmatites, and further south as anastomosing networks of veins, or massive concordant sheets. These rocks are often less readily weathered than the host-rocks, forming upstanding exposures, and providing copious float. Typically they are composed of quartz and felspar intergrowths, though small garnets were noted in several instances.

Giant white quartz veins barren of mineralization were mapped cutting the Basement System gneisses in several places. The veins are usually composed of coarsly crystalline glassy white quartz but the example south of Baraton is of fine-grained granular texture.

5. Tertiary

The succession of Tertiary rocks in the Kapsabet area is summarized in the table below and contrasted with the succession suggested for the area east of the Kavirondo Gulf by Shackleton (1951, p. 350 and p. 385) and correlated with the succession of the Tinderet suite of the Kericho area recognized by Binge (1962, Table p. 38, pp. 27-29, 39).

(1) Miocene Sediments

The oldest rocks overlying the Precambrian in the area are sediments of Miocene age, which are seen only in small exposures. In the south they form the continuation of sediments in the Songhor area described by Kent (1944), Shackleton (1951) and Binge (1962). The age of sediments forming extensive outcrops in the Kavirondo Gulf area, in particular Rusinga Island, has been established as Miocene (Hopwood, 1929; Kent, 1944; Shackleton, 1951; Whitworth, 1953) and correlation has been made with the lithologically similar beds at Songhor and Koru, where fossil evidence suggests that deposition was confined to Lower Miocene times.

Shackleton pointed out (1951, p. 365) that the beds at Songhor are more tuffaceous than those at Koru, and certainly in the present area near its southern margin at the foot of the scarp, well north of Songhor, the sequence consists mainly of waterlain tuffs, with occasional impure limestones.

The occurrence of these Miocene beds suggests that in early Miocene times lakes existed in hollows in an undulating topography formed of Precambrian rocks. Basal conglomerates and sandstones, representing deposition of debris carried in by torrential streams from neighbouring hills, have been described at Koru (Kent, 1944, p. 106; Shackleton, 1951, p. 364) and may well underlie the sequence in the present area; the junction between the Miocene sediments and the underlying gneisses was nowhere seen. Intermittent volcanic activity later resulted in the deposition of agglomeratic and tuffaceous beds, and in more quiescent phases less common, alternating fossiliferous clays and limestones were laid down. The major eruptive period of Tinderet then ensued and the Miocene deposits were inundated by several hundred feet of coarse nephelinitic agglomerate.

TERTIARY SUCCESSION IN THE KAPSABET AND SURROUNDING AREAS

Age	Tinderet Suite of Kericho Area (Binge, 1962)	Tertiary Rocks of Kapsabet Area (present report)	Tertiary Rocks east of the Kavirondo Gulf (Shackleton, 1951)
Lower Pleistocene . .	Decomposed basic lava flows on Kano plains.		
Pliocene	Basanites and tephrites	Basanites of the Mtetei valley	
Upper Miocene		Phonolites of Tinderet	
Middle Miocene	Melanephelinites Nephelinites	Lavas of Tinderet (Phonolitic nephelinites, basalts, nephelinites, basanites, melilite-bearing types)	
	Phonolitic trachyte (Koru) Coarse volcanic agglomerate	Agglomerate (Nephelinitic ,mela-phonolitic, mela-nephelinitic, etc.)	
	Tuffs and Kericho phonolite	Uasin Gishu phonolites	Plateau phonolites (Losuguta type)
			Tinderet Lavas (Augite-rich nephelinites, nepheline basalt, olivine basalt, tephrite, melilite-bearing types)
Lower Miocene	Coarse volcanic agglomerate	Agglomerate (Nephelinitic-, mela-phonolitic, mela-nephelinitic, etc.)	Nephelinite agglomerate and tuffs
	Melanite tuffs and agglomerates Koru Beds (Limestones, biotitic tuffs, marls, ash beds, micaceous clays, etc.)	Miocene sediments (Limestones, biotitic tuffs, bleached tuffs, marls, consolidated clays, etc.)	Koru Beds (Limestones, biotitic tuffs, marls, silts and sands with gneissic boulders)

(Dotted lines indicate unconformity)

More than 100 feet of ashes and tuffs, most of which are apparently waterlain, are exposed in the eastern side of the Ainopsiwa valley on the southern boundary of the area. These are overlain by a sedimentary sequence about 100 feet in thickness containing several impure limestone bands. Up-stream of the road bridge over the Kamaasae, stratified ashes and tuffs are exposed sporadically on the southern bank of the river and on the hillside to the south, but it is often doubtful whether they are waterlain.

(*a*) *Limestones*

The limestones are confined to the outcrops of Miocene beds near the foot of the Nyando scarp. They are variable in appearance within their outcrops, one of which forms an important feature west of the road for a mile from a point some 600 yards north of the equator.

A pale buff, well-bedded sample from the centre of this outcrop (34/75) consists of well-defined bands of relatively pure limestone, with alternate broader, more tuffaceous units. In thin section calcite is seen to replace all the tuff fragments, their original shape and size being indicated by concentrations of iron ore or clay particles. Secondary apatite crystals are present and fragments and crystals of yellow and brown perovskite.

At a slightly higher horizon in the same exposure a breccia is present, consisting of limestone fragments cemented by calcite. Specimen 34/315, from just west of the Kamaasae bridge, is dark grey-brown and is a recemented fine-grained fragmental limestone, with much of the cement stained by secondary iron ore.

East of the road limestones can be seen in several small exposures. The Kamaasae river cuts a diminutive gorge through horizontal sediments, which include a limestone band high in the sequence, a quarter of a mile up-stream from the bridge. On the equator, east of the road, a series of bedded tuffs are exposed in the river bed, and outcrops of banded limestone of a few yards lateral extent occur sporadically at different heights on the hillside to the north.

A solitary fossil gastropod was found in a highly calcareous biotitic tuff (34/78) in the stream-bed a few yards west of the road, one and a half miles north of the equator.

Exposures of limestone remote from the main outcrops occur some two and a half miles north-east of the Kamaasae bridge, at a height of over 5,600 feet and some 1,000 feet higher than the outcrops west of the road. Assuming that all the sediments were laid down in a single continuous lake or in neighbouring lake-filled hollows on the sub-Miocene peneplain their present considerable difference in elevation can be taken as an indication of the magnitude of rift faulting along the north side of the Kavirondo gulf graben since Lower Miocene times (Shackleton, 1951, p. 366).

(*b*) *Bleached Tuffs and Mudstones*

Much further north than the Miocene outcrops mentioned above a number of isolated exposures of agglomerate, tuff and white mudstone occur, preserved in hollows in the mild topography of the Uasin Gishu plain by the plateau phonolites which overran the area from the east.

Five miles east of Kabiyet a considerable thickness of friable bleached agglomerate and tuff with mudstone bands, apparently waterlain, is preserved beneath a tongue of phonolite and exposed on both the east and west sides of it. Although heavily overgrown, a total thickness of 130 feet can be measured in the eastern exposure, with a compact white mudstone band attaining a thickness of 4 feet preserved near the base

of the sequence. Among the tumbled blocks at the foot of the small cliff formed by the compact mudstone band overlying highly friable and altered tuffs, a boulder was found that contained two poorly preserved indeterminate fossils, probably small lamellibranchs, which however disintegrated on inspection.

Two miles further south another small outcrop of faintly greenish blotched mudstone has been preserved under the phonolite and is now poorly exposed in the stream-bed (34/183).

Both consolidated clays and bleached tuffs also occur within the Kapsaret Forest (specimens 34/216, 34/217), where it is difficult to determine their correct relation to the phonolite. Small-scale faulting is assumed to account for their apparent dip of 45° S.E., and also the fact that they occur in the stream-bed above the lowest phonolite outcrop. A gully south of the main stream has exposed a small sandstone lens (34/218) interbedded between the bleached tuff and claystone.

(2) Pyroclastic Rocks of Tinderet

The greater part of the south-eastern section of the area is composed of pyroclastic rocks, originating from the volcanic centres at Tideret. The agglomerates and tuffs accumulated on the undulating surface of the pre-Miocene landscape, blanketing the topography. Subsequent erosion has exposed the tops of the higher Basement System hills, which now overlook valleys still filled with volcanic debris. Most of the agglomerate outcrops in a region of high rainfall, and weathering produces rich red-brown soils that support thick natural forest cover and after clearing are extensively utilized for tea cultivation. The drainage remains highly immature and the rivers consist of series of rapids over lava-flows or the harder better-cemented pyroclastic bands, with alternate broad swampy stretches. The presence of better cemented pyroclastic material and a greater concentration of lava flows near the top of the volcanic pile has resulted in an erosion scarp being formed by the rapid removal of the less consolidated underlying material. This irregular scarp borders the Tinderet Forest Reserve, and runs at approximately 7,500 feet for several miles south of Lessos.

The basal member of the volcanic sequence is seen overlying the sediments of Lower Miocene age north of Songhor at a height of 4,800 feet while, north of the scarp, in the valley of the Mokong river it lies directly on Precambrian gneisses, at a height of 6,000 feet. Traversing east from the latter exposure one remains on strictly comparable rock types for some 16 miles, where an altitude of 8,000 feet has been attained. Reconnaissance mapping failed to reveal any major stratigraphical or petrological distinction within the 2,000-foot sequence, nor was an adequate widespread marker horizon located. A number of general trends were noted, however.

The rocks outcropping peripherally are more widely variable from one another than those higher in the sequence. They are sometimes distinctly stratified and include most of the finer-grained members. The included fragments show wide variety in size and colour index and they are usually set in a copious fine-grained tuffaceous matrix. The agglomerates contain fragments of fossil wood, whose occurrence is most frequent in these lower members, though they are still found as high as 7,000 feet. The coarsest agglomerates outcrop on the ridges north of Kapchorua, where boulders 12 feet in diameter are displayed in a new road cutting. The exposures here preserve evidence of numerous explosive cycles, as included fragments within the largest boulders are themselves second and third generation pyroclastic rocks. Lava flows in the lower part of the sequence are rare, and of small lateral extent.

The higher members of the sequence tend to be more massive, more coherent, and to consist of closely packed angular fragments of a single rock type in a matrix almost identical with that of the lower members. Often the matrix and interstices have allowed the passage of percolating fluids and the size and shape of the included fragments are emphasized by marginal deposits of white zeolite.

The mode of origin of some of the fragmental rocks occurring high in the volcanic pile is difficult to state categorically, though most are tuffs and agglomerates formed from fairly homogeneous pyroclastic material, ejected and compacted while still at high temperatures. Some smaller outcrops may well be highly contaminated lava-flows, which were extruded on to surfaces of unconsolidated fragments of similar composition, and picked up a high proportion of "xenoliths". Other textures suggest the fracturing and re-cementing of partly consolidated lavas, as a possible mode of origin.

A major mineralogical characteristic throughout this pyroclastic suite, and the lavas within the pile, is the preponderance of nepheline among the leucocratic minerals, often altered and part-replaced and sometimes accompanied by melilite or felspar. The normal ferromagnesian mineral is aegirine-augite, often as part-resorbed, highly zoned phenocrysts, while euhedral sphene and fine-grained iron ore are usually present. Calcite and zeolite occur almost universally as accessory minerals.

Agglomerates and tuffs, tentatively assumed to originate from the Tinderet volcanic centres, occur as far afield as Kapsaret Forest. At the waterfall where the Kipkarren river passes off the lava on to the Basement System gneisses a thin intervening layer of pyroclastic material occurs, and occasional blocks of tuff are preserved in the base of the phonolite flow. This indicates that the earliest phonolite flow was preceded by a period of eruption of fragmental rocks that formed a thin mantle over much of the countryside.

One mile east of Chemuswa, at the western extremity of the phonolites, there are exposures of pre-phonolite pyroclastic rocks with a wide variety of fragment size, some of the larger pieces being derived from pre-existing agglomerates. Usually they are greenish rocks with fragments of about one centimetre diameter, set sparsely in a fine-grained, highly calcareous groundmass. Much fossil wood is present and within the calcite-replaced outer shell of some specimens the wood-fibres remain unaltered. This exposure has been exploited extensively, but unsystematically, for building-stone.

Coarse-grained tuffs, containing biotite flakes one centimetre square and augite crystals five millimetres long, outcrop both north and south of Kilibwoni in the lower ground between the phonolite scarp and the hills of Basement System gneiss to the west. The level is only slightly higher than that of the adjoining Kingwal and Kipterges swamps. Thus it is possible that a considerable thickness of pyroclastic rocks is preserved beneath the mantle of black-cotton soil extending over a large area to the north.

Specimen 34/286, an agglomerate exposed in a well dug just east of Lessos Lake, proves to be phonolitic with fine-grained dark fragments of about one inch diameter. The highly vesicular nature of some fragments can be seen in hand-specimen, and an occasional glassy felspar and pinkish nephelines can be recognized. A fragment cut in thin section has phenocrysts of biotite and orthoclase in a dense groundmass, packed with minute felspar laths, with trachytic texture.

Exposures three miles south-west of Kibebet have been sporadically quarried for building-stone. The yellowish outcrop includes a wide variety of rock types in fragments up to one inch in diameter, set in a buff highly calcareous matrix containing euhedral aegirine-augites. In thin section (34/234) it is seen that the pyroxenes present include zoned and unzoned aegirine-augite, and aegirine-augite with augite cores. Pseudomorphs after euhedral nepheline are present and felspars with carlsbad twinning. Fragments of phonolite and nephelinite are present, but as a whole the rock has the composition of a melanocratic phonolite.

Specimens 34/247, 34/272 and 34/350 are all examples of the more compact and uniform upper part of the agglomerates, though in each case the mode of origin of the rock is in some doubt. They may be recemented fragmented lavas. Specimen 34/272, from near Singhalo sawmill, is a homogeneous fine-grained dark rock conspicuous only for its large nepheline crystals and occasional small ferromagnesian

prisms. The fragmental nature of the rock is readily noted in exposures, owing to the preferential weathering of the matrix, but in hand-specimen is barely discernible. In thin section the rock is found to be composed of numerous small zoned aegirine-augite crystals, large pseudomorphs after euhedral nephelines and occasional euhedral sphenes, set in an isotropic groundmass crowded with aegirine-augite prisms. The composition is, therefore, melanephelinitic.

Specimen 34/247, from seven miles east of Lessos, is a similar fragmented rock, but is altered and has introduced zeolite and calcite. The composition of the matrix is very similar to that of the included fragments and boundaries are difficult to discern. The larger crystals are waxy yellow nephelines, smaller more common aegirine-augites and iron ores, and occasional sphenes. The part-isotropic groundmass of some fragments carries numerous small laths of felspar, giving a trachytic texture and a resulting composition of a phonolitic melanephelinite.

A rock consisting of larger closely-packed angular fragments of phonolitic nephelinite composition, is exposed four miles north of Nabkoi. The matrix is only slightly paler than the inclusions but is highly replaced by whte zeolites. Corroded nephelines and rare felspars, and zeolitic patches after nepheline, constitute the leucocratic minerals.

(3) Tertiary Lavas

(a) *Classification*

The lavas in the area show a wide range in composition. They consist of the plateau phonolites, and a gradational series of characteristically basic and undersaturated rock types from Tinderet. The difficulty of accurate classification is enhanced by the fine-grained nature of the groundmass in many cases, when it is impossible to determine with certainty the presence or absence of diagnostic minerals, other than the phenocrysts. In examples with part-isotropic groundmass it is sometimes difficult to distinguish between analcime and glass.

The types of lava present are indicated in the table below. When the total ferromagnesian minerals exceed the total leucocratic minerals in amount the prefix "mela" is employed in the case of the phonolitic and nephelinitic types, e.g. melanephelinite, phonolitic melanephelinite. Where distinctive but non-diagnostic minerals occur, or a second felspathold is present in subordinate amount, the names are modified by the insertion of the mineral name as a prefix, e.g. melanite nephelinite, analcime basanite, melilite mela-nephelinite.

Classification of the Tertiary Lavas of the Kapsabet Area

Rock Name		Leucocratic Minerals		Ferromagnesian Minerals		
		Felspar	Felspathoid	Clino-pyroxene	Olivine	Melilite
(Mela-)	Phonolite	Alkali	Nepheline	X	—	—
(Mela-)	Phonolitic Nephelinite	Alkali (subordinate amount).	Nepheline	X	—	—
(Mela-)	Nephelinite	—	Nepheline (>50%)	X	—	—
	Melilitite ..	—		X	X	(>50 %)
	Basanite ..	Plagioclase (subordinate amount)	Analcime or Nepheline	X	X	—

(*b*) *Plateau Phonolites*

(i) *Distribution*

Plateau phonolites of Shackleton's Uasin Gishu Phonolite (Shackleton, 1945, p. 6) cover some one-third of the area mapped. The lavas dip gently to the west and it is thought that their source was somewhere beyond the eastern margin of the area. Two major flows are distinguished, and the high ground to the east may represent subsequent flows, although no field distinction could be discovered between exposures, and no obvious topographic features representing margins of flows were observed, except for a few miles south of Kaptagat Station. In the area to the north a lava-flow has been mapped by Sanders that is earlier than those recognized south of Eldoret. Where it occurs in the present area it has been included with the lower of the two main flows already mentioned.

The lower of the two phonolites distinguished is a sparsely porphyritic lava, and the upper contains abundant large nephelines and glassy felspar phenocrysts, easily distinguished in hand-specimen. The basal flow forms the greatest part of the flat land of the plateau, while the later flow in the east and north overlies it forming a pronounced near-continuous erosion scarp at the junction. Where the later lava spreads to the west in the middle of the area it is at a similar, or even lower level than the earlier member flooring the plateau to the north, owing to the fact that as it spread to the west it overlapped the earlier flow, coming to rest on Basement System gneisses, and in places Miocene sediments. Both flows tend to terminate with distinct scarps on the west except, as in the region of Chemuswa, where the flow feathers out against a ridge of gneiss, in this case an upstanding spur from the Algabbyet hill mass. A double feature, where upper and lower scarps are nearly coincident, north of the Kingwal swamp, results in a drop in ground-level from 7,000 feet at the top of the upper scarp, to 6,500 at the foot of the lower.

The lower flow apparently lies directly on Basement System gneisses in the north, though the presence of a thin intervening layer of pyroclastic material, at least locally, is indicated by the occasional blocks of tuff preserved near the Kipkarren waterfall, and the agglomerate outcrops of the region of Chemuswa (see p. 24). East and south-east of the Kingwal swamp the phonolite everywhere rests directly on the lower volcanic rocks of Tinderet. This can be seen at many places along the south-west margin of the lower flow, and is also well demonstrated in the upper reaches of the Kipterges river where, traversing downstream, one remains on the Tinderet volcanic rocks until the lower phonolite outcrops on the ridges on either side of the valley.

North-east of Lessos the earlier lava was prevented from flowing further south by hills of the lower Tinderet volcanic rocks, though the hills did not presist to the west of Lessos, allowing a tongue of lava to flow in a more southerly direction until again blocked by agglomerate ridges south of the Kibebet river, which has etched the junction. The upper plateau phonolite east of Lessos lake was similarly banked against the lower Tinderet agglomerates which can be seen at all levels in the valley of the Masaba east of the lower phonolite outcrop.

A small exposure of tuff occurs between the phonolite flows four miles west of Kapekabush trigonometrical beacon, and reports were obtained of the occurrence of a narrow band of similar material in now-overgrown gullies where the Sosiani river runs off the upper onto the lower flow. This confirms that there was a sufficient time lapse between the phonolite flows for the accumulation of a thin mantle of pyroclastic debris which weathers more rapidly than the lavas, and has resulted in the greater recession of the upper phonolite scarp.

(ii) *Composition*

Specimen 34/219 from the lower lava flow, two miles north-west of Lessos, has a fine-grained porcellaneous blue-black groundmass with numerous small phenocrysts, mainly glassy felspars and less common waxy nephelines. A thin section shows that the phenocrysts are euhedral and part-resorbed carlsbad-twinned sanidine, less common nephelines, occasional aegirine-augites with narrow aegirine rims, and iron ore. Iron ore also occurs as aggregates of closely-packed granules produced by the alteration of a ferromagnesian mineral. The groundmass is fine-grained and composed of aegirine, kataphorite and felspar, and probably nepheline. A second specimen, 34/212 from the Onyoke valley two miles north-east of Lelmokwo market, is more typical in its phenocrysts, which are sparse and consist of nephelines and felspar showing a hint of anorthoclase twinning. The fine-grained groundmass again consists of brown sodic amphibole, aegirine, felspar and probably a zeolite mineral in the base. In this case the amphibole of the matrix predominates over the pyroxene.

The upper flow on the scarp west of Ndubenet is represented by specimen 34/220, which is a fine-grained blue-black rock carrying euhedral nephelines and clusters (1 cm. in diameter) and felspar plates (1 cm.) with a hint of flow alignment. The phenocrysts and clusters of nepheline are seen in thin section to be partly rounded, but with occasional crystal faces. The clusters include iron ore and apatite grains. The felspars consist of carlsbad-twinned columns with zones of inclusions of iron ore and amphibole towards their ends. An isolated olivine crystal was cut in the thin section; it is partly replaced by a talc-like material and coated with small aegirine crystals. Augite occurs as rare euhedral crystals. The fine-grained groundmass consists of felspar laths, cossyrite, aegirine, kataphorite and nepheline. Specimen 34/363 from the scarp on the Nabkoi-Eldoret road is markedly vesicular, the cavities being part-filled with zeolite and calcite.

(c) *Lavas of Tinderet*

A number of rare lava types occur intercalated as minor flows within the low Tinderet agglomerate formation, and field relationships suggest that some form plugs and intrusions of limited lateral extent. Higher in the volcanic pile lavas come to form a progressively larger proportion of the sequence and in the best exposed regions north-east of Lessos a succession of lavas and alternate tuffs can be mapped with some precision. The absence of a similar sequence on the map further south may be attributed in part to the nature of the soil and vegetation cover, which make that part of the area less amenable to detailed mapping, though it is true also that massive agglomerate remains the predominant member to a much higher level in the forest area to the south.

It appears probable that while a major vent, or series of vents, continued emitting pyroclastic material sporadically throughout the life of the Tinderet volcano, subsidiary vents were responsible for the extrusion of localized lava-flows, and small series of flows as occur near Burnt Forest.

In the highest part of the area the massive agglomerates are capped by a number of variable phonolite lavas with a high proportion of interbedded light-coloured tuffs and ashes. Again the standard of exposure is below that required to make the delineation of individual flows possible.

The agglomerates of the area about Lessos and to the west and south have several intercalated basic lava flows which prove to be melanephelinites and melilite-bearing rocks. In the area about Burnt Forest this agglomerate is overlain by a distinctive phonolitic nephelinite, phonolitic melanephelinite and melaphonolite.. The uppermost flows of Tinderet are more normal phonolites.

(i) *Phonolitic nephelinites*

The main phonolitic nephelinite occurs as a substantial flow extensively exposed between Lessos and Kipkabus. Except in the extreme east, where it lies directly on the upper plateau phonolite, it caps flat-topped ridges, overlying softer agglomerate and often forming a small scarp feature.

In hand-specimen the rock (34/240) is variable both in size and density of phenocrysts. Typically, large euhedral nephelines carrying cores of inclusions occur singly or in clusters averaging 1.2 cm. diameter while abundant prisms of a black feromagnesian mineral (0.5 cm.) and euhedral amber-coloured sphenes (0.5 cm.) are conspicuous in the green-black groundmass. Large felspar phenocrysts (1.5 cm.) occur occasionally and smaller felspar crystals are locally common. On weathering the nephelines are rapidly destroyed, leaving the rock surfaces liberally pock-marked and with an occasional upstanding glassy felspar. In thin section the large euhedral and subhedral nephelines are seen to have altered along cracks with the formation of cancrinite. They include occasional magnetites and pyroxenes, are sometimes intergrown with the pyroxenes, and sometimes include groups of small pyroxene crystals at their middles. The ferromagnesian mineral is green aegirine-augite, and the phenocrysts occasionally have cores of augite pyroxene and are overgrown by narrow bright green fringes of aegirine. The phenocrysts are often finely zoned, the zones usually being conspicuous between crossed nicols as series of chevrons crossing the crystals for the greater part of their length. The pyroxenes occur sometimes as clusters, associated with sphene, magnetite and small prismatic apatites. In hand-specimen the rock 34/230 from two miles south-east of Lessos is richer in felspar phenocrysts, and with smaller nephelines. The groundmass retains the green-black appearance, and proxene prisms and amber-coloured sphenes can both be distinguished. The cores of some of the larger zoned aegirene-augite crystals are neutral or pale green in colour. The carlsbad twinning displayed by the felspars is visible both in hand-specimen and in the slide, where the felspar crystals form small clusters, and are partly resorbed.

In both specimens just described distinct flow structure is apparent among the felspar laths of the groundmass. The pyroxene of the groundmass consists of small aegirine-augites overgrown with aegirine, and is accompanied by fine-grained mossy flecks of late stage, interstitial, brown sodic amphibole. The low refracting, weakly birefringent matrix is probably mainly nepheline.

(ii) *Phonolitic melanephelinites*

Traversing up the lava pile the phonolitic nephelinites become less porphyritic. Apart from the lack of large leucocratic phenocrysts the lavas are, however, strictly comparable with those lower down, but it is impossible to say whether the higher exposures represent the upper part of a single flow or a separate subsequent flow from the same source.

Specimens 34/281 and 34/245 from west of Burnt Forest have fine-grained green-grey bases carrying a few small nephelines, a few amber-coloured sphenes and numerous ferromagnesian prisms. In a thin slice of 24/281 the nephelines are found to occur in well rounded clusters, totally including small sphenes and pyroxene crystals, while 24/245 they also occur as sharply idiomorphic crystals and as clusters of idiomorphs. The pyroxene crystals, sometimes in radiating clusters, are zoned aegirine-augite, with cores lighter in colour and with wider extinction angles. In 34/281 idiomorphic and rounded microphenocrysts of iron ore are common. The groundmasses consist of felspar laths, aegirine-augite, magnetite and nepheline.

(iii) *Nephelinites and melanephelinites*

Mafic undersaturated rocks occur at a number of exposures among the Tinderet agglomerates. They usually appear as lava-flows of limited extent, as in the Mtetei valley and west of Lessos, but also occur as small irregular intrusions, as at Nabkoi road-junction.

A nephelinite, 34/329, collected from a minor flow to the north of the Mtetei valley road, is in hand-specimen a green-grey rock with waxy hexagonal nepheline phenocrysts up to 4 mm. in length. In thin section the larger nephelines are seen to be altered along anastomosing cracks and to lie in a highly altered groundmass carrying remnants of poikilitic crystals of faintly pleochroic aegirine-aguite. Small fresh and pseudomorphosed nepheline crystals are abundant in the groundmass, which now consists of some 50 per cent calcite and zeolites in crude spherules.

A second type (34/334), from beyond the end of the motorable track, contains 3 mm.-diameter nepheline phenocrysts and a high density of ferromagnesian prisms. It is classified as a melanephelinite. Phenocrysts of aegirine-aguite with aegirine fringes are common and the phenocrysts of nepheline are mainly euhedral, but some are resorbed and irregular, while some are highly altered. The groundmass consists of aegirine-aguite, nepheline and iron ore in an isotropic felspathoidal base.

Specimen 34/222, from one mile south-west of Lessos, is a pale grey rock with abundant pyroxene and olivine phenocrysts and is classified as an olivine nephelinite. The pyroxene is augite, weakly pleochroic from a pinkish tinge to greenish, in euhedral or slightly resorbed crystals up to 3 mm. across which are sometimes zoned and occasionally twinned. The olivines are less common, and are rounded and fringed by coronas of expelled iron-ore granules. Alteration has occurred along cracks to iddingsite, and in the cores of the crystals to serpentine minerals. Large grains of iron ore showing euhedral, subhedral or highly embayed shapes are common, while the groundmass is composed of abundant nepheline, small augite prisms and specks of iron ore.

The small exposure of basic lava at Nabkoi (34/256) displays large augites up to 1.5 × 0.8 cm. and olivines (0.6 cm.) and proves to be an analcime-olivine nephelinite. In thin slice the augites show pale greenish-buff cores with outer mauve titaniferous zones dusty with iron-ore granules and the smaller rounded olivines are again part-altered to iddingsite and serpentine. Irregular phenocrysts of iron ore are possibly ilmenite. Small phenocrysts and aggregates of ragged plates of phlogopite, pleochroic from pale yellow-brown to bright red-brown, are also present. The groundmass contains abundant rods and prisms of pyroxene and small euhedral grains of iron ore in a weakly birefringent base composed of nepheline and analcime.

A nephelinitic lava carrying melanite garnet occurs high within the Tinderet agglomerate on the Highland Sawmills' road (34/359). Pitch-black garnet crystals of almost circular section can be recognized in hand-specimen, lying in a green-grey groundmass crammed with euhedral nephelines. The latter are large and usually clear, but sometime include aegirine-augite crystals and small sphenes. The bright green aegirine-augite is sometimes highly zoned, and occasionally has faint grey or brownish grey zones near the centre. Sphene is common as euhedral crystals, singly or in clusters, one cluster including a small irregular grain of perovskite, while the melanite garnets are parts of euhedral crystals, zoned, and with inclusions of aegirine-augite and nepheline. The groundmass contains smaller sphenes, needles and short prisms of aegirine-augite, and nephelines in a near-isotropic base.

(iv) *Melaphonolites*

Mafic lavas classified as melaphonolites occur among the Tinderet agglomerates two and four miles south-east of Lessos. The first (34/287) is a fractured blue-grey rock carrying numerous dull euhedral augite crystals up to 3 mm. across. In thin section the augites are seen to have pink titaniferous outer zones. Clusters of iron ore and apatite occur in the interlocking groundmass of augite, carlsbad-twinned prisms and irregular crystals of orthoclase, iron ore and probable nepheline.

The other example, 34/251 from four miles south-east of Lessos is tephritic, has pale yellowish green euhedral and partly rounded phenocrysts of augite of varying sizes, and subhedral and skeletal crystals of iron ore. Sphene occurs as large and small euhedral phenocrysts, and microphenocrysts of felspar consist of carlsbad-twinned prisms of orthoclase and lamellar-twinned prisms of plagioclase. The prismatic phenocrysts are orientated to give a hint of flow structure. The groundmass consists of a weakly birefringent base largely composed of nepheline, crammed with laths of plagioclase, rods and short prisms of pyroxene and granules of iron ore.

Overlying the phonolitic melanephelinite in the upper part of the lava sequence there is a distinctive felsparphyric rock, which provided specimens 34/366 from two miles south-west of Burnt Forest and 34/252 from 4½ miles north-west of Nabkoi junction. The groundmass proves identical with that of the phonolitic nephelinites and phonolitic melanephelinites which underline this melaphonolite and have already been described. The matrix contains aegirine-augite, nepheline, felspar prisms and occasional sphene. The phenocrysts are euhedral or subhedral nephelines, occuring singly or in clusters, and aegirine-augite as euhedral or partly resorbed zoned crystals with aegirine fringes. Sphene is a common accessory, and often associated with iron ore. Large euhedral felspar crystals, up to 3 cms. long, show carlsbad and anorthoclase twinning. Some are marginally resorbed, displaying a zone of inclusions near the margin.

(v) *Melilite nephelinites and melilite melanephelinites*

In several places east of Lessos, in particular in the valleys of the Nderaguti and Daragwa rivers, a thin band of compact black lava forms a subsidiary feature below that of the phonolitic nephelinite. The distribution of the mapped outcrops suggests that the flow is probably present as a thin sheet over a considerable area, though often giving no surface indication. The rock is locally vesicular and contains small waxy phenocrysts. Scattered phenocrysts of clear nepheline are present and occasional aegirine-augites. In speciments 34/280 and 34/283 the melilite phenocrysts have been almost obliterated by alteration and in 34/244 are preserved as irregular resorbed crystals, giving anomalous, low-order birefringence colours. The groundmass is crammed with prisms of weakly birefringent mineral with rounded and hexagonal isotropic sections (probably nepheline), needles of aegirine-augite, flecks of kataphorite and iron ores.

A melilite nephelinite (34/114) of rather different appearance was found in an exposure of a few yards extent among the agglomerates, three miles south-east of Kapsabet. It could not be determined whether it is an intrusive rock. The hand-specimen is a fractured light grey rock with numerous small amber-coloured phenocrysts with rounded or prismatic sections. On microscope examination these are seen to be melilite, often partly resorbed and in prismatic sections carrying inclusions along their median line. Small fresh euhedral nepheline phenocrysts occur singly or in clusters, in an indeterminate murky groundmass rich in iron ore.

Specimen 34/113 from a similar exposure of lava a quarter of a mile to the north is a pale grey rock rich in ferromagnesian prisms and proved on inspection to be a melilite melanephelinite, with resorbed zoned aegirine-augites and altered nepheline and melilite.

Pyroxene-rich lavas occur indifferently exposed west of Lessos, and several superficially similar types were mapped as a single unit. Specimen 34/235 from near the Roman Catholic school is a fresh dark grey-green rock, with lustrous ferromagnesian phenocrysts. These prove to be colourless to pale yellowish augites, up to 8 mm. in length, some being idiomorphic while others are zoned and highly resorbed. Perovskite is abundant as large dull pink subhedral granules, deeply cracked and often with cores peppered with minute inclusions, and displaying typical cross-hatch twinning. Melilites in plates up to 1 mm. in diameter, sometimes with median

cracks and alteration parallel to the c-axis giving a resemblance to peg structure, and scattered small nephelines are present. Magnetite occurs in crystals and grains of various sizes up to 1 mm. diameter and sometimes includes small perovskites and at others is included within the augites. The groundmass is composed of augite prisms, abundant nepheline crystals, perovskite and iron ore and includes large clear patches of analcime and local concentrations of green alteration products associated with the melilite.

(vi) *Melilitites*

A pale grey fractured rock (34/233) forms a pronounced hummock-like exposure among the agglomerates in the bed of the river one mile south-west of Kibebet. A solitary large biotite phenocryst is visible in hand-specimen and a greenish ferromagnesian crystal, which proved to be olivine. In thin section the rock displays altered remnants of nepheline phenocrysts in a fine-grained groundmass crammed with small melilite crystals of euhedral shape. Augite phenocrysts are also present.

(vii) *Basanites*

A series of basic lava flows entered the area from the south at a late stage in the Tinderet volcanicity and is now extensively exposed in the Mtetei valley, dipping at approximately 10° to the north towards the foot of the agglomerate scarp. Specimen 34/339 from the Mtetei valley road at the equator, is a fine-grained slate-grey rock with occasional vesicles part-filled with calcite, and carrying large pyroxenes and rather smaller altered olivine phenocrysts. In thin section the olivine gives evidence of two periods of growth, with slight alteration to iddingsite at the intermediate state, while larger iron ore grains display highly resorbed amoeboid shapes. A mesh of laths of plagioclase of mid-labradorite composition are present and a felspathoid mineral, probably analcime, occurs interstially in the groundmass.

A similar rock (34/320) from the eastern fringe of the flows shows large euhedral augites, rounded pseudomorphs of olivine in serpentine minerals, felspathoid-mosaic patches after nepheline and abundant labradorite microphenocrysts. A melilite basanite (34/326) from further north carries perfect, fresh euhedral augites and olivines (0.8 cm.) and highly corroded melilites surrounded by fringes of fine-grained alteration products. Part-resorbed nepheline remnants occur and crude spherules of zeolite.

A small flow of coarsely crystalline basanite (34/338) forms a hill one mile north of the end of the Mtetei valley road. Here both the olivines and augites exceed 1 cm. in length. The augites are euhedral but slightly rounded while the olivines often show fresh skeletal cores, while microphenocrysts of plagioclase and felspar prisms in the groundmass are lamellar-twinned and have a composition within the labradorite range.

(*d*) *Phonolites of Tinderet*

On the highest ground in the south-east part of the area a selection of lavas of variable appearance, but typically with phonolite composition, outcrop together with subordinate tuffs and ashes.

Loroki hill is capped by a porcellanous blue-black lava (specimen 34/347), sparsely porphyritic with occasional glassy felspars. The phenocrysts cut in a thin section were aegirine-augite and iron ore, while the blotchy groundmass included aegirine-augite, kataphorite, felspar and stumpy prismatic nephelines. A much more coarsely porphyritic phonolite (34/353) mapped within this group caps the hills at the extreme eastern end of the Mtetei valley. It carries conspicuous carlsbad-twinned glassy felspar crystals and fewer smaller waxy euhedral nepheline prisms.

6. Metamorphism of the Basement System

It is generally accepted that the rocks of the Basement System of Kenya have been derived by regional metamorphism and granitization from an original succession composed of sedimentary rocks. Throughout Archaean times these rocks were probably subjected to several phases of injection and metamorphic alteration.

Locally in the Kapsabet area well-foliated biotite gneisses occur but give way further south, in the region of Soyet, to more highly granitized leucocratic quartzo-felspathic and granitoid gneisses. In the north, in the region of Kabiyet and Sangalo, an extensive zone of migmatites grading into patches of migmatitic granite continues out of the area to the north, where Sanders has mapped an exensive belt of granodiorite and granodioritic migmatite around Turbo.

In a chapter on metamorphic facies in relation to magma, Turner (Fyfe, Turner and Verhoogen, 1958, p. 202) has discussed the development of palingenetic granite migmatites in zones of high-grade regional metamorphism. He states that under these conditions metamorphism has culminated in partial fusion of rock complexes to give granitic liquids which may subsequently have crystallized in place or may have migrated to somewhat higher levels, in either case giving rise to migmatite complexes. In this situation the physical conditions of metamorphism overlap those at which granite melts are stable and there must be a wide range of temperature and pressure at which metamorphic rocks of various kinds can co-exist with granite melts of varied water content.

The sediments which on metamorphism produced the banded gneisses in the area around Kapsabet were of a fairly homogeneous semi-pelitic variety and, as a consequence, the paragneisses produced display similar mineral assembleges. The general trend throughout subsequent metasomatic alteration of the rocks has been toward petrological uniformity. Late-stage introduction of alkali felspar can often be detected and the most common mineral assemblage noted is quartz-plagioclase-microcline-biotite, only sometimes accompanied by epidote and muscovite. Both the latter minerals may be produced on alteration of biotite. Much of the alkali felspar in these rocks is poorly twinned, and it is notable that some orthoclase was recognized though microcline is the predominant potash felspar. Diagnostic mineral assemblages are better displayed by the orthogneisses represented by plagioclase amphibolite rocks.

The rocks of the area display assemblages which indicate that they must be included in the staurolite-quartz sub-facies of the almandine-amphibolite facies (Fyfe, Turner and Verhoogen, 1958, p. 229). Turner states that the typical mode of occurrence of this facies is in the high-grade zones of progressive regional metamorphism—from the middle of the garnet zone through the zones of staurolite, kyanite and sillimanite. Rocks of this facies commonly grade into migmatites veined with granitic materials. In fact, the three index minerals quoted were not themselves recognized in the area.

The fourth mineral assemblage quoted by Turner for the staurolite-quartz sub-facies is derived from basic rocks, and is hornblende-plagioclase-almandine-epidote (quartz-biotite). Specimen 34/199 from one and a half miles north of Chemnowet market (p. 18) contains these four essential minerals plus quartz and diopside. Similarly specimen 34/208 from eastern Algabbyet (p. 17) and 34/405 from two and a half miles, south-east of Kipkarren market (p. 18) contains hornblende, plagioclase and garnet and clinozoisite in place of ferruginous epidote. Quartz is common to all three specimens, while biotite is absent. Specimens 34/199 and 34/405 both contain diopside, and therefore show affinities to the calcareous assemblage diopside-hornblende-epidote (-plagioclase).

Specimen 34/71 from a mile and a half north-east of Kapsabet (p. 12) was recognized by its field relations as a metamorphosed dyke rock and on mineral composition also falls in the staurolite-quartz subfacies. It contains hornblende, plagioclase, epidote, quartz and biotite.

Specimen 34/308 and 34/316 (p. 13), both granitoid gneisses from south of Soyet, have the mineral assemblage of the quartzo-felspathic group of the staurolite-quartz subfacies. They contain quartz, microcline, plagioclase, biotite, muscovite and epidote.

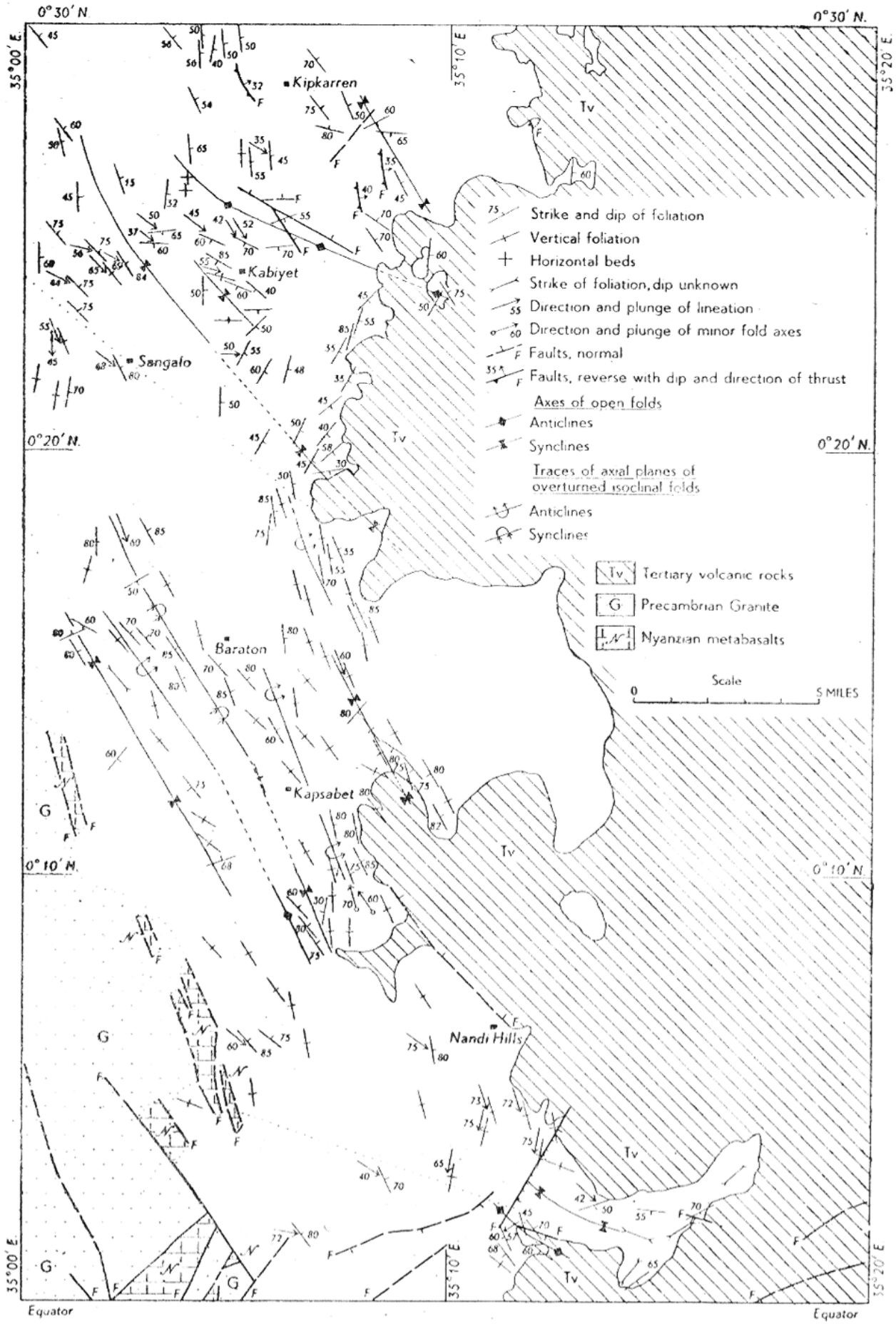


Fig. 3—Structures in the Basement System rocks of the Kapsabet area

7. Structure

(1) Basement System

The Basement System gneisses of the area display a regional strike of N.N.W.-S.S.E. with steep dips to the north-east (Fig. 3), but in two localities the strike swings more nearly N.N.E.-S.S.W. with corresponding south-easterly dips.

In the north the rocks have been sufficiently mobilized locally to destroy the original gneissose foliation, such fabrics as occur being the result of limited plastic flow. Further south, near Kabiyet, the foliation dip in the migmatites parallels the dip of the Algabbyet amphibolite giving a region of south-westerly dips. A strike swing to a N.N.E.-S.S.W. trend is visible for some six miles near Chemuswa, and a similar foliation strike is present in the rocks of the hills at the foot of the Nyando scarp. In both cases the foliation dip is moderate and to the south-east. Locally lineations are not well displayed in the rocks of the area, but where seen were variable in direction between 90° and 192° and in plunge between 35° and 75° to the south-east quadrant (Fig. 3).

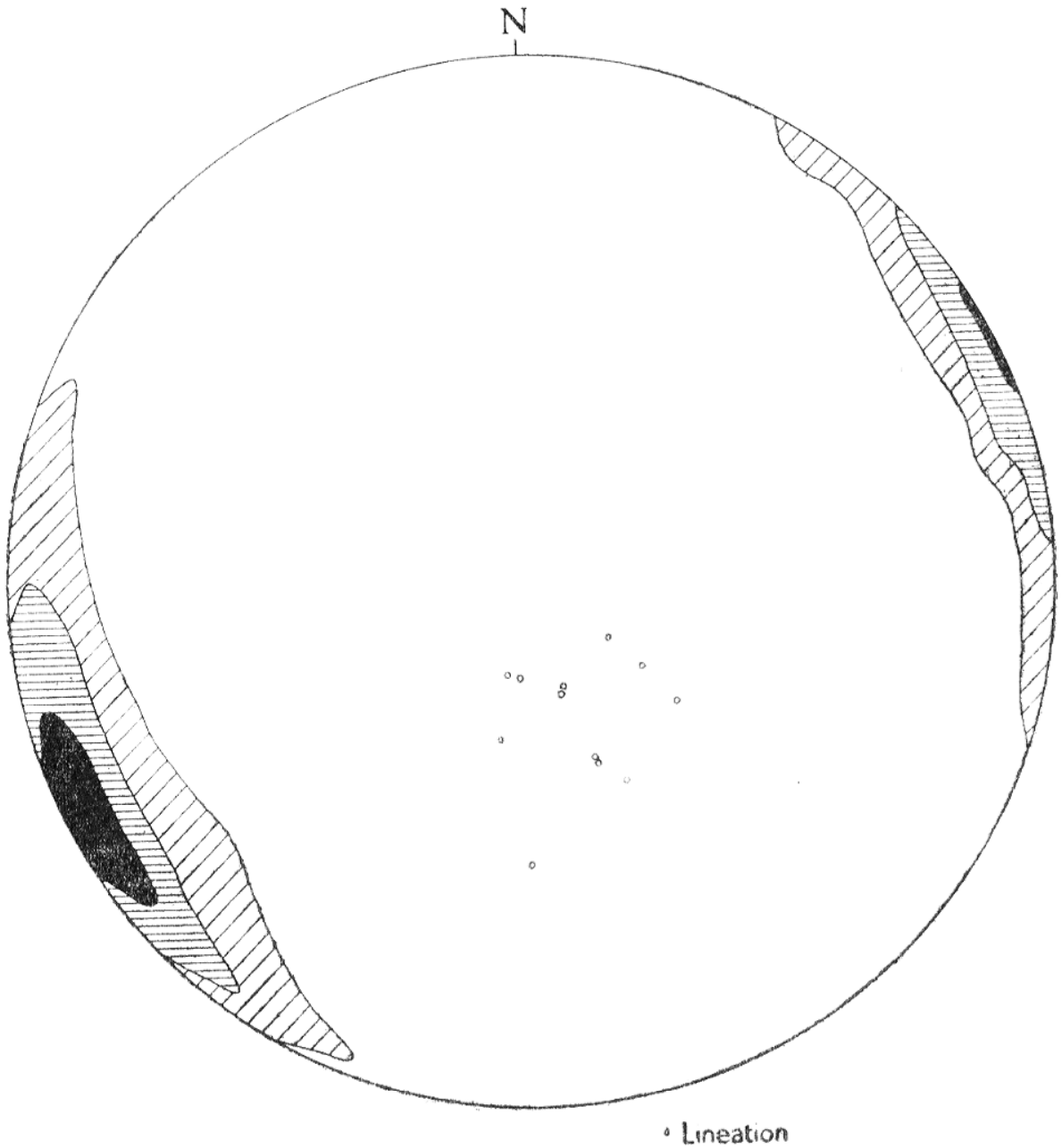


Fig. 4—Stereographic projection of poles to foliation and lineation for the rocks of the Basement System in the area around Kapsabet. Poles to foliation density contours at 2 per cent, 8 per cent and 16 per cent (122 readings)

All information on the dip and strike of foliation and the direction and plunge of lineation of the gneisses of the Basement System is shown on Fig. 3. The style and degree of folding was not obvious in the field and the evidence collected is not conclusive. The following suggestions are therefore tentative.

In the area about Kapsabet the gneisses are isoclinally folded about near-vertical axial planes and overfolding, where it occurs, is to the west. Lineations suggest that the fold axes trend N.N.W.-S.S.E. and plunge steeply to the south-south-east at about 66° (Fig. 4). The only minor fold-structures recognized, $3\frac{1}{2}$ miles south-east of Kapsabet, have axes in planes parallel to the axial planes of the major folds, but punging at 60° and 70° to the north-north-west, i.e., the minor fold axes and regional lineation intersect at 60°.

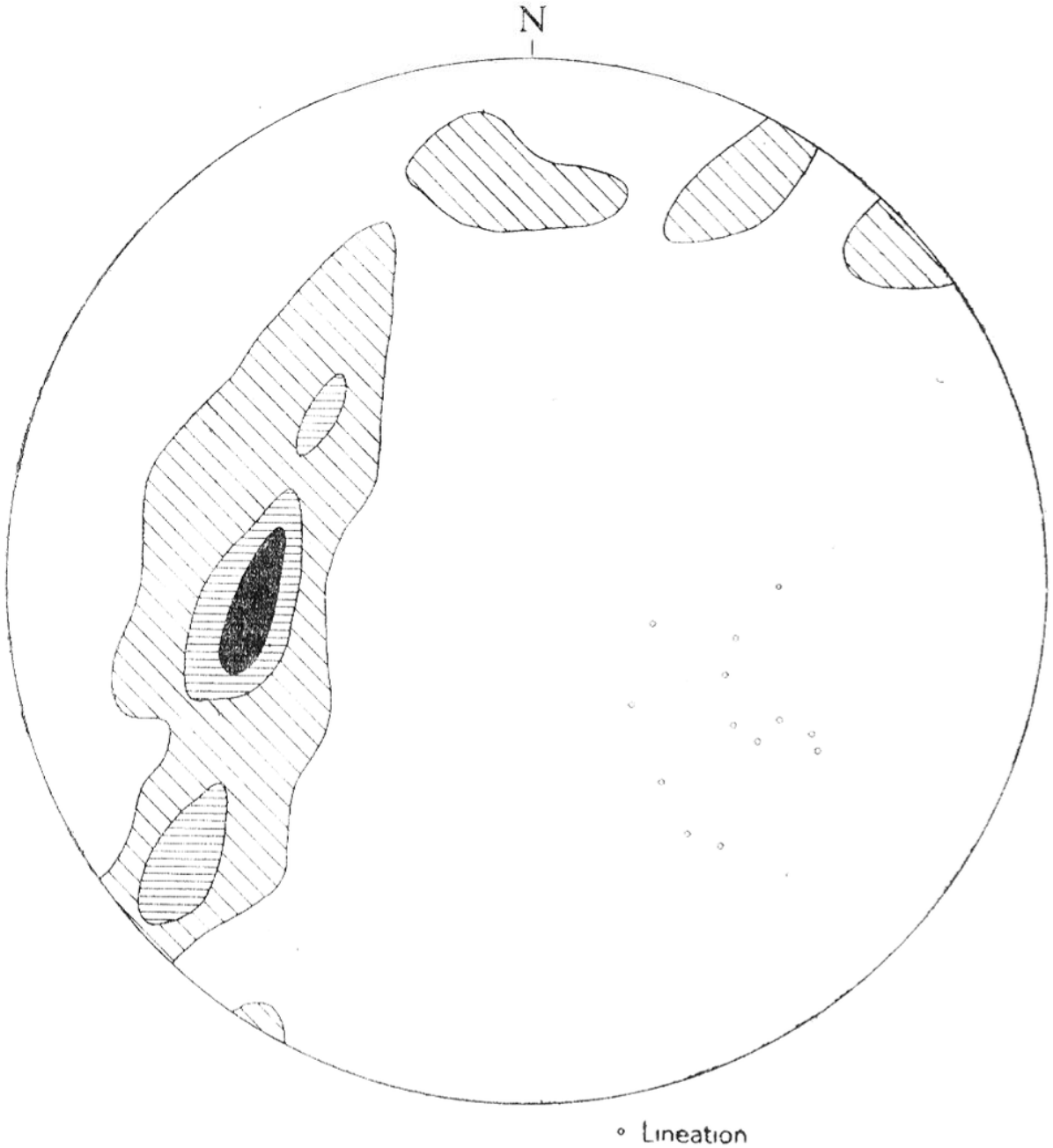


Fig. 5—Stereographic projection of poles to foliation and lineation for the rocks of the Basement System in the area around Kabiyet. Poles to foliation density contours at 2 per cent, 6 per cent and 10 per cent (85 readings)

Further north, in the sub-area north and east of Sangalo (the boundary of the sub-area is shown by a dotted line on Fig. 3), the degree of folding is less extreme, more gentle open structure being formed. Lineations suggest the fold axes trend more

W.N.W.-E.S.E. and plunge at shallower angles, variable about 49° (Fig. 5). The rocks in the extreme south of the area have been disturbed by the Kavirondo Gulf rift faulting and information is inconsistant, but again suggest shallow folds with axes trending W.N.W.-E.S.E.

(2) Faulting

The Kabsabet-Plateau area is structurally an upstanding block, bounded to east, south and west by major faults.

The Elgeyo scarp fault runs sub-parallel to the eastern margin, but considerably further east than the area mapped. No indication of subsidiary faulting of this trend was observed in the area, where ground-level rises progressively to the east, terminating in the low phonolite hills of Kaptagat, and the higher ground composed of the uppermost volcanic rocks of Tinderet further south. The widespread, uniform, gently dipping nature of the plateau phonolites suggests a fissure source rather than a central cone and the general north-south trend of contours on the lava surface indicates that such a fissure would probably run on the Elgeyo escarpment fault-trend.

The major fracture to the west is known as the Nandi fault. It runs N.N.W.-S.S.E. and has been traced from its emergence beneath the volcanic rocks of Mt. Elgon (Gibson, 1954) to its disappearance into the South Nandi Forest (Huddleston, 1954), and again from its crossing of the Nyando scarp to its disappearance beneath the alluvium of the rift valley plain (Shackleton, 1950; Binge, 1962). Over most of this distance south of Broderick Falls a pronounced west-facing scarp resulting from recent rejuvenation of the fault indicates the fault-line, but this feature dies out southwards so that the point of entry of the fault into the present area is in some doubt.

Shackleton (1951, pl. XXVII) indicated the south end of the Nandi fault as cutting the Nyando escarpment, and confining Nyanzian meta-volcanic rocks to the west, with Basement System gneisses on the east. More detailed mapping has shown that several faults of N.N.W.-S.S.E. trend cross the scarp and the country north of it, and that Nyanzian rocks are exposed, apparently as minor fault-blocks, marginal to the granite and at a number of places within the gneisses east of the main fault. These blocks are considered comparable with the blocks of Nyanzian on the top of the Nandi fault scarp in the Kakamega area (Huddleston, 1954). Mapping is complicated by the presence of roof-pendants of sheared Nyanzian lavas in the intrusive granite, and by the difficulty of distinguishing between granitized Basement System gneisses and foliated contaminated granite where they are faulted against one another. As a result of the present mapping the granite is considered to extend well to the east of the Nandi fault.

A major fault-zone runs along the western half of the southern boundary of the area and is the continuation of the Nyando fault, i.e., the northern fault of the Kavirondo Gulf rift valley. For some fifteen miles west of the present area the fault forms a notable scarp bounding the rift valley. Within the present area, however, the fault branches and the fault-zone swings more E.N.E.-W.S.W. and becoming less conspicuous finally becoming smothered by the uppermost flows on the eastern flank of the Tinderet volcano. In the extreme south-east an east-west drainage pattern is maintained (Fig. 1) suggesting control by subsequent movement on the Nyando fault-zone.

The faulting post-dated the deposition of the Miocene sediments as is shown by the occurrence of these beds at heights differing by 1,000 feet near the Songhor road, and also post-dated the majority of the Tinderet pyroclastic rocks, while preceding the final phase of Tinderet volcanic activity. Binge (1962, p. 47) has postulated that it predated the Nandi fault, though no evidence of relative ages was seen in this area. The

south-facing agglomerate scarp of the Mtetei valley region is a receded and much eroded fault-line scarp, and the basanite lavas entering the area from the south and dipping towards the foot of the scarp at about 10° are post-faulting extrusives. Both the Mtetei and Kipkurere valleys, which follow approximately E.N.E.-W.S.W. lines, run contrary to the anticipated drainage pattern on the volcanic pile and are interpreted as channels eroded preferentially along fault-zones in the volcanic rocks. Fault-brecciated volcanic material is rarely visible owing to the copious cover of derived boulders, particularly from the easily eroded, poorly-cemented agglomerates of the south-facing scarp. The small lava flows of basic composition in the Mtetei valley are probably some of the most recent extrusions of the area, and they were derived from vents, significantly aligned on a roughly east-west trend.

Hills of Basement System rocks at the foot of the Nyando scarp lie to the north of the assumed line of the major faults, and in the scarp face gneisses can be seen underlying several hundred feet of agglomerate at a height of 7,000 feet. This is the height to which the hill tops further west approximate, the level of Shackleton's (1951, p. 379) "high" peneplain. The hills south of the scarp are, therefore, considered denuded of their agglomerate cover, but not seriously displaced by faulting relative to the rocks to the north.

The Nyanzian outcrop at Koyo hill was mapped as a down-faulted block with tectonic boundaries against Basement System gneiss, and granite of post-Nyanzian age. More than 600 feet of Nyanzian metavolcanic rocks are displayed between the top of Koyo and the bottom of the valley to the north-east, and more than 1,000 feet in the dissected scarp face to the south. Faults responsible for this magnitude of throw cannot be referred to a Tertiary age if the correspondence of peak levels of Koyo (Nyanzian meta-volcanics), the hills to the west (granite), and those to the east and north-east (Basement System gneisses) owes its origin to peneplanation in pre-Cretaceous times. The Nandi fault passes through these hills without apparently disturbing the peneplain level. Accepting that the hills on the top of the Nyando scarp represent remnants of a pre-Cretaceous peneplain both the Koyo hill faulting and the Nandi fault on evidence solely within the area mapped must be referred to a still earlier tectonic period, and might even be Precambrian age.

A number of thrust faults, traced only for a limited distance, occur in the migmatites in the north of the area. They trend approximately north-south and the thrust-planes dip at 30° to 45° to the east. Mylonite occurs at the sole of the thrust near the Kipkarren river bridge, three and a half miles south-east of Kipkarren market. These thrust faults represent the continuation of more extensive zones of westerly thrusting mapped by Sanders in the area to the north.

VI—MINERAL DEPOSITS

No new mineral deposits were located during the survey.

1. Gold

The Nyanzian rocks of the area are highly fractured and sheared, and injected by mineralized quartz veins. They are part of the same volcanic suite, and occupy a similar position adjacent to the major granite as do the Nyanzian rocks near Kibigori at the foot of the scarp, where the injecting quartz veins carry gold in economic quantity. The present survey has extended the outcrop of this rock type considerably to the north, but rapid investigation indicated that extensive gold mineralization is not likely.

The granite in the Koyo area is cut by numerous small quartz veins, some of which carry gold, and it was in this region that Gari Hansen Elijah carried out opencast mining on a small scale from 1949 to 1953 as indicated in the following table.

SUMMARY OF HISTORY OF GARI HANSEN ELIJAH'S CLAIMS

Year	Ore treated	Gold recovered	No. of claims held
	(tons)	(ozs.)	
1949	11	12·32	40
1950	126	47·27	42
1951	29	4·51	22
1952	*	6·56	20
1953	30	6·75	14
1954	—	—	6
1955	—	—	6
1956	—	—	6

*No figures available.

At the time of the present survey no work was in progress at Gari Hansen Elijah's gold-mine at Koyo and most of the workings had been infilled and were thoroughly overgrown. The mine was visited in July, 1950, however, by E. P. Saggerson, a Government geologist, who described the form of mining as entirely open-cast work with some trenches up to 20 feet deep. At that time there were five main workings grouped together about a mile south-east of Koyo beacon, all entirely within quartz-rich granite. The gold-bearing quartz is a blue variety occurring in lenses which rapid prospecting showed did not exceed 60 feet long, 2 feet wide and 20 feet to 30 feet in depth.

Traces of gold also occur in quartz veins in the Basement System gneisses to the east. The mineralization of the quartz veins on the top of the scarp north of Koyo and within the South Nandi Forest is apparently mainly pyrite and gold has been reported from streams north-west of Kaptumo. Of the 22 samples submitted for assay all but three gave negligible gold values, none from the northern extension of the Nyanzian outcrop yielding more than trace amounts of gold while only low values were obtained from stringers in the granite and gneiss south and north-east of Koyo. Many streams were panned without traces of gold being found.

2. Scheelite

In 1952 a small deposit of scheelite was located in one of Gari Hansen Elijah's claims, east of Koyo. L. D. Sanders, a Government geologist, examined the mineralized quartz vein, but found the scheelite sporadically developed, and of negligible quantity.

In a report on the scheelite mineralization, Sanders stated that about 1,000 yards south-east of Koyo beacon ("Keiwa" location) a trenched working exposed three thin gold-bearing quartz veins, which occur in quart-rich biotite granite and trend approximately north-east to south-west with a dip of 70° to 80° south-east. They showed minor transverse faulting which caused displacements of up to 1 foot.

One of these veins showed scheelite mineralization but the work accomplished indicated that the maximum width of the vein was 9 inches, thinning downwards to 6 inches and pinching out to 4 inches at the north-easterly extremity of the working. Green-brown, coarsely crystalline aggregates of scheelite occurred in scattered pockets in the quartz and had led to deep pitting on weathered surfaces. Over a strike distance of about 10 feet there was a workable concentration and a channel-sample was taken from this part of the reef. Subsequent assay showed that the sample contained 5.5 per cent of WO_3, but channel-samples taken from neighbouring parts of the vein in which there was little visible scheelite proved to contain only 0.07 per cent of WO_3 on assay.

Other gold-bearing veins which had been worked by Elijah and veins cut by neighbouring streams were examined for scheelite in vain. Float samples from unworked reefs were also investigated without success.

No further occurrence of scheelite was seen during the present mapping, nor has any been reported from the area by prospectors.

3. Limestone

No crystalline limestones occur among the gneisses of the Basement System in the area, but there are small bands of impure limestone among the clays and tuffs of the Miocene sediments near the Songhor road at the foot of the Nyando scarp. Many of the Tinderet tuffs and agglomerates are, in addition, highly calcareous.

The Miocene limestones have been worked to a small extent in the past. In the area further south such limestones are being burnt for lime, but the limited extent of the limestones in the present area and their variable composition as inferred from appearance in hand-specimen, suggest that apart from small-scale burning for agricultural lime it would be difficult to exploit them economically. A similar conclusion was reached with regard to small limestone deposits at Keben. Here limestone boulders, some possibly derived from the agglomerates, are abundant in the proximity of the spring. Other blocks occur as bluffs in the steep walls of a dry valley running north-westerly from the pool below the spring, and one outcrop of limestone of limited lateral extent occurs in the floor of the gully. The origin of this limestone is in doubt but, in a report on the mineral spring at Keben, Pulfrey suggested that it may be a relic of Miocene lake-beds comparable with those on the southern boundary of the area.

4. Brick-clays

Clay is dug and baked as bricks at several localities, both from deposits on gneisses and on phonolite lava. One of the largest pits is situated half a mile north of Cheptet mission.

5. Building-stones

Tuffs and agglomerates consisting of small rock fragments, suitable for exploitation as building-stone, are of wide distribution throughout the south-east of the area. The potential supply might be classified as unlimited. Many small quarries are apparently worked periodically, mostly in a rather unsystematic manner.

6. Mineralized Waters

Water emerging from the volcanic rocks of Tinderet carries a high proportion of dissolved salts, in particular calcium bicarbonate. Pebbles in some of the streams in the Northern Tinderet Forest are coated with re-precipitated calcium carbonate, and spring waters, both from the eastern end of the Mtetei valley and from Keben, five and a half miles south-east of Lessos, have reputed medical value. The Keben water carries a high concentration of carbon dioxide. The Nandi have certainly considered the latter water beneficial to the health of their cattle for many years, happily contravening stock movement regulations in order that their herds might visit the spring periodically. The Keben Spa Hotel, no longer operating, was built for the economic exploitation of the Keben Spring.

A water specimen was submitted for analysis to the Government Chemist's Department in 1945. The results, together with a partial comparison with an analysis of Vichy water, are given below with a summary of the Government Chemist's observations. No mention was made of the fluorine content.

ANALYSIS OF KEBEN SPRING WATER*

	Keben	*Vichy*
	parts per 100,000	
Alkalinity: Carbonate	Nil	
Bicarbonate	322·00	560
Ammonia: Free	0·015	
Albuminoid	0·002	
Oxygen absorbed (4 hrs. at 80°F.)	0·03	
Nitrates	Nil	
Nitrites	Nil	
Chlorides (as Cl)	1·0	
Sulphates (as SO_4)	0·55	
Calcium (as CaO)	15·26	36
Magnesium (as MgO)	10·39	7
Iron	0·1	0·1
Total soluble solids	352·4	
Dissolved CO_2	Not measured	97
Hardness: Total	49·00	
Permanent	Nil	
Temporary	49·00	
pH	6·7	

Analyst: Government Chemist

* Laboratory specimen No. 612, received 24th September, 1945

(1) The free ammonia figure is high for spring water and can only be assumed to arise from a harmless source if the possibility of organic contamination can be excluded without doubt.

(2) The water contains a considerable concentration of carbon dioxide gas; the amount was not determined.

(3) The hardness is entirely temporary due to calcium and magnesium bicarbonates.

(4) The predominant salt in solution is sodium bicarbonate which has an alkaline reaction, which will become evident only after the expulsion of dissolved carbon dioxide.

(5) The iron content is higher than normally present in potable waters. It is held in solution by the carbon dioxide gas.

7. Water-supply

Water-supply proves little of a problem over most of the area, as an adequate rainfall maintains perennial springs throughout the African land and a good flow in the rivers running off the Tinderet highland mass. A number of bore-holes (Fig. 6) have been drilled on the plateau and the northern foothills of Tinderet, the results being tabulated below.

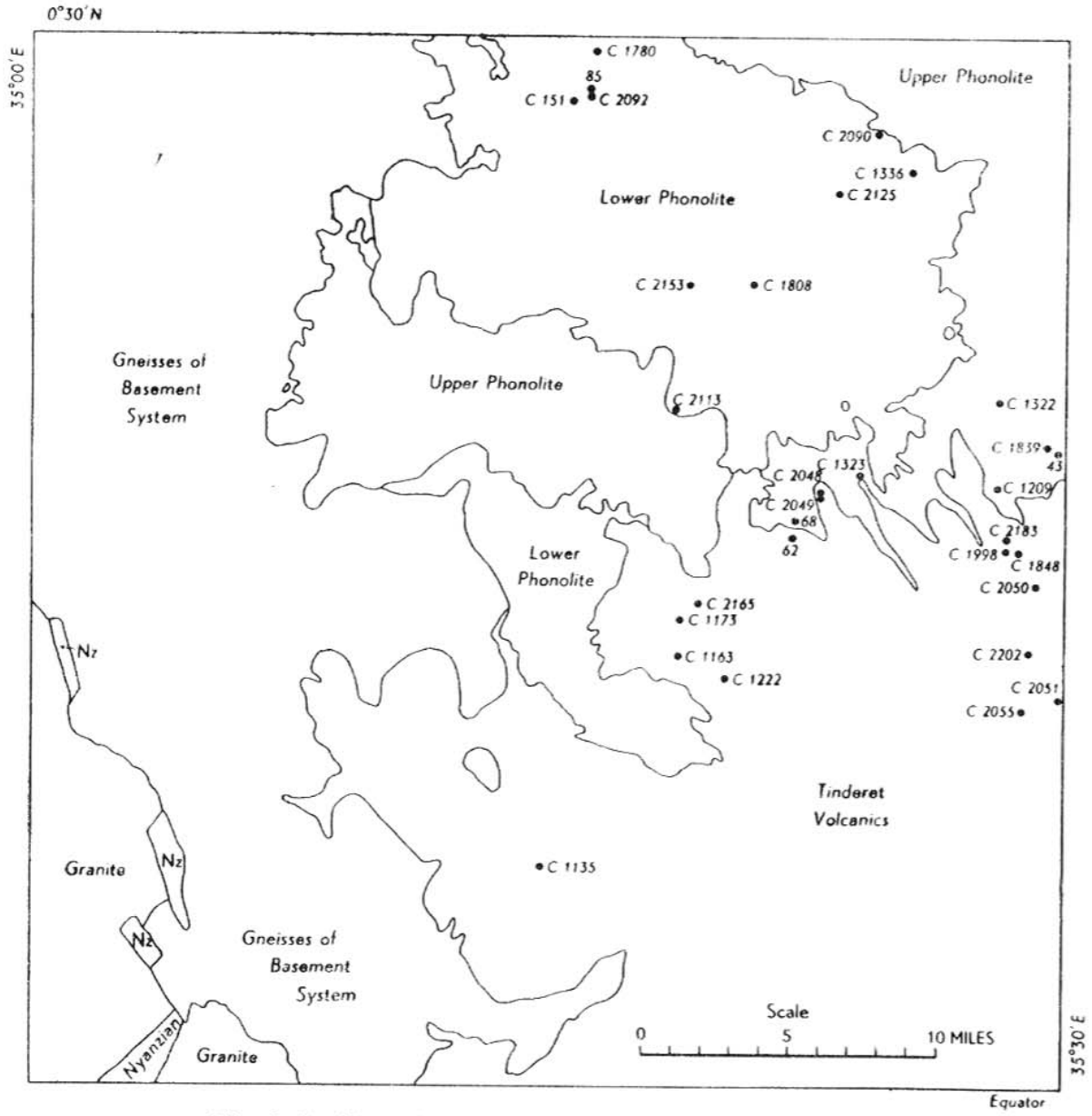


Fig. 6—Position of bore-holes in the Kapsabet-Plateau area

Drilling logs for the bore-holes in the entire phonolite plateau area indicate that the lava cover was probably pierced and the height of the surface of the Basement System rocks established at one drilling site only. This is bore-hole C. 1808 situated four miles south of Plateau station where the log indicates the following succession:—

	Depth		
	From Ft.		*To* Ft.
Soil and murram	1	..	12
Phonolite	12	..	468
Sand	468	..	477

The height of the "sand" must be about 6,800 feet, but no water was obtained at this horizon. At no other bore-hole on the plateau was the phonolite bottomed and all water must be obtained from fissured lava and horizons between successive lava flows.

Deep weathering of rocks in the Kipkabus area and of the agglomerates further south has resulted in drilling logs indicating successions consisting largely of clay, tuffs and clay with boulders. Bore-hole C. 1998 sited four miles south-west of Kipkabus

station pin-points the height of the top of the plateau phonolite, indicating a thickness of 344 feet of overlying agglomerate. The log of bore-hole 68 from two miles east of Lessos lake indicates 97 feet of weathered upper phonolite and agglomerate overlying the earlier phonolite flow.

Among the volcanic rocks of Tinderet levels at which water is struck seem unpredictable.

BORE-HOLES IN THE KAPSABET–PLATEAU AREA

Ministry of Works Bore-hole No.	Date Bored	Depth (feet)	Depth water struck (feet)	Water level; static (feet)	Gals. hour
North-east of Plateau Station:					
C. 2090	28–6–53	80	42	33	280
C. 1336	30–1–51	300	42	35	60
C. 2125	9–1–54	333	290	—	80
Kipkabus and to the south:					
C. 1322	7–10–50	230	198	16	105
C. 1839	25–9–52	200	65	42	500
43	15–8–29	295	212	12	2,400
C. 1209	19–8–50	350	250:300	58	335
C. 2183	15–4–54	400	—	—	Nil
C. 1998	1–6–53	600	190	330	30
C. 1848	12–10–52	138	109	95	300
C. 2050	22–4–53	300	188:250	40	1,000
C. 2202	29–4–54	410	280	100	320
C. 2051	25–4–53	300	240	150	550
C. 2055	23–5–53	200	184	80	1,200
South of Eldoret:					
C. 1780	30–5–52	416	85:123	10	130
85	22–7–30	355	215	54	375
C. 2092	10–53	83	—	—	Nil
C. 151	15–10–41	400	60:100	—	120
Centre of the plateau:					
C. 2153	14–2–54	100	45	28	250
C. 1808	23–7–62	477	20:110	6	220
C. 2113	30–11–53	188	70	40	650
Lessos area:					
C. 1323	30–12–50	270	136	21	400
C. 2048	6–3–53	200	—	—	Nil
C. 2049	25–3–53	230	—	—	Nil
68	16–1–30	236	230	112	1,350
62	21–9–29	37	—	—	Nil
C. 2165	25–2–54	300	145	80	500
C. 1173	9–10–50	400	95:165: 300:390	172	500
C. 1163	20–9–50	473	165:460	273	270
C. 1222	7–11–50	600	90	204	20
Nandi Hills area:					
C. 1135	20–7–50	600	—	—	Nil

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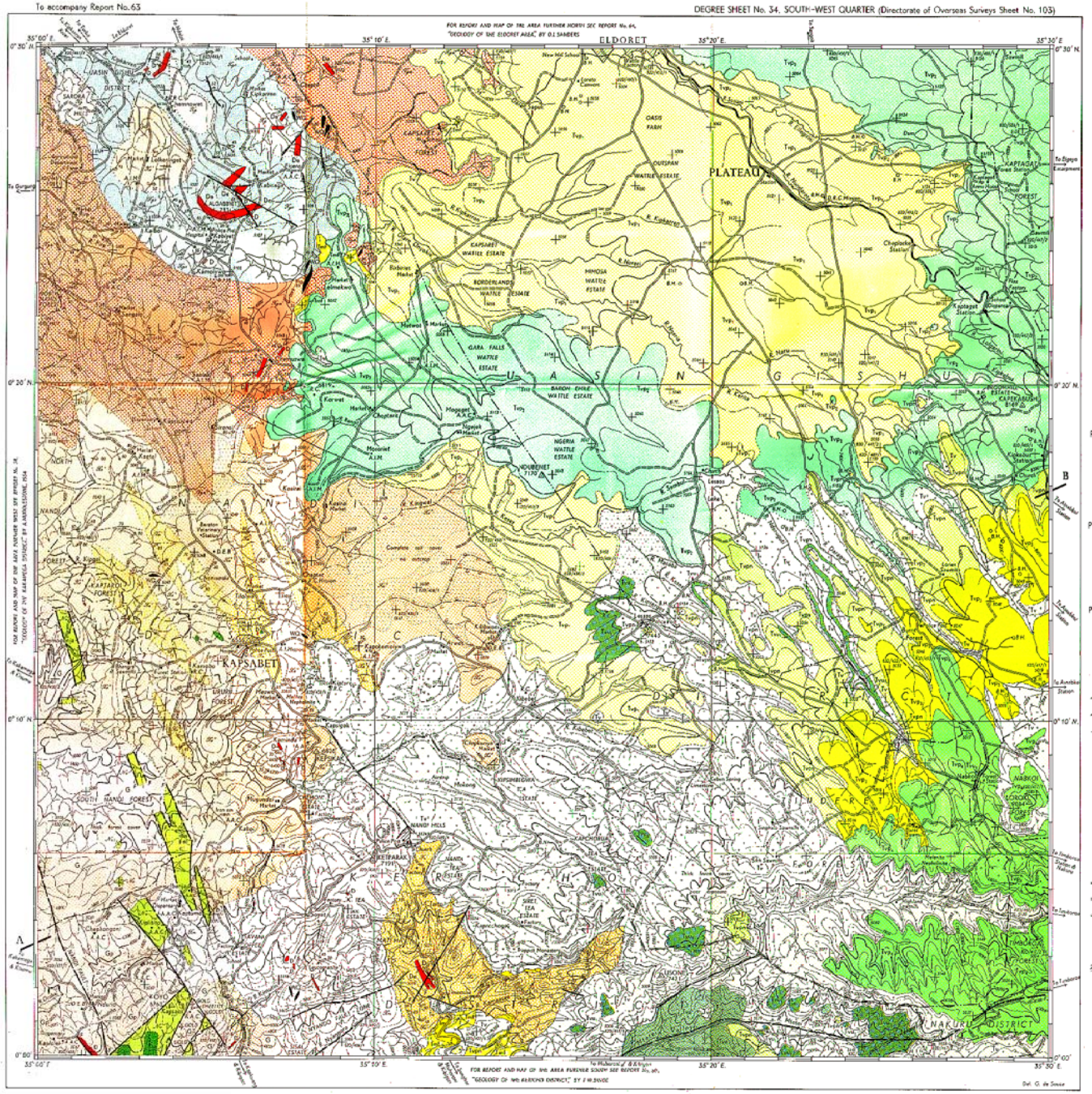
* Not consulted in original.

G.P.K. 911—1m—4/61

GEOLOGICAL MAP OF THE KAPSABET - PLATEAU AREA

To accompany Report No. 63

DEGREE SHEET No. 34, SOUTH-WEST QUARTER (Directorate of Overseas Surveys Sheet No. 103)



EXPLANATION

RECENT
- Black-cotton soil

TERTIARY
- Tvb — Basanites
- Tvp$_4$ — Phonolitic lavas with subsidiary ashes and tuffs
- Tvp$_3$ — Melanocratic phonolites
- Tvpn — Phonolitic nephelinites
- Tvx — Melanephelinites and melilite nephelinites

BASIN GISHU PHONOLITES
- Tvp$_2$ — Upper phonolite
- Tvp$_1$ — Lower phonolite
- Tv — Agglomerate of phonolitic, nephelinitic and melanephelinitic composition, with subsidiary tuffs and lava flows

Lower Miocene
- Tmf — Tuffs and ashes
- Tm — Limestones

NYANZIAN SYSTEM

PRECAMBRIAN
- Ng — Undifferentiated volcanic rocks, mainly metabasalts

BASEMENT SYSTEM
- Gn — Banded gneisses
- Gn^{bt} — Biotite gneisses
- Gn$_{gn}$ — Biotite migmatites
- Gn$_{gn}$ — Hornblende migmatites
- Gn — Granitoid gneisses

PRECAMBRIAN ?
- Mg — Migmatitic granites

INTRUSIVES

PRECAMBRIAN ?
- G — Granites; Gp Porphyritic granites
- Gd — Granodiorites
- Ep — Epidiorites
- D — Dolerites
- Ds — Highly metamorphosed basic intrusive rocks

- Geological boundaries, observed
- Geological boundaries, approximate
- Geological boundaries, gradational or inferred
- Dip of bedding
- Dip in lavas
- Horizontal beds
- Dip of foliation
- Vertical foliation
- Horizontal foliation
- Strike of foliation, dip not known
- Plunge of lineation
- Plunge of minor anticlinal folds
- Faults, normal
- Faults, inferred
- Faults, reverse with dip and direction of thrust
- Mineral deposits
- Prospect, derelict
- Giant quartz veins
- Lava scarps

- Railway
- Main roads
- Motorable tracks (not all shown)
- Trigonometrical stations
- Spot-heights in feet
- Form-lines at 200-ft. vertical intervals
- Principal points of aerial photographs
- Bore-holes
- Swamps
- R.C. School, Roman Catholic
- A.I.M. School, African Inland Mission
- A.A.C. School, African Anglican Church
- D.E.B. School, District Education Board
- D.C. District Commissioner's office
- Electric power line
- District boundaries
- Forest boundaries
- Line of section

Topography based on 1:50,000 sheets 34/3, 34/4, 34/7, 34/8 NE, 34/8 SW and 34/12 NE, 34/12 SE

Magnetic declination approximately 3° 00' W.

MINES & GEOLOGICAL DEPARTMENT
KENYA

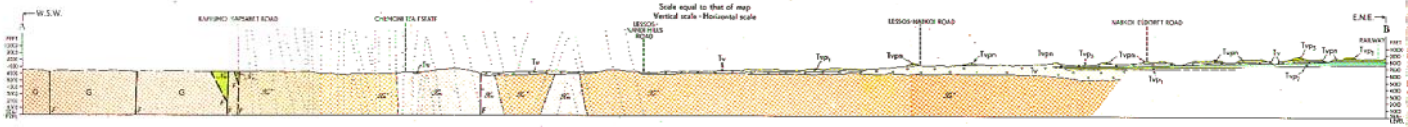
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Scale 1:125,000

1 inch = 1·972 miles or 1·014 inches = 2 miles

GEOLOGICALLY SURVEYED BY D. J. JENNINGS, GEOLOGIST
Between November 1956 and July 1957

SECTION FROM A to B
Scale equal to that of map
Vertical scale = Horizontal scale



KEY



AIR PHOTO FLIGHT DIAGRAM

