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COLONY AND PROTECTORATE OF KENYA

—————
GEOLOGICAL SURVEY OF KENYA
—————

GEOLOGY OF THE KISUMU DISTRICT

DEGREE SHEET 41, N.E. QUADRANT
(with coloured map)

By

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FOREWORD

Several reports have been published within the last fifteen years on areas in the goldfields of western Kenya, both north and south of the Kavirondo Gulf. Mr. Saggerson's report on his reconnaissance of the area between Homa Mountain and Miwani, which for convenience is referred to as the Kisumu district, bridges the gap between the areas on either side of the gulf. Although only half of Homa Mountain fell within his map area, mapping was continued westward to include the whole of the Homa peninsula, in view of the economic importance of its limestone deposits. The survey has shown that the mountain is a group of diatremes with carbonatite cone-sheets, comparable in some respects with the famous occurrences at Alnö in Sweden.

Homa peninsula has already been made famous by its deposits of Pleistocene sediments which have yielded remains of a Palaeolithic man. Mr. Saggerson gives a resumé of results obtained by previous observers, and an account of new discoveries made during his necessarily hurried survey.

The Kisumu district straddles the Kavirondo Gulf rift valley, which has been regarded as a flaw in the side of the main rift valley that runs through central Kenya. Mr. Saggerson's work has provided much additional evidence on the locality and nature of the faults that make up the gulf rift valley, and brings out well the intervention of faulting oblique to the east-west trend that is usually ascribed to it.

During the survey a few promising gold-bearing localities were noted, and at one point fluorite—a rare mineral in Kenya—was discovered.

Nairobi,
29th January, 1952.

WILLIAM PULFREY,
Chief Geologist.

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ABSTRACT

The report describes an area in the Kavirondo Gulf region of western Kenya, some 1,250 square miles in extent, including 280 square miles of lake, bounded by the Equator and latitude $0^{\circ} 30' S.$, and by longitudes $35^{\circ} 00' E.$ and $34^{\circ} 30' E.$ Physiographically the area is divided into the two faulted strips on either side of the Kavirondo Gulf and a central portion including the Gulf and the Kano Plain.

Rock types are numerous and include: (1) lavas, basic to acid in character, and banded ironstones of the Nyanzian System, commonly sheared and highly folded; (2) granitic intrusions which have invaded the Nyanzian; (3) basaltic and rhyolitic lavas and quartzite of the Bukoban System (Kisii Series) which are younger than the granitic intrusions; (4) various dyke intrusions, mainly intermediate to basaltic in composition; (5) Tertiary to Pleistocene phonolitic lavas; (6) Miocene sediments; (7) Pleistocene sediments deposited during the East African Pluvial Periods; (8) the Homa Mountain ring-complex and carbonatite intrusions with associated soda-rich rocks; (9) Recent deposits including lateritic ironstone and limestone.

A detailed account is given of the various rocks and particular attention is paid to the structure of the Kavirondo rift valley. Economic deposits with reference to gold, building stone, limestone and ironstone are described.

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GEOLOGY OF THE KISUMU DISTRICT

I—INTRODUCTION

The area described in this report comprises the north-east quadrant of Degree Sheet 41 (Kenya Colony), which is bounded by the Equator and latitude $0^{\circ} 30' S.$ and by longitude $35^{\circ} 00' E.$ and $34^{\circ} 30' E.,$ and is some 1,250 square miles in extent. For convenience an account of that portion of the Homa peninsula outside the boundary of the quarter-degree sheet to the south-west has also been included.

The area includes portions of the Central and South Nyanza Native Land Uni's, administered from Kisumu and Kisii respectively. In only one part of the area is the land utilised as non-African farmland, that being the sugar plantation between Kibos and Miwani.

Occurrences of gold in quartz stringers and in river alluvials drew the attention of prospectors to South Nyanza as early as 1907. Subsequently in the mid-thirties considerable exploration and prospecting was carried out both north and south of the Kavirondo Gulf, and some small mines were developed. The possibility of further occurrences in the present area, together with the search for other metalliferous deposits associated with the many granitic intrusions, gave reasons for a geological study of the area which would guide future prospecting. Although no deposits of other metals were found indications of new deposits of gold were seen, whilst an occurrence of fluorite in one of the granites is worthy of more detailed examination. Homa Mountain has long been exploited for its limestone and mapping there was carried out in an endeavour to discover further deposits of economic value. Small deposits of building stone were mapped in the Kendu district and rock suitable for road metal was found to be abundant.

MAPS

Existing topographical maps include: Karungu, South A36/E (1:250,000) published by the Ordnance Survey in 1916; Kisumu, E.A.F. No. 1551 (1:500,000), published by the Army in 1944; and cadastral sheets South A36/E (1:250,000), S.A36/E II A (1:62,500), S.A36/E II B (1:62,500). Topographical detail on these maps was found to be very approximate and for the map accompanying this report form lines were surveyed by barometer using lake level and trigonometrical points as datum levels.

The entire area has been aerially photographed on a scale of approximately 1:30,000 by the Colonial Survey Department, and although preliminary plots were not available a reasonably accurate map was produced from the photographs as a groundwork for the geological survey. Previous trigonometrical points have been supplemented by numerous Colonial Survey beacons which gave adequate control for the production of the map.

Field work was carried out between the months of January and July, 1950, and was based entirely on the aerial photographs without reference to previous maps.

COMMUNICATIONS

The area is well served with roads and tracks, a large proportion of which are usable even during the heaviest rains. Except in Kisumu, where the main roads are tarmacadamized, all roads are surfaced with murrum which is abundant in many parts on the north side of the Kavirondo Gulf. Although the road across the Kano Plain between Sondu and Ahero has been recently resurfaced it is often flooded and unusable to many vehicles in heavy rains such as occurred in 1951. Tracks are impassable to motor vehicles in wet weather where constructed on black cotton soil, but over a greater part of the area solid rock is not far below the present-day surface, providing a firm foundation. Homa peninsula has a circular track, now broken on the north-western side of the mountain where a journey on foot is generally necessary to complete the circuit.

Kisumu is the main town in Nyanza Province, being linked by rail with Nairobi, and Butere in the Kakamega goldfields. Main roads also connect it with Nairobi, Trans Nzoia, Uganda, South Nyanza and Tanganyika. It is the terminus for the Lake Victoria steamers and the distribution of African food to Tanganyika is of great importance. Kisumu airport is used by East African Airways planes on the Nairobi-Entebbe route. Although its landing strip conforms with International regulations it is rarely used now by the larger air services. This is also true of flying-boats which made extensive use of the sea-plane base during the war.

A new major road from Kisumu to Uganda is to be constructed and will make faster road communication possible between Nairobi and the Protectorate.

CLIMATE

Compared with many parts of Kenya the area receives ample rainfall enabling good crops to be grown over a wide area. A great deal of the rainfall occurs, however, as torrential thunderstorms which is not beneficial but produces rapid erosion and large gullies in the thick red soil cover of the cultivated areas. Soil erosion is most active in South Nyanza and Central Nyanza west of Kisumu. A great drive is now in progress to reafforest portions of land which have been stripped of their natural vegetation, low scrub and bush. The Provincial and District Agricultural Departments are teaching the African modern farming methods with a view to preventing active gullying and loss of the soil cover in those parts most affected by the heavy storms.

Central Nyanza is the most heavily populated part of the area and it is here that erosion is greatest, as all land capable of cultivation is under crops. South of the lake, although the population is dense there are still uncultivated portions of ground and erosion does not assume the alarming proportions seen in other areas. Perhaps the most rapid erosion is seen on Homa peninsula where vegetation is sparse and crops poor. Here gullies are more than 30 ft. deep and are being further eroded by rain falling during severe thunderstorms.

The rainfall is good over the whole area (Table I) and nowhere does it fall below 30 in. per annum, and the average over a number of years is somewhat higher than that. The heavy precipitation along the top of the Nyando scarp provides water for rivers such as the Kibos Awach. The proximity to Lake Victoria accounts for the many thunderstorms which pass from east to west and occur throughout the year. Fifteen per cent of the rain falls in April corresponding with the "long rains".

TABLE I.—RAINFALL STATISTICS OF THE KISUMU DISTRICT

| STATION | Altitude | Total Rainfall in Inches, 1948 | Number of Rainy Days 1948 | Average Total Rainfall Over Period | Years Recorded | Heaviest Single Rainfall |
|-------------------------|----------|--------------------------------|---------------------------|------------------------------------|----------------|--------------------------|
| Maseno, Vet. Station | 4,800 | 51·61 | 145 | 60·99 | 14 | 2·14 |
| Kisumu, Met. Station | 3,800 | 40·23 | 131 | 48·94 | 9 | 3·05 |
| Kisumu, P.C.'s Office.. | 3,800 | 34·82 | 106 | 44·82 | 45 | 1·44 |
| Ahero | 3,800 | 37·42 | 145 | 43·60 | 8 | 1·57 |
| Miwani, Railway Stn. | 4,000 | 35·05 | 65 | 49·46 | 18 | 1·30 |
| Miwani, Living Qrtrs. | 4,200 | 42·60 | 124 | 55·92 | 22 | 1·71 |
| Nyabondo, R.C.M. . . | 5,200 | — | — | 45·84 | 3 | — |
| Nyakach, A.M. . . | 5,000 | 32·04 | 64 | 41·88 | 6 | 2·30 |
| Oyugis, Dispensary . . | 4,800 | 53·92 | 118 | 53·16 | 7 | 3·00 |
| Doho Kasele | 4,400 | 35·64 | 68 | 44·93 | 5 | 3·29 |
| Karachonyo | 4,000 | 35·15 | 86 | 45·46 | 10 | 1·62 |

Those parts of South Nyanza occurring outside the confines of the area described in this report have a still greater rainfall and provide abundant water for the permanent streams to the south of the lake.

African crops are generally good and grasslands abundant where the rainfall is heavy. New agricultural methods and the encouragement of draining on the Kano Plain is producing new and better crops, on land which was originally scrubland.

POPULATION AND SETTLEMENT

The greater part of the area is inhabited by the Jaluo tribe, but the Nandi tribe lives on top of the Nyando scarp in the north-east and the Maragoli tribe occupy the ground between them and Maseno. The pastoral Nandi tribe are a reserved people and often suspicious so that it is difficult to obtain from them information as to place names and local labour. On the other hand the Jaluo and Maragoli tribes who farm their reserves extensively are most helpful with information and raise no difficulty over supplying labour.

During the mapping local tribal place names were preferred, as names in use vary from tribe to tribe. Even then the same river may have a different name in different parts of its course within the same tribal reserve.

European and Asian settlement is confined mainly to Kisumu, the Provincial capital, and there is only one non-African farm throughout the remaining districts. Maseno is the only other centre of any size and has now a large agricultural training centre for Africans. Christian missions are of various denominations and include: Seventh Day Adventists (S.D.A.) at Gendia (Kendu), American Missions (A.M.) at Maseno, Ogada Nyangori and Nyakach, and Roman Catholic Missions (R.C.M.) at Nyabondo and Ojolo. These have numerous schools throughout the gulf area and the degree of literacy must be high compared with many other native reserves.

The only Europeans in the area, apart from those at Kisumu, are prospectors and miners and their families, but they are few and only those at Homa Lime Works are permanent residents.

The sugar plantation at Miwani, now owned by Indians but originally by Europeans, is the largest single farm in the region. Sisal and cotton growing is assuming some importance, whilst experiments in the marshy areas on the Kano Plain have produced rice crops. In Kisumu small industries are few but include the manufacture of soap. The Africans of the area are farmers producing crops for their own needs as well as for sale and export, including abundant maize, whilst herds of goats and cattle are common.

ROCK EXPOSURES

Exposures are numerous and suitable for reasonably close mapping of geological boundaries. In certain areas, however, such as the Kano Plain, a thick soil-cover hides all rock outcrops, whilst the red lateritized soils derived from the Nyanzian and Bukoban Systems conceal the rock under a thick mantle in many places.

ACKNOWLEDGEMENTS

Assistance given by Europeans and Asians in the area, some of whom provided accommodation during part of the mapping period, is gratefully acknowledged. Doctors Leakey and MacInnes of the Coryndon Museum have been most helpful in their identification of fossil vertebrate remains. I wish to thank Dr. Leakey for permission to quote in part the Pleistocene correlation table from his paper (1950)* read at the International Geological Congress in 1948.

* References are quoted on pages 83 and 84.

II—PREVIOUS GEOLOGICAL WORK

H. B. Muff (Maufe) of the Geological Survey of Great Britain prepared a geological report on East Africa for the British Government in 1908. The report is in the form of traverse notes and little is said regarding the present district, though it refers to the scarp slope north-west of Port Florence (Kisumu) and to the lavas round the town.*

The first report of geological work in the southern part of the district was by J. S. Coates, Government Geologist, who in 1909 examined South Kavirondo, including the reported mineralization of the rocks of Wire and the surrounding area. He inspected graphite localities but found them unpromising, and also paid particular attention to gold deposits which were also disappointing.

These pioneer geologists were followed by Dr. F. Oswald (1914) who visited South Nyanza in 1911. He examined the Miocene deposits of the Karunga area and made a geological traverse to Homa, Lake Simbi and Kendu.

In 1919 Dr. J. W. Gregory undertook his celebrated *safari* in East Africa and visited Kisumu, drawing attention (1921, p. 123) to the northern scarp slope, the phonolites, the granites and the syenites of the Maseno area.

During 1928 the late A. D. Combe of the Geological Survey of Uganda carried out field work on the Katring Plain south of the Maragoli Hills (1929, pp. 10-11). He commented on the Maragoli, Kisian and Nyando scarps and inspected the phonolites of the area near Nyhera.

In 1931 the area was inspected by E. J. Wayland, then Director of the Geological Survey of Uganda. He examined the granite in the Rai Valley east of Andingo and the Nyabondo phonolite plateau. From here he visited the Oyugis-Kendu area and described (1931) a traverse to the summit of Wire Hill.

Sir Albert Kitson submitted a geological report on Nyanza Province to the Kenya Government in 1934, his results being shown as traverse notes. He visited the Kendu-Oyugis-Kabondo district and also reported on the Nyabondo plateau and granites and the Pleistocene deposits at Homa Mountain.

In 1931-32 and 1934-35 the East African Archæological expeditions, headed by Dr. Leakey of the Coryndon Museum, Nairobi, visited Homa Mountain. The geologist to the second expedition was Dr. P. E. Kent who subsequently wrote a number of papers (1942, 1944) describing the Miocene and Pleistocene deposits.

Kenya Consolidated Goldfields, Ltd., took out an Exclusive Prospecting Licence over 1,000 squares miles in South Nyanza and the area was mapped in reconnaissance style by Messrs. C. D. Hallam, A. A. Fitch, W. Edgeworth-Johnstone during 1936-38. Copies of their reports were submitted to the Mines and Geological Department and reference to them has been made in certain instances.

In 1943 F. Dixey visited the Colony to make a hydrographical survey of the Northern Frontier District. He passed through Central and North Nyanza and compared the peneplains of the region with those of neighbouring areas (Dixey, 1945).

During the war W. Pulfrey (1946) geologically surveyed Maragoli, part of which is in the Kisumu District. C. S. Hitchen, while a member of the Mines and Geological Department, examined the ground west of the present area including a small portion of the north-western boundary, on the north side of Kavirondo Gulf, but his results have not been published.

* E. E. Walker (1903, p. 7) had passed through the district previously in January, 1903, noting the granites and phonolites of the Maragoli area.

Reports covering various areas in Nyanza by C. S. Hitchen, W. Pulfrey, R. M. Shackleton, A. Huddleston and J. Schoeman dealing with rocks similar to those found in the present area have been consulted for comparison and correlation. G. M. Stockley's (1943) nomenclature for the East African Precambrian systems has been adhered to.

III—PHYSIOGRAPHY

The district may be physiographically divided into three distinct regions, a central plain, and the two areas bordering either side of the Kavirondo Gulf. The most prominent feature of the two higher areas is the sub-Miocene peneplain, whilst the central plain is a Pleistocene feature resulting from valley infilling following on rift faulting.

The oldest erosion surface present is that formed by the summit level of the Upper Bukoban rocks in the south-east. This is part of the Kisii Highlands peneplain which Shackleton (1946, p. 52) postulated as being possibly of Cretaceous age. Faulting has thrown down the surface which now stands at an average height of 5,600 ft., which is somewhat lower than is seen in the areas further south. From the Oyugis-Sondu road the splendid erosional scarp that bounds the surface can be seen dipping gently southwards.

The Nyando scarp is surmounted by a dissected upland 5,700 to 6,000 ft. in altitude which is residual upon the sub-Miocene surface. The upland forms "a western spur of the 6,500 ft. plateau, the latter being continuous with the Elgon-Kitale plateau" (Dixey 1945, p. 244). To the west the summit level of the Maragoli Hills (6,100 ft.) is similarly part of the Elgon-Kitale surface. The precise age of the peneplain is unknown but it is later than the Cretaceous surface which surmounts the Nandi scarp at a height of approximately 7,000 ft. (Huddleston, unpublished report).

Subsequent erosion produced another peneplain now known as the sub-Miocene surface, which can be seen on both sides of the Kavirondo Gulf. This bevel declines gently westwards at a gradient of approximately 1:150. The Mariwa Miocene deposit, overlain by the Rata Tertiary phonolite, at a height of nearly 4,800 ft. west of Maragoli, formed on the sub-Miocene surface at its original level. Other Miocene deposits formed on the surface have been down-faulted to the south.

In the south the Nyabondo phonolite rests on the surface at 5,000 ft., whilst at Wire the peneplain lies at 4,500 ft., and continues to drop gradually towards Homa Bay.

The consequent drainage across this sub-Miocene surface was from east-north-east to west-south-west in the north and from east-south-east to west-north-west in the south which may indicate a depression along the Kavirondo Gulf during Miocene times. The original drainage direction is still followed at the present day, the Gem Awach, Nyamgul and Kahera rivers flowing into the gulf from the north whilst the Miriu, Awach and South Awach rivers flow from the south.* Prior to the Pleistocene times other major streams such as the Lela, Kibos and Shianda were consequent streams flowing south-westerly into Lake Victoria.

Dixey (1945, p. 243) refers to "a Pliocene surface lying 500 ft. or more below the level of the main peneplain", but this surface was not recognised in the present area.

Faulting and lava flows completely altered the topography with the onset of Pleistocene times with consequent modification of the drainage pattern. The formation of the Kavirondo Rift Valley produced a new base-level of erosion, and diversion of the old drainage to a north to south pattern in the north, and a south to north pattern in the south. Short impersistent streams are now eroding both fault-scarps.

* There are five Awach rivers in the area. The three referred to in this report will be termed Awach and South Awach, both of which occur south of the Kavirondo Gulf, and Gem Awach, which occurs in the north-west corner, south of Ramula.

The Tertiary phonolites in the area north and north-west of Kisumu flowed across the sub-Miocene surface from east to west, and in the south the Kericho phonolite flowed westwards forming the Nyabondo plateau. These phonolites, especially those in the north, covered and preserved Miocene deposits which are now being re-exposed through severe erosion of the Pleistocene fault scarp. The lavas diverted such rivers as the Lela, Shianda, Kibos and Sondu and the headwaters of the Nyamgul and Lela, causing the rivers to flow in a north to south or even south-easterly direction, except for the Sondu which now flows into the Miriu. The river Lela has been so diverted that it first flows north-south but later flows west to east, three miles south-west of Kisian. The river Kibos flows south-westwards in the area north of the present district, but after passing through the escarpment flows north to south, having been diverted by the Kisumu phonolite from its original course, which was towards the large bay at Kisumu.

The main rivers do not have complicated feeder systems and their diversion by the phonolites has not usually led to river capture. River capture is present, however, an excellent example being that of the river Miriu which has captured the now marshy headwaters of the river Rigari and considerably broadened its catchment area. Prior to the development of the Kendu fault scarp its headwaters flowed from the vicinity of Nyakach but rejuvenation resulted in extensive river piracy and the headwaters now extend well to the south-west of the area where the drainage was originally south-westerly to the Kuja river.

The river Shianda in Maragoli has also cut its course back into the hills capturing the headwaters of the river Sifwafa which originally drained the northern slopes of the Maragoli Hills.

On the Kano Plain the rivers flow from east to west, which was probably their direction during Miocene times. The rivers meander in mature courses, debouching into a swamp near the lake. Most of the meanders are entrenched and little lateral shift is noticeable at the present day, though the presence of dried-up oxbow lakes and abandoned river-courses indicate that lateral shift has taken place at one time. The best examples of entrenchment are shown by the Miriu and Nyando rivers, both of which now flow in valleys notable for sheer walls and the lack of slip-off slopes. Such incision appears to be due to the continued drop in the lake level during Pleistocene times, and to the intensity of rainfall during the semi-annual rainy seasons. During these periods there is a vast increase in the volume of water in the valleys and the alluvium over which the rivers flow is rapidly eroded, leading to deepening of their courses.

The physiography of the area has a marked effect on the rainfall, the higher ground to the north and south receiving as much as 60 in. per annum whilst the lower ground at the foot of the scarps are rain-shadow areas. Most of the larger rivers and streams are permanent water-courses, as they receive abundant water from adjacent areas. This is particularly true of the River Miriu, the headwaters of which are supplied with water from the Kericho district, an area with one of the heaviest rainfall records in Kenya.

IV—SUMMARY OF GEOLOGY, GEOLOGICAL SUCCESSION AND CORRELATION

The principal rock types seen in the Kisumu district can be closely correlated with those of neighbouring areas in North and South Nyanza (Table II). Some differences are prominent however, for example the difference in order of extrusion of the Nyanzian lavas in the present area compared with that in Maragoli.

Massive dolerites invade the Nyanzian rocks, and may correspond to the older dolerites in the Kisii and Migori areas. Compared with neighbouring areas Tertiary and Pleistocene deposits are much better developed and it has been possible to subdivide them according to their relative ages.

TABLE II.
THE GENERAL CORRELATION OF THE SEQUENCE IN THE KISUMU DISTRICT WITH THAT OF NEIGHBOURING AREAS

| General Chronology | North Nyanza Maragoli—Pulfrey, 1946 | Central and South Nyanza Kisumu District—Present Report | South Nyanza Kisii District—Huddleston, 1951 | South Nyanza Migori Area—Shackleton, 1946 |
|---------------------------------|--|--|--|---|
| Recent Quaternary | Superficial deposits | Superficial deposits including lateritic ironstone, kunkar and sheet limestones of Homa Mountain. | River alluvium | Plateau gravels. |
| Pleistocene | Phonolites | Sediments of Homa Mountain and Kavirondo Gulf. Kenya type phonolite. Homa volcanics. Losaguta phonolite. Nyabondo phonolite. | Basic lavas and agglomerates | Gwasi and Isuria volcanics. |
| Pliocene (?) | | Sediments of Seme | Quartz—dolerites D ₃ | Karungu sediments. |
| Miocene | | Dolerites D ₃ | 3. Felsites, andesites, rhyolites with tufts, fine-grained sediments and conglomerates. | Quartz—dolerites D ₂ . |
| Post-Bukoban | | 3. Felsites and andesites | 2. Quartzite and chert | 3. Red felsites, andesites. |
| Bukoban | | 2. Quartzite and chert | 1. Porphyritic basalt, non-porphyrific basalt and soapstone. | 2. Quartzites. 1. Basalts. |
| Upper Pre-Cambrian ? | | 1. Porphyritic basalt and non-porphyrific basalt with minor tuff development. | Quartz dolerites D ₂ , lamprophyres and other minor intrusives including some quartz-porphyrates. | |
| Pre-Cambrian | Intrusion of dykes and small igneous masses mainly dolerites. Quartz veins. Late veining and invasion of granites by granite and syenite. Maragoli granites. Ibuyu and Siadiga adamellites with slight earlier intrusion of major syenite masses. Dolerite dykes now epidioritized. | Dolerites D ₂ , lamprophyres, andesites and other minor intrusions. Maragoli and Kisian granites G ₃ | Wanjare, Kilgoris and Nyagongo granites G ₃ and part at least (?) of Kitere granite. | Granites G ₃ and Syenites S ₃ . |

(Continued on next page)

TABLE II.—(Contd.)
THE GENERAL CORRELATION OF THE SEQUENCE IN THE KISUMU DISTRICT WITH THAT OF NEIGHBOURING AREAS

| Genera Chronology | North Nyanza Maragoli—Pulfrey, 1946 | Central and South Nyanza Kisumu District—Present Report | Kisii District—Huddleston, 1951 | South Nyanza Migori Area—Shackleton, 1946 |
|-------------------|---|--|--|--|
| Kavirondian | Sediments, mainly grits and mudstones. | | Conglomerates, grits and sandstones with subordinate mudstones. | 3. Conglomerates with dioritic porphyrite boulders. 2. Dioritic porphyrite, granite porphyry. 1. Conglomerate. |
| Nyanzian | 6. Basalts. 5. Minor tufts. 4. Andesites. 3. Conglomerates west of Suera. 2. Major tuff developments with some breccias and agglomerates. 1. Rhyolites. 2. Earlier basic division represented by tufts. | Oyugis and Asembo granite and Asembo adamellite G ₂ . Miriu granodiorite G ₂ . Massive dolerites and epidiorites D ₁ | Granite—porphyry and some quartz-porphyry. Kitere granite (part) and Oyugis granite (G ₂). Dolerites D ₁ and epidiorites D ₂ | Granodiorite and syenite (G ₂ suite). Quartz porphyries. Dolerites and epidiorites. |
| Pre-Cambrian | | 4. Rhyolites, dacites and banded-ironstones with subordinate tufts. 3. Major tuff development. 2. Andesites, Trachy-andesites and dacites. 1. Basalts with subordinate banded ironstones and tufts. | 5. Andesitic tufts and argillaceous felspathic sandstones. 4. Andesites of Sare-Oyami area. 3. Rhyolites with associated tufts and agglomerates. Subordinate cherts and ironstones. 2. Andesites, dacites and dellonites, small tuff developments. 1. Pillow basalts, subordinate banded ironstones and mudstones. | 3. Slaty group with Masara andesitic rocks. 2. Greywackes and conglomerates. 1. Basaltic group and dolerites (D ₁ part) with banded ironstones in all three groups. |
| Basement System | | | | ? Orthogneiss of Brannstrom collection. 2. Quartzites of Lemeck Hills. 1. Schists and gneisses of Mara Valley and Isuria Scarp. |
| Archaean | | | | |

The main rock types present, and their age relationship are shown below. It will be seen that no representatives of the Basement or Kavirondian Systems are exposed in the district.

Recent

14. Superficial deposits, black cotton soils, lateritic ironstone, kunkar and sheet limestone, valley alluvium and lateritized red soils.

Pleistocene

13. Homa Mountain deposits and isolated outcrops near the shore of the Kavirondo Gulf.
12. Faulting.

UNCONFORMITY

Tertiary

11. Faulting accompanied by tilting.
10. Phonolites, Homa volcanics and Lower Miocene sediments.
9. ? Faulting.

UNCONFORMITY

? Upper Pre-Cambrian

8. Intrusion of D_2 dolerites.
7. Extrusion and deposition of Bukoban System.

UNCONFORMITY

6. Intrusion of dykes—dolerites D_2 , lamprophyres, andesites, etc.
5. Emplacement of quartz veins.
4. Major plutonic phase. Intrusion of Maragoli, Kisian, Oyugis, Miriu and Asembo granites, granodiorite and adamellite.

IGNEOUS CONTACTS

Pre-Cambrian

3. Folding.
2. Intrusion of D_1 dolerites.
1. Extrusion and deposition of the volcanic series of the Nyanzian System.

In neighbouring areas after the period of Nyanzian folding severe erosion, and deposition of the Kavirondian sediments, took place, the sediments unconformably overlying the Nyanzian rocks. Further folding took place subsequently, accompanied by the intrusion of the granites. In the present area this period of folding and granitic intrusion has been recognised.

THE NYANZIAN SYSTEM

The Nyanzian rocks are basalts, andesites and rhyolites with major and minor tuff developments, generally in the more acid divisions of the System. Banded ironstones are mainly developed in the southern part of the district associated with the rhyolites and less frequently with the basalts.

A number of gold occurrences are found in the Nyanzian rocks near their contact with the granites.

THE GRANITES

Five major granitic masses are seen to invade the Nyanzian rocks, viz: the Miriu, Oyugis, Asembo, Maragoli and Kisian intrusions. The Maragoli and Kisian masses, similar in type and characteristically forming large tors which dominate the scenery on the northern side of the Kavirondo Gulf, are probably part of the Mumias granite batholith. All show basification around their peripheries, and all are associated with gold mineralization.

THE BUKOBAN SYSTEM (KISII SERIES)

The Kisii series is represented in the south-east corner of the district where it overlies Nyanzian rocks and "granites". Small exposures of porphyritic basalts are covered by more widespread non-porphyritic types which thin towards the north, where they were probably more extensive at one time but have now been removed by erosion. Overlying the basalts is a quartzite band over 350 ft. thick, which in parts passes laterally into an ironstained siliceous chert. The youngest group is an Upper felsite and andesite series which is typically red in colour.

MINOR INTRUSIONS

Most of the minor intrusions are post-Nyanzian and probably pre-Bukoban in age and consist of dolerites, lamprophyres, andesites and rhyolites, all of which cut the Nyanzian rocks and the granites.

TERTIARY

The Tertiary lavas and sediments exposed in the area play an important part in the dating of the Tertiary and Pleistocene faulting along the Kavirondo Gulf. The lavas are phonolites and nephelinites of various types and are related to other similar lavas in Kenya. They are associated with faulting on the north side of the gulf and are apparently fissure eruptions. In the same area they overlie fossiliferous Lower Miocene beds which are now being excavated by subsequent streams of post-faulting age.

The most interesting of the Tertiary rocks are those on the Homa peninsula where felspathoidal intrusions are associated with phonolites, nephelinites and carbonatites.

PLEISTOCENE

Pleistocene deposits are widely scattered round the edges of the Kavirondo Gulf and many have been found to be fossiliferous. An important section is seen on the northern slopes of Homa Mountain from which part of the type succession for Central Africa has been described. Archæological expeditions to the area discovered human remains which have helped in the elucidation of problems concerning Stone Age Man in Africa.

RECENT

The post-Pleistocene deposits are represented by various soils and superficial lateritic ironstones, with occasional alluvial patches in the larger streams. Black cotton soil covers the large area of the Kano Plain, where only a single rock outcrop is visible.

V—DETAILS OF THE GEOLOGY

1.—THE NYANZIAN SYSTEM (N)

The rocks of the Nyanzian System are mainly volcanic, ranging from basic to acid in character. They are the oldest rocks in the district and occur in six separate areas, the largest being a triangular block in the Kendu-Oyugis-Kabondo district, whilst the smaller occurrences are seen near Homa Bay, west of Maseno and at Kaloka, Miwani and Sondu. Granites everywhere invade the System and numerous roof pendants and xenoliths of Nyanzian rocks are included in the intrusions. To the north and south of the present district the volcanics are separated by an unconformity from the overlying sediments of the Kavirondian System.

No positive proof of the order of extrusion of the lavas was seen but from the nature of the folding and the metamorphism of some of the rocks, a succession similar to that in the Kisii district (Huddleston 1951, p. 7) has been established. In the Maragoli district Pulfrey (1946, p. 9) has considered, on comparison with other areas in central Nyanza, the order of extrusion to be acid to basic with a possible earlier basic divi-

sion. The northern outcrop near Ramula shows every division of the Systems found in the present area and it seems likely that extrusion was in fact basic to acid. The succession appears to be—

3. Rhyolites and dacites with banded ironstones and subordinate tuffs.
2. Andesites, trachy-andesites and dacites.
1. Basalts with subordinate banded ironstones and tuffs.

Rare metamorphosed non-volcanic sedimentary rocks were recorded on the promontory west of Kaloka and in some of the streams east of Kendu.

The thickness of the series is impossible to estimate on account of the high degree of overfolding. Suffice to say that there must be thousands of feet of lava (Pulfrey (1946, p. 9) mentions 10,000 ft. in Maragoli). Variations in thickness are great and perhaps the thickest succession is seen near Wire, whilst only a thin skin of folded lava covers the Asembo adamellite between Ramula and the Gem Awach river. Here the andesite is being removed by erosion exposing small bosses of basic "granite" and diorite in the river and east of Ramula trigonometrical point.

(1) Basalts (Nb)

The Nyanzian basalts in this district, as in most other parts of Nyanza, are invariably altered and, though in hand-specimens they bear a resemblance to their original appearance, their microscopic constitution has been radically changed. The intense folding to which they have been subjected is responsible for the major alteration effects seen in them, while metasomatic alteration has occurred near the granite contacts.

Those basalts seen on the north side of the lake, viz. south-west of Maseno and east of Kaloka, 12 miles west of Kisumu, show least alteration and their basaltic nature can be recognized in thin section. The basalts on the south side of the lake, however, are now schistose rocks and in the slides are seen to be highly altered.

The Northern Basalts are dense fine-grained, blackish blue to greenish grey in colour, some with small white feldspar phenocrysts and often abundant pyrites. They commonly break with splintery and conchoidal fracture. Microphenocrysts of feldspar, hornblende and pyroxene are set in a matrix of the same minerals, in which the feldspars form a fine interlocking mat of lath-like crystals, though radial and lined arrangements were also noted. Zeolitization, sericitization and epidotization of the feldspars is common, rendering them unidentifiable in some cases. The matrix feldspars vary in composition from oligoclase (An_{10}) to bytownite (An_{70}), the microphenocrysts being more sodic. The pyroxene is generally unaltered but granular augite is recognizable in the groundmass of some specimens. Prismatic hornblende is the most prominent dark mineral and occurs as microphenocrysts or as small fibrous laths or needles in the matrix. In most specimens it is accompanied by actinolite and both are seen pseudomorphosing the pyroxene. In one specimen from the stream north of Lela no hornblende, but only biotite, was found whilst specimen 41/769, occurring near the granite margin half a mile east of Rata is melanocratic and consists of 60 to 70 per cent hornblende and 20 to 30 per cent of labradorite. Accessory minerals include pyrite and abundant euhedral or granular magnetite, whilst apatite and leucoxised ilmenite are more rare. Chlorite, epidote, and quartz occur as secondary minerals but are never conspicuous. Specimen 41/853 was the only vesicular basalt noted, the vesicles being filled with quartz. Pulfrey (1946, p. 12) remarks on the metasomatic effects of the granite on the basalts and the production of spessartine in the thermal aureole.

The Southern Basalts are more altered than those just described and in many places are low-grade schists. The non-schistose types are bluish-black crudely banded rocks, whilst the schistose rocks vary from dark blue to light greenish blue in colour and are often lustrous in appearance and with well-developed schistosity. Both are very fine-grained, but in the non-schistose types relics of small feldspar phenocrysts can be seen. The chief minerals are albite, calcite, epidote, chlorite, quartz, hornblende and actinolite. They occur in varying proportions, the higher grades of metamorphism

being represented by rocks containing hornblende. In one specimen, 41/471, a little biotite was seen. The rocks are granular aggregates of three or more of the minerals mentioned, the felspar often tending to have porphyroblastic development (e.g. 41/494). The lighter and darker minerals appear as alternating streaks, the darker bands being emphasized by abundant granular magnetite. In specimen 41/471 muscovite was also seen associated with the lighter bands together with actinolite. The hornblende and actinolite occur as long needles or ragged fibrous crystals and are often associated with small epidote prisms. In most specimens the original felspar has been completely sericitized and is associated with granular quartz and shreds of calcite and epidote. Original vesicles are now represented by pale green augen elongated in the direction of schistosity. Some of the basalts appear to have been mylonitized, magnetite dust emphasizing the flow-like structure of the fine-grained groundmass. In the Andingo area there are numerous xenoliths and sheets of schistose Nyanzian basalts. In many instances the rocks resemble lit-par-lit injections, granodiorite alternating with the altered basalt in thin sheets up to 2 ft. thick.

Rocks Associated with the Basalts.—An altered sediment was seen lying between the Nyanzian basalt and rhyolite on the promontory west of Kaloka. It is a greenish brown crudely banded rock. In the slide the rock is seen to be ill-graded with large irregular quartz grains set in a granular mosaic of quartz, calcite, and chlorite. The chlorite occurs in irregular streaky bands and is obviously an alteration product of original ferromagnesian minerals in the sediment. It is considered likely that the rock was originally a normal clastic sediment.

North of Doho Kasele 6 miles south-east of Kendu, a tuff is intercalated in the meta-basalts. It has been thrown into a number of small open or carinate folds, having acted as an incompetent bed between the basalts during the period of folding (Fig. 1). Calcite was deposited in gaps opened during the folding.

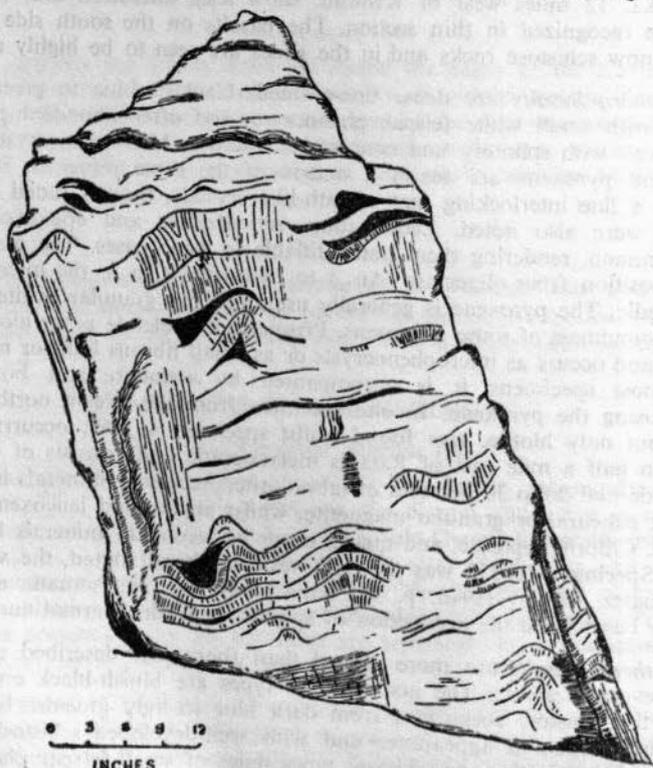


Fig. 1—Field sketch of a tuff intercalated in the Nyanzian basalts north of Doho Kasele.

(2) *Andesites and Trachyandesites (Na)*

The andesitic group has only a minor development in the district, occurring north and south of the lake in the major outcrops of Nyanzian rocks and as large xenoliths in the granite. The andesites appear as narrow lenticular bands exposed over an area of not more than two or three miles. The rocks are bluish grey, dense, and flinty and occasionally porphyritic with felspar and ferromagnesian minerals recognisable in the hand-specimens. They are often veined by pyrite. Near the granite contacts they have been sheared and altered and are now schistose and lustrous in appearance.

The felspar microphenocrysts vary in size from 2 mm. to 0.3 mm. and have a sub-trachytic arrangement in most cases, although a roughly radial disposition was noted in one specimen (41/760). Oligoclase and andesine ($An_{20}-An_{26}$) are the commonest felspars whilst the more basic lavas contain labradorite. Sericitization, epidotization, and zeolitization have been considerable but never so severe as in the basalts. Fibrous platy hornblende crystals are associated with subhedral pyroxene (augite and diopside) microphenocrysts, the former probably being pseudomorphs of the latter in many instances. Chloritization of the augite has also taken place. The phenocrysts are set in a very fine pilotaxitic felt of interlocking felspar needles and microlites with interstitial ferromagnesian minerals, quartz and isotropic glass. The constituents in the matrix are the same except that scattered acicular needles of secondary actinolite are often present. This matrix is sometimes wholly sericitized and epidotized, the epidote being accompanied by granular quartz. Quartz, however, is mostly primary and at times is so abundant as to give the rock a dacitic composition. Leucoxenized ilmenite, calcite and magnetite are common.

(3) *Rhyolites (Nr)*

The rhyolites form the greater proportion of the Nyanzian rocks both north and south of the Kavirondo Gulf. The largest outcrop is a triangular area east of the line Kendu-Oyugis and extending as far east as Kabondo. Lesser occurrences are seen near Homa Bay and west of Maseno where they are associated with the other Nyanzian lavas. On both sides of the gulf rhyolite outcrops occur associated with granite on the downthrow side of the Kavirondo Gulf faults. Another occurrence is seen as Miwani.

The southern outcrop is particularly noticeable for its associated banded ironstones which form a major development within the acid lava group. Banded ironstones are absent from the northerly exposures, except on Ndere Island.

As was seen in the Kisii area (Huddlestone, 1951, p. 12) a high degree of shearing is noticeable in many of the rhyolites round the granite contacts, particularly in the River Awach north of Mkaye, where a series of shear-zones are associated with much younger faulting. Near fault- or shear-zones the rhyolites are crushed and weathering has emphasized the rod-like structure of the broken rock. Epidotization is sometimes extremely severe in such cases, the rocks being a bright green in colour. Jointing, which is sometimes rectangular yielding small blocks, is a common feature of the rhyolites but more so in non-porphyrritic varieties.

The most common rhyolites are fine-grained, dense, flinty rocks, a few being porphyritic. Such rhyolites vary in colour from greyish green to blackish blue, weathering often to a yellow or pale pinkish white friable rock commonly stained or spotted dark brown by iron solutions. Near Homa Bay a very fine-grained siliceous type is a mottled dark maroon colour whilst yet another has the appearance of a black chert. Occasional vesicular varieties of the rhyolites are seen. Other types are markedly porphyritic rocks with clear quartz phenocrysts up to 6 mm. across set in a fine-grained green to pinkish white groundmass. These are the typical rocks of the Wire area and at Wire hill are associated with less massive rhyolites. Finally there is a non-porphyritic spherulitic type of rhyolite, of which only a single occurrence was seen. It forms part of the hill north of Mkaye, 7 miles east-south-east of Wire Hill, and is flanked on either side by ironstones. The band is not more than 200 ft. thick, and forms a distinct ridge striking east-west along the crest of the hill. The spherulites form large globular masses varying in size up to 2 ft. in diameter, which on weathering gives the rock the appearance of a conglomerate.

In thin section the less porphyritic type of rhyolite is found to consist of microphenocrysts of feldspar, quartz, and more rarely hornblende, set in a microfelsitic or cryptocrystalline groundmass. The tabular feldspar phenocrysts measure up to 3 mm. in length and are invariably altered to sericite, epidote, chlorite, calcite or kaolin, and hence are often indeterminate. Those identified, however, are predominantly orthoclase with a smaller proportion of oligoclase and albite. The alteration of the feldspar occurs along the cleavage planes and in specimen 41/956 chlorite occurs as blebs or streaks within the mineral giving it a patchy appearance. In hand-specimens some of the rhyolites are flecked with white due to zeolitization of the feldspars, which in slides is seen to be rarely complete but occurs as an alteration round the crystal margins. Dark borders around the crystals are due to ironstaining.

Hornblende microphenocrysts are green and pleochroic, tabular in habit, and where sheared are drawn out into fibrous crystals associated with actinolite needles and granular magnetite. Small quartz microphenocrysts up to 2.55 mm. across are embayed and contain strings of bubbles and other inclusions. Specimen 41/922 contains biotite flakes up to 0.5 mm. in length. The microfelsitic groundmass consists of a granular mosaic of quartz and feldspar or an aggregate of granular quartz and feldspar needles in which the crystal boundaries are sutured (41/653). In many specimens there is a tendency to micrographic intergrowth between the quartz and feldspar of the groundmass whilst in others the feldspar needles have a flow arrangement. Often the matrix is cryptocrystalline and in one specimen is so abundant as to give the rock the appearance of a pitchstone. Hornblende needles and less frequently flakes of greenish brown biotite, are scattered throughout the groundmass. Epidotization and chloritization of the groundmass give the rocks their greenish colour. Accessories include magnetite, apatite, leucogenized ilmenite and occasional minute idiomorphs of sphene. The more altered and friable rhyolites are invariably stained by hydrated iron ores in anastomosing veinlets which renders the matrix practically unidentifiable. In the Homa area the introduction of carbonates has altered much of the groundmass and has even led to the development of microphenocrysts of calcite.

East of Kendu at the foot of the escarpment intense shearing has altered the rhyolites into low grade schists. They are grey purplish or pinkish rocks consisting essentially of quartz, sericite, epidote, and less frequently actinolite, occurring in alternate light and dark bands.

The porphyritic rhyolites resemble very closely quartz-porphyrries, but could not be separated from the remaining rhyolites as no intrusive contacts were seen in the field. The quartz phenocrysts are much larger than in the non-porphyritic varieties being prominent in the hand-specimen, and in thin sections showing intense strain polarization. The groundmass is similar to that of the non-porphyritic types, having the same tendency to micrographic intergrowth and exhibiting the same alteration products. Ferromagnesian minerals are however not so common, and have been replaced by chlorite.

Dacites.—Two dacite occurrences were seen associated with the rhyolites on the south side of the Gulf. They are similar to the rhyolites but the dacites contain a little granular pyroxene associated with the hornblende. Feldspar prisms in the matrix, unlike those in the rhyolites, have a tendency to be zoned.

Rhyolitic Tuffs and Agglomerates (Nrt).—Tuffs and agglomerates occur only as a minor development associated with the Nyanzian rhyolites. Most often they are small lenticular bodies, though occasional larger intercalations were noticed, as in the Awach valley east of Ramula and near Homa Bay. In the field the tuffs are very similar to the rhyolites, from which they are difficult to separate. The Ramula tuff unlike the remaining pyroclastics is a dense blue green rock containing visible rhyolitic fragments. Others weather to a whitish or greenish pink friable rock, very often iron-stained. Banded tuffs are not uncommon and one specimen, 41/539, is current-bedded indicating that the tuff was laid down in water.

In thin section the fragments, measuring up to 5 mm., are seen to consist mainly of broken feldspars, quartz, and more rarely rhyolitic grains. Orthoclase and oligoclase are the predominant feldspars, but andesine and labradorite were recognised in specimen 41/638 indicating derivation from more basic rocks. Intense sericitization of the feldspars is common. The larger quartz fragments show resorption.

Various proportions of feldspar and quartz occur and either may be preponderant. The larger fragments are set in a epidotized and chloritized base of quartz, feldspar, and sericite. Granular magnetite and ilmenite are also present in the matrix. Although many of the tufts have been veined and impregnated by calcite those at Homa Bay are unusually affected, suggesting contamination by the later Homa Mountain eruptions. Part of the Ramula tuff has a vitric groundmass, iron-staining emphasizing the flow structure in the cryptocrystalline base.

(4) *Banded Ironstones and Cherts (Nbi)*

Fine-grained banded ironstones and cherts are found associated with the Nyanzian rhyolites and basalts and occur mainly in the southern part of the area, with a single development in the north of Ndere Island. They are impersistent bands generally 50 to 200 ft. thick but often occur in thinner bands up to 20 ft. Ndere Island is composed almost entirely of ironstone but like some of the other larger outcrops consists of alternations of ironstone and iron-rich rhyolitic bands. The ironstones form outstanding ridges and hills the most noticeable being Godnyango and Ndere.

The ironstones are brittle, shattered or brecciated, banded rocks subsequently veined by ramifying networks of quartz veinlets, although those richer in iron do not show such structures so well. Often the bands are broken by small faults some of which are only a fraction of an inch in length and related to stronger faults and other tectonic structures in the Nyanzian rocks. In spite of the brecciation and fracturing little or no mineralization has been associated with the ironstones. One small ironstone band, near the granite contact one mile north of Doho Kasele, yielded a trace of gold which is probably due to mineralization by the granite along fractures in the rock.

The ironstones consist mainly of waxy bluish black chert alternating with reddish to purplish brown limonite. These alternating bands are sometimes quite thin, often only a few millimetres thick, whilst at other times they are considerably thicker. Weathering emphasizes the varieties in colour the purplish type being developed from those rocks containing less iron. In extremely weathered specimens the ironstone is now almost a red ochre.

In thin section the ironstones are microcrystalline or cryptocrystalline, consisting of an aggregate of quartz interbanded with ferric oxide grains and minute siderite rhombohedra. Magnetite dust and hematite are also sometimes scattered throughout the slides. In those specimens in which the chert content is high cryptocrystalline quartz is preponderant and is wavy banded in a manner that suggests bedding. Small irregular veinlets of iron-rich material penetrate the chert and may have been original siderite, now represented by pseudomorphs of goëthite.

Shackleton (1946, p. 13) discussing the origin of such rocks has considered them to be of colloidal origin, the fine banding being due to rhythmic precipitation of colloidal silica and ferric hydroxide. The fact that the major development of the ironstones occurs in the rhyolites would indicate that the iron oxides necessary for the precipitation of the colloids came from some other source. Such may be the case in the present area where the earliest lavas of the Nyanzian system are basalts which, when decomposed, would provide ample iron oxide to allow the precipitation of ferric hydroxide at a later period. Thin ironstone bands do occur also in the basalts, but may be accounted for by penecontemporaneous weathering and erosion during the period of basalt extrusion.

2.—THE BUKOBAN SYSTEM (KISII SERIES) (B)

The Kisii Series covers some 70 square miles in the south-eastern part of the district. It unconformably overlies Nyanzian rocks which lie to the west and north, whilst the upper members of the series form a prominent escarpment which declines gently to the south. The hills forming the upper part of the series can be well seen near Sondu and the Kabondo-Sondu road, where they consist mainly of quartzites and overlying felsites (Plate 3A).

Although the whole of the Kisii Series has now been mapped (Shackleton 1946, Schoeman 1949, Huddleston 1951, and Binge (in preparation)) no evidence has been forthcoming to prove its age. The late A. D. Combe (1948, p. 8) suggested that the series comprises the upper portion of the Bukoban System as it is known in Tanganyika, but precise correlation is still a matter for conjecture.

A full succession such as was mapped by Huddleston in the Kisii district is not seen in the present area, where the Series is similar to that reported by Shackleton in the area south of the Kisii district. The complete series representing the Bukoban of Kenya is present only in the Kisii area, whilst one or more of the lower divisions are missing as one progresses away from that area. Huddleston noted that the banket-like conglomerate underlying the quartzite at Kimoro in the Sotik area (Schoeman 1949, p. 20) is absent from the Kisii succession. The conglomerate is, however, of restricted occurrence and was probably a river deposit formed in a south-westerly flowing stream.

Dips are generally low but two dips of 30° and 34° in the porphyritic basalt group at Mkaye and north of Kabondo were recorded. Dips of up to 20° were noted in the quartzite band in the most westerly outcrop. The higher figures are probably due to faulting but the topography indicates that the series as a whole dips gently to the south or south-east. Faults complicate the structure, and do not necessarily follow strike directions as seen elsewhere (Huddleston, 1951, p. 47). Dolerite dykes and quartz veins seen in other parts of the Bukoban in South Nyanza were not found in the present area.

The succession in the present area is:—

| | <i>Feet</i> |
|--|----------------|
| (3) Upper Group— | |
| (b) Andesites and dacites | |
| (a) Porphyritic and non-porphyritic felsites | unknown 400 |
| (2) Middle Group— | |
| (b) Ferruginous cherts | |
| (a) Quartzite | thin 350 |
| (1) Lower Group— | |
| (b) Non-porphyritic often highly vesicular basalts | 1,500–2,000 |
| (a) Porphyritic basalts | Maximum 280 |

(1) KISII SERIES, LOWER GROUP

(a) *Porphyritic and coarse-grained basalts*

The lowest basalts are exposed in two places at the northernmost outcrop of the lava flows. The more southerly exposure can best be seen where it outcrops in the river at Mkaye, the basalts dipping 30° in a south-easterly direction. North of Kabondo similar rocks dip 34° also in a south-easterly direction and form a series of prominent hills—Godokombo, Godiniogo, Miogo, and Ogo—which stand over 200 ft. above the surrounding country. These hills form the edge of an erosion scarp but it is considered unlikely that the lavas flowed much further north.

The basalts flowed over an old land surface of Nyanzian and granitic rocks, and their thickness is nowhere more than 280 ft. and in most places considerably less. This is well seen in the Mkaye area where the lavas flowed up against Nyanzian rhyolite hills which barred further progress to the north.

In the hand-specimen the basalts are bluish or greenish-grey to grey speckled rocks with a conchoidal or splintery fracture. The typically porphyritic varieties contain prominent phenocrysts up to 10 mm. long, whilst the remaining rocks are more even-grained. Blue-black vesicles, some as much as 2 cm. in diameter, are often present in the basalts and indicate the tops of individual flows, none of which are of considerable thickness. In thin sections of various specimens the feldspars, both phenocrysts and groundmass feldspars, are seen to range from oligoclase to andesine (An_{20} to An_{30}), and show various stages of alteration. In some cases epidotization and chloritization (by penninite in part) has proceeded so far that the crystals are barely recognisable, whilst in others alteration has occurred only along cracks. Occasional sericitization and sheaf-like zeolitization was also noted but is of minor occurrence only. Alteration has been so intense in certain cases that the basalts have been altered to epidotes consisting of granular epidote and quartz (e.g. Akwaro basalt, 2 miles south-west of Nyakach Mission). The texture is generally intersertal but seriate, hyalopilitic and vitrophyric textures are common, whilst the groundmass is often glassy having a tendency to be spherulitic with comb structure.

The columnar feldspar phenocrysts are set in an intersertal matrix of fine skeletal crystals and a felt of feldspar laths, with pyroxene and a brown glassy base. The pyroxene is either granular or forms ragged microphenocrysts and consists of brown to colourless diopside (fresh or partially altered to a bright green hornblende), augite and rarer pigeonite, and enstatite (41/672). Ilmenite, magnetite, hematite, and sphene are common accessories and are associated with the products of intense alteration which has reduced some minerals to a fine aggregate. The break-down of the feldspar and pyroxene has resulted in a granular aggregate in which magnetite forms small irregular strings (Fig 2A). The ilmenite forms skeletal crystals and has been partially leucogenized. Specimen 41/657 shows no true development of phenocrysts, being more even and coarse-grained than the normal basalts. The amygdalae in the vesicular varieties are filled with sheaf-like chlorite (penninite), zeolites, and chalcidonic silica, the latter forming a concentric ring round the chlorite. Specimens 41/671 and 41/672 are more andesitic than basaltic.

(b) *Non-porphyritic Basalts*

Non-porphyritic, well-jointed basalt flows form the greater proportion of the Bukoban outcrop in the present area, comprising something like three-fifths of the total outcrop. Exposures can best be seen in most of the rivers and along the Oyugis-Sondu road. The basalts are built up of numerous flows never more than 50 to 100 ft. thick each, repeated vesicular horizons indicating the multiplicity of flows.

A single thin agglomerate band 3 to 5 ft. thick is intercalated in the basalts near the top of Konundo hill. The rock is composed of one inch indeterminate fragments cemented by quartz the whole being heavily iron-stained. It indicates explosive activity late in the lower group. The basalt flows, which gradually thicken towards the south, dip south to south-east and form an erosion scarp overlooking the River Miriu. Where they directly overlie the granite they are some 350 ft. thick but at their thickest are of the order of 1,500-2,000 ft. Two basalt outliers are seen north of the River Miriu and south of the Nyabondo plateau, representing an original more northerly extension of the basalts than is seen at present.

In hand-specimens the basalts are dense, fine-grained, grey or blue to greenish-blue, frequently vesicular, splintery rocks. Occasionally columnar structure is seen, especially in outcrops in the River Luanda near Kabondo. The vesicles are spherical or ovoid generally between 3 mm. and 2 cm. across, but some 5 cm. in diameter were noted (41/709). Some are dark blue-green to black whilst others are white due to the quartz content. They often contain small crystals of iron pyrites. Where intense alteration of the basalts has taken place they are now bright green due to epidotization, and are then often difficult to distinguish from similarly coloured and altered Nyanzian rocks. On weathering a thick red crust forms on the rocks and where vesicular the amygdalae have weathered out giving a pitted appearance.

The textures of the basalts vary considerably, being mainly hyalopilitic but at times seriate, variolitic, holocrystalline hypidiomorphic granular or holocrystalline

porphyritic. In the commonest type the feldspar and pyroxene form a fine-grained aggregate or felted mat in a brown glassy mesostasis. The feldspars are narrow, often simply twinned, laths with forked ends, and vary in composition from albite to andesine though they are mainly oligoclase. All stages of alteration of the feldspars can be seen and include replacement by albite, sericite, zeolite, chlorite and epidote, quartz being liberated during the formation of the last. Ragged microphenocrysts or granular aggregates of pyroxene often show alteration to dark green hornblende, but others are chloritized and epidotized, the alteration generally taking place from the centre outwards as with the feldspars. Pigeonite, diopside and diallage were noted in association with the more common augite. The glassy groundmass is generally isotropic with refractive index greater than 1.54; occasionally it has devitrified. It contains microlites of all shapes (predominantly H-shaped) arranged radially or in criss-cross fashion. The needle-like crystals include pale brown lamprobolite, augite and delicate brush-like radially disposed feldspars.

The vesicles contain numerous minerals including green-blue chlorite, ripidolite, spherulitic chalcedony, calcite, thomsonite and stilbite. They are often concentrically arranged.

Those basalts which have been extremely altered (e.g. 41/739 and 41/745) have little of the original textures preserved. Specimen 41/739 is a dense green rock veined by quartz stringers, and consists of a fine aggregate of altered feldspar with a little granular quartz. The feldspars are so altered as to be nearly unrecognizable but some andesine was identified. They are often replaced by epidote which would account for the quartz present. In specimen 41/745 (see Fig 2) which is now composed of pale-green chlorite, magnetite and relic feldspar the alteration has taken place from centres which were originally pyroxene optically intergrown with feldspars. Both are now so altered as to be almost unidentifiable. The alteration of the pyroxene produced granular magnetite which occurs as arcuate or linear strings radiating from the centres of alteration. With high magnifications it can be seen that many of the magnetite grains form a crude rectangular pattern, suggesting their formation along the pyroxene cleavages.

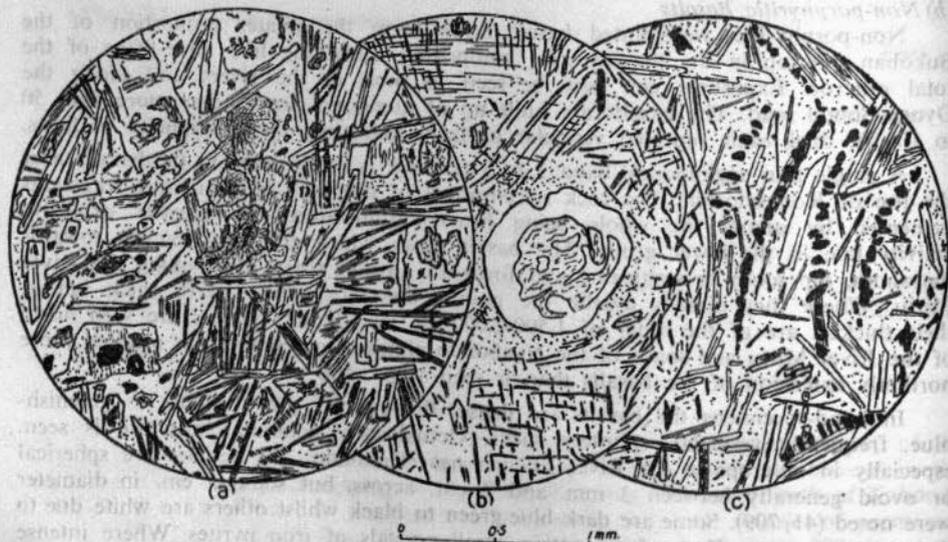


Fig. 2—Microscope drawings of thin sections of the Kisi lavas.

- (a) 41/669. Non-porphyritic basalt. The feldspar and pyroxene are set in an intersertal groundmass containing skeletal and fibrous amphibole. Zeolite-filled vesicles are common.
- (b) 41/745. Altered vesicular non-porphyritic basalt. Lattice-like magnetite set in a chlorite groundmass containing relic feldspars.
- (c) 41/744. Upper Andesite. Original ferromagnesian minerals are now represented by arcuate bands of granular magnetite set in a chloritized groundmass.

(2) KISII SERIES, MIDDLE GROUP

(a) *Quartzite*

The quartzite division varies considerably in thickness and is thickest where exposed on the erosion scarps. It averages between 250 and 360 ft. but in the extreme south-east corner of the area where the ground is broken by a number of faults it is very thin. Scarp faces are not so prominent as they are further south but the quartzites do form resistant ridges above the lower basalts as can be seen from the Oyugis-Sondu road. West of Kichura the quartzite has been disturbed by a number of small faults whilst further north-east near Konundo and Kisigoro two larger faults have dropped a section of the quartzite to the north, forming a discontinuous outcrop. Further south-west the headwaters of the River Awach flow eastwards before turning in a north-westerly direction. The east-west valley was probably excavated along the line of a fault which passes eastwards, cutting off the southerly extension of the quartzite scarps. The quartzite has been dropped to the north and is everywhere at a lower level than it is further south. Immediately east of Konundo the River Rigari has cut through the quartzite and now flows on the underlying basalt, whilst other streams have cut steep-sided gullies into the quartzite. In the south-east corner quartzite outliers including Mugwa are separated by a north-south fault, and it is here that the quartzite is thinnest being apparently no more than 50 feet. The quartzite is cut by giant quartz veins in three instances, the first being an east-west brecciated vein which cuts the top of the Godpala ridge, the second a north-south vein exposed in a narrow col on the ridge on the west side of Kyamachinga whilst the third occurs in a fault zone one mile south of Godpala. Minor quartz veining is insignificant.

The quartzite is a hard, fine- to medium-grained rock, creamy to bluish-white or even bluish-green in colour, the whiter varieties being invariably selectively iron-stained to a pinkish maroon. Current-bedding occurs on a minor scale, individual beds being 1 cm. or less in thickness and emphasized by the selective iron staining.

In thin sections the quartzite is found to consist of nearly equidimensional, rounded quartz grains set in an even fine-grained groundmass of quartz. The quartz grains are generally rounded but angular grains also occur. They vary in size from 0.2 mm. to 0.5 mm. and are occasionally embayed or corroded around the edges. The grains frequently exhibit intense strain polarization and not uncommonly contain strings of gas bubbles. The matrix often contains chalcedonic silica, magnetite, hematite, flaky chlorite and sericite shreds. The hematite and sericite are most common round the quartz margins. The selective iron-staining has affected the matrix giving it a distinct banded appearance, the bands being no thicker than 0.1 mm.

Groves (in Wayland, 1931, p. 54) has described a heavy mineral assemblage from the quartzites from Nagichenchi Hill near Kamagambo, which included zircon (abundant), cassiterite (very common), biotite and iron ores (common), muscovite, garnet, tourmaline, anatase, diopside and amphibole. This assemblage was compared with that of the Bukoban sandstone of Uganda. Recent work (Huddleston 1951, p. 30) has shown that little or no cassiterite is present in the quartzite of the Kisii area and that its distribution must be very sporadic.

(b) *Cherts*

The Bukoban chert is seen in only two small thin patches overlying the quartzite. One outcrop is 3 miles south of Konundo and the other on the top of the quartzite scarp west of Kyamaringi. The rock is extremely fine-grained and dense, and pale pink to deep red in colour. Fine banding is emphasized by selective iron-staining. The staining is sometimes patchy but unlike the cherts further south the dark-grey colours of unstained relics are never seen. Very small quartz grains can be distinguished with the naked eye whilst fine quartz veinlets transect the bedding. In thin sections the rock is seen to contain small quartz grains (0.1 mm.) set in a fine cryptocrystalline, almost isotropic, quartz matrix. Sericite laths occur in a parallel arrangement as does the hematite and limonite which stain the rock. Rare, finely granular chlorite, is present and again as in the quartzite, there is a complete lack of felspar.

Conditions of deposition.—From the study of the quartzites in South Nyanza it appears that they were deposited in shallow waters under quiet conditions. Fine current-bedding and ripple-marking with an absence of coarse bands suggests quiet deposition. The cherts are a chemical deposit similar to the banded cherts of the Nyanzian, and were formed in regions where normal sedimentation was absent or nearly so.

(3) KISII SERIES UPPER GROUP

(a) *Porphyritic and non-porphyritic Felsites*

These rocks outcrop to the south or south-east of the quartzite and everywhere overlie it. Like the underlying rocks they dip gently southwards but do not form prominent scarps. They attain their greatest development on the east side of the River Rigari where they are over 400 ft. thick. Faulting has affected their disposition as in the case of the quartzite and isolated outcrops such as Godpala are found north of the main exposures.

The felsites are massive, showing few structural features. They are dense purplish red fine-grained rocks, some of which are porphyritic. In the porphyritic varieties the felspar phenocrysts are green, up to 5 mm. in length and have rounded terminations. Vesicular varieties are not uncommon but are never strongly developed.

In thin section the felsites show little variation. The felspar phenocrysts are generally chloritized and highly corroded. Their fine cross-hatched twinning indicates that they are anorthoclase. They are set in a fine-grained matrix of orthoclase and quartz, often graphically intergrown, the felspar being altered and occasionally kaolinized. The groundmass also contains embayed phenocrysts or granular pools of quartz. Chlorite pseudomorphs are common and suggest original hornblende, and in one slide (41/722) a single augite crystal was noticed. Skeletal and leucogenized ilmenite, pyrite, altered sphene and occasional apatite are the most common accessories, but are never abundant. The felsites are distinguished in this area by their colour, which is due to a fine but heavy dusting of red iron oxides, and obscures the relationship between the minerals and makes their identification difficult.

(b) *Andesites and Dacites*

The andesitic rocks are not strongly developed and occur in small patches generally on the south-eastern boundary of the area. They are fine- to medium-grained purplish red rocks and are occasionally vesicular (41/722).

In thin section they are found to be holocrystalline even-grained rocks in which simply twinned felspar laths form a dense mat. Oligoclase, andesine, and occasionally orthoclase were recognized but the intense kaolinization of the crystals renders them unidentifiable in many instances. Small ragged altered hornblendes set in an intensely chloritized groundmass, are also difficult to recognize. Alteration has taken place along arcuate bands containing finely granular magnetite and hematite, (41/744, Fig. 2c). Accessories include apatite, granular epidote, and iron ores. In the dacites (e.g. 41/749) essential quartz is micrographically intergrown with the felspar. Vesicles are usually filled with chalcedony or chlorite.

3.—MIOCENE SEDIMENTS (Tm)

The Lower Miocene deposits of the Kavirondo Gulf area have been described by various authors in the past. In the present area only certain of those already described occur, viz: at Mariwa, Ombo, Majiwa and Kiboko (Maboko or Karongo); three deposits at Nyabondo, Samanga and Homa Bay—discovered during the present survey—are described below. Contacts between the Miocene beds and the Tertiary phonolites are not clearly seen, but there appears to be little doubt that the phonolites overlie the Miocene sediments in every case but one.

Kent (1944, p. 113) has considered the deposits of the northern side of the Kavirondo Gulf as "deposited on the Rift Valley floor near the foot of the fault scarp and in the small valleys cut into the upthrown block". He speculates

as to their formation in lakes dammed by forests. During the present mapping it was found that deposits on the north side of the Kavirondo Gulf are separated by at least three major faults. Deposition of the Miocene sediments probably took place in a lake or lakes on the sub-Miocene peneplain, which is represented by the pre-Rata phonolite surface, on which the Mariwa deposit is still lying. It is improbable that all the deposits were continuous. Had the lakes been dammed by forests it is likely that fossil evidence of the fact would have been found as is the case on Rusinga Island at the western entrance to the Kavirondo Gulf.

Lava outpourings subsequently covered the deposits and, later still, rift faulting threw down to the south all but the Mariwa deposit. The fact that in all the northern Miocene locations faulted Losaguta-type phonolite overlies the sediments substantiates this. Post-Tertiary erosion has dissected the major fault-scarp and re-excavated deposits such as those at Ombo.

From the evidence of fossils collected from the beds it is known that the age of the northern deposits is Lower Miocene, but no positive dates can be given to those on the south side of the Kavirondo Gulf.

Mariwa.—One and a half miles east of the rest camp at Rata are the small relic deposits of the Mariwa archaeological reserve. These deposits, together with those at Ombo, were first discovered by Archdeacon Owen during the period of his mission work in the area (MacInnes, 1942, p. 34). There are four small patches, the larger two lying immediately beneath the Rata phonolite outcrop, whilst two smaller deposits are to be found half a mile to the south-east beneath another phonolite scarp. They all lie at an approximate height of 4,800 ft. (according to Kent, 1944, p. 103, 4,600 ft).

| | |
|--|-------------|
| The succession given by Kent (loc. cit. p. 103) is:— | Ft. |
| Blue and brown clay, weathered above | 3 (exposed) |
| White sandy clay | 3 |
| White and buff gravelly clay and silt with gravelly lenticles and calcareous bands yielding fossils | 7 |
| White sand becoming gravelly below, passing down into weathered granite | 4 |
| | — |
| | 17 |
| | — |

Fossil bones are common but erosion has rendered them most friable and often unidentifiable. *Deinotherium*, *Mastodon*, *Trionyx* and a crocodile have, however, been recognized.

Ombo.—This exposure, larger than those at Mariwa, lies 300 ft. below them at a height of 4,500 ft. (according to Kent loc. cit. p. 103, they are 500 ft. lower than the Mariwa beds). It rests on porphyritic granite and is overlain by Losaguta-type phonolite.

| | |
|--|-------------|
| | Ft. |
| Blue grey clay | 3 (exposed) |
| Soft clay, grey in the west becoming irregularly reddened to the east | 9 |
| Pale green soft sticky clay with a thin fossiliferous sandstone band near the top yielding fossils | 6 |
| Pale grey clayey sand containing an increasingly large number of quartz grains and pebbles towards the base | 4 |
| | — |
| | 22 |
| | — |

As at Mariwa recent denudation is re-excavating a Miocene-filled valley which was originally covered by the neighbouring phonolitic lava flow.

Majiwa.—This badly exposed deposit outcrops at a height of 3,800 ft., one and a half miles west-north-west of Rare peninsula and is also overlain by Losaguta-type phonolite. The succession already established (Kent loc. cit. p. 104) is :—

| | <i>Ft. ins.</i> |
|---|------------------|
| Tabular dark grey phonolite | 7 0 |
| Blue grey sandy clay, yellow and indurated above | 6 0 |
| Conglomerate with rounded pebbles, predominantly of lava with some granite and limestone in a sandy calcareous matrix | 17 0 |
| Hard grey calcareous clay | 1 0 |
| Purple grey and white tuff, current-bedded with leaf impressions in the upper part | 9 0 |
| Brown clay, mottled red and green, tuffaceous and calcareous, with small gastropods in the upper part | 3 3 |
| Grey and purple ash and tuff with lava fragments | 9 0 |
| | <hr/> 49 3 <hr/> |

Kent (loc. cit. p. 104) states that an isolated hill capped by phonolite 500 yards further north has a section of 20 ft. of beds with a middle limestone yielding Miocene gastropods.

Kiboko Island.—Kiboko Island consists mainly of Losaguta-type phonolite except for a small low-lying portion dividing the island in two near its eastern side, which is formed of sediments of Miocene and Pleistocene age. Owen and MacInnes have recognized the following Miocene sequence (Kent loc. cit. p. 105):—

| | <i>Ft. ins.</i> |
|---|-----------------|
| Yellow green tuff with occasional streaks of quartz sand | 10 |
| Pebble bed with rounded and sub-rounded pebbles of quartz and limestone | 6 |
| Grey sticky clay with small nodules of limestone | 1 6 |
| Very pale yellowish fine ash | 2 0 |
| Hard limestone | 2 |
| Light-brown bentonitic clay forming a jelly-like mass when wetted | 2 0 |
| | <hr/> 7 0 <hr/> |

The Miocene sediments are confined to the more westerly portion of the section and it is there that the bulk of the fossils have been discovered. Derived Miocene fossils were also found in the Pleistocene sediments. During the present visit the pits, which had been previously dug to expose the section, were filled with water.

Nyabondo.—Beneath the Nyabondo phonolite on the eastern boundary of the area is a water-laid calcareous tuff. No fossils were found in it but the deposit may represent the initial stages of volcanic activity which occurred in Miocene times.

Samanga.—Half a mile east-north-east of Nyangwesso on the southern side of the Kavirondo Gulf and ten miles south-west of Kendu is a small isolated hill on the southern side of the road opposite the conical peak of Samanga. Essentially the hill is composed of Miocene phonolite and has formed a resistant mass round which the South Awach river has made a wide detour. On the north-eastern flank of the hill the lava overlies ashy mudstones which have been baked by the lava. The mudstone and the lava dip north-east, both having been affected by later faulting. This lava is of the Gwasi nephelinitic suite which has been determined (Oswald, 1914, p. 140) as post-Lower Miocene in age. The unfossiliferous ashy mudstone is therefore probably of Miocene age.

Homa Bay.—At the extreme south-west corner of the area and outcropping on the south-east shores of Homa Bay is a pyroclastic deposit slightly above present lake-level. It consists in the east of 6 ft. of grey-yellow to green tuffs with thin mudstone bands, all veined by calcite and containing prominent volcanic bombs. The section is thicker to the west but badly exposed. The deposits are cut by two thin dykes of phonolite which dip 71° to the south-east. The dykes have close affinities with neighbouring post-Lower Miocene lavas, suggesting that the deposits are possibly Miocene in age. Large unidentifiable tree trunks and roots were found in the tuffs and it is likely that they are the remains of a Miocene forest which was buried by tuff and agglomerate, the whole being later covered by phonolite.

The Miocene Fauna

A number of fossil mammals, reptiles and other animal remains have been collected by previous observers and during the present survey from the Miocene beds in Kavirondo. All are extinct forms except for some of the gastropods which belong to existing species. It has been proved, however (Kent, 1944 and Hopwood, 1929, p. 112) that the mammals are as old as the deposits in which they lie, and have not been derived from older beds.

The latest Miocene vertebrate faunal list (Le Gros Clarke and Leakey, 1951, p. 5) is given below:—

TABLE III.—FOSSIL MAMMALS AT KIBOKO AND OMBO

| | Kiboko | Ombo |
|--|--------|------|
| <i>Proconsul</i> | × | |
| <i>Sivapithecus</i> | × | × |
| <i>Mesopithecus</i> | × | × |
| <i>Hyænodon</i> | × | |
| <i>Pleiodon</i> | × | |
| <i>Felidæ</i> | × | × |
| <i>Carnivora</i> | | × |
| <i>Hyobooops (Merycops)</i> | × | |
| <i>Listriodon</i> | × | × |
| <i>Suidæ (indet.)</i> | | × |
| <i>Anthracotheriidæ (including Brachyodus)</i> | × | × |
| <i>Tragulidæ</i> | × | |
| <i>Climacoceras</i> | × | × |
| <i>Rhinocerotidæ</i> | × | × |
| <i>Deinotherium</i> | × | × |
| <i>Trilophodon</i> | × | |
| <i>Protonancus</i> | | × |
| <i>Cycloderma (indet.)</i> | | × |
| <i>Crocodylia (indet.)</i> | | |

TABLE IV.—ANALYSES OF PHONOLITES OF THE KISUMU DISTRICT COMPARED WITH
ROCKS OF OTHER DISTRICTS IN KENYA

| | A | 1 | 2 | 3 | B | C | D |
|--------------------------------------|-------|--------|--------|--------|-------|-------|-------|
| | % | % | % | % | % | % | % |
| SiO ₂ | 54.70 | 54.38 | 54.66 | 54.24 | 58.37 | 52.10 | 53.98 |
| Al ₂ O ₃ | 19.62 | 18.34 | 20.03 | 20.12 | 16.65 | 22.29 | 19.43 |
| Fe ₂ O ₃ | 2.98 | 3.09 | 1.87 | 2.25 | 4.09 | 1.73 | 4.39 |
| FeO | 3.04 | 2.53 | 3.42 | 2.94 | 3.03 | 4.10 | 2.05 |
| MgO | 0.45 | 0.64 | 0.77 | 0.94 | 0.37 | 1.17 | 1.07 |
| CaO | 1.90 | 1.54 | 1.88 | 1.76 | 1.66 | 2.42 | 2.04 |
| Na ₂ O | 7.71 | 8.23 | 7.50 | 6.77 | 7.28 | 8.60 | 8.81 |
| K ₂ O | 5.47 | 6.09 | 5.56 | 6.13 | 5.46 | 4.66 | 5.27 |
| H ₂ O + | 1.50 | 1.79 | 2.47 | 2.19 | 1.40 | 0.75 | 1.66 |
| H ₂ O - | 1.50 | 1.13 | 0.43 | 0.73 | 0.96 | 1.00 | 0.13 |
| TiO ₂ | 0.92 | 0.30 | 0.60 | 0.58 | 0.21 | 0.30 | 0.57 |
| P ₂ O ₅ | 0.04 | 0.07 | 0.14 | 0.17 | 0.08 | 0.46 | 0.30 |
| SO ₃ | — | 0.14 | — | — | — | — | — |
| Cl | — | 0.31 | 0.002 | 0.068 | — | — | — |
| F | — | 0.035 | — | — | — | — | — |
| MnO | 0.11 | 0.33 | 0.16 | 0.15 | 0.43 | 0.23 | 0.26 |
| CO ₂ | — | 0.06 | — | 0.06 | — | — | — |
| Less O for F and Cl | — | 0.08 | — | — | — | — | — |
| TOTALS | 99.94 | 99.005 | 99.492 | 99.098 | 99.99 | 99.81 | 99.96 |
| | | | NORMS. | | | | |
| | | * | | | | | |
| or | 32.25 | 36.14 | 32.80 | 36.14 | 32.25 | 27.80 | 31.14 |
| ab | 31.96 | 26.0 | 30.92 | 27.77 | 40.87 | 25.68 | 26.46 |
| an | 2.64 | — | 4.45 | 6.39 | — | 8.34 | — |
| ne | 18.03 | 18.46 | 17.61 | 15.90 | 7.67 | 25.56 | 23.71 |
| ac | — | 3.70 | — | — | 6.01 | — | 3.70 |
| di | 5.42 | 4.42 | 3.53 | 3.12 | 7.28 | — | 6.64 |
| ol | — | 3.22 | 2.94 | 1.62 | — | 6.31 | 0.14 |
| mt | 4.41 | 2.55 | 2.78 | 3.25 | 3.02 | 2.55 | 4.64 |
| il | 1.74 | 0.41 | 1.22 | 1.06 | 0.46 | 0.61 | 1.06 |
| ap | — | 0.34 | 0.34 | 0.34 | — | 1.34 | 0.67 |
| cc | — | 0.10 | — | 0.10 | — | — | — |

* Also includes hl 0.94, th 0.38 fr 0.07

- A. Phonolite (Kenya type). From Kisumu-Kaimosi Road, immediately south-west of brickyard at Kibos River. W. H. Herdsman, anal. (W. Campbell Smith, 1931, p. 235.)
1. Phonolite (Kenya type), 41/934, immediately south of Kisumu Yacht Club. W. P. Horne, anal.
2. Phonolite (Losaguta type), 41/858, near Rare. W. P. Horne, anal.
3. Phonolite (Kericho type), 41/715, Nyakach Mission. W. P. Horne, anal.
- B. Phonolite (Kenya type), foot of the west face of Mount Höhnel, Mount Kenya. G. T. Prior, anal. (W. Campbell Smith, 1931, p. 235.)
- C. Phonolite (Kapiti type), North-east of Amboni River, Meru Road. W. H. Herdsman, anal. (W. Campbell Smith, 1931, p. 240.)
- D. Kenyte. From the central core of Mount Kenya, above Lewis Glacier, Teleki Valley, G. T. Prior, anal. (W. Campbell Smith, 1931, p. 246.)

4.—TERTIARY VOLCANICS (TV)

Tertiary phonolite lavas cover wide areas on the north side of the Kavirondo Gulf, and on the south there is a single flow at Nyabondo and others at Homa. The Homa lavas are dealt with in a separate section (p. 31). The Nyabondo and northern lavas flowed out across the gently west-dipping sub-Miocene peneplain but did not extend far. In Central Nyanza the lavas are related to the later Pleistocene faults and it is likely that they are fissure eruptions associated with the commencement of movement along what were later to be fault lines. Two isolated patches of lava on top of the Nyando escarpment are probably relics of once much more extensive flows which have been subsequently diminished by erosion. The Nyabondo flow is part of the phonolite which now covers the Kericho district and flowed westwards.

The phonolites are divisible into three main groups, the Kenya type, the Losaguta type and the Kericho type, with distinct characteristics. Both the Losaguta and Kericho types are porphyritic varieties whilst Campbell Smith (1931, pp. 230-234) has drawn a comparison between the Kenya type of the Kisumu district with that of Mt. Höhnel (Mt. Kenya) and with the apachite from West Texas. Analyses of the various types are given in Table IV. Two miles south-west of Nyhera, phonolite of the Kenya type is seen overlying the Losaguta-type phonolite, and the same relationship is found in other places. The exact age of the lavas is indeterminable but at Mariwa, Ombo and Kiboko Island they overlie fossiliferous Lower Miocene deposits. Faulting has everywhere affected the flows and their age must certainly be pre-Lower Pleistocene.* In the Lumbwa district, east of the present area, Binge (unpublished report) considers the Kericho-type phonolites to be the oldest in age. The Nyabondo phonolite is a late flow belonging to the same episode and is probably about the same age as Losaguta-type phonolite near Tinderet which is associated with the late Kericho flows. It is considered that the Losaguta-type phonolites of the present area are the equivalent of the similar types in the Tinderet area. The Kenya-type phonolite is one of the latest flows at Tinderet and may therefore be late Tertiary in age.

Individual flows cannot be easily recognized. In the River Saini, north-west of Kisumu, weathered phonolite is seen between unweathered rock indicating the presence of at least two flows. Banding and local dips are prevalent especially in the Kenya type, but can be attributed to the uneven surface over which the lavas flowed. Only at Kisumu are the phonolites associated with pyroclastic rocks, the phonolite overlying 13 ft. of yellow to brown coarse tuff containing siliceous nodules, in exposures by the roadside at the head of Kisumu Bay. Thicknesses of the lavas vary considerably from a few feet up to nearly 300 ft. The thickest sections are seen where the lavas cap the tor-forming granite. Characteristically the lavas show spheroidal weathering (Plate 2c), which ultimately produces a crumbly whitish soil. Lateritic ironstone is a common weathering product and when not developed the immediate rock surface is covered by a one inch white to red-brown crust. The phonolites are overlain by a very thin soil cover, the surface being strewn with a mass of boulders, as is well seen 10 miles west of Kisumu. In nearly every case where the flows have flat surfaces there are shallow depressions which are either swampy or carry a soil richer than that on other lava surfaces and suitable for crop growing.

Phonolite—Kericho Type

This phonolite caps the granite escarpment at Sondu and north of the River Miriu, in the south-west corner of the district. It flowed from the area immediately to

* Gregory (1921, p. 130) considered the Kenya-type phonolites to be upper Cretaceous in age, but it should be noted that he was unaware of the underlying Miocene deposits.

the east, across the sub-Miocene peneplain and it is likely that it originally extended some miles further to the south-west. The lava is at least 100 ft. thick but probably is nowhere thicker than 150 feet. In character it is related to the Kenya and Losaguta types but the phenocrysts are generally larger, ranging up to 7 to 12 mm., and include pyroxene. The rock is blue-black and porphyritic, fissile with an uneven fracture, and containing zeolite-filled vesicles which are sometimes elongated in the direction of the banding. Phenocrysts include anorthoclase, aegerine-augite, foxy red biotite and subhedral magnetite. They are set in a pilotaxitic to hyalopilitic groundmass of aegerine, green diopside, sanidine needles, nepheline and occasionally isotropic glass. The pyroxene occurs in mossy patches with cossyrite, occasional kataphorite, and magnetite. The sanidine and pyroxene are often poikilitically intergrown. The nepheline occurs as small idiomorphs or as zeolitized crystals associated with octahedral and granular magnetite. In the few slides examined, rare pleochroic deep blue to blue grey pleochroic arfvedsonite was found, a mineral absent from the other phonolites.

Phonolite—Losaguta Type.

The Losaguta type is confined to the western portion of the area on the north side of the Gulf and two isolated outcrops on top of the Nyando escarpment. Erosion has isolated many patches such as the Rata outlier, and the original flows must have extended well beyond the present day boundaries. It is this lava which overlies the lower Miocene deposits and is itself overlain by the Kenya type. The lava has been affected by Pleistocene faulting and is found at every height between 5,000 ft. and lake level. The general dip of the lavas immediately west of Kisian is about 7° to the south-south-east and may be attributable to the faulting. The phonolite outcrops near the lake provide the best examples of faulting, which has given rise to prominent but low scarps. Certain of the scarps, however, are due to erosion which has removed the weaker rock adjacent to phonolite that flowed down pre-existing valleys.

The Losaguta type of phonolite has been classified by Campbell Smith (1931, p. 236) as intermediate between the Kenya type and the Kapiti type and kenytes (*see analyses*). The rock is porphyritic, varying from grey to greenish black to dark blue-grey, somewhat fissile, and having a conchoidal to splintery fracture. Such types are often vesicular and sometimes highly so, the vesicles being milky white. The phenocrysts are platy soda-orthoclase, prismatic aegerine-augite, sanidine, and biotite. The feldspars vary in length up to 12 mm. but are generally from 2 to 5 mm. and frequently show alteration to zeolite, sericite or chlorite round the edges. The biotite phenocrysts are strongly pleochroic from pale yellow to foxy red or deep red and altered around the edges, which are bordered by magnetite granules. The matrix is occasionally zeolitized (in one specimen, 41/846, natrolite was recognized) or replaced by analcime.

The groundmass is pilotaxitic to nearly hyalopilitic being rather blotchy due to light coloured patches free from dark minerals. Often it is granular containing microphenocrysts of nepheline and aggregates of pyroxene, cossyrite, kataphorite, magnetite and red iron ore. The pyroxene includes grains of pale green aegerine and aegerine-augite, while small prisms of aegerine-augite, green diopside and brown augite also occur. Invariably the pyroxene is altered resulting in aggregates of black granular magnetite. The nepheline in the groundmass is so highly altered as to be practically unidentifiable. Accessory apatite, analcite and possible hauyne have been recognized. In those specimens containing glass the groundmass is a dark brown, often devitrified, glass containing abundant disseminated granular magnetite. The vesicles, which are mainly spherical but occasionally elongated in the direction of the flow, are generally infilled natrolite, and in one case (41/813) calcite was seen to be surrounded by a zeolite resembling chabazite.

PLATE I



(a) Homa Mountain from the south-west showing the heavy, Upper Pleistocene to Recent soil and gravel cover at the foot of the mountain. Rapogi lies at the bottom of the slope on the right-hand side of the photograph.

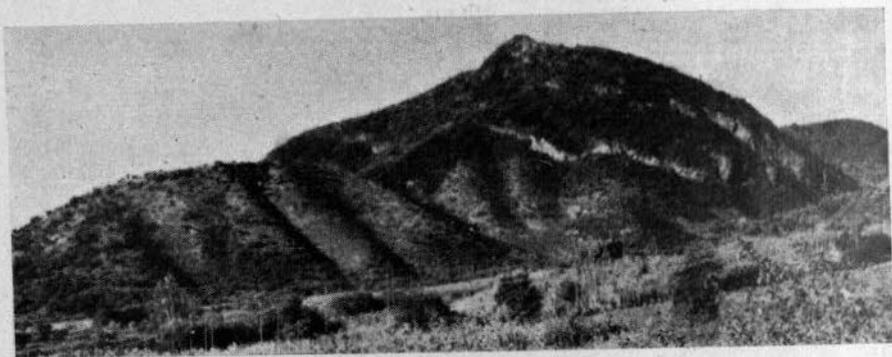


(b) Nyanja from the north-east showing Upper Pleistocene to Recent soils and gravels overlying Kanam deposits at the foot of the hill.



(c) Samanga, a phonolitic nephelinite plug.

PLATE II



(a) Nyasanja from the west. The hill is composed of cone-sheets of sövite breccia whilst the hill to the left consists of shattered Nyanzian andesite. A fault passes at the foot of the hills from right to left.



(b) Beforsite veining sövite breccia, along minor fault directions. Note the knotted weathered surface of the breccia. The veins are not more than a foot in width.



(c) Spheroidal weathering of Losaguta-type phonolite, in a railway cutting south of Lela.

Phonolite—Kenya Type

The Kenya-type phonolite is confined to the central portion of the northern part of the area with two outliers 5 miles east of Kisumu on the Kisumu-Ahero road. It outcrops at an altitude of 5,000 ft. at Nyangori and also at lake-level at Kisumu, being best exposed along the Kakamega road where, however, weathering and hill-wash mask the evidence of possible faults. The impression given as the road is traversed from north to south is that the phonolite has flowed over a series of three steps in the underlying granite. The stepping is best interpreted as the result of faulting and is dealt with in the section on tectonics.

In hand-specimens the phonolite is black or grey-brown, occasionally white or greenish tinged, and aphanitic to medium-grained granular. Rarely it contains feldspar phenocrysts and occasional vesicles occur. When the ferromagnesian minerals occur in clots the rock is very melanocratic and the presence of streaks relatively free from the dark minerals gives a crude banding to the rock which is unrelated to the flow banding. Typically the Kenya-type phonolites contain soda-orthoclase and sanidine (up to 1.2 mm. in length), nepheline (up to 2 mm.), occasionally green pleochroic diopside, aegerine, and rarely barkevikite. The feldspars have a typical criss-cross arrangement and are associated with nepheline idiomorphs. They are set in a moss-like ophitic aggregate of subhedral or ragged pyroxene, coesite, kataphorite and iron ore. The aggregates of iron-rich minerals are often unidentifiable, and they are perhaps best described as "opacite". Accessories in the groundmass are rare but include magnetite, occasional apatite, and frequently small idiomorphs of analcime. In specimen 41/835 the groundmass has been partially zeolitized.

Those specimens which are more porphyritic and contain large feldspar phenocrysts (up to 15 mm.) and vesicles are related to the Kamasian type (cf. Campbell Smith, 1931, p. 30). The rare vesicles are filled with zeolites.

5.—TERTIARY TO PLEISTOCENE OF HOMA PENINSULA

Homa Mountain, the site of an active volcano in Tertiary and Pleistocene times, dominates the country west of Kendu and occupies most of the Homa peninsula, which protrudes into the Kavirondo Gulf and forms the east flank of Homa Bay. The mountain is composed of a number of massive separate peaks which include Homa, Nyasanja, and Apoyo (Fig. 11), the largest being Homa which rises to a height of over 5,200 ft. The depression between the peaks does not, however, represent an old volcanic crater, nor does the circle circumscribing the peaks bear any relation to the ring structure described below.

The mountain is cloaked, on its lower slopes, by a thick mantle of Pleistocene and Recent sediments comprising, in the main, Upper Pleistocene to Recent gravels and soils on the western and southern slopes. Fossiliferous Lower and Middle Pleistocene beds cover the northern slopes.

The mountain has a well-defined radial drainage, the streams flowing into the Kavirondo Gulf and Homa Bay. Despite the deep gullies which have been eroded in the pediment of soft sediments, in only one place (the stream south-east of Apoyo) is there seen the solid rock which formed the pre-Lower Miocene landscape.

Kent (1944 (a) p. 114) rightly mentions the fact that Homa is situated on the line of the Kendu fault. The Samanga fault passes to the south-east of the mountain where it has disturbed the phonolite lavas. At Homa Bay the north-westerly throw of the fault must be small as no prominent features are apparent. The location of the mountain is, therefore, in a weakened zone near the intersection of these two sets of fractures (cf. Kent, loc. cit.). Table V shows a chronological sequence of events which took place after the onset of Miocene times.

TABLE V.—SEQUENCE OF EVENTS AT HOMA MOUNTAIN

| Deposition | Volcanic Outbursts | Intrusive Phases | Fractures |
|--|---|---|------------------------------|
| 14. Pleistocene beds. | 14. Minor activity (agglomerate and tuff). | 13. Carbonatite and barytes veining. 12. Hematite replacements. 11. Concentric dykes. 10. Sövite plug. | 13. Fracturing and faulting. |
| | 10. Rongo and Ndiru centres. 9. Nyasanja, Ratieng, Odiawo centres. Rapogi, Nyamatoto, Osiri and Samanga fault phonolitic nepheline plugs. | 8. Rapogi and Rawa ijo-lite, urteigite and nepheline syenite. 7. Alvikite cone-sheets. | 6. Cone fracturing. |
| | 3. First Homa explosion. 2. Phonolite lava flows south of Homa Mountain. | 5. Sövite breccia. 3. Sövite plug. | 4. Cone fracturing. |
| 1. Lower Miocene sediments of Homa Bay area. | | | |

Pre-Miocene Surface.

Pre-Miocene Surface

The country rock to the south of the mountain is composed of rhyolitic, andesitic, and basaltic Nyanzian lavas which have been highly folded and form an anticlinorium pitching south-westwards. From an examination of the mountain it is apparent that these Nyanzian rocks also extended northwards and are the rocks through which the Homa vent was formed. During sub-Miocene times the area was peneplaned, the drainage being towards the west and into a central depression along the Kavirondo Gulf (see p. 6). The River South Awach draining the area to the south-east of Homa now flows into the south end of Homa Bay. It seems likely that the river originally flowed north-westwards over the site now occupied by Homa Mountain, the mountain mass as it was formed diverting the river to the south. Occasional boulders of granite were discovered in the agglomerate of Homa and it is suggested that they are relics of gravels deposited by the river near to their present location. Had there been any large granitic intrusion into the Nyanzian rocks beneath the mountain it is felt that more than occasional boulders of the granite would have been discovered.

Typical Nyanzian hills form the western foot of Nyasanja (Plate II A), Apoyo and north-east Kuwur, and other Nyanzian outcrops are frequent. They all consist of highly altered lavas, mainly rhyolites, quartz-trachyandesites, trachyandesites and andesites. On Apoyo the rock is cut by at least one quartz-porphry dyke and a small quartz vein.

The rocks are all highly shattered and often broken into small pieces up to 2 in. in length. Fragments of them are frequently scattered throughout the Homa agglomerate and distinction between the agglomerate and the Nyanzian outcrops is often difficult. Some of the andesitic varieties are remarkably fresh but most show intense zeolitization and hematitic staining like the other rock-types. Many have been impregnated with calcite, whilst others show evidence of fenitization in its initial stages, marked by the introduction of clots or subradiating groups of dark green,

pleochroic, small prismatic aegerines. In one case the aegerine has crystallized along microscopic cracks in the rock which it has partly penetrated. An analysis of a Nyanzian andesitic tuff from near Ochimbo, west of Nyangwesso, is quoted in Table VI. The rock has been highly impregnated with calcite and the feldspars have been pseudomorphosed by that mineral. The introduction of the carbonate into the rock is presumed to be due to the proximity of the rock to the phonolitic nephelinite and Homa centres.

TABLE VI.—ANALYSIS OF A NYANZIAN ANDESITIC TUFF

| | Per Cent |
|--|--------------|
| SiO ₂ | 50.32 |
| Al ₂ O ₃ | 14.18 |
| Fe ₂ O ₃ | 1.71 |
| FeO | 6.85 |
| MgO | 5.07 |
| CaO | 5.73 |
| Na ₂ O | 1.17 |
| K ₂ O | 2.57 |
| H ₂ O + 110°C. .. | 3.72 |
| CO ₂ | 7.14 |
| TiO ₂ | 1.00 |
| P ₂ O ₅ | 0.28 |
| MnO | 0.15 |
| F | Nil |
| S | 0.04 |
| Less O for S | 0.02 |
| TOTAL .. | 99.91 |

Analyst: W. P. Horne.

Phonolites

The phonolite lavas form widespread flows south-west of the mountain. In most instances they are horizontal but near the Samanga fault at Nyangwesso they dip north-westwards. They are assumed to form the easterly extension of the Gwasi volcanic series which flowed over the sub-Miocene peneplain and have been shown to be later than Lower Miocene in age (Oswald, 1914, pp. 140 and 163). Phonolite dykes have invaded the Miocene sediments of Homa Bay and the sövite breccia in the Bala area.

The rocks exhibit great variations in colour ranging from green to blue or black often having a greasy appearance and a smooth or splintery or sub-conchoidal fracture. Some are fine-grained dense rocks but others are vesicular and/or porphyritic containing visible pyroxene, resinous nepheline, and feldspar phenocrysts. The pyroxene and nepheline are usually small but the feldspar phenocrysts range up to 1.5 mm. in length.

In thin sections the phenocrysts are seen to be set in a fine-grained groundmass with a colourless apparently glassy base which may possibly be analcime. The feldspar phenocrysts are orthoclase (including sanidine) and occur as narrow prisms up to 1.5 cm. in length but are generally of the order of 0.5 cm. Alteration of the crystals is common and takes the form of zeolitization. Zoned aegerine and aegerine-augite phenocrysts (up to 0.5 mm.) are strongly pleochroic from deep green to yellow green. The complete range of variation in composition from the margins inwards is: aegerine, aegerine-augite, pale brown acmite and purplish-green augite. Some microphenocrysts are now so altered that they are represented by nebulae of aegerine microlites, in which the centre is intense green and the outside brownish. The nepheline is generally small (1 mm.) occurring as short prismatic crystals with typical hexagonal cross-sections. Zonal structures are in some cases emphasized by zeolitic alteration whilst pyroxene microlitic inclusions are common.

The phenocrysts are set in a fine mat of the same crystals, the nepheline forming minute euhedra between acicular crystals of sanidine and aegerine. Accessories include magnetite, which is often abundant, due to the alteration of the pyroxene, biotite, and rarely barkevikite. When vesicles are present they are filled with zeolites, which in one case was recognised as stilbite, whilst calcite often forms the outer part of the vesicles.

Nephelinites and Phonolitic Nephelinites

These rocks are similar to the phonolites except that they are darker green in colour, more massive, and rarely porphyritic. The nephelinites form very prominent isolated conical hills of which Samanga, Rabuor, and Rapogi are typical (Plate 1c). Those at Homa Mountain are associated with the Homa intrusion but are no doubt contemporary with those to the south which cut the phonolite.

The rocks are characterized by their microphenocrysts of pyroxene set in a felted groundmass containing pyroxene, nepheline and, in the case of the phonolitic nephelinites, feldspar. The pyroxene is variably a strongly pleochroic aegerine, aegerine-augite or less frequently, titaniferous augite. It occurs as stumpy or subhedral prisms up to 0.5 mm. in length which are sometimes marginally altered to acmite surrounded by a black magnetite border.

In the groundmass the pyroxene occurs as needles and microlites associated with generally turbid euhedral nepheline. The nepheline is sometimes fresh but usually shows zeolitic alteration along cracks. A micrometric analysis of a more coarse-grained nephelinite showed 44.16 per cent nepheline and 49.68 per cent pyroxene.

Apatite, magnetite and rarely cossyrite are accessories. In specimen 41/531 the apatite forms microphenocrysts and is prominent in the groundmass. Calcite also forms euhedral microphenocrysts in some rocks, occurring as rhombohedra or lath-like crystals.

TABLE VII.—ANALYSES OF PHONOLITES AND NEPHELINITES AT HOMA MOUNTAIN

| | 1 | 2 | 3 | 4 |
|--------------------------------------|-----------------|-----------------|-----------------|-----------------|
| | <i>Per cent</i> | <i>Per cent</i> | <i>Per cent</i> | <i>Per cent</i> |
| SiO ₂ | 51.50 | 45.86 | 48.52 | 35.68 |
| Al ₂ O ₃ | 18.41 | 16.49 | 18.11 | 7.00 |
| Fe ₂ O ₃ | 3.13 | 4.15 | 3.60 | 4.09 |
| FeO | 1.60 | 3.70 | 2.10 | 8.71 |
| MgO | 1.33 | 2.09 | 1.85 | 12.24 |
| CaO | 3.98 | 9.26 | 6.34 | 18.62 |
| Na ₂ O | 7.31 | 6.62 | 7.47 | 1.80 |
| K ₂ O | 4.52 | 3.19 | 4.98 | 1.78 |
| H ₂ O + | 4.20 | 4.72 | 2.92 | 3.58 |
| H ₂ O - | 0.58 | 0.64 | 0.60 | 0.26 |
| CO ₂ | 1.18 | 1.06 | 0.05 | 0.14 |
| TiO ₂ | 0.55 | 1.43 | 0.90 | 4.06 |
| P ₂ O ₅ | 0.27 | 0.15 | 1.10 | 2.77 |
| Cl | 0.029 | 0.005 | 0.21 | 0.02 |
| F less than | 0.01 | 0.01 | Trace | 0.02 |
| MnO | 0.17 | 0.15 | 0.06 | 0.09 |
| S | 0.049 | 0.041 | 0.03 | 0.13 |
| Less O for F, S, Cl | — | — | 0.06 | 0.07 |
| TOTALS | 98.818 | 99.566 | 98.78 | 100.92 |

Analyst, W. P. Horne,

Norms.

| | | | | |
|----------------------------|-------|-------|-------|-------|
| or | 26.69 | 18.90 | 29.47 | 10.56 |
| ab | 33.54 | 14.67 | 14.67 | 11.00 |
| an | 4.17 | 5.84 | 1.11 | 5.84 |
| ne | 15.34 | 22.44 | 26.41 | 2.27 |
| CaSiO ₃ | — | — | — | 20.64 |
| di | 2.20 | 17.16 | 11.41 | — |
| wo | — | 4.76 | 4.06 | — |
| ol | 7.70 | — | — | 25.91 |
| mt | 4.41 | 6.03 | 4.41 | 6.03 |
| hm | 0.16 | — | 0.64 | — |
| il | 0.97 | 0.76 | 1.67 | 7.75 |
| ap | 0.67 | 0.34 | 2.69 | 6.72 |
| cc | 2.70 | 2.40 | 0.10 | 0.30 |
| py | — | — | — | 0.20 |

1. Phonolite (Gwasi type), 41/516, west of Nyangwesso, south of Homa Mountain.
2. Phonolitic nephelinite, 41/531, Samanga east of Nyangwesso.
3. Phonolitic nephelinite, 41/1012, Nyamatoto, Homa Mountain.
4. Melilite nephelinite, 41/992, Western slopes of Homa Mountain.

A single exposure of melilite nephelinite outcrops on the lower western slopes of Homa Mountain and appears to take the form of a small plug. Melilite nephelinites were also found as boulders in the agglomerate on the north side of the mountain. These rocks contain abundant green pleochroic aegerine-augite and are not so rich in melilite as that in the west. The latter is grey-black, fine-grained and speckled with lustrous ferromagnesian minerals. In thin section the rock is seen to contain abundant granular and euhedral magnetite and perovskite. The magnetite occurs as typical octahedral crystals whilst the pale brown perovskite occurs as rhombs, some showing polysynthetic twinning. Microphenocrysts, measuring up to 12 mm. in length, are colourless pyroxene while pale brown clinopyroxene and calcite occur in the groundmass intergrown with melilite. The melilite is in the form of platy crystals without a medial crack in most cases and often poikilitically intergrown with the pyroxene. Nepheline, small dodecahedra of melanite garnet and a little interstitial isotropic glass are also present. Table VII shows analyses of a typical phonolite and two phonolitic nephelinites, and a melilite nephelinite.

The phonolitic nephelinite analyses indicate that some are more phonolitic than others. The Nyamatoto rock approaches the phonolite composition very closely and it is probable that a great deal of the unidentifiable groundmass in this rock is feldspar. Ochimbo, another of these conical plugs, south of Nyangwesso is in fact a phonolite. Thus a complete range, from phonolite to phonolitic nephelinite to nephelinite occurs in the form of plugs in the Homa area, the plugs representing the final stage of the lava outflows which took place from these centres.

Ijolites, Urtites, Melteigites and Nepheline Syenite.

The main ijolite-urtite outcrop is seen at the base of the mountain on the south side whilst a second small ijolite outcrops at the foot of Apoyo just north of Rawera. Isolated boulders of the ijolite occur west of the main outcrop and may indicate an extension which cannot actually be seen. A single xenolith of melteigite was found in the Samanga phonolitic nephelinite plug near Nyangwesso. Nepheline syenite boulders were found in the agglomerate on Homa whilst Pulfrey discovered a xenolith of nepheline syenite in the Rapogi phonolitic nephelinite.

The ijolites are medium to coarse-grained, mottled, black and white rocks containing a large proportion of prominent dark reddish brown melanite garnet. Micrometric analyses* of various specimens reveal a variation not always apparent in the field. The urtitiic varieties occur near the northern boundary of the outcrop, whilst the intrusions as a whole become more coarse-grained towards the centre. The analysis of a typical melanite ijolite from Homa Mountain is quoted below together with a similar rock from Usaki south-west of Homa.

TABLE VIII.—VOLUMETRIC ANALYSES OF URTITES, IJOLITES, AND A NEPHELINE SYENITE FROM THE HOMA DISTRICT

| | A | 1 | 2 | 3 | 4 | B | C | 5 | 6 | 7 |
|-----------------|-------|------|------|------|------|-------|------|------|------|------|
| | % | % | % | % | % | % | % | % | % | % |
| Nepheline .. | 39.2 | 64.0 | 55.1 | 51.2 | 30.2 | 35.5 | 27.4 | 45.0 | 37.5 | 37.3 |
| Zeolite .. | 38.7 | — | — | — | 18.3 | 10.3 | 17.8 | 0.1 | 0.5 | — |
| Cancrinite .. | 4.1 | — | 0.3 | 1.3 | 0.6 | 4.2 | 5.0 | — | — | — |
| Natrodavayne .. | 0.4 | — | — | — | — | 0.8 | — | — | — | — |
| Analcite .. | 1.7 | — | — | — | — | n.t.* | — | — | 0.2 | — |
| Pyroxene .. | 4.3 | 10.7 | 27.2 | 29.8 | 31.0 | 17.0 | 1.8 | 37.8 | 17.3 | 31.9 |
| Wollastonite .. | 2.2 | — | 0.9 | — | — | 0.1 | — | — | 1.4 | — |
| Melanite .. | 5.0 | 22.9 | 13.0 | 12.1 | 16.3 | 26.3 | 10.3 | 12.6 | 28.0 | 5.0 |
| Apatite .. | 0.2 | — | — | 2.8 | — | 1.2 | 2.1 | 0.1 | — | — |
| Calcite .. | 4.2 | 1.2 | — | 2.9 | 3.7 | 4.8 | 6.8 | 4.0 | 7.5 | — |
| Biotite .. | Trace | — | — | — | — | 0.1 | 3.3 | 0.1 | 2.0 | — |
| Sphene .. | — | — | — | — | — | 0.1 | — | 0.4 | 5.3 | — |
| Magnetite .. | — | — | — | — | — | — | 1.1 | — | — | — |
| Perovskite .. | — | — | — | — | — | — | 1.1 | — | — | — |
| Opacite .. | — | — | — | — | — | — | 23.4 | — | — | — |
| Felspar .. | — | — | — | — | — | — | — | — | — | 25.3 |
| Other minerals | — | 1.0 | 3.5 | 1.3 | — | — | — | — | 0.3 | 0.5 |

* Not traversed

A. Urtite, IV 225 (4) Homa Mountain. Pulfrey, 1950, p. 428.

1. Urtitic ijolite (41/1036). Northern side of Rapogi ijolite, Homa Mountain.

2. Wollastonitic ijolite (41/1005). Rapogi, Homa Mountain.

3. Melanite ijolite (41/1037). Rapogi, Homa Mountain.

B. Wollastonitic ijolite (IV 225). Rapogi, Homa Mountain. Average of three sections. Pulfrey, 1950, p. 434.

C. Biotite ijolite (IV 226B). Rapogi, Homa Mountain. Average of two sections. Pulfrey, 1950, p. 437.

4. Melanite ijolite (41/1015). Rawera, Homa Mountain.

5. Melanite ijolite (41/1003). Rapogi, Homa Mountain.

6. Melanite-biotite wollastonitic ijolite (41/1000A). Rapogi, Homa Mountain.

7. Nepheline syenite (41/1035). Boulder in agglomerate, Homa Mountain.

*All modal analyses in this report are volumetric.

TABLE IX.—ANALYSES OF TWO IJOLITES FROM THE HOMA DISTRICT

| | 1 | | A | | NORMS | | | | |
|--|--------|-----------|---|-------|-------|--|---|--|--|
| | % | | % | | 1 | | A | | |
| SiO ₂ | 40.27 | 41.69 | or | 1.11 | 6.67 | | | | |
| Al ₂ O ₃ | 18.02 | 14.57 | an | 8.90 | 8.06 | | | | |
| Fe ₂ O ₃ | 4.78 | 7.02 | lc | 14.39 | 7.85 | | | | |
| FeO | 3.18 | 2.81 | ne | 28.68 | 23.86 | | | | |
| MgO | 3.38 | 3.90 | Na ₂ CO ₃ | — | 0.53 | | | | |
| CaO | 14.24 | 15.27 | di | 21.08 | 21.17 | | | | |
| Na ₂ O | 6.26 | 5.49 | wo | 11.02 | 14.96 | | | | |
| K ₂ O | 3.21 | 2.79 | mt | 3.48 | 2.55 | | | | |
| H ₂ O + 110° C. .. | 1.44 | 2.78 | hm | 2.40 | 5.28 | | | | |
| H ₂ O - 110° C. .. | 0.16 | 0.72 | il | 4.71 | 4.71 | | | | |
| CO ₂ | 1.39 | 0.40 | ap | 0.67 | 1.24 | | | | |
| TiO ₂ | 2.48 | 2.50 | cc | 3.20 | 0.40 | | | | |
| P ₂ O ₅ | 0.28 | 0.54 | | | | | | | |
| Cl | 0.02 | — | | | | | | | |
| F | Trace | not found | | | | | | | |
| MnO | 0.12 | 0.18 | | | | | | | |
| S | 0.003 | — | | | | | | | |
| SrO | — | Trace | | | | | | | |
| Less O for F, S, Cl .. | 0.01 | — | | | | | | | |
| | 99.223 | 100.66 | | | | | | | |
| | | | MODES | | | | | | |
| | | | | 1 | A | | | | |
| | | | | % | % | | | | |
| nepheline | | | | 26.9 | 23.7 | | | | |
| zeolite (not specific) | | | | 21.3 | — | | | | |
| natrolite | | | | — | 26.4 | | | | |
| stilbite | | | | — | 1.2 | | | | |
| cancrinite | | | | — | 20.2 | | | | |
| pyroxene | | | | 32.0 | 27.8 | | | | |
| melanite | | | | 8.0 | 1.0 | | | | |
| biotite | | | | 4.0 | 1.4 | | | | |
| apatite | | | | 2.5 | Trace | | | | |
| calcite | | | | 4.5 | — | | | | |
| magnetite | | | | *n.t. | — | | | | |
| Other minerals .. | | | | 0.5 | — | | | | |

*n.t. = not traversed.

1. Melanite ijolite (41/1000). Rapogi, Homa Mountain. W. P. Horne, anal.
 A. Ijolite IV.145 B, Usaki. W. Pulfrey, 1950, p. 429. W. P. Horne, anal.

In thin section it is seen that the nephelines occur as stumpy prismatic crystals which are turbid when altered and invariably enclose needles of aegerine. Zeolitization of the nepheline is common and accounts for the cloudiness of the crystals. Various minerals replace the nepheline, and in doing so develop idiomorphic form. Aegerine-diopside often grows along the contact between nepheline crystals, whilst replacement of the nepheline sometimes occurs by the growth of pyroxene granules at scattered points within it. In other cases subhedral pyroxene encloses patches of nepheline which it is replacing. The pyroxene is often a euhedral green strongly pleochroic variety of aegerine-augite. Magnetite is commonly associated with it as a result of alteration. The pyroxene itself is sometimes replaced by calcite which in one instance tends to be radially grouped. A first generation of apatite is represented by crystals enclosed by the nepheline whilst interstitial apatite represents a second generation enclosed by the nepheline. Melanite occurs as large sub-idiomorphic crystals but is also aggregated in allotriomorphic masses. The garnet is frequently zoned having a light reddish brown border and a deep blackish brown centre. In many instances it has grown at the expense of the pyroxene and nepheline and forms anastomosing veinlets along cleavage cracks and between minerals. This feature is particularly noticeable in hand-specimens, the garnet forming very ragged irregular crystals. Wollastonite, when present, forms long satiny prisms up to 4 mm. in length. Pinkish brown crystals of perovskite (1 mm.) were noted in the biotite ijolite. Apatite, sphene, cancrinite,

orange-brown biotite and magnetite all occur as accessories, whilst calcite is present as a primary mineral in addition to its occurring as veins in the rock. Three zeolite stages can be recognized, the first represented by zeolitized nephelines enclosed in pyroxene, the second by zeolites round the pyroxene borders, whilst the third stage has developed round the garnet. In the biotite ijolite only the third stage was recognized.

The nepheline syenite is a dark grey, rather greasy looking rock with occasional large nephelines and thin pink and white pegmatitic veins. The rock is coarse-grained and invariably altered. Orthoclase crystals vary from long prisms to more stumpy crystals, whilst the rectangular nepheline is highly zeolitized and replaced by pyroxene, which is pale green and predominantly aegerine. Aegerine and apatite are occasionally enclosed by the nepheline and calcite occurs as large euhedral crystals. Ragged granular sphene is a later product, whilst accessory iron ore is often a result of the decomposition of the pyroxene.

Micro-ijolites

Three micro-ijolite dykes outcrop in the Bala river and two others in the quarries south of Gogo. They are medium- to fine-grained, blackish or bluish green in colour and usually altered, the surface being covered by a white powdery decomposition product. The fresher rock is mottled white and green and is rather greasy in appearance. One specimen is feebly porphyritic and contains black lustrous pyroxene phenocrysts. The rocks are very similar to the more coarse-grained ijolites and the paragenesis has been very similar in both cases. Although the pyroxene occurs as micro-phenocrysts it is more often present as short prismatic crystals or as small granular aggregates replacing the nepheline. Slight lineation of the pyroxene is noticeable in some specimens. Sphene is common whilst euhedral or granular melanite is not so prominent as in the ijolites. The melanite is black with pale yellowish brown borders.

An agglomerate boulder of micro-ijolite, found in the tuffs on the north side of the mountain, contains patches of pink thulite, a mangianian zoisite, which is probably an alteration of original feldspar.

Micro-urtite

A single micro-urtite dyke cuts the sövite breccia on the top of Oyolo. The rock is medium-grained and greenish in colour containing resinous nepheline crystals. The garnet occurs as dodecahedra with dark borders whilst the pyroxene is a deep green slightly pleochroic prismatic aegerine-augite. Modal analyses of a micro-ijolite and a micro-urtite are given in Table X.

TABLE X.—VOLUMETRIC ANALYSES OF TWO DYKES FROM HOMA MOUNTAIN

| | 1. | 2. |
|-----------|-----------------|-----------------|
| | <i>Per cent</i> | <i>Per cent</i> |
| Nepheline | 43.3 | 73.3 |
| Pyroxene | 27.2 | 12.5 |
| Calcite | 19.6 | — |
| Melanite | 7.2 | 10.5 |
| Remainder | 3.7 | 3.9 |

1. Micro-ijolite dyke in the Bala River.

2. Micro-urtite dyke in sövite breccia, Oyolo.

Micro-syenite

A thin micro-syenite dyke has cut the carbonatite in the quarries south of Gogo. It is a porphyritic rock with phenocrysts of bright brown mica up to 2 mm. across, the large crystals enclosing pools of calcite. Stout crystals of apatite up to 1 mm. in length are common. Ragged calcite is abundant in the matrix together with clouded sub-idiomorphic feldspar. Irregular grains of iron ore are also present. An analysis of the rock is given in Table XI.

TABLE XI.—ANALYSIS OF A DYKE IN CARBONATITE FROM HOMA MOUNTAIN

| | % |
|--|--------|
| SiO ₂ | 40.36 |
| Al ₂ O ₃ | 13.59 |
| Fe ₂ O ₃ | 5.04 |
| FeO | 3.10 |
| MgO | 1.64 |
| CaO | 13.80 |
| Na ₂ O | 0.25 |
| K ₂ O | 9.39 |
| H ₂ O + | 2.58 |
| H ₂ O - | 0.42 |
| CO ₂ | 8.23 |
| TiO ₂ | 1.25 |
| P ₂ O ₅ | 0.45 |
| Cl | 0.02 |
| F | 0.04 |
| MnO | 0.21 |
| S | 0.03 |
| Less O for F and S and Cl | 0.04 |
| | 100.36 |

Analyst, W. P. Horne.

The rock was probably originally a nepheline syenite which has been altered. Although nepheline was not recognised it is possible that part of the groundmass consists of that mineral.

Carbonatites

The carbonatites at Homa include three types: sövite, a medium- to coarse-grained rock composed almost entirely of calcite, alvikite, the hypabyssal equivalent of sövite, and beforosite, a fine-grained dolomitic carbonatite.

Biotite sövite has invaded the largest ijolite outcrops and is a plug-like intrusion plunging steeply to the north. Other sövite outcrops include Rongo to the south of Apoyo, and possibly Ndiru. These sövites have the highest dips of the carbonatites, indicating a focus much deeper below the present-day surface than that of the more gently-dipping alvikitic types. The Rongo exposures of sövite breccia and carbonatite at least represent a separate centre, and the sövite there as at Ndiru, forms a conical hill. The hill forms the southern part of an incomplete ring surrounding a central depression such as is characteristic of some other carbonatite intrusions (cf. Tororo in Uganda). Where the ring is broken the sövite breccia is highly impregnated with carbonatite. The rock at Rongo is bluish-grey and is the freshest carbonatite seen at Homa; the colour may be partly due to slight fluorite staining. Although actual fluorite veining was not seen in any of the outcrops, an analysis (p. 81) shows that the carbonatites contain at least a little fluorine. Towards the north the Rongo ring thins and is not entirely complete although the adjacent sövite breccia is everywhere impregnated with calcite and small alvikitic and beforositic veins. At Ndiru the sövite is again like a plug and has been dyked by sövite breccia and hematite veins, some of which are up to 1 ft. in width though they are usually only about 2 or 3 inches. It is likely that at some depth a core of sövite exists beneath the main centre.

The *alvikites* occur in the form of cone-sheets and dykes associated with sövite breccia. They usually have sharp contacts although the larger ones, such as those in the Bala River, have a more diffuse boundary where alteration by metasomatic processes has taken place. The cone-sheets occur over the whole peninsula with dips varying from 65° to 30°. Many are distinctly brecciated the calcite showing dynamic

straining (see von Eckermann, 1948, Plate 30, Fig. 1). Away from the mountain the sheets contain greater proportions of pyroxene and apatite and may be termed pyroxene alvikites. Many of the sheets are rich in magnetite and all those seen on the mountain are magnetite alvikites. Others recognised were biotite-orthoclase-pyroxene-alvikite and biotite alvikite.

The alvikites are greyish brown, often iron-stained, the weathered surfaces being nearly black in colour and frequently fluted. The more coarse-grained varieties are sugary in appearance and sometimes contain large resinous calcite crystals. Phenocrysts of magnetite, pyroxene, and lustrous biotite are common, the magnetite where prominent being arranged in planes with an appearance of "streaming". The weathering of the pyroxene has resulted in a pale green staining of the yellowish calcite from which the pyroxene crystals stand out prominently.

In thin section the calcite is found to occur as medium-sized crystals associated with prisms of apatite up to 0.5 mm. in length, which characteristically have rounded ends. Pyroxene phenocrysts measure up to 3 mm. in length and are dark green aegerine and aegerine-augite. Mica when present is a pale to dark brown somewhat reddish variety pleochroic to dark brown or black, and may be a magnesia-rich biotite or phlogopite. Accessories include sphene (up to 1 mm. in length), melanite, and in one case, dahllite which is secondary after apatite.

The Oyolo and Onya outcrops consist of a number of parallel sheets dyked by breccia though they are themselves intruded into sövite breccia. Isolated exposures further west may be the continuation of these sheets. The alvikite cone-sheets on the mountain are usually thinner than those to the south of it, being generally 20 ft. in thickness or less, and they dip more gently towards a focus below Homa. Three prominent sheets can be seen on various spurs on the south-eastern side of Homa and probably form fairly complete rings although they could not be traced continuously. Apatite and magnetite form only a minor proportion of such rocks.

The orange-brown *beforsite* dykes are generally small (up to one foot wide) and finely crystalline. They follow fractures which are minor strike-slip faults, and often intersect one another, indicating at least two periods of movement and/or injection (Plate 2b). The dykes are commonly associated with the sövites and alvikites and are best seen where they cut the country rocks and the sövite breccia at Rongo, Ndiru, Oyolo and Onya.

Sövite Breccia

Homa Mountain is dominated by an orange coloured breccia which forms the main mountain mass and the smaller hills of Nyasanja, Ratieng and Odiawo. On the western side, in particular, the rock forms splendid vertical or nearly vertical cliffs. Its orange colour is most striking and is due to severe limonitic staining which often masks the character of the rock when viewed in thin section. The breccia includes fragments of Nyanzian rocks but is also heavily impregnated with calcite whilst this mineral often replaces the feldspar in the rock. Apatite and magnetite are common accessories. The same rock forms the bulk of the Oyolo outcrops and part of Ndiru, whilst at Bala the bulk of the rock exposed is of this type. At various exposures the breccia is seen to dyke other similar breccias and carbonatites, occasionally with slickensides along the contacts, indicating at least two phases during which such rocks are formed.

The mode of occurrence of the breccias is very similar to that of the alvikitic dykes as they form cone-sheets which can be seen to dip towards the main centre. The sheets are resistant to weathering and may be traced by their protruding outcrops mainly along the south-western, south and south-eastern sides of the mountain. The cone-sheets have higher dips nearer the centre, the outer sheets dipping at an angle as much as 15° less than the inner ones. Nyasanja, Ratieng and Odiawo, probably represent separate centres which were later than the main Homa centre,

Agglomerate

Forming the more gently sloping ground round the base of the sövite breccia is a collar of unsorted agglomerate, and tuff. This represents the consolidated portion of the original fragmentary material which was thrown out of the Homa vent. The collar must form a thick cover and represents the accumulation of material over a long period which commenced in Miocene times and continued throughout the Pleistocene period. Associated with these beds are minor vents which have yielded coarse agglomerates. A quarter of a mile east of the main ijolite outcrop on the south side of the mountain is a small hill of grey black tuff and agglomerate. This also represents a small vent as the beds are seen to dip inwards towards what must have been an explosive vent. Such tuffs and vents probably represent the last stages of the explosive activity of the Homa volcano, the agglomerate on the main peaks representing an earlier phase. The volcanic episode although violent to begin with must have been intermittent towards the end, as is indicated by the association of bedded mudstones and thin limestones with the later tuffs.

The tuffs and agglomerates are variably massive or bedded, and when bedded often show excellent dips, generally away from the mountain. This, however, is not always the case, and variation in dip and strike may be accounted for by continued tectonic movement throughout Pleistocene times.

Fragments found in the agglomerate include: rhyolite, trachyandesite, quartz andesite, andesite, ironstone, phonolite, phonolitic nephelinite, nephelinite, micro-ijolite, nepheline syenite, porphyritic hornblende granite and crystallolithic tuff. The tuff represents some of the more fine-grained material which was blown from the vent, and in one case resembles ignimbrite (welded tuff).

Iron Ores

Hematite and *magnetite* are of common occurrence in the Homa area. Magnetite occurs as small octahedra and dodecahedra, which are particularly noticeable on some of the weathered surfaces of the alvikites and in the sands and gravels of the stream beds. Hematite replacements occur in various places; there is a small patch east of Asumbi and a larger mass one mile north of Bala, whilst small veins cut the sövite breccia and carbonatite at Ndiru. The Bala outcrop is not extensive although scattered boulders round the knoll may indicate a greater lateral extent than can be actually observed. It is considered that its extension in depth may be considerably greater than its lateral extent. A chemical analysis of a grab sample of this ironstone is given in Table XII.

TABLE XII.—ANALYSIS OF HEMATITE FROM BALA, HOMA MOUNTAIN

| | % |
|--|----------------|
| SiO ₂ | 5.20 |
| Al ₂ O ₃ | 0.81 |
| Fe ₂ O ₃ | 83.49 |
| FeO | 3.48 |
| MgO | 0.43 |
| CaO | 1.03 |
| H ₂ O | 0.20 |
| CO ₂ | 0.32 |
| TiO ₂ | 3.50 |
| P ₂ O ₅ | 0.36 |
| Cr ₂ O ₃ | 0.002 |
| V ₂ O ₃ | 0.17 |
| MnO | 0.99 |
| S | 0.10 |
| TOTAL | 100.082 |

Analyst, W. P. Horne.

Barytes

Boulders of green barytes showing coxcomb structures were discovered in the Upper Pleistocene gravels of a stream one mile east of Kuwur. No trace of any barytes dyke further upstream could be found. It is possible that the boulders were derived from a dyke associated with the main ijolite outcrop, the dyke now being hidden by a thick gravel cover of later age.

Pleistocene Beds of the Homa Peninsula

The Pleistocene deposits are found in steep-sided gullies and are overlain in many places by a thick covering of more recent gravels and loams. Torrential thunderstorms are rapidly eroding the nearly vertical exposures and many fine sections will soon disappear. The beds are lacustrine in origin, but were formed at a time when the Homa Mountain volcano was still active, and the succession often shows an alternation of tuffs, with the normal lake sediments, clays, sands, gravels and thin limestones. In many of the gullies coarse agglomerates indicate the presence of minor volcanic vents contemporaneous with the deposition of the other sediments. It is to be noted that patches of Middle and Upper Pleistocene beds and post-Pleistocene wash which, in addition to contemporary fossils, sometimes contain redeposited fossils derived from earlier deposits, rest in hollows on the Lower Pleistocene. Massive sheet limestones are a feature of the area but are mainly confined to the western and southern slopes of Homa Mountain.

Kanam Beds

The Kanam beds consist essentially of light brown clays and greenish tuffs, the latter varying from fine-grained volcanic ash to fine-grained agglomerate. Gravel beds occur throughout the sequence and often contain well-rounded pebbles. Contemporaneous volcanic vents are of common occurrence.

In Kanam East there is at least 83 ft. of alternating clays and green tuff (Kent, 1942, p. 122). The beds in the northern end of the valley, described by Kent, bear a close resemblance to all the Kanam exposures and are probably not the Rawe beds as he suggested (*loc. cit.*). Further west at least 50 ft. of similar beds are exposed in Kanam Central. Towards the northern end of the valley, horizontal Rawe clays and loams disconformably overlie the upper Kanam series, whilst at the southern end the Rawe beds dip 33° in a north-westerly direction and disconformably overlie typical horizontal Kanam brown clays. At Kanam West the succession is very similar but becomes increasingly tuffaceous southwards.

Nearer the lake are the Kokkoth exposures and here again the Rawe beds are seen to overlie the Kanam series, the latter being more tuffaceous than the main deposits. Intercalated gravels are lenticular whilst the associated clays vary from pale yellow to deep reddish brown.

Typical sections of the Kanam beds are as follows:—

| Kanam East (Kent) | | Kokkoth | |
|---------------------------|-------------|--|-------------|
| | Ft. in. | | Ft. in. |
| Brown Clay | 2 0 | Light brown tuff with white bands | 4 0 |
| Fine blocky ash | 6 0 | Brown tuff with 3 in. white bands | 5 0 |
| Brown gravel | 3 0 | Grey green tuff | 5 0 |
| Ash | 9 | Light brown sandy ash | 1 0 |
| Yellow clay | 2 0 | Greenish laminated tuff | 3 6 |
| Yellow coarse ash | 4 0 | Brown sandy tuff | 9 |
| Warm brown clay | 18 0 | Grey white laminated tuff | 2 0 |
| Brown gravel | 2 0 | Brown sandy gravel (average) | 3 0 |
| Grey silty ash | 3 0 | Grey green laminated ash with slump structures | 10 0 |
| Grey clay | 4 0 | White laminated ash | 2 0 |
| Yellow clay | 6 0 | | |
| Grey ash | 3 0 | | |
| | <u>53 9</u> | | <u>36 3</u> |

Correlation of one gully with another is difficult because of the rapid repetition and interdigitation of similar beds, intra-formational erosion denoted by gravel lenticles, and the absence of marker horizons and fossils.

Vertebrate remains from the Kanam beds are listed in Table XIII.

TABLE XIII.—FOSSIL VERTEBRATES FROM THE KANAM BEDS

| | |
|---|---|
| <i>Lepus</i> sp. | <i>Equus oldowayensis</i> Hopwood. |
| <i>Crocota crocuta</i> Erx. | <i>Ceratotherium sinum germano-africanum</i> (Hiltz). |
| <i>Anacus kenyensis</i> (MacInnes). | <i>Diceros bicornis</i> (Linnaeus). |
| <i>Stegalophodon nyanzae</i> (MacInnes). | <i>Potamochoerus majus</i> . |
| <i>Stegodon Kaisensis</i> Hopwood. | <i>Hippopotamus immaguncula</i> (Hopwood). |
| <i>Archidiskodon planifrons</i> Falconer. | <i>Sivatherium olduvensis</i> (Hopwood). |
| <i>Deinotherium bozasi</i> Arambourg. | <i>Giraffa</i> cf. <i>capsensis</i> (Geoffrey). |
| <i>Hypsihipparion</i> cf. <i>albertensis</i> Hopwood. | Unidentified antelopes. |
| <i>Stylohipparion</i> sp. | |

Stone age artifacts of pre-Chellian type, of earlier age than the Oldowan culture, and the mineralized mandibular fragment of *Homo Kanamensis* have also been found in the beds.

The higher strata with the *Palaeoloxodon* (*Elephas*) *antiquus* fauna and the Chellian culture as seen at Kanjera are missing.

Rawe Beds

To the west of Kanam and lying at the foot of Nyasanja (see Fig. 11, at end) and on its north side are the Rawe Fish Beds. They consist of over 53 ft. of brown to yellowish laminated clays, tuffs, sandstones and siltstones with thin iron-stained limestone partings. The limestones are often finely laminated with bands less than one millimetre thick, and of an orange-buff colour, whilst at Fish Cliff they are more flaggy and contain much fragmentary lithic material. Rain-pitting, ripple-marks and the occurrence of gaylussite pseudomorphs at two horizons are evidence of the deposition of the beds in shallow water. Alternate light and dark banding of the beds suggests seasonal variation and, together with their shallow-water deposition, indicates an inter-pluvial period (second Inter-pluvial). Nearer the lake the Lower Rawe series consisting of brown clays and tuffs is exposed.

At Kokkoth, where the Rawe series overlies the Kanam series, the upper beds pass laterally into grey ashy bands with thin limestones. Further exposures can be seen at Homa Point and Ragua where laminated yellow and brown clays with silty bands are prominent, the latter area being capped by a sandstone one foot thick. Fossils extracted at Ragua, however, indicate a slightly later age than the typical Rawe series.

The Rawe vertebrate fauna is listed in Table XIV.

TABLE XIV.—FOSSIL VERTEBRATES FROM THE RAWE BEDS

| | |
|---|---|
| <i>Simopithecus</i> Sp. | <i>Hippopotamus immaguncula</i> (Hopwood). |
| <i>Ceratotherium sinum germano-africanum</i> (Hiltz). | <i>Giraffa</i> cf. <i>capsensis</i> Geoffrey. |
| <i>Potamochoerus majus</i> Hopwood. | <i>Taurotragus</i> sp. |
| <i>Notochoerus dietrichi</i> Hopwood. | <i>Redunca</i> sp. |
| <i>Hippopotamus gorgops</i> Dietrich. | <i>Tilapia nigra</i> . |

Fragmentary and complete remains of *Tilapia nigra* are common in the sandstone beds and are interesting in so far as the species is now peculiar to the eastward-flowing Athi and adjacent rivers.

Kanjera Beds

The Kanjera exposures lie to the east of Kanam in the banks of the Kanjera sand-river (Lime Gully of Kent, 1942) near the lake and up to 3 miles southwards from the shore. Kent (*loc. cit.*, p. 126) recognized a three-fold division: basal greenish tuffs and ash, a middle group of clays and limestone, and upper transgressive beds of brown and greenish clays.

The lower sequence, showing much discordance in bedding, consists mainly of 20 ft. of thin-bedded to coarse gravelly green and yellow brown tuffs, clays, and limestones, the topmost beds being yellow tuffs. Clay is sometimes interbedded with one- to two-inch beds of gravel, whilst a calcite band was noticed in the gravel in one section. High dips recorded indicate current-bedding rather than faulted or tilted beds although tectonic disturbance has also occurred. Fossil bones are found in the middle and upper parts of this lower group.

Leakey (1933) found tools of the later Chelles-Acheul culture associated with the Kanjera deposits. Cultures found in underlying beds were found to be more primitive and to consist of pre-Chelles-Acheul pebble tools. The mineralized skull fragments of Kanjera Man were also found in these beds in 1932 and 1934-35.

The middle group consists of yellowish clays with thin limestone bands, tuffs and agglomerates, the whole varying in thickness up to a maximum of 22 ft. These beds often have steep dips, and minor faulting is not uncommon. Coarse agglomerates indicate contemporaneous explosive activity. At the lake side the beds form a broad syncline dipping 20° to S.S.E. on the west side and 50° to N.N.W. 150 yards further east. The folded beds are overlain by transgressive, relatively undisturbed clays of the upper group which in their lower part are buff and yellowish, thinning westwards and overlain by upper grey to green clays.

The vertebrate remains obtained from the Kanjera beds are named in Table XV.

TABLE XV.—FOSSIL VERTEBRATES FROM THE KANJERA BEDS

| | |
|--|--|
| <i>Simopithecus Oswaldi</i> Andrews. | <i>Potamochoerus majus</i> Hopwood. |
| <i>Lepus</i> sp. | <i>Phacochoerus africanus</i> Cuvier. |
| <i>Orycteropus cf. aetheopicus</i> Sundeval. | <i>Metridiochoerus andrewsi</i> Hopwood. |
| <i>Archidiskodon recki</i> (Dietrich). | <i>Hippopotamus gorgops</i> . |
| <i>Archidiskodon planifrons</i> Falconer. | <i>Giraffa cf. capsensis</i> Geoffrey. |
| <i>Elephas atlanticus</i> Pomel. | <i>Strepsiceros</i> sp. |
| <i>Hypsihipparion cf. albertensis</i> Hopwood. | <i>Taurotragus</i> sp. |
| <i>Stylohipparion</i> . | <i>Bularchus arok</i> Hopwood. |
| <i>Equus oldowayensis</i> . | <i>Hippopotamus equinus</i> Cuvier. |
| <i>Equus</i> sp. | <i>Alcelaphus kattwinkeli</i> Schwartz. |
| <i>Ceratotherium sinu germano-africanum</i> (Hiltz). | <i>Gazella</i> sp. |
| | <i>Phenotragus recki</i> Schwartz. |

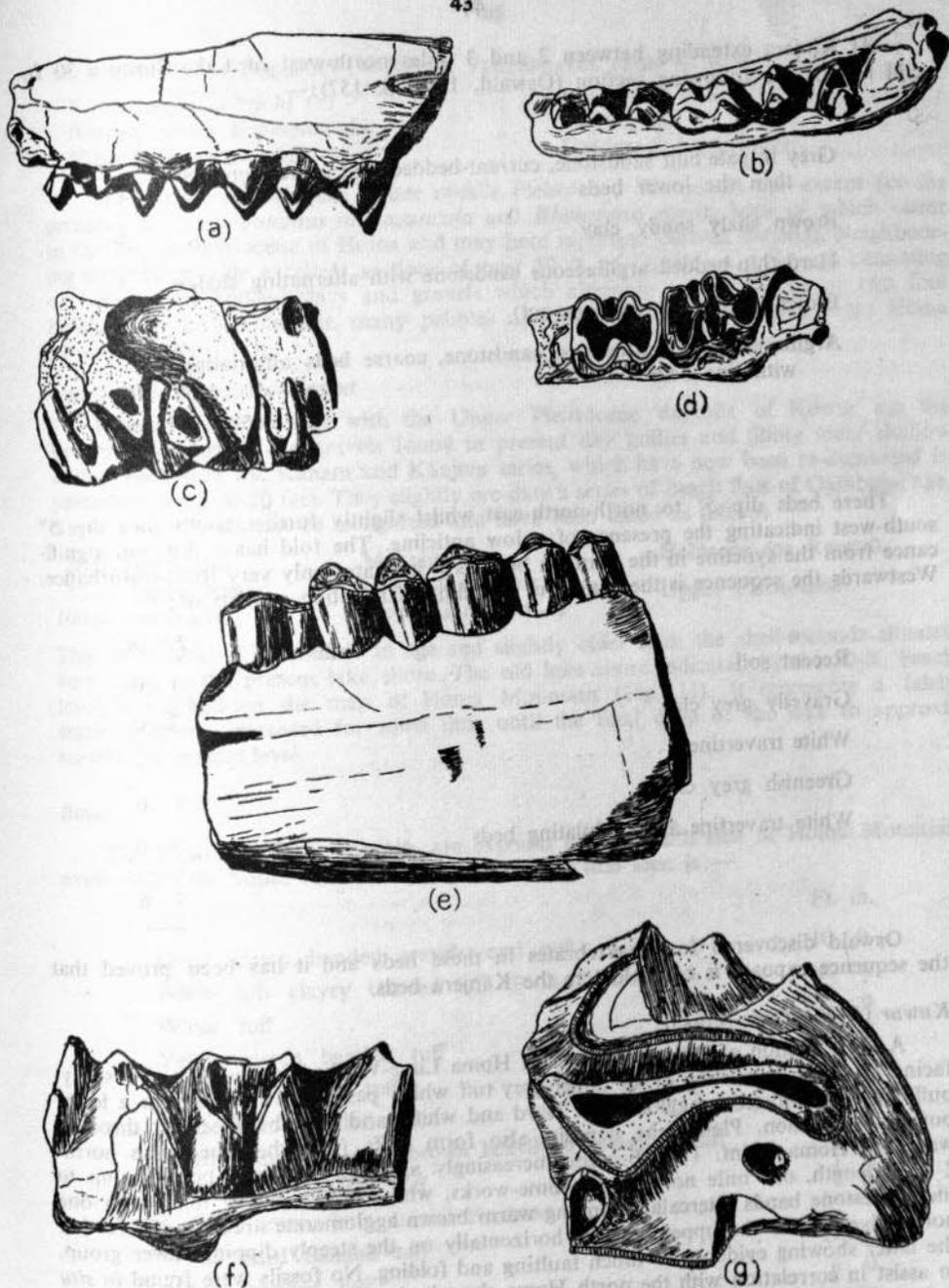


Fig. 3—Teeth of fossil mammals; (a)-(b) Miocene of Ombo, (c)-(g) Pleistocene of Homa Mountain.

- (a) and (b) Part of the right maxilla of a Miocene anthracothere, with deciduous teeth.
 (c) Part of the maxilla of *Simopithecus oswaldi* (male?).
 (d) Part of the left mandible of *Simopithecus oswaldi* (female?).
 (e) Part of the mandible of an antelope (about the size of a sable).
 (f) Third lower molar of *Hippopotamus immaguncula*.
 (g) Upper molar of *Rhinoceros simus*.

At Kimera extending between 2 and 3 miles north-west of Lake Simbi a 30 ft. cliff reveals the following section (Oswald, 1914, p. 157):—

| | Ft. |
|---|-----|
| Grey to pale buff sandstone, current-bedded and coarser-grained than the lower beds | 5 |
| Brown shaly sandy clay | 3 |
| Hard thin-bedded argillaceous sandstone with alternating shales | 3 |
| Brown shaly clay (wedges out) | 3 |
| Argillaceous current-bedded sandstone, coarse beds alternating with fine beds | 10 |
| | — |
| | 24 |
| | — |

These beds dip 5° to north-north-east whilst slightly further south they dip 5° south-west indicating the presence of a low anticline. The fold has a different significance from the syncline in the Kanjera beds as it indicates only very local disturbance. Westwards the sequence is the same but an additional section consists of:—

| | Ft. in. |
|--|---------|
| Recent soil | 1 0 |
| Gravelly grey clay | 2 0 |
| White travertine | 6 |
| Greenish grey clay | 1 0 |
| White travertine and undulating beds | 3 0 |
| | — |
| | 7 6 |
| | — |

Oswald discovered fossil vertebrates in these beds and it has been proved that the sequence exposed is equivalent to the Kanjera beds.

Kuwur (Homa Lime-Works)

A 65-ft. section of Pleistocene beds at Homa Lime-Works is exposed in a westerly-facing lake cliff, consisting of an upper grey tuff which passes downwards into a lower buff, bedded, tuffaceous agglomerate. Hard and white, and dark bands occur throughout the succession. Pleistocene deposits also form cliffs from the lime-works northwards to Homa Point. They become increasingly agglomeratic, with boulders up to 2 ft. in length, one mile north of the lime-works, whilst brown clayey tuffs, with one inch limestone bands intercalated among warm brown agglomerate are seen still further north. Everywhere the upper beds lie horizontally on the steeply dipping lower group, the latter showing evidence of much faulting and folding. No fossils were found *in situ* to assist in correlation with the north Homa deposits but the disturbance of the lower series suggests a Middle Pleistocene age. The average height above lake level of the upper horizontal beds is about the level of the 100-ft. beach as found on the north side of Homa mountain suggesting that they are of Upper Pleistocene, i.e. Gamblian age.

Deposits of several ages as well as material derived from earlier beds are found in the Kuwur district. In a gully 200 yards east of the lime works an assemblage of mammalian teeth and bones were found in soils and gravels of Upper Pleistocene age. (Table XVI.)

TABLE XVI.—FOSSIL VERTEBRATES FROM KUWUR

Notochoerus deitrichi (?)
Hippopotamus immaguncula
Hippopotamus gorgops.

Rhinoceras simus.
Elephas sp.
 Unidentified Antelopes.

The assemblage suggests a late middle Pleistocene (Kanjera) age except for the presence of *Hippopotamus immaguncula* and *Rhinoceras simus*, both of which occur in the Lower Pleistocene of Homa and may here represent derived material. Neighbouring streams provide excellent sections of over 50 ft. of Gamblian sediments consisting of horizontally bedded clays and gravels which alternate rapidly in one or two foot bands. The gravels contain many pebbles and barytes boulders derived from Homa Mountain (Plate 1A).

Upper Pleistocene and Recent

Probably concomitant with the Upper Pleistocene deposits of Kuwur are the brown clays, loams and gravels found in present day gullies and filling older shallow valleys eroded in the Kanam and Kanjera series, which have now been re-excavated in parts to a depth of 20 feet. They slightly pre-date a series of beach flats of Gamblian age. Three beach levels can be recognized and have been dated as follows:—

| | | |
|---------------------|----------------|-----------------------|
| 20 ft. beach level | Makalian | Holocene (or Recent). |
| 35 ft. beach level | Lower Gamblian | Upper Pleistocene. |
| 100 ft. beach level | Upper Gamblian | |

The 20-ft. level is Mesolithic in age and slightly older than the shell-mounds situated very close to the present lake shore. The old lake shore indicated by the 20-ft. beach level is marked on the map of Homa Mountain (Fig. 11). It represents a fairly static level that persisted for some time until the final drop of the lake to approximately the present level.

Bala

The Bala Pleistocene deposits are exposed on the south side of Homa Mountain overlooking the South Awach River flats. The section seen is:—

| | Ft. in. |
|---|---------|
| Grey brown banded gravels and tuff | 10 0 |
| White soft clayey banded tuff (9 in. bands) | 90 0 |
| White tuff | 12 0 |
| Yellow green banded tuff | 77 0 |
| White soft clayey tuff | 17 6 |
| White hard banded tuff | 4 0 |
| Bright orange to deep brown heavily iron-stained tuff | 1 |
| White hard banded tuff | 4 0 |
| Orange brown iron-stained limestone | 6 |
| White hard banded tuff | 2 0 |
| White banded tuff | 4 0 |
| | 221 1 |

The upper 10 ft. are horizontal Gamblian to Recent deposits whilst the remaining beds dip at 27° in a northerly direction and probably represent a Middle Pleistocene age. The beds are younger than the surrounding breccia against which they have been laid. At the base of the section is a small embayment in the stream and here a hot spring is to be seen which, like all the hot springs of the Homa area, deposits a white sodic encrustation over the surface of neighbouring rocks.

The remaining Pleistocene deposits of the Homa area are numerous and scattered, and have not yielded any reliable fossil evidence with perhaps one exception at Kendu. Although certain dating of the beds cannot be made their lithology and topographical position indicate an Upper Pleistocene age. Figure 3 shows a number of drawings of mammalian teeth of Miocene and Pleistocene age.

Disturbances in the Pleistocene Beds

The Kanam, Rawe and Kanjera beds have all been gently folded and faulted but perhaps the most interesting structures are those produced by slumping (Kent, 1945, p. 130) in the Kanam and Rawe beds. It has produced both minor flexuring and recumbent folding together with associated structures (see Fig. 4). The contorted beds are intraformational and developed their structures contemporaneously with deposition as is indicated by the fact that overlying beds are undisturbed. Deformation is not confined to a single horizon, however, the slumping having taken place at various times during the deposition of the Upper Kanam and Lower Rawe series. Examination of beds which show marked lithological alternations indicates that tectonic movement took place throughout the period of their deposition, producing tilted surfaces on which sliding and slumping took place.

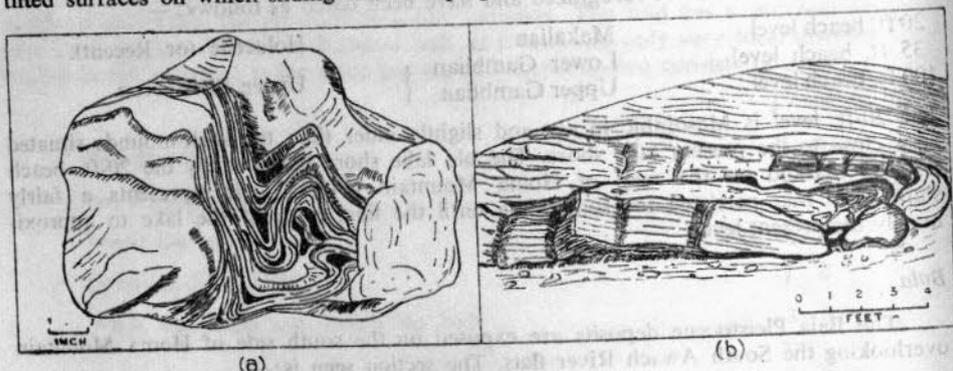


Fig. 4—Contemporaneous disturbances in lacustrine beds in the Pleistocene beds at Kokkoth, north of Homa Mountain.

(a) Contorted greenish-white volcanic ash.

(b) A recumbent fold in bedded volcanic ash.

Kent (1942, p. 132) remarks on the "... unbroken slope from 300 ft. down to a short distance above lake level; it is probably an originally flat surface which has been tilted, for the Pleistocene Beds show a similar northward dip". This is at variance with recent observations. All the series show a wide range in dip and strike bearing no relation to the present-day surface, which is a recent erosional feature. The variation in dip and strike over the whole area indicates extensive minor faulting and flexuring throughout the deposition of the Pleistocene at Homa and is connected with the movements which produced the Kavirondo Gulf Rift Faults.

Tectonic History

The mapping at Homa suggests that there is a concentric arrangement of the alvikite and other dyke rocks with relation to the main centre on Homa Mountain. More than one centre is present, however, and this fact together with the lack of suitable exposures due to the thick superficial soil and gravel cover, make it difficult to arrive at positive conclusions regarding the depth of foci of the separate centres.

The main Homa centre has an alvikite focus which is situated at a depth of between 3,000 and 3,300 ft. from present erosion level. The sövite breccia cone-sheets which form screens at surface between the alvikites apparently have a much more gentle dip and their focus is probably no more than 2,500 feet.

The Rongo centre is probably plug-like with a depth of focus for the sövite at 700 ft. below present erosion level, whilst the focus of the alvikite and breccia dykes in the Bala river (which may be associated with the centre) is about 10,000 feet.

The tectonic history of Onya, Ndiru and the Rapogi ijolite are difficult to elucidate, the first two being isolated from the main centres. As has been previously stated, it is possible that Ndiru and the ijolite, like Rongo, are separate centres. The Onya, Oyolo and nearby carbonatites are likely to be associated with the Ndiru centre, the estimated depth of focus being nearly 7,000 feet.

The estimated depth of foci are approximate, especially it is improbable, as von Eckermann points out (1948, p. 85), that the cone-sheets have at depth the inclinations observed at the surface. As at Alnö (*loc. cit.*, p. 86), the cone-sheets have increasingly gentler inclinations the further away they are from the centres. In the case of the alvikite cone-sheets on the mountain itself dips can be observed to increase inwards, whilst the outstanding sövite breccia cone-sheets can be seen to do the same when viewed from the track between Ndiru and Obong.

The remaining dykes associated with these centres especially those in the Bala river are steeply dipping intrusions and probably represent concentric dykes.

Faulting, fracturing and intrusion of later carbonatitic material, on a rectangular plan, has affected all the rocks of the complex but is particularly noticeable in the sövite breccia. The late carbonatites are themselves faulted and veined by later carbonatitic fluids. The prevalent strike directions of veins, dykes, faults and fractures as shown in Fig. 5 indicate that Ndiru, Onya, Oyolo and Gogo are part of the same centre whilst the entirely different trends at Rongo are substantiation of the suggestion that Rongo is a separate centre.

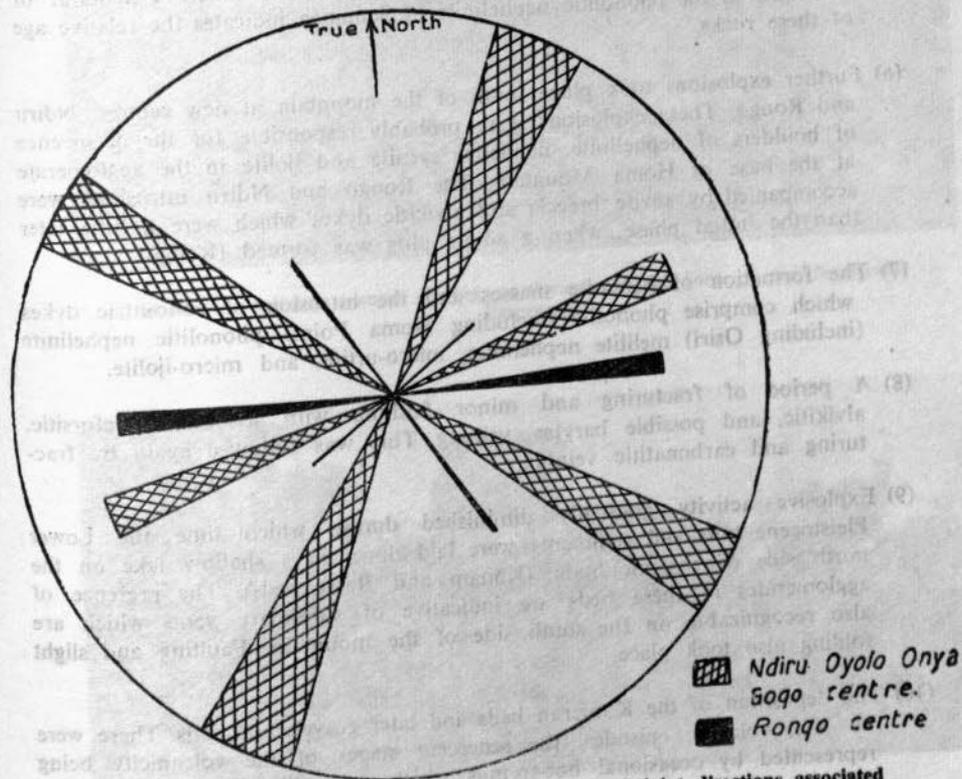


Fig. 5—Diagram showing prevalent fault, fracture and joint directions associated with the Rongo and Ndiru centres.

A chronological sequence of the tectonic history of Homa Mountain is as follows, of which some of the stages are illustrated in Fig. 6 (at end):—

- (1) Initial phonolite lava flows which covered the area to the south of the mountain. These flows overlie and dyke the presumed Lower Miocene deposits at or near Homa Bay.
- (2) The first explosion at Homa Mountain, which it is assumed was accompanied by the intrusion of a central sövite plug which is not exposed.
- (3) Renewed upward pressure which led to cone-sheet fracturing from a focus (2,500 ft.) probably lower than the central sövite plug. The fractures were injected by sövite breccia.
- (4) Rejuvenation of upward pressure from a still lower focus (3,000 ft. approximately) leading to another system of cone-sheet fractures, into which alvikites were injected.
- (5) Continued pressure was accompanied by intrusion, at various points round the main centre, of nepheline syenite, ijolite, melteigite and urtite, and phonolitic nephelinite (Rapogi and Nyamatoto), followed slightly later by the intrusion of sövite in the centre of the Rapogi ijolite. It appears that at about the same time the sövite breccia of Nyasanja, Ratieng and Odiawo were emplaced. The nephelinites and phonolitic nephelinites aligned along the Samanga fault probably developed at the same time. A xenolith of melteigite in the phonolitic nephelinite of Samanga indicates the relative age of these rocks.
- (6) Further explosions took place south of the mountain at new centres, Ndiru and Rongo. These explosions were probably responsible for the occurrence of boulders of nephelinite, nepheline syenite and ijolite in the agglomerate at the base of Homa Mountain. The Rongo and Ndiru intrusions were accompanied by sövite breccia and alvikitic dykes which were a little later than the initial phase, when a sövite plug was formed (Rongo).
- (7) The formation of hematite masses and the intrusion of concentric dykes which comprise phonolite (including Homa Point), phonolitic nephelinite (including Osiri) melilite nephelinite, micro-urtite, and micro-ijolite.
- (8) A period of fracturing and minor faulting with associated beforstic, alvikitic, and possible barytes, veining. This was followed again by fracturing and carbonatitic veining.
- (9) Explosive activity gradually diminished during which time the Lower Pleistocene tuffs and sediments were laid down in a shallow lake on the north side of the mountain (Kanam and Rawe beds). The presence of agglomerates in these beds are indicative of subsidiary vents which are also recognizable on the south side of the mountain. Faulting and slight folding also took place.
- (10) The deposition of the Kanjeran beds and later gravels and soils. There were no later volcanic episodes, the senescent stages of the volcanicity being represented by occasional hot-springs which are still active at the present day.

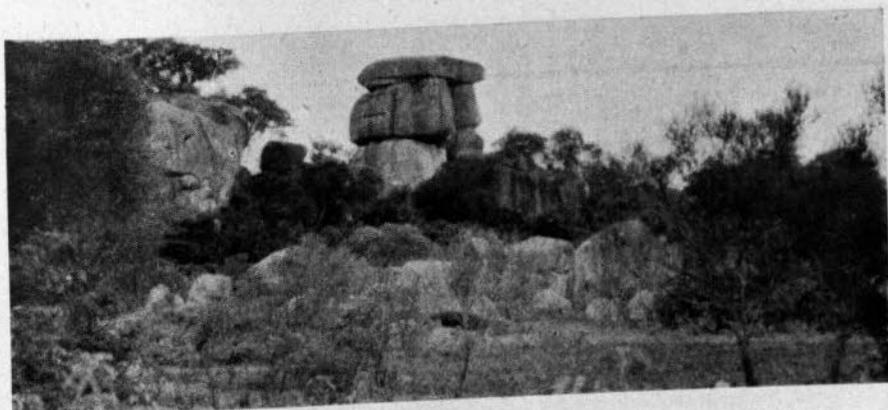
PLATE III



(a) The Kisii hills looking south-west from the Sondu-Kabondo Road. Komela in the background is composed of a thin capping of Upper felsite overlying the quartzite which in turn overlies the non-porphyrific basalts. The foreground is also covered by the basalt.



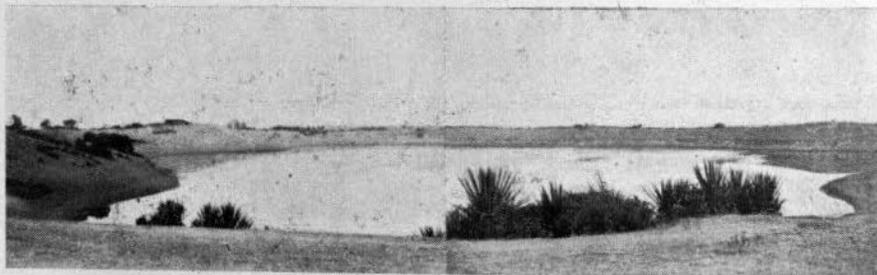
(b) Rotted, foliated granite dipping northwards at the foot of the Nyabondo Escarpment.



(c) Kit Makaye, a granite tor, south of Kombewa. The rock is a Jaluo god which is presumed to have been once a woman who was petrified.



(a) Orto tuff, showing its jointed and blocky nature.



(b) Lake Simbi, a crater-lake, looking north-west.



(c) Maragoli and Rabuor hills, looking north-east. The Maragoli fault passes to the south of the phonolite-capped Rabuor hill (right). The Maseno fault passes across the foreground from left to right.

The Homa Mountain complex is similar to that mentioned by Pulfrey (1950) in the Usaki-Ruri area, to the south-west of the Homa Peninsula. Their general resemblance to one another and the similarity of the sequence of events at each centre indicates their consanguinity, whilst the period of intrusion can be proved to be the same. In both areas the origin of the limestone is obscure. The Nyanzian rocks near Homa are devoid of limestone, whilst the numerous sheet limestones at Homa are younger in age than the complex. The period of the intrusion was long continued, from post-Lower Miocene until early Pleistocene times, when deposits of limestone were laid down in various localities around the Kavirondo Gulf. Search for thick Miocene limestones in the neighbouring areas has, however, proved fruitless, the nearest being the 100 ft. thick limestone at Muhoroni, 45 miles to the east. This limestone is of local occurrence only.

It is possible that the material required to form the carbonatites could have been derived from crystalline limestones in the Basement System, which may underlie the area at considerable depth, but no Basement System rocks have been seen in this or adjacent areas, nor were fragments of such rocks found in the Homa agglomerates. As the foci of the explosions lay at relatively shallow depths it is, however, unlikely that Basement System rocks would actually be involved in the diatreme.

6.—PLEISTOCENE (Pl)

Pleistocene deposits are widely scattered throughout the area consisting of lacustrine sediments deposited near the shores of the Kavirondo Gulf and varying greatly in lithology. Those at the base of Homa Mountain (described in the previous section) are important in so far as they provide part of the type succession for East Africa. Oswald (1914) first reconnoitred them in 1911, and since then they have been subjected to detailed mapping and investigation. Kent (1942, p. 119) recognised a three-fold division for the succession on the north side of Homa Mountain. The table below attempts a correlation between Kent's succession and the remaining deposits discovered during the present survey.

TABLE XVII.—PLEISTOCENE DEPOSITS OF THE KISUMU DISTRICT

| | | |
|-----------------------|---|--|
| Upper Pleistocene .. | Fluviatile loams, sheet limestones, etc., of Homa. South Kisian, Rare and Kanuto deposits. Upper Kuwur deposits. Upper Bala tuffs and gravels. } | Agglomerates in part contemporaneous with the lacustrine beds. |
| Middle Pleistocene .. | Nyakach, Miwani and Kisumu gravels. Kendu gravels. Lower Bala tuffs and limestone. Lower Kuwur tuffs. Kanjera beds (including Kimera). Upper Rawe fish beds. | |
| Lower Pleistocene .. | River Miriu gravels. Lathiri sandstone and Orio tuff. Lower Rawe beds. Kanam beds. | |

The Kanam beds have an added importance on account of the human remains (*Homo kanamensis*) which were found in them during the 1932 East African Archaeological expedition. Leakey has previously correlated the East African Pleistocene deposits with reference to the Pluvial periods, mammalian fossils and Stone Age cultures. In a paper to the International Geological Congress in 1948 (Leakey, 1950), he quoted the sequences shown in Table XVIII.

TABLE XVIII.—CHRONOLOGY OF THE PALEOLITHIC IN EAST AFRICA AND OTHER PARTS OF THE WORLD

| CLIMATIC CHANGES IN EAST AFRICA | EAST AFRICAN DEPOSITS | EAST AFRICAN CULTURE SEQUENCE | EAST AFRICAN FAUNAS |
|--|--|--|--|
| Nakuran (2nd Post-Pluvial Wet Phase). | | | |
| Makalian (1st Post-Pluvial Wet Phase). | | | |
| NEOLITHIC. | | | |
| MESOLITHIC. | | | |
| 1st Post-Pluvial Dry Phase | Deighton's Cliff, etc. | Magosian | |
| Gamblian 4th Pluvial .. | Enderit Drift. Malawa Gorge. Gamble's Cave. Yala River, Mugeruk, etc. | Upper Kenya Capsian C. Upper Kenya Capsian B. Upper Kenya Capsian A. Lower Kenya Capsian. | Mainly as today but with some extinct species such as <i>Equus hollisi</i> , <i>Homotoceras nillsont</i> (Lonn). |
| 3rd. Interpluvial .. | Major unconformities everywhere between foregoing and later beds. | Kenya Fauresmith. | Fauna very scarce. The majority of the species of the earlier period become extinct as they do not reappear in next series of deposits. |
| Kanjeran 3rd Pluvial (formerly called Upper Kamasian). | Olduvai Upper part of Bed IV and upper part of Ologesaille, etc. Olduvai. Minor Red Bed at Ologesaille. Olduvai Lower part of Bed IV and Kanjera, etc. | Early Fauresmith. Acheulean stages of the Chelles-Acheul culture. | <i>Paleofoxodon antiquus</i> . <i>Pelorovis</i> . <i>Bularchus</i> . <i>Notochærus</i> . <i>Hippopotamus gorgops</i> . <i>Sivatherium</i> . <i>Giraffe</i> . <i>Phacocheerus</i> . <i>Afrocheerus</i> . <i>Stimopithecus</i> . <i>Papio</i> , etc., etc. |
| 2nd Interpluvial .. | Rawe fish beds. Olduvai Bed III. | Acheulean Stage 1 of the Chelles-Acheul culture. | Fauna scarce. Many genera found earlier become extinct including <i>Deinotherium</i> , <i>Archidiskodon</i> , <i>Schizotherium</i> , etc., and many fish die out. |
| Kamasian 2nd Pluvial (formerly called Lower Kamasian). | Olduvai Bed II and Lower Rawe Beds. Olduvai Bed I and Letotil. | Chellean stages of the Chelles-Acheul culture. Oldowan. | <i>Deinotherium</i> . <i>Archidiskodon</i> . <i>Schizotherium</i> . <i>Paleofoxodon</i> . <i>Stylohipparion</i> . <i>Sivatherium</i> . <i>Pelorovis</i> . <i>Bularchus</i> . <i>Notochærus</i> . <i>Stimopithecus</i> . <i>Equus Hippopotamus gorgops</i> , etc. |
| 1st Interpluvial .. | Kaiso and Marsabit. | | As below but with <i>Paleofoxodon</i> appearing and some of the earlier forms such as <i>Anacus</i> dying out. |
| Kageran 1st Pluvial .. | Kanam Omo River. Kagera River. | Early Oldowan. Advanced Kafuan. Early Kafuan. | <i>Archidiskodon</i> . <i>Anacus</i> . <i>Deinotherium</i> . <i>Stegodon</i> . <i>Sivatherium</i> . <i>Stylohipparion</i> . <i>Gerontochærus</i> . <i>Pro-notochærus</i> . <i>Hippopotamus protamphibius</i> , etc. |

TABLE XVIII.—CHRONOLOGY OF THE PALÆOLITHIC IN EAST AFRICA AND OTHER PARTS OF THE WORLD—(Contd.)

| CLIMATIC CHANGES IN EAST AFRICA | CLIMATIC STAGES IN EUROPE (Zeuner, 1946) | THE CLASSICAL ALPINE SUCCESSION | EUROPEAN CULTURE SEQUENCE (Zeuner, 1946) | | |
|--|--|---------------------------------|--|---|--|
| Nakuran (2nd Post-Pluvial Wet Phase). | Last Glacial III. | Würm Glacial. | NEOLITHIC. | | |
| Makalian (1st Post-Pluvial Wet Phase). | Last Glacial II. | Riss-Würm Interglacial. | MESOLITHIC. | | |
| 1st Post-Pluvial Dry Phase | Last Glacial I. | Micoquian. | Mousterian } Final Levallois. | Magdalenian. Solutrean. Upper Aurignacian. Middle Aurignacian. Lower Aurignacian. | |
| Gambian 4th Pluvian | Last Interglacial. | Upper Acheulean. | Mousterian } Middle Levallois. Tayacian | | |
| 3rd Interpluvial | Penultimate Glacial II. | Riss Glacial. | Middle Acheulean. | Middle Levallois. Early Levallois. | |
| Kanjera 3rd Pluvial (formerly called Upper Kamasian). | Penultimate Glacial I. | Mindel-Riss Interglacial. | Middle Acheulean. Lower Acheulean. | Clactonian II. | |
| 2nd Interpluvial | Antepenultimate Glacial II. | Mindel Glacial. | Abbevillian. | Clactonian I. | |
| Kamasian 2nd Pluvial (formerly called Lower Kamasian). | Antepenultimate Glacial I. | Gunz-Mindel Interglacial. | Cromerian. Norvician. Ipswichian. | | |
| 1st Interpluvial | Early Glacial II. | Gunz Glacial. | | | |
| Kageran 1st Pluvial | Early Glacial I. | | | | |

The Plio-Pleistocene Boundary.

Lathiri-Orio Deposits

The Lathiri and Orio deposits outcrop midway between Kendu and Nyangwesso and consist of lacustrine bedded tuffs, gritty sandstone and quartzite. They now occur in separate patches but have probably been continuous in certain cases at one time, subsequent erosion having isolated the various occurrences. All the deposits were laid down on the low-lying ground to the north-west of the Oyugis granite and only two patches are seen to lie against it. A slightly lower lake level than that of the lake in which the Rawe beds were deposited is indicated, as they are found slightly below 4,000 feet. Although no fossils have been found associated with the beds they have been disturbed and probably faulted and hence are possibly earlier in age than the Samanga fault.

At the small village of Lathiri 3 miles south-west of Kendu there are extensive deposits of the Lathiri sandstone. The village is built on a small horizontally bedded deposit, 60 ft. thick on its northern side and thinning towards the granite against which it was deposited. It varies from a brownish coarse-grained rock to a more fine-grained yellow sandstone, but all varieties are well-bedded, the coarser material showing current bedding. The rock is suitable for building stone but is brittle and friable. In thin sections it is found to consist essentially of ungraded fragmentary quartz and feldspar, the larger grains measuring up to 2.5 mm. A limonitic cement gives the rock its characteristic colour. To the immediate north-west is a large low hill of the same rock, separated from the village deposit by stream flats. This northerly deposit is some 50 ft. below the village deposit and has been thrown down by the Samanga fault.

Further west at Orio, 3 miles north-east of Nyangwesso, is an extensive lacustrine tuff, well-bedded and exposed over the larger part of its outcrop. The rock, blocky and dark chocolate brown to yellowish buff in colour with lighter yellow grey mudstone intercalations, is horizontally bedded on the west and north sides but to the south dips at 15° to S.S.E. (Plate 4A).

To the east at Rabur another outcrop of similar rock has been deposited against the Miocene phonolite. The Rabur deposit dips steeply (47°) to the west having been affected by Pleistocene tilting. The same heavy iron-staining as in the Lathiri sandstone can be seen and hence the beds must have formed in the same lake as the sandstone. Deposition took place in fairly shallow water probably near the shore of a small Pleistocene lake, as rain pitting and mudcracks are common on the bedding surfaces.

Midway between the Lathiri and Orio deposits is yet another similar light yellow tuff but which is here associated with quartzite and magnesite. Exposures are seen at Obura school where the sediments lie against the neighbouring granite. The magnesite forms a small circular patch on the quartzite and is milky white and powdery in appearance. Its association with the quartzite and tuff indicates that it was deposited in water, contemporaneously.

The nature of the major deposits with their occasional outliers shows that towards Homa Mountain these sediments became increasingly tuffaceous and iron-stained. The Lathiri sandstone is a product of the disintegration of the neighbouring granite, whilst the iron-staining common to both tuff and sandstone was produced by the waters of the lake in which they were deposited. The lake was fed by north-westerly and easterly flowing streams, and the bulk of the iron washed into it was derived from Homa Mountain where magnetite is abundant in the rocks and surrounding soil.

Kendu

South-south-west of Kendu are a number of small Pleistocene deposits which outcrop in small gullies on the granite escarpment. Many are difficult to locate on account of the thick thorny bush cover prevalent in this area. One deposit is situated 3½ miles south-west of Kendu in an impersistent stream-course. The outcrop is composed of 50 ft. of light grey to nearly white gravels and mudstone with sticky clay bands, the near-surface gravels containing abundant siliceous nodules. The height of the beds (4,170 ft.), together with the fact that they lie on the side of the escarpment, indicate that the deposit was not formed in a small lake but in the main Middle Pleistocene lake, which rose to a height of approximately 4,200 feet. A single

tooth of *Palaeoloxodon antiquus* was discovered in the upper gravels, dating the deposit as Middle Pleistocene.

River Miriu

At a height of 4,500 ft., west of the point where the River Miriu plunges over the Kendu escarpment, there is a small gravel deposit in the Anyona valley. It lies in a small basin on the granodiorite and is a river deposit of probable Pleistocene age which has been affected by Pleistocene faulting. The southern portion consists of horizontally bedded coarse gravels, whilst in the north gravels dip at 45° to the north into a fault which strikes W.N.W.-E.S.E. along the northern margin of the beds.

Nyakach

Two and a half miles north-west of Nyakach Mission, at a height of approximately 900 ft. above lake level, there are unfossiliferous gravels, 10 ft. thick, exposed in the bed of a stream. The gravels have a basal conglomerate containing boulders up to 2 ft. in diameter, grading gradually upwards into fine gravels, and recent alluvium. The present stream is re-excavating an old lake bed or river course and is now flowing over granodiorite on which the basal conglomerate was laid.

Two other deposits are found to the east and are isolated patches of very calcareous tuff lying at heights of 5,000 ft. and 4,730 ft. respectively. Both deposits are horizontally bedded and were deposited in water rich in lime. It would seem that there was an old lake in this area which was dammed on its northern side by a barrier, which has been subsequently eroded and possibly faulted down along the line of the Kendu Fault.

Half a mile south-west of Papanditi Rest Camp there are outcrops of gravels exposed in steep-sided gullies. They consist of 40 ft. of horizontal, slightly bedded deposits, a lower 20 ft. of yellow gravels being overlain by 20 ft. of limonitic red gravels with pebbles up to 2 in. in diameter. Their altitude (4,200 ft.) indicates that they formed as a beach deposit of the main Pleistocene lake, whilst their position half way down the granodiorite escarpment indicates that they cannot be of recent origin.

South Kisian, Kanuto and Rare

Three lakeside deposits (two of which were visited) occur south of Kisian on the north side of the Kavirondo Gulf. The westerly deposit outcrops two miles north-east of Rare Peninsula and is approximately a mile long. It is an old beach deposit consisting of a 20 to 30 ft. thick strip of brownish grey mudstone capped by a band of cellular lateritic ironstone. Its shallow-water origin is indicated by the numerous mudcracks which occur at various horizons. Towards the centre of the deposit, it grades into a sandstone which may represent part of the bed of an original stream that flowed into the Pleistocene lake.

The more easterly deposit occurs at Kanuto, south of the prison. Two typical sections are:—

| | West | Ft. in. | East | Ft. in. |
|--|------|---------|--|---------|
| Lateritic ironstone | | 4 0 | Lateritic ironstone | 3 0 |
| White siltstone | | 3 0 | Fine brown mudstone with organic remains | 3 0 |
| Yellow siltstone | | 2 3 | Yellow siltstone | 2 6 |
| Yellow-white gritty siltstone and gravels with intercalated thin grey mudstone bands | | 10 0 | Light yellow-white mudstone | 1 4 |
| Yellow-grey siltstone | | 1 0 | Yellow-brown mudstone | 1 0 |
| Grey mudstone, which thickens eastwards | | 1 6 | Very fine grey-blue mudstone with leaf impressions | 1 6 |
| Whitish mudstone | | 1 0 | Light reddish-brown gritty mudstone | 3 3 |
| (Base not seen) | | | Very coarse gravels and mudstone with hard white bands | 10 0 |
| | | <hr/> | (Base not seen) | <hr/> |
| | | 22 9 | | 25 7 |

Some well-preserved leaf impressions were collected from grey-blue mudstone in the easterly section. Gradations in colour and degree of coarseness occur rapidly but the beds are typically a succession of gritty mudstones, 30 ft. thick.

Kiboko

Although the vertebrate remains discovered on Kiboko Island are of Lower Miocene age some are derived material in deposits, mainly gravels, of Pleistocene age. A Pleistocene elephant was reported, however, by MacInnes (1942), from the south-west corner of the Pleistocene sediments.

Miwani and Kisumu

Water bore-holes sunk near Miwani and Kisumu reveal the presence of possible Pleistocene lake sediments in depth (see Appendix). Bore-holes at Kisumu indicate lake or terrestrial deposits to a depth of 58 ft., whilst at Miwani a bore-hole reveals sediments to a depth of 455½ feet.

Conditions of deposition of the Pleistocene Sediments

The Pleistocene sediments are nearly all lacustrine in origin. The deposits vary from gravels and mudstones, derived directly by erosion from the neighbouring land masses, to volcanic tuffs thrown out from the Homa Mountain volcano. Throughout the period of deposition prior to Gamblian (fourth Pluvial Period) the spasmodic eruption of Homa and minor vents occurred, while the beds already laid down were being gently folded and faulted. In the lower Pleistocene, Lake Victoria stood at a much higher level than at the present day. During the second interpluvial period, tilting towards the west took place whilst further deposition, faulting, and folding took place during Kanjeran (Third Pluvial) times, and was followed by a period of erosion. The later Gamblian deposits are mostly horizontal and indicate a period of deposition generally quiet and free from severe faulting and folding. Falls in lake level produced the two Gamblian beach levels at 100 ft. and 35 ft. and in Mesolithic times the still diminishing lake approached its present level forming the 20 ft. beach. Shell mounds below the 20 ft. beach level and near the present shore are accumulations left by Neolithic Man. Their presence indicates a fairly constant lake level throughout recent times.

7.—RECENT

The Recent deposits include hill-wash, gravels, soils, alluvial flats, lateritic ironstones, sheet limestones and the gravel, sandstone, and clay deposits round Lake Simbi.

Hill-wash accumulations are widespread and occur along the northern and southern escarpments and at the foot of the Maragoli hills. They include coarse talus as well as finer material, and their thickness at the foot of the escarpments must be as much as 100 feet. Erosion by the streams flowing off the steep hills has cut into the deposits to depths of up to 50 ft. without reaching bedrock.

Alluvial flats are of two types, the first genetically connected with the Kavirondo Gulf and the second with the rivers. The largest flats form the Kano Plain, the river Kahera flats, the river S. Awach flats at Nyangwesso and the Kimera swamps. In Pleistocene times the area between the Karivondo Gulf scarps was part of the lake floor but since the fall of the lake, the rivers have meandered across the plains and deposited large quantities of silt and extended their courses in the form of deltas. The best example of this is the delta of the river Miriu which is gradually closing Nyakach Bay with the help of the river Nyando to the north. Nearer the lake, flats are extremely marshy and are now being partly reclaimed by the Provincial Agricultural Department. Other flats and marshes occur south-east of Maseno and along certain river courses on the southern side of the Kavirondo Gulf. Those south-east of Maseno are swampy or consist of extensive superficial deposits in depressions which may have once been occupied by shallow lakes. The river Rigari at the extreme south-east corner of the area flows in its upper reaches through flat swampy ground which has been formed by the capture of its head-waters by the river Miriu. Many of the smaller streams flowing across the peneplain between Sondu and Oyugis have swampy

upper reaches, whilst further downstream the water flows through rocky channels flanked occasionally by small alluvial terraces.

Gravels are confined to the valleys and can be seen where the streams have cut through terraces in the hill-wash on the escarpments. Such terraces and the alluvial flats were probably initiated in the latest pluvial periods of the Pleistocene but their accumulation has been principally due to Recent aggradation.

Soils.—The soils in the district may be divided into three principal types: black cotton soil, red lateritized soils and granitic soils. These types may be subdivided according to the rock from which they are derived. The distribution of the various types of soil seen in the area is indicated in Fig. 7.



- | | |
|---|---|
|  Black Cotton Soils, Calcareous. |  Lateritized Lava Soils incl. 'Murrum' |
|  Black Cotton Soils, Undifferentiated. |  Homa Mountain Soils. |
|  Red Soils (Lateritized). |  Hill wash. |
|  Red Pink & Grey Soils on Granites |  Alluvium. |

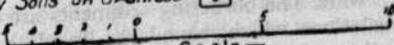
Miles  — Scale — Miles

Fig. 7—Soil Map of the Kisumu District.

The black cotton soils are calcareous and black or grey in colour. Invariably they occur on the large alluvial flats. They are ill-drained soils having a siliceous clay fraction (Milne, 1936, p. 9) and are plastic when wet and crack deeply when dry. Pits at the side of the road near Ahero illustrate the calcareous nature of the sub-soils under black cotton soils, lines of calcareous nodules giving them a banded appearance. The Kano Plain is covered by a vast stretch of black cotton soil and supports both scrub vegetation and good crops.

The red lateritized earths vary in colour but are typically deep warm brown and are well-drained, and acid in reaction. They have a uniform and porous texture, and support good grasslands and crops. They form a capping to the larger part of the district especially over the Nyanzian and Bukoban rocks and sometimes form a cover as much as 20 ft. in thickness. The soil on the granites has been classified (Milne, 1936, p. 9) as of red type but such soils are uncommon, the soils derived from the granites being white to light grey consisting of quartz and felspar and generally having arisen by residual accumulation of granite debris.

The phonolites carry a lateritised soil cover or, more often, a lateritic ironstone capping. Many of the phonolite outcrops, however, carry practically no soil cover and only stunted bushes grow on the rocky surface where slight soil accumulation has occurred amongst the boulders.

At Homa the soil cover consists of grey-brown loams and gravels which are decomposition products of the earlier Pleistocene tuffs and gravels and the calcareous Homa breccia. These soils are rich in magnetite.

Lateritic ironstone is found at various levels throughout the area but is mainly confined to the more gentle slopes. It is found capping all types of rock except the Homa Tertiary Volcanic series and is most abundant on the phonolites of Central Nyanza. The rock is red brown, cellular and concretionary, and varies in thickness from a few inches to over 15 feet. The greatest thicknesses (15 ft.) are seen one mile north of Kisumu on the Kakamega road, where the phonolite has been deeply decomposed. Two miles south of Lela pits alongside the railway track also expose over 15 ft. of murrum. West of Kisian the phonolite is frequently capped by lateritic ironstone but its development is patchy. Thinner coverings are found in the granite areas whilst the Nyanzian and Bukoban rocks are capped by a slightly thicker covering but rarely greater than 2 feet.

The ironstone has grown in certain cases by gradual replacement of decomposed rock whilst other, thinner, deposits are apparently related to ephemeral surface waters and form in the sub-soil where the run-off water is held up and evaporation is most effective. In certain cases the thickness is partly controlled by the water table and when this is high as at Kisumu, a thick deposit has formed.

Most of the lateritic ironstone in the area is of Recent age and was probably initiated in the Pleistocene period in certain cases. As in most parts of Nyanza the ironstone occurs at all levels and formed on a surface which differs little from the present-day surface. The thickness at any point does not appear to be related to age for the Kisumu deposit must have formed very recently, as that part of the area was probably still covered by the Pleistocene lake in Lower Gamblian times. Recent erosion has cut gullies into the ironstone, the streams now flowing on the surface on which the ironstone rests.

Lake Simbi

Lake Simbi (Plate IVB) is situated at or near the junction of the Kendu and Samanga faults, being one and a half miles south-west of Kendu and 9 miles east of Homa Mountain, and was first described by Oswald (1914, p. 156). It is a slightly elliptical crater lake, the longer axis running north-west to south-east, and is about 2,600 ft. long and 1,800 ft. wide. The bordering sediments are composed of gravels and sandstone with clay intercalations which, round the lip of the crater, dip quaquaversally at 35°, whilst the sediments on the lower outer slopes have a dip of only about 5°. Animal remains of comparatively recent age were discovered in these beds.

In the grey-brown gravels are many well-rounded pebbles and it seems likely that the explosion that produced the vent broke through the old course of the River Awach which now flows to the east of the lake. The gravel pebbles include chert, travertine, ironstone nodules, granite, Nyanzian rhyolite and Bukoban felsite. Most of these have been transported from the areas further south and east where a great variety of rock types is known.

The lake was probably formed within historical times; a native legend to that effect and the finding of Recent fossils tend to substantiate that view. The lake is yellow-green and an unpleasant odour pervades the area. The colour is due to confervae whilst bright green lumps of *Nostoc* occur along the water's edge together with a thin, white, sodic, crystalline crust, similar to that deposited around the hot springs near Homa Mountain. The water is bitter and alkaline, the main component being sodium carbonate, but it also contains iron, calcium, and magnesium salts, phosphates, sulphates, and silica.

Lake Simbi appears to be fed by groundwater and occasional heavy thunderstorms, though it may also receive waters from concealed springs. The rapid evaporation from its surface is not sufficient to dry it up and stagnation results. The level of the lake is apparently about 100 ft. above the level of the Kavirondo Gulf.

Limestones.—An important source of supply for the Homa Lime Works is the sheet limestone found at scattered places round Homa Mountain. The limestones are confined to the lower slopes of the mountain at varying heights up to 4,100 feet. The greater proportion of the limestone outcrops occur on the southern and south-western flanks of the mountain, whilst a single outcrop was mapped east of the Kanjera river on the north side. The limestones are frequently covered by a thin layer of soil so that new deposits are often found, as was recently the case at Kandiega. They are generally massive and pure, and related to the present-day surface or occur as intercalated beds in the Gamblian loams, gravels, agglomerate and tuff. It is probable that they began to form during the late Pleistocene and that accretion has continued into more recent times.

The limestones are of two kinds, kunkar or sheet limestone developed in the soil, and travertine deposited from springs. The kunkar limestones occur in the form of superficial sheets rarely greater than 3 ft. thick, passing laterally into nodules or cellular deposits of concretionary form resembling a pisolitic rock. The sheets are probably still growing, extending laterally whilst the thickness, in general, never increases beyond 3 feet. The soil cover is calcareous and contains many limestone nodules. Occasionally deposits appear to be much thicker than usual (e.g. at Rongo north of Kuwur where it is 20 ft.) but fine soil, tuff or agglomerate intercalations are found between the limestone bands, indicating formation at more than one period. At a quarry immediately south of Homa beacon, limestone bands rapidly alternate with intercalated tuff whilst the same is true of the Kanjera deposit. In nearly every case the limestones are compact, varying in colour from pinkish orange-grey to yellowish white, the surface being covered by manganiferous dendrites. Impurities form a low percentage of the rock and include apatite, phlogopite flakes, magnetite and rare spherulitic chalcedony (41/995), and tuffaceous inclusions. Small grey irregular branching calcite stringers vein the limestones, whilst occasionally more coarsely crystalline calcite occurs in patches. A slightly porcellaneous variety (41/971) was recorded whilst rarely pisolitic limestones occur. The pisolites measure up to 3 cm. across and, on weathering, such rocks develop a knotty surface.

A travertine outcrops half a mile west of Bala where leaching has taken place along the bands leaving cavernous holes, in which secondary clear or clouded white calcite crystals have formed. This limestone varies from white or yellow to brownish grey showing dark undulating or highly twisted bands. A second travertine is seen at the roadside 3 miles south-west of Nyangwesso. The deposit is bright orange in colour, and has excellent banding some of which has a botryoidal form. The thickness has been proved to be not greater than 3 feet. As in many of the other limestones impurities are few, chemical tests showing 96.88 per cent CaCO_3 in a grab sample (Huddleston, 1951, p. 63).

The limestones are related to the present-day surface. A large quarry 2 miles north of the Lime-Works has exposed the base of the limestone sheet, showing that it is dome-shaped and conforms to the land surface, but formed prior to the incision of the present-day streams. The formation of the limestones took place in shallow ponds or in periodically water-logged soils. The presence of sövite and various other carbonate-rich rocks at Homa Mountain provided the source of the material required for their formation. Near Bala the sheet limestone, as is the case with many other occurrences, overlies sövite.

One outcrop only, at the western Rongo, yielded fossil gastropods, all of which are recent genera and include *Gulella*, *Planorbis sudanicus*, *Limicolaria* sp., juvenile *Limnaea nyanzae* and *Achitridinae*, and a costulate planorbid *Planorbis kisumuensis* Preston. Fossilised plant roots are occasionally seen. The gastropods probably lived in the soil or in the shallow marshy ponds, the shells being enveloped as the sheet limestone extended, and thus preserved.

8.—MAJOR INTRUSIVES

(1) *The Miriu Granodiorite (Gd)*

The Miriu granodiorite mass extends in an east-west direction from Kendu to Sondu, which is just east of the map boundary, and outcrops over an area of 125 square miles. To the south-west it has invaded Nyanzian rhyolites whilst to the south-east it disappears under the lower basalts of the Kisii series. At Nyakach and Nyabondo it is overlain by the Tertiary phonolite of the Nyabondo plateau.

The granodiorite does not form strong physiographic features and only occasionally, as at Opanga, are small tors seen. The country it underlies is generally undulating, with a slight rise towards the north, facing Kendu escarpment. The river Miriu flows from south-east to north-west across the granite, having incised itself due to Pleistocene rejuvenation, finally tumbling through the escarpment in a series of falls. Although no granite outcrops are seen further south than the Oyugis-Sondu road, from evidence to the east of the district, it would appear that the mass plunges steeply downwards under the Bukoban rocks of the present area. In the north it is bounded by the Kendu fault whilst the south-west boundary is apparently faulted in part, viz. where it adjoins with the Oyugis Granite and Nyanzian rhyolite. Nyanzian roof pendants occur along the line of the Kendu fault and are seen at the north-east corner of the Nyabondo plateau and near Kendu. The north-east margin of the granodiorite is foliated and excellent dips and strikes were recorded along the boundary north-east of Andingo (Plate III (b)). The foliation has a steep northerly dip and probably developed during intrusion, though it may be connected with ancient faulting. It bears no causal relationship to the Pleistocene fault, although the faulting has probably emphasized the foliation.

Joints are most prominent in stream sections and were seen to dip steeply or to be nearly vertical. Two major joint directions strike on bearings of 50° to 67° and 135° to 164° whilst a third set strikes between 20° to 32°. The major joints greatly influence the stream pattern especially east of the River Miriu.

Little mineralization has been reported associated with this intrusion. A quartz vein containing 0.2 dwts./ton of gold was discovered during the present survey 2 miles south-east of Kendu and nearby a little molybdenite was found in a small quartz stringer.

Macroscopically the granodiorite varies considerably, being pink in the west and grading to a greyish-pink variety rich in hornblende to the east. The pink type is fairly leucocratic containing large flesh coloured orthoclase feldspars, whilst portions of the greyer rock contain up to 50 per cent of ferromagnesian minerals. Near the Kendu fault zone the granodiorite is highly rotted. Cataclastic structures are not uncommon in the rock near the lines of faulting and specimens such as 41/484 show typical examples (see Fig 8).

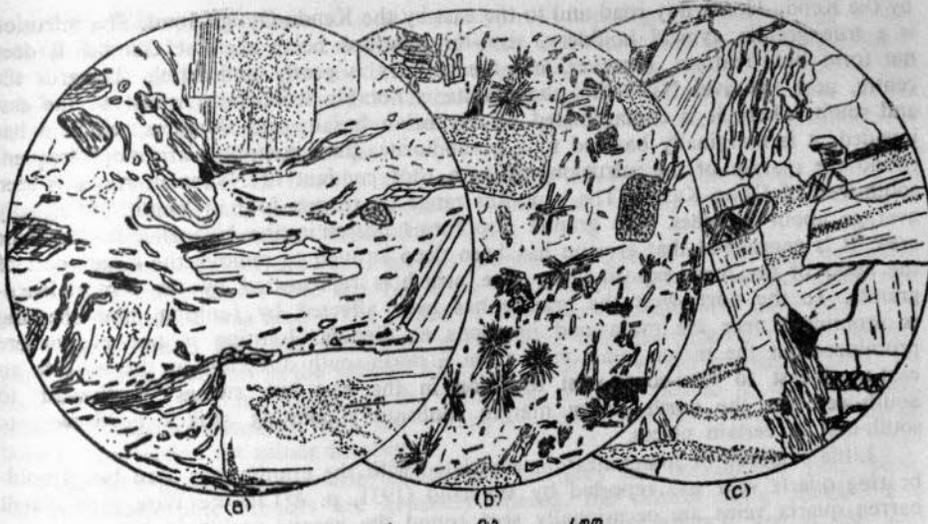


Fig. 8—Microscopic drawings of thin sections showing alteration in granitic rocks.

- (a) 41/484, three miles east of Kendu. Sheared Miriu granodiorite in which torn, ragged, hornblende appears to flow round the felspar prisms.
- (b) 41/796, Kaloka. Porphyritic microgranite showing stellate aggregates of hornblende partly replacing the small felspar laths.
- (c) 41/462, two miles south-east of Kendu. Miriu granodiorite. Albitization of the felspar has resulted in the release of calcium and formation of calcite which has veined the felspar and quartz.

The felspars are generally pink to pinkish white, subhedral, stumpy, crystals up to 5 mm. in length and show various stages of alteration due to sericitization and koalination. The main felspars are plagioclase, varying from oligoclase to andesine, but orthoclase and microcline were often noted especially in the porphyritic varieties. The dark minerals are hornblende and biotite, which often occur as clots derived from incompletely assimilated basic material. The biotite is green brown in colour with wavy extinction, and occurs as bent plates. Where altered it is sometimes associated with muscovite. Ragged prisms of green hornblende are occasionally intergrown with the felspar and sometimes with the quartz, forming a peg structure, the enclosed quartz being optically continuous with the interstitial quartz of the rock. Sphene is commonly associated with the biotite and hornblende, whilst apatite, allanite, magnetite and leucoxyenized ilmenite are also accessories.

Variation in the granodiorite occur. An adamellite near Kabondo rest-camp contains shreddy biotite which is the preponderant dark mineral, whilst a tonalite 2 miles south-east of the Kendu Pleistocene outcrop, has green deeply pleochroic hornblende which occurs as large interlocking prisms and pseudomorphoses original pyroxene. Where alteration has taken place clots of dark brown biotite are present. Xenoliths occur along the margins of the granodiorite but are rare compared with the number enclosed in the Oyugis granite, although roof pendants are common. Near the faulted contact at Kendu, specimens 41/461 and 41/462 show an interesting relationship. Rimming of the felspars and patches of soda-rich plagioclase in more potash-rich felspar indicate that alkali metasomatism has taken place. Calcite-rich veinlets have formed as a result of the release of Ca ions and the addition to CO_2 . It appears that the rock has been metasomatically altered along a fault-zone with the release of calcium from the original hornblende and plagioclase. The calcite veining in the rock has taken place along fractures which are mostly tight in the quartz. The closed fractures are represented by fine dusty bands in the quartz (Fig. 8 (c)), though in some cases the calcite also veins it.

(2) The Oyugis Granite (G)

The Oyugis granite outcrops between Kendu and Oyugis, and extends into the area south of the present one (Huddleston, 1951). It is bounded on the north-west

by the Kendu-Homa Bay road and to the east by the Kendu-Oyugis road. The intrusion is a true granite, typical bouldery, semi-tor outcrops being seen at Gendia. It does not form bold features, however, and the country is gently undulating. Towards the centre, near the river Nyapetho, the granite is notably leucocratic whilst to the east and south, where it is contaminated by Nyanzian basalts and rhyolites, which it has invaded, it is marginally basified to a granodiorite. Basic xenoliths are more frequent round the margin of the intrusion, whilst a roof pendant of Nyanzian rocks is seen south-west of Doho Kasele. The xenoliths range up to one foot in length, but usually average about 3 inches. The granite also forms bosses in the Nyanzian in the same area. It is considered that erosion has been deep enough to remove the larger part of the hood of the mass exposing the core, which is represented by the central leucogranite. To the north-west the granite has been affected by faulting, and shearing is prominent near the main-road junctions at Gendia. Jointing is not everywhere prominent but the major joints vary from a north-south direction in the west to an east-north-east to west-south-west direction in the east but swings north-west to south-west on the north-eastern margin. Subsidiary jointing strikes north-west to south-east in certain places.

Little evidence of mineralization associated with the granite was seen but a gold-bearing quartz vein was reported by Wayland (1931, p. 41) in the Wire area. Small barren quartz veins are occasionally seen round the granite periphery but are never strongly developed.

The normal granite is a grey to pinkish grey coarse even-grained rock. The feldspars are large subhedral tabular crystals, clouded by sericite flakes, and are preponderantly orthoclase though a little oligoclase is also present. Perthite and myrmekitic intergrowths were recognized. The coloured mineral is a deep green pleochroic hornblende occurring as prisms up to 2 mm. in length. Occasionally they are poikilolithically intergrown with the feldspar, and are associated with apatite needles. Less common are ragged bent plates of brownish green biotite associated with magnetite grains. Quartz is interstitial and often shows strain shadows. Accessory minerals include sphene, zircon, magnetite and chlorite. In one sheared specimen the hornblende plates have been bent and broken and show a crude flow-like structure round the feldspar.

The leucogranitic variety contains in addition to orthoclase and oligoclase, microcline and albite. Ferromagnesian minerals are not common and consist mainly of shreds of hornblende and chlorite associated with magnetite and leucoxenised ilmenite. Allotriomorphic quartz is abundant and penetrates the feldspar in lobes, suggesting a replacive relationship.

As opposed to the eu-granitic nature of the main part of the mass the granodiorite margins have hypidiomorphic granular texture often with well-developed euhedra. Many of the constituent minerals are now altered and both the feldspar and hornblende have been patchily chloritized and pseudomorphosed by granular epidote and in the case of the feldspar are also partly kaolinized. The brown shreddy biotite is too occasionally chloritized. Quartz grains include rows of bubbles and are embayed and corroded round the edges. Apatite and calcite are common accessories whilst magnetite is practically absent. Xenoliths now appear as ghosts or darker patches unlike those seen in the non-basified rock.

At the immediate contact between the granite and the Nyanzian basalts the rock in places is microgranodioritic (p. 67). This rock dykes the Nyanzian rhyolite south-west of Doho Kasale and appears as a boss in the basalt. To the north of Doho Kasele a microgranite occurs as a boss in the basalt where the granite margin has not been so basified. The microgranite passes marginally into a micro-syenite which has a much higher colour index.

(3) *Asembo Granite*

The eastward extension of the Asembo granite occupies the north-western part of the area. Pulfrey (1938, p. 28) considered that the intrusion in the Asembo area is probably sheet-like in form, dipping to the south or south-west. Although the direction of extension of the granite is the same a sheet-like form cannot be proved in the present area. In the extreme north-west corner Nyanzian rocks form a thin covering

over the granite which erosion is now removing and exposing the granite. Two bosses east of Ramula have also been exposed and seem to indicate that the upper surface of the intrusion declines to the south-west, being much steeper than the slope of the sub-Miocene peneplain. Nowhere were indications of the nature of the base of the intrusion seen. Faulting has affected the granite and outliers are seen at Kaloka to the south-east of the main outcrops.

The granite tends to outcrop with a bouldery effect like the Oyugis granite at Gendia. It forms gently undulating country without any strong features and is therefore quite different from the Maragoli granite.

Gold mineralization accompanied this granite and mining of the gold has taken place along the contacts with the Nyanzian rocks. In the river Nyamgul south-west of Rata the granite was seen to be veined by fluorite associated with some gold.

Near Asembo the rock is a true granite and this also applies to the central portion of the intrusion in the present area. Marginally, however, variations occur, the rock being partly granodioritic in the south-east and adamellite to the north-west. Minor intrusions associated with the granite are still more basic and are described later in the section on minor intrusives.

The true granite is a coarse, non-porphyritic, grey but occasionally pink, rock. The subidiomorphic feldspars are generally altered, the centres being clouded and surrounded by a clear border. The common alteration products are sericite and kaolinite which in some cases render the feldspar practically unidentifiable and in other cases emphasize the zoning in the plagioclase. Orthoclase is preponderant and accompanied by oligoclase and micropertite. The ferromagnesian minerals are pleochroic light green, blade-like, hornblende together with torn plates of green to pale brown biotite. Quartz occasionally forms graphic intergrowth with the feldspar. Accessories include sphene, magnetite and apatite needles.

In hand-specimen the character of the marginal rocks does not vary appreciably from that of the interior of the granite although along the intrusive contacts with the Nyanzian the rock is somewhat sheared and finer-grained with a tendency to be microporphyritic.

The "granodiorite" east of Kaloka is free from orthoclase and can be termed a quartz-tonalite. The rock as a whole is highly altered and the original hornblende is chloritized and associated with tabular shreddy muscovite. Accessories include magnetite and ilmenite and a little granular sphene. Specimen 41/796 shows stellate groupings of amphibole which replace in part small feldspar prisms.

The adamellite of the north is sometimes a grey rock like the granites but is often pinkish in colour and often microporphyritic. The ferromagnesian mineral is a pleochroic, brown, ragged, platy biotite, which is sometimes associated with hornblende. Near the Nyanzian contacts assimilation and contamination is obvious and darker patches, clots of hornblende, and hybrids are common. In the hybrids hornblende pseudomorphoses pyroxene whilst small chloritized primary hornblende prisms less than 0.5 mm. long are not common. The feldspars are mostly altered but oligoclase, orthoclase and some microcline were identified. In one specimen (41/775) labradorite was recognized. The large microphenocrysts are set in a granular mosaic of quartz, feldspar and shreds of hornblende and sericite.

The fishing village of Kaloka stands on a porphyritic microgranite which is associated with the nearby Asembo granite. It is a mesotype rock containing abundant hornblende which often replaces the feldspar and occurs as scattered radial aggregates. Some highly altered biotite was also noticed. These minerals are set in a granular mosaic of quartz, feldspar and hornblende, all of which are partly altered.

(4) *Maragoli Granite (G)*

The Maragoli granite occupies the northern part of the area and except for the phonolite capping, north of Kisumu, it outcrops from Maseno in the west to Miwani in the east. It forms part of a batholith extending into the Kakamega district where it invades Nyanzian and Kavirondian rocks. The granite forms the conspicuous Nyando and Maragoli fault-line scarps (Plate IV (c)). Groups of granite joint-blocks isolated by erosion form massive tors, which are most noticeable on the top of the escarp-

ments. The most famous is Nandi Rock (Girgige) from which in the past the Nandi women hurled their prisoners. The major joint directions are nearly at right-angles to one another on bearings of 32° to 51° and 114° to 169° , whilst a third direction strikes at 76° . Horizontal jointing is in evidence in various parts of the intrusion and in the western tributaries of the Kibos river erosion has emphasized the mural jointing.

As in the area north of Maragoli this granite is accompanied by gold mineralization. Small gold-bearing quartz veins were noted during the survey whilst a promising area is that immediately north of Miwani. Here the granite has invaded Nyanzian rocks and variable gold values were obtained by assay of quartz from the various veins near the contacts. This portion of the escarpment with its Nyanzian rocks is an extension of the Kibigori area further east, where high gold values were discovered in quartz veins in 1948 and are now being worked. Further work to the west of the Robo river may yield economic deposits.

The granite varies in colour and where pink the colour has been attributed in some cases to hematite flakes in the feldspars (Pulfrey, 1946, p. 24), though it was also considered that in other cases the colour may have been produced by iron-rich solutions derived from the phonolites at Nyahera which once overlaid the granite further north-west. This is also true of the granite-syenite outcrops north-west of Kibos where many of the rocks are a deep pink colour.

The granite is not uniform throughout and every variation from syenite to granodiorite and granite can be seen, indicating a complex intrusion or a number of intrusions. The rock is predominantly porphyritic and similar to the Kisian granite to which it is obviously related, if not part of the same intrusion. Like the Kisian type the rock is unfoliated and there is no orientation of the phenocrysts, but the uniformity of the Kisian type is not displayed by the Maragoli granite which is variably porphyritic or even and coarse-grained, and it is hornblende or biotitic in character the colour varying from pink to greyish white. Granite is seen in the vicinity of Maragoli, the rock grading into a leucocratic variety north-west of Kibos where it has a saccharoidal texture. The rock of the Nyando escarpment is more granodioritic but leucocratic patches do occur, whilst the greatest variations are seen near the Nyanzian contact to the east. Here syenites, adamellites, biotite granite and a quartz monzonite provide a wide diversity in types. Despite this variation the rocks are predominantly porphyritic, except the biotite granite which is more evenly coarse-grained. The monzonite is associated with the Nyanzian inliers and, as in the remainder of the granite, variations are possibly a result of contamination. North-east of Kibos large syenitic intrusions were mapped and these are associated with syenodioritic basic patches, xenoliths and other hybridized rocks. The granite often contains xenoliths, which are sometimes up to 2 ft. in length, though some areas are practically devoid of them. Thin aplite veins and occasional quartz veins are the only evidence of late-stage veining.

In thin sections the pink phenocrysts are recognized as mostly microcline with some microcline-micropertite, though orthoclase and plagioclase are also present. The phenocrysts are set in a coarse-grained matrix of hypidiomorphic granular texture, which includes large tabular crystals, up to 3 mm. in length, of orthoclase, oligoclase (An_{30}) and rarely micropertite together with microcline. The microcline and orthoclase show less alteration than does the plagioclase but all the feldspars are clouded and sericitized. In certain specimens clots of epidote are noticeable, and in such rocks epidotization of the feldspar has taken place together with a little chloritization. Myrmekite was seen in one specimen. Hornblende is the predominant dark mineral, occurring as long green pleochroic blades, often chloritized, and associated with shreddy biotite flakes and granular magnetite. The amphibole in some cases consists of small flakes of lamprobolite (41/904), together with hornblende. Where it occurs in groups it shows up as black lustrous clots in the hand-specimen. In the leucocratic varieties the hornblende is not always conspicuous in the hand-specimen and in slides is then seen to consist of small ragged prisms. The pale brown to greenish brown biotite is mostly associated with the hornblende and consists of dark-bordered, shreddy, bent plates, as in the porphyritic hornblende-bearing types of the granite. In even-grained biotite-rich types the biotite is clearly visible in the hand-specimen

as small lustrous plates. In only one specimen was granular augite recorded—in a microgranular variety of the granite. Quartz forms large allotriomorphic crystals but is also often interstitial or forms a graphic intergrowth with the feldspars. Accessory minerals include apatite, often in the form of small needles, magnetite, sphene, rare allanite, and ilmenite. Chlorite and epidote are products of alteration.

When xenoliths are common they can be recognized as inclusions of the wall-rock, the xenoliths having a granular character and being often quite basic. In the shear zones the inclusions resemble granulites. The larger xenoliths are now only ghosts in the granite and are coarse-grained rocks of plutonic character, which probably represent incorporations of the earlier phases of the intrusion. Other smaller patches often consist mostly of hornblende, magnetite euhedra and a little ilmenite, quartz, feldspar and biotite.

Diorite segregations consisting of melanocratic medium-grained rock showing slight banding were noted in the Nyando scarp. In these, twinned stumpy augites are the predominant dark mineral and acicular crystals of actinolite are present.

A microdiorite intrusion was seen 2 miles north of Kombewa on the western boundary of the area. It is a melanocratic mottled even-grained rock, and some specimens have a tendency to be porphyritic though the majority display hypidiomorphic granular textures. They contain a pale brown diopsidic augite, patchily chloritized, and rimmed with granular magnetite. Shreddy biotite and small irregular flakes of hornblende are also present. Altered oligoclase and some orthoclase form a pale groundmass of subhedral crystals associated with a little allotriomorphic quartz. Towards the contact the microdiorite grades into the Asembo granite and may represent metasomatized wall rock.

A quartz monzonite has been faulted in the Nyanzian north of Miwani and is highly altered. The feldspars are highly epidotized and the hornblende crystals are shreddy and allotriomorphic. Quartz forms a granular aggregate with feldspar in the groundmass but is never abundant.

Syenites occur as hybrid marginal facies or masses associated with both the Maragoli and Asembo granites. They are medium-grained, dark grey to black and white speckled rocks in which the black ferromagnesian minerals are prominent in a pale felspathic matrix. Chloritized diopsidic augite is common together with long tabular crystals of hornblende. Accessory minerals are similar to those found in the major intrusions.

(5) *Kisian Granite* (Gp)

The most distinctive granite on the north side of the lake is the Kisian granite, a coarsely porphyritic type. It occupies the greater proportion of the granite outcrop forming the Seme hills near the Kavirondo Gulf and extends northwards almost to Daraja Mbili. Its outcrops consist of enormous blocks or massive tors, some over 300 ft. high, and form strong features everywhere throughout its extent (Plate III (c)). This resistance to erosion is no doubt due to the stability of its microcline phenocrysts which in weathered hand-specimens are practically unaltered and form outstanding crystals. The tors are aligned along the major axis of the intrusion, i.e. from north-east to south-west, and it is along this direction that later faulting has taken place.

No mineralization was seen to accompany this granite but a little alluvial gold, which may have been derived from veins associated with it, has been reported by the Mines Office, Kisumu, from the river near the Kisumu Prison, west of Kisumu.

The phenocrysts are large clouded flesh-coloured microclines, some over one inch in length, and are scattered haphazardly but abundantly throughout the rock. They are set in a medium to coarse-grained granodioritic groundmass of hypidiomorphic granular to granitic texture. The feldspars of the matrix are large tabular crystals up to 3 mm. in length and commonly altered due to kaolinization and sericitization. Zoning is not infrequent and the feldspar can be recognized as oligoclase with some small anorthoclase euhedra. The dark mineral is an olive green, strongly pleochroic hornblende, which also exhibits slight zoning and, when altered, is associated with magnetite octahedra. Subsidiary small shreddy plates of biotite occur along the margins of the hornblendes.

Quartz is generally interstitial and often occurs as a granular aggregate with the feldspars, though occasionally it forms large allotriomorphic crystals containing rows of bubble inclusions. Accessory minerals include apatite, magnetite, occasional sphene and rare allanite.

Basic clots are frequently found in the granite and are microdiorites, containing a large proportion of hornblende and biotite. West of Kisian, near Ojolo Mission, the granite displays a Rapakivi texture, the pinkish orthoclase and microcline feldspar being bordered by white sodic plagioclase. Along the northern border of the intrusion at Rumo, north of Kisian, the rock is a microgranodiorite, in which the hornblende and biotite are both chloritized. Occasional feldspar phenocrysts are present but are unidentifiable owing to severe alteration.

A small number of chemical analyses, which are quoted in Table XIX, have been made during the present survey. The porphyritic "granites" are similar rocks but the analyses indicate variations which are not always apparent when examining the rocks in thin section as it is often difficult to estimate the proportion of microcline phenocrysts.

TABLE XIX.—ANALYSES OF "GRANITES" OF THE KISUMU DISTRICT

| | 1 | 2 | A | 3 |
|--------------------------------------|---------|-------|-------|-------|
| | % | % | % | % |
| SiO ₂ | 71.24 | 65.10 | 65.47 | 76.02 |
| Al ₂ O ₃ | 15.29 | 15.66 | 14.90 | 12.36 |
| Fe ₂ O ₃ | 0.60 | 1.54 | 1.83 | 0.42 |
| FeO | 1.39 | 2.07 | 1.89 | 0.25 |
| MgO | 0.36 | 1.90 | 2.17 | 0.06 |
| CaO | 2.54 | 3.64 | 3.81 | 0.86 |
| Na ₂ O | 5.13 | 4.31 | 3.99 | 3.18 |
| K ₂ O | 2.34 | 4.52 | 3.69 | 5.31 |
| H ₂ O + | 1.70 | 0.60 | 0.92 | 0.43 |
| H ₂ O - | 0.06 | — | 0.19 | 0.05 |
| TiO ₂ | 0.13 | 0.35 | 0.66 | 0.08 |
| P ₂ O ₅ | 0.08 | 0.14 | 0.35 | 0.05 |
| MnO | 0.025 | 0.06 | 0.11 | 0.01 |
| Cl | — | 0.005 | — | — |
| CO ₂ | 0.06 | — | — | 0.06 |
| F | 0.05 | 0.065 | — | 0.01 |
| SO ₃ | 0.04 | 0.02 | — | 0.02 |
| Less O for F and Cl | 0.02 | 0.03 | — | — |
| TOTALS .. | 101.015 | 99.95 | 99.98 | 99.17 |
| | NORMS | | | |
| qz | 26.10 | 5.40 | 18.06 | 36.18 |
| c | 0.10 | — | — | 1.33 |
| or | 13.90 | 35.58 | 21.68 | 31.69 |
| ab | 43.49 | 36.68 | 34.06 | 26.72 |
| an | 11.40 | 5.56 | 11.68 | — |
| wo | — | — | — | 1.39 |
| di | — | 9.39 | 4.38 | 1.43 |
| hy | 2.62 | 2.39 | 4.39 | — |
| mt | 0.93 | 2.32 | 2.55 | 0.70 |
| il | 0.30 | 0.61 | 1.22 | 0.15 |
| ap | 0.34 | 0.34 | 0.67 | — |
| cc | 0.10 | — | — | 0.10 |

1. Leucogranite, 41/619, Oyugis granite, four miles south-west of Wire Hill. W. P. Horne, anal.
2. Porphyritic granite, 41/783, Kisian granite, Kit Makaye, 15 miles west of Kisumu. W. P. Horne, anal.
- A. Porphyritic granodiorite, Seme Hills near Kit Makaye. Dr. N. Sahlbohm, anal. (W. Pulfrey, 1946, p. 22.)
3. Granophyre, 41/902, Maragoli granite, one mile north of Miwani Sugar Factory. W. P. Horne, anal.

(6) *The age of the Major Intrusives*

The "granites" in western Kenya have been dated relatively with reference to the Nyanzian and Kavirondian systems. In Central and Northern Nyanza, the post-Nyanzian—pre-Kavirondian granites have been labelled G_1 , and the post-Kavirondian as G_2 (Hitchen, 1937, Pulfrey, 1938). In South Nyanza granites of presumably similar age were indicated as G_2 and G_3 by Shackleton (1946, p. 21), who was followed by Huddleston (1951, p. 36) when describing the Kisii district immediately south of the present area.

In the Kisumu district, precise ages cannot, however, be determined, for nowhere are there outcrops of Kavirondian sediments in the area, though every granite either invades the Nyanzian or contains roof pendants of it. The granites, therefore, are all at least G_2 in age, if not later. Pulfrey (1946, p. 22) has shown that north of the present area the Maragoli granite invades Kavirondian sediments and must, therefore be G_3 in age. The Kisian granite is probably part of the same intrusion. The remaining granitic masses can only be stated to be post-Nyanzian in age although west of Kaloka, it appears that the Kisian granite has invaded the Asembo granite.

Although post-Nyanzian—pre-Kavirondian and post-Kavirondian ages have been postulated for the granites in Nyanza, apparently post-Nyanzian granites may be in fact post-Kavirondian as well. Shackleton has considered (1946, p. 39) that the magma that gave rise to the post-Nyanzian granites remained fluid long into Kavirondian times, indicating a connexion between the Nyanzian and Kavirondian orogeneses and that the granites are co-magmatic.

9.—MINOR INTRUSIVES

(1) *Rhyolite*

An 8 ft. wide rhyolitic dyke outcrops half a mile due north of Kisian railway station, along the phonolite-granite contact. It is a greyish blue rock of fine grain but containing occasional phenocrysts of orthoclase, oligoclase and hornblende. Chlorite, sericite and epidote are common alteration products.

(2) *Dacite porphyrite*

One dacite was noted in a westerly-flowing stream half a mile south-west of Kisumu water-works. It is a fine-grained, dense, bluish-green, well-jointed blocky rock, consisting essentially of interlocking oligoclase laths and prismatic green hornblende, set in a groundmass of granular pyroxene, quartz and feldspar.

(3) *Granodiorite porphyrite*

A granodiorite porphyrite dyke invades the Nyanzian one mile south-west of Doho Kasele and is genetically connected with the neighbouring granitic intrusion. The rock is dense and porphyritic with white altered oligoclase feldspars set in a blue fine-grained granular mosaic of quartz and feldspar, which are graphically intergrown, together with ragged epidotized and chloritized hornblende.

(4) *Aplites and Pegmatites*

Thin impersistent veins of aplitite (e.g. 41/902 alaskite aplitite) and pegmatite veins up to 14 ft. wide cut the granitic rocks in many places. The pegmatite veins are most prominent north of the Nyabondo phonolite and lie roughly parallel to the escarpment.

(5) *Andesite porphyrites*

The dyke andesites are blue to grey fine-grained or porphyritic rocks, often with visible ferromagnesian blades or laths which are arranged in a lineated or radiating fashion (41/495, 41/496). Pinkish brown blade-like augites or tabular hornblendes are set in a lathy aggregate of andesine or oligoclase. Various stages of alteration have taken place, and in one specimen (41/681 from near Opanga), the feldspar is completely sericitized whilst in specimen 41/495 the oligoclase phenocrysts are in part replaced by calcite.

In specimen 41/681, pyroxene and hornblende occur in equal amounts the pyroxene being diopside and aegirine-augite. In other specimens either augite or hornblende predominates. Granular augite occurs in the groundmass of a dyke in the River Nyamgul. The augite and hornblende are sometimes altered around their margins with development of granular magnetite and chlorite. The largest andesite dyke, outcrops on the road half a mile north of Kombewa and is one and a half miles long and up to 75 yards wide.

(6) Basalt

A basalt dykes the granites in the South Awach river. The basalt is a fine-grained dense blue rock and well-jointed, yielding small blocks. It consists of criss-cross laths of andesine or labradorite together with pyroxene prisms. The pyroxene is a brown to nearly colourless bladed augite with corroded borders. Felspars are invariably epidotized or sericitized.

(7) Lamprophyres

Two lamprophyre dykes only were recorded: one on either side of the Kavirondo Gulf. The northern dyke outcrops one and a half miles south-east of Rata and the southerly one four miles north of Godnyango. Both cut granite. The southerly dyke, a spessartite, is a dense, fine to medium-grained blue-grey rock with minute diopside phenocrysts embedded in a melanocratic groundmass. The larger diopside crystals have been highly chloritized and are practically unrecognisable. The groundmass consists of prismatic oligoclase and lathy greenish brown oxy-hornblende associated with granular magnetite. The northern dyke is more strongly porphyritic, the phenocrysts which are mainly a green strongly pleochroic hornblende, measuring up to 7 mm. in length. They are set in a groundmass of needle hornblende and cloudy oligoclase. Iron pyrites, quartz and sphene are accessories.

(8) Dolerites

The dolerites in the district are in the main post-granite pre-Bukoban in age (D_2). A single apparently pre-granite epidiorite cuts the Nyanzian rhyolite north of Miwani whilst the dolerites which have invaded the Nyanzian rocks between Rata and Ramula are all of pre-granite age. The D_1 dolerites strike north-west to south-east and the D_2 dolerites mostly strike north-east to south-west or north-west to south-east. The latter types outcrop frequently in the Nyando and Kendu escarpments but are not so prominent in other areas. The D_2 dolerites invade both granite and Nyanzian rocks and it is of interest that many of their strike directions are similar to fault-lines especially in the Kaloko, Kibos and Kendu areas. As these faults are probably late Tertiary to Pleistocene in age it is likely that they represent rejuvenation of movement along ancient lines of weakness which in Pre-Cambrian times allowed the passage of doleritic fluids. In the Awach valley, south of Ramula, the dolerites are massive lens-shaped intrusions up to two miles in length and half a mile broad, giving rise to characteristic bouldery outcrops.

Prominent among the D_2 dolerites are the *granophyric dolerites* cutting the granite of the Nyando escarpment. They are bluish black, medium-grained rocks flecked with whitish-green felspars and quartz. In thin sections they are seen to contain interlocked laths of feldspar and blades of pale greenish-brown augite. The augite blades are invariably twinned, partly chloritized and often pseudomorphosed by hornblende. The felspars are blade-like or occur as long needles (41/908) and in one specimen, 41/919, are radially grouped. They range in composition from albite to andesine but are mainly andesine, and show considerable sericitization and occasionally partial replacement by actinolite needles. The matrix is nearly all composed of graphic intergrowths of quartz and feldspar, the granophyric texture being linear, radial or irregular. One specimen shows pronounced runic texture. In certain specimens prismatic felspars and granular pyroxene are embedded in the graphic matrix.

In the more normal D_1 and D_2 dolerites subordinate graphic intergrowth is confined to the borders of the larger felspars which range in composition from oligoclase to labradorite (An_{30} to An_{60}). Pale dark-bordered augite and ragged diopside

are optically intergrown with the felspar laths and in specimen 41/800 pale enstatite euhedra were seen, whilst in specimen 41/565, the pyroxene is, in part, schillerized bronzite. In one example (41/880) brown pleochroic biotite is developed, associated with lamprobolite, hornblende and magnetite. Many specimens contain fibrous hornblende prisms which generally show patchy chlorite alteration. Quartz pools occur in the matrix but generally never constitute more than 5 per cent of the rocks.

Some dykes show greater alteration than the remainder and may be termed metadolerites (e.g. 41/533) whilst the epidiorite north of Miwani exhibits alteration to an even higher degree.

Three reddish-green dykes, striking north-west to south-east and outcropping two miles east of the Kendu dykes, are tentatively considered as post-Bukoban intrusions (D_3).

10.—GIANT WHITE QUARTZ VEINS

Large white, barren, quartz veins such as are seen in other parts of Nyanza Province are not numerous in the Kisumu district. Examples were mapped east of Daraja Mbili, at Opanga, half a mile south-west of Kendu, and in the south-east corner of the area. Some may be related to the granitic intrusions but others are at least of post-Middle Bukoban age as three such veins were seen cutting the quartzite on Godpala, two miles south of this hill and two and a half miles west of Kichura.

In two cases the veins are aligned north-south, one being emplaced in a fault and possibly contemporaneous with it.

The veins are composed of coarsely crystalline, glassy, white quartz occasionally cut by second generation quartz veinlets. Locally as in the vein at Godpala, the quartz is brecciated. It also contains fragments of its quartzite walls.

11.—METAMORPHISM

Regional metamorphism exhibited by the Nyanzian rocks of the area is due to the intense folding and faulting to which they were subjected prior to Bukoban times. The grade of metamorphism is low being characterized by the development of chlorite, epidote, albite, sericite and less frequently actinolite and biotite. The rocks are only slightly altered except in the area north of Wire. Here the lower basalt group shows an increase in metamorphism, from south to north, and its members near the Kendu faults become schistose and lose their identity as basalts. The rhyolites east of Kendu are similarly altered and have become converted to phyllites.

The Nyanzian rocks are mostly sheared along the major intrusive contacts and near Ramula and Rata the andesites are somewhat schistose though they still retain their original textures. In the same area alteration has been mainly due to thermal action by the granite. The zone of thermal metamorphism round the granite peripheries is not wide and alteration effects are mainly confined to a very narrow border, where dense slaty rocks are seen. North of Lela near the syenite contact almandine-spessartine has developed in the Nyanzian basalt and is undoubtedly due to thermal metamorphism by the neighbouring granite. The rhyolites show little thermal alteration in the aureoles except for a certain degree of recrystallization.

Xenoliths of basic Nyanzian rocks in the granites have been highly altered and in thin sections are seen to be granular rocks rich in hornblende. Some of the more massive roof pendants, however, are schistose and resemble amphibolites, being particularly prominent in the Andingo area.

The younger (D_2) dolerites where intrusive into the Maragoli granite of the Nyando escarpment have a strong development of micrographic intergrowth in the groundmass. Dolerites elsewhere do not show this feature to such a marked degree and it is considered that the granophyric dolerites have possibly been modified by the absorption of quartz from the granite. Other dolerites have been partly or completely epidioritized. In these the original augite remains only as a core which is enclosed by large euhedral hornblendes, whilst the groundmass is a fine-grained aggregate of quartz, felspar and epidote.

Pneumatolytic action is relatively slight and is indicated by the presence of tourmaline which occurs in an adamellite on the road north of Lela. It occurs as long needles in small aggregates or irregular growths. Apatite may also be a pneumatolytic mineral when it occurs in unusual amounts in lavas close to the granite contacts.

In the south-east part of the district the Nyanzian and Bukoban rocks have been highly epidotized, many of the rocks now being bright green epidosites consisting entirely of granular quartz and epidote. Such alteration makes it impossible to discover the nature of the original rock and some difficulty is experienced in the mapping of Nyanzian and Bukoban contacts. Epidotization is most severe near the Sondu faults, along which the metasomatic alteration has taken place.

More recent metasomatic effects have been produced by the intrusions of the Homa Mountain complex. Solutions rich in carbon dioxide have percolated the Nyanzian rocks near Homa Bay and calcitization of the feldspars and the introduction of calcite into the rocks is a common feature.

Shearing and crushing is noticeable along most of the faults and the metamorphism of the Wire Nyanzian basalts may be due partly to the proximity of the fault zones.

12.—TECTONICS

The structure of the Kisumu district (Fig. 9) is complicated by the Kavirondo Rift faults which bound a central graben occupied by the Kano plain and the Kavirondo Gulf.

Nyanzian System

The Nyanzian rocks have been involved in two periods of folding, one of post-Nyanzian age and the other of post-Kavirondian age (Hitchen, 1936, 1937; Pulfrey, 1936, 1938, 1946; Shackleton, 1946; Huddleston, 1951). In the present area near Maseno, the fold axes strike north-east to south-west, and in the Wire area, north-west to south-west, both being common trends for the post-Nyanzian orogenesis. In the Homa Bay area, however, the fold axes strike more nearly east to west which is characteristic of structures due to folding in post-Kavirondian times (see Fig. 9).

The wave-length of the folds in general varies but is usually of the order of one to two miles. Generally there appears to be a series of simple folds as in the Maseno district, but in the south where there is an anticlinorium and a synclinorium most of the folds have been overturned with the production of isoclinal folding, the limbs dipping steeply northwards, indicating that the direction of greatest pressure was probably from north to south. In the Homa Bay area the pitch of the anticlinorium is to the west whilst the Wire synclinorium pitches south-eastwards. Yet another direction is seen in the north when the pitch is gentle to the north-east. Faulting has affected the folding in the Wire area and is indicated by disturbances in the banded ironstones. The ironstones may represent the same band, the folding repeating the outcrop in various places, as at Sickli, Godnyango and Kendu. The wave-length of the major folds here would, therefore, be in the order of four miles. Dips are generally steep averaging 55° , and often steepen towards the granite margins. Near Maseno, however, dips are much more gentle averaging 30° only. Shearing is locally intense.

An interesting minor structure is seen in a metamorphosed banded tuff in the metabasalts near Doho Kasele. Here the rock has been thrown into a series of small folds the amplitude of which is about 6 inches (Fig. 1). Fracture cleavage is prominent in the bands and radiates from the crest of each fold. The rock has been veined by calcite and most of the cleavage planes and gaps between folds are filled with calcite.

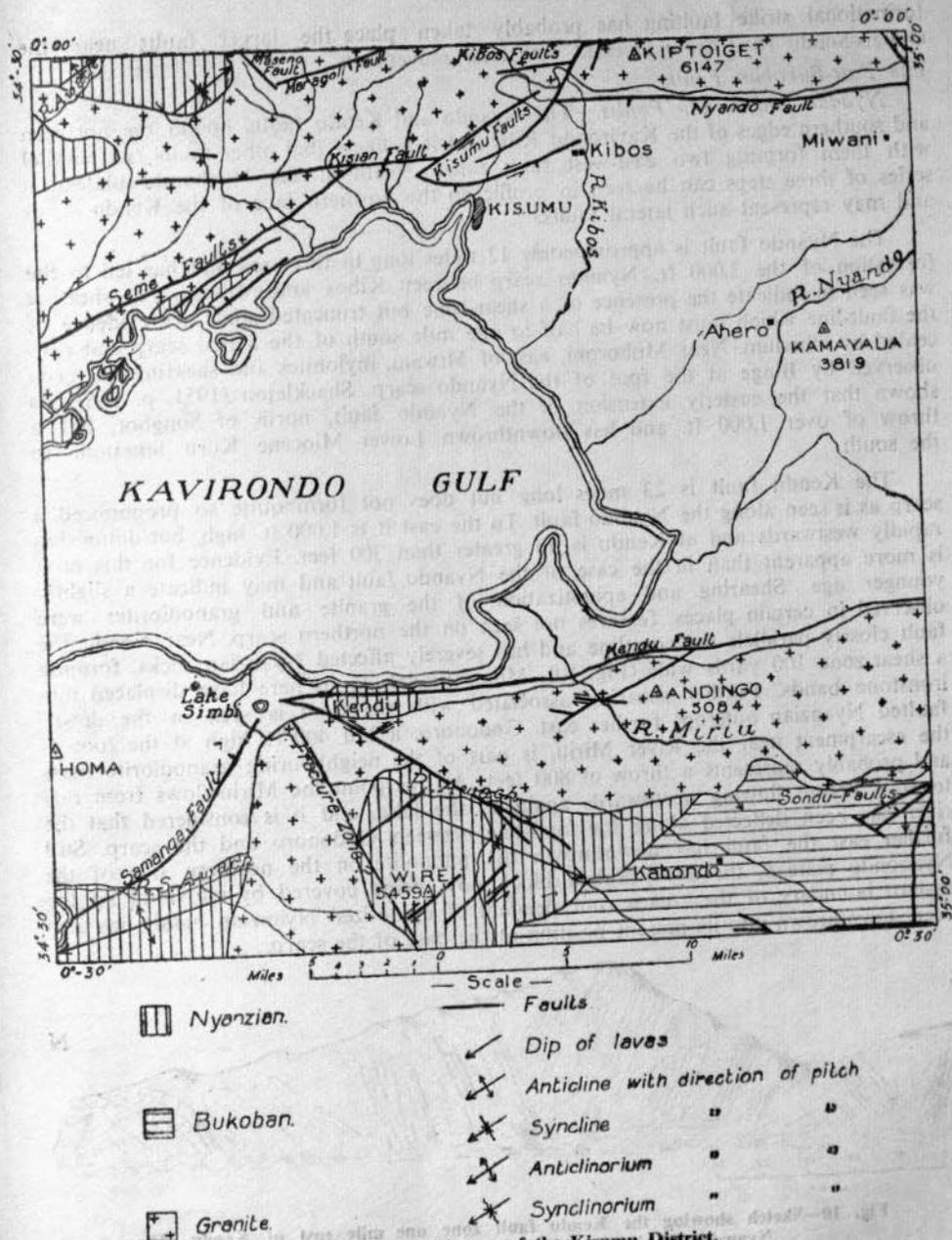


Fig. 9—Structural map of the Kisumu District.

Bukoban System

The Kisii Series does not show the complicated structures of the Nyanzian rocks, indicating that movements after the post-Kavirondian orogenesis have not been marked. Dips are gentle, generally 10° to 20° , except near faults where they steepen, and in the porphyritic basalt outcrop at Kabondo where dips of 34° were recorded. The series when laid down was probably almost flat-bedded, but horizontal compression which gave rise to shallow open folds further south (Huddleston, 1951, p. 47) also affected the present area causing the rocks to dip gently between south and south-east. Along the southern boundary an east-west fault has dropped the quartzite to a lower level than is seen in the Kisii district. Although some intra-

formational strike faulting has probably taken place the larger faults near the Oyugis-Sondu road are associated with later movements.

The Post-Bukoban Faults

Nyando and Kendu Faults.—The Nyando and Kendu faults bound the northern and southern edges of the Kavirondo Rift, and it is likely that other faults run parallel with them forming two east-west fault zones. North of the Nyabondo plateau a series of three steps can be seen in profile on the northern face of the Kendu scarp and may represent such lateral faults.

The Nyando fault is approximately 12 miles long in this area and has led to the formation of the 2,000 ft. Nyando scarp between Kibos and Miwani. No shearing was seen to indicate the presence of a shear-zone but truncated spurs are evidence of the fault-line which must now be half to one mile south of the actual scarp and concealed by alluvium. Near Muhoroni, east of Miwani, mylonites and shearing has been observed by Binge at the foot of the Nyando scarp. Shackleton (1951, p. 366) has shown that the easterly extension of the Nyando fault, north of Songhor, has a throw of over 1,000 ft. and has downthrown Lower Miocene Koru limestone to the south.

The Kendu fault is 23 miles long but does not form quite so pronounced a scarp as is seen along the Nyando fault. To the east it is 1,000 ft. high, but diminishes rapidly westwards and at Kendu is no greater than 300 feet. Evidence for this fault is more apparent than in the case of the Nyando fault and may indicate a slightly younger age. Shearing and epidotization of the granite and granodiorites were observed in certain places, features not seen on the northern scarp. Near Kendu the fault closely parallels the coastline and has severely affected Nyanzian rocks, forming a shear-zone 100 yards wide (Fig. 10). Minor branch faults here have displaced thin ironstone bands. Further shearing associated with the fault is seen in the down-faulted Nyanzian outcrops further east. Godonoro, a hill 400 ft. high at the foot of the escarpment near the River Miriu, is part of the neighbouring granodiorite mass and probably represents a throw of 800 feet. At this point the Miriu flows from east to west before flowing northwards again to the lake, and it is considered that the river has been deflected along the fault-line between Godonoro and the scarp. Still further east the fault has downthrown the phonolite on the northern side of the Nyabondo plateau, the down-faulted block now being covered by alluvium. At the eastern boundary of the area a roof pendant of epidotized Nyanzian basalt has also been downthrown into its present position at the base of the scarp.

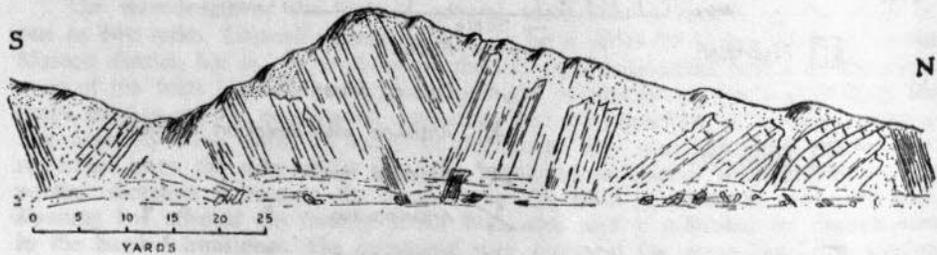


Fig. 10—Sketch showing the Kendu fault zone one mile east of Kendu. The Nyanzian rhyolite involved is highly sheared and broken.

Pegmatites have been injected along east-west directions between Andingo and Chimo near the base of the scarp and are obviously associated with the Kendu Fault. In the same area foliation in the granodiorite is most pronounced, and the granodiorite contains many Nyanzian roof pendants (now hornblende schists) which have been in many places invaded by granitic fluids in the form of lit-par-lit injections. The injections near the base of the escarpment strike approximately east-west whilst those up to 2 miles further south have been injected along a north-south direction. The facts indicate that the pegmatites and granitic fluids were injected along a fracture zone which was re-established as a zone of movement in Pleistocene times when the foliation of the granite became emphasized.

The Kendu fault extends eastwards beyond the present area but at Kendu it diminishes rapidly and no trace of the fault can be seen beyond Lake Simbi.

Associated with the Kendu fault is another, one mile north of Godonoro, which strikes north-east to south-west. The fault was seen in the field in the River Anyona where originally horizontal Pleistocene gravels dip northwards into the fault. Its extension to the north-east as shown on the map has been traced from aerial photographs. It has caused pronounced alignment of streams, which flow in steep-sided valleys.

A second fault-zone has affected the rocks 2 miles south of the main fault at Kendu. Near Kendu a series of basic dykes are cut by two strike-slip faults which have displaced them in two places and sheared the neighbouring granodiorite. The fault strikes north-west to south-east, and both in the field and on aerial photographs it can be seen that it steps the Nyanzian rhyolite-granodiorite contact. The south-eastern end of the fault consists of a zone of intense shearing which is especially noticeable on the aerial photographs, but which can also be seen in the field near the River Awach. Towards the south-east end of the major fault the direction of displacement appears to be opposite to that at the Kendu end of the fault and may indicate that more than one fault is present. The dolerite dykes 2 miles south of Kendu have been injected along zones of weakness. The most southerly dyke strikes north-west to south-east and this direction coincides with a topographical feature near Doho Kasele, the strike of a second dolerite dyke at this village, and the southwestern boundary of Wire Hill. Although no fault was traced in this area it is considered that this line represents a fracture and possibly a fault in the Wire district. It is interesting to note that the north-westerly extension of the line passes near or through Lake Simbi.

Samanga Fault.—The Samanga fault strikes north-east to south-west between Kendu and Homa Bay and is a continuation of the Lambwe fault, which is seen in the Gwasi district to the south-west of the present area. Near Homa Bay the fault is not seen but it controls the form of the southern coastline of the Bay. At Orio Pleistocene tuff dips south-eastwards at its southern outcrop whilst near Nyangwesso on the south side of the Kendu-Homa Bay road the Tertiary phonolite and underlying sediments dip north-westwards. It seems that the fault passes between these two outcrops and that six conical hills, including Samanga, Adiele, Rabuor and Niadete, formed from nephelinite and phonolitic nephelinite plugs, lie on the fault. Still further north at Lathiri the Pleistocene sandstone outcrops on either side of the fault, the north-western outcrop lying 50 ft. lower than the south-eastern. This is a measure of the throw of the fault at Lathiri and possibly indicates a normal fault with downthrow to the north-west. Like the Kendu fault the Samanga fault dies out towards Lake Simbi which may have been formed at or near their junction.

Sondu Faults.—A number of north-north-east to south-south-west faults have disturbed the quartzite and upper divisions of the Kisii Series in the south-east corner of the district. The faults are normal and have downthrown the quartzite and overlying felsites to the north-west. Shearing is locally intense and can be seen at the bridges over the River Rigari and its tributary. Two faults converge at the road near Sondu passing into a single fault which strikes north-east towards Sondu. The fault on the north-east which passes to the east of the River Rigani also converges on the same fault.

Homa Mountain Faults.—A number of small faults and broad folds in the Lower and Middle Pleistocene beds of Homa are indicative of movement until a very recent period. The faults often run east-west and it may be that the effect of the Kendu fault extends feebly west of Lake Simbi being represented by the small folds at Kimera and the minor disturbances further west. It has been shown in the section on Pleistocene deposits that slumping is a common feature of certain beds, movement being pene-contemporaneous with deposition. Recurrent movement, causing disturbance of the surfaces receiving detritus, throughout the period of Pleistocene deposition, would readily cause water-logged beds to slide, producing peculiar structures such as that seen at Rawe and Kokkoth (Fig. 4).

Kisumu Faults.—These are three parallel faults running from north-east to south-west, of which the most southerly forms the prominent wooded scarp which can be seen to the north from Kisumu township. One mile north of Base "B" the Kenya-type phonolite has been downfaulted against the Losaguta-type phonolite, and the same relationship is seen at the foot of the scarp further east. Coming down the escarpment from Nyangori there are two noticeable steps both of which may represent fault scarps. Exposures on the road, however, yield no evidence as the spheroidal weathering of the lava has concealed structures which may be present. At least one exposure, nonetheless, may indicate a fault zone, whilst a dry valley on the east side of the road is probably the trace of the central fault.

The three parallel faults form a zone which cuts the Nyando and Kisian faults. Movement along their zone has caused the Nyando block and Kisian blocks to move relative to one another, the Nyando block apparently having moved northwards and the Kisian block to the south.

Kibos Faults.—North of Kibos railway station a number of faults have affected the granite. One is an east-west fault which is represented by a prominent fault-zone at the foot of the 600-ft. scarp, where intense shearing can be seen on the water-works road and in the River Alama. The fault passes into the phonolite below Nyangori but could not be traced further west. A north-north-east to south-south-west fault which follows the line of the Kibos River cuts out the east-west fault to the east. This second fault has been traced north of the Equator together with a number of minor, east-west and north-south faults. It has sheared the granite on the westerly-facing flank of the Nyando Escarpment and a dolerite dyke near the fault has been mylonitized. The dyke indicates that the throw was about 200 ft. to the west.

Kisian Fault.—The Kisian fault is probably a normal fault striking east-west and the cause of the 500 ft. high Kisian scarp. Shearing is absent at the base of the scarp but highly epidotized granite was seen in the valley of the River Ogungu. Near the western boundary of the area the fault dies out but forms a 50 ft. scarp in the phonolite at Magwarro, whilst at the loop in the railway line one mile west of Kisian the phonolite is again seen to be faulted. Here the lavas on the northern side of the fault dip southwards at 14° whilst those on the southern downthrown side dip 7° also southwards, the fault passing between the two and giving rise to a noticeable dry valley.

Seme Faults.—The Seme faults strike north-east to south-west and are responsible for the strike of the coastline between Ndere and Kaloka. There are at least three faults all of which form 50 to 100 ft. scarps in the phonolite. These faults, like the westerly extension of the Kisian fault, have downthrown to the south-east, Nyanzian, granite and Lower Miocene rocks. The phonolite flows are aligned in a similar direction to the faults and must be connected with the faulting. The northern Seme fault forms a north-facing scarp in the phonolite and is a normal fault with the downthrow side to the north and hence the phonolite has been faulted down between it and the Kisian fault. The northern Seme fault can be traced as far west as Holo but probably continues beneath the alluvium of the Kahera valley where there is a marked north-east to south-west break in the granites, the top-forming variety on the south-east side striking in a similar direction. The central Seme fault probably continues towards Ndere where it divides a number of the islands near the coast. Both the Central and the Southern Seme faults are normal in character.

Maragoli and Maseno Faults.—The Maragoli fault crosses the entire length of the ground south of the Maragoli hills and strikes north-east to south-west. The fault has a throw of about 200 ft. at Rabuur Hill, decreasing rapidly to the west, and no evidence of it can be traced west of the Maseno road. Eastwards, where there is a well-defined scarp the throw is upwards of 1,000 ft., the Maragoli hills dominating the downthrown Tertiary plain (Plate IV (c)). As with many of the other faults of the area it is probable that other fractures run parallel to it as may be indicated by the marked steps on the southern face of New Maragoli.

Pulfrey (1946, p. 38) quotes the following paragraph regarding the nature of the Maseno fault which strikes nearly at right-angles to the Maragoli fault towards which it decreases. "The Maseno fault has also given rise to a marked escarpment and has greatly influenced the drainage of the River Nyakina. Additional evidence for the fault is presented by the granite between Lela Hill and the fault, where unusual numbers of xenoliths and hybrids are found. The area is presumed to represent the hood of the granite which has been let down and so preserved. It is probable that lateral as well as vertical movement accompanied the faulting, though it is doubtful that the apparent displacement of a mile near Maseno is a measure of the amount of lateral tear."

Miwani Faults.—The River Robo flows southwards along the north-eastern boundary of the area and its valley is probably a fault valley, as a series of five steps are present in the western side and three on the eastern indicating a fault zone. Heavy shearing is evident and the Nyanzian has been faulted with the granite.

Tectonic Chronology in Post-Bukoban Times

Regional uplift, warping and peneplanation took place long after Bukoban times and are attributable to movements and erosion mainly in Mesozoic, Tertiary, and Pleistocene times. Further south the age of the Kisii Highlands peneplain has been presumed to be Cretaceous (Shackleton, 1946, p. 52), and the surface of the down-thrown Kisii Series in the present area probably represents that old erosion plain. The area, however, is dominated by the sub-Miocene peneplain which on both sides of the Kavirondo Gulf has a gentle slope westwards of 1:150 approximately. On this surface the Lower Miocene deposits of Mariwa, Ombo, Majiwa and Kiboko were laid down in shallow lakes.* Apart from modifications produced by Pleistocene faulting the present drainage follows an east-north-east to west-south-west pattern north of the Gulf and an east-south-east to west-north-west pattern south of it. This indicates an east-west median trough along the axis of the present Rift during Tertiary times. The trough was probably shallow and followed lines of shearing and possibly faulting that existed long before the Pleistocene faulting gave rise to the graben as seen at the present day.

The Lower Miocene trough was probably bounded by faults of no great magnitude, aligned east and west, and now rejuvenated in the form of the Kisian, Kibos, Nyando and Kendu faults. During Lower Miocene times, however, a series of north-east to south-west fractures initiated lava outpourings. They were followed by other phonolite flows in the north where a large part of the sub-Miocene peneplain and the lower Miocene sediments were covered. Although erosion has removed a great deal of the lava, scattered remnants persist and two such outcrops are still to be seen on the top of the Nyando escarpment. During Pleistocene times there was renewed faulting along the fracture zones already initiated. North-east to south-west trends are represented by the Samanga, Sondu, Seme, Kisumu, Kibos and Maragoli faults, with complementary faults as seen at Maseno and Miwani. Renewed faulting along the east-west trend also took place and the graben as seen to-day was formed. The faulting can be shown in many cases to be normal which in some parts of the area has led to the development of horst and graben structures. Downthrows are however, predominantly to the south. The ancient east-west trend has been cut across by the new Pleistocene trend and a large central block north of Kisian has moved south-westwards offsetting the Kisian and Nyando fault lines which were originally concurrent.

Kent (1942, p. 130) has drawn attention to the significance of the Rawe fish beds. The formation of the Eastern Rift in central Kenya caused the headwaters of certain of the eastward-flowing streams to be diverted into the Kavirondo Gulf where *Tilapia nigra* died and were buried on the salty flats of a Lower Pleistocene lake. The Pleistocene lake did not occupy the present Kavirondo Gulf but was a distinct lake

* Kent (1944, p. 112-113) considers that there was one large lake occupying the Kavirondo Gulf and the surrounding area.

which periodically dried up at the foot of Homa Mountain. The banding of the Rawe beds suggest seasonal variations of deposition and the presence of gaylussite pseudomorphs indicates a small lake of no great extent. Following the period of faulting, invasion of the trough by the waters of Lake Victoria took place. Marked rejuvenation of the Miocene rivers with subsequent river capture, westerly tilting of the Miocene peneplain and initiation of a Pleistocene peneplain are also features of this rift-faulting. Pebbles of various rocks have been found at 4,000 ft. and represent the old beach deposits of this Pleistocene lake, but sand and gravel deposits in the streams at the base of the Nyando scarp, in the water boreholes at Miwani and in the Muhoroni-Lumbwa district indicate that the lake reached a height of approximately 4,200 feet. The invasion probably took place in Kanjeran times when it also reached its maximum height, flooding the area now represented by the Kano Plain. Since that time lake level has continually dropped until the present level was reached in Mesolithic times, probably owing to the continued downwarping of the Lake Victoria basin and the continued drainage of the Kavirondo Gulf to the west.

Brooks (1925), correlates very recent fluctuations of lake level between 1896 and 1925 with sunspot phenomena. High levels recur at intervals of about 11 years whilst the maxima for spots on the sun also have an almost identical 11-year periodicity.

Tectonic Synthesis

The formation of the rift valleys of Africa has been variously ascribed to tension, to horizontal compression, and to vertical upward movements. Kent (1944 (*b*), p. 25) considers that no hypothesis postulating tension in the crust can explain the cessation of volcanic activity but that the compressional hypothesis can explain the closing of vertical channels with the onset of lateral pressure. He also considers that there is no close relationship between the extrusions and the throw of the faults. Continuing, he comments "... although the rift faults and the volcanoes are closely associated, the size of the former bears no relation to the proximity of the latter. Thus the southern fault is prominent in the east, but becomes insignificant close to Homa Mountain and fails to reappear as a marked scarp near the large Gwasi volcanic centre. The northern scarp shows no diminution as it passes away from Tinderet volcano in the east, but forms a prominent wall of constant height from north of Koru to Kisumu and then diminishes in the neighbourhood of the phonolite flows further to the west". Incorrectly Kent mentions the lack of a marked scarp near Gwasi, there being a westerly-facing scarp to the east of this volcanic mass caused by the Lambwe valley fault. It appears that the greater lava extrusions took place at Tinderet and Gwasi whilst only minor extrusions appeared in the intervening areas, viz. between Homa and Kisumu. These areas also correspond to regions where the major rift faults are nearly at a minimum. It has also been proved that faulting took place after consolidation of the lavas which were extruded from earlier fractures zones, the forerunners of the later faults. In other words in the present district the lava flows and fractures are at a minimum towards the centre of the Kavirondo Gulf region and indicate a much closer relationship to one another than has been supposed.

It is considered that the Kisumu faults are essentially a set of strike-slip faults which have moved the Nyando and Kisian blocks relative to one another (Fig. 9). The Sondu faults merge north-eastwards in the area to the east of the present one into a strike-slip fault which has moved the Andingo and Sekuani blocks relative to one another. The relative movement in either case is the same, the easterly block having apparently moved to the north. The faults in the Anyona valley immediately west of Andingo show a reversal in direction the westerly block having apparently moved northwards.

Now, these directions indicate either a north-south compressional force or possibly a couple acting on particular blocks. A compressional force might tend to give overthrusting and this would account for the east-west trend of the Kavirondo

Gulf, representing a down-pressed graben. On the other hand if the forces acting were in the form of an anticlockwise couple there would be a tendency for an east-west trend produced by either tension cracks or a shear zone. The possible lateral shift along the Maseno fault (Pulfrey, 1946, p. 38) and that along the fault near Kendu which has faulted the basic dykes, are opposite to those already described. Such apparently contrary movements could be explained as the result of differential movement between the blocks formed by the initial, compressional movements or operation of the couple.

VI—ECONOMIC GEOLOGY

1.—GOLD

As with most other parts of Nyanza the present district has long been searched for gold. A little gold mineralization was reported by Wayland (1931, p. 41) in the Oyugis area but no economic veins were discovered. During the present survey a search of the pegmatite veins and small quartz stringers at the base of the escarpment north of Nyabondo, yielded only traces of gold. A private prospector also concentrated on this area some time later and obtained similar results.

The more favourable indications of gold are confined to the northern part of the area where gold mineralization accompanied the intrusion of the Asembo and Maragoli granites. At the extreme north-east corner of the district there is a strongly faulted and sheared zone of Nyanzian rocks similar to those that occur at Kibigori, where rich gold-bearing reefs are now being worked. The granite of the Nyando scarp contains many quartz stringers some of which yielded traces or low values of gold. By comparison with similar veins further east it is considered that they are likely to be small quartz lenses with locally good values but of little economic importance. In the north-western part of the area quartz veins in the dioritic rock at the Nyanzian contact in the upper reaches of the River Nyamgul yielded 2 dwt. gold per ton, whilst further down-stream similar values were obtained from quartz veins associated with fluorite veining. Stream gravels were panned at various points here and a showing of gold was obtained in every case. Signs of gold were found one mile north-east of the fluorite locality and just south of the Maseno-Rata road, when after heavy thunderstorms occasional fine specks of gold can be seen in the red soil. Pitting and panning of the soil failed, however, to reveal any sub-surface trace of gold. A value of 0.2 dwt. per ton was discovered in a small quartz stringer in the River Marora, south-west of Maragoli, whilst further west a pyrites-bearing basalt at the sharp right-angle bend in the railway south-west of Maseno yielded 0.6 dwt. per ton. Perhaps the most interesting discovery in the area during the survey was the gold-bearing gravels in the Seme Awach at a point nearly due south of Ramula. The assay of a grab sample of the gravel showed 19 dwt. gold per ton. An Exclusive Prospecting Licence has recently been granted to a private prospector over an area around the river south of Rata.

Brief descriptions of claims and properties that have been worked in the district are given below.

Kiboko Mine.—The mine lies on the western boundary of the area, two and three-quarter miles south-west of Ramula. It was developed by Asembo Mines Ltd., during the period 1935-42. Approximately 100 claims were prospected and 7,061 tons of ore from the mine were treated yielding gold to the value of £58,804. In 1947 and 1948 Nyanza Gold Mines registered 42 claims in the same area but allowed them to expire in 1951. During the period 1947 to June, 1951, the company developed part of the mine and 4,810 tons of ore were treated for the production of gold valued at £6,489.

The mine was examined in 1936 by Dr. W. Pulfrey of the Mines and Geological Department, whose previously unpublished plan showing the details of the three major quartz veins then being worked is reproduced as text-figure 12. The extent

of the workings in 1949 is shown in Fig. 13. The quartz veins are associated with the neighbouring granite intrusion which has invaded Nyanzian andesites and associated dolerites.

J. Maxwell and Co., Ltd.—During the period 1935 to 1940 claims were developed by this company 2 miles west of Lela. More than 3,000 tons of ore were treated and gold to the value of £3,908 produced. Mining was mainly by open cast up to 1938, rubble and quartz from short veins being milled. Later, shafts and winzes were sunk.

M. D. Hindocha pegged nine claims in 1950 in the north-eastern corner of the area where the Nyanzian rocks and the granite are severely faulted. Assays on samples supplied indicated generally low gold values. During the present survey the area was visited and a number of quartz veins discovered. They yielded gold values varying from a trace to 12 dwt. per ton, whilst a grab sample from the main vein was found to contain 112.4 dwt. gold per ton. Little work has been carried out on the prospect since July, 1950.

J. E. Coxon.—An Exclusive Prospecting Licence with effect from December, 1950, was granted in 1951 to J. E. Coxon over an area of 6.5 square miles straddling the River Awach between Rata and Ramula.

2.—OTHER MINERAL OCCURENCES

Pyrite

J. S. Coates, Government Geologist in 1909, reported on a pyrite occurrence in altered rhyolite in the Awach River north of Wire. The mineral is common in the Nyanzian lavas but is never abundant enough for economic extraction, being sparsely disseminated. A rhyolite in the Hindocha claims at Miwani, for example, carries abundant pyrite which, however, is not present in sufficient quantities to be economically workable.

Molybdenite

A little molybdenite was seen in a thin quartz vein at the rhyolite-granodiorite contact near the Kendu Pleistocene deposit.

Ironstone

Ironstones, of which assay results are quoted below, are chiefly associated with the Nyanzian rocks. The tonnages available are not great and it is unlikely that any economic use can be made of the deposits.

TABLE XX.—ANALYSES OF NYANZIAN IRONSTONES

| | 1 | 2 | 3 | 4 | 5 |
|-----------------------------------|-------|-------|-------|-------|-------|
| | % | % | % | % | % |
| Fe ₂ O ₃ .. | 55.31 | 33.36 | 64.72 | 38.91 | 25.45 |
| SiO ₂ .. | 39.10 | 62.10 | 21.00 | — | — |
| S .. | 0.10 | 0.076 | 0.09 | — | — |
| TiO ₂ .. | 0.085 | 0.12 | Trace | — | — |
| P ₂ O ₅ .. | 0.28 | 0.12 | 0.17 | — | — |

Analyst, W. P. Horne.

1. Twenty-foot band, Wire.
2. Hill east of Kendu (41/498A).
3. Band north-east of Iweche Cotton Store (41/630).
4. Average of two analyses, Sickli (41/646 and 41/647).
5. Ndere (41/947).

The analyses show a wide variation in iron content. The southern ironstones, Nos. 1-4, being richer in iron, weather a typical reddish brown colour whilst the northern variety is purple to purplish red.

One mile north of Bala near Homa Mountain there is a hill composed entirely of hematite which has a much greater iron content than the Nyanzian ores and which, if available in large quantities, would be economically workable, though mining costs would be high. The deposit has a short strike, but probably has a considerably greater extent in depth. The estimated possible ore reserve per 100 ft. depth is 10,000,000 tons.

In every stream bed on Homa Mountain black granular magnetite forms a large proportion of the sand. The proportion is, however, not greater than 20 per cent and as the sand is confined to the stream beds, the tonnage would not warrant the mining of the mineral.

Graphite

In 1930 J. S. Coates commented on a reported graphite deposit a few miles north-east of Wire Hill. He could gather no information locally regarding the deposit except that it was possibly not so good as the graphite seen just south of the present area at Oyugis. During the present survey no traces of graphite were seen.

Fluorite

In the upper reaches of the Nyamgul valley nearly 2 miles south-east of Rata a number of small veins of fluorite veining the Asembo granite were discovered during the present survey. The veins are never thicker than half an inch and consist of clear fine- to medium-grained mauve crystals associated with orange calcite, feldspar and gold. No further traces of fluorite veining were seen in the area, but its association with the gold indicates that it was due to mineralization by the granite during the late stages of intrusion.

Barytes

In gravels of Upper Pleistocene to Recent age, forming the banks of a stream one mile east of Homa Lime Works, are a number of boulders of light green crystalline barytes. The source of the barytes could not be traced but it is believed that the mineral was derived from Homa Mountain. In the Alnö district in Sweden, von Eckermann discovered and described extensive veins of barytes associated with an alkaline-carbonate complex comparable with Homa Mountain (1948, pp. 82-83). It is possible that careful prospecting of Homa may reveal veins similar to those known at Alnö.

Magnesite

A creamy white coating of magnesite covers parts of exposed surfaces of the Lathiri quartzite. It was probably deposited in a lower Pleistocene lake, the water of which was rich in magnesium and calcium derived from Homa Mountain.

Clays

Clays were examined with a view to their use in ceramics by Huddleston in the Kisumu township area in 1948-49 but were found to be calcareous. Clay from the Kano Plain is used for building and modelling. The Roman Catholic Mission at Nyabondo makes extensive use of this clay in teaching modelling to African children, whilst bricks used in the construction of the various buildings were made from clay from the same source.

Road Metal

There are abundant supplies of good road-metal in the area. The dolerites and phonolites provide excellent material but the latter is the only rock that can be quarried economically at present, being nearest to roads or the railway. At Daraja Mbili the phonolite is broken up by hand into small chips and used for road surfacing but this was not observed elsewhere.

Sand

The rivers that flow over the granites often have sandy beds. Perhaps the most interesting are the rivers south of Maragoli of which one, east of Rabuor hill, is a sand-river. It extends over three-quarters of a mile and where it joins the main valley forms a wide and prominent stretch of sand. The Kisumu division of the P.W.D. is utilizing this deposit for construction purposes.

Building Stone

The only suitable building materials in the district are the Lathiri sandstone, the Orio tuff and lateritic ironstone at Kisumu. The Lathiri sandstone and Orio tuff are being worked by Africans and used for building shops both locally and at Kisii. The sandstone is a brownish yellow, fine- to coarse-grained rock showing good bedding, the coarser material being current-bedded. It is a brittle well-jointed rock, fairly soft, easily worked and dressed but not entirely suitable for exterior work, as it weathers readily on exposure. The Orio tuff has similar characteristics but is a much darker reddish brown rock and contains mudstone intercalations. Assuming an approximate average thickness of 25 ft. for the tuff and 15 ft. for the sandstone the approximate amount of stone available in the ground is estimated to be 565,500,000 cu. ft. tons of tuff and 19,000,000 cu. ft. of sandstone. Assuming that one cubic foot is equivalent to 2.7 running feet and that wastage in extraction would amount to 60 per cent, the amount of material available is 61,000,000 running feet of tuff and 20,500,000 running feet of sandstone.

The Kisian and Maragoli granite would make an excellent ornamental stone, whilst the more compact Oyugis and Asembo granites would also be utilized as building stone in countries where building stone is scarce and masons are accustomed to dressing hard stone.

Lateritic Ironstone ("Murram")

Lateritic ironstone forms a capping on many of the phonolites and very occasionally on other rocks. Only two large deposits were seen in the area, one at the foot of the escarpment north of Kisumu and the second at the side of the railway line one mile south of Lela. The latter is already being worked by the railway for ballast but the former is untouched. The Kisumu "murram" averages about 10 ft. thick, the volume of the deposit being about 935,800,000 cu. ft., and the material may prove suitable for the construction of African housing. Smaller deposits west of Kisian are being worked by the P.W.D. for repairing roads.

Limestone

The Homa Lime Co. Ltd. began quarrying limestone at Homa Mountain in the early 1920's. The deposit worked at this time was the sheet limestone at Kanjera. Later quarrying was started on the south side of the mountain and the lime-works established at Kuwur. The limestones now quarried are carbonatites and sheet limestones, which are calcined at Kuwur, the products including lime for the East African sugar industry, building limes, lime grit and agricultural lime. Between 1943-50 41,157 tons of lime was sold which was valued at £145,192.

Various samples of sheet limestone and carbonatite have been analysed in the Mines and Geological Department, and the results are quoted below.

TABLE XXI.—ANALYSES OF SHEET LIMESTONES FROM HOMA MOUNTAIN

| | 1 | 2 | 3 | 4 |
|--------------------------------------|-------|-------|--------|--------|
| | % | % | % | % |
| SiO ₂ | 0.52 | 0.30 | 2.81 | 0.52 |
| Al ₂ O ₃ | 0.53 | 1.06 | } 0.59 | 0.28 |
| Fe ₂ O ₃ | 0.36 | 1.44 | | 0.86 |
| MgO | 0.79 | 0.10 | 1.92 | 0.07 |
| CaO | 54.32 | 52.47 | 52.06 | 55.77 |
| Na ₂ O | — | — | — | } 0.37 |
| K ₂ O | — | — | — | |
| TiO ₂ | — | 4.47 | 0.22 | — |
| P ₂ O ₅ | — | — | — | 0.08 |
| MnO | — | — | — | — |
| BaO | 0.20 | 0.09 | — | — |
| SO ₃ | — | 0.21 | — | — |
| CO ₂ | — | — | 42.70 | — |
| Loss on ignition .. | 43.07 | 39.43 | 0.26 | 42.36 |
| Moisture | — | — | — | 0.26 |
| | 99.79 | 99.57 | 100.56 | 100.64 |

Analyst, Miss A. F. R. Hitchins.

1-3. Kanjera Limestone.

4. A limestone south of Homa Mountain.

TABLE XXII.—ANALYSES OF CARBONATITES FROM HOMA MOUNTAIN

| | 1 | 2 | 3 | 4 | 5 | 6 |
|---|--------|--------|---------|--------|-------|--------|
| | % | % | % | % | % | % |
| SiO ₂ | 0.29 | 2.30 | 2.00 | 1.03 | 0.39 | 1.30 |
| Al ₂ O ₃ | 0.18 | 1.06 | — | 2.07 | 2.87 | 0.05 |
| Fe ₂ O ₃ | 0.12 | 1.44 | 1.92 | 2.28 | 1.99 | 3.91 |
| MgO | 0.80 | 0.57 | 0.23 | 0.44 | Trace | 0.16 |
| CaO | 54.48 | 52.47 | 52.51 | 52.20 | 52.59 | 51.39 |
| Alkalies | — | — | 0.037 | 0.12 | 0.19 | 0.97 |
| TiO ₂ | Nil | — | 0.57 | 0.30 | 0.28 | 0.23 |
| P ₂ O ₅ | Trace | 4.47 | — | 1.23 | n.d. | 2.90 |
| BaO | — | 0.09 | — | — | — | 0.62 |
| F | n.d. | — | 0.50 | n.d. | Trace | — |
| MnO | n.d. | — | 0.37 | 0.33 | — | — |
| S | 0.44 | — | 0.45 | — | — | — |
| SO ₃ | 0.07 | 0.21 | 0.09 | — | 40.31 | 38.68 |
| Loss on ignition .. | 43.68 | 39.43 | 41.40 | 40.00 | 0.29 | 0.21 |
| Moisture | — | — | — | 0.35 | — | — |
| | 100.06 | 102.04 | 100.077 | 100.35 | 98.91 | 100.66 |
| Less O ₂ equivalent for F | — | — | 0.22 | — | — | — |
| | 100.06 | 102.04 | 99.857 | 100.35 | 98.91 | 100.66 |

1-3. Precise locality unknown—South Homa Mountain. A. F. R. Hitchins, anal.

4. Composite sample of carbonatite exposures near Homa beacon. East African Industrial Research Board, anal.

5. Ndiru. East African Industrial Research Board, anal.

6. Carbonatite exposure 250 yards west of Ndiru. East African Industrial Research Board, anal.

3.—WATER SUPPLY

Although the area receives a heavy rainfall compared with many other parts of Kenya, the rain comes as heavy thunderstorms which are not always beneficial. Many of the rivers are permanent streams but receive the bulk of their water from neighbouring districts where rainfall is even heavier.

Most of the streams flow over solid rock or a very thin covering of alluvium and hence little reserve of water is stored in river alluvials. Exceptions do occur, as on the plain south of Maragoli, where the stream-beds during the present survey were dry. Ground water will be found relatively close to the surface on the Kano Plain on to which streams discharge but soon disappear by the absorption of the water below ground.

A large proportion of the area consists of granites most of which are strongly jointed. The joints generally dip steeply from 60° to nearly vertical, and as the success or failure of water bore-holes in such ground is often dependent on the size and number of joints, it is anticipated that the greatest success in tapping groundwater supplies in such areas will be by inclined bore-holes. Mission stations on granite rock areas are finding great difficulty in obtaining water supplies. Groundwater supplies in the Nyanzian and Bukoban rocks will also probably depend mainly on the joint systems in the lavas. The Nyanzian rocks are highly folded, so relation of topography to structure may be obscure and detailed examinations may be required before bore-holes can be sited. The Nyanzian and Bukoban basalts all show a high degree of weathering and the weathered zone may be as much as 20 ft. thick. These weathered zones are usually excellent aquifers and will account for the excellent crops which are grown on soils produced from the weathered basalts.

The Tertiary lavas are compact rocks overlying the undulating sub-Miocene surface which dips gently to the west. Aquifers are likely to be found along the contact between the lavas and the underlying rock, the intake being towards the east with a tendency for the discharge to take place towards the west.

4.—POSSIBILITIES OF THE AREA

Gold.—Although little systematic prospecting for gold has been carried out in the past round the granite margins it is thought that more detailed investigation might reveal further gold deposits near the Asembo and Maragoli granites. Streams in the north-west that were panned revealed gold values, of which one (River Awach) showed promising results. These streams flow south or south-westwards, meandering across large stretches of alluvium near the lake. Any gold which is carried by them is likely to be dropped in such areas and prospecting there may prove fruitful.

Other Economic Deposits.—Vast reserves of various types of road metal are present and may prove valuable in the future development of this part of the country. Building stone and limestone are present in limited quantities but are not extensive, insufficient of the latter of suitable chemical composition being available for a cement industry.

Hydro-electricity.—The River Miriu is a permanent river and the largest in the area. After flowing across the sub-Miocene peneplain it plunges over the Kendu scarp, having a drop of nearly 1,000 feet. It is thought that this river could be utilized for the generation of electricity. Maximum head could be obtained by diverting part of the flow over the escarpment slightly east of the area at Sondu. The water thus diverted would also help to irrigate the Kano Plain which is devoid of water throughout a large part of the year.

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APPENDIX—BOREHOLE LOGS

(ADAPTED FROM RECORDS OF THE PUBLIC WORKS DEPARTMENT)

Borehole C.46—Kisumu Township

Total depth—420 feet. Depth from surface at which water was struck—50 gallons per hour at 70 feet. Depth from surface to which water rises—93 feet. Estimated yield per 24 hours—2,400 gallons.

Depth in Feet

0- 10
10- 58
58- 65
65-145
145-206
206-216
216-292
292-409
409-420

Lithology

Laterite
Clay
Lava
Old surface deposits
Lava
Old surface deposits
Lava
Old surface deposits
Lava

Borehole C.275—Kisumu Township

Total depth—224 feet. Depth from surface at which water was struck—135 gallons per hour at 170 feet; remainder from 220 feet. Depth from surface to which water rises—32 feet. Estimated yield per 24 hours—4,800 gallons.

Depth in Feet

0-157
157-215
215-224

Lithology

Clay and boulders
Lava
Clay and boulders

Borehole C.874—Miwani

Total depth—300 feet. Depth from surface to which water rises—59 feet. Estimated yield per 24 hours—117,600 gallons.

Depth in Feet

0- 5
5- 20
20- 50
50- 99
99-145
145-149

Lithology

Black cotton soil
Buff-coloured clay containing lava and weathered granite fragments
Pink, coarse sandy granitic detritus with scattered lava fragments
Drab clay (granitic detritus and lava fragments)—Inland sediments
Mottled grey and white detritus composed of coarse lava and granitic fragments
Dark clay (granitic detritus) and large, well-rounded lava pebbles

Borehole C.81—Miwani

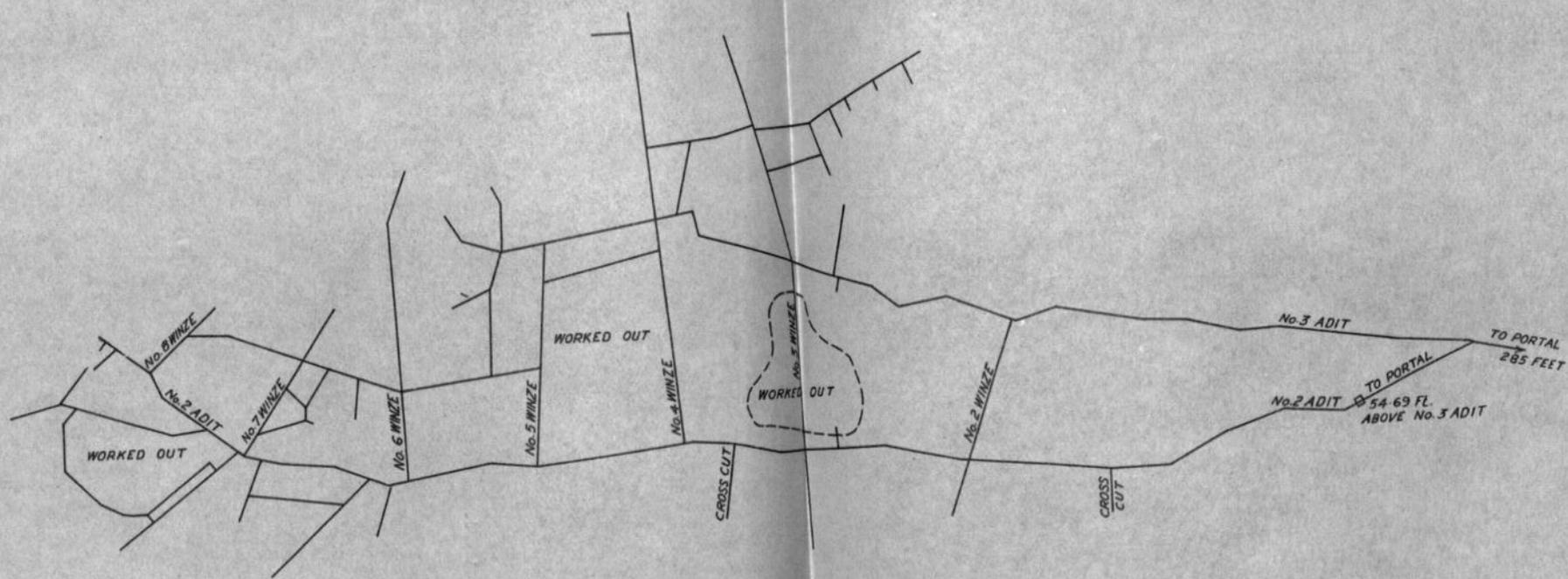
Total depth—470 feet 3 inches. Depth from surface at which water was struck—70 feet and 416 feet. Depth from surface to which water rises—8 feet. Estimated yield per 24 hours—40,000 gallons.

| <i>Depth in Feet</i> | <i>Lithology</i> |
|----------------------|--------------------------------|
| 0 - 5 | Black cotton soil |
| 5 - 94 | Lake sediments |
| 94 -100 | Granite boulder |
| 100 -103 | Lava |
| 103 -108 | Hard clay and sand |
| 108 -113 | Softer clay |
| 113 -119½ | Harder clay |
| 119½-275 | Lake sediments |
| 275 -279½ | Sediments |
| 279½-371 | Lake sediments and yellow clay |
| 371 -384 | Schist |
| 384 -445 | Yellow clay |
| 445 -445½ | Schist |
| 445½-470½ | Granite |

Borehole 118—Miwani

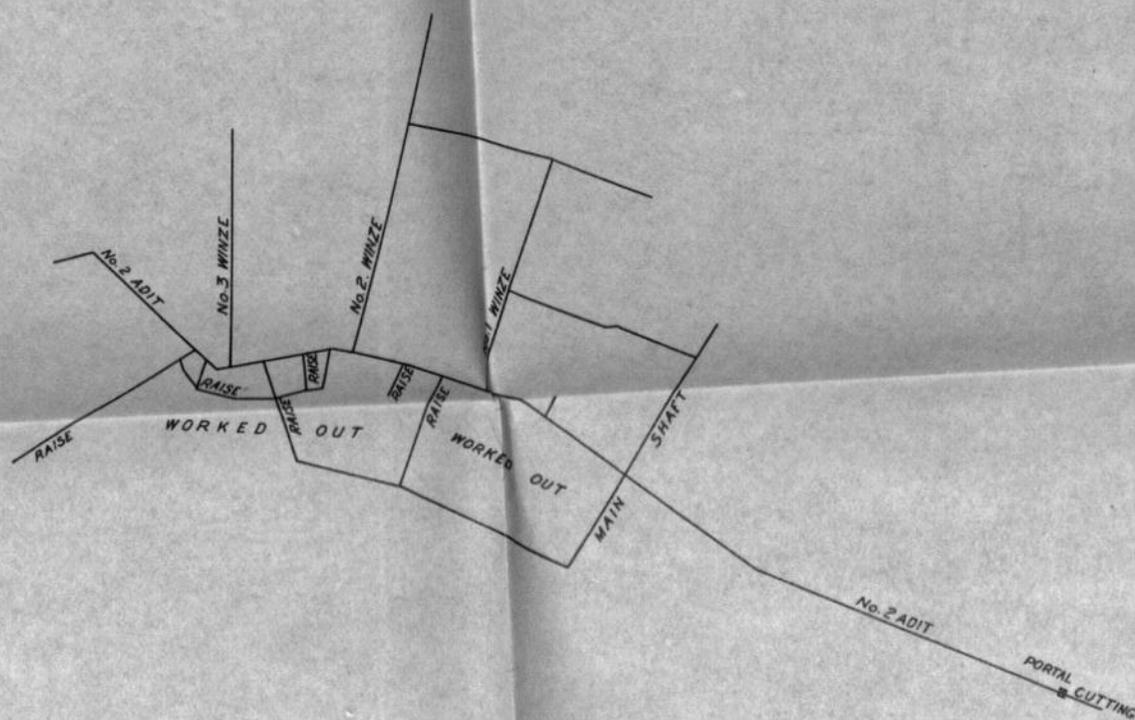
Total depth—525 feet. Depth from surface at which water was struck—100 feet and increasing in depth. Depth from surface to which water rises—70 feet. Estimated yield per 24 hours—57,600 gallons.

| <i>Depth in Feet</i> | <i>Lithology</i> |
|----------------------|-------------------|
| 0- 8 | Black cotton soil |
| 8-525 | Lake sediments |



No. 2 VEIN

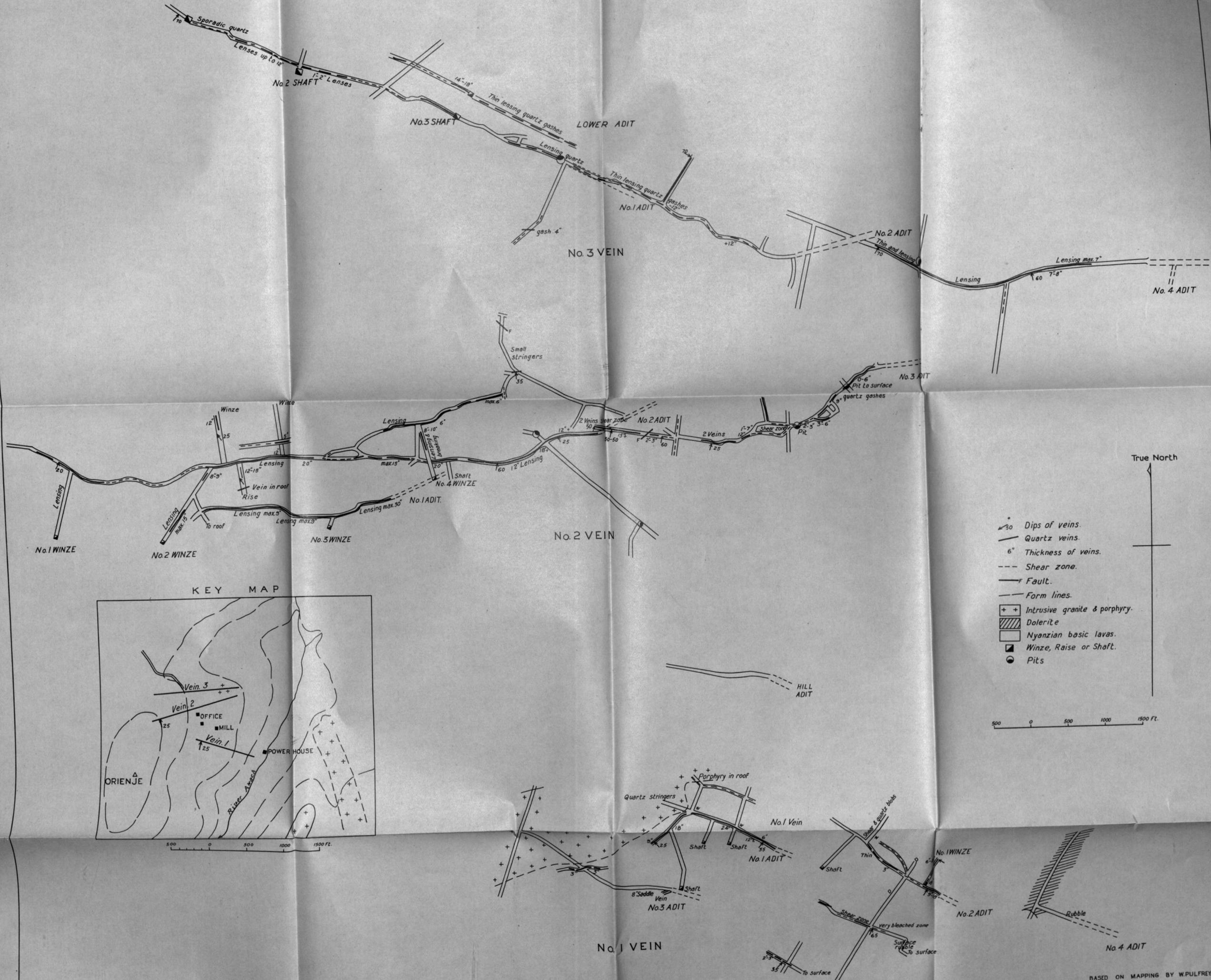
TRUE NORTH



No. 1 VEIN

ADAPTED FROM MINE PLAN BY D.K. WILLIAMS.

Fig. 13.—Mine Plan of Veins 1 and 2, Kiboko Mine, 1939



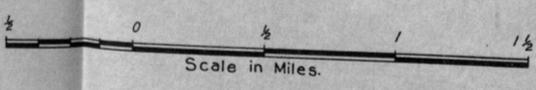
Figs. 12.—Geological Plan of Veins 1, 2 and 3 Kiboko Mine, 1936

KAVIRONDO GULF



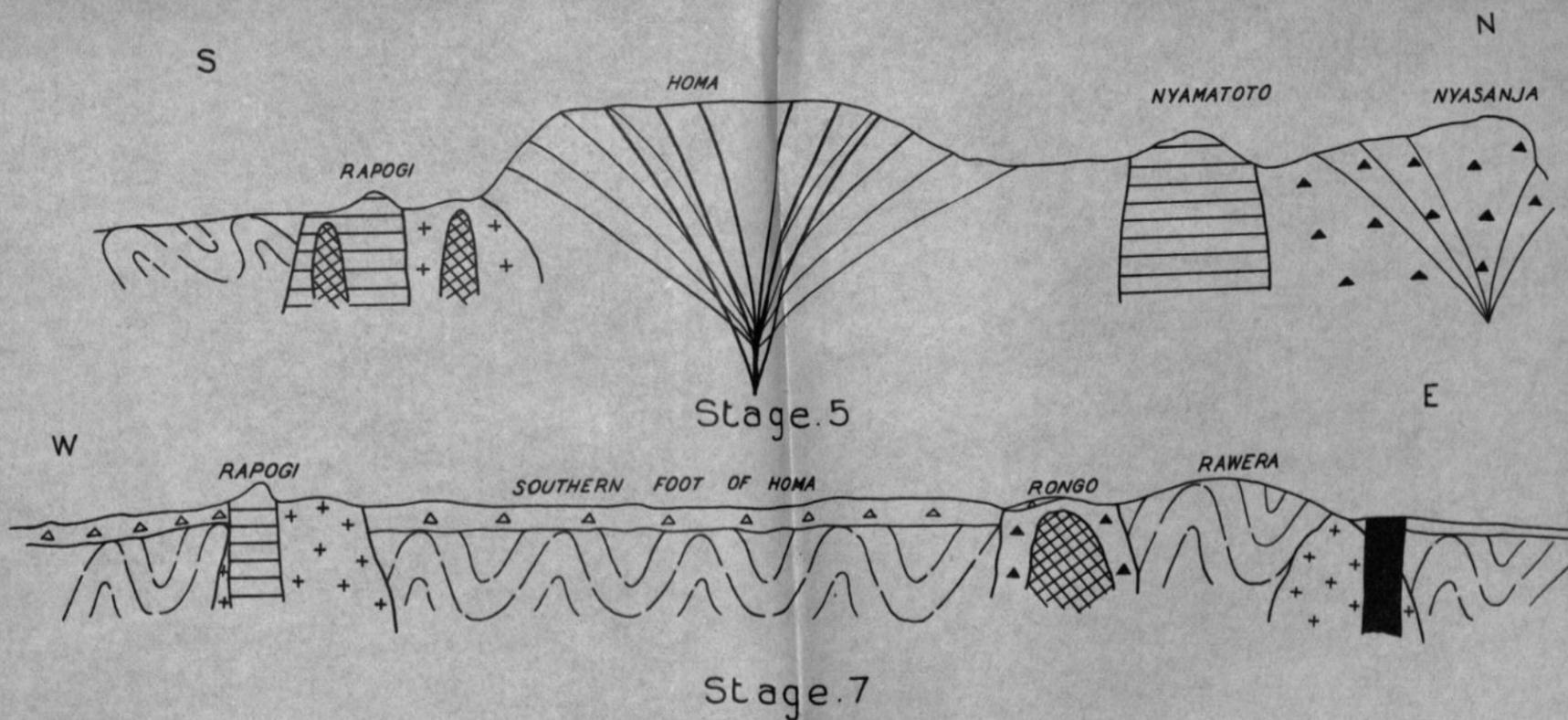
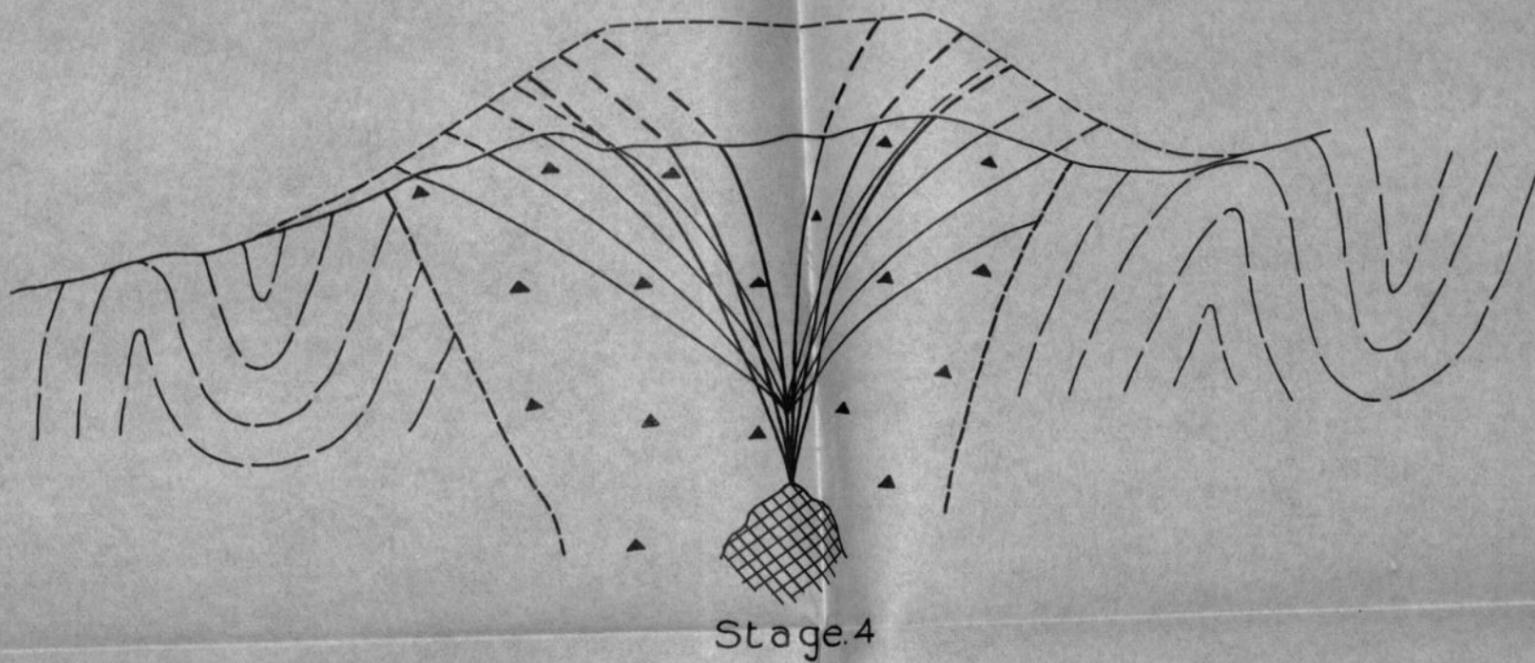
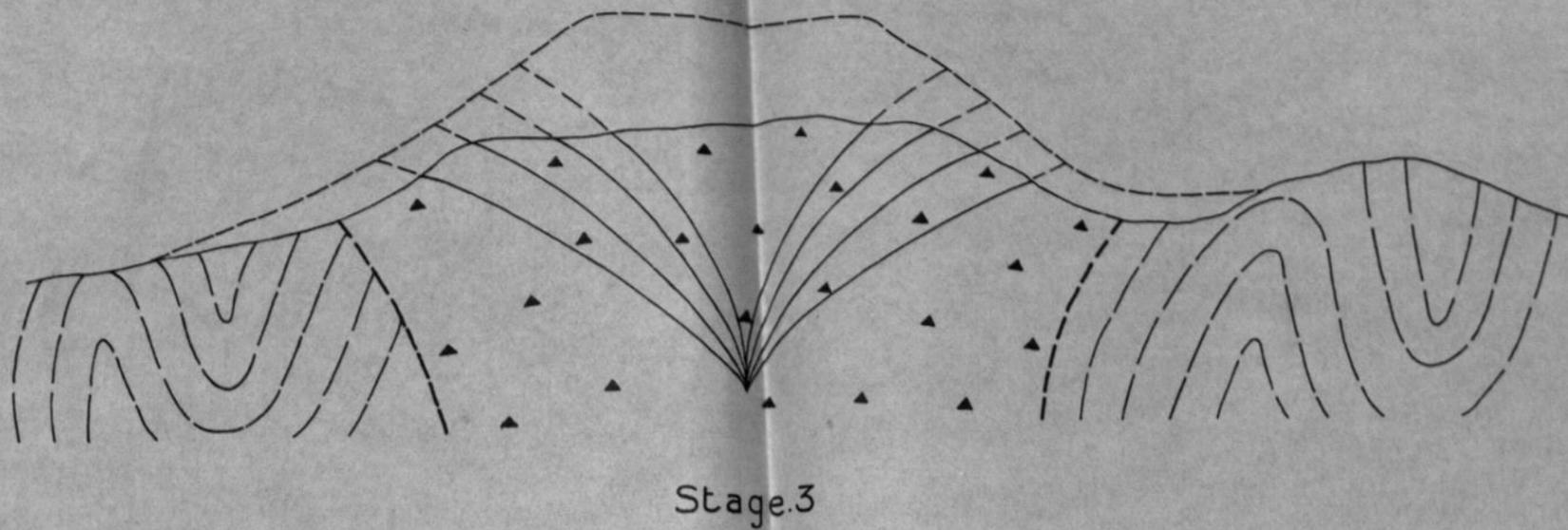
- Alluvium with Shell-Mounds (Qsm).
- Pleistocene to Recent Limestone sheets.
- Upper Pleistocene to Recent Soils & Gravels.
- Middle Pleistocene beds.
- Kanjera beds.
- Rawa beds.
- Kanam beds.
- Sövite & Alvikite cone-sheets & dykes & plugs.
- Agglomerate.
- Sövite Breccia.
- Ijolite & Urtite.
- Tertiary Volcanics. { Tvp-Phonolite.
Tvpn-Phonolitic nephelinite
- Nyanzian.
- Dykes. { nP-Phonolite. npN-Phonolitic nephelinite.
nmN-Melilite nephelinite
ni-Micro-ijolite nu-Micro-urtite
- Hematite.
- Quartz Vein (wq) & Quartz-Porphry Dyke (qp)

- Dip of cone-sheets & beds.
- Horizontal beds.
- Dip of Lava.
- Faults.
- Fossiliferous localities.
- Hot Springs.
- Swamps.
- Roads.
- Tracks.
- Trigonometrical point.
- Form Lines at 200 ft. intervals.
- Houses and Schools.



HOMA BAY

Fig. 11.—Geological Map of Homa Mountain



Sövite.

Agglomerate.

Sövite Breccia.

Ijollte.

Phonolitic nephelinite plug.

Nyanzian.

Phonolitic nephelinite dyke.

Sövite Breccia cone-sheets.

Alvikite cone-sheets.

Fig. 6.—Diagrams illustrating the sequence of events at Homa Mountain

STAGE 3.—INTRUSIONS OF SOVITE BRECCIA ALONG CONE-SHEET FRACTURES.

STAGE 4.—INTRUSION OF ALVIKITE ALONG CONE-SHEET FRACTURES

STAGE 5.—FORMATION OF SUBSIDIARY CENTRES AS AT RAPOGI AND NYASANJA AND THE FORMATION OF PHONOLITIC NEPHELINE PLUGS (NYAMATOTO AND RAPOGI).

STAGE 7.—FORMATION OF CONCENTRIC DYKES — PHONOLITIC NEPHELINE AT RAWERA