Report No. 26



COLONY AND PROTECTORATE OF KENYA

GEOLOGICAL SURVEY OF KENYA

GEOLOGY
OF THE
BRODERICK FALLS AREA

DEGREE SHEET 33, N.E. QUADRANT

(with coloured geological map)

by

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FOREWORD

The Broderick Falls area of Kenya, though it has so far attracted little attention from prospectors, is geologically the northern continuation of the Kakamega goldfield. Mr. Gibson, while mapping the area for the purposes of the present report, was unable to discover any indications that the gold mineralization, so prominent adjacent to large granite masses in areas further south, extends along the northern margin of the Kitosh granite batholith. As his work, however, was necessarily carried out in a reconnaissance style, so that little time was available for detailed examination of any particular part of the area, the absence of gold deposits is not necessarily proved. It is hoped that the provision of a geological map, showing the ground in which the occurrence of gold veins is likely, will be of assistance in future prospecting.

With the mapping of the Broderick Falls area the geological survey of a north-south strip of country, a little over 30 miles in width, extending from the Tanganyika border to the country north of Mount Elgon has been completed. The publication of a report on the Kakamega quarter-degree sheet in the near future will complete a series of six reports describing the geology of the strip.

The Broderick Falls area is particularly important from the geological viewpoint, in so far as it yields evidence of the relative age of the Basement, Nyanzian and Kavirondian systems, which are the three most ancient groups of rocks known in the Colony. A few years ago Professor Arthur Holmes, of Edinburgh University, propounded a new theory on the ages of the ancient rocks of Africa. The result of his theory was that the succession of rocks established in Kenya over the last 20 years would have to be inverted, the oldest rocks becoming the youngest. The theory was a challenge to doctrinaire opinion and an incentive to the search for new facts. Mr. Gibson's research at Broderick Falls indicates that the work of his few predecessors, who built up the first account of the geological history of the Colony was, in fact, not ill-founded. Corroboration will be required from other areas and from other lines of evidence, but it is gratifying that at this early stage evidence has been produced to support the foundations of pre-Cambrian stratigraphical geology that had already been established in the country.

Nairobi,
31st October, 1952.

WILLIAM PULFREY,
Chief Geologist.

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MAP

Geological Map of the Broderick Falls Area (Degree Sheet 33 N.E. Quadrant) Scale 1:125,000 .. At end

ABSTRACT

The report describes an area in western Kenya of about 1,250 square miles extent, bounded by parallels 0° 30′ N. and 1° 00′ N. and longitudes 34° 30′ E. and 35° 00′ E. The main physiographic units of the area are, (*a*) the southern and eastern slopes of Mount Elgon; (*b*) the Nandi escarpment; (*c*) the Nandi highlands; (*d*) the Uasin Gishu plateau; and (*e*) a gently sloping peneplained surface of Basement System and Kavirondian rocks, with granite tors in places, and inselbergs and ranges standing above the general level in the Basement terrain. An account of various peneplain bevels is given.

The rocks exposed in the area include: (1) biotite gneisses, hornblende-biotite gneisses, migmatites, quartzites, and intrusives of the Basement System; (2) Nyanzian rhyolites; (3) Kavirondian sediments; (4) various post-Kavirondian granitic and granodioritic intrusives; (5) Tertiary volcanics of Mount Elgon and the Uasin Gishu plateau; (6) minor intrusives of varying ages; and (7) late Tertiary and Pleistocene gravels and other deposits.

A general description of the various rock types is given and their structures and relative ages discussed.

GEOLOGY OF THE BRODERICK FALLS AREA

I—INTRODUCTION

The Broderick Falls area as defined for this report is the north-east quarter of Degree Sheet 33 (Kenya), bounded by latitudes 0° 30′ N. and 1° 00′ N. and by longitudes 34° 30′ E. and 35° 00′ E., and is some 1,250 square miles in extent. It includes part of Trans Nzoia, Uasin Gishu, Nandi, and North Nyanza administrative districts. With the exception of the Mount Elgon Forest Reserve the portion of North Nyanza district lying within the area is entirely native reserve, forming part of the Kavirondo Native Land Unit. The parts of Trans Nzoia and Uasin Gishu within the area consist wholly of European farms, whilst the portion of Nandi district forms part of the Nandi Native Land Unit.

The area was surveyed in reconnaissance style between December, 1950, and June, 1951, as part of the programme for the primary mapping of the Colony. Particular attention was paid to a search for deposits of economic value, but the area apparently holds little promise of development in this direction.

1. Nature of the Country

Agriculturally the area may be divided into five main units as follows:—

(1) The part of North Nyanza lying north of the Kimilili–Chuele road.

(2) The part of North Nyanza lying south of the Kimilili–Chuele road.

(3) The slopes of Mount Elgon.

(4) The farming lands of Trans Nzoia and Uasin Gishu.

(5) The Nandi Native Land Unit.

The first is one of the most densely populated and intensively cultivated areas of North Nyanza. An accurate estimation of the population is not possible but the Kimilili Location probably contains about 60,000 persons in an area of roughly 200 square miles, south of Mount Elgon and bounded by the Trans Nzoia district boundary and the Nzoia River. The intensive cultivation is due mainly to the presence of a dark, rich soil derived from the breakdown of the rocks of the Elgon Volcanic Series, aided by a moderately heavy rainfall, fairly well distributed throughout the year. Every available inch of ground is utilized to the best advantage, due in a large measure to the assistance and guidance of the Agricultural Betterment Fund. Crops include maize, matama, wimbi, bananas, coffee, sugar cane and vegetables. Sirisia lies on the eastern edge of the cotton producing area. Large herds of cattle are also maintained. Increasing use is being made of mechanical methods of cultivation, and as a large number of earth dams have been constructed by the North Nyanza Dam Construction Unit there is no appreciable shortage of water in the area. Slopes are terraced wherever necessary and no serious example of soil erosion or shift was seen anywhere.

The second unit provides a marked contrast and is essentially devoted to livestock farming, large herds of oxen and sheep being maintained. Cultivation is confined to small areas immediately surrounding the native huts, the main crops being maize and wimbi. Elsewhere much of the original bush remains, as in the vicinity of Broderick Falls. This part of the area is moderately well populated, except in the west, to the south of Sirisia, where the land is only slightly developed, due to its highly dissected nature, the less fertile sandy soil and poor water supplies.

The lower slopes of Mount Elgon grade into the first area discussed and are similarly well cultivated. Above the cliffs bounding the mountain the slopes are clothed with dense forest and cut by steep-sided river valleys. Here there is a small, scattered population which cultivates clearings and maintains small herds of cattle. The soil cover is usually thin, but where it does occur in workable depth it is good and almost permanently moist. On the higher slopes the inhabitants are mainly Wandorobo.

The fourth unit consists of European farming lands and is intensively cultivated. Large herds of dairly cattle are kept and crops consist of maize, coffee and passion fruit. On the eastern slopes of Mount Elgon the climate and soil are suitable for the growing of wheat. There are two large sisal estates in the area, one at Lugari and the other west of Kitale, and wattle plantations are maintained on the western edge of the Uasin Gishu plateau.

The last unit lies south of the line joining Bwanga T.S.* and Osorongai T.S. and is a deeply dissected, hilly locality, rising to over 7,000 ft. It is quite densely populated by the Nandi who maintain large herds of cattle. In spite of the nature of the country large areas are cultivated, little regard being shown for soil conservation. Terracing is rare even on the steepest slopes and, unless preventative measures are taken, loss by soil-wash will soon become a serious matter.

2. Climate

Rainfall over the area is moderately heavy as shown by the following representative figures for 1950. Stations 9, 11 and 12 lie a very short distance outside the area to the north-east, north and east respectively.

Station	Altitude in feet	Total inches, 1950	Number of rainy days, 1950	Annual average inches	Years recorded
1. Kavujai Dispensary	5,250	53·39	147	52·17	10
2. Kimilili Dispensary	5,500	53·33	165	57·40	5
3. Sangalo Veterinary Station ..	4,500	53·65	159	60·21	17
4. Kitale, Cotton Farm	6,700	47·29	160	51·11	8
5. Kitale, Gloucester Vale Estate	6,000	?	?	50·51	35
6. Lugari, Lugari, Ltd.	5,300	54·99	131	56·47	18
7. Lugari Railway Station ..	5,199	60·47	125	57·46	18
8. Turbo Valley, Murogosi Estate	6,150	46·18	112	51·11	25
9. Kitale, District Office	6,200	40·25	153	45·26	28
10. Kitale, Meteorological Station	6,300	?	?	46·74	3
11. Endebess, Mt. Elgon Forest Station	7,300	42·25	147	47·05	20
12. Turbo, Farmers' Co-op. Ltd. ..	5,935	62·84	114	48·94	12

Little significant variation is shown by these figures apart from a suggested decrease in the number of rainy days to the east of the Nandi escarpment, as indicated by stations 6, 7, 8 and 12. The maximum intensity of rainfall over the area appears to be in the months of April and May. Localized showers continue throughout the "dry" season.

The climate is on the whole pleasant, the average daily temperature showing a slight increase to the south-west with decreasing elevation.

3. Communications and Settlement

As the map indicates, the area is exceptionally well served by roads and tracks. All the roads are of murram, those of Trans Nzoia being very good and well maintained. The Trans Nzoia roads are normally closed to lorry and tractor traffic except by special permit during the wet season, in an endeavour to preserve the surfaces. The roads in the remainder of the area are of poor quality murram and badly drained. They deteriorate rapidly at the onset of the rains due to the heavy lorry and native bus traffic, and chains are necessary over long stretches.

* T.S. = Trigonometrical Station.

Native bus services run on all the main roads. The main Kenya–Uganda railway line runs through the area, with stations at Kipkarren River, Lugari, Broderick Falls and Bungoma. The first has telegraphic facilities only, the remainder both postal and telegraphic facilities.

The outskirts of Kitale lie in the north-eastern corner of the area and garage, shopping and hotel facilities are available. There is one good Indian shop catering for European needs and supplying petrol, at Kirk's Bridge Trading Centre. Kimilili, Bungoma and Broderick Falls all have shops at which most requirements may be obtained, and petrol is obtainable at all of them. There are small native shops at Chuele, Musikhu, Sirisia and Kamakuiwa.

Bungoma is in a rapid state of development as an administrative centre and a District Officer is in residence. A large native hospital has been built. There are police stations with European Inspectors at Bungoma, Kimilili and Kiminini, and police posts at Naitiri, Lugari and Crompton's Police Post. Government rest-houses or District Commissioner's camps are situated at Sirisia, Kimilili, Kaptama and Chepteravoi, and another is about to be built at Broderick Falls.

Not all farm access roads or tracks are shown on the map, nor have all farmhouses been represented.

4. Maps

The topography of the geological map is based on G.S.G.S. 1764, Sheet $\frac{\text{North A–36,}}{\text{W}}$ 1913, with modification throughout based on aerial photographs. The form-lines are not accurate and serve only to show the general shape of the ground and its elevation. The topography and drainage of Mount Elgon have been sketched in with the aid of aerial photographs where available. The position of the Mount Elgon Forest Reserve Boundary has been taken in part from cadastral sheet $\frac{\text{North A–36}}{\text{WIIa}}$ and in part from aerial photographs.

Locality names have been taken from G.S.G.S. 1764 and from cadastral sheets $\frac{\text{North A–36}}{\text{WIIa, b, c and d}}$, and as many local native names as possible have been added to features not previously named.

The Broderick Falls–Bungoma road is of recent construction and as it does not appear on the aerial photographs, it was surveyed by compass, range-finder and cyclometer. Similarly, part of the Kimilili–Chuele road and the tracks to the north, for which there was not air cover, were surveyed by compass and range-finder.

The mapping of the geology was done directly on to aerial photographs and thence transferred to field sheets by reduction.

Acknowledgments

Much assistance, information and advice obtained from the District Officer at Bungoma, and the Agricultural Officer at Kimilili, the late E. J. Paulson, is gratefully acknowledged, and thanks are tendered to the European farmers of the area, many of whom spent considerable time in pointing out the locations of the few outcrops on their land.

II—PREVIOUS GEOLOGICAL WORK

The first mention of the area was made by G. F. Scott Elliot and J. W. Gregory (1895, page 677)* who recorded the existence of a series of ancient sedimentary rocks in Nyanza and gave an account of the succession on the Nandi escarpment.

Prior (1903) described the petrology of the Basement System gneissess and the Uasin Gishu phonolites. He noted the occurrence of diabases in Kabras (the area surrounding Broderick Falls village). Gregory mentioned parts of the area and suggested an Upper Cretaceous age for the Uasin Gishu phonolite (1921, page 115). For the formation of the latter he favoured the overlapping of a series of flows from vents rather than fissure eruptions, since it was to be expected that some of the fissures, if they existed, would by now have been exposed by erosion (op. cit., page 100). He stated that granite, gneiss and schist form the Nandi scarp and that to the east these rocks are covered by the volcanic rocks of the Uasin Gishu plateau (op. cit., page 120).

Ödman (1929, page 80) noted that along the Nandi fault-line the rocks are "locally turned into gneisses, schists, and even mylonites", and that in the area of the Broderick Falls "a series of supra-crustal rocks intruded by granites" are exposed along with "lavas and clastic rocks". He also noted a muscovite-bearing quartzite outcropping on the east side of Mount Elgon in two places about 30 kilometres apart, probably part of the same belt as that seen near Round T.S.

Sir Albert Kitson (1934, page 3) noted that North Kavirondo (now North Nyanza) consists mainly of granites with engulfed strips of sediments. His traverse notes applicable to that part of North Kavirondo dealt with in this report were not published, as it was at that time held under an Exclusive Prospecting Licence by Tanganyika Concessions, Ltd.

Hitchen (1937, page 6) considered the rise of the Nandi escarpment to have occurred in comparatively recent geological times, and that movements associated with it resulted in the westward tilt of the country towards Lake Victoria.

Shackleton (1944) described the geology of the Malakisi area and visited Broderick Falls. He suggested that the faulting associated with the Nandi escarpment was not so simple as hitherto supposed, and found what he believed to be altered Kavirondian sediments within the fault zone. He noted the presence of most of the formations described in this report, and postulated a pre-Cambrian age for the faulting which produced the Nandi escarpment.

Holmes (1951), discussing the sequence of pre-Cambrian orogenic belts in South and Central Africa, and applying the principle of orogenic cut-offs as a means of dating, suggested that the Kavirondian and Nyanzian Systems are older than the Basement System.

Shackleton (1951) discussed the rocks of the Nandi fault area, noting their strong deformation, and the abundance of epidote. He described (op. cit., page 348) a garnetiferous hypersthene-bearing meta-dolerite and compared it with others found in the Nanyuki–Maralal area (Shackleton, 1946B, page 19). He noted that the foliation strike of the Basement System is generally somewhat west of north with steep dips to the east, and that in one part of the area the strike "swings sharply round almost at right-angles as though the rocks were bent into a large fold". In discussing the nature of the Nandi fault he suggested that it is a reversed fault dipping steeply to the east, on the evidence of the greater extent of mylonites to the east of the fault-line than to the west. On the subject of peneplains (1951, page 377) he noted the fact that the Mount Elgon volcanic rocks appear to rest on the sub-Miocene surface which continues to the south-west as a regular slope. He maintained that the Kitale peneplain (Dixey, 1948, page 26) does not exist as a separate entity, but that the even slope of the sub-Miocene peneplain continues unbroken up to Kitale. He recognized that the Uasin Gishu phonolites rest on the sub-Miocene surface, and that a higher erosion surface is represented by the summit on the ridge of gneisses east of the Nandi escarpment.

* References are quoted on pages 43–4.

Searle (1952) recognized two principal peneplain surfaces, the higher and older occurring at 6,200 ft. (the Kitale peneplain), and the younger at 4,300 ft. extending from the base of the Trans Nzoia escarpment northwards and westwards into Uganda. The older peneplain is regarded as being pre-Miocene in age and the younger mid-Tertiary.

To turn to the geology of Mount Elgon, Hobley published a paper (1897) on a journey round Mount Elgon, in which he expressed an opinion that the Elgon Caves were due to natural causes and were excavated by water. He made further reference to them in a paper published in 1919 and considered that they have been excavated in relatively incoherent beds of volcanic ash and tuff. Sir Harry Johnston (1902) noted that they occur always in the same material at the foot of high precipices and usually under waterfalls which screen the entrances. He suggested that they were made by former underground streams, the channels of which became blocked, and were subsequently enlarged by human agency.

Prior (1903) described the petrology of the Mount Elgon nephelinites and other volcanic rocks. Wayland (1921, page 10) named the volcanic rocks of Mount Elgon the Mount Elgon Series and pointed out the presence of an impersistant sedimentary horizon separating it from the Basement System. In a later paper (1928, page 40) he noted the presence of fossil wood in the Mount Elgon Series, and drew the inference that forests clothed the slopes of the volcano during a period of quiescence, later to be overwhelmed during a renewal of activity. A report of Bowen's observations on Mount Elgon appears in a later Annual Report of the Uganda Geological Survey (1930, page 7).

Gregory (1921, page 115) suggested a Pliocene age for Mount Elgon, and stated his belief that the caves were partly made by stream action under the glacial conditions of the Lower Pleistocene (op. cit., page 206).

Ödman discussed the volcanic rocks of Mount Elgon (1930) and concluded that at the time of commencement of activity the Basement surface possessed more or less its present characters. He thought that the volcanics of Mount Elgon never spread very far to the south or east beyond their present position. The petrological characters of the lavas were described. In the same year Davies named the sediments underlying the Elgon Volcanics the Bugishu Series (1931, page 11) and divided it into a lower Sedimentary and an upper Volcanic Group. Scott (1932, page 6) noted the presence of lake beds of volcanic muds showing regular ripple marks on the south side of Mount Elgon. Davies later (1934, page 69) described the Middle Tertiary Bugishu topography and the erosion surfaces around Mount Elgon. He ascribed the main Elgon activity to the Upper Pliocene.

Moysey (1935) excavated a cave floor in the base of the Mount Elgon Series, west of Round T.S., and postulated human habitation from the post-Makalian dry period almost up to historic times. Shackleton (1944) examined the southern side of Mount Elgon and noted the occurrence of the Bugishu Series in several localities. He dated the peneplain on which the Mount Elgon Series rests as sub-Miocene and considered that its surface was not disrupted by the Nandi fault-line.

King (1949) correlated the volcanic activity of Napak, Uganda, with that of Mount Elgon and discussed the nature of the pre-volcanic terrain. A sedimentary series comparable with the Bugishu Series was found to underlie the Napak volcanics. Searle (1952) dealt extensively with the topography, history and petrology of Mount Elgon and the Mount Elgon Volcanic Series, and also discussed the Elgon caves and their mode of formation.

Geological reports by Murray-Hughes (1933), Hitchen (1936 and 1937), Pulfrey (1936, 1945 and 1946), Shackleton (1946A), Dixey (1948) and Huddleston (1951), describing rock suites and structures similar to those found in the present area have been consulted for purposes of comparison and correlation.

III—PHYSIOGRAPHY

1. Topography

The main topographic divisions of the area are as follows:—

(*a*) The southern and eastern slopes of Mount Elgon.

(*b*) The Nandi escarpment.

(*c*) The Nandi highlands.

(*d*) The Uasin Gishu Plateau.

(*e*) The gently sloping peneplained surface south of Elgon and west of the Nandi escarpment.

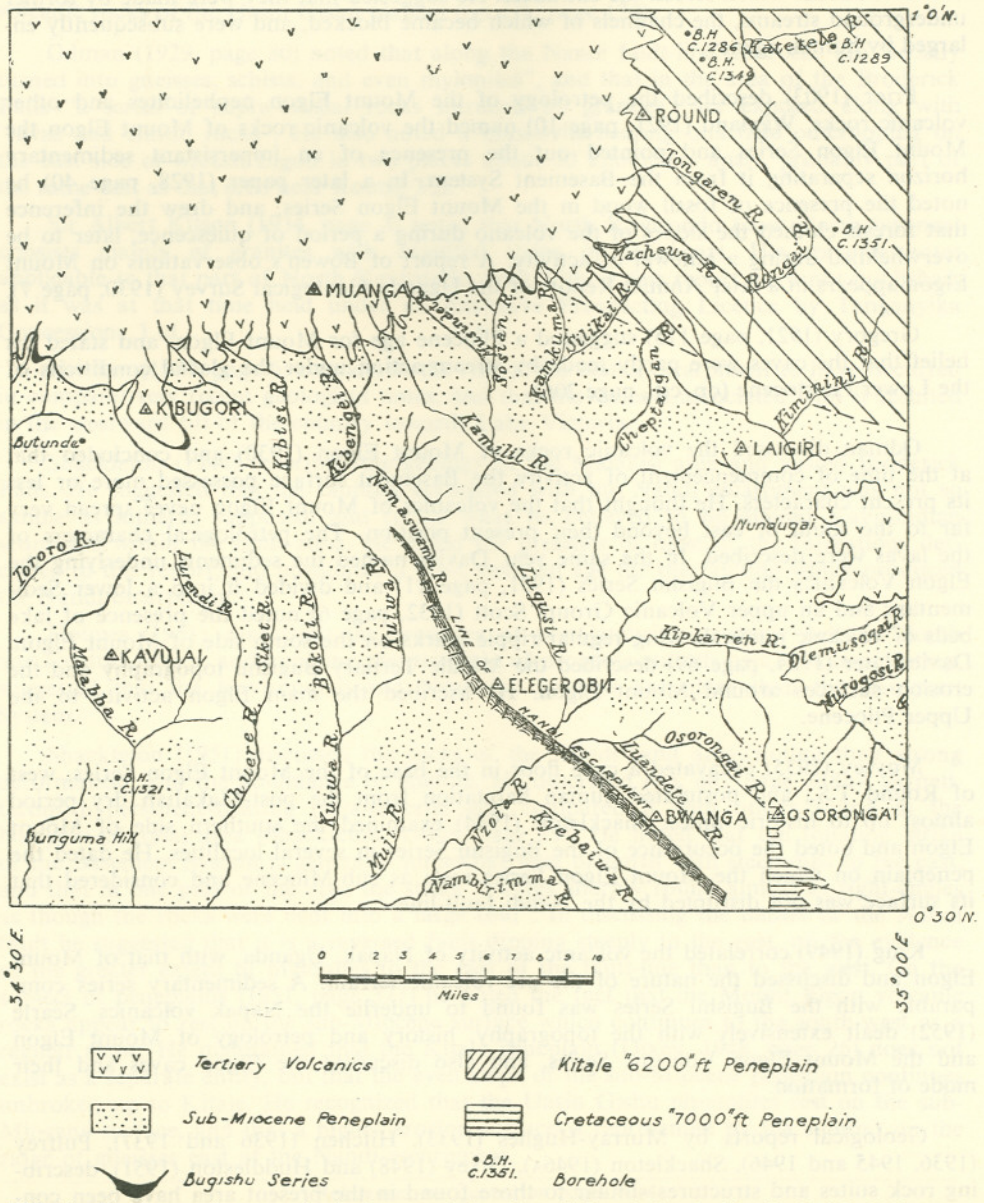


FIG. 1.—Erosion surfaces, main drainage and location of bore-holes in the Broderick Falls area.

The southern slopes of Mount Elgon rise abruptly from the plains as sheer cliffs up to 200 ft. in height, cut by deep river gorges with frequent waterfalls. These cliffs decrease in elevation to the east and north and retreat from the actual junction of the volcanics with the underlying Basement System rocks. This may be attributed to the fact that owing to the more resistant nature of the rocks the pre-volcanic Basement terrain on the east side of the mountain had not been reduced to a uniform level before the commencement of volcanic activity, with the consequence that the volcanic rocks either piled up against hills of Basement rocks, as is the case south of Round T.S., or formed thin cappings over hills of less relief.

The Nandi escarpment trends in general in a north-westerly direction, having in the south of the area an elevation of about 1,000 ft. above the country to the west. It decreases steadily in height to the north and ceases to be a noticeable feature in the area between Misikho and Kibengei schools. The escarpment appears to be a fault-line scarp which, as a result of erosion, has retreated somewhat from the position of the main fault. It is backed in the south-east by the Nandi highlands, a deeply dissected area of rugged hills and steep-sided valleys rising to a height of over 7,000 ft.

The Uasin Gishu Plateau is visible from a distance as a flat-topped area bounded by fairly steep cliffs which vary in height from 50 ft. to 200 ft., the variation resulting from the burial by volcanic rocks of an uneven Basement System as in the case of the east side of Mount Elgon.

The rest of the area is the remains of a gently sloping erosion surface falling from over 6,000 ft. in the north-east to 4,400 ft. in the south-west. The surface is not now continuous but consists of wide, nearly flat divides separated by broad, shallow river valleys. More resistant inselbergs and ranges stand above the general level in the Basement System terrain, as at Round T.S., Liagiri T.S., Schist Hill and other hills in the same area, and there are similar higher areas of crags and tors, such as Bungoma Hill, Sangalo, Kavujai T.S. and Butunde in the granitic areas.

2. Drainage

The main river, to which the remainder of the drainage of the area is related, is the Nzoia, which flows in a south-westerly direction across the area. To the north of the Nzoia, Mount Elgon is the dominant feature controlling the drainage, a radial pattern having been initiated on its slopes, with the consequence that the rivers and streams flow south and east and eventually into the Nzoia.

The main south tributary of the Nzoia is the Kipkarren River which receives tributaries draining the Uasin Gishu Plateau and the Nandi highlands, the Osorongai T.S. ridge forming a marked water-shed.

The majority of the rivers north of the Nzoia reached a stage of maturity on the sub-Miocene peneplain, meandering in broad, shallow valleys, but rejuvenation has resulted in re-excavation of their beds so that they now flow in gorges up to 30 ft. in depth. This is well seen in the case of the River Kuiwa. To the west of the Nandi escarpment the Nzoia River is mature and flowing on a grade related to the present level of Lake Victoria. At the Broderick Falls there is a marked nick where the river descends in falls and rapids for about 200 ft. Above this point the river is in a more youthful state, cutting down into bed-rock and flowing often in a deep valley. The Kipkarren River and its tributaries draining the Nandi highlands are similarly in a youthful state, the erosion rate is high, and rapids are common on the stretch of the Kipkarren parallel to the railway line.

Most of the rivers and streams are of a perennial nature, the main exceptions being the River Toroso and its tributaries, and the upper reaches of the River Chuere. These only flow during the height of the wet season, being for the remainder of the year typical sand rivers in which water may usually be obtained at a depth of a few feet.

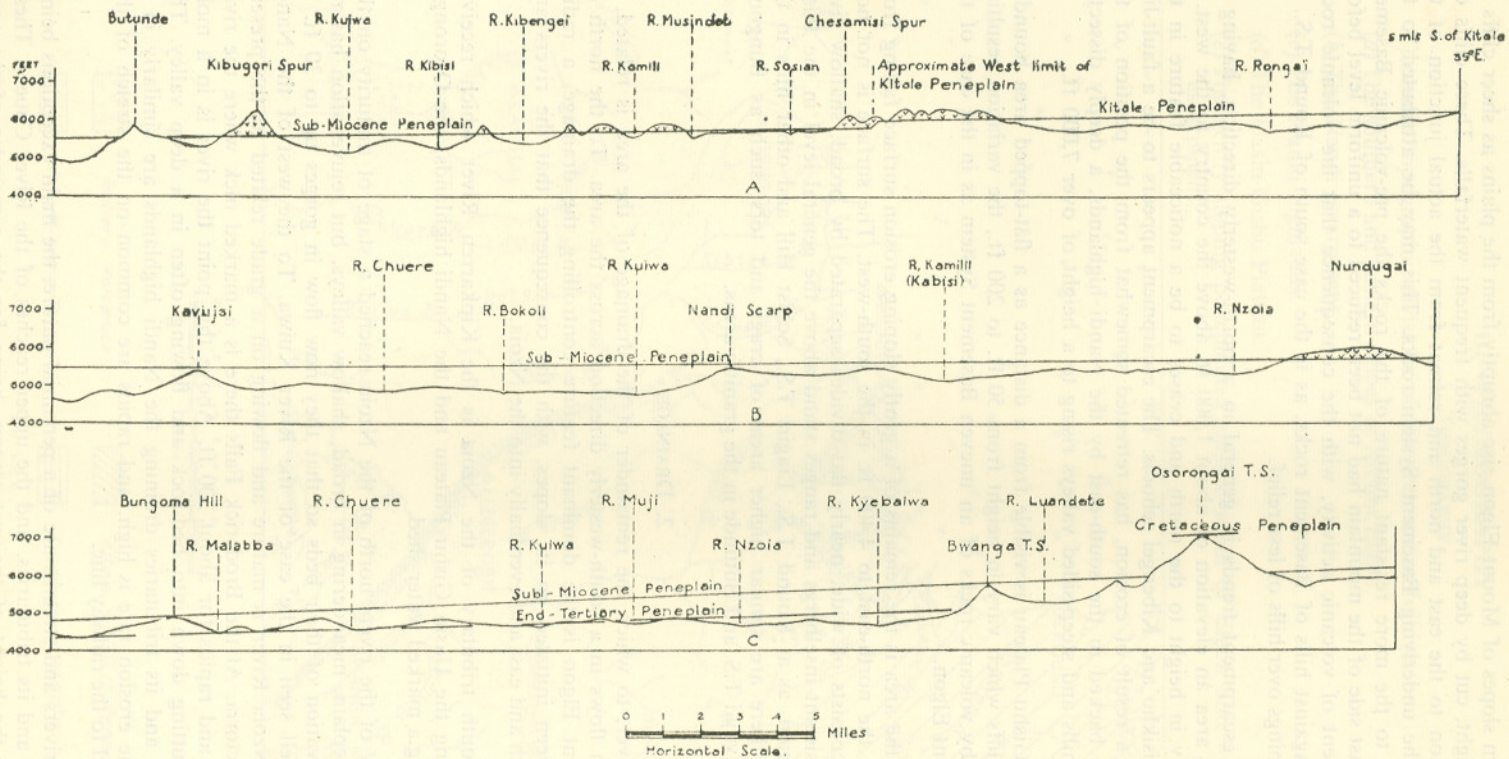


FIG. 2.—Sections to show the various erosion surfaces present in the Broderick Falls area. Vertical exaggeration X5.

A.—From Butunde to 5 miles south of Kitale (bearing 30° north of east).

B.—From Kavujai T.S. to Nundugai (bearing 10° north of east).

C.—From Bungoma Hill to Osorongai T.S. (bearing 2° north of east).

VVV = Tertiary Volcanics.

3. Peneplanation

Four main erosion surfaces can be recognized in the area—

(*a*) The "7,000-foot" peneplain.

(*b*) The "6,200-foot" Kitale peneplain.

(*c*) The sub-Miocene peneplain.

(*d*) The end-Tertiary peneplain.

The "7,000-foot" peneplain is represented by a chain of high points of uniform elevation in the Nandi highlands (Osorongai T.S., 7,006 ft.; Sumayat, 7,005 ft.), and continues south of the present area at similar levels (Huddleston). The age of this peneplain is thought to be Cretaceous and it has been correlated with the Kisii Highlands peneplain some 100 miles further south (Shackleton, 1944, page 13 and 1946A, page 52).

The "6,200-foot" Kitale peneplain was recognized by Dixey (1948, page 26 and map facing page 30) who suggested it was pre-Miocene in age and residual on the Uganda peneplain. Shackleton (1951, page 379) does not recognize it as a separate erosion surface and states that the sub-Miocene peneplain and the Elgon–Kitale plateau are parts of one uniformly sloping surface. Without losing sight of the facts that (*a*) the study of peneplains is essentially of a continent-wide nature and one cannot therefore make dogmatic statements on a quarter-degree sheet basis, and (*b*) the various surfaces have been subject to some degree of warping and therefore need not necessarily be represented by surfaces at approximately the same level at the present time, there are two lines of evidence which tend to suggest the existence of the Kitale peneplain as a distinct entity.

Firstly, a section through the southern slopes of Mount Elgon (Fig. 2A) shows a marked change in the level of the base of the volcanic rocks to the east of Chesamisi village. West of this point the volcanics rest on a surface 200 ft. lower than to the east. It is noteworthy that this point marks the eastern limit of known outcrops of the Bugishu Series, regarded as being of about Middle Tertiary age by Chaney (1933, page 50). Secondly, in the area north of Kitale, Searle (1952) found a difference in elevation of 1,900 ft. between the Kitale level and the sub-Miocene level along the Trans Nzoia escarpment, which appears to be largely an erosion scarp. If south and east of Mount Elgon the Kitale peneplain and the sub-Miocene peneplain are regarded as one and the same, it is difficult to reconcile the wide separation of the two levels north of Kitale.

It would seem from this evidence that the Kitale peneplain does exist as such, its ill-defined nature south-east of Mount Elgon being attributable to the fact that its edge has been considerably planed. (Fig. 1.)

The Kitale peneplain is then a residual on the sub-Miocene surface, on which a greater part of the Mount Elgon Series and the Uasin Gishu phonolites lie. (Fig. 1 and Fig. 2A and B.) The sub-Miocene surface is deeply eroded and is now represented by the tops of certain more resistant hills, which include Kavujai T.S., Bwanga T.S. and the Nandi escarpment, Bungoma Hill and an apron-like area around the north end of the Osorongai T.S. ridge, flanking the Kipkarren River (Shackleton, 1951, page 379), which represent a uniformly sloping bevel declining in a south-westerly direction at a rate of about 40 ft. to the mile. Certain of the divides between the rivers, especially in the north towards Mount Elgon, also approach this level. In the Butunde area the peneplain surface appears to be somewhat higher and some degree of up-warping may have occurred, possibly associated with the commencement of the Elgon activity, as suggested by King (1949, page 15), who noted similar features in association with the volcanic activity of the Napak area of Uganda. The sub-Miocene peneplain continues uninterrupted over the supposed position of the Nandi fault as noted by Shackleton (1944, page 13).

The majority of the rivers, and also some of the divides in the southern half of the area, are now on, or below, the level of the end-Tertiary peneplain which lies here some 300 to 500 ft. below the sub-Miocene surface and has a similar tilt towards Lake Victoria. Its presence is suggested by the plateau gravels, consisting of well-rounded quartz pebbles located by Shackleton (1944, page 13) near the railway a little more than two miles west of Broderick Falls station at about 4,900 ft. and thought by him to be of Lower Pleistocene age.

Similar erosion bevels, and some possible intermediate ones, have been located by Huddleston in the area to the south, where further evidence is available in favour of the existence of the Kitale peneplain.

IV—SUMMARY OF THE GEOLOGY OF THE AREA

The principal geological events in the evolution of the area are summarized below:—

RECENT

Superficial deposits, black valley soils, lateritic soils (murram cappings), and sandy soils.

PLEISTOCENE

Plateau and terrace gravels of the pluvial periods.
Completion of the formation of the end-Tertiary peneplain.

TERTIARY

Eruption of the *Mount Elgon Series.*
Deposition of sediments of the *Bugishu Series.*
Eruption of the *Uasin Gishu phonolites.*
Warping of the sub-Miocene peneplain.
Completion of the sub-Miocene peneplain.
Disturbance and erosion.

?EARLY TERTIARY

Completion of the Kitale peneplain.
Disturbance and erosion.

?CRETACEOUS

Completion of "7,000-foot" peneplain.

———Long period of erosion———

Emplacement of minor intrusives (age unknown).

PRE-CAMBRIAN

Late phase of post-Kavirondian orogeny. Nandi fault formed.
Intrusion of granites and granodiorites.
Early phase of post-Kavirondian orogeny.
Deposition of sediments of the *Kavirondian System.*
Disturbance and erosion.
Deposition of volcanic rocks of the *Nyanzian System.*
Disturbance and erosion.

ARCHAEAN

Orogenic earth movements.
Formation of the *Basement System.*

This sequence can be correlated with those of other areas surveyed in the Kavirondo area, no major differences being recorded.

The Basement System.—The Basement System rocks of the area are comparable with those of the area to the north described by Searle (1952). They do not show the diversity of high-grade regional metamorphic types which characterize other areas of Basement System rocks surveyed in Kenya to date. They consist of schists, gneisses and migmatites derived from an original sedimentary succession, which has been transformed by regional metamorphism and recrystallization during orogenic earth-movements into foliated quartz and felspar-rich rocks with variable amounts of biotite and/or hornblende, locally abundant epidote and more rarely garnet. Originally pure quartzose sandstones now occur as granular quartzites, with small amounts of muscovite, and originally less pure sandstones are now represented by quartz-mica schists. Hornblende schists and garnetiferous hornblende schists are believed to represent original basic intrusives. Granitic sheet and vein intrusions and pegmatite veins are common, especially in the south of the area. Some degree of granitization has affected all the Basement System rocks of the area, with the exception of the quartzites and related rocks, which show little or no evidence of the action of granitizing alkaline fluids.

In the north where the Basement System is last seen before it disappears beneath the Elgon Volcanic Series there is some suggestion of folding, on the evidence of the repetition of quartzite and quartz-mica schist bands. Further south structures are highly confused, a fact not without significance as is indicated on a later page. Dips are usually steep and as noted in other localities (e.g. Schoeman, 1948, page 7) the foliation planes parallel the original stratification.

The Nyanzian System.—Rocks of the Nyanzian System are exposed over a relatively small area and consist of sheared, but otherwise unaltered, rhyolites with some small tuff (?) intercalations. The main outcrop occurs as a narrow band bounded by faults, on or near the crest of the Nandi escarpment and continues into the area to the south (c.f. Huddleston). This band continues as numerous lenticular discontinuous thrust sheets in the area east of Broderick Falls and, further north, in the Kibengei school and Teremi village areas. Further small, poorly exposed areas of Nyanzian rocks occur in the extreme south between Butale Mission and the foot of the escarpment. Nyanzian rocks or their equivalents have not previously been found in contact with rocks of the Basement System in Kenya or Tanganyika.

The Kavirondian System.—Kavirondian rocks are poorly exposed except in the valley of the River Nzoia, where they are much more finer-grained than is usual elsewhere in Nyanza. Conglomerates and coarse grits are absent, the rocks consisting of somewhat cleaved quartzo-felspathic sandstones, siltstones and shales, the last occasionally exhibiting "spotting" close to intrusive contacts. Little structural information emerges from the outcrops of the area, apart from the simplicity of the folding in comparison with that of the Basement System. An extremely poorly-exposed area of doubtful Kavirondian rocks, resting on Basement System rocks in the Lugusi Valley, is of considerable interest. Small roof pendants of Kavirondian rocks are numerous in the granite areas.

The Granites and Associated Rocks.—Most of the granite of the area forms the northern margin of the Kitosh batholith, and therefore marginal contaminated and basified modifications are common. The intrusions east and west of Broderick Falls are almost certainly parts of the same mass, and the roof of the granite probably lies close to the surface beneath the Kavirondian of the Nzoia Valley. The area north of Kavujai T.S., including Chuele and Sirisia villages and passing beneath the Elgon Volcanic Series, is occupied by a somewhat gneissose pegmatite-rich leuco-granite. Patches of basic hybrids, including mela-syenodiorites, diorites, and hornblendites are fairly common in both types of granite. The granites are of post-Kavirondian age, the leuco-granite of the north being probably slightly older than the main granite mass.

The Minor Intrusives.—Dolerite dykes of various types are intrusive into all the formations except the Tertiary volcanics and probably range in age from pre-Cambrian to Tertiary. The area is exceptional in containing remarkably fresh olivine dolerites in

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dyke- and sill-like form, in the latter case in association with hypersthene-bearing dolerites. One dyke of granite porphyry was located, and a small mass of fresh augite peridotite occurs intrusive into Basement System rocks on the Kiminini River.

The Bugishu Series.—Sediments of the Bugishu Series occur at the base of the Elgon Volcanic Series and are impersistant and poorly exposed. They consist of impure limestones, calcareous sandstones and conglomerates. The lower members are mainly normal clastic sediments and contain fragments derived from the granites and from the Basement System rocks, whereas the upper members consist mostly of volcanic material. This bears out the division suggested by Davis (1931, page 11) into a lower Sedimentary Group and an upper Volcanic Group.

The Mount Elgon Series.—At the time of the survey the higher slopes of Mount Elgon proved inaccessible. The lower slopes were found to consist almost entirely of agglomerate and breccia of which the main constituent is a mela-nephelinite lava, with boulders frequently reaching a very large size. Xenoliths of jacupirangite were identified in the agglomerate. Minor fine-grained tuffaceous bands occur, some showing perfectly preserved ripple marks. Silicified fossil wood is common. No lava flows were located, those shown on the map in the north-west having been plotted on the evidence of aerial photographs as the continuations of flows indicated by Searle (1952) in the area to the north.

The Uasin Gishu Phonolite.—The phonolite shows little variation in field or microscopic appearance. It is a dense, fine-grained rock with large platy felspar and yellowish, waxy, nepheline phenocrysts. Outcrops are rare, cliffs at the eroded edges of the outcrop being composed mainly of loose boulders. No vesicular layers or tuffaceous intercalations were located and it is probable that only one flow is present, which at its maximum did not extend any appreciable distance beyond its present limits.

Pleistocene and Recent Deposits.—These are represented by river terrace and plateau gravels, black valley soils, laterite and an often deep soil cover.

V—DETAILS OF THE GEOLOGY

1. The Older Rocks

(1) *Basement System*

Rocks of the Basement System cover most of the area east of the Nandi fault and underlie the Uasin Gishu phonolites and a greater part of Mount Elgon. The mode of origin and subsequent alteration by regional metamorphism and granitization of the Basement System have been described in previous reports by Shackleton (1946B), Schoeman (1948, 1949 and 1951), Parkinson (1947) and Searle (1952).

The present composition of the Basement System rocks is considered to be largely the result of metasomatic processes acting upon an original sedimentary succession, the products of interaction between country-rock and aqueous magma, presumably derived from a granitic magma, being called migmatites. Migmatization ultimately leads to the production of a rock of granitic composition and texture but which is not a *true* granite in that it has not crystallized from a magma, the writer holding the view that the use of the term "granite" should be confined to rocks formed in the latter manner, and that alternative names or qualifying adjectives should be applied to rocks of granitic appearance and composition which have originated by other means. Cheng (1934) has suggested that metasomatic addition from mainly sodic solutions and the simultaneous loss of silica, without any disturbance of original bedding, results in the formation of permeation gneisses. Bodily penetration of the gneisses by granitic fluids following the permeation gives rise to injection gneisses which have fairly distinct banding of quartzo-felspathic layers of "igneous" origin and biotite-rich layers of sedimentary origin. These are typical migmatites.

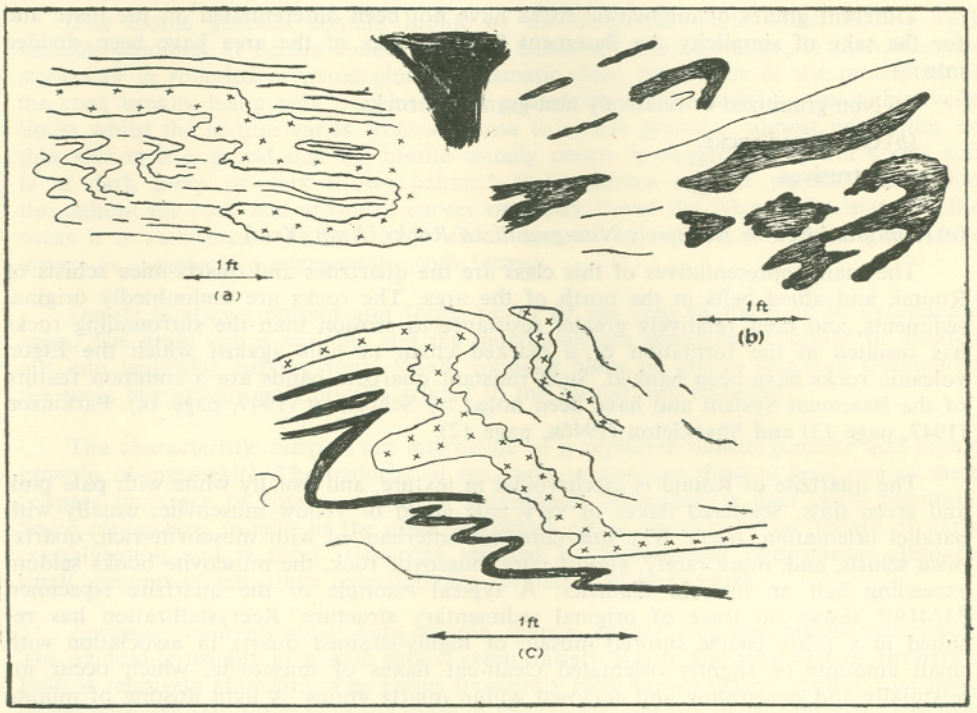


FIG. 3.—Structures in migmatitic gneisses—

(a) Quartzo-felspathic vein material in biotite gneiss. Stream south-west of Lugulu Mission.

(b) Dark hornblende-biotite schistose material in white quartzo-felspathic biotite gneiss with pink felspar bands and augen. Railway at Mile 161, east of Lugari.

(c) Quartzo-felspathic pegmatitic and dark hornblende-biotite schistose bands in biotite gneiss. Kiminini River, Farm 5540.

According to this definition the greater number of the Basement System rocks of the present area are permeation gneisses derived from semi-pelitic and pelitic host rocks. Locally there are patches of migmatite in which injection bands of quartzo-felspathic pegmatitic and granitic material can be seen. It is probable that the combined effects of the introduced material, and great heat and pressure, produced in some cases a practically molten or rheomorphic condition, resulting in local contortion, ptygmatic folding, apparent flow structures and skialiths such as are seen in various localities in the present area. (Fig. 3.)

Different grades of migmatitic rocks have not been differentiated on the map, and for the sake of simplicity the Basement System rocks of the area have been divided into:—

(*a*) Non-granitized or relatively non-granitized rocks.

(*b*) Granitized rocks.

(*c*) Intrusives.

(*a*) *Non-granitized or Relatively Non-granitized Rocks* (*Xqm, Xsm*)

The main representatives of this class are the quartzites and quartz-mica schists of Round, and allied belts in the north of the area. The rocks are undoubtedly original sediments, and their relatively greater resistance to erosion than the surrounding rocks has resulted in the formation of a marked chain of hills against which the Elgon volcanic rocks have been banked. Such resistant quartzite bands are a common feature of the Basement System and have been noted by Schoeman (1949, page 14), Parkinson (1947, page 13) and Shackleton (1946B, page 12).

The quartzite of Round is saccharoidal in texture, and usually white with pale pink and green tints. Scattered flakes of very pale green or yellow muscovite, usually with parallel orientation, occur. The quartzites are interbanded with muscovite-rich, quartz-mica schists, and, more rarely, almost pure muscovite rock, the muscovite books seldom exceeding half an inch in diameter. A typical example of the quartzite (specimen 33/419)* shows no trace of original sedimentary structure. Recrystallization has resulted in a fairly coarse sutured mosaic of highly-strained quartz in association with small amounts of slightly orientated clean-cut flakes of muscovite, which occur interstitially and penetrating and enclosed within quartz grains. A light dusting of minute ore grains is usually present and more rarely larger grains are present. Fresh felspar is absent, although kaolinitic material is sometimes seen in hand specimens. Secondary red iron-staining is common beneath the soil cover.

Specimen 33/318 is unusual in being grey and somewhat glassy in appearance. In thin section it is seen that small, orientated grains of pale green epidote occur in association with moderate amounts of muscovite, small amounts of dark biotite, and rare apatite. The greater part of the rock is a sutured mosaic of strained quartz, with small amounts of orthoclase and sodic plagioclase. It probably marks a transitional stage between a quartzite and an aplo-gneiss.

A thin band of fine-grained, hard, grey quartzite (not differentiated on the map) gives rise to Maua Hill. In thin section (specimen 33/270) the rock consists of about 20 per cent of granular epidote-zoisite in a fine-grained sutured quartz mosaic, and may be classified as an epidosite that was probably formed by the metamorphism of an original impure sandstone with a calcareous cement.

As was noted elsewhere by Schoeman (1949, page 15) the quartzites and related rocks have been relatively unaffected by granitization. It is possible that some of the muscovite may be due to potash metasomatism, though Schoeman doubted this.

* Numbers refer to specimens and thin sections in the Regional collections of the Department of Mines and Geology at Nairobi.

(b) Granitized Rocks (Xs, Xm and Xg)

Granitization in the area has resulted in the production of broadly and finely banded, streaky and glomeroplasmatic gneisses, and of gneisses approaching granites in composition. Either hornblende or biotite or both are present in highly variable amounts in all cases. The main rock types falling within this category are biotite gneisses, hornblende-biotite gneisses, porphyroblastic gneisses, mylonitic gneisses and aplo-gneisses, all of which are permeation gneisses or migmatites of varying degrees of granitization.

The biotite gneisses contain biotite as the dominant mafic constituent in very variable amounts. It occurs concentrated in bands of various widths, in discontinuous streaks or in rounded or ovoid glomeroplasmatic clots, the colour of the remainder of the rock usually being pink or white. The granularity of the rocks varies within wide limits whilst the texture varies from schistose to coarse granular, almost pegmatitic. In thin section it is found that the biotite usually occurs in ragged flakes and books and is of dark green or dark brown colour.* It sometimes exhibits parallel orientation throughout the rock and at others curves sinuously round the felspars. In many of the rocks it is associated with muscovite which appears to replace it, and in some cases occurs as symplectitic intergrowths with felspar.

Quartz is always present and forms up to 40 per cent of the rock in exceptional cases. The grain size is variable and the individuals are sometimes rounded or sheared out into lenticular curving folia. Small, rounded blebs of quartz scattered throughout the rock, but usually poikilitically related to the felspar, are common.

The characteristic felspars are microcline of a replacive nature, perthite and lobate growths of myrmekite. The majority of the rocks in question show at least one of these felspars in larger or smaller amounts. Untwinned orthoclase is also fairly common. Sodic plagioclase, usually in the albite-oligoclase range, appears to be mainly of early crystallization and is most frequently affected by replacement phenomena, although small amounts of late albite enter into the formation of myrmekite.

Accessory minerals noted were epidote, sphene, apatite, iron ore, orthite and zircon. The epidote is usually of a pale yellow-green variety and in the area east of Broderick Falls is relatively abundant. The grains frequently have brown orthite centres, and associated with apatite, occur as chadacrysts in the felspar and the mafic minerals. The iron ore is often titaniferous and coated by granular sphene. Secondary calcite and chlorite occur, although some of the latter may be of metasomatic origin—Cheng in describing permeation gneisses frequently reports the presence of biotite split by pennine and of pennine plates (1943, pages 117 and 125).

The hornblende-biotite gneisses are similar, with the addition of deep blue-green hornblende in variable amounts, occurring usually in ragged poikilitic anhedral prisms and aggregates often intergrown with and partly replaced by biotite. The hornblende frequently occurs segregated into clots in close association with biotite and the other mafic minerals, and with increase in granitization appears to be progressively eliminated in favour of biotite. In distribution the hornblende-biotite gneisses are relatively more common south of the Nzoia River, whereas to the north biotite gneisses and aplo-gneisses, in which mafic minerals are rare or absent, are more common.

Mention may be made of a few of the more unusual specimens. Specimen 33/448, from Liagiri T.S., contains sub-hedral spindle-shaped sphenes up to one millimetre in length and a small anhedral pale pink poikilitic garnet. Specimen 33/394, from Farm 6657, two miles N.W. of Sikendi, shows larger amounts of a similar sub-hedral pink garnet riddled with inclusions. Specimen 33/274, from the Nzoia River, north of

* Colours of minerals referred to in descriptions of thin sections are the colours seen with the mineral orientated in the position of maximum absorption.

Lundete village, is a finely-banded biotite aplo-gneiss and is unusual in containing several sub-hedral tourmaline prisms. The tourmaline may be a product of contact metamorphism related to the nearby granodiorite intrusive. Specimen 33/211 is an edenite-biotite gneiss in which bands rich in edenite and iron ore alternate with bands containing less of these minerals and greater amounts of pale brown biotite and pale pink orthite (?).

The aplo-gneisses exhibit similar features, but contain negligible amounts of dark minerals. Specimen 33/455, from two miles east of Nundugai, a pink and white coarse-grained rock, has very small amounts of biotite and orthite and shows large-scale replacement by microcline. Specimen 33/425, from north of the Elgon Central Road, is of a similar nature and contain large numbers of the quartz blebs which are a feature of these granitized rocks. The aplo-gneisses have a scattered distribution and occur as narrow bands within the other types of gneisses over the whole area.

The porphyroblastic gneisses occur throughout the area but are especially characteristic of the area east of Broderick Falls and the Nandi escarpment. They are usually massive, grey, foliated rocks with large ovoid white felspar porphyroblasts and commonly with sheared out "bird's eye" quartz lenticles. The porphyroblasts are usually oligoclase with indistinct twinning and in some cases have marginal lobate growths of myrmekite. Rarely microcline is present as porphyroblasts. A faint suggestion of spiral arrangement of peripheral inclusions indicates rotation during formation, and some degree of shearing is present in most of the examples examined. The twin lamellæ of the plagioclase are sometimes bent or the porphyroblasts fractured and displaced. They enclose chadacrysts of epidote-clinozoisite and apatite (which are often abundant, especially near to the fault-zone) and occasionally flakes of biotite. The biotite is of a dark green-brown variety and is usually orientated parallel to the foliation, curving sinuously round the porphyroblasts. The quartz similarly is often sheared out into curving lenticular folia and shows marked strain shadows. The groundmass consists of granulose quartz, microcline and sodic plagioclase often arranged in a type of mortar structure around the porphyroblasts. Accessory minerals are epidote, which is often abundant, apatite, sphene, magnetite and zircon. Blue-green hornblende is sometimes present.

In the fault-zone these gneisses are often highly sheared. The biotite is broken down and forms fine-grained brown streaks and folia, which curve round the broken porphyroblasts (specimens 33/247 and 33/485, both from the area of Bwanga T.S.). Such rocks with more intense deformation pass into mylonites, which are fine-grained, dense, dark grey rocks often with black streaks, the original nature of which is usually open to doubt (specimen 33/132, from the road south of Broderick Falls). Often the only remaining recognizable minerals are highly sheared lenticles of quartz and epidote. In specimen 33/112, from Broderick Falls road bridge, some porphyroblasts of felspar with epidote chadocrysts still remain.

Shackleton (1944, page 3) considered that the porphyroblastic gneisses were usually formed at a fairly high grade of metamorphism by the migmatization of pelitic sediments, and noted similar structures and mineral assemblages produced in xenoliths in the granodiorite which intrudes Kavirondian shales south-west of Broderick Falls.

(*c*) *Intrusives* (*Xh, Xah, Xg*)

The rocks of this group are usually melanic in appearance, with black, shining hornblende either in long-bladed orientated crystals or as larger sub-hedral phenocrysts. They weather to a mustard yellow or reddish-brown colour and, because of their relatively low resistance to erosion, are poorly exposed or form areas of low ground in the majority of cases. The areas delimited as belonging to this group on the map are those in which a preponderance of such rock types occur, but bands of biotite and hornblende-biotite gneiss occur within them. The impression is therefore gained of a series of sheets or dykes of the basic types invading a more normal felspathic succession.

The rocks of the lower Kamilil Valley and of the Nzoia below its confluence with the Kipkarren are mainly garnetiferous hornblende schists. Specimen 33/388 (*see* Fig. 4 (*a*)) is typical, consisting of 75 to 80 per cent of blue-green hornblende, orientated

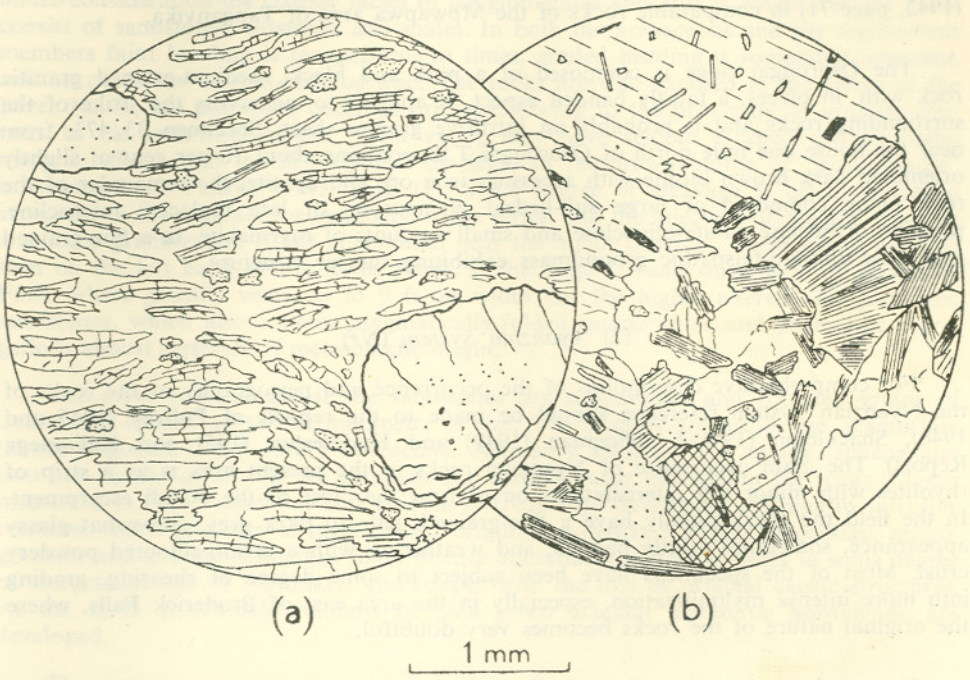


FIG. 4.—Microscope Drawings—

(a) Garnetiferous hornblende schist. Specimen 33/388. Kamilil River south-east of Kabisi school. Small grains, high relief—epidote; large grains, high relief—garnet; prisms—hornblende; clear interstitial material—quartz and plagioclase.

(b) Gneissose granodiorite. Specimen 33/197. Intrusion east of Broderick Falls. Close shading—biotite; cross shading—hornblende; small prisms, high relief—apatite; stippled grains—epidote; wide shading—plagioclase; clear material—quartz.

in stout, ragged prisms which are often slightly bent due to post-crystallization deformation, the whole rock exhibiting acute angular contortion. Sub-hedral pale pink garnets up to 1.5 millimetres in diameter and crowded with inclusions and accessory epidote are present. The granular interstitial groundmass is composed of strained quartz and plagioclase felspar which, where determinable, was found to be in the andesine-labradorite range. A few quartz veins one millimetre wide of later introduction are present. The remainder of the rocks of this belt lack garnet but are otherwise similar. The hornblende is on occasions pale green and actinolitic.

Specimen 33/273, from the Nzoia River north of Luandete village, is intensely contorted and injected by quartz-plagioclase felspar veins. Occasionally fan-shaped radiating aggregates of prochlorite are present. Specimen 33/110, from near Luandete village, is unusual in its fineness of grain and in the presence of an epidote-rich vein one millimetre wide cutting across the foliation direction of the rock. Specimen 33/344, from the Kunva R. north of the Kimilili–Chuele road, consists of over 90 per cent of hornblende in markedly orientated prisms, and with very small amounts of interstitial quartz and felspar. Specimen 33/117, from the roadside one mile south of Kamakuiwa village, provides an example of a rather coarser plagioclase-epidote amphibolite with blue-green hornblende in sub-hedral poikilitic ragged plates, large grains of epidote, and a groundmass of quartz and plagioclase felspar.

Rocks of a similar nature have been described in other areas of the Basement System (for example, Schoeman, 1948, page 33, and Shackleton, 1946B, page 20). It is possible that some of these rocks are derived from original dolerite sills and dykes by reactions that took place during the process of granitization, as suggested by Temperley (1942, page 71) in comparable rocks of the Mpwapwa area of Tanganyika.

The Osorongai ridge is composed of a pink and black, medium-grained granitic rock with, in places, a faintly banded aspect. It appears to cut across the strike of the surrounding rocks and is probably an intrusive granite sheet. Specimen 33/473, from near the house one mile north of Osorongai T.S., contains about 10 per cent of slightly orientated dark brown biotite with accessory iron ore and apatite, the remainder of the rock being composed of large sub-hedral phenocrysts of late replacive microcline, perthite, orthoclase, albite-oligoclase and small amounts of myrmekite, in a fine-grained granulose quartzo-felspathic groundmass exhibiting mortar structure.

(2) *Nyanzian System* (*Nr*)

For comprehensive descriptions of the occurrence and petrography of the rocks of the Nyanzian System reference should be made to the reports of Pulfrey (1945 and 1946), Shackleton (1946A), Schoeman (1949) and Huddleston (1951 and Kakamega Report). The main occurrence of Nyanzian rocks in the present area is as a strip of rhyolites with minor tuff intercalations on or near the crest of the Nandi escarpment. In the field the rocks usually have a fine-grained, pale to dark grey, somewhat glassy appearance, sometimes faintly banded, and weathering with a cream-coloured powdery crust. Most of the specimens have been subject to some degree of shearing, grading into more intense mylonitization, especially in the area east of Broderick Falls, where the original nature of the rocks becomes very doubtful.

Commonly the rhyolites contain only very small phenocrysts of felspar and quartz, which are usually rounded or with embayed margins, in a cryptocrystalline quartzo-felspathic sericitized groundmass. The felspar is mainly orthoclase, oligoclase being somewhat rare. Accessory minerals are epidote, sphene and chlorite, probably representing original ferromagnesian minerals. Specimen 33/208 of a somewhat coarser variety shows marked shearing and displacement of phenocrysts. Specimen 33/246, from near Bwanga T.S., is a mylonitized version in which little remains recognizable apart from some small patches of quartz, felspar and chloritic material.

Specimen 33/201, from the bends in the road on the escarpment N.E. of Matete, is an epidotized tuff and contains rhyolitic rock fragments and broken orthoclase and oligoclase felspar phenocrysts in a sericitized and epidotized quartzo-felspathic groundmass. Specimen 33/104, from the same locality, is a finer-grained, more sheared version in which similar rock fragments are recognizable. Specimen 33/490A, from the road south-east of Broderick Falls, is a highly-sheared epidotized and sericitized rock, probably derived from a rhyolite, in which small, pale pink, sub-hedral broken garnets crowded with inclusions occur. Almandine garnets have been reported previously in the Nyanzian rhyolites by Pulfrey (1946, page 10).

Specimen 33/317, from the Kuiwa River bridge on the Kimilili–Chuele road, is a black somewhat glassy rock containing patches and stringers of pink felspar. In thin section the rock is seen to be slightly mylonitized and to consist essentially of a cryptocrystalline quartzo-felspathic groundmass in which there are a few identifiable rounded patches of quartz,felspar, epidote and iron ore. Specimen 33/343, from the Kibisi River at the end of the Kibengei school track, is a dark and medium grey finely banded rock with occasional pink felspar "augen". In thin section it is found that the rock is traversed by chloritic mylonitized bands. The remainder of the rock contains recognizable quartz, felspar and epidote.

(3) *Kavirondian System (Km and Kg)*

Typical rocks of the Kavirondian System have been described by Pulfrey (1945 and 1946), Shackleton (1946A) and Huddleston (1951 and Kakamega Report). In the area under consideration the coarser facies of conglomerates and grits is absent and the rocks consist of sandstones, siltstones and shales. In both the arenaceous and the argillaceous members faint banding is recognizable at times, graded bedding is sometimes apparent, and on occasions current-bedding also. The rocks are well exposed in the valley of the River Nzoia, but elsewhere outcrops are rare. Owing to the proximity of granitic contacts to the sediments of the Nzoia valley they have seldom escaped contact metamorphic effects, and the development of flakes of red-brown biotite or "proto-biotite" is common (cf. Pulfrey, 1945, page 11). Some degree of cleavage is often developed especially in the argillaceous members of the series, and the injection of granitic material and some granitization is not uncommon near the major contacts. These effects are well seen on the left bank of the River Nzoia at the large U-bend south-west of Broderick Falls, where granitic veins up to 9 ft. in width cut the highly altered and granitized sandstones, which also contain ptygmatically-folded quartz veins and pegmatitic segregations almost certainly of metasomatic origin.

The main constituents of the sandstones are sub-angular and rounded grains of quartz and felspar up to one millimetre in size. The felspars are orthoclase, plagioclase (about oligoclase), and rarely microcline. Accessory minerals are apatite, sphene and iron ore. Specks of sericite are common and usually occur throughout the rocks. Clastic muscovite is fairly common, and epidote is frequently developed adjacent to intrusive contacts, and is probably of metasomatic origin. The matrix is highly chloritized, microgranular and quartzo-felspathic, more intense alteration resulting at times in some degree of recrystallization of the quartz and felspar with the loss of original clastic structures. At the same time small amounts of pale green acicular actinolitic hornblende are developed.

The shales and siltstones are frequently well cleaved and often slate-like. In thin section they are found to consist in the main of fine-grained opaque material, probably in a large measure composed of chlorite and minerals of the kaolinite group. Quartz grains are usually present and, in the thermal aureoles, orientated flakes of brown biotite or "proto-biotite". In specimen 33/128, from the Nzoia River about 1½ miles below Broderick Falls road bridge, spots have developed and stand out on the weathered surface as dark ovoid specks in a silver-grey, somewhat phyllitic rock. In thin section they are seen to be sericite- and chlorite-rich patches, which are lighter in colour than the matrix, and elongated in the direction of the cleavage. Similar features have been noted by Pulfrey in the Maragoli area (1946, page 17).

Several unusual types are worthy of mention. Shackleton first noted the presence of what he called "hornfelsed Kavirondian greywackés" in the fault-zone east of Broderick Falls (1944, pages 3 and 4). Specimen 33/106, from the road on the escarpment east of Matete village, is a grey slate-like rock showing a faint banding parallel to the cleavage. In thin section the rock is seen to be highly altered and sheared, having a fine-grained groundmass containing much sericite, chlorite and epidote in association with micro-crystalline quartzo-felspathic material. A few larger rounded patches of identifiable sericitized quartz and felspar remain.

Specimen 33/138, from a railway culvert above the Nzoia gorge at mile 173/13*, is of a pale pink-grey, faintly banded, silty rock, showing in places marked wedge-shaped current bedding. In thin section the rock is found to contain numerous sub-angular grains of quartz up to 0.3 millimetre in size, and less frequent similar grains of orthoclase, sodic plagioclase and microcline, in a fine-grained quartzo-felspathic groundmass, containing specks of brownish-green chlorite, "proto-biotite", and small amounts of sericite. The rock is quite fresh in appearance and appears to be without doubt a sedimentary siltstone.

* The figures after the stroke in railway mileages refer to sixteenths of a mile.

Specimen 33/142, from the right bank of the Nzoia River below the falls, is a hard, grey, slabby rock, somewhat cleaved and with a faint suggestion of banding. In thin section the rock appears to be a silty shale having grains of recognizable quartz, orthoclase and sodic plagioclase, in a fine-grained, highly sericitized quartzo-felspathic groundmass. Grains of epidote with brownish orthite centres are also present and small amounts of greenish chloritic material.

Specimen 33/200, from the valley approximately 1¼ miles N.N.E. of Matete, is a dark and light grey, finely banded rock with occasional large pink felspars. In thin section it is comparable with specimen 33/142 but has rather more large grains, amongst which microcline is identifiable. Chlorite-sericite-rich bands curving round the grains are probably derived from more argillaceous groundmass material and indicate original bedding. These specimens leave little doubt of the presence of Kavirondian sediments in the fault-zone east of Broderick Falls.

The identity of the Kavirondian sediments shown on the map around the Lugusi Valley must remain somewhat doubtful, since outcrops are rare and only two specimens of rock *in situ* were collected from that area. Towards the head of the Lugusi River several float pieces of what was thought at the time to be Kavirondian siltstone were located. Specimen 33/187, from below a water-mill on the River Lugusi, south-west of Magemo school, is a pink and grey, faintly banded, fine-grained rock with numerous dark, rusty specks. A thin section of the rock reveals small amounts of somewhat orientated, anhedral, deep green hornblende and a few small grains of sphene in a clear, unaltered quartzo-felspathic mosaic, which contains orthoclase, sodic plagioclase and a small amount of microcline. There is a suggestion of orientation and elongation of some of the quartz grains, possibly due to recrystallization under pressure. Whilst unconvincing as a Kavirondian rock it is equally unlike Basement System types in view of the lack of biotite and the meagre amount of microcline present, both of which minerals are usually present in greater quantity in the normal Basement rocks of this area.

In the hand specimen, specimen 33/210, from the track about one mile west of Lugusi village, is more convicing as a sedimentary rock. It is pinkish and fine-grained, faintly banded, and with apparent current-bedding. In thin section the rock is found to be composed of about 50 per cent of granulose quartz, the remainder being a felt of slightly orientated small prisms of iron-poor epidote-clinozoisite with some secondary limonitic material. Again it is questionable whether the rock is Kavirondian, but it is equally doubtful that it is a member of the Basement System.

Of the numerous roof-pendants of Kavirondian material in the granitic areas, that at Bungoma is the largest and provides the best example. The main outcrops are in the valley of the River Malabba and consist of grey and brown, much-weathered, cleaved and schistose sandstones, somewhat granitized and injected, with the development of moderate amounts of dirty brown biotite and "proto-biotite". The rocks are essentially quartzo-felspathic rocks of the usual type, often sericitized and recrystallized, and having occasional flakes of muscovite. Specimen 33/300 is a less altered type in which quartz grains, somewhat elongated, orthoclase and sodic plagioclase are identifiable in a lightly sericitized quartzo-felspathic groundmass.

The so-called "talcy" clays of the Bungoma area are no doubt derived by the break-down of these Kavirondian rocks. The presence of talc is, however, doubtful as examination of washed material from the clay revealed pale brown biotite and "proto-biotite" only, and it is possible that the talcose, slippery feeling of the clay is due to the presence of these minerals and to the somewhat phyllitic nature of the original material.

2. The Younger Rocks

(1) *Bugishu Series* (*Tmi*)

The Bugishu Series has an impersistant distribution at the base of the Elgon Volcanic Series, and in the area under review occurs in four main localities. An excellent section across the series was found where the track north from Chesamisi village ascends the escarpment. No actual junction with the quartz-mica schists of the Basement System is visible but its position may be defined to within a few yards. The succession is as follows:—

Normal volcanic agglomerate.
Current-bedded and ripple-marked tuff—2½ ft.
Tuffaceous rock—4 ft.
Coarse agglomerate—10 ft.
Conglomerate with water-worn pebbles—6 ft.
Water-laid tuff or ash—18 ft.
Basal conglomerate.
Basement System.

The fairly well-cemented basal conglomerate has a tuffaceous matrix. The whole rock has a silver-grey colour, but the individual pebbles are clearly defined. Some larger boulders appear to have fallen into the conglomerate before it was completely consolidated, causing depression of the under-lying material. In thin section the constituents are seen to consist mainly of lavas, predominantly nephelinitic, with abundant green zoned ægirine-augite and euhedral nepheline and its pseudomorphs. Interstitial material consists of calcite with fringing rims of radiating zeolites, and dirty green-brown tuffaceous material.

The tuff overlying the conglomerate is a much-weathered, siltstone-like rock with many solution cavities and much secondary calcite veining. Some indication of graded bedding is present in parts. In thin section the rock is found to contain much fine-grained, brown amorphous material, specks of iron ore, a few fragments of pyroxene crystals and zeolitic material. The rock appears to be a water-laid ash or tuff.

The second conglomerate horizon is well cemented and has an irregular base. It contains water-worn pebbles and is cut by vertical pipes, filled by material derived from the over-lying sediments, up to 2 ft. in diameter and probably representing infilled pot-holes. As in the lower conglomerate the pebbles consist of volcanic types containing an abundance of pale green and colourless pyroxene, euhedral zeolitic pseudomorphs after nepheline, and much amorphous dirty green-brown material, in a tuffaceous zeolitic matrix.

The coarse agglomerate overlying the second conglomerate is of a sandy nature in places and contains scattered water-worn pebbles. The succeeding tuffaceous rock is shaly and pale grey, and the tuff above it is current-bedded and ripple-marked and has graded bedding in parts. According to Davies' division of the Bugishu Series these rocks would fall into the upper Volcanic Group (1931, page 11). The remainder of the outcrops to the west appear to belong mainly to the Lower or "Sedimentary Group".

At the foot of the cliffs near the River Kamilil loose boulders of impure sandy limestone and conglomerate occur. Specimen 33/375, of the former, is a fine-grained, buff to pink rock with calcite veining. Shale-like galls are present and there are some indications of truncated current-bedding and graded bedding. In thin section the rock is seen to be composed mainly of dirty calcite with limonite patches and staining, cut by secondary clear calcite veins. A few flakes of brown biotite are present and one or two grains are doubtfully referred to apatite. The associated conglomerate is buff coloured, well cemented, and has rounded pebbles of volcanic rocks up to two centimetres in diameter. The conglomerate may be the lowest bed of the Volcanic Group at this locality.

Further outcrops, mainly represented by loose boulders, occur on the nose of the Kibugori spur. The most outstanding amongst them is an almost pure white, chalky rock (specimen 33/121) traversed by fine calcite veins and resembling a chemical precipitate.

On the spur east of Chesakaki village boulders were found of impure, yellowish, dolomitic limestone with limonite staining, and containing occasional apatite crystals. Shackleton (1944, page 11) suggested that because of the presence of apatite and magnetite these rocks might be carbonatites rather than sediments. This may be so in some cases, but evidence of current-bedding in others points to a sedimentary origin, when the apatite and magnetite could have been derived from Basement System rocks, in which they are common. Further down-stream on the River Malakisi, and stratigraphically below these rocks, is a striking red conglomerate with rounded green and brown pebbles, forming a cliff for some distance at the side of the river. A thin section of specimen 33/367A shows a large amount of material obviously derived from the gneissose leuco-granite, including strained and composite quartz, microcline, myrmekite, acid plagioclase and small amounts of biotite. Small infrequent pebbles of lava are found in the rock. Limonite pellets with oolitic habit are present and secondary iron-staining, the cement being calcareous.

There is a striking parallel between the Bugishu Series south of Mount Elgon and the Kopopwa Series of Uganda described by King (1949). He attributed (op. cit., page 15) the red colour of the sediments of that series and the presence of shale chips to a climate similar to that of to-day, with a prolonged dry season and a short but heavy period of rains. He concluded that the sediments collected in shallow depressions in the surface of the sub-Miocene peneplain, where temporary lakes formed.

The sediments may also be correlated with others described by Searle (1952) from Sagat Hill to the north-east of Mount Elgon.

No fossils were located in any of the rocks examined, but Chaney (1933) after examination of fossils found in similar rocks in Uganda, dated them as not later than middle Tertiary.

(2) *Mount Elgon Series* (Tv and N_1)

Mount Elgon, with a maximum height of 14,150 ft., is an extinct volcano of considerable dimensions, the diameter of its base measuring 60 miles. The mode of eruption was mainly explosive and huge boulders of lava were ejected and mixed with smaller boulders and ash to form an agglomerate of which most of the volcano is composed. A description of the eastern sector of the mountain, its history, morphology, glaciation and the petrography of its rocks, have already been given by Searle (1952).

Caves occur usually at the same horizon, between 6,000 and 7,000 ft., in ash or tuff bands and are almost certainly of natural origin, and it is considered that they can be attributed to the action of downward percolating meteoric waters charged with carbonic acid as suggested by Searle.

A characteristic feature of the agglomerate is the presence of silicified fossil wood representing the remains of trees which grew on the slopes of the Elgon volcano during periods of quiescence. Some of these fragments are quite large and their original structure is fairly well preserved. A fossil cyatheoid stem from the mountain has been described by Miss H. Bancroft (1932) and also some fossil dicotyledonous woods (1935 and 1936).

Searle (1952) has divided the Mount Elgon Series into—

(*a*) The Lower Pyroclastic Series and Lake Beds.

(*b*) The Middle Pyroclastic Series.

(*c*) The Lower Lava Series.

(*d*) The Series of the Caldera Rim.

(*e*) Minor Intrusives.

Of these only the first was located and examined in the present area. Features of the junction between the Basement System and the Volcanic Series have already been described (page 9), and although seldom actually visible it can usually be delimited within a very few yards.

The greater part of the rock examined on Elgon was agglomerate with some less coarse breccia bands and, in places, fine-grained water-laid tuffaceous horizons. No lava flows were located on the lower southern and eastern slopes. On the south side of the mountain there are at least two, and in many places more, step-like interruptions of the agglomerate cliffs at about 200 ft. intervals which, when viewed from a distance, demonstrate the horizontal disposition of the beds. The benches of rock probably represent material derived from successive explosive episodes. In several localities a pale grey ash horizon about 10 ft. thick was located about 20 ft. above the base of the agglomerate. The ash tends to weather out easily and gives rise to small caves and overhanging cliffs of agglomerate. Specimen 33/395 from the cliff north of Mr. Morgan's house (Farm 6658, about one mile east of Chesamisi) shows excellently preserved ripple-marking and graded bedding and indicates the existence of shallow lakes on the flanks of the volcano during the early stages of eruption.

The agglomerate is remarkably uniform in appearance, containing boulders of a great range of size, which are usually considerably altered, having patches and veins of secondary calcite and cavities lined and fringed with radiating crystals of a zeolite resembling natrolite. Petrologically the boulders of the agglomerate vary little and are mostly nephelinites and mela-nephelinites of Class N as defined by Searle (1952).

The nephelinites have euhedral phenocrysts of nepheline and similar amounts of euhedral pyroxene, in a microcrystalline groundmass of nepheline, pyroxene and iron ore with much dirty, brownish-green, amorphous material. The mela-nephelinites have a preponderance of pyroxene phenocrysts and few or no porphyritic nephelines, the latter occurring in microcrystalline form in the groundmass.

The pyroxene is characteristically euhedral and occurs in elongated prismatic form. It varies from colourless augite, through pale green ægirine-augite, to deep grass-green ægirine. Frequently the phenocrysts are zoned from colourless centres to green rims.

The nepheline commonly exhibits "square" and hexagonal cross-sections and some crystals are zoned by inclusions lying in concentric planes. Most frequently it is altered and pseudomorphously replaced by aggregates of calcite, zeolites, cancrinite and sericite, and in some cases it has been completely removed by solution, leaving cavities in the rock. Magnetite is a common important accessory, and perovskite, analcite and melanite garnet occur occasionally.

The agglomerates contain fragments of a suite of rocks ranging in composition from jacupirangite to urtite (Shackleton, 1944, page 12). These are abundant in places and specimens of the melanocratic jacupirangite, consisting chiefly of large crystals of green pyroxene, were identified in the Kaptama area. Extraction of specimens is difficult since the included fragments usually appear as dark patches on the surface of smooth boulders.

The presence of the Bugishu Series at the base of the Elgon Volcanic Series dates the commencement of activity as post-Middle Tertiary. Davies (1934) has suggested that activity reached a maximum in Pliocene times.

(3) *The Uasin Gishu Phonolites* (Tvp)

Phonolite lavas occur on the eastern border of the area as a large lobate flow and as a smaller spur. Further east, in the area of Turbo, the flows unite and cover a more continuous area through which project occasional inselbergs of Basement System rocks. From this, and also from evidence in the present area (page 10), it is apparent that the phonolite flowed over a very uneven surface of the ancient rocks. The lava is dense, black and heavy, with platy white felspar phenocrysts up to 1¼ in. long, and yellowish,

rounded, resinous, nepheline phenocrysts up to ½ in. in diameter. Small vesicles partly filled with zeolites are fairly common, representing original gas bubbles. The rock weathers with a soft, rusty brown crust containing many cavities, and on which the bladed felspar phenocrysts stand out, often exhibiting a blue-grey play of colours. The phonolite is remarkably uniform throughout the outcrop and it is more than probable that it represents the edge of a single flow which never extended far beyond its present limits.

In thin section the phonolite is seen to have a micro-crystalline base containing about equal amounts of mafic and felsic minerals. The dark minerals, except for occasional patches that are somewhat more leucocratic, are fairly evenly distributed throughout and are intergrown in a mossy manner with microcrystalline felspar laths, which in specimen 33/454 have a slightly trachytic arrangement. Colourless isotropic material, probably analcite, forms the base between the felspar and mafic minerals. Minute oblong or square-sectioned grains of nepheline also occur in the groundmass. Amongst the mafic minerals of the groundmass are green ægirine-augite, cossyrite (pleochroic from dark brown to dark red-brown, nearly opaque), katophorite (pleochroic from yellow-brown to a pale mauve-brown) and magnetite.

Very few phenocrysts were cut by the thin sections. The felspar appears to be anorthoclase, simply twinned on the Carlsbad Law. The fine cross-hatched twinning supposed to be characteristic of anorthoclase is absent, but the optic angle of about 45° is too high for sanidine. A zone of fine inclusions lying a short distance inside the rim of the crystals is common, e.g. specimen 33/454. Marked cleavage cracks are common, along which zeolitization has occurred in some cases. Nepheline is somewhat more rare and occurs as stout euhedral units, often partly replaced by analcite. Sometimes subhedral phenocrysts of very pale green non-pleochroic pyroxene occur (as in specimen 33/454, from Farm 5560, 2½ miles south-east of Nundugai) reaching about 1 millimetre in length. Occasionally longer thin individuals with slightly deeper colour and having an extinction angle of 45° are present. A small pale green anhedral phenocryst of olivine occurs in specimen 33/453 from the escarpment on the Turbo road.

These phonolites are somewhat similar to those of the Kapiti type as described by Campbell Smith (1931, page 238), and are also closely comparable with the Mau phonolite described by Schoeman (1949, page 27). No evidence can be adduced in the present area as to the nature of the eruption which gave rise to the flows (*see* page 4). From the absence of phonolite float in the area surrounding the flow, and the absence of pebbles and boulders of phonolite in the rivers and streams draining it, it is reasonable to assume that erosion of the margins of the flow has been negligible, and therefore if the eruption was of fissure type, the fissures need not necessarily yet have been exposed.

Similarly, little evidence as to the age of the activity is obtainable in this area, since the under-lying rocks belong entirely to the Basement System. The phonolites do, however, rest on and preserve the surface of the sub-Miocene peneplain, and are assumed to be of Miocene age.

(4) *Superficial Deposits*

River Deposits.—Broad belts of marshy, black, valley soil occur in the valleys of many of the rivers as indicated on the map, rejuvenation having resulted in the re-excavation of these deposits so that often the rivers now flow in steep-sided gorges up to 30 ft. deep. This type of river deposit is especially characteristic of the Kavirondian terrain. In the Basement area small alluvial sand and gravel deposits are more common.

Terrace Gravels or Torrential Conglomerates are found along the Malakisi, Kibisi and Sosian Rivers. They consist of ungraded, rounded, water-worn pebbles up to 6 in. in diameter, mostly of agglomeratic types but with some derived from granite and Basement System gneisses, in a sandy, uncemented matrix of the same materials. In places such deposits reach a thickness of 20 ft. and are unrelated to the present river-levels. They may be attributable to one of the Pleistocene Pluvial periods, possibly the

Gamblian (Shackleton, 1944, page 13), when increased rainfall and the melting of the Mount Elgon glaciers (Searle, 1952, page 7) would result in a considerably increased river flow. It is probable that at this time many of the now dry or nearly dry valleys on the south side of Mount Elgon were formed.

Plateau Gravels discovered by Shackleton west of Broderick Falls and thought by him to be of Lower Pleistocene age have been mentioned elsewhere (*see* page 12). They were not located during the present survey.

Surface Ferruginous Laterite ("murram") is widespread and occurs on all the rock types examined, with no marked preferences for the one or the other, attaining thicknesses of 10 to 15 ft. in some excavations and wells. The hardness varies, the surface layer at times being indurated, whilst in other cases harder bands occur at depth. Whilst some of these deposits are undoubtedly of late Pleistocene to Recent age, others may be Tertiary, particularly those that form a hard capping on many of the divides and which, by their presence, have preserved the surface sub-Miocene peneplain.

Quartz Gravel.—A 1 ft. thick band of quartz gravel float occurs at varying depths over much of the north-east of the area below brown and red sandy soils.

Soils.—A deep soil cover has formed over much of the area, especially south-west of Kitale. The decomposition of the Tertiary volcanics produces a rich, dark red-brown soil regarded locally as the best soil for agricultural purposes. The remainder of the area is covered by somewhat lighter-coloured sandy soils on the peneplain, with the exception of the area of gneissose leuco-granite which has a cover of highly quartzose acid soil but little removed from freshly disintegrated rock and of little agricultural value.

Surface Limestone.—Deposits of surface limestone are rare, only very occasional small nodules being seen. The absence of more extensive deposits may be due to the heavy rainfall resulting in complete leaching of the soluble lime.

(3) The Major Intrusives

Granites and Associated Hybrids

Although a large part of the area is underlain by rocks of a granitic nature, only small parts of it assume the aspect of typical granite country. These areas of crags and tors have been indicated on the map, and it is possible that some or all of them represent separate intrusive phases, the contacts of which may be revealed by more detailed survey.

Four main rock types can be distinguished in the granite complex (cf. Shackleton, 1944, page 6). They are:—

Biotite, and biotite-hornblende granite forming the hills and some of the lowland areas (Gb and Gc).

Xenolithic granodiorite (Gh) and gneissose granodiorite.

Gneissose leuco-granite.

Hybrid rocks (H) and xenoliths.

(1) *Biotite and Biotite Hornblende Granite* (Gb and Gc)

The main mass of the granite, stretching along the southern border of the area from Butale, west to Bungoma and north to Kavujai, is biotite granite forming the northern limit of the Kitosh batholith. In the course of recent work (Huddleston, Kakamega Report) the Mumias granite, a part of the Kitosh batholith, has been found to be essentially similar to the Maragoli granite (Pulfrey, 1946, page 21). In fact, with the exception of marginal contact modifications the granites of the present area are similar to the biotite granites described elsewhere in Kavirondo (Pulfrey, 1945 and 1946; Shackleton, 1946A; and Huddleston, 1951).

The granite is not of uniform type throughout and as has been stated it is possible that more than one intrusion is present. A common type is fairly coarse-grained, mottled pink, greenish-white and black having pink felspar phenocrysts up to 1 in. in length. Also common is a buff to grey coarse-grained less porphyritic type in which the felspar phenocrysts rarely reach ½ in. in length. The tor-forming granites show some diversity of type, that of Bungoma Hill being a fairly leucocratic, pink and white, medium-grained, felspar-porphyritic rock, that of Sangalo Hill being a brown-grey, medium-grained, leucocratic rock with grey felspar phenocrysts up to 1 in. in length, in association with a fine-grained, grey microgranite, and that of Kavujai T.S. being a darker brown and black, mottled, coarse rock with pink and white felspar phenocrysts up to ½ in. in size.

Common features in all the granites are: (*a*) the presence of dark crystalline xenoliths and schlieren representing engulfed fragments of the country-rock; (*b*) some degree of marginal shearing; and (*c*) the presence of marginal hybrids, and of hybridized areas surrounding the larger xenoliths. The xenoliths and schlieren range up to 2 to 3 ft. in length and are especially large and frequent close to the contacts, to which they show parallel alignment.

The age of the granite is undoubtedly post-Kavirondian as is proved by its cross-cutting relations towards that System, and by the presence of Kavirondian rafts on it. Kavirondian sediments have also been injected and thermally metamorphosed by the granite.

In thin section the granite is closely comparable to that described by Pulfrey (1945, page 13) and only brief repetition of the salient features are necessary. The phenocrysts are usually found to be fresh microcline or microcline-albite vein perthite, poikilitically enclosing grains of the other constituent minerals, and having irregular tongue-like margins. Phenocrysts of orthoclase and oligoclase are also present. Apart from the phenocrysts the granites consist largely of orthoclase, microcline, microcline-microperthite and oligoclase, with interstitial quartz, which is sometimes highly strained. The orthoclase is usually anhedral and sericitized, the oligoclase being also anhedral and highly sericitized. Clear albitic rims are sometimes present around the plagioclase and the twin lamellæ are occasionally bent.

The biotite is commonly of a very dark brown or green-brown variety in ragged plates containing abundant zircons with pleochroic haloes, and is often intergrown with sub-hedral green hornblende. Hornblende is often present in only small amounts and is sometimes completely absent. Accessory minerals are sphene, often in large grains, magnetite, apatite and zircon. The secondary minerals are chlorite replacing biotite, sericite and epidote, the last of which may be abundant. Rarely no primary ferro-magnesian minerals remain, having been entirely replaced by chlorite and epidote. Small amounts of interstitial pale mauve fluorite were noted in one specimen.

The microgranites contain similar mineral assemblages in comparable states of alteration.

Marginal modifications of the main mass are especially common on the River Kuiwa. Leuco-granitic types have a wide distribution, containing the same constituents as the normal granites with the exception of the mafic minerals, which are present in small amount or totally absent. Such rocks are usually buff-coloured, fairly coarse-grained and non-porphyritic. Quartz-rich leuco-granites containing muscovite and stumpy prisms of tourmaline (var. schorlite) are also frequent and are probably the result of pneumatolysis.

The more normal marginal modifications are similar to but more basic than the granite itself, showing a diminution in the amount of quartz, and an increase in the amount of hornblende and biotite present. These types grade from granodiorite through syenodiorites and mela-syenodiorites to diorites and mela-diorites. Similar compositions are exhibited by the xenoliths in the granite, indicating that the more basic marginal

modifications are due to assimilation of the country rock by the granite during its emplacement. It is probable that the original granitic magma was of a leucocratic nature and that a large proportion of the dark minerals now seen in the granite owes its origin to the assimilation of Kavirondian sediments.

(2) *Granodiorites*

The intrusions east and west of Broderick Falls are of granodioritic composition and are thought to be cupolas on the surface of the main batholith. As such they are marginal modifications of the main granite mass and probably in depth approach more nearly the composition of the biotite granites. The boss west of Broderick Falls, being intrusive into Kavirondian sediments is undoubtedly of post-Kavirondian age. That to the east is intrusive into Basement System rocks and appears to be bounded by a fault on the west, and so can only be dated as post-Archæan—pre-faulting. Whilst having a different appearance and mineral assemblage from the remainder of the post-Kavirondian granites, it is thought that this mass probably is a post-Kavirondian granite and, if the Kavirondian sediments of the Lugusi River area are finally proved to exist as shown on the map, the age of the intrusion will also have been established satisfactorily.

The intrusion west of Broderick Falls is poorly exposed, and is a coarse, speckled black and white rock with white felspar phenocrysts up to $\frac{3}{4}$ in. in length. Ferromagnesian minerals are present in moderate amounts, sometimes in aggregates up to $\frac{3}{4}$ in. in diameter. Xenoliths up to 6 in. in diameter and schlieren are common, especially near to the margins where they are orientated parallel to the contacts. In places the rock assumes a gneissose appearance with folia of dark minerals curving round ovoid felspars.

In thin section the chief felspar is found to be oligoclase in large sub-hedral heavily sericitized phenocrysts which often have clear albitic rims. Smaller amounts of clear, late, interstitial microcline and microcline-microperthite and orthoclase are present than are found in the main granite mass. The same felspars form a granulose groundmass associated with highly strained quartz, which is often sheared out into lenticular granulose folia curving around the phenocrysts. Shackleton (1944, page 7) considered this foliation to be protoclastic and due to movement during crystallization of the magma.

Euhedral and sub-hedral pale green hornblende is the main mafic mineral, associated with smaller amounts of biotite, often showing alteration to chlorite. Accessory iron-ore, sphene, apatite and zircon are present, and secondary sericite, chlorite and epidote. Specimens from marginal areas show marked shearing. The boss in the Kyebaiwa school locality is similar but with rather more microcline and perthite, and rather less mafic minerals, so that it approximates more closely to the normal biotite granite.

Associated with the intrusion west of Broderick Falls are highly sheared and mylonitized rocks believed to be original granites and granodiorites. Increasing mylonitization is demonstrated by specimens 33/231, 33/230 and 33/113, which were taken from the area between the western Nandi fault and the Broderick Falls–Kakamega road, north of the Nzoia River. Specimen 33/231, the most westerly of the three, is a mottled dark and pale green and white rock, with bluish, glassy quartz, showing slight shearing. In thin section sericitized oligoclase phenocrysts, often bent and broken and with clear albitic rims, are identifiable. The quartz is in large pools, and is highly strained but not noticeably sheared out. Aggregates of brown biotite, epidote and chlorite are present. Specimen 33/230 from further east shows much more marked shearing, the identity of the individual phenocrysts being lost, and the quartz now occurring as parallel bluish streaks. In thin section a few recognizable areas of fractured felspar remain, and it is seen the quartz is sheared out and at times assumes a lenticular form. The biotite has mostly disappeared and is represented by chlorite and abundant epidote. This increase in epidote is characteristic of the fault-zone and the rocks of the area to the east of Broderick Falls usually contain large amounts of it. Specimen 33/113 is somewhat

similar in appearance consisting of parallel pale green and dark green streaks and bluish quartz lenticles. In thin section only small fragments of felspar remain recognizable. The quartz is highly sheared out into long, continuous stringers, some augen consisting of bent, brown, biotite crystals remain, and sericite and epidote are present. Specimen 33/114 from the west of the road, 1½ miles south-east of Broderîck Falls, is a dark grey rock with white patches and black streaks of very fine-grained material. It probably represents one of the most highly mylonitized types, showing in thin section possible original felspar phenocrysts with epidote chadacrysts, sheared-out quartz and darker mylonitic streaks, the rock being cut by transverse fractures on which lateral displacement has occurred.

These rocks provide good evidence of the post-granite age of the faulting, and of the intense shearing and mylonitization within the fault-zone.

The intrusion east of Broderick Falls across the fault-zone is a gneissose xenolithic black, pink and white mottled granodiorite, in places approaching diorite in composition. It contains schlieren orientated parallel to the foliation and to the direction of elongation of the intrusion. They are usually dark green to black, up to 1 ft. in length, and are especially abundant near the margins of the intrusion. Occasional larger rafts of Basement System rocks are present as indicated on the map. The felspars of the granodiorite usually appear white or glassy, and are rounded grains up to ¾ in. in length, surrounded by sinuous biotite folia. Parts of the intrusion give rise to crags and tors whilst other parts underlie low ground, as is also the case with the biotite granites.

In thin section (specimen 33/197, Fig. 4*b*) the main felspar is seen to be oligoclase, usually simply twinned, in sub-hedral phenocrysts crowded with chadacrysts of epidote and apatite. Subordinate microperthite, orthoclase and microcline are present, the latter being late, clear, anhedral and interstitial. Myrmekitic intergrowths are also frequently present. All the felspars with the exception of the microcline are usually sericitized to varying degrees. The matrix is quartzo-felspathic, the quartz often being granulose or sheared out and lenticular, invariably highly strained, and with a tendency to be gathered into patches rather than evenly distributed.

The biotite is usually clearly defined and well crystallized, and pleochroic from straw yellow to dark brown. In the gneissose varieties it occurs in curving folia around the felspars, and in the less gneissose rocks as thick books. The hornblende is blue-green, sub-hedral and closely associated with biotite, of which it usually contains inclusions. Accessory minerals are apatite, zircon, sphene, often in large grains, and iron ore. Secondary pale green epidote is abundant, in some cases being more or less universally disseminated throughout the rock, in others (e.g. specimen 33/189, from the area of the water-mill on the Lugusi River north-east of Elegerobit T.S.) occurring as vein-like segregations.

In the fault-zone the granodiorite is highly sheared and mylonitized in a manner similar to the intrusion west of Broderick Falls. Specimen 33/103 from the road on the escarpment, east of Matete village, is a fine-grained black rock with rounded patches of white felspar. In thin section somewhat rounded blastoporphyritic felspars with epidote chadacrysts of the usual type are seen and appear to have suffered some rotation. They are enclosed in a sheared groundmass containing smaller felspars, granulose sheared-out quartz, epidote and folia of dark brown slightly pleochroic chloritic material in which fragments of biotite are occasionally identifiable, representing the break-down of the original ferromagnesian minerals.

It is probable that the mineralogical differences between this boss and the main Kitosh granite are attributable to the fact that the magma that gave rise to it was intrusive into the Basement System, and therefore must have assimilated somewhat different material from that incorporated by the other granites during its rise into place. The abundant epidote may be in part due to late deuteric phenomena, and in part a product of regional metamorphism, during which some of the coloured silicates and part of the anorthite component of the plagioclase felspar were broken down.

(3) *Gneissose Leuco-granite*

The area between Kavujai T.S. and the cliffs of Mount Elgon and east to Chuele village is occupied by a gneissose leuco-granite which is not well exposed and does not characteristically form tors. Small areas of crags and bouldery outcrops are present, however, and a few tors occur north of Sirisia village. The main exposures occur in the river valleys and are commonly in a highly-weathered condition. Patches and rafts of assimilated Kavirondian sediments occur, and in the contact area south of Chuele tongues of the leuco-granite can be seen invading Kavirondian sediments. At the contact between the leuco-granite and the biotite granite tongues and veins of the latter are seen passing into the former, and according to Shackleton (1944, page 8), along the foliation direction in the gneissose type. From this evidence it appears that the leuco-granite is of post-Kavirondian age, and of a somewhat earlier phase of intrusion than the main biotite granite. Its leucocratic nature may, perhaps, be attributable to intrusion into an arenaceous rather than an argillaceous facies of the Kavirondian System.

In the field the granite is of a somewhat heterogeneous nature, varying from white to brown and buff in colour. The felspars are usually white or pale blue, and are sometimes present as phenocrysts up to 1 in. in length, and at other times as a finer-grained equigranular mass. Muscovite is common, biotite somewhat more rare, but when present it emphasizes the marked foliation. Pegmatite veins consisting of quartz, pink and white felspar, and small books of muscovite and biotite are common throughout the granite. The foliation strike of the granite varies widely and exhibits local swirls and contortion, though the main trend appears to be east-west. Occasional dark schlieren and xenoliths are present, orientated parallel to the foliation.

It is probable that the foliation is a protoclastic structure due to flow in the partly-crystallized magma (Shackleton, 1944, page 9) but at the same time the possibility of some degree of tectonic deformation during crystallization cannot be ruled out.

In thin section oligoclase is found to be the main felspar occurring as phenocrysts. The phenocrysts are variably rounded or anhedral, often showing some degree of bending or fracturing and being lightly to moderately sericitized. They often contain epidote chadacrysts analogous to those previously described in the intrusion east of Broderick Falls. Small, rounded quartz inclusions occur in some of the phenocrysts, which are occasionally marginally replaced by microcline. The oligoclase phenocrysts lie in a groundmass of sericitized orthoclase, rarely perthite, late clear interstitial microcline which on occasions shows crystal faces and strained quartz, which is segregated in sinuous folia in some specimens. Myrmekitic intergrowths are present in a small number of the specimens examined.

Muscovite with sub-parallel orientation is present in most cases and also dark green-brown biotite containing zircon and pleochroic haloes. Sub-hedral blue-green hornblende was noted in one specimen (33/305, from the road west from Chuele village) and may be due to contamination. Accessory sphene and iron ore are rare. Secondary epidote is fairly abundant, chlorite rare. Small, sub-hedral, pale pink garnets were noted in three specimens (e.g. specimen 33/340, from the stream west of Namilama village) from marginal areas, and one of them (specimen 33/304, from the Chuere River two miles north-west of Kachunga) also contains tourmaline (not cut by the section) and is very similar in appearance to some of the marginal leucocratic modifications of the biotite granite as found on the Kuiwa River.

(4) *Hybrid Rocks and Xenoliths* (H)

Areas containing a preponderance of hybrid rocks have been indicated on the map. In all these areas the most basic rock present is a melanic hornblendite, varying in crystallinity, but usually a coarse-grained rock composed mainly of dark, shining hornblende crystals and a small amount of interstitial white material. The outcrops are

usually poorly exposed and it is difficult to obtain a clear picture of the mutual relations of these rocks to the granites. However, it seems fairly certain that they represent assimilated masses of basic intrusive rocks which originally occupied areas now composed of granite. Specimen 33/291, from the stream in the south-west corner of the area, is less altered than most and is fairly typical in thin section, being composed mainly of large euhedral and sub-hedral plates of pale green hornblende patchily replaced by biotite, pleochroic from nearly colourless to a bright red-brown. There are interstitial patches of cloudy sericitized quartz and plagioclase. Accessory minerals are iron ore and apatite in small amounts.

Associated with these rocks are others of less basic composition which differ from the host granite in having a greater proportion of mafic minerals and less quartz. The felspar component of the rocks is usually highly altered and indeterminable. Amongst the identifiable felspars, plagioclase between basic oligoclase and andesine is the most common, microcline and orthoclase being rare. Quartz is present in small amounts in all the specimens examined. The hornblende is normally of a pale green variety, and is often replaced by chlorite and red-brown biotite. Pale green-brown biotite is also almost always present. Accessory minerals are apatite, iron ore and epidote. These rocks have compositions ranging from quartz syenites to mela-diorites, and similar compositions are exhibited by the xenoliths, the only major difference being that the xenoliths usually contain a small amount of microcline, no doubt introduced from the enclosing granite. It is likely that most of the xenoliths and many of the hornblende-rich hybrids are derived from assimilated argillaceous sediments of Kavirondian age.

4. The Minor Intrusives

(1) *Granite Porphyry* (Pg)

One dyke of granite porphyry was located in the south of the area cutting the Nzoia and Muji Rivers. Typically the rock is buff-coloured and leucocratic, having euhedral felspar phenocrysts up to five millimetres in length in a fine-grained base. In thin section it is found that the rock contains microcline and oligoclase phenocrysts in a fine-grained quartzo-felspathic groundmass, some of the quartz being in vein-like segregations. The plagioclase shows patchy replacement by the microcline. Dark brown biotite is present in one specimen. The granite porphyry is of post-granite age.

(2) *Pegmatites and Aplites*

Thin veins of pegmatite and aplite cut the biotite granite and the granodiorites, and are usually of a simple quartz-felspar type. Somewhat thicker pegmatite veins consisting of quartz, felspar, muscovite and biotite are present in the gneissose leuco-granite. Locally on the Kuiwa River near the granite contact tourmaliniferous muscovite-bearing pegmatite occurs. These veins are all of post-granite age.

Other quartz-felspar veins and segregations occur in the Basement System and are of Archæan age. They are usually pink in colour and often contain small amounts of muscovite which sometimes impart a slightly gneissose texture to the rocks, when they should, perhaps, be more correctly called pegmatitic gneisses. They are infrequent as surface outcrops, but have been cut at depth by wells excavated in the north-eastern part of the area, and appear to be more resistant to weathering than the enclosing quartzo-felspathic gneisses, since they occur as hard bands in totally decomposed rock.

(3) *Granophyre*

A dark, fine-grained rock veining the Kavirondian sandstones near mile 174/6 on the railway, north-west of Broderick Falls road bridge, appears in thin section to be a crushed granophyre. The veins are thin and ramify through the rock in an anastomosing manner. In thin section quartz-felspar micrographic intergrowths are well shown and comprise the greater part of the rock. Some highly-altered felspar phenocrysts are present, and some patches of clear interstitial microcline.

(4) *Microgranite*

Small anastomosing veins of microgranite occur in places in the biotite granites and contain the same constituent minerals.

(5) *Quartz Veins*

Small white and colourless quartz veins are widespread throughout the area. The only blue quartz veins noted were in the road at the Kyebaiwa River bridge south of Matete village and in the track north of Bokoli village. Few giant white quartz veins occur in the area, the largest being that south of Bungoma Hill, which forms a marked elongated hill. The quartz is in all cases barren of mineralization.

(6) *Augite Peridotite* (Ua)

Augite peridotite forms a small bouldery outcrop on an intrusion of indeterminable shape on the Kiminini River. The rock is melanic, holocrystalline, and rusty weathering being not unlike dolerite in general appearance and mode of occurrence. No contacts with the adjacent Basement System gneisses are visible and the age of the intrusion is doubtful. It may be of post-Archæan age, and may be related to the basic and ultra-basic suite of rocks described from West Suk by Searle (1952). In thin section the rock was found to be exceptionally fresh and to consist of about 55 per cent of colourless olivine in large sub-hedral crystals, with small amounts of magnetite on its internal fissures, and about 45 per cent of very pale green sub-hedral augite (Fig. 5*a*). Small amounts of red-brown biotite and interstitial material (plagioclase?) are present.

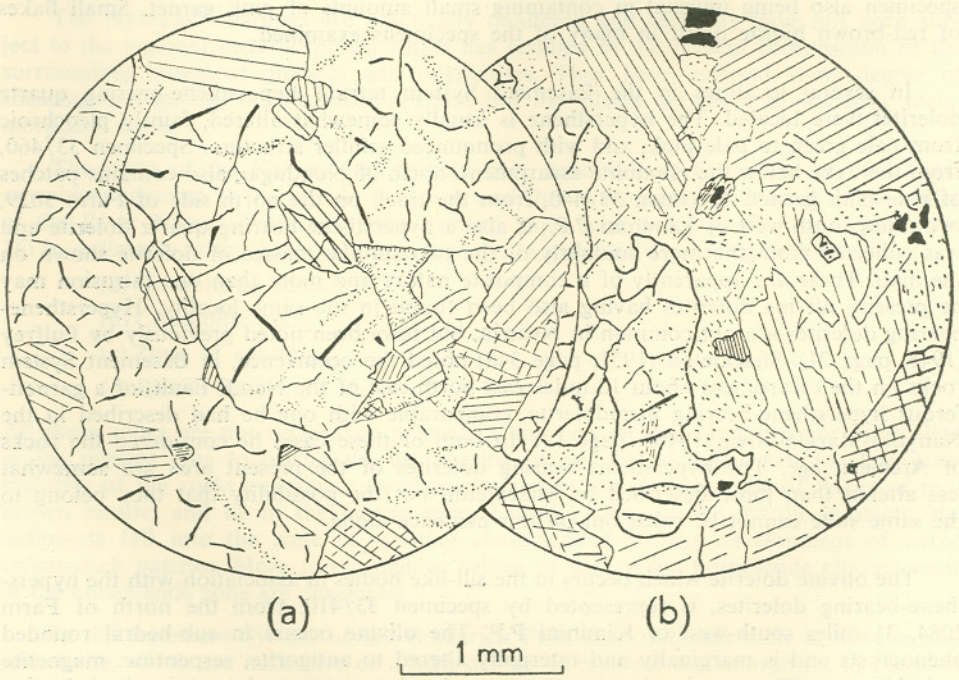


FIG. 5.—Microscope Drawings.

(a) Augite peridotite. Specimen 33/451. Kiminini River.

(b) Olivine dolerite. Specimen 33/109. Road two miles west of Maturu school. Dark stipple—magnetite in olivine; light stipple—plagioclase; dark shading—biotite; black—ore; broad shading and cross hatched— pyroxene.

(7) *Dolerite,* (D, Dh, Dg, Do, Dq)

Dolerite dykes are fairly widespread throughout the area, trending usually in north-south, north-west–south-east, or east-west directions. Amongst the types distinguished are quartz dolerite, olivine dolerite, granophyric dolerite and hypersthene-bearing dolerite with and without quartz. Whilst some of the dolerites are, from their field relations, obviously post-Kavirondian, it is not possible to assign any age to those which are intrusive into the Basement System on evidence available in the present area. It is possible that most of the quartz dolerites are of D_2 age (i.e. post-Kavirondian–pre-Bukoban) whilst the olivine dolerites may be of D_3 age (post-Bukoban).

The dolerites are characteristically medium-grained, dark grey-green holocrystalline rocks, rusty weathering and forming outcrops of loose boulders. Occasionally they give rise to chains of low elongated hills, but more often their presence at depth is indicated at the surface by boulders only. One of the major dykes in the area has been picked out by the River Lugusi for much of its course and so now occurs in a valley, the reverse of the usual form of topographic expression of dolerite dykes in Nyanza.

In thin section it is found that the textures of the dolerites vary from ophitic to intersertal. The felspar is of the composition of basic andesine or labradorite, often with poorly defined twinning and saussuritized, or with cloudy brownish alteration, darkest in the centre of the prisms. The pyroxene is colourless augite, patchily uralitized and often largely replaced by pale green or nearly colourless hornblende. Chlorite, epidote and serpentine are frequently secondary minerals and iron ore is present as skeletal growths of ilmenite, sometimes with marginal leucoxene. In the quartz dolerites interstitial quartz is present in variable amounts, and in specimen 33/371, from the Kibengei River micrographic intergrowths are present (cf. Pulfrey, 1945, page 21), the specimen also being unusual in containing small amounts of pink garnet. Small flakes of red-brown biotite occur in many of the specimens examined.

In several localities in the Basement System terrain hypersthene-bearing quartz dolerites were located. The hypersthene is usually somewhat altered, faintly pleochroic from pale green to pale pink, and with pronounced schiller structure. Specimen 33/460, from the dyke below the phonolite escarpment, north of Nundugai, also contains patches of pale pink garnet. Specimen 33/440, from the track on the north side of Farm 3029, two miles south-west of Kiminini P.P., is also a hypersthene-bearing quartz dolerite and was collected from the more southerly of the two sill-like masses of dolerite shown on the map. These are apparently of a composite nature and more than one intrusion may be present, olivine dolerites having also been found in the same locality. Hypersthene-bearing dolerites are not common in Nyanza, but have been noted previously by Pulfrey (1945, page 21). Shackleton (1951, page 348) noted the occurrence, in Basement System rocks on the escarpment about 12 miles east-north-east of the Nandi Fault, of a garnetiferous hypersthene-bearing metadolerite, comparable with one he had described in the Nanyuki-Maralal area (1946B, page 19). In both of these cases he considered the rocks of Archæan age. The hypersthene-bearing dolerites of the present area are somewhat less altered than those described by Shackleton but the possibility that they belong to the same suite cannot be ruled out on this evidence alone.

The olivine dolerite which occurs in the sill-like bodies in association with the hypersthene-bearing dolerites, is represented by specimen 33/410, from the north of Farm 2084, 3½ miles south-west of Kiminini P.P. The olivine occurs in sub-hedral rounded phenocrysts and is marginally and internally altered to antigorite, serpentine, magnetite and iddingsite. The associated pyroxenes are colourless augite and enstatite, both having purple-brown pleochroic rims and patches, which are probably titaniferous. Some patches of questionable schillerized bronzite-hypersthene are also present and small amounts of dark brown biotite. The plagioclase is fresh and of the composition of calcic andesine.

The large dyke in the Lugusi River–Luandete area is composed of remarkably fresh olivine dolerite (Fig. 5*b*). The texture is semi-ophitic to intersertal, the fresh sodic labradorite plagioclase having long prismatic habit. The sub-hedral olivine is only slightly altered, with magnetite concentrated on the internal fissures. The augite is of euhedral to sub-hedral habit and is colourless to pale green with distinct cleavage. A few small flakes of brown biotite suggest late reaction by potassic solutions. Small amounts of accessory ore are present. The estimated mode by volume is—

	%
Plagioclase	45
Augite	40
Olivine and iron ore	15

The rock is closely comparable with that described by Schoeman (1949, page 32) from the Ainabgoi River, near Sotik Township, though somewhat fresher in appearance. These further occurrences of olivine dolerite provide additional evidence for the correlation of the younger dolerites of Nyanza with the late Karroo dolerites of South Africa as suggested by Schoeman (1949, page 33) since du Toit (1939, page 330) states that some of the late Karroo dolerites are olivine-bearing.

An originally similar olivine dolerite now in a highly altered state was located in the River Toroso, north-east of Kimukungi, and may be of the same age.

5. Metamorphism

Two types of metamorphism have been operative in the area, namely: thermal or contact metamorphism in the areas surrounding the intrusive masses and regional dynamo-thermal metamorphism, which has principally affected the Basement System.

The Nyanzian rhyolites are practically unaltered and certainly have not been subject to the regional metamorphism which has resulted in the present composition of the surrounding Basement gneisses and migmatites. They have suffered some degree of shearing in reaching their present position but the effects are those of dynamic metamorphism alone.

The rocks of the Kavirondian System have been subject to normal contact metamorphism adjacent to the granite contracts and this is especially noticeable in the valley of the River Nzoia. Zones of metamorphism have been noted by Pulfrey (1946, page 36) in sediments in the Maragoli area, namely, in order of decreasing intensity—

(*a*) Hornblende zone.

(*b*) Chiastolite zone.

(*c*) Zone of spotting.

(*d*) Biotite zone.

All these zones are not necessarily present in any one section. Outcrops are insufficient in the present area to permit the deciphering of any broad zonal pattern. The great majority of the rocks examined are characterized by the development of flakes of red-brown biotite, and lie in the biotite zone. Locally, close to the granite contacts, the sediments fall into the zone of spotting characterized by the development of ovoid sericite-rich patches. More rarely slender prisms of pale green hornblende characteristic of the hornblende zone are developed.

In the Basement System of the Broderick Falls area minerals such as kyanite and sillimanite, which are indicative of a high degree of regional metamorphism in rocks of suitable composition, are absent. The majority of the rocks contain hornblende, biotite and occasionally pink garnet, and are characteristic of the meso-zone of Grubenmann in which intermediate temperatures and high directed pressures were operative. According to the metamorphic facies concept of Eskola the rocks belong to the Epidote-Amphibolite and Amphibolite Facies (Turner, 1948).

6. Structure

(1) *General*

The Basement System.—The foliation strike of the Basement System rocks of the area shows a marked deviation from the more normal north-south direction noted in the area to the north by Searle (1952) and to the south by Huddleston (Kakamega Report). The strike of the foliation, which parallels the original sedimentary bedding,

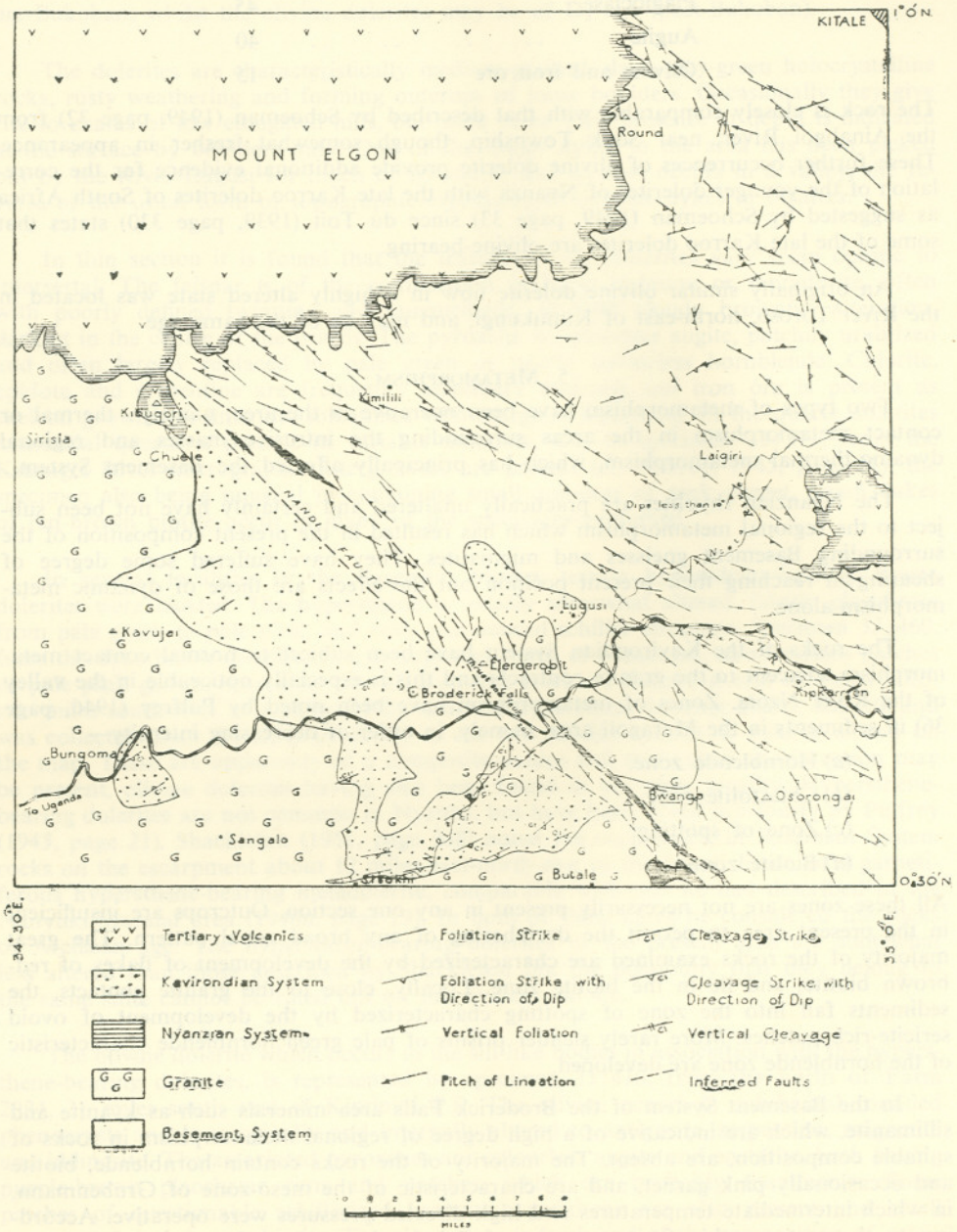


FIG. 6.—Structure map of the Broderick Falls area.

shows in the central part of the area a pronounced east-west swing. North and south of this central area the strike tends to swing into a north-west to south-easterly direction and there are indications that it is assuming a more normal north-south direction at the northern and southern boundaries of the area. This main north-west to south-east trend is confused in places, where the strike of the foliation appears to have a completely random orientation, as in the area south-west of Kitale. The strike in the neighbourhood of the Nandi fault in general parallels the trend of the fault-lines. Over the greater part of the area dips are steep, lying between vertical and 70°, on either side of vertical. An exceptional area in this respect occurs east of the Uasin Gishu plateau where the dips are of less than 10° and in some cases almost horizontal.

In view of this confusion of strikes it is difficult to decipher the fold pattern over the greater part of the Basement System of the area. The dips and outcrops do, however, tend to suggest a duplication by folding of the quartzite and quartz-mica schist bands in the north beneath the Elgon Volcanic Series, as has been tentatively indicated on the section on the map. On the available evidence these folds appear to pitch out to the south but they may have continued further and their identity may have been lost in the confused structures further south.

It is probable that the intrusions in the Basement System occurred as dykes, or inclined sheets, the present irregular nature and lensing of the outcrops being a result of subsequent deformation.

Many of the Basement System rocks exhibit intense lineation which often has nearly the same trend as the foliation, as noted by Shackleton (1944, page 4), and pitches at low angles usually to the north-west. South-easterly pitch is less frequent, occurring mainly in the area west of Kimilili. Similar observations on the direction of pitch of the lineation have been made by Shackleton in the Nanyuki–Maralal area (1946B, page 26) and Schoeman in the Embu–Meru area (1951, page 52).

The Nyanzian System.—The strike direction of the Nyanzian rocks occurring within the fault-zone parallels the main fault direction, dips being very steep to the east or vertical. Some degree of mylonitization is evident in the lenticular areas east of Broderick Falls and in those further to the north.

The Kavirondian System.—In the Nzoia Valley the strike of the Kavirondian rocks in the west is almost east-west with dips of the order of 70° to 80° to the south. Approaching the Nandi fault zone the strike swings smoothly into a north-south direction. This change in strike direction may be attributable either to drag as a result of lateral movement on the fault, or to the incomplete preservation of a pitching anticlinal structure. In the northern part of the Kavirondian terrain outcrops are rare and no reliable indication of the structure is obtainable. Similarly no structural information is available regarding the supposed area of Kavirondian sediments resting on the Basement System in the Lugusi River area. The structure of the large Kavirondian raft in the Bungoma area appears to be synclinal but it is doubtful if this is a tectonic feature as it may be attributable to the pinching up of the sediments of the roof of the magma chamber during intrusion of the granite.

The Granites.—Generally near the border of the main mass of the Mumias granite schlieren and xenoliths are orientated parallel with its margin. Away from the margins the main trend of flow structures is east-west as noted by Shackleton (1944, page 9). The intrusion east of Broderick Falls is markedly foliated, the strike of the foliation and the orientation of the schlieren being parallel to that of the surrounding Basement System, with moderate to steep dips to the east. The leuco-granite of the Butunde area is also foliated, the strike direction being inconstant but showing a preference for an east-west direction. Shackleton (1944, page 9) has noted some lineation in this granite, of a more or less horizontal nature, and having the same trend as the foliation.

The Tertiary Volcanics.—Where observations are possible the rocks of the Elgon Volcanic Series are found to be either horizontally bedded or to have very low dips outwards from the centre.

The preferred orientation of the felspar phenocrysts in the Uasin Gishu phonolites is consistant with their having flowed from the east.

(2) *The Nandi Fault and Correlation of the Basement System with the Kavirondian and Nyanzian Systems*

Opinions regarding the Nandi Fault have changed considerably since Hitchen (1937, page 6) regarded it as being of comparatively recent origin. Shackleton (1944, page 13) described it as a pre-Cambrian structure in no way connected with the Rift faults, and considered that in the Broderick Falls area it was a thrust along which the Basement System had been driven upwards over the gold-fields formations (1944, pages 2 and 9). In 1951 (page 348) he was still of the opinion that the fault is a thrust steeply inclined to the east—"a reversed fault, the steep sole of an intense zone of deformation" —on evidence which he accumulated much further south on the edge of the Kavirondo Gulf Rift.

In the area under consideration the fault itself is nowhere visible, nor, with the possible exception of a small area immediately west of Broderick Falls station, can its position be defined within other than very broad limits. As has been stated the Nandi escarpment is undoubtedly a fault-line scarp to which the fault must be related, but the escarpment has retreated some distance from the fault during its long history and can now be regarded as no more than a guide to the general trend of the fault-line. When the escarpment fades out there is little evidence as to the position, or indeed, the existence of the fault, apart from an absence of outcrops to the west of its supposed position and an abundance of outcrops to the east.

The idea that "the fault" is of a simple nature must be discounted at the outset. It is a fault complex and probably far more faults are present than are depicted in the maps. The more westerly fault in the north marks the limit of the Basement System, *in which mylonites are conspicuously absent.* The eastern fault follows the swing of the diminishing escarpment, which appears to be offset by the cross-fault indicated north of Broderick Falls, and also passes through various small mylonitized areas. Between these two faults, in the Teremi village and Kibengei school areas, patches of mylonitized Nyanzian lava occur.

In the proximity of Broderick Falls the western boundary fault can be determined in a similar manner between Kavirondian sediments and post-Kavirondian granite on the west, and mylonitized granite and Basement System on the east. A succession of lenticles of sheared Kavirondian, Nyanzian and Basement System rocks lie between this fault and the eastern boundary fault which is followed by the gorge of the Nzoia River, and accounts for the marked right-angled bend at the foot of the Broderick Falls. At the other end of the gorge the river executes another right-angled bend in passing from this fault-line to the line of a complementary cross-fault.

Further to the south the western fault lies between Kavirondian sediments and granite on the west, and *non-mylonitized* Basement System gneisses on the east. The various cross-faults are inserted on the map from the evidence of off-setting of the escarpment. The nature of the boundaries of the strip of Nyanzian on the escarpment is obscure since they are nowhere visible, but it seems certain that they are thrusts or faults. Similarly no evidence on the nature of the continuation of these contacts could be adduced by Huddleston in the area to the south. Taking into consideration the absence of mylonitization on the western fault it seems reasonable to assume that it is of a normal nature. It is also apparent that, both in the present area and in that to the south (Huddleston, Kakamega Report), the fault pattern as mapped is far more con-

sistent with its being a normal rather than a thrust fault. It is therefore suggested that the western boundary fault is a normal fault with a down-throw of over 1,000 ft. to the west, that the eastern boundary fault may or may not be normal though it appears most likely that it will be, whilst the intervening area consists of a number of steeply inclined thrust sheets dipping east and giving rise to the lenticles of Kavirondian, Nyanzian and granitic rocks, and to the strip of Nyanzian on the escarpment. The structure is comparable to the imbricate structure so common in the Northern Highlands of Scotland. The sole of the thrust sheets may be the lowest thrust mapped, or there may be further undetected thrusts within the area of mylonitized granite, but it is certain that the western boundary fault is not the sole of the thrust. In addition it is possible that there may have been lateral movement on the western boundary fault if the swing in the direction of strike of the Kavirondian rocks is taken as evidence of such movement (*see* page 35). If this is so it would explain the presence of the lenses of Nyanzian lavas in the northern part of the fault-zone, since they could have had their origin further to the south, where Nyanzian rocks occur to the west of the fault-zone. On the present evidence, however, lateral movement on the fault cannot be assumed to have definitely occurred.

Holmes (1951), applying the principles of orogenic cut-offs and age determinations of radio-active minerals as means of dating orogenic belts and cycles, maintained that his Mozambiquian belt (i.e. Basement System) was younger than the Kavirondian and Nyanzian System. His evidence in the case of the first method was based on the fact that the Kavirondian–Nyanzian east-west strike appears to be truncated by the Mozambiquian north-south strike. Shackleton, in the discussion on this paper (Holmes, 1951, page 8), considered that the presence of Kavirondian rocks in Basement migmatites at Broderick Falls tended to support this view. Shackleton himself originally mapped this Kavirondian as faulted into the Basement (1944, page 4), and since then has obtained no new evidence on the subject. It may then be ruled out as support for the younger age of the Basement System, since thrust or fault relationships provide no evidence of true age relationships.

All the structural evidence in the area points to a superposition of the east-west Kavirondian–Nyanzian strike on the Mozambiquian north-south strike giving rise to the pronounced east-west structures in some parts of the Basement System of the area, and to the confusion of strike in others, in direct contrast to the simple strike of the Kavirondian sediments. There is no evidence whatsoever for supposing a superposition of the Mozambiquian strike on the Kavirondian–Nyanzian but an abundance of evidence in favour of the reverse; in fact, no orogenic cut-off exists, the east-west strike clearly occurring on both sides of the fault-zone. It may be noted in passing that in other areas of the Basement System of the Colony east-west strikes have been noted. Schoeman (1948, page 39) noted a general gradual curving of the strata to the north-west in the north of the area west of Kitui, and in the Embu–Meru area (1951, page 51) he noted large-scale transverse folding or more probably disruption and rotation over the central part of the area, where the general strike of the strata, more or less east-west, was almost at right-angles to the regional strike.

Additional evidence in favour of the younger age of the Kavirondian and Nyanzian System may be available in the relatively unaltered state of the strip of Nyanzian rhyolite on the escarpment. It is difficult to imagine how such a receptive rock could avoid the effects of the regional metamorphism and metasomatism which have affected the surrounding Basement System rocks if indeed it was older than them. This point has also been dealt with by Huddleston (Kakamega Report) who has also provided an example of the restricted value of age determinations based on radio-active minerals from pegmatites. Similarly, the sediments of the Kavirondian System in general do not show the effects of high-grade regional metamorphism or granitization, many of them

retaining a remarkably fresh and typically sedimentary appearance. The area of supposed Kavirondian sediments on the River Lugusi is sufficiently doubtful not to be cited as evidence. If it is Kavirondian, however, then it here rests on rocks of the Basement System with an apparently normal unconformable relationship, since there is nothing to suggest thrusting or inversion of the succession. Intensive investigation with trenching and pitting will probably be necessary to prove or disprove the suspected relationship.

From the evidence available it would appear that the age of the Nandi fault is later than the last post-Kavirondian granite intrusion, the faulting probably being initiated before the complete consolidation of some portions of the granite which would, for example, explain the foliation of the intrusion east of Broderick Falls. Discounting the possibility of lateral movement the fault pattern is consistent with its having been formed by dominant north-south pressures, and it is probably attributable to a late phase in the Kavirondian orogeny, which earlier produced the dominant east-west strike of the Kavirondian sediments and superimposed the same strike on the Basement System. If lateral movement has occurred it could be attributed to direct shearing caused by north-west–south-east pressures, in which case the north-south cross-faults and shear-zones in the granite lie on one of the planes of maximum tangential shear. Such north-west–south-east pressures could alone produce the structural pattern exhibited by the Kavirondian–Nyanzian and Basement System rocks, or alternatively the dominant pressures may first have been north-south, producing the folding in the rocks, followed by a change in the direction of pressure to north-west–south-east resulting in the faulting. It may be noted that Shackleton (1944, page 9) takes the structural data which he accumulated in the Broderick Falls–Malakisi area to indicate that "the whole region was being deformed by pressures directed in a general north-south direction throughout the period of granitic intrusions so that these bodies of magma were squeezed in that direction and flowed in response to regional tectonic stresses".

It is concluded that there has been no movement on the northern section of the fault since before middle Tertiary times, in view of the fact that the Elgon Volcanic Series passes undisturbed over the site of the fault, but intermittent movement probably occurred on this section of the fault before this time, and perhaps even more recently on sections of the fault south of Broderick Falls, resulting in the rejuvenation seen in some of the rivers. Such posthumous movements may have occurred at the time of the main Rift Valley faulting.

VI—ECONOMIC GEOLOGY

1. General

No mineral deposits of importance were located during the survey. The few quartz veins noted are devoid of mineral enrichment and the pegmatite veins are of simple nature. Either the grade of metamorphism was not sufficiently high, or the original composition of the rocks was unsuitable for the production of kyanite and sillimanite in the Basement System. In view of persistant rumours of traces of gold in the rivers flowing across the Basement System, several of them were panned, but without success. The Olemusogai River has been prospected by Mr. Russel, on whose land it lies, and he maintains that it contains traces of gold.

The stanniferous gneiss containing cassiterite which was reported in the Annual Report of this Department for 1933 (1934, page 13) to exist in the Ligari (Liagiri T.S.?)–Hoey's Bridge area could not be located.

There is no shortage of "murram" for road-making purposes in the area as it has been found to occur on all the rock types examined, if not at the surface, then at no great depth, and it is usually readily uncovered by bulldozers. The decomposed material

associated with the quartzite belt in the area of Round T.S. has been used for road surfacing with considerable success by the Trans Nzoia District Council, and because of the high quartz content maintains a hard surface even in wet weather.

In the north-east of the area there is a marked shortage of stone suitable for building or road-metal. The Basement System gneisses are difficult to quarry and trim due to the absence of suitable planes of weakness. One of the oldest houses in the area has, however, been built from this material, which appears remarkably resistant to weathering, and if modern methods could facilitate extraction it would be a good source of building stone. Certain farmers use the stone as road-metal, the usual method of extraction being to light large fires on the surface of the outcrop followed by quenching with water, when thin ex-foliation layers of rock split off, which can be broken with a sledge hammer. The agglomerate of the Elgon Volcanic Series has been used to construct some native shops in Chesamisi village with fairly satisfactory results, quarrying and trimming being fairly easy, but the presence of secondary calcite and zeolitic cavities will tend to reduce the resistance to weathering. The leuco-granite occurring at the junction of the Kuiwa and Muji Rivers is used for the manufacture of mill-stones as used in the many water-mills in the area.

Bricks are made at numerous places throughout the area with varying degrees of success, from practically every type of soil. The black valley soils tends to produce the best results, provided firing is carried out satisfactorily. The bricks produced from the sandy soils over-lying the Basement System are somewhat less satisfactory due to the high percentage of quartz gravel present. Bricks of local manufacture are used on practically all the farms and are being increasingly used by Africans for the construction of huts and shops.

Locally on the rivers and streams, particularly in the Basement terrain, deposits of quartz sand occur. These are usually fully utilized by the farmers on whose land they occur. Moderate deposits of impure quartz sand occur on either bank of the Nzoia River for a distance of about one mile down-stream from Broderick Falls road bridge.

The clay of the Bungoma area is derived from the break-down of rafts of Kavirondian sediments which rest on the granite. The micaceous clay has been found in the vicinity of Bungoma hospital and shops during the construction of wells and soakage pits, in the valley of the River Malabba, and in the area of Sangalo Veterinary Station during the excavation of pits for the storage of silage. It usually lies a short distance below the surface and in the pits dug in the Hospital Compound at Bungoma has been proved to be at least 40 ft. in thickness, extending to the base of the pits at about 53 ft. below the surface. The higher material is usually pink or red due to staining by iron-bearing solutions, passing in depth to a uniform pale buff coloured material. The Bungoma clay was examined by the East African Industrial Research Board, whose report is abstracted below:—

BUNGOMA CLAY

Laboratory No.	*Field Location*
7532	From P.W.D. murram pit on the Kavujai road, north of Bungoma.
7533	From a pit in Bungoma Trading Centre.
7534	From Bungoma Hospital Compound.

The samples were screened through a 30-mesh sieve and then ground to pass a 120-mesh sieve. The products were made into briquettes and baked, and tests carried out to determine the contraction on firing, and the absorption and crazing properties of the baked material, with the following results:—

Laboratory Number	Contractions %			Water Absorption %		Crazing*
	On drying	To 1,080°C. after heating	To 1,100°C. after heating	1,080°C.	1,100°C.	
7532 –30	0·25	1·25	N.D.†	22·05	N.D.	
7532 G–120	5·00	5·50	10·00	18·60	19·05	1
7533 –30	3·50	2·75	N.D.	21·50	N.D.	
7533 G–120	4·25	7·00	5·00	8·70	30·60	2
7534 –30	5·00	3·00	N.D.	24·20	N.D.	
7534 G–120	2·75	4·50	3·75	22·70	33·60	2

* Number of dips heated to 200°, and plunged into water at room temperature.

† N.D. = Not determined.

Sample No. 7534 was not plastic enough to form on the wheel, but with the addition of 10 per cent of black cotton soil it could be thrown. As a result of the admixtures the wet to dry contraction was then increased to 6.25 per cent, the firing contraction at 1,080° C. decreased to 2.74 per cent and the absorption to 11.82 per cent. The crazing resistance remained at 2 dips. Difficulty was experienced in grinding the "talc" content of the clay sufficiently fine. This deposit might be useful to a studio pottery.

Similar material has been found to occur over much of the north-eastern part of the area overlying Basement System rocks, and probably arises by their weathering and break-down *in situ*. Small white patches of kaolin are also present due to the decomposition of large felspar units, but an average sample on washing produced only 15 to 20 per cent of kaolin, the remainder of the material being mainly quartz and mica. The material is therefore of little or no economic value for ceramic purposes.

Small amounts of worn crystals of corundum have been located in tributaries of the Nzoia River in the Lugari area. No corundum-bearing rocks were found *in situ* so the crystals have either been transported from elsewhere by river action or represent the accumulation from countless years of weathering of the Basement System gneisses, in which scattered crystals of corundum or an occasional corundum-rich band may have been present.

The suitability of the Broderick Falls as a means for the generation of hydro-electric power is worthy of examination. The river is perennial and even in the dry season has an appreciable rate of flow. The falls descend approximately 200 ft. nearly vertically, and it should be possible to find suitable sites at the foot of them for buildings to house generators. Whilst the country above the falls is not suitable for the construction of a large impounding dam, it will be satisfactory for the building of large weirs across the river from which the inlet pipes may be led. The railway passes within a few hundred yards of the falls and if a siding was constructed transport difficulties would be negligible. Kitale and Kisumu are within relatively easy reach of power transmission lines.

2. Alleged Oil Occurrence

At the beginning of December, 1952, it was reported that a bore-hole which had been sunk in Kimilili Trading Centre to provide a domestic water supply yielded a mixture of water and crude oil when tested. The Warden of Mines visited Kimilili to report on the occurrence, and collected samples of material alleged to have come from the bore-hole. The following information is derived from his report.

The bore-hole was drilled to a depth of 200 ft., the diameter of the bore of the first 58 ft. being 10 in., and of the remainder 6 in. According to the driller's log soft ground was encountered up to a depth of 58 ft., after which a hard granitic rock was struck. This continued until at a depth of from 105 ft. to 116 ft. a red "sandstone" was passed through, followed by granite and dolerite down to a depth of 200 ft.

An oily smell was reported as first occurring at a depth of 123 ft. When the bore-hole was placed on test the first 1,000 gallons of water obtained appeared to be clear and pure, but after this a mixture of water and supposedly crude oil was pumped out. It has been stated that some 200 to 300 gallons of oil were so removed and allowed to collect in a nearby pit. Local inhabitants were not slow to take advantage of this free supply of oil, especially as it was found possible to use the oil with satisfactory results in Dietz and pressure lamps.

At this point, owing to the supposed danger of fire, the bore-hole was filled in, most unfortunately before the arrival of the Warden of Mines, who was therefore compelled to collect samples of oil and water reputed to have come from the bore-hole from local inhabitants, instead of from the bore in actual production.

Examination of one of the mixed water and oil samples was carried out by the Government Chemist and Assayer. The clearly defined oily layer was separated from the water and distilled. No fraction was recovered below 200° C., and the oil was found to possess the characteristics of kerosene. Further samples possessed a similar appearance, many of them being clear, pale yellow liquids quite unlike crude oil. The absence of light fractions on distillation also suggests that the oil is a refined spirit and not crude oil.

Turning to geological considerations, it is generally acknowledged that oil is formed originally by the anærobic decomposition under pressure of minute marine organisms. The source rock of oil must therefore be a sedimentary rock, but in view of the migratory properties of oil the host-rock need not necessarily be of the same nature, since the oil will migrate in an upwards direction through porous rocks until it escapes at the surface or is held by some form of sub-surface structural or stratigraphic trap.

Although there are no actual outcrops of rock in the immediate vicinity of Kimilili, it is surrounded on all sides at no great distance by outcrops of recognizable Basement System rocks. Samples taken from the bore-hole confirm that the sub-surface rocks are composed of Basement System biotite gneiss, with some more pegmatitic patches, cut by veins or dykes of a more basic, possibly doleritic, nature. It is known that many of the rocks of the Basement System were originally sediments, probably of a marine geosynclinal type, but since they were deposited before the dawn of life on the earth they cannot possibly be the source rock of oil. By crustal upheaval it would be possible, if improbable, for rocks of the Basement System to become the host-rock of oil. There are, however, no suitable sediments in the Kimilili area or for many miles in any direction around Kimilili which could possibly be the source rocks of oil. The only rocks of a suitable geological age near at hand are the volcanics of Mount Elgon and the Uasin Gishu Plateau, both of which may be ruled out as possible source rocks of oil.

Two worn boulders of phonolite have been produced, presumably extracted from the pit dug at the start of boring, but no information is available as to the exact depth at which they occurred. In thin section they are found to be typical of the Uasin Gishu phonolites, the nearest outcrop of which is some 18 miles from Kimilili. It is highly improbable that the Uasin Gishu phonolites ever extended as far as Kimilili, and hardly less improbable that they reached the position in which they were found by any natural agency.

In view of the evidence available, although the writer did not see the bore-hole "in production", it seems reasonable to suppose that, on geological grounds, no crude oil occurs, or could reasonably be expected to occur in the Kimilili locality, and that the material produced is a refined spirit, possessing the properties of kerosene, which was introduced into the bore-hole either accidentally or by design.

3. Water-supply

With the exception of the Kavujai–Butunde–Sirisia area the majority of the rivers and streams of the area are perennial and there is no shortage of water. Wells excavated in the north-eastern part of the area up to depths of 70 ft. have located water in adequate supplies at depths varying from 10 ft. to 50 ft. This area is also well served with springs, many of which have a high rate of flow.

Five bore-holes have been sunk in the area, their positions being indicated on the map. All were successful and such details concerning them as are available are summarized in Appendix I.

In the Native Locations earth dams are being constructed with success and elsewhere individual farmers build dams sufficient to meet their own requirements.

It is not possible to make any accurate recommendations as to the siting of wells and bore-holes in the area or the possibility of obtaining water on the evidence available. The following tentative suggestions may be made:—

(*a*) In areas of the Basement System with deep soil cover most wells seem to be successful at moderate depths, due probably to the tapping of perched water tables resting on resistant bands of pegmatitic gneiss in pervious weathered biotite gneiss.

(*b*) In areas where Basement System rocks outcrop as large crags and lie close to the surface in an unweathered condition the excavation of wells or sinking of bore-holes is unlikely to meet with success unless a major joint on which water is flowing is tapped. From the appearance of surface outcrops it is judged that such joints are not frequent.

(*c*) In granitic areas bore-holes may meet with success, for example, near Bungoma, since the granite there has a more well developed joint system than usual, which may be assumed to afford free passage to water.

(*d*) There is a lack of evidence concerning the areas of Kavirondian sediments, but it is possible that some of the argillaceous horizons may be impervious and support bodies of water.

4. Recommendations for Future Work

Although the present survey has failed to indicate any economic mineralization the margins of the granitic intrusions do warrant further examination for gold. Particular attention should be paid to the marginal granitic area on the Kuiwa River, the area of Nyanzian rocks in the Namaragua school area and to the numerous sand-rivers draining the areas of pegmatite-rich gneissose leuco-granite south-east of Sirisia village.

The Broderick Falls area is of great importance in deciphering the nature of the Nandi fault and resolving the various ages of the pre-Cambrian Systems of Kenya, and when time is available it should be mapped in detail with special reference to the area east of Broderick Falls and Matete and south of Musikhu villages.

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APPENDIX

Bore-hole Logs

Details of bore-holes were supplied by the Hydraulic Engineer, Public Works Department.

*Bore-hole No. C.*1286, *Farm No.* 4840—

Total depth	130 ft.
Weathered Basement System rocks at	77 ft.
Yield on 24-hour test	10,000 gal.

*Bore-hole No. C.*1349, *Farm No.* 5774—

Total depth	130 ft.
Red clay	from 0 ft. to – 50 ft.
Micaceous clay	from – 50 ft. to – 75 ft.
Pale yellow sandstone (? weathered and decomposed Basement System rocks)	from – 75 ft. to – 130 ft.
Yield on 24-hour test	10,000 gal.

*Bore-hole No. C.*1351, *Farm No.* 7059/1—

Total depth	115 ft.
Red soil	from 0 ft. to – 30 ft.
Micaceous soil	from – 30 ft. to – 65 ft.
Sandstone (? weathered and decomposed Basement System rocks)	from – 65 ft. to – 100 ft.
Basement System Gneiss	from – 100 ft. to – 115 ft.
Yield on 24-hour test	2,400 gal.

*Bore-hole No. C.*1289, *Farm No.* 6484—

Total Depth	121 ft.
Old well	from 0 ft. to – 28 ft.
Coarse micaceous gneiss	from – 28 ft. to – 55 ft.
Decomposed gneiss	from – 55 ft. to – 67 ft.
Weathered gneiss	from – 67 ft to – 121 ft.
Yield on 24-hour test	4,800 gal.

*Bore-hole No. C.*1321, *Hospital Compound, Bungoma*—

Total depth	203 ft.
Red soil and murram	from 0 ft. to – 20 ft.
Micaceous clay	from – 20 ft. to – 60 ft.
Weathered granite	from – 60 ft. to – 85 ft.
Finely powdered granite	from – 85 ft. to – 96 ft.
Fresh hard granite	from – 96 ft. to – 203 ft.
Yield on 24-hour test	22,200 gal.
Water table	from – 80 ft. to – 120 ft.

G.P.K. 2,400—600—11/53.