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GEOLOGY OF THE KAKAMEGA DISTRICT

DEGREE SHEET 33 S.E. QUARDRANT

(with colored map)

by

A. HUDDLESTONE, M.Sc., F.G.S., A.M.I.M.M.

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Foreword

The Kakamega area was the first to be mapped when the Geological Survey of Kenya was created as a section of the Mining and Geological Department in 1933. Unfortunately, at that time, mapping was restricted to the more obvious lithological units and, though portions of the district and areas adjacent to it were surveyed in detail between 1936 and 1940, the unravelling of the complicated geology of the whole area was not attempted until the present work was begun. With the completion of the map included with the report, the whole of the known North Nyanza goldfields area has been covered by reasonably detailed geological survey.

The district has been the most important producer of gold in the Colony. Since 1931, when production of alluvial gold began, to be followed soon after by the exploitation of vein deposits, some three and a half million pounds worth of gold has been recovered, representing more than half the total production from the Colony. Again, more than half of that value of gold was produced from the Rosterman Mine, near Kakamega township. The mine was worked to a depth of over 2,000 ft., and represents by far the deepest and most extensive mine that has been developed in the Colony.

The goldfield area is cut off on the east by the Nandi scarp, the result of a major fault, along which the goldfield rocks were dropped down relative to the country further east. High up on the eastern side of the fault, in the northern part of the area, there is however an infaulted strip of the goldfields Nyanzian rocks that offers valuable evidence on the age relationship of the gneisses of the Basement System and the lightly metamorphosed Nyanzian lavas. A few years ago arguments were advanced that the Basement System rocks were younger than the much less metamorphosed rocks of the Nyanzian and Kavirondian Systems which make up the goldfields. On the evidence of the rocks along the Nandi fault in this area, and more particularly in the Broderick falls area which lies immediately to the north, there seems no doubt that the Basement System is in fact the oldest series of Precambrian rocks in Kenya.

The Nandi fault is believed to have originated in Precambrian times, but Dr. Huddleston adduces evidence to suggest that new movement along it occurred in Tertiary times, probably at the same time as Rift Valley faulting was taking place in Central Kenya and along the Kavirondo Gulf. Such movements probably had an important effect on the dispersal of alluvial gold deposits in North Nyanza.

Nairobi,
18th November, 1952.

WILLIAM PULFREY,
Chief Geologist.

CONTENTS

LIST OF ILLUSTRATIONS

MAP

ABSTRACT

The report describes an area of some 1,200 square miles in western Kenya, bounded by the Equator and latitude 0° 30′ N. and longitudes 35° 00′ E. and 34° 30′ E. The most striking physiographic feature is the Nandi Scarp and its crest highlands, which are possibly relics of the end-Cretaceous (?) peneplain, rising in places to over 7,000 ft. To the west of the scarp lie the gently undulating Kavirondo peneplain, said to be of sub-Miocene age, and the rugged Maragoli Hills.

The rocks exposed in the area include: (1) highly granitized gneisses of the Basement System, east of the Nandi fault; (2) steeply-dipping acid to basic volcanics with minor pyroclastic developments comprising the Nyanzian System (Precambrian), overlain by (3) conglomerates, grits and mudstones of the Kavirondian System (Precambrian); (4) the Maragoli and Mumias (Goldfields) granites, altered dolerites of more than one age and a variety of minor intrusives, which invade both Nyanzian and Kavirondian rocks; (5) Tertiary phonolites resting on a generally highly uneven surface in the south-central portion of the area; and (6) Pleistocene and Recent soils, gravels and lateritic ironstones.

A brief account is given of the various rocks and their structures and metamorphism.

Gold deposits are described in some detail, particularly those of the Rosterman Mine. Reference is made to other deposits of possible economic value such as pyrites, and also to water-supplies and local sources of building material. The future economic possibilities of the area are briefly assessed.

GEOLOGY OF THE KAKAMEGA DISTRICT

I—INTRODUCTION

The Kakamega district described in this report is the south-east quadrant of Degree Sheet 33 (Kenya), bounded by the Equator and latitude 0° 30′ N. and by longitudes 35° 00′ E. and 34° 30′ E., and is some 1,200 square miles in extent.

The greater part of the quarter-degree sheet lies within the North Nyanza native reserve, administered from Kakamega. The eastern portion of the area, part of the Nandi native reserve, is administered from Kapsabet, which is some distance east of the area mapped. Several forest reserves are also included in the central and eastern portions of the area.

The Eldoret Mining Syndicate Concession*, together with the Maramma and Maragoli area, which are portions of the quarter-degree sheet, have already been mapped and described in detail by Pulfrey (1936, 1945 and 1946)†, while the area west of the Yala–Butere branch line of the East African Railways has been mapped and part of it described by Hitchen (1937). Pulfrey also mapped a small area in the vicinity of Rosterman Mine, and his unpublished report has been freely drawn upon in the present work. These portions of the district are not dealt with in this report except when references are necessary to establish correlations. The areas previously mapped are shown in Fig. 1.

The east-central portion of the area is made up of rocks of the Kavirondian and Nyanzian Systems invaded by granites with associated gold-bearing quartz veins, several of which have been worked for a number of years, though in October, 1951, only one large property, the Rosterman Mine, was in active production. Since 1931 some 437,000 ounces of fine gold, valued at over £3,450,000, are recorded as having been produced in the area.

About eight months, between October, 1950, and July, 1951, were spent in reconnaissance field mapping and mine examinations.

Climate and Vegetation.—Altitudes vary from about 4,200 ft. in the western portion of the area to over 7,000 ft. in the east, on top of the Nandi Scarp, but the climate may be said to be equable over the whole area. Rainfall is adequate and well distributed, annual averages varying between sixty and seventy-five inches, with the highest averages tending to be found in the central portion of the area. Records of selected stations are given below:—

Station	Altitude	Rainfall 1950	No. of rainy days	Average rainfall	Years recorded
		inches		*inches*	
1. Kaiboi Dispensary	6,000	45.75	—	63.03	10
2. Kabras Dispensary	5,200	68.44	123	72.85	9
3. Kakamega District Office ..	5,100	72.76	170	74.59	26
4. Kakamega Forest Station ..	5,500	72.04	165	75.43	13
5. St. Peter's Seminary ..	5,600	71.34	?	67.93	3
6. Musingu School	5,150	73.82	149	61.55	2
7. Mumias, St. Peter's Mission	4,396	63.89	149	70.79	16
8. Maramma Dispensary ..	4,700	64.14	119	69.98	10
9. Bukura Agricultural School	4,800	63.21	152	66.89	26
10. Kisa Dispensary	4,800	64.62	180	73.47	9
11. Bunyore Dispensary ..	5,000	53.06	135	64.98	10
12. Kaimosi, Tea Estates ..	5,800	—	—	66.77	not known
13. Kaimosi, Musini Estate ..	5,700	—	—	69.34	10
14. Kaimosi, Friends African Mission	5,300	—	—	71.46	36

* Referred to subsequently as the E.M.S. Concession.

† References are quoted on p. 59.

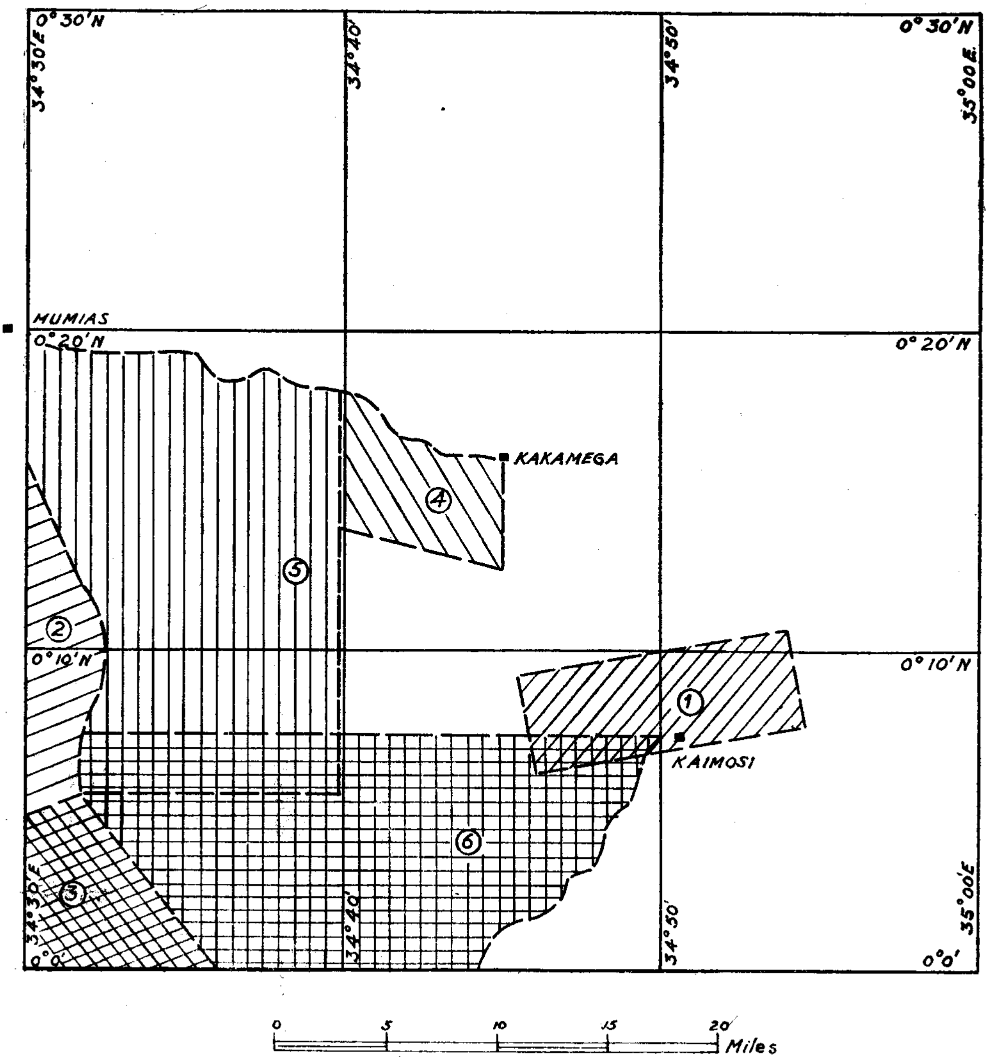


FIG 1.—Areas previously mapped in the Kakamega district. 1.—E.M.S. Concession (Pulfrey, 1936). 2.—Hitchen, 1937. 3.—Hitchen (unpublished). 4.—Pulfrey (unpublished). 5.—Pulfrey, 1945. 6.—Pulfrey, 1946.

Stations Nos. 1, 12 and 13 are in the eastern portion of the area, Stations 2 to 6 and 14 in the central portion and Stations 7 to 11 towards the west.

The area as a whole is thickly populated and heavily cultivated except in the Forest Reserves and the Nandi Reserve. The main crop grown is maize, considerable tonnages of which are exported from the district annually. Wimbie, mtama, yams, cassava and sweet potatoes are also grown extensively. Cattle breeding is the main activity in the Nandi Reserve where relatively little crop farming is practised.

Communications.—With the exception of the Forest Reserves and portions of the Nandi Reserve, the area is well served by a close network of good earth roads, some of which, however, become impassable for considerable periods after heavy rain. The Forest Reserves are for the most part difficult of access, except along cleared lines and tracks cut for the extraction of timber by the various saw-milling companies operating in the area.

Maps.—The topography on the accompanying geological map is based on the Kakamega 1 : 62,500 sheet published in 1933 and the Mumias Sheet, Africa North A. 36/W, scale 1 : 250,000, published by the Geographical Section, General Staff, in 1916, adjusted where necessary from an interpretation of air photographs. Roads, tracks and streams were plotted from air photographs, which were available for the whole of the area. This work was done mainly in the field as the geological mapping progressed, field maps being produced on a scale of 1 : 50,000.

Rock Exposures.—Exposures generally, except in the granite areas, are not good. In the Forest Reserves and over large tracts at the foot of the Nandi escarpment, thick soils mask the solid geology, and in such areas geological boundaries shown on the map are largely conjectural. In the central portion of the area, made up of Nyanzian and Kavirondian rocks, exposures are generally few on the divides, though adequate in the stream beds. Between the streams considerable use was made in mapping of the changes in soil types, as stream clearing could not be carried out in the time available.

II—PREVIOUS GEOLOGICAL WORK

The earliest references to the geology of the area are those of Gregory and Scott Elliot (1895, p. 677) who reported that near Mumias the Archæan Series was represented by fine-grained syenitic gneiss, almost identical in character with some in the Taita Hills. Sediments were mentioned as occurring in the Nandi Hills but no precise locality was given.

Gregory later (1921, pp. 125, 126) recorded that the section north-east of Kisumu towards Kaimosi was a plateau consisting of a foundation of Eozoic gneiss with some granite, and vogesite dykes. The gneiss was said to stretch to within three and a half miles east of Kaimosi Mission, where it was succeeded by granite. Phonolite (of "Kenya" type and identical in character with that at Kisumu, a specimen of which was described by Miss Neilson in a petrological appendix, *loc. cit.* p. 391) was said to form the ridge at 5,100 ft., above the west branch of the Kibos River, some ten miles north-east of Kisumu. Reference was made to two main erosion levels, one at 4,600 ft. and an older peneplain at 5,600 feet of which the higher hills are the remnants. The country between the Nandi Hills and Lake Victoria was described as being made up of sedimentary rocks of the Karagwe Series (*loc. cit.* p. 44).

Combe (1928, 1929 and 1930) examined a considerable part of North Nyanza, mainly west of the present area, and noted the presence, between the Edzawa River and the Bukura Ridge, of a broad belt of Karagwe-Ankolean sediments which he considered had a broad synclinal structure. Conglomerates in the sediments, referred to as "Kisendo conglomerates", were noted to carry boulders identifiable with rock types found in a nearby "green-grey rock" series, some of which were considered to be ancient lavas. These lavas were said to be much altered and decomposed but were considered to be mostly phonolites, with andesites, doleritic rocks and rhyolites. Combe suggested that they might be compared with the Ventersdorp System of South Africa and that the Karagwe-Ankolean might be equivalent to the Nama-Transvaal System.

Ödman (1929, pp. 80–89), also in 1927, made a rapid reconnaissance of a large part of North Nyanza as an extension to more detailed work in the Mt. Elgon area. He recognized both volcanics and sediments in what he termed the Kavirondo Series*, thought to be equivalent to the Karagwe-Ankolean System of Uganda. The volcanics were shown as wedging out east of Yala. The basic lavas were considered to be the oldest members of the Series and the abundant tuffs and agglomerates associated with the more acid members were thought to indicate a decline in volcanic activity. Volcanic pebbles in the conglomerates of the sedimentary part of the series were taken to indicate the age relationship of the two divisions of the series, both of which were clearly seen to be injected by granites. Isoclinal folding was suggested, as only locally were dips other than to the south noted.

A few years later Campbell Smith (1931, p. 230) redescribed the phonolite collected by Gregory from the Kisumu–Kaimosi road.

Kitson (1932) reported that the general strike of the "Karagwe-Ankolean" rocks in the Kakamega Goldfield was east-west but that in the basins of the Koa and Lugusidz rivers there was a pronounced northward swing. The general structure was said to include at least two synclinès and two anticlines. Granites of "four different kinds and ages" were noted, both north and south of the "Karagwe-Ankolean" rocks.

Murray-Hughes (1933 A, p. 4) confirmed that the volcanics of the Kakamega district are older than the sediments, which he equated with the Muva-Ankolean, and that the pebbles and matrix of the conglomerate are sometimes largely composed of volcanic material. In the same year his geological map of the Kakamega district (1933 B) was published, but no details of the volcanic and sedimentary rocks were shown.

Pulfrey (1936) mapped in detail an area of about thiry-five square miles known as the E.M.S. Concession, situated on the northern slope of the Yala–Edzawa divide, some sixteen miles north-north-east of Kisumu. He found that the "Muva-Ankolean" sediments, invaded by igneous material of several ages, had a simple structure there, consisting of two folds separated by a long "flat intermediate limb". The two folds were considered as subsidiary folds in the major folds of the Kakamega area and were said to be themselves gently, and occasionally sharply, folded. Dips were found to be steep and usually to the north. Only rarely were southerly dips observed and these were thought to be local inversions. The wide metamorphic aureole, two to three miles across, in the sediments north of the Maragoli granite, was considered to reflect the gentle dive of the granite contact and the shallowness of the Kakamega roof pendant.

Shackleton (1951, p. 348) suggested that the Nandi fault is reversed and also dealt with the various erosion surfaces observed in the area.

In addition to the above there are several unpublished departmental and private reports by Hitchen and Pulfrey on the surface and underground geology of various gold mines and prospects in the area.

*The Kavirondo Series included both the Nyanzian and Kavirondian Systems of present usage.

III—TOPOGRAPHY

Broadly speaking the area may be divided into three major physiographic units—

(*a*) the Nandi Scarp and the highlands to the east of it;

(*b*) the generally only slightly undulating peneplain, occupying the northern, central and western portions of the area; and

(*c*) the southern hill belt.

Pulfrey (1946) noted a further sub-division in the south—the southern peneplain, considered as a down-faulted portion of (*b*)—but its extension into the newly-mapped portion of the quarter-degree sheet is too insignificant to warrant attention here.

The Nandi Scarp forms the most prominent physical feature. It runs a little west of north from its point of emergence from the thick Kapwaren forest, just south of the Kakamega–Kapsabet road about two miles from the eastern boundary of the area, and crosses the northern boundary some five miles further west. The main scarp rises in a distance of about a mile from a general elevation of 5,400 ft. to 6,600 ft. over most its length, but south of the Kakamega–Kapsabet road it rapidly dies out. Isolated features such as Chapkaigat, Tobolwa, Kimoror and Sumayat on top of the scarp, rise to just over 7,000 ft. and may be remnants of a peneplain of the same age as the Kisii highlands peneplain (Shackleton, 1946, and Huddleston, 1951).

The northern peneplain has an average slope from the foot of the Nandi Scarp to the western boundary of the area of a little over twenty-five feet per mile, and above it rise remnants such as Akarra, Mbaga, Asare, Rekeya, Kisa, Kavugai, Kakunga, Kapsugur and Kamabiri. A tangent to the summits of these hills has the same general slope from east to west as the main peneplain, and they may be relics of the Kitale plain (Dixey, 1945, p. 246). Other remnants—Lugulu, Hakege, Samia and Butunde—have still higher altitudes but a tangent to them is again parallel to the lower surfaces, and they may represent a down-faulted portion of the 7,000-foot surface. The main peneplain has been said to be part of the sub-Miocene surface (Kent, 1944). Dixey, however (1945, p. 243), is inclined to regard it as terminating in later Miocene times, while King (1949) postulates a Jurassic-Cretaceous age for this surface though implying its maturity in post-Cretaceous times. In the area under review, however, no positive age data are available.

The southern hill belt is built up of rugged granite tors rising in places to heights of up to 6,400 ft. Pulfrey (1946, p. 5) suggested that those in the Maragoli area and the tops of the Nyangori hills might represent the remains of a peneplain of greater age than the main peneplain, while Dixey (1945, p. 244) correlated them with the Kitale surface.

While the writer feels that many variables (e.g. variable resistance to erosion of different rock types, warping and differential movement of fault blocks, etc.) render difficult the accurate delimiting of peneplains, the section and profiles given in Fig. 2 do seem to suggest the possibility of the presence of four (and possibly a fifth) erosion bevels in the present area. Shackleton (1951, p. 379) would reduce them to three, postulating that the sub-Miocene and Kitale surfaces are one and the same. He remarks that the sub-Miocene surface is traceable by the regular sloping interpluves up to the foot of the "Kakamega" (Nandi) Scarp while, to the west, such small flat-topped hills as Rekeya and Akure and others mark the former extent of the surface. The section and projections do not, however, agree with this suggestion. If the interpluves are considered to represent the sub-Miocene surface the remnants mentioned are some hundreds of feet above it. Rekeya for instance, as mentioned above, is probably a relic of the Kitale surface.

There are three major river systems in the area—the Nzoia, Yala and Kibos systems. Of these, the Nzoia with its major tributaries the Lusumu, Sioka and Feradzi, is by far the largest. In the Mumias granite area these streams flow in a general N.E.-S.W. direction but, on reaching the Kavirondian System, they all swing to an east-west line, roughly

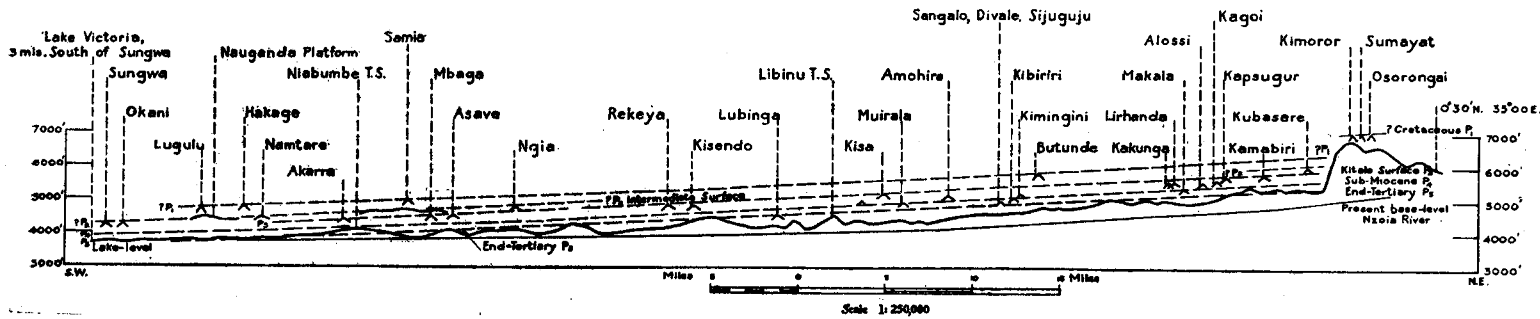


FIG. 2.—Possible erosion surfaces in the Kakamega district. The profile is projected on to a line through Niahumbe and Libinu trigonometrical stations. Vertical exaggeration x10.

following the strike of the rocks. Though the drainage system is mature, the major rivers and their tributaries show evidence of rejuvenation in the form of waterfalls, rapids and rock-bars, with intervening stretches of papyrus-choked swamps, while broad, gently-sloping divides often drop sharply to the newly-incised modern stream valleys. This rejuvenation has probably been caused by renewal of movement involving general uplift along the Nandi fault in fairly recent times, which has also tilted the peneplained surfaces to their present slope towards the south-west.

IV—SUMMARY OF GEOLOGY AND GEOLOGICAL SUCCESSION

The main rock types seen in the area can be closely matched with those of the Maramma and Maragoli area, with the exceptions that the Nyanzian volcanics are less well represented and there is a strong development of Basement System rocks east of the Nandi fault. The main types present and their age relationships are as below.

Pleistocene and Recent—

Superficial deposits—black clays, sandy soils, laterite and valley alluvium.

Tertiary—

Phonolites in the south-central portion of the area.

——— Unconformity ———

?*Upper Precambrian*—

Dyke intrusions—mainly dolerites (D_2-type), but some lamprophyres and quartz porphyries.

Emplacement of quartz veins.

Major plutonic phase—intrusion of the Maragoli and Mumias granites and slightly earlier intrusion of the Kakamega diorites.

Precambrian—

Folding and faulting.

Deposition of the Kavirondian conglomerates, grits and mudstones.

——— Unconformity ———

Intrusion of Older Dolerites (D_1).

Folding.

Extrusion of the Nyanzian volcanics—basalts, andesites, andesitic tuffs and agglomerates, and rhyolites.

——— Unconformity ———

Basement System—

Granitoid gneisses, migmatites and hornblende schists.

The Basement System rocks are confined to the eastern portion of the area and show little variation in type, being mainly composed of granitoid gneisses, augen gneisses, migmatites and hornblende schists, the latter forming only a minor part of the succession.

The Nyanzian System is not well developed in the area mapped and is composed entirely of acid to basic volcanics with tuffs and agglomerates of intermediate composition. No pyroclastics were found associated with either the acid or basic members of the series.

The Kavirondian System has a wide development in the central portion of the area where a thick series of coarse conglomerates, grits (often highly felspathic) and finely banded mudstones are well seen. A metamorphic aureole often two to three miles wide, associated with the major granite intrusions, extends across these rocks both from the north and south.

The Granites, consisting of two major masses—the Maragoli granite in the south and the Mumias granite in the north—are intrusive into the rocks of the Nyanzian and Kavirondian Systems. There is little to distinguish them either in hand-specimen or in thin slice and it is possible that they are part of one large batholith. Smaller masses are seen near Kakamega and also intrusions into the Basement System rocks just north of the Kaimosi–Kapsabet road. Diorite and diorite hybrids are associated with the Kakamega granite and probably slightly ante-date it.

Older Minor Instrusives.—Meta-dolerites and epidiorites cut the Nyanzian rocks but have not been seen invading the Kavirondian System. Quartz porphyries are intrusive into both systems.

Younger Dolerites.—Fresh-looking coarse-grained quartz dolerites invade the granites and the Nyanzian and Kavirondian rocks in wall-like masses, which can often be traced across country for several miles. Only one example of olivine dolerite was seen—in the granite just east of Kamabiri Hill.

Giant White Quartz Veins, which are known locally as "buck reefs", appear to be devoid of valuable gold mineralization. They follow two main directions, one almost north-south and the other east-west, and are emplaced in rocks of the Nyanzian and Kavirondian Systems and the granites. None have been noted in the Tertiary rocks of the area. Such veins form sharp hog's-back ridges and can often be traced for several miles with only minor breaks.

Tertiary Phonolites.—The phonolites are the only rocks of Tertiary age in the area. No detail of true age relationships is obtainable here but, further west, Hitchen (1937) has mapped similar phonolites overlying Miocene sediments. Kent also (1944, p. 17) considered that the phonolites were at least as recent as Lower Miocene. In the portion of the quarter-degree sheet mapped, the lavas are of small extent and are found only in the extreme south where they cross the Kiboswa–Kaimosi road, about one mile north-east of Gambug, and then swing south out of the area about one mile east of that village.

Pleistocene and Recent Deposits.—Post-Tertiary deposits are represented by soil and laterite covers, the latter being particularly prominent and often of considerable thickness in the area north of the Nzoia River, both east and west of the Mumias–Bungoma road. In addition fairly extensive deposits of gravelly alluvium, several of which have yielded considerable quantities of alluvial gold, are found in the flats of the larger streams. Many streams are also choked with recent deposits of black silt carrying a luxurious growth of papyrus and tall swamp grass.

V—DETAILS OF THE GEOLOGY

1. The Basement System

Rocks of the Basement System are confined to a triangular strip of country between the Nandi fault and the eastern boundary of the quarter-degree sheet. They extend about one mile west of the Nandi scarp and form the scarp itself and the highlands east of it. The rock types represented are few in number, with granitoid gneisses and migmatites predominant. There are also minor developments of augen gneisses, quartz-muscovite schists and hornblende schists. Pegmatite veinlets, in which small books of biotite and muscovite are common, and meta-dolerites are the rare minor intrusives. There are also small intrusions of fresh younger unsheared granites in the area below Chakiakak T.S.* All the Basement rocks are highly foliated. In the vicinity of the Kakamega–Kapsabet road the foliation direction is usually about east-north-east but further north there is a swing to a more west-north-west direction. All dips are to the east, varying between 40° and 70°.

* T.S. = Trigonometrical Station.

The gneissic and migmatitic rocks show only minor differences in hand-specimen, except in the presence of felspar augen in some of the gneisses and variations in the amount of mafic minerals present. Specimen 33/58 is typical of the augen gneisses and in hand-specimen is a coarse-grained pink granitic type, showing closely packed felspar augen up to half an inch long set in swirls of mafic minerals. In thin section the felspar augen, mainly clear microcline but with a little orthoclase and subordinate medium oligoclase, are seen to be intensely crushed and corroded and set in a fine-grained interlocking mosaic of quartz and similar felspars. Fine myrmekitic intergrowths of quartz and felspar are present in the groundmass and are often concentrated peripherally to the augen. The only dark mineral is biotite, pleochroic from dark brown to light golden brown, in shreddy form and strung out in parallel bands which swirl round the felspar augen. With the biotite is associated a considerable amount of rather pale green epidote, and there is also a fair development of fine muscovite flakes. A little apatite and black iron ores were the only accessories noted.

Other types are similar but without the development of augen. In several examples also, microperthite forms a fair proportion of the felspathic material. A bluish green horneblende is occasionally (as in specimen 33/36) preponderant over biotite, which appears to replace it partly. Quartz grains show intense corrosion and marked strain polarization in certain examples, and relics of it occur as rounded blebs in both felspars and hornblende, when isolated relics are often optically continuous over fair distances. Granular sphene is occasionally relatively abundant but only rarely were minute golden brown garnets and colourless zircons noted.

The hornblende schists, of which specimen 33/24 is a good example, are fine-grained, dense, glistening black rocks which outcrop only over narrow widths, suggesting dyke-like forms. In thin-section close packed hornblendes with rather rounded outlines show pleochroism from a medium brownish green to rather dark green, and have a maximum extinction angle $Z \wedge c$ of 24°. They have a sub-parallel arrangement and interstitial to them is finer-grained clear andesine, about An_{46}, and minor amounts of quartz. Epidote is fairly common in long crystals, which occasionally penetrate both amphibole and felspar.

Quartz-muscovite schists were recognized at only one locality, just east of Mukhuru School, where they form a series of low but sharp hog's-back ridges. They are medium-grained leucocratic rocks with a fair development of muscovite spangles on the foliation planes. Thin slices show narrow alternating bands of finer and coarser-grained interlocking quartz mosaics separated by parallel bands of muscovite plates. Epidote and tourmaline are uncommon and there is also a little limonitic material and minute black iron ore grains.

2. The Nyanzian System

The Nyanzian System in this area is clearly younger than the Basement System though all observed junctions between the two formations are faulted.

Rocks of the Nyanzian System occur in two portions only of the newly-mapped portion of the area—(*a*) in the immediate vicinity of Kakamega and (*b*) in the area east of Malaba towards the Nandi Scarp, with a long narrow infaulted wedge in the Nandi Scarp itself. In addition there are small roof pendants in the Mumias granite in the vicinity of the Nzoia River.

The System is here made up predominantly of acid to basic lavas, with minor tuff and agglomerate bands associated only with the intermediate rocks. Further west Pulfrey (1945 and 1946) noted a strong development of tuffs mainly associated with the acid members of the series. ¨dman (1929), Stockley (1943), Shackleton (1946) and the writer (1951) have considered that the succession ranges from basic rocks at the base to acid at the top. Pulfrey (1946, p. 9), however, preferred to reverse this succession though he mentioned the possibility of an earlier basic division which might be represented by some unusual tuffs in the vicinity of Esarua. During the present mapping no positive proof of the age relationships of the various groups was obtained though it is noteworthy that no basic tuffs, such as might be expected if the basalts were in fact the oldest rocks, have been found.

No sedimentary material of Nyanzian age, such as cherts, banded ironstones, felspathic sandstones, etc., as are present in the Nyanzian of the Migori and Kisii areas, has been noted in association with the Nyanzian rocks of the present area.

The characteristics of the main rock types are briefly described below. More detailed descriptions of rocks identical with those found in the present area may be found in earlier publications, e.g. Hitchen (1937), Pulfrey (1945, 1946), Shackleton (1946) and Huddleston (1951).

(1) *Rhyolites* (N_r).—Rhyolites are represented in both major areas of Nyanzian rocks and form the long, narrow wedge infaulted in the Basement System of the Nandi Scarp. They are usually light to dark grey cherty-looking rocks carrying small quartz and felspar phenocrysts. A slabby fracture is often developed, and they weather with a thin creamy-coloured skin. Flow banding in them has not been recognized megascopically in the present area.

Microscope examination of typical specimens shows small highly corroded phenocrysts of quartz and felspar set in a fine microgranular base of the same minerals. Mafic minerals are extremely rare and are generally of pale brown (or occasionally dirty greenish), fine, shreddy biotite, which is usually scattered though the groundmass but sometimes rims the quartz and felspar phenocrysts. The felspar phenocrysts are sometimes dusty with alteration products but occasionally, as in specimen 33/41 (from the Nandi Scarp area), they are clear and glassy. In this particular example they may be sanidine as they have a small optic axial angle, being almost uniaxial in some cases. In the same specimen there are, in addition, smaller phenocrysts of microcline and a little sodic oligoclase, and a faint suggestion of banding, possibly due to flow, in alternating bands of very fine and slightly coarser groundmass material. Colourless or very pale epidote and pale brownish sphene in granular aggregates are common in most specimens and tiny cubes of black iron ores are also usually present.

(2) *Andesites* (N_a).—The andesites are best developed in the vicinity of Kakamega. Elsewhere in the area they are of little importance. In hand-specimen they are medium grey-green and often carry felspar phenocrysts up to three-eighths of an inch in length. Less commonly mafic minerals are also visible to the naked eye.

Microscope examination of thin slices of the andesites shows that they are usually highly altered, but generally not so much as the more basic members of the System. Felspar phenocrysts are commonly highly saussuritized but less altered examples, e.g. specimen 33/84, show andesine ranging from An_{34} to An_{42}. Occasionally, as in specimen 33/81, cloudy cores are rimmed by clear plagioclase and a fine concentric zoning can sometimes be distinguished. The phenocrysts, like the felspars of the groundmass, which are similar, have a sub-trachytic arrangement. Certain examples of the andesites, e.g. specimens 33/82 and 33/83, are intensely carbonatized and the felspars in them can be recognized as ghost laths only. Uralitic hornblende, replacing augite, small relics of which are often enclosed in it, occurs both as ragged phenocrysts and as needly and shreddy forms in the groundmass. Quartz is also usually present in the felspathic groundmass but never in important amount, and occasionally it forms larger anhedral grains. Sphene, epidote and black iron ores are the usual minor constituents.

(3) *Andesitic Tuffs* (N_{at}).—The andesitic tuffs with minor developments of agglomeratic grade are seen as thin intercalated bands in the andesites of the Kakamega area. The tuffs themselves do not form conspicuous outcrops, but the agglomerates have a tendency to produce rough, toothed exposures. Hand-specimens of the tuffs show

small rock fragments and fragmental felspars and mafic minerals set in an extremely fine-grained grey-green base. In the agglomerates the size and number of the rock fragments are greater and many are up to ten inches or more across.

Thin sections of the tuffs show them to be predominantly felspathic, with rough broken crystals of oligoclase and andesine in large amount, together with subordinate orthoclase. Quartz and rock fragments (the latter of andesitic type) occur in almost equal proportions, but the rock fragments are of greater size than the quartz grains. The mafic minerals are now entirely chloritized or replaced by aggregates of quartz, epidote and chlorite but the shapes of the psuedomorphs suggest original augite. Magnetite is also present in fair amount. The fragmental material is set in a fine-grained dusty base showing alternate finer and coarser bands. Individual minerals in this base are difficult to identify but there is a heavy dusting of fine leucoxenized sphene.

(4) *Basalts* (N_b).—The basalts are all considerably altered, a feature commonly noted throughout Nyanza. Many are highly epidotized and, where they occur as roof pendants in the granites, a considerable degree of recrystallization, and often shearing, is noticed. They have their widest development in the area east of Malaba, where they do not normally form conspicuous outcrops and much of the area underlain by them is covered with a thick, deep red, rather clayey soil.

In hand-specimen they are dense, fine-grained, dark green rocks in which only occasionally are minute felspar crystals recognizable to the unaided eye. Outcrops are normally blocky due to strong joint development. In the present area no vesicular or pillow types were seen.

Thin slices of the basalts yield little information of value because of their extremely fine grain and high degree of alteration. Minute felspar laths and shreddy uralitic hornblende form a tight felt-like mass in a sparse, almost isotropic, dirty brown base. The felspar laths are often dusty with alteration products, but occasionally are clear and some were identified as calcic andesine between An_{46} and An_{50}. Only rarely are small ragged residuals of original augite seen among the aggregates of hornblende and chlorite. There is usually considerable sphene in granular clots, and epidote and zoisite are commonly associated with a little secondary clear quartz. Pyrite, magnetite and dusty leucoxenized ilmenite are present in most sections examined.

In the more altered varieties, occurring as small roof pendants in the granite and often veined by it, as at the Nzoia River bridge on the Malaba–Sangalo road, felspars are usually unrecognizable and are now represented by sericite-epidote-zoisite aggregates, though in a few specimens they have been identified as andesine, An_{46}. Occasionally also a little clear microcline, as in specimen 33/62, is recognizable, and may have been introduced by the granite. Shreddy hornblende is sometimes brownish in colour, and in specimen 33/53 has been replaced by brownish green biotite. Accessories are similar to those of the less altered varieties except that apatite is also usually present.

3. The Kavirondian System

The sedimentary Kavirondian System of the present area lies with strong angular unconformity on the upturned edges of the folded Nyanzian rocks. This unconformable relation is well demonstrated by the strong discrepancies in dip and strike between the two systems. The System is unfossiliferous and its age is not definitely known, but is probably Pre-Cambrian.

The Kavirondian rocks have a wide distribution in the central portion of the area between the Maragoli and Mumias granites, both of which are intrusive into them. Conglomerates, grits and mudstones are the main members of the series, with pebbly grits and sandy mudstones making up a subordinate part of the sequence. Various suggestions have been made regarding the order of deposition of the sediments. Combe (1927, p. 16) interpreted the succession as:—

3. Upper Division of shales and phyllites with interbedded argillaceous sandstones.
2. Middle Division of felspathic sandstones, quartzites and grits, grading into arkoses, and containing the Kisendo conglomerate.
1. Lower Division of shales and phyllites.

Combe considered that the conglomerates did not lie in a definite horizon but occurred at various levels in thick lenses up to three miles in length, grading laterally into felspathic quartzites.

Hitchen (1937, p. 9) suggested a somewhat different succession:—

3. Upper Division of felspathic grits with pebble bands.
2. Middle Division of slates and mudstones.
1. Lower Division of felspathic grits and conglomerates.

Pulfrey (1945, p. 9), suggested that as no constant datum horizons had been found, no useful attempt could be made to split up the series into sub-divisions, and with this view the writer is inclined to agree, though the evidence just south of Kakamega does rather suggest a basal section which is predominantly conglomeratic, with minor grit bands, followed by an alternating series of grits and mudstones. In the grits of the latter series pebble bands are rare in the present area and only occasionally, as just south of Busali, do they become distinctly conglomeratic, though here they contain flattened pebbles of mudstone and cannot therefore belong to a basal conglomerate group. Other pebbly bands are found in the area north of the Rondo Saw Mills on a logging track. They are rarely more than twelve inches thick and are intercalated among normal Kavirondian grits.

Pulfrey (1936, 1945 and 1946) paid particular attention to the thermal metamorphic aureoles in the Kavirondian sediments between the Maragoli and Mumias granites. In the present study few observations have been made on this problem and little can be added to the earlier findings.

The Conglomerates (K_c).—The major development of the conglomerate surrounds the Nyanzian inlier south of Kakamega. In this area the pebbles and boulders, up to two feet in diameter, and occasionally larger, are almost entirely of Nyanzian volcanic material, though granitic pebbles have also been found. Hitchen (1936, p. 12) reported crystalline schists and quartzites and two varieties of granite among the pebbles of the conglomerate west of the present area. The granite pebbles cannot be derived from the Maragoli or Mumias masses as the latter are definitely intrusive into the Kavirondian sediments. The pebbles, which normally make up some fifty per cent of the rock, have a completely unsorted and random arrangement, and it is only when narrow grit bands are intercalated that any evidence of structures can be obtained. No striated pebbles or boulders have been found in the conglomerates. Thin sections of the matrices of the conglomerates show that they are identical with the Kavidondian grits described below.

This main conglomerate occurrence fingers out to both west and east into the grit and mudstone sequence, in which only occasionally are thin scattered pebble bands found. Other conglomerate occurrences were mentioned in the previous section.

The Grits (K_g) are strongly developed south of the main conglomerate outcrop and are associated with the mudstones into which they often grade laterally. Several varieties including pebbly, sandy and muddy types, in addition to the more usual medium-grained felspathic grits, were noted, but are not differentiated on the geological map. The grits are medium to dark grey rocks in which quartz and felspar grains are visible to the naked eye. On weathering they assume a buff or occasionally a pinkish colour and, when completely broken down, yield light brown sandy soils.

In thin slices it is found that unsorted quartz and felspar grains are normally set in a rather sparse matrix of fine-grained similar material. The felspars are mainly orthoclase, oligoclase and andesine with, more rarely, microcline and perthite. The amount of felspar varies considerably in different examples and in one case (33/16) from just south of Busali, felspar is present in small amounts only but consists almost entirely of microcline and perthite. The quartz and felspar grains have a typical fragmental appearance and show little evidence of rounding, being generally angular to sub-angular. The quartz often shows undulose extinction, while the felspars are variably clear and fresh or cloudy and altered. Rock fragments, mainly of Nyanzian volcanic material, are also occasionally present, and they tend to be more rounded than the quartz and felspars. Only rarely were rough hornblende grains and chlorite shreds noted.

The grits of the thermal aureoles are usually darker in colour than the normal grits and in thin section recrystallization of the matrix is obvious. Characteristically, brown biotite is developed in flaky or shreddy form and is occasionally considerably chloritized. In a more calcareous variety (33/93), pale green diopsidic augite with euhedral to anhedral form has developed in fair amount, while in specimens 33/64 and 33/65 apatite is very common and attains unusually large size. Sometimes tourmaline is relatively common, and in specimen 33/6 euhedral sphene is prominent as large individuals.

Mudstones (K_m).—The mudstones, with which are included all the finer-grained members of the series, are usually dark grey or purplish soft rocks which are sometimes banded and weather to lighter colours, of which mauve, blue, green and khaki are characteristic.

Thin sections of the mudstones are not normally very informative due to the extremely fine grain of the rocks. Minute quartz and felspar grains can usually be distinguished in a highly sericitic base in which is included considerable fine, dusty material, some of which is iron ore. The felspars are heavily sericitized and show no relics of twinning. Ragged plates of very pale green to colourless mica are occasionally seen while muscovite is present in most slices, together with pale brownish green chloritic material. Epidote in fine-grained granular aggregates is ubiquitous while sphene and small rounded detrital tourmalines are rare.

When altered by the granites some of the mudstones develop white spots. These spots are seen in thin section to have clear square outlines, and to be composed of shreddy fine-grained sericite aggregates probably representing original chiastolite. There is usually also a considerable development of pale brown biotite and less common pale green hornblende, while often apatite and sphene are present in fair amount.

Conditions of deposition of the Kavirondian Sediments

The variability of the Kavirondian sediments, and their often lenticular form, suggests rapid and variable conditions of deposition. The boulder conglomerates were undoubtedly deposited under torrential conditions, possibly at the mouths of rivers debouching from high hills. The highly felspathic nature of most of the grits, which would have been deposited under conditions of lower rainfall, suggests their derivation from predominantly granitic rocks, though a fair proportion of the material was contributed by the Nyanzian volcanics. That their provenance must have been fairly local is evidenced by the generally slight degree of rounding of the fragments. The freshness of the felspars probably indicates cool climatic conditions. The mudstones were probably deposited in deeper water under quiet conditions.

4. The Age of the Nyanzian and Kavirondian Systems and Their Relation to the Basement System

Holmes (1951) has suggested that the Basement System of Kenya is younger than the Nyanzian and Kavirondian Systems. He based this theory on two major lines of evidence—

(*a*) that the Basement System trend-lines (Mozambiquian trend of Holmes) cut across those of the Nyanzian and Kavirondian Systems; and

(*b*) on age determinations of radio-active minerals from the pegmatites of the Basement System.

There appear however to be several objections to the arguments put forward by Holmes in support of his theory. If, as he asserts, the fact that the Nyanzian-Kavirondian trend-lines are cut off by the Mozambiquian trends indicates that the latter is the younger orogeny, it seems that the argument may equally well be reversed. The writer knows of no case of the superimposition of north-south trend lines on the predominantly east-west trends of the Nyanzian-Kavirondian, but several examples of the opposite relationship have been noted in recent mapping. In the present area east-west structures in the Basement System are only feebly and locally developed, but in the Broderick Falls area immediately to the north Gibson has mapped a well-marked east-west structure. Schoeman (1948) also noted the development of east-west trends in the Basement System north-west of Kitui.

Pulfrey, at the Interterritorial Geological Conference held in Uganda in 1951, pointed out that where the Goldfields granites of Kenya invade the Kavirondian grits they granitize them only patchily and in narrow zones, producing rocks similar to some of the less highly felspathized para-gneisses of the Basement System, so that evidently the fluids associated with the granites were only feebly energized. He suggested that a gradual diminution of energy of the fluids available for granitization must have taken place fairly regularly between earliest and latest Precambrian times, and that therefore any system which is intensely granitized (like the Basement) can be regarded as most probably older than other Systems that show negligible or no granitization. This is the case with the Nyanzian and Kavirondian Systems, in which completely ungranitized rocks are found lying against the Nandi fault which separates them from the highly granitized Basement System rocks to the east. Similar conditions are also evident in the wedge of Nyanzian rhyolites infaulted in the Basement System along the Nandi fault. It is difficult to believe that this narrow strip of acid volcanics would have escaped the widespread granitization that gave many of the Basement System rocks their present aspect, if it were in fact older than the Basement System.

The dating of the orogenies by the age of the pegmatites associated with the principal rock types calls for more than a little care as the pegmatites may obviously belong to any one of several orogenies. It seems to the writer that all that can be proved by this method is that the rocks are not younger than the age determined from minerals in the pegmatites. Point is given to this argument by the fact that a recent age determination for samarskite (*see* Ann. Rept. for 1950, Mines and Geological Department, Kenya, p. 14) derived from pegmatites in the Basement System north of Mt. Kenya places it at roughly 480 million years—i.e. Palæozoic, while other ages quoted by Holmes for pegmatites from the Mozambique belt range up to 1,320 million years.

It is considered from the above evidence that there can be no doubt that the Nyanzian and Kavirondian Systems are younger than the Basement System of western Kenya.

5. Tertiary Volcanics

The only rocks of Tertiary age in the newly-mapped portion of the area are phonolites of "Kenya" type (Gregory, 1921, p. 391), which occur along the Gambug–Kaimosi road and south of it. They are dark grey fine-grained rocks, sometimes with a greenish tinge and a tendency to split into slabby blocks. Only rarely are small vesicles and pale-green felspar phenocrysts developed. Spheroidal weathering is common. In this area the phonolites are nowhere very thick and indeed, along their eastern margin, are little more than a thin skin over the granites which can be seen outcropping high up on the west side of the Zerwerogi valley. They were obviously poured out over a very uneven surface.

Microscopic examination of thin sections of the phonolites shows that they contain microphenocrysts of clear anorthoclase and nepheline, set with a random criss-cross arrangement in a fine-grained matrix of orthoclase and nepheline, the latter often showing euhedral outlines. Mafic minerals are common and are all soda-rich varieties such as aegerine, aegerine-augite and cossyrite with, very rarely, a little arfvedsonite. These minerals tend to form fine-grained anhedral aggregates with the exception of the aegerine-augite which occasionally forms microphenocrysts. The rare accessories are mainly apatite and black iron ores. No vesicles were seen in the slices examined but Pulfrey (1946, p. 20) reported them in the phonolites of Maragoli where they are filled with zeolites, which in one case were determined as chabazite.

6. Pleistocene and Recent Deposits

Superficial deposits of Pleistocene to Recent age are represented by large spreads of hill-wash, particularly near the Nandi Scarp, and by terrace gravels, lateritic ironstone cappings, semi-consolidated river alluvium, quartz rubble and recent river alluvium and swamp deposits. Nowhere in the present area do they attain any great thickness.

The lateritic ironstone cappings are particularly well preserved north of the Nzoia River where they mask the Mumias granite on the low, wide divides, and also in certain places in the Kakamega Forest area where gossanous cappings to hills and ridges such as Lirhanda and Akwirangi, where there are pyritic impregnations of the country rocks, are prominent. Over a great deal of the remainder of the area the laterite capping has decomposed, giving rise to bright red iron-rich soils.

High-level gravels, presumably of lower Pleistocene age, have been noted in only one locality, along the Lupao-Malaba divide of the Lusumu and Sioka River headwaters. Here, fairly widespread though thin deposits of small, rounded quartz pebbles may be seen at heights of up to one hundred feet above the sources of the nearest tributary streams.

Semi-consolidated clayey rubble deposits are found in the valleys of several of the streams in the area, some six to eight feet above the present river banks. Pulfrey (1945, p. 13) suggested that such deposits might belong to a later Pluvial period of the Pleistocene.

Alluvial flats and marshes are common along the courses of most of the rivers in the area, but nowhere are they of any great extent. Several such recent deposits have, however, been washed for alluvial gold with, in some cases, extremely profitable results.

Soils vary in type, corresponding largely with the underlying bedrock, though there is a modification in certain portions of the area due to the disintegration of the laterite caps. Over the basic Nyanzian volcanics and basic minor intrusives, dark red-brown clayey soils are produced, while the more acid volcanics give lighter brown, more sandy, soils. Buff or light brown sandy soils are produced by the breakdown of Kavirondian grits and bright red clayey soils by the mudstones. Where, however, there is close interbanding of the grits and mudstones the grit type soils are obscured by the mudstone disintegration products. The granites give rise to coarse light brown, sandy, soils more subject to soil erosion than the more clayey varieties mentioned above, while the diorites, syeno-diorites and syenites, having a greater proportion of mafic minerals, give darker red brown, more clayey, types. This also applies to areas in the granite rich in basic xenoliths.

7. The Major Intrusives

(1) *The Maragoli Granite.*—The Maragoli granite has a wide development in the southern section of the area and indeed, apart from the small outcrop of Tertiary phonolites in the vicinity of Gambug, makes up the whole of the southern boundary of the area mapped. Marginally, in the area around and between Kissas and Kuranja, basified types are developed over a width of up to two miles in places. Much of the country underlain by the granite is extremely rough and tors are common. Strong vertical jointing has in many places given rise to towering monolithic blocks, which are particularly well developed along the southern boundary of the area. In several localities the granite is closely packed with basic xenoliths while in others relatively large masses of hybrid syenites, diorites and syenodiorites have been produced, possibly by the extreme alteration of roof pendants of earlier intrusives or wall-rocks.

The granite varies from fine-grained to extremely coarse-grained and Pulfrey (1946, p. 21) suggested the possibility that more than one intrusion is present. The coarse-grained variety often carries close-packed pink felspar phenocrysts up to two and a half inches in length, though they are usually smaller, containing inclusions of dark minerals. The usual colour is mottled pink or white and black but sometimes the rock has a distinct greenish tinge due to a strong development of epidote. In the vicinity of the Nandi fault, distinct shearing was noted, producing strong foliation in the granites, which may here be termed gneissic. In such cases it is sometimes difficult to distinguish in hand-specimen between the gneisses of the Basement System and the foliated Maragoli granite. Narrow aplitic and pegmatitic veinlets are present in the granite but are not especially common.

No direct age determination can be made but the presence of a distinct thermal metamorphic aureole in the Kavirondian sediments north of the granite indicates that it is at least post-Kavirondian. It is also earlier than the original movement along the Nandi fault.

Examination of thin slices shows that the felspar phenocrysts are set in a granular anhedral matrix of quartz and felspar in varying proportions. The felspar phenocrysts are commonly cloudy orthoclase and clear microcline with rarer microcline-microperthite and medium oligoclase. Occasionally clear oligoclase is seen rimming cloudy orthoclase. Chadacrysts of the mafic minerals are occasionally seen in the felspar phenocrysts (specimen 33/48). The felspars of the groundmass are similar to those of the phenocrysts and the quartz usually shows strain shadows. Rarely there is a small development of a myrmekitic intergrowth of quartz and felspar in the matrix. The mafic minerals are green hornblende and biotite which are present in variable proportions, in some cases the amphibole predominating, in others the mica. The biotite is commonly pleochroic from dark brown to pale golden yellow, but certain specimens show pleochroism from deep green to very pale yellow brown. Chloritization of the mafic minerals is accompanied by the release of magnetite in tiny cubes. Granular bright green epidote and colourless zoisite are present in most slices examined and sphene occasionally forms rather large crystals. Apatite, tourmaline and zircon are the less common accessories.

The marginal basified granite developed between Kissas and Kuranja is much darker in general colour than the normal granites, with quartz not obvious in the hand-specimen. Hornblende is the only mafic mineral present and is occasionally lightly chloritized. A micrometric analysis of specimen 33/10, a typical example of this rock, is given below.

(2) *The Mumias Granite and Kakamega Diorite.*—The granite outcrops over almost the whole of the northern half of the quarter-degree sheet except in the east where the Nyanzian volcanics form an embayment into it and, further east, where there are Basement System rocks. Megascopically and microscopically it is mostly identical with the main types of the Maragoli granite. There is, however, a large development of a finer-grained leucocratic type in the Mumias granite and one occurrence, between Sijuguju T.S. and the Nzoia River, has a length of about eight miles and a width of some five

miles: the contact between the leucocratic granite and the normal granite was not seen in the present area so that their age relationship is uncertain. In the leucocratic type (e.g. specimen 33/67) quartz is only slightly less in amount than the felspars, which are mainly clear microcline with subordinate cloudy orthoclase and a little medium oligoclase. Mafic minerals are not common and consist of fine-grained shreddy green biotite, which often rims larger muscovite plates. Apatite and zircon are rare accessories. In specimen 33/60 epidote is common as a fine dusting in the felspars.

Micrometric analyses of typical examples of the granites of the Kakamega district are given in the table below:—

VOLUMETRIC MODES OF TYPICAL GRANITES FROM THE KAKAMEGA DISTRICT

	Maragoli Granite				Mumias Granite			Leuco-granite	
	33/12	33/20	33/30	33/10	33/49	33/54	33/66	33/60	33/67
	%	%	%	%	%	%	%	%	%
Quartz	19.5	22.7	24.1	10.6	13.1	23.6	19.2	39.2	40.1
Alkali felspars	58.2	58.9	49.9	65.1	58.8	50.3	45.3	48.2	47.6
Plagioclase	9.1	4.6	9.2	5.9	15.9	11.2	21.1	4.1	4.0
Biotite	6.7	1.7	3.6	—	8.6	12.2	8.8	2.4	3.7
Hornblende..	3.5	9.1	12.3	16.6	2.6	0.6	—	—	—
Muscovite	—	—	—	—	—	—	—	—	4.1
Accessories, etc.	3.0	*6.0	0.9	0.8	1.0	2.1	*5.6	*6.1	0.5

*Includes a large proportion of epidote

A boss of the Mumias granite occurs just south of Kakamega and associated with it is an apron of varying width of diorite and quartz-diorite hybrids. No direct evidence of the relative ages of the granite and the diorite was noted during the present survey, but Pulfrey (unpublished report, 1938) suggested that in part at least the intrusions were almost contemporaneous. In the Wokadzi River he found that there was a transition from diorite through quartz monzonite types to the normal granite without a distinct break. The diorite bodies in the vicinity of Rosterman Mine are presumably of the same age as the marginal diorites.

In hand-specimen the diorites are variably fine- to coarse-grained, mottled, black or dark grey and white rocks with felspar phenocrysts up to three-sixteenths of an inch in length and, occasionally, small irregular patches richer in mafic minerals than the body of the rock. Examination of thin slices shows plentiful plagioclase felspars, usually andesine of composition An_{34}, forming stout prisms with less common microcline and orthoclase, generally interstitial to the more or less euhedral andesine. All the felspars except microcline are usually heavily clouded with alteration products. Quartz is present in variable amount in the different slices examined and again is interstitial. The main mafic minerals present are hornblende, augite, biotite and hypersthene, which together make up from twenty-two to thirty per cent of the rock by volume. The hornblende is actinolitic and relic patches of augite enclosed in it suggest its derivation from that mineral. Biotite in certain cases appears to replace the hornblende, while chloritization of the biotite and hornblende is occasionally intense. Hypersthene is not present in specimen 33/91, collected from the north bank of the Sioka River on the old Shinyello–Kakamega track from the separate diorite body, but was found in three other specimens collected from the diorite surrounding the granite boss. It shows typical pink to green pleochroism and forms from 4.3 to 8.6 per cent by volume of the specimens examined. There has usually been liberation of a little magnetite along the cleavages of this mineral. A few grains of a mineral doubtfully referred to enstatite is present in specimen 33/87. Accessories are, fairly common, rather large apatites, black iron ores, epidote and zoisite, and less common sphene.

Micrometric analyses of typical specimens of the quartz diorite are given in the table below.

VOLUMETRIC MODES OF DIORITES FROM THE KAKAMEGA DISTRICT

	QU-DIORITE	QU-HYPERSTHENE DIORITES		
	33/91	33/87	33/96	33/97
	%	%	%	%
Quartz	18·1	13·4	10·8	8·9
Alk. Felspar	13·2	16·4	18·5	26·3
Plagioclase	44·1	41·2	38·7	35·5
Hornblende	22·1	6·7	10·5	7·1
Biotite	—	4·2	7·9	3·0
Augite	0·7	6·0	6·4	12·6
Hypersthene	—	8·6	4·9	4·3
Accessories	1·8	3·5	2·3	2·3

8. The Minor Intrusives and Hybrids

Minor intrusives, with the exception of dolerites, are not common in the newly-mapped portion of the area, nor is there any great variety of types. They occur mainly as dykes and small bosses and also as large hybrid patches or xenoliths within the granites. Their ages are variably pre- to post-granite. The principal types recognized are briefly described below.

(1) *Alaskitic Granite.*—A small boss of coarse-grained leucocratic rock carrying large quartz phenocrysts and covering an area of about one square mile just east of Kaimosi Mission, where it is intrusive into Kavirondian System grits and mudstones, is identified as an alaskitic granite. The quartz: felspar ratio in thin section is seen to be about 30 : 70, the felspars being mainly cloudy orthoclase with only minor amounts of clear microcline and some finely twinned albite, about An_8. The large quartz phenocrysts often show strain shadows. A small amount of very pale brown biotite with twisted lamellæ is present and there is also a little shreddy chloritic material. A fair amount of granular epidote was noted and apatite and sphene are rare accessories.

(2) *Quartz Porphyry.*—One example of this type only was noted, as a dyke in the Kavirondian grits north of Rondo. It is a pinkish brown rock with a high degree of shearing, and quartz phenocrysts set in a fine-grained base. Thin sections show that the quartz phenocrysts are intensely resorbed and lie in a sericitic, quartz-rich, extremely fine-grained groundmass. No original felspars were recognized, and they are now probably represented by sericite.

(3) *Aplites and Pegmatites* occur as thin veins and dykes in the granite. Nowhere do they attain any great thickness or extent.

(4) *Syenites, Syenodiorites and Diorites* are seen as small xenoliths and large hybrid patches in both the Maragoli and Mumias granites. They are darker than the enclosing granites and are usually coarse-grained. Similar types have been described by Pulfrey (1946, pp. 30-32).

(5) *Older Dolerites and Epidiorites.*—The older dolerites and epidiorites occur usually as dykes but also occasionally, as north of the Kaimosi–Kapsabet road, as irregular-shaped bodies of considerable extent. The dolerites are usually fine-grained dark green rocks, but when thermally altered by the later granites become coarse-grained with a characteristic development of large, glistening, black hornblende crystals.

Under the microscope the older dolerites are usually found to be intensely altered. The felspars are often indeterminable and sometimes have a sub-ophitic relationship with original augite, which now is partly altered to pale greenish brown hornblende. A high percentage of epidote is commonly present in granular aggregates, while quartz usually occurs as clear interstitial pools. Magnetite and skeletal plates of leucoxenized ilmenite are the usual accessories, while sphene and pyrite are also generally present in smaller amount.

(6) *The Younger Dolerites* may be divided into two groups, the quartz dolerites and the olivine dolerites, though only one representative of the latter group has been found in the area. The quartz dolerites again may be divided into porphyritic and non-porphyritic types. It seems probable from the more advanced stage of alteration of the quartz dolerites that they are older than the olivine dolerites, though precise information on this point is lacking.

The quartz dolerites commonly occur in roughly co-linear groups with strikes either north-east—south-west or north-west—south-east, though occasionally strikes approaching east-west were noted. They can, in some cases, be traced for several miles across country and, though generally no more than one hundred feet wide and having a tendency to form rough blocky outcrops, they often stand out as ridge features, which are particularly prominent on aerial photographs. They are normally heavy, dark green, fine- to coarse-grained rocks, a gradation from fine to coarse grain often being noticeable from the margins inwards towards the centres of the dykes.

In thin section they are seen to have an ophitic to sub-ophitic texture with considerably altered andesine, An_{46}, in long prisms. The main mafic mineral is augite, raggedly replaced by fibrous green actinolitic hornblende. Chloritization is occasionally intense. Quartz is interstitial to the felspars and mafic minerals but is not prominent. Epidote, zoisite, apatite and leucoxenized ilmenite in skeletal plates are the common accessories.

The porphyritic types are usually finer-grained in the main though carrying felspar phenocrysts up to half an inch in length. The phenocrysts are seen in thin section to range, in different specimens, from oligoclase to calcic andesine (An_{28} to An_{48}). Slight zoning is occasionally present.

Chloritized augite phenocrysts are rarely seen, the mafic minerals being largely confined to the dusty-looking matrix, in which is present a very little interstitial quartz. Black iron ores and sphene are accessories.

The only olivine dolerite seen in the area outcrops as a sharp but low ridge in the granite just east of Kamabiri Hill, and in hand-specimen is a coarse-grained, heavy, dark grey fresh-looking rock. Thin slices exhibit text-book examples of the ophitic intergrowth of lathy fresh andesine (An_{42}) with greyish or neutral coloured augite. The olivine is not always fresh and many individuals show reaction rims of feathery green chloritic material separated from the olivine remnants by narrow bands of released, granular, black iron ores. In addition there are large ragged grains of black iron ore with rims of shreddy brown biotite, and many ragged plates of biotite scattered throughout the sections.

The only other reported occurrence of olivine in the younger dolerites of Kenya appears to be that of Schoeman (1949, p. 32) in the Sotik district, though several other examples have recently been mapped by Gibson in the Broderick Falls quarter-degree sheet, immediately north of the present area. These latter rocks are identical with the material described above except that in certain cases rather more basic felspars have been determined.

9. Giant White Quartz Veins

Giant white quartz veins, locally referred to as "buck reefs", often form conspicuous, sharp, hog's-back ridges, particularly in the southern half of the area. They transect all the major rock groups except the Tertiary phonolites, in which they have not been observed. They tend to occur in co-linear groups and outstanding examples are as follows: —

(*a*) A co-linear group running almost north-south from Kaimosi Mission to the southern boundary of the area, a distance of about nine miles, with only short discontinuities. The veins are emplaced mainly in the granites but, just south of the Mission, pass into Kavirondian grit and mudstone bands almost at right-angles to their strike.

(*b*) An almost east-west group stretching for a distance of some fifteen miles from New Kisa through Engeri, Amohira and Kimingini to Akwirangi with only slight breaks, emplaced in grits and mudstones and roughly following their strike. This group forms most conspicuous features with ridge-tops rising to elevations of up to four hundred feet above the general level of the surrounding country. The quartz reefs forming the backbones of the ridges are up to three hundred feet in thickness.

(*c*) A north-east–south-west group between Kibiriri and the Bukura ridge, emplaced in Nyanzian rocks of different types for a distance of some four and a half miles.

(*d*) A north-west–south-east vein some two and a half miles long near the northern boundary of the area, east of Kabula school on the Mumias–Bungoma road, emplaced in the Mumias granite.

The veins are composed of stony or crystalline white quartz with anastomosing networks of younger bluish quartz veinlets. There are no signs of gold mineralization in these veins in the present area though occasional low gold values have been reported in similar reefs in the adjacent Maragoli area (Pulfrey 1946, pp. 42 and 51). Their age is doubtful but as they cut the granites they must be younger than them. Hitchen (1936, p. 52) has suggested that they are of pre-mineralization age while Shackleton (1946, p. 33) considered those of the Migori Gold Belt to be all post-mineralization. Some at least of the similar veins in South Nyanza are post-Bukoban (Huddleston, 1951, p. 44).

10. Metamorphism

(1) *Metamorphism of the Basement System.*—Metamorphism of the Basement System rocks of this area has been confined to intense granitization with the production of migmatites and granitoid gneisses. This process appears to have reached a culmination in the Koiban-Osorongai ridge with the production of a granite gneiss in which foliation is barely perceptible and which is almost indistinguishable in hand-specimen from a true granite. Thin sections, however, show crushing and corrosion of the quartz and felspar grains and strongly developed mortar structure in the matrix.

(2) *Metamorphism of the Rocks of the Kavirondian and Nyanzian Systems.*—Thermal metamorphism due to the intrusion of the two major granite masses is responsible for most of the metamorphic changes exhibited by these rocks. Few observations have been made on this subject in the course of present survey and these do little to extend the previous findings of Pulfrey (1936, 1945 and 1946) in the course of more detailed work. Pulfrey (1946, p. 36) was able to delineate two major zones in the Nyanzian volcanics of Maragoli: (*a*) the diopside zone, which is not persistent

and (*b*) the horneblende-biotite zone which covers the remainder of the volcanics. Garnets were also noted in five separate localities in the volcanics. In the Kavirondian sediments four major zones were plotted outwards from the granites, viz.—

(*a*) the hornblende zone;

(*b*) the chiastolite zone;

(*c*) the zone of spotting;

(*d*) the biotite zone;

though it was noted that all the zones are not necessarily present in any one section. A strong development of diopside has also recently been noted in altered Kavirondian grits close to the quartz-diorite south of Kakamega.

Pneumatolysis.—The effects of pneumatolytic action in this area are slight and confined to the production of tourmaline, apatite and possibly sphene. The tourmalines are usually small and dichroic from brownish to bluish colours, while the apatites attain unusually large size in both Nyanzian basalt and Kavirondian grit roof-pendants in the Mumias granite (specimens 33/64 and 33/65). Sphene is particularly prominent, with euhedral form, in the two examples quoted and is not thought to be of detrital origin.

Dynamothermal Metamorphism.—Pulfrey (1946, p. 35) suggested that the garnets found in the Nyanzian volcanics and the restricted production of granulites might be due to regional dynamothermal metamorphism earlier than the intrusion of the main plutonics. No additional evidence on this point was adduced in the course of the present survey.

Dynamic Metamorphism.—Evidence of dynamic metamorphism on anything but a minor scale is seen only in a restricted area to the west of Rosterman Mine, in certain parts of the underground workings there at the mine (*see* later section), and associated with the Nandi Scarp faulting. In the latter case the faulting has given rise to intense shearing in the granites and rocks of the Nyanzian and Kavirondian Systems and many instances of mylonitization were noted. Mylonitization of the infaulted strip of Nyanzian rhyolites in the Nandi Scarp was also observed. It is not particularly intense and is confined to bands not exceeding a quarter of an inch in width.

11. Structures

Structures exhibited by the Nyanzian and Kavirondian rocks appear to be relatively simple in this area (*see* section at foot of map). There have obviously been two major periods of deformation. In the earlier one the Nyanzian rocks were folded prior to the deposition of the Kavirondian sediments on their eroded upturned edges. The denudation of the up-lifted Nyanzian volcanics contributed largely to the make-up of the coarser-grained members of the Kavirondian sequence. The Kavirondian itself was then infolded with the Nyanzian and thrown into a series of generally broad folds the axes of which, over most of the area, follow an almost east-west direction. Slight overfolding is occasionally noted and locally, as in the Akwirangi–Rondo and Kibiri areas, there has been a strike swing to a north-east–south-west direction. Dips in both Kavirondian and Nyanzian rocks are generally high, ranging from 65° to vertical, and shearing, particularly in the Nyanzian rocks, is locally intense. The Kavirondian mudstones occasionally show a certain degree of cleavage, but the arenaceous types are never cleaved and only in proximity to major faults do they show any signs of shearing.

Few faults have been mapped, with the exception of the main Nandi fault system, and it is likely that many more than are shown on the map exist in the area. The thrust fault west of Rosterman Mine was mapped by Pulfrey (unpublished report, 1938) and evidence from the underground workings suggests that it is largely pre-mineralization in age.

The Nandi fault system is complex and in all probability is a fault-zone of some considerable width rather than a single fault. Shackleton (1951, p. 348) suggested that it is a reversed fault steeply inclined to the east. He based this suggestion on the fact that there is a wide zone of mylonitization to the east of the fault but that mylonitization is not noticeable for more than a short distance west of it. The present mapping, however, together with that of Gibson to the north in the Broderick Falls area, is more consistent with the idea that the western fault of the zone is normal, with downthrow to the west.

The fault-zone is offset in several places by smaller cross-faults which are well shown on the aerial photographs. The age of the Nandi fault is a matter of some conjecture but the following facts are known—

(*a*) it is older than the main peneplained surface on which Mt. Elgon was built up; and

(*b*) it is younger than the main goldfields granites which are post-Kavirondian in age.

It would appear, however, to be older than the fresh unsheared granites intruded into the Basement System rocks of the Nandi Scarp in the neighbourhood of Chakiakak T.S. which, if pre-faulting in age, would be expected to show similar foliation and crushing effects to those noted in the goldfields granite in proximity to the fault. It is considered on these grounds that the faulting was initiated before the intrusion of the younger granites, possibly in late Pre-Cambrian times. It seems probable too that further movements took place at various times, the most recent possibly during the early Pleistocene, causing the tilting which rejuvenated the river systems of the Nzoia, Yala, etc. That such late movement was localized is proved by the fact that the sub-Elgon surface north of the present area was not disturbed by it.

VI—ECONOMIC GEOLOGY

The only minerals of economic importance so far exploited in the Kakamega district are gold and silver, though a small amount of scheelite, occasional diamonds and other possibly valuable minerals have also been found. Some 437,000 oz. of gold, valued at about £3,500,000, are recorded as having been produced in the area between 1931 and 1950. The discovery of the Kakamega Goldfield may be attributed indirectly to the late A. D. Combe of the Uganda Geological Survey who, concluding his report (1930) on a geological reconnaissance of parts of North Nyanza, suggested that prospecting should be carried out along the granite contacts in Maragoli and Nyangori. The first recorded production of gold was in 1931 when some 404 oz. of alluvial gold were won. This figure rose to over 6,000 oz. in 1932 and the extraction of lode gold followed in 1933, when 4,427 oz. were produced.

In December, 1951, Rosterman Gold Mines Ltd. were the only large producers, though two small workers were active in the area just north of Kaimosi.

The approximate positions of a number of mines and prospects that have been worked are shown in Fig. 3.

The only mine examined by the writer was Rosterman Gold Mine. In all other cases adits, shafts and trenches were inaccessible due to infilling and overgrowth by vegetation. The details of certain mines and prospects given below are culled from Departmental files and Company annual reports. Each mine or prospect is numbered as on Fig. 3.

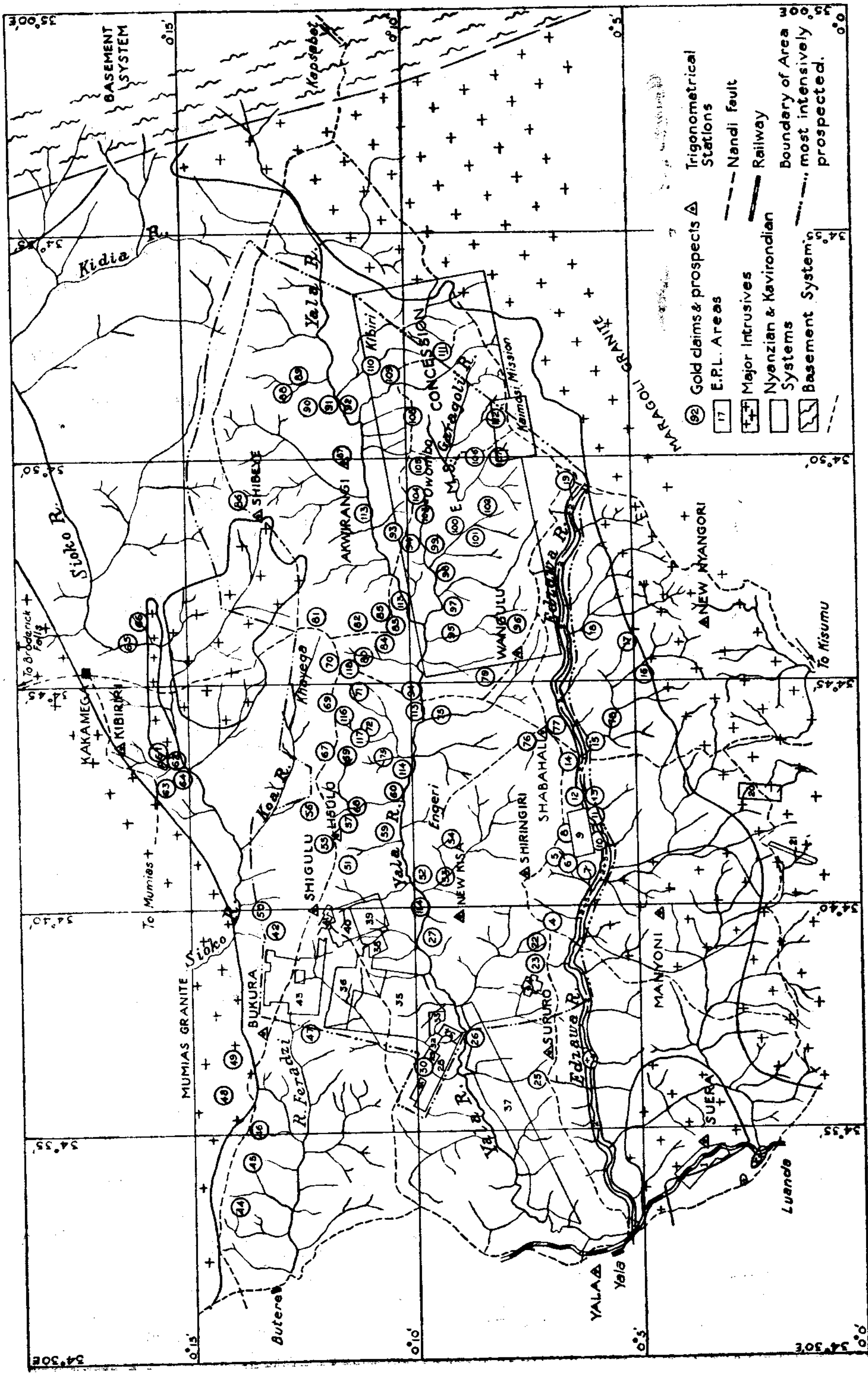


FIG. 3.—Locations of a Number of Mines and Prospects in the Kakamega district.

1. Molite Syndicate
2. Alphega
3. H.S.F. Syndicate
4. Sood Syndicate
5. Eregi Syndicate
6. W. G. Smart
7. W. G. Smart
8. Morgan
9. Edzawa Ridge Mining Co.
10. Mrs. du Preez
11. M. W. Bekker
12. Kakamega Ore Reduction Co. Ltd.
13. Kakamega Ore Reduction Co. Ltd.
14. Waverley Syndicate
15. Capt. Rocco
16.
17.
18. Kia-Ora Syndicate
19. Hobden
20. B. D. Hayes
21. R. M. de Saram
22. Rob Roy Syndicate
23. Wilson
24. Max Best Syndicate
25. White
26. Tintax Property
27. W. Blain
28. Bechgaard and Melson
29. Prichard and Cowper
30. Ballard
31.
32. Prichard and Cowper
33.
34. Melson
35. Feza Ltd.
36. Feza Ltd.
37. Tanganyika Concessions Ltd.
38. A. Balbach
39. R. Klapprott
40. Bryant
41. Pym
42. Bukura Mining Co. Ltd.
43. Slaughter and Howe
44. Kummick
45. Pearson, Wadema, Kirk
46. Chant
47. Touche
48. Hoey and Anderson
49. Selby Lowndes
50. East African Industries
51. Minor Mines Ltd.
52. Duffy
53. Kia-Ora Syndicate
54. Eregi Co.
55. Yala Koa G.M. Co. Ltd.
56. Blue Reef
57. Lisulu Bukura Mining Co. Ltd.
58. Taylor's Bukura Mining Co. Ltd.
59. Mgusi Syndicate
60. Alego Syndicate
61. Rosterman Gold Mines Ltd.
62. Ross
63. Kia-Ora Syndicate
64. Wellwood
65. Enah Syndicate
66. Lake Victoria G.F. Ltd.
67. Kakamega Ore Reduction Co. Ltd.
68. Guy Fawkes Syndicate
69. Muchang
70. Risks — later Kavirondo Gold Mines Ltd.
71. Kavirondo Gold Mines Ltd.
72. Lodge
73. Harries Bros.
74. Kuhu Syndicate
75. Kenya Reefs Ltd.
76. Amohira Ltd.
77. Kenya Reefs Ltd.
78. Kia-Ora Syndicate
79. Lake Victoria G.F. Ltd.
80. Mangan
81. Musgraves
82. Kakamega Mining Syndicate
83. Kimingini G.M. Ltd.
84. Kampala Syndicate
85. Yala Koa G.M. Co. Ltd.
86. Equipoise Syndicate
87. East African Industries
88. Pearce
89. Van Deventer
90. Border Syndicate
91. Fotheringham
92. Collier
93. H. N. Beresford
94. H. N. Beresford
95. Sama Syndicate
96. Mangan
97. E.M.S. Ltd.
98. Stepney
99. Sorre Mines Ltd.
100. E.M.S. Ltd.
101. E.M.S. Ltd.
102. Kakamega Mining Co. Ltd.
103. Elbon Mines Ltd. (Mackenzie)
104. Owombo (E.M.S., and Bukura Mining Co. Ltd.)
105. Kaimosi G.M. Ltd.
106. Williams
107. Smallwood and O'Brien
108. Kaimosi G.M. Ltd.

109. Forest Edge Mining Co.
110. Kibiri Mine (Zawadi Ltd.)
111. Forest Edge Mining Co.
112. Kaimosi Prospect
113. H.S.F. Syndicate
114. Kenya Reefs Ltd.
115. D. V. Broadhead-Williams
116. Button and Mason
117. D. V. Broadhead-Williams

It is realized that many names have been omitted from the list but this is unavoidable as, throughout the area, claims have been pegged and re-pegged repeatedly by a succession of different holders, and following the history of each block of claims is almost impossible in view of the scanty records available. At one time—about 1932-1933—there were over 1,000 prospectors active in the area, the majority of whom left no permanent record of their workings. The exodus of prospectors from the district to No. 2 Area further south-west began about 1934. The mines and prospects in the Maramma and Maragoli areas have been described by Pulfrey (1945, 1946) and are not referred to in this report.

1. Gold—Details of Mines and Prospects

(61) *Rosterman Gold Mines Ltd.*—This company was incorporated in January, 1935, with an authorized capital of £400,000 in five shilling shares. The claims, situated about two miles south-west of Kakamega just north of the Sioko River, were first worked by the Ross Mining Syndicate which produced, from the outcrop to a depth of fifteen feet, 2,783 oz. of gold from 2,274 tons of ore milled. This, with the tailings, represented a mill-head average of 32 dwts./ton. Milling was commenced by the new company in the latter half of 1935 and up to June 30th, 1952, when the mine was closed down, about 655,000 tons of ore had been milled, producing 259,142 oz. of fine gold, i.e. over half the recorded total production from the area. The highest production was in 1940 when 23,915 oz., worth £200,886, were produced.

A considerable amount of geological work has been carried out on this property, mainly by Hitchen and Pulfrey, the former both as a Government geologist and also as consulting geologist to the company. Dr. W. R. Jones, acting as consultant to the company, also reported on the surface and underground geology in 1936. Recently the writer spent five weeks on underground surveys of the lower levels and in logging fifty bore-hole cores, derived from 12,756 ft. of diamond drilling. The following geological notes and diagrams are a compilation of all the above-mentioned work. Grateful thanks are extended to the company for their permission to use the reports and maps of their consulting geologist, and to the mine manager and his staff for the assistance afforded the writer in his recent work at the mine.

(a) Surface Geology, Rosterman Gold Mine

In 1937 Hitchen mapped the area in the vicinity of the mine. A larger area around the mine was mapped in 1938 in considerable detail by Pulfrey (Fig 4). The detail near the mine was entirely remapped with the exception of the western margins of the two diorite masses which were taken from the earlier map by Hitchen. The succession as determined by Pulfrey is given below:—

9. Alluvium

——— Unconformity.

8. Dolerite dykes.
7. Quartz veins and large quartz reefs.
6. Lamprophyre, quartz porphyry, porphyrite and felsite dykes.
5. Granite.
4. Diorite.
3. Kavirondian System sediments, mainly conglomerates in the south-eastern portion of the area and grits and mudstones in the northern and south-western portions.

——— Unconformity.

2. Dolerite (epidiorite) and diorite porphyrite dykes.
1. Nyanzian System volcanics; tuffs, basalts, andesites and a small development of acid lavas. Highly sheared and phyllitic west of the thrust.

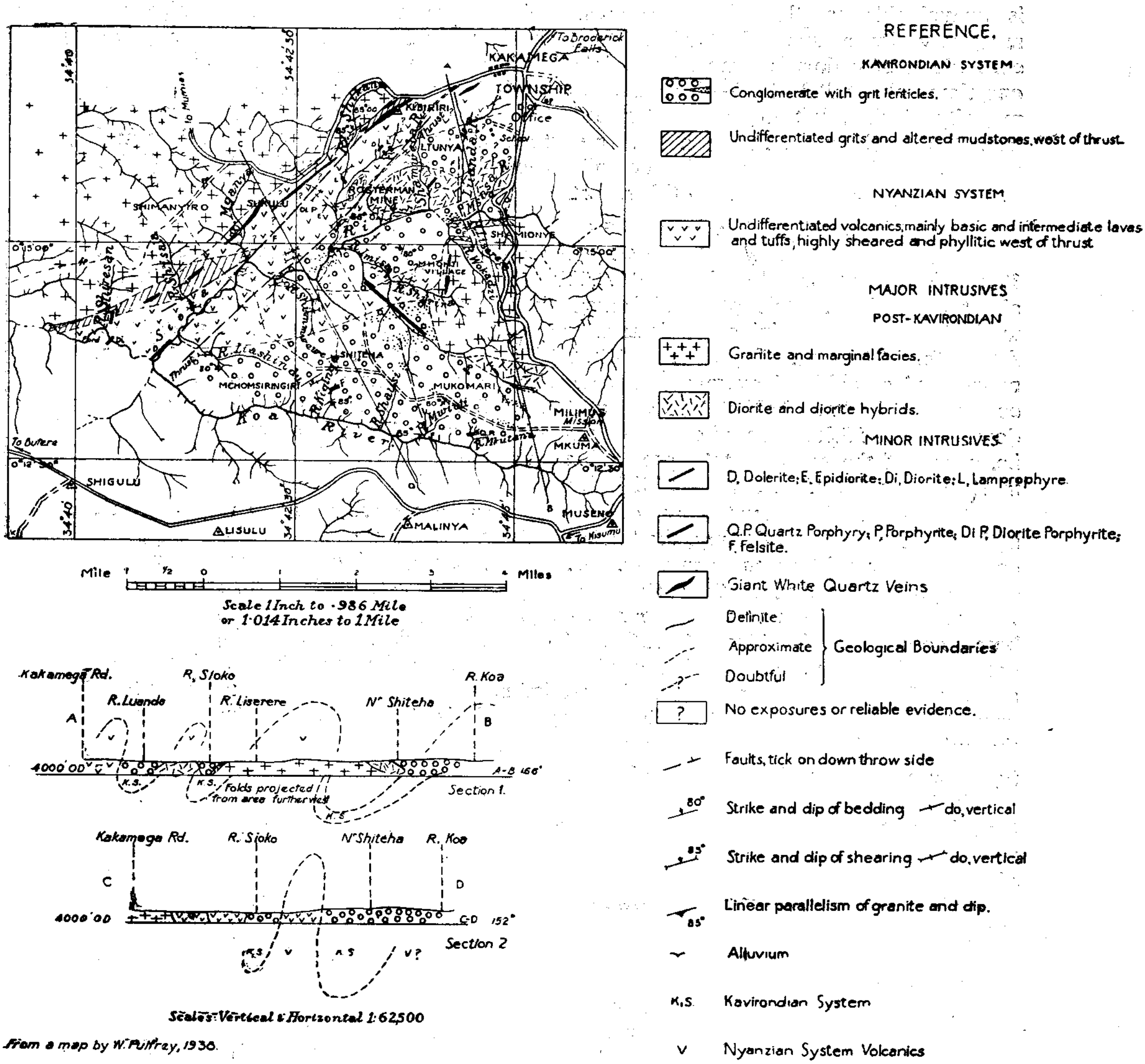


FIG. 4.—Geological map of an area near Rosterman Mine.

These rocks are similar to those described in earlier sections of the present report and further notes on them are unnecessary.

The structure of the area is rather complex and may, for the sake of convenience, be treated in two sections:—

(*a*) *East of the Thrust* the Nyanzian volcanics and the Kavirondian sediments exhibit a series of folds (*see* sections on Fig. 4) slightly overturned to the south and with axes running approximately east-west. Northwards the synclinals become shallower, i.e. the underlying volcanics as a whole are approaching nearer to the surface. The normal faults along the rivers Luanda–Liserere and west of Mukomari are of minor importance.

No sedimentary conglomerates were found west of the thrust, where the country in a belt about half a mile wide consists almost entirely of highly sheared and phyllitic members of the Nyanzian System. The thrusting caused an elevation on the west with the result that the Kavirondian sediments, except in the area south of the Liashindu River, were raised to such a level that they have been entirely removed by denudation. Pulfrey considered that the small boss of diorite at Rosterman Mine west of the thrust was probably a portion of the larger diorite cupola to the east, carried upwards in the thrust mass.

(*b*) The greater portion of the *north-west part of the area west of the thrust* is made up of a portion of the Mumias granite. The dip of linear parallelism of the granite and the dip of the shearing in the contemporaneously sheared marginal facies in the Shipana River indicate that the batholith has been considerably denuded, and that the margin now seen is part of its almost vertical wall. Between the granite contact and the thrust there is evidence of other N.E.–S.W. faults but their nature was not discovered. Between these faults and the granite there is imperfect evidence of the fold system implicating the Kavirondian sediments and the underlying volcanics. The sediments are of the grit and mudstone type and nearer the granite exhibit marked effects of dynamothermal metamorphism.

Shearing is a constant feature throughout almost the whole of the area mapped, but is especially marked north of Rosterman Mine and in the Sioko Valley south and south-west of the mine. The strike of the shearing varies between E.–W. and N.E.–S.W. and the dip is everywhere almost vertical. Shear-zones, as the term is usually understood, are nowhere mappable. Instead, an area of shearing is present which, being situated between and among the major intrusive masses, suggests that a great accentuation of the shearing imposed during the folding of the non-intrusive rocks occurred during the period of intrusion of the igneous masses. The thrust was also considered by Pulfrey to have originated during this period, probably a little before the complete solidification of the granite, when that mass was having to compensate for its bulk and the subjacent pressure of magma by thrusting against its walls, leading to the production of marginal upthrusts.

Crush conglomerates are found in addition to the normal sedimentary Kavirondian conglomerates and Jones, in his 1936 report and also in comments on reports by Hitchen and Pulfrey, was most definite in his opinion that all the conglomerates found in Rosterman Mine are crush conglomerates. Neither Hitchen nor Pulfrey were able to agree with him on this point, nor is the writer as a result of his recent work. The crush conglomerates all occur in or near the thrust or in small branch thrusts, notably in the River Mlumbari, north of Rosterman mine, in the north-western portion of the mine, a little south-west of the footbridge south-west of the mine and in the small tributary of the Sioko River south of Sukulu. They are characterized by a complete similarity of constitution of "pebble" and matrix, by their occurrence in narrow bands and by passage into sheared rocks of composition and constitution similar to that of the "pebbles" and matrix of the conglomerate. Crush conglomerates are well exposed at various points underground recently examined by the writer, notably in the north-west crosscut on the 12th level, where massive phacoids up to three feet in length are present in the west terminal shear in a zone 270 ft. wide, and also in the west drives on the No. 4 Footwall Reef and Quartz Vein Reef on the 21st level.

The distribution of the sedimentary conglomerates is shown in Fig. 4. In the Sioko valley in the vicinity of Rosterman Mine they are extensively sheared but in other places, e.g. proceeding up the River Imisa from the Sioko River, they can be traced through less and less sheared material to almost unsheared rocks at about half a mile from the main stream. At depth in the mine, e.g. towards the end of the main S.W. crosscut on No. 21 level, normal Kavirondian conglomerate in its fresh unsheared condition can be seen. It is also recognizable in many drill cores, apart from the examples mapped by Hitchen in the upper levels of the Mine.

The age of the Rosterman diorite in relation to the main granite intrusion is a matter of some doubt. Jones believed the diorite to be pre-granite in age, as did Pulfrey, though he thought it might be only slightly earlier or even pene-contemporaneous with the granite. Hitchen, however, was inclined to regard it as post-granite. There is no direct evidence of their age relationship but if the granite intrusion is considered to be responsible for the gold mineralization then it would appear that the diorite must indeed be the earlier member of the sequence. Both the granite and the diorite are post-Kavirondian in age.

(b) Underground Geology, Rosterman Gold Mine

The gold-bearing quartz veins developed in the Mine are, in order of their occurrence from the surface downwards, the Ross, Horst, No. 1 Footwall, No. 2 Footwall (or X), Y, Quartz Vein*, No. 3, No. 4 and No. 5 Footwall Reefs. They have been developed from a main three-compartment shaft to the 21st level at 1,940 ft. below the collar, and by winzes to the 24th level and slightly beyond it (July, 1951). Intensive diamond drilling has been a feature of the exploratory work almost from the outset, and has been in no small measure responsible for the discovery of most of the reefs below the Horst Reef. The veins occur in a series of marginal tension cracks which strike more or less parallel to the axis of the diorite cupola. Their general relations to one another are shown in the transverse section, Fig. 11, and the North-south sketch model of the veins, Fig. 5. Geological details of various sections of the mine are given below.

The Ross, Horst and Forbes Reefs are all composed of a white quartz of waxy appearance which is unlike the usual types of auriferous quartz found in other parts of the goldfield. These veins appear to consist wholly of this one variety of quartz and there is no evidence of them having received later infillings of different varieties of quartz during subsequent stages of mineralization. Thin wisps of chloritized wall-rock are often engulfed in the quartz and, where they occur, the vein is said to be rich. Chalcopyrite and pyrite occur sparingly in the veins and abundantly in the wall-rocks, while tellurides are also present to a small extent.

The main shear-zone is seen in the western ends of the workings on the Ross and Horst Reefs, and Hitchen thought it unlikely that lateral extensions of these veins would be found west of the shear. On each level the veins narrow to a mere fracture without quartz several feet before reaching the shear-zone, which is considered to be a pre-mineralization feature, though further movements may have taken place along it after the emplacement of the veins. It does however, appear to have formed a barrier against which the Ross and Horst Reefs terminate naturally. A plan of the upper levels on these reefs is given in Fig. 12. There is also marked shearing in the hanging-wall of the veins near their western extremities.

From the mine sketch model (Fig. 5) it is apparent that the Ross Reef forms the uppermost member of the Footwall Series of veins and is a relatively weak body. Little work was done on this ore-body below the 4th level and the workings are now

*For the relationship between the Quartz Vein and No. 1 Footwall Reefs *see* p. 32.

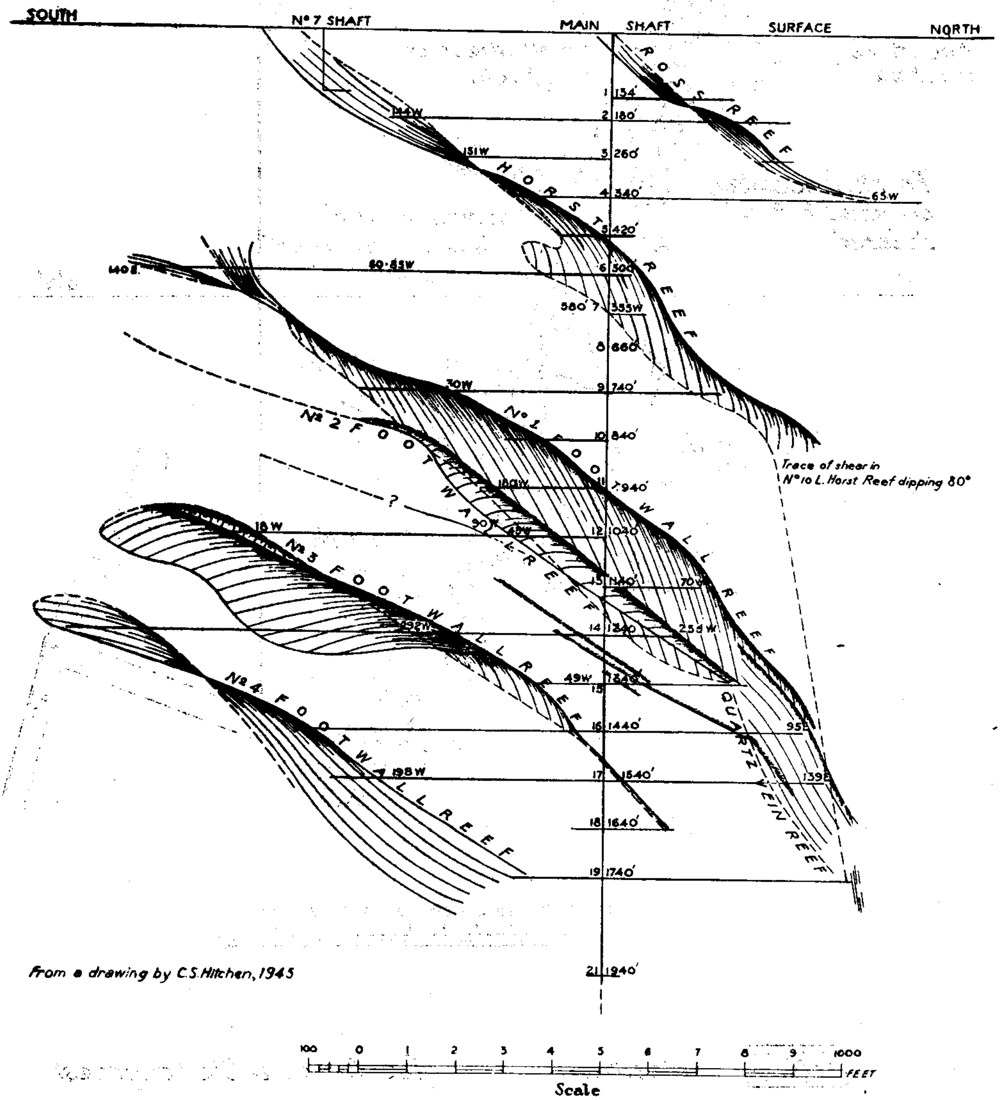
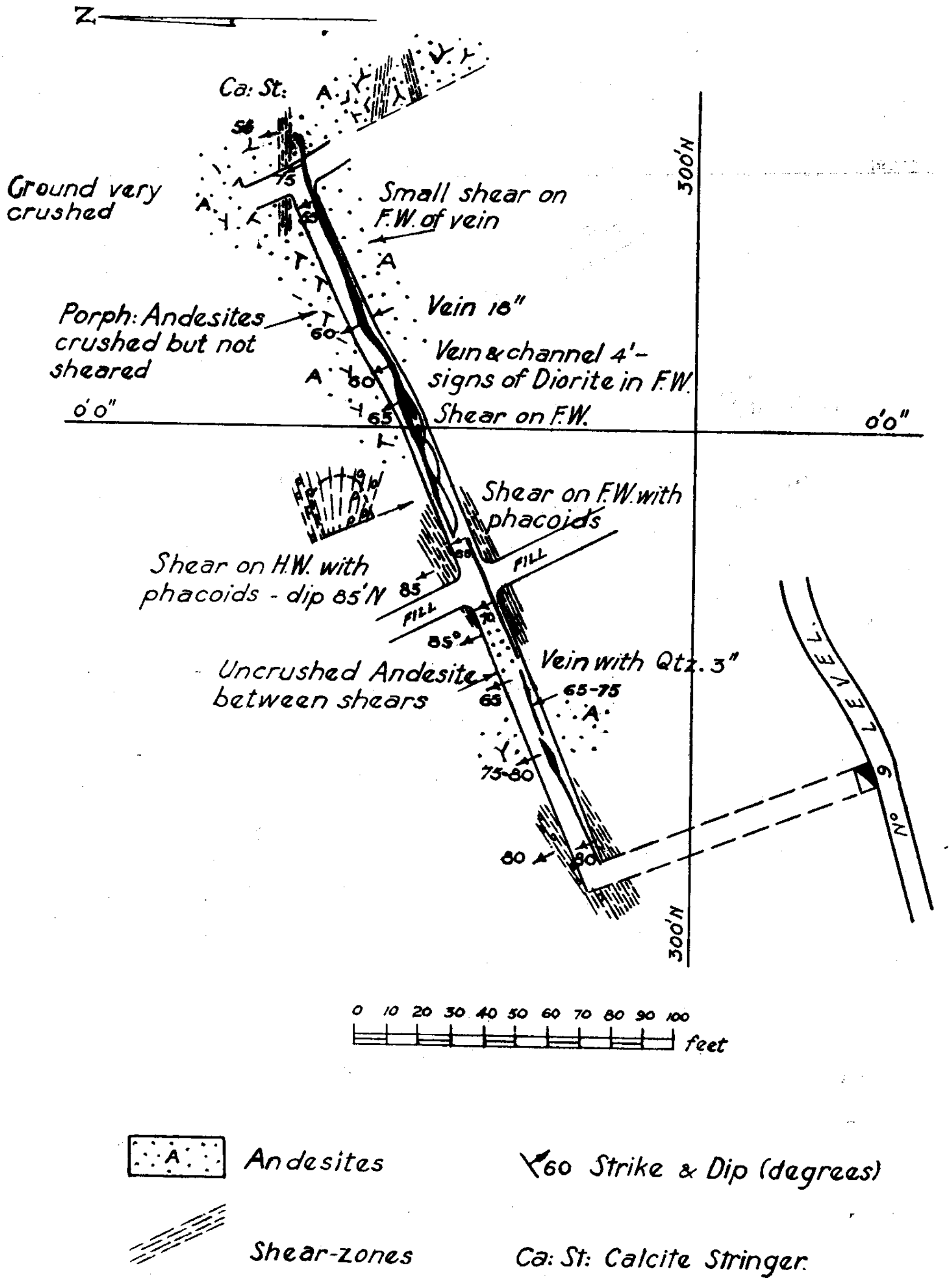


FIG. 5.—North-south sketch model of the veins, Rosterman Mine.



From a drawing by C.S. Hitchen 1945.

FIG. 6.—Geological plan, Horst Reef, No. 10 Level, Rosterman Mine,

abandoned. The Horst Reef was a much stronger body than the overlying Ross Reef but even so was bottomed at the 10th level. Hitchens in 1945 made a special study of its characteristics and environment on this level and his findings are shown in Fig. 6. The country-rock on this level consists almost entirely of andesites and is greatly affected by shearing. Penetration by the diorite was noted in the footwall at only one point, 160 ft. from the entrance winze*. The vein is traceable the whole way along the level but, although eighteen inches of quartz is present in one place and a four-foot channel occurs in another, it is represented for the main part by a mere fissure.

The shearing occurs in three principal planes, namely:—

1. The western terminal shear which dips at about 80° to the north-west, and is confined to the western end of the level. It strikes at approximately 55° and is well seen in the hanging-wall opposite the entrance winze.

2. A pronounced hanging-wall shear striking at 60° and dipping at 85° to the north-west. It leaves the vein at 150 ft. along the drive.

3. A footwall shear associated with the vein which persists throughout the level. It is very variable in intensity, having its greatest development at about 100 ft. (*see* Fig. 6).

There is also a small shear associated with the calcite stringer at the far (eastern) end of the level, but this does not appear to be important.

Most of the shear-zones seen in No. 10 level contain phacoids of the volcanic rocks.

Conditions on No. 10 level closely resemble those found in W.D. 300 N. on the No. 1 Footwall Reef on the 15th level, where both a west terminal shear and a hanging-wall shear are present. In both cases also, the hanging-wall shear leaves the vein or disappears and does not persist along its whole length.

The western terminal shear in No. 10 level, against which the Horst Reef attenuates, may be in vertical continuity with the western terminal shear seen in the end of W.D. 940 N. on level No. 19 and also in the main north cross-cut end of that level.

As regards the footwall shearing, it was suspected that this might be due to a subsidiary footwall branch vein which joins the Horst Reef a little above the 10th level horizon. (A narrow channel, yielding promising values, was later opened up in E.D. 125 N. on the 9th level. This was probably a footwall branch lying under the Horst Reef, and proved to be only a minor occurrence).

In May, 1942, Hitchen reported briefly on the geological features displayed in the western ends of levels Nos. 11 to 15 on the No. 1 Footwall Reef, and in the western end of the 14th level on No. 4 Footwall Reef, with special reference to the termination of these veins. It was found that in no case was the vein or its accompanying mineralization cut off by the shearing. In the west drive on the 11th level a minor shear, one to two feet wide, with phacoids, was visible at the extreme end but the vein had dwindled to a mere fissure before the shear was encountered (*see* Fig. 13). The fissure is not intersected by the shear. In No. 12 level, west drive, the vein splits and dies on entering the andesites and no major shearing was observed. In the west drives on the 13th, 14th and 15th levels a well defined shear is visible in the hanging-wall but, in all cases, the vein was parallel with the shear and was not cut off by it.

The dip of the No. 1 Footwall Reef is generally less than that of the shear but as the vein approaches the shear its dip steepens and it diminishes to a mere channel without quartz.

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*All footages are measured from the entrance winze north-eastwards along the vein. Abbreviations used in following pages are:—E.D. = east drive, W.D. = west drive, D.D.H. = diamond drill-hole.

The volcanic rocks exposed in the ends of the various levels are generally andesitic or basaltic in type. They contain "pebbles", mostly of similar composition to the matrix but sometimes of obviously foreign material. Hitchen concluded that they represented a type of flow breccia in which fragments of the already solidified outer crust was incorporated in, and partly assimilated by, the still molten interior of the flow, together with pebbles of foreign material. In one case pillow structures were observed. The formation of phacoids in shear-zones would appear to depend on such heterogeneity. In all cases the volcanics are very much jointed and crushed by reason of their proximity to the tough diorite.

In the western end of No. 14 level on the No. 4 Footwall Reef, the vein terminates after entering the volcanics. Its flat dip suggests that it has been intersected near its upper termination.

Thus in all cases, the No. 1 and No. 4 Footwall Reefs terminate on the west, not as a result of having been cut off by shearing and/or dislocation but because they have entered unfavourable country, i.e. the volcanic rocks.

The well-marked zone of shearing striking in a general north-easterly direction, seen on the various levels, has doubtless been caused by adjustments between the volcanics and the diorite. Hitchen was of the opinion that the shearing was earlier than the veins, a point with which the writer is in agreement, as the Quartz Vein Reef on No. 21 level may be seen to persist in the main western terminal shear in the west drive, though it carries negligible values only. This shearing indicates movements of some intensity in a north-easterly direction relative to the diorite. As a result of these movements, forces tangential to the periphery of the diorite boss were set up which resulted in torsion in, and consequent tension fracturing of, the diorite. At a slightly later date the tension cracks so produced became the foci of gold mineralization and are now represented by the Ross, Horst and Footwall Reefs. Hitchen points out that an upward component may have been involved in the N.E.-S.W. shearing and, according to Pulfrey, the small diorite body containing the Forbes Reef is an upthrust mass. It may also be borne in mind that the tension fractures now represented by the various reefs dip at 35° to the north. Had the forces been more truly horizontal, the tension fractures might reasonably have been expected to display a steeper dip. A study of the underground workings shows that shearing is not general round the periphery of the diorite but that it is localized in a number of more or less parallel curved shears, each of limited width, and probably of limited extent.

The No. 1 Footwall Reef and the Quartz Vein Reef.—Hitchen examined the workings on these reefs in 1945 and concluded that on the 15th level the two veins were connected and were in fact one and the same body in the extreme east. At a point 190 ft. east along E.D. 300 N. on the 15th level, however, the two veins separate, the Quartz Vein Reef lying under the No. 1 Footwall Reef and occurring in E. and W.D.'s 275 N. (*see* Fig. 14).

In the extreme west (W.D. 300 N.) on the 15th level, No. 1 Footwall Reef attenuates against a marked shear with phacoids, which strikes at an oblique angle to the drive and which is a familiar feature of the western ends of most of the levels in the north-western part of the mine (i.e. as the western terminal shear). Apart from this shear and apparently distinct from it, there is considerable shearing on certain sections of the hanging-wall of No. 1 Footwall Reef. This hanging-wall shearing seems to be in some way connected with the attenuation of No. 1 Footwall Reef in depth.

On No. 16 level the Quartz Vein Reef has been followed in E. and W.D.'s 410 N. and also in E.D. 325 N. The fissure followed in the latter drive appears to be a branch.

The channel followed in E. and W.D.'s 385 N. on the 16th level, which is marked No. 1 Footwall Reef on the mine plans, can hardly be called a vein at all. It consists of a shear-zone with very little quartz occasionally present in the footwall. In the western end of W.D. 385 N. the shear is fairly intense and dips north at 50°. On following it eastwards, however, its intensity is found to decrease while its dip progressively steepens. At 160 ft. along E.D. 385 N. (at the cross-cut leading to E. and W.D.'s 410 N.) it is seen in the face as a narrow "fissure", one to three inches wide and dipping north at 70°. Hitchen believed that the No. 1 Footwall Reef passed into this shear-zone between the 15th and 16th levels.

On No. 17 level the Quartz Vein Reef is well developed and is nearly 400 ft. in length. It is terminated as usual by intense shearing in the extreme west, but there is no appreciable hanging-wall shear.

On No. 19 and No. 21 levels this vein again attenuates against the west terminal shear, also seen in the main north cross-cut end, 19th level, and is bounded by a marked hanging-wall shear which varies considerably in intensity but which persists as far as the vein has been explored. It is possible that the shear occurring in E.D. 385 N. on No. 16 level may pass down and connect with this hanging-wall shear on the Quartz Vein Reef on the 19th level. The dip of the shearing in W.D. 385 N. on the 16th level is too shallow (50° to 60°) to connect with this hanging-wall shear on No. 19 level so that if it persists in depth it must run into the west terminal shear (Fig. 14).

In appearance and characteristics the Quartz Vein Reef differs markedly from the other Rosterman veins; in fact, "Quartz Vein" is rather misleading as the body contains far less quartz than the normal veins. It is essentially a mineralized shear-zone. Some quartz is usually present as partings or layers intercalated with mineralized mylonite, often heavily impregnated with pyrite and pyrrhotite. This was the typical make-up of the Quartz Vein Reef down to the 17th level, but at 105 ft. along E.D. 490 N. on the 19th level, quartz of the more normal Rosterman type began to appear in the channel. At 118 ft. considerable quartz was present and some of it carried visible gold, obviously of primary origin, in the form of a fine mist in the translucent quartz. This persisted to 123 ft., where the vein channel was twelve feet wide with quartz making up about sixty per cent and the remainder consisting of mineralized shear material with sulphides. At 130 ft. a "horse" of diorite was encountered in the centre of the vein channel, which was at that point twenty-one feet across with excellent gold values. The vein was then followed on both foot- and hanging-wall sides of the "horse" till it was cut off by a post-mineralization fault as described later. No further values were found east of the fault though the channel was followed for a considerable distance. On the 21st level, even on the west side of this fault, the vein is very irregular both in width and values and at 150 ft. along the west drive passes into the main west terminal shear (in volcanics with phacoids). The shear here strikes at about 60° and dips practically vertically to the north-west. The drive remains in the shear to its western end at 490 ft. East of the fault the line of the vein was followed for some 330 ft. without any payable values being disclosed and over much of its length was a mere fissure with no quartz. A flat fault striking at 290° and dipping to the south-west at 35° to 40° was struck in the east drive at 435 ft., but no evidence as to its nature could be adduced.

The behaviour of the Quartz Vein Reef below No. 21 level is not known as the winze to the 22nd Level was flooded at the time of the writer's visit to the Mine.

It may be noted that the Quartz Vein Reef is not a normal Footwall Reef though it lies beneath and runs into the No. 1 Footwall Reef, and may well have formed the channel-way for the mineralizing solutions and fluids which formed the latter.

Post-Mineralization Faults affecting the Quartz Vein Reef.—On levels Nos. 15 to 17 the reef is dislocated on the extreme east by a post-mineralization fault trending at 355° and dipping to the west. On the 15th level the vein is dragged northwards against the fault indicating that the block east of the fault has slipped to the north. Confirmation of this was obtained on the 16th level where the vein was first located in D.D.H. 234 and subsequently proved by cross-cutting and driving. The actual displacement to the north appears to be thirty to thirty-five feet. On levels 15 to 17 the observed inclination of the fault varies from 70° to 78° but the position of the fault on these levels indicates that the average dip must be 75° to 76°. When E.D. 490 N. was being driven on No. 19 level it was anticipated that this fault would be encountered at about 195 ft., but instead, what appeared to be an entirely new fault was struck just past the "horse" mentioned above. Hitchen was surprised to find volcanics beyond the fault on the footwall side of the "horse", indicating a slip to the south on the east side of the fault. This was supported by other evidence including a slight southward drag of the quartz. Subsequent driving on the hanging-wall of the "horse" and DDH.s 240 and 244 and further driving, have confirmed this displacement to the south.

The coincidence of the two faults occurring in proximity to each other and throwing considerable distances in opposite directions is unusual. Such an arrangement necessitates a third fault which Hitchen suggested was probably a flat thrust fault on which movement took place parallel to the strike of the veins. The observed inclination of the new fault on the 19th and 21st levels is approximately 70°. If the fault were to continue upwards at this inclination it should have been encountered on No. 17 level, but no sign of it was observed there. Hitchen considered that its average dip was 60° to 65°, in which case both the faults should meet the inferred thrust fault a little below the 17th level. The thrust fault being horizontal or nearly so, would not affect the veins.

No. 2 Footwall Reef (also known as the X Reef).—The writer has no knowledge of the nature of this reef, which appears from mine plans to have persisted from a little above No. 10 level to the 15th level, where its strike length is only 140 ft. and its width varies from that of a stringer up to eighteen inches.

No. 3 Footwall Reef below the 16th level passes downwards into unfavourable country consisting of Nyanzian volcanics and diorite porphyrite (*see* Fig 15). In this environment the vein has dwindled to the merest fissure-filling and the possibility that it will develop again in depth was considered by Hitchen to be remote. Nothing was observed in the main north cross-cuts on the 19th and 21st levels that might correspond with it.

No. 4 Footwall Reef on the 14th level was examined by Hitchen in 1942 and he formed the opinion that it had there been intersected near its upper natural limit. Its strike was short and curved and the dip flat.

This reef was subsequently developed by driving, raising and winzing on the 15th to 21st levels. Down to the 16th level results were eminently satisfactory—the strike lengthening, the dip becoming normal—and a considerable tonnage of ore was blocked out. Between the 16th and 17th levels the results of development were still satisfactory, but the vein began to be influenced by certain pre-mineralization factors which assumed even greater significance below the 17th level. Some difficulty was experienced in intersecting the vein from the main south cross-cut on the 17th level and in raise 575 W. from that level the vein split into two branches.

Even greater difficulties were experienced in developing the reef by winzing below the 17th level, and in locating and following it on the 19th level. The vein disappeared completely at 35 ft. in winze 300 W. from this level. Throughout the whole of winze 450 W. down to and below the 18th level it was represented by a mere fissure, which in places was difficult to follow, and six diamond drill-holes failed to locate other branches in the foot- and hanging-walls of this winze. The vein was, however, developed satisfactorily in winze 600 W.

Locating the vein and following it once it had been found on the 19th level again proved difficult. At approximately 95 ft. along W.D. 175 S. the vein split but, as the hanging-wall branch is represented by a fissure only, driving has been confined to the footwall branch.

The No. 4 Footwall Reef was intersected in the main shaft a little below the 20th level, where it was well defined. It was also encountered in the main north cross-cut on the 21st level at about 100 ft. north. On this level the vein carries good values but peters out a few feet before the western terminal shear is reached, at 390 ft. west of the main north cross-cut (*see* Fig. 16). A footwall branch of the vein was followed for only a short distance in low values over a narrow width.

No. 5 Footwall Reef, the lowest of the footwall series of reefs so far discovered, was developed from winzes from the main south-west cross-cut on the 21st level, the reef first appearing a little above the 22nd level close to the contact of Nyanzian volcanics with the Kavirondian conglomerates. The geology of the whole of the 21st level is shown on Fig. 17. Geological details of the 22nd and 23rd levels on the No. 5 Footwall Reef are shown in Fig. 7.

On both levels the vein is strong and often highly pyritic, but values, except for a short stretch just west of raise 600 W. on the 23rd level, are disappointingly low. During the recent examination it was obvious that No. 5 Footwall Reef in the 22nd-23rd level section was not emplaced in a solid diorite body (known to be the most favourable environment in this mine for well mineralized veins), nor is there any evidence available from boreholes or other workings that the diorite body extends so far to the west at this depth, or deeper, in this locality. Evidence on this point on higher levels (17th, 18th and 19th) would in fact suggest that it does not, but the diorite-volcanics contact is so irregular throughout the mine that it may well do so. It is possible that values might increase towards the west, as is the case with most of the veins at Rosterman Mine, and it was accordingly suggested in August 1951 that information on these points be sought by drilling, or by concentrating development below the 23rd level on winze 600 W. and westward drives from it.

Forbes Area, No. 12 Level.—Recently a long north-west cross-cut was driven from the western end of W.D. 55 N. on the 12th level to investigate the ground below the outcrop of the Forbes Reef—a contact reef on the western margin of the small diorite body west of the main Rosterman workings. This cross-cut and drives from it were examined by the writer in July, 1951. Fig. 8 shows the results of this examination. The cross-cut starts in fine-grained volcanics but passes within a few feet into the main western terminal shear-zone with phacoids, which extends over a true width of some 490 ft. The shear strikes at 60° and here has an almost vertical dip to the north-west but, at 200 ft. from the mouth of the cross-cut, the dip swings to the south-east. A small vein was struck at 850 ft. and driven on for 400 ft. to the south-west and 90 ft. to the north-east, but no payable values were found and work was stopped.

Summary of Underground Geology, Rosterman Gold Mine

Hitchen in 1945 proposed a theory of intensive dioritization to account for the variations of the diorite exposed in the underground workings and diamond drill cores. He had noted that several distinct types of diorite existed. In addition to the so-called "typical" Rosterman diorite, which is an easily recognizable medium- to coarse-grained rock of an even mottled greenish-black and white appearance, there are also present fine-grained "murky" varieties. Other types also present include (i) a variety similar in texture to the typical diorite but with a curiously speckled appearance ("speckled" diorite), (ii) a type characterized by a preponderance of augite and hornblende and (iii) a type which appears to contain relics of hornblende phenocrysts. Hitchen suggested that the various modifications had been produced by the dioritization of the Nyanzian volcanics surrounding the diorite intrusion. He pointed out that certain of the andesites bordering the intrusion were porphyritic and contained very characteristic small square or oblong felspar phenocrysts, the survival of which, after the rest of the rock had been completely dioritized, was thought to account for the speckled appearance of one type of diorite. He was of the opinion that the "murky" fine-grained variety had resulted from the dioritization of non-porphyritic andesites and basalts, though clear proof of

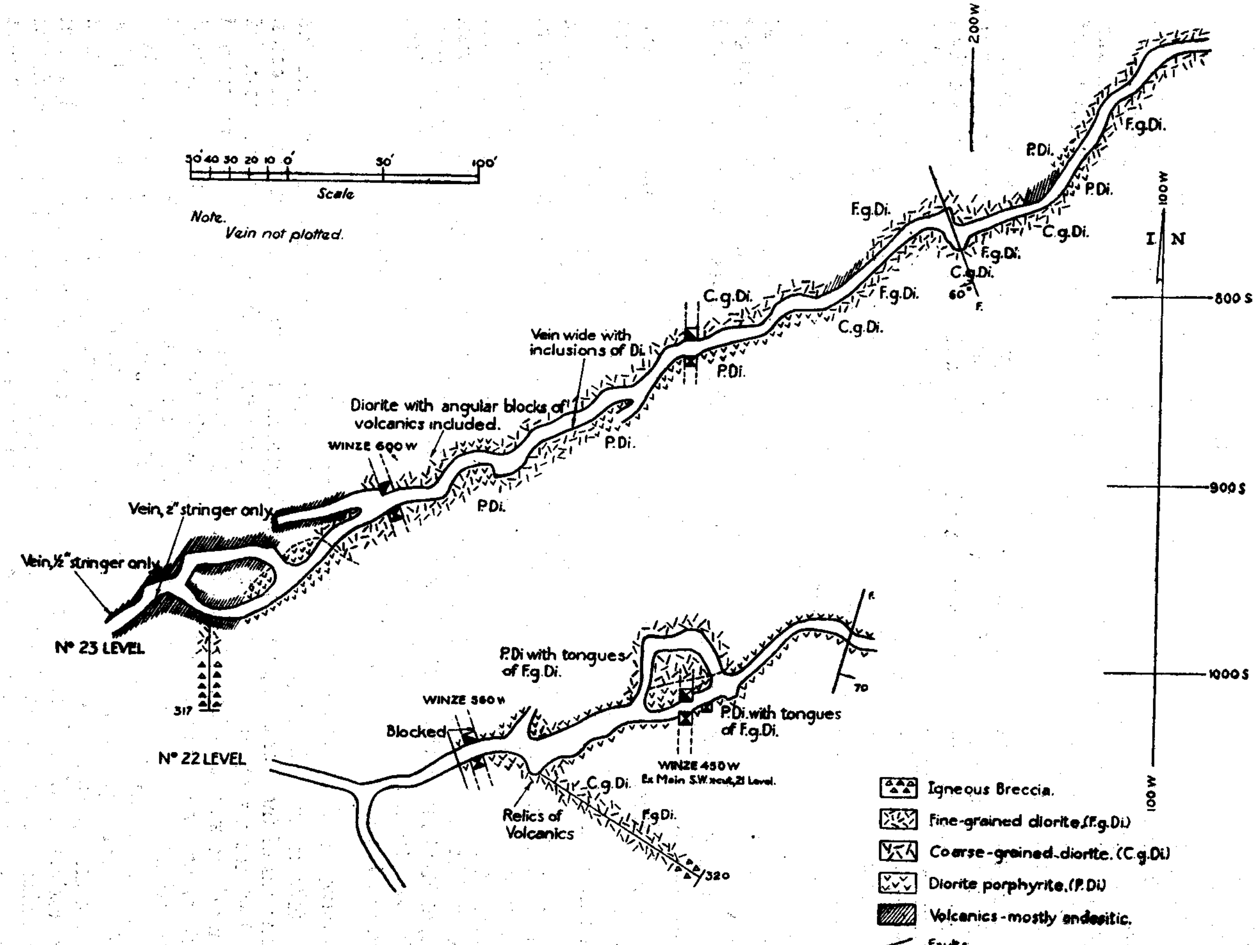

FIG. 7.—Geology of No. 5 Footwall Reef, 222nd and 23 levels, Rosterman Mine.

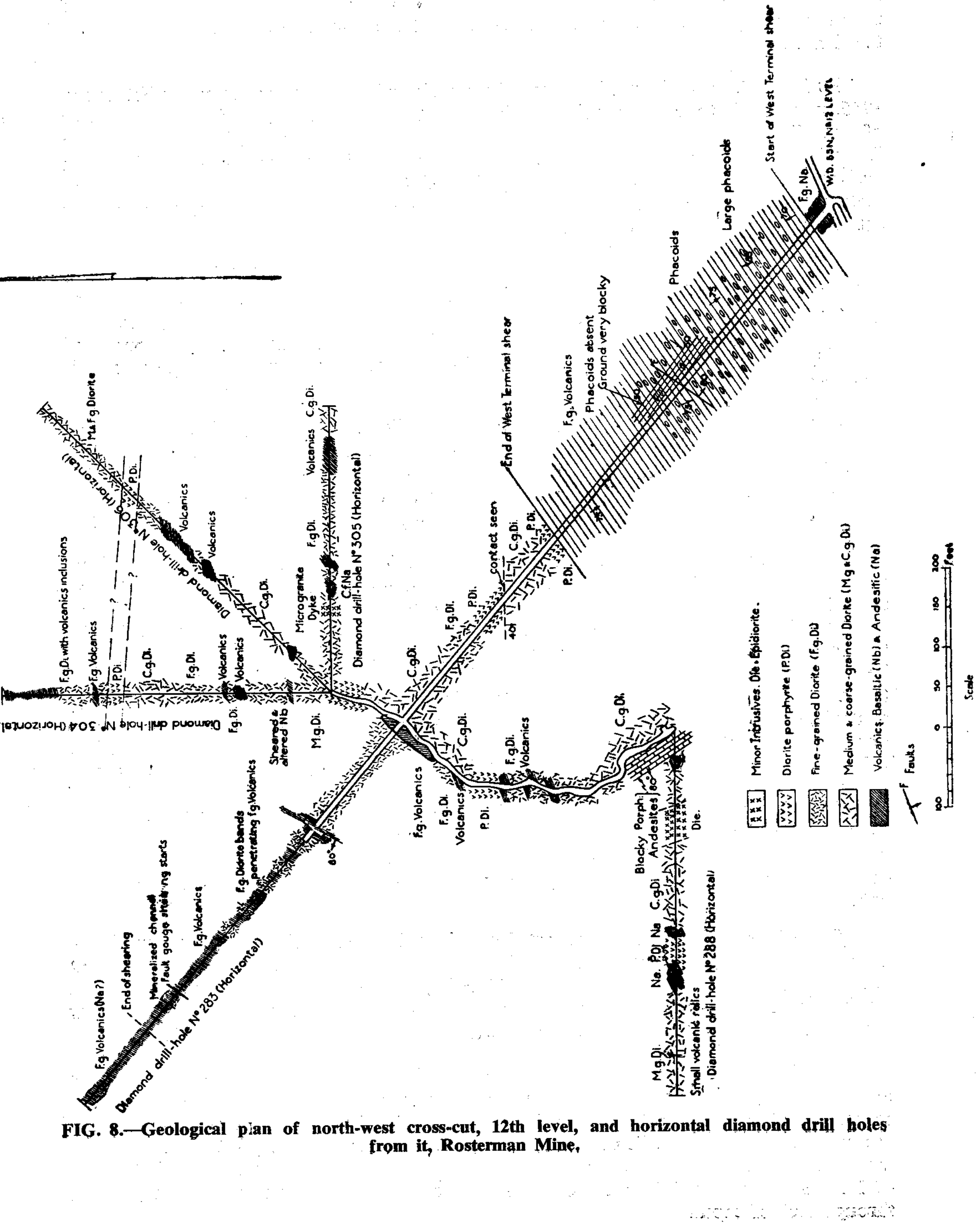

FIG. 8.—Geological plan of north-west cross-cut, 12th level, and horizontal diamond drill holes from it, Rosterman Mine.

(57) *Bukuru Mining Co. Ltd., Taylor Section,* situated just south of Lisulu (*see* (58) below), showed very high-grade ore consisting of little visible quartz in mineralized country-rock, in the upper levels. The 3rd level is said to have averaged 10.4 dwt. per ton over a good strike length, but the 4th level showed no payable values and operations ceased in 1945. It is of interest that several rich pockets were found in this ore-body, one of which gave 712 oz. of gold from half a sack of ore.

(58) *Bukura Mining Co. Ltd., Lisulu Vein* was of a similar nature to (57) and was of high grade throughout. It was mined down to about 400 ft. when pumping difficulties (6,000 g.p.h.) caused work to be abandoned.

(59) *Mgusi Syndicate* operated between Lisulu and the Yala River between 1933 and 1936 when a shaft was sunk to a depth of 48 ft. and an adit driven for a distance of 160 ft.

(69) *Muchang.*—The Muchang claims were among the first to be pegged in the Kakamega area and are situated about half-way between Lisulu and Shikonde. The original pegging, over two veins, appears to have been done by the Eldoret Mining Syndicate. Tanganyika Concessions Ltd. held an option over the claims till 1938 when they abandoned it. The reefs were narrow down to the 50 ft. level. A third vein was discovered (No. 3 Reef) by S. Everett in 1939. The property was reported on by Hitchen in 1941 and the following notes are abstracts from his unpublished report. The reefs are located in felspathic grits and mudstones of the Kavirondian System, the former being predominant in the underground workings. The workings on No. 1 Vein were not accessible at the time of the survey but the geological map produced by Tanganyika Concessions Ltd. indicates that a small apophysis of porphyritic granite was encountered. No granite was seen in the workings on the Nos. 2 and 3 veins. The relative positions of Nos. 2 and 3 veins are shown in Fig. 18, while No. 1 vein is located 1,230 ft. due south of No. 3 vein. Several smaller veins striking N.E. were also encountered, the most important of which, the "Fig tree" vein, lies about 200 ft. E. of No. 2 vein and has produced a small quantity of ore.

No. 1 *Vein* could not be examined as all workings had been infilled. According to a Tanganyika Concessions geological plan prepared by N. W. Wilson in 1932, the strike of the vein was east-west over some 550 ft. of strike length, and the dip steep to the south. A narrow subsidiary vein 300 ft. long lies 150 ft. south of No. 1 vein and has a similar strike direction.

No. 2 *Vein.*—A plan showing the results of the mapping carried out by Hitchen on the 160 ft. level is given in Fig. 19. The plan incorporates former surface work though slight discrepancies were noted at certain points. The vein system is somewhat complex, the structure being dominated by a "horse" which causes the vein to split. The general strike direction is W.N.W.–E.S.E. and the dip approximately 48° to N.N.E., though a flattening is noticed between the 50 ft. and 80 ft. levels.

No. 3 *Vein* is structurally and mineralogically different from the Nos. 1 and 2 veins. At the eastern end, the strike is a few degrees north of west and the dip 79° to the south (*see* Fig. 20). Proceeding westwards the strike progressively curves and finally assumes an E.N.E.–W.S.W. trend on the 150 ft. level and a N.E.–S.W. trend on the 215 ft. level. At the same time the dip becomes progressively flatter until, at the western extremity, the vein finally dies out in a number of narrow stringers dipping at about 45°. It appeared that the ore-shoots pitched to the east.

Quartz and concentrates from the three veins were examined and it was found that while veins Nos. 1 and 2 were more or less simple pyrite-arsenopyrite types, No. 3 vein was a tourmaline-pyrite type with no arsenopyrite or magnetite, but containing a small amount of copper and lead ores.

It is recorded that between 1941 and February, 1943, when operations ceased, due to a fall in values, some 9,600 tons of ore milled produced gold to the value of £23,000. Earlier production from these veins is not known.

(70) *Kavirondo Gold Mines Ltd. (formerly Risks Ltd.)*.—Risks Ltd. operated in the vicinity of Shikonde, the Company being formed in 1933 by the transfer of blocks of claims by several holders. Production from the pilot mill to December 1935 was 4,931 oz., excluding gold contained in concentrates stored for further treatment. Kavirondo Gold Mines Ltd. was formed in 1936 with an authorized capital of £375,000 in Sh. 10 shares. Active mining operations ceased in 1943, but there was a small amount of gold produced until 1946 from mill clean-ups, etc. Between 1937 and 1946 some 30,000 oz. of gold, valued at £240,000, were produced.

Workings were on a number of small veins, and a large number of shafts and adits were excavated, the deepest shaft being the Koa Mulima vertical shaft which was sunk to a depth of 500 ft. Other sections, e.g. "Dudgeon", were stoped to a depth of 400 ft. None of the workings were accessible at the time of the survey and there is no information available on the general geological features of the various sections mined. The company went into liquidation in 1950.

(74) *The Kuhu Syndicate* held claims south-west of Kimingini and sank several small shafts about 1935. There is no record of any production from the claims which were abandoned in November, 1937.

(75) *and* (77) *Kenya Reefs Ltd.* held lode gold claims on Amohira Hill and sank several shafts and adits in this locality between 1934 and 1935 on small stringers, some of which gave good values. There is, however, no recorded production. The main activities of the company from 1935 were confined to the production of alluvial gold—mainly from the Yala River flats where alternating stretches were worked with the H.S.F. Syndicate. Production of 2,941 oz. valued at £22,957 is recorded. Operations ceased in June, 1940, and the company went into liquidation in July, 1941.

(81) *Musgraves*.—This mine was developed by the Kimingini Gold Mining Co. Ltd., and is situated about one and a half miles north of the Kimingini property. No details of the geology are known but records indicate that good values were obtained over narrow reef widths down to the 250 ft. level. The 340 ft. level showed no payable values and operations ceased. A large volume of water was encountered (4,500 g.p.h. at the 150 ft. level), and this may in part have accounted for the closing down of the mine.

(83) *Kimingini Gold Mining Co. Ltd.* was incorporated in July, 1934, with an authorized capital of £600,000. The property is situated just north of the Yala River a little to the east of the main Kisumu–Kakamega road. The strike at surface was said to be 1,400 ft., and at adit level 1,127 ft. of vein averaged 12.64 dwt. over 39.4 in. The western ore-body, some 600 ft. long, persisted only 30 to 40 ft. below the adit level but was located again on the 300 ft. level where, however, it was only 50 ft. long. The eastern ore-body petered out at about the 550 ft. level and on the 640 ft. level—the deepest point reached in mining—110 ft. of driving showed no payable values. Three diamond drill-holes to depths of 1,000 ft. below the outcrop showed no further payable reef. Milling was commenced in June 1935 and from that date until November, 1938, when the mill closed down due to exhaustion of ore reserves, some 102,000 tons milled from both Kimingini and Musgraves, gave 29,650 oz. of fine gold valued at £209,000.

The mining lease was transferred to Kerebe Mines Ltd. in 1939 and up to June, 1941, a further 2,500 oz. of fine gold were recovered by this company. Further small amounts of gold have been produced by other workers from the property, the most recent being D. J. Erasmus who ceased operations there in November, 1951.

A considerable amount of geological work has been carried out at the Kimingini mine by Hitchen and Pulfrey and the following notes have been abstracted from their various departmental reports. The surface geology in the vicinity of the mine is illustrated in the sketch map (Fig. 9 at end). The Kimingini ridge forms a prominent physiographic feature produced by the resistance to erosion of a massive white "buck" quartz reef which strikes in a general west-south-west direction. This quartz body often attains a considerable thickness—e.g. in underground bore-hole* No. 7, which was horizontal and drilled due south from the 450 ft. level, the drill penetrated the quartz for 130 ft. without clearing it. The "buck" reef is emplaced in felspathic grits and mudstones of the Kavirondian System though a small anticlinal inlier of altered Nyanzian basalts occurs in the latter. The outcrop of the lavas is obscured at the surface by soil, quartz rubble and boulders but their presence is proved by cores from U/G B.H. No. 7. The basalt carries veinlets, pools and impregnations of quartz, chlorite, epidote, zoisite, sericite, calcite and pyrite, apparently connected with the formation of the "buck" reef. North of the Kavirondian grits and mudstones is a further narrow inlier of Nyanzian volcanics, the southern contact of which with Kavirondian rocks is characterized by a zone of intense shearing thought by Hitchen to mark a major dislocation. Hitchen named this zone the "Green Shear Zone" because of the highly chloritic nature of the rocks composing it.

Careful plotting of observations both on the surface and underground reveals a pronounced bend in the course of the Green Shear Zone in the vicinity of the main shaft. West of the main shaft it strikes a few degrees north of west, while east of the shaft it follows a roughly east-north-east direction and appears to join shearing observed where the Esther Bridge road crosses the Gwambuni River. The true hade of the shear cannot be discovered at the surface due to hill creep which has produced a false hade to the south. Examination of the shear between levels Nos. 1 and 2 gives the true hade which, though variable, is generally to the north; 600 ft. west of the main shaft the inclination is 23½°, while in the vicinity of the main shaft it is 5° to 8°. At the road-crossing of the Gwambuni River it also hades north, at less than 10°, so there is obviously a tendency for the plane of the shear to flatten west of the main shaft. Owing to lack of data, however, it was impossible to calculate the displacement due to the Green Shear Zone.

Details of the geology on levels Nos. 1, 2 and 3, and on the adit level are shown in Fig. 21. It will be seen that the Kimingini vein lies in Kavirondian System sediments, but that, eastwards, it converges upon and meets a zone composed of intensely sheared chloritic rocks—the Green Shear Zone—which marks a faulted boundary between the sediments and Nyanzian volcanics to the north. The down-throw is to the south. Although movement may have taken place along this shear-zone subsequent to the emplacement of the vein, the continuation of the vein within the shear-zone in the form of stringers points to the shear being in existence prior to mineralization.

Between the surface and No. 1 level, the vein appears to dip very steeply to the south, but below No. 1 level the dip is steep to the north. This change in the direction of dip appears to be largely due to hill-creep which would also account, not only for the considerable depth at which decomposition occurs, but for the presence of numerous minor cracks, faults, etc., which are characteristic of the upper part of the mine.

In the early days of the mine general consideration of the local geological conditions indicated that, with continued sinking, the underlying Nyanzian volcanics must eventually be reached, though at what depth this change of country would occur it was impossible to state in the absence of any reliable criterion. Underground diamond drill-holes subsequently proved this point and the geology below No. 4 level (642 ft.), as inferred by Hitchen from a study of results obtained from U/G. B.H.s 8, 9 and 10, down to a depth of approximately 1,000 ft., is illustrated on the section, Fig. 22. In

*Abbreviated to U/G. B.H. in subsequent pages.

general the specimens from the three boreholes were of rock types similar to those encountered in the upper parts of the mine. They were found to be more highly altered, however, in some cases to such a degree that precise identification was impossible, a circumstance which rendered the compilation of the section a matter of some difficulty.

The section shows a narrow and steeply dipping isocline of sediments of the Kavirondian System, sandwiched between Nyanzian lavas and pyroclastics, and intersected in its lower extremity by a flat-dipping fault—probably similar and roughly parallel to that known to exist between levels Nos. 2 and 3 in the mine. The existence of this fault was based on the following evidence:—

(*a*) The solid quartz vein encountered between 357 and 380 ft. in B.H. No. 10 is wholly out of line with the quartz vein intersected in B.H. No. 9 and cannot be connected with it unless an abnormal change in dip, or a fault is assumed.

(*b*) Volcanic rocks similar to those represented in B.H.s Nos. 8 and 9 are not seen in B.H. No. 10. Instead, the latter appears to display a repetition, in depth, of the reef channel and adjacent pyroclastics.

(*c*) After passing through undoubted Kavirondian felspathic grits and mudstones, B.H. No. 9 encountered a lava at 269 ft. similar in type to that previously encountered between 145 ft. and 191 ft. Beyond 269 ft. felspathic grits were again intersected and persisted to beyond 306 ft. The significance of these facts, taken in conjunction with (*a*) and (*b*) above will be apparent from the section.

From the information afforded by the bore cores the vein at depth appears to have left the Kavirondian sediments in which it is emplaced in the upper part of the mine. On the hanging-wall the vein adjoins the intensely sheared volcanic rocks of the Green Shear Zone while on the foot-wall undoubted lavas were encountered in B.H.s 8 and 9. Below No. 4 level the vein is evidently lenticular and is accompanied, especially in the hanging-wall, by intense mineralization of the country-rock.

Although the vein is well developed on No. 4 level, B.H. No. 8 did not intersect any considerable body of quartz though it could not have failed to intersect the vein however much it had deviated from its course. The inference is therefore that the vein pinches below No. 4 level, a conclusion strengthened by the fact that the vein was intersected in B.H. No. 9 between 125 and 143 ft. on its correct plane of dip. Another mineralized zone with quartz veinlets but no body of quartz was passed through in B.H. No. 10 between 170 and 250 ft., again on the dip extension of the Kimingini vein. It is evident, therefore that the vein below No. 4 level is more lenticular than in the developed parts of the mine. Assay results from mineralized portions of the cores were usually disappointingly low, though occasional good values were found.

Hitchen suggested that an internal shaft be sunk from No. 4 level at a point about mid-way along cross-cut N. 164 E. to a depth of about 120 feet, to intersect the vein encountered in B.H. No. 9 between 125 and 143 feet. This suggestion, as far as records show, was not followed and mining operations ceased shortly after his report was written.

Mineralization at Kimingini is of a composite type and its characteristics have been somewhat obscured, at least in the upper part of the mine, as a result of supergene influences.

The vein is exceptional in that it is the largest gold-bearing vein so far found in the Kavirondian sediments. Gold veins in these sediments are usually small and the majority of the veins worked in the Kakamega district are emplaced either in Nyanzian volcanics or in masses of diorite and other intrusive rocks.

Pulfrey considered that veining at Kimingini was marked by at least four phases:—

4. Felspathic phase (minor)
3. Coarse white quartz phase
2. Dense white quartz phase
1. Blue quartz phase—ore vein.

(Phases 4, 3 and 2: Non-auriferous and related to the "Buck" reef of Kimingini Ridge.)

Hitchens suggested that between phases 1 and 2 minor cracks and fissures became filled with solutions depositing gold, arsenopyrite and quartz, which produced local hypogene enrichment of the existing ore vein and wall-rocks. The solutions appear to have been sufficiently concentrated and active to produce arsenopyrite impregnations in the wall-rocks.

Careful plotting of assay results suggests the possibility of two ore shoots pitching eastwards at about 70°, the original characters of which have, however, been largely obliterated by the redistribution of gold caused by subsequent processes. Hitchen suggested that two processes had been largely responsible for this redistribution of gold values—

(*a*) "dilution" of the ore vein by barren white hydrothermal quartz during a decadent stage of mineralization; and

(*b*) secondary enrichment processes—which became all the more effective as a result of subsidence and hill-creep.

Secondary enrichment of a mechanical or residual type was proved by a series of experiments carried out by Hitchen in 1937.

(84) *The Kampala Syndicate* held claims adjacent to the Kimingini claims. These were taken over on option by East African Concessions Ltd. in 1934 and a certain amount of surface prospecting and diamond drilling was carried out before the option was relinquished in October, 1936. There is no record of any gold production from the claims and the Syndicate went into liquidation in June, 1939.

(93) *and* (94) *H. N. Beresford* worked various small veins north and south of Kibeye and at various other places in the Kakamega district for a number of years. No details of his activities are recorded except that 131 oz. of fine gold were produced in 1949 and 1950.

(95) *Sama Syndicate* obtained an exclusive prospecting licence over 2.25 square miles at Iwore, south of the Yala River, in June, 1938. Several small blue quartz veins and a certain amount of surface rubble were found in the area. Three shafts were sunk to depths of 50 ft., and some 250 ft. of driving done from them. This work proved the veins to be impersistent below 50 ft. A 25-tons-per-day-mill was erected and before it was closed down in 1939, some 3,600 tons of ore and rubble had been treated, giving gold to the value of £6,940.

(97), (100), (101) *The Eldoret Mining Syndicate* pegged various claims within their exclusive prospecting licence area. This E.P.L., granted in October, 1931, was the first to be registered in the Kakamega district and covered an area of 35 square miles. A considerable amount of prospecting and geological work was carried out before Kentan Gold Areas Ltd. was formed in 1934 to take over the Eldoret Mining Syndicate and other holdings.

(103) *Elbon Mines* (D. W. Noble) worked various claims on the south side of the Garagoli River close to Owombo Mine. Here a mineralized zone in Kavirondian grits and mudstones carries short gash veins and stringers, some of which were extremely rich. Between 1939 and 1943, when work ceased on the claims, 2,494 oz. of gold, valued at £20,830, were produced. In February, 1941, a 50 oz. nugget was found and 400 oz. of gold were obtained from ten tons of ore. The claims have since been repegged by Kaimosi Gold Mines Ltd. and G. McKenzie who are now producing a few ounces

of gold per month from them by selectively mining and milling rubble. Several adits are being driven and shallow shafts sunk in an attempt to follow the reef channels but there is at present no development below 60 ft. depth.

(104) *Owombo Mine,* on a white quartz vein, with a maximum width at surface of 12 ft., was originally opened up by the Tanganyika Concessions Ltd. but was eventually taken over and worked by the Bukura Mining Co. Ltd. Few details are available except that on the upper levels pumping at a rate of 6,000 g.p.h. was necessary, but a winze below the 230 foot level was dry. The second level gave mill-heads of 14 dwt./ton but the width of the vein at that depth is unknown. All work on this property was abandoned some time ago but whether this was due to exhaustion of reserves or high mining costs is not known.

(109) *and* (111) *Forest Edge Mining Syndicate,* formed in June, 1937, became Forest Edge Mines Ltd. in April, 1938. They worked a low-grade ore-body and several small but rich stringers, the latter to water-level only. The silver content of the ore worked was said to be high and bullion produced carried up to 50 per cent of that metal. Operations ceased in 1940.

(110) *Kibiri* Mine was originally prospected by the Eldoret Mining Syndicate and later by Tanganyika Concessions Ltd. A considerable amount of development was done by open-casts, shafts, adits, drives and cross-cuts, and a few bore-holes were sunk. One large and two smaller low-grade ore-bodies of irregular shape, consisting of felspathic grits and conglomerates of the Kavirondian System, mineralized by arsenopyrite, were proved. No mineralization was observed in the Kavirondian mudstones of the area. A sketch map of the surface and adit level compiled from observations by Pulfrey in 1933 is given in Fig. 10 (at end).

Zawadi Ltd. eventually worked this ore-body by open-cast methods, starting production in September, 1940. When operations ceased in November, 1943, 64,500 tons of ore had been treated for a recovery of 1,815 oz. of gold valued at £15,240, i.e. the average recovery was the amazingly low figure of 0.56 dwt./ton.

(113) *H.S.F. Syndicate* worked various stretches of the Yala and Edzawa Rivers and their tributaries for alluvial gold, and it is recorded that between 1939 and 1945, when all claims were abandoned, produced 3,972 oz. of gold valued at £32,880.

(114) *Kenya Reefs* held and operated on stretches of the Yala River alluvials, alternating with the H.S.F. Syndicate.

(112) *Kaimosi Prospect* again was originally discovered by the Eldoret Mining Syndicate and was later prospected by Kentan Gold Areas Ltd. between 1934 and 1936, but without any really encouraging results. Fig. 23, compiled from observations by Pulfrey in 1934, gives an indication of the geology of the deposit, which to the depth then worked was still gossanous.

The shafts and trenches were sunk on gossans in an area of steeply dipping Kavirondian sediments which have been disturbed by gentle crushing and shearing. The gossans are irregular in shape, size and strike.

A few high gold values were obtained but generally speaking the bodies appear to be of low-grade. The silver content is high and there is also a certain amount of lead in the form of galena and pyromorphite, while traces of copper have also been reported. Pulfrey regarded the sulphides and other copper and lead minerals as original metasomatic minerals or their decomposition products, but he was doubtful whether they would have any greater development at depth than in the known parts of the prospect. No production is recorded from these bodies and work ceased on them in 1936, though they have been pegged from time to time since that date. The area was recently closed to prospecting by Government which may later carry out a re-examination of the prospect.

(116) *Button and Mason* (Terauro Syndicate) operated on several narrow veins just west of Shikonde, and a three stamp mill was producing gold in 1933. The claims were held under option by Kenya Development Ltd. and a shaft was sunk to 148 ft. with a certain amount of cross-cutting at the 138 ft. level. Work by the option-holders ended in May, 1935, but further work was carried out from an adit and inclined shaft by the original holders. Recorded production to August, 1938, when mining ceased, was £5,200 worth of gold from 4,350 tons of ore milled.

(115) *and* (117) *D. V. Broadhead-Williams* originally pegged claims in the Shikonde area in January, 1932, but work on these ceased in 1935 without any recorded production. In August, 1938, a new ore-body was found a short distance east of the Muchang Mine and values were said to range at surface from 3 dwt. to 10 oz. per ton over widths of two to three feet and a strike length of 200 ft. It was later established that the ore-body was lens-shaped with a maximum width of 14 ft. tapering over a distance of 150 ft. on each side of the maximum point. Values were found in 4 to 6 ft. of the hanging-wall in mineralized grits, and a shaft was sunk to 125 ft. It is recorded on mining returns that gold to the value of £3,900 was recovered from 3,900 tons of ore milled, before the mine closed down at the outbreak of World War II. Reserves at that time were estimated at 4,000 tons averaging 8 dwt./ton over a width of 5 to 6 ft. It is now proposed to re-open this property and sink diamond drill-holes to prospect the ore-body at depth.

2. Other Minerals (W.P.)

Silver

Silver is present in all the gold ores of the Kakamega district and, wherever gold has been extracted, silver has necessarily been obtained as a by-product. Its value, compared with that of the gold produced has, however, been negligible. The figures for the Rosterman Mine illustrate this—between 1938 and 1952 silver produced amounted to 9,065 oz. which realized £1,308. In general the fineness of gold bullion produced in the goldfield has been between 800 and 900, but in some cases, such as the deposits worked by the Forest Edge Syndicate, bullion of an approximate fineness of 500 was obtained.

Scheelite

Scheelite was discovered by I. W. Anderson in 1947 in an epidote-actinolite-quartz vein on the Kakamega–Kapsabet road, near Kuywa at the edge of the Kaimosi settled area.

Clear scheelite in crystals up to a quarter of an inch across were found in the original samples, which on analysis were found to contain 2.35 per cent WO_3, equivalent to 3.67 per cent of scheelite. During further examinations crystals of scheelite up to one and a half inches across were discovered and traces of gold. Analysis of a 25 lb. sample of such material, stated to be representative of the vein, indicated the presence of 2.66 per cent of scheelite and 0.2 dwt./short-ton of gold. Little work was done on the occurrence, and it is probable that the scheelite was sporadically distributed in the vein and that the values indicated by analysis are not representative of the vein taken as a whole.

Small amounts of scheelite have been discovered in concentrates obtained during the milling of gold ore, for example at Bukura mine. It is probable that many of the gold veins worked contained small amounts of the mineral, but that in most cases it was not recognized.

Diamonds

It is stated by prospectors and others who worked in the Kakamega goldfield in its early days that a few small diamonds were recovered during the washing of stream gravels. Their derivation is not known, but it is possible that they occur as rare grains in some of the Kavirondian conglomerates. A diamond stated to be from Kakamega, produced for examination in the Department, was a clear white stone weighing 0.7 carat, and of octahedral shape with gently curved faces.

Molybdenite

Traces of molybdenite are known in the syenites at Suera, in western Maragoli, and the occurrence has been described previously (Pulfrey, 1946, p. 43). It has been examined on several occasions but no hope has been found to expect that workable deposits might be present.

Quartz Crystals

A vuggy quartz vein north-east of Kaimosi, on the Kakamega–Kapsabet road, in which a few clear small quartz crystals had been found by A. R. Dresser was extensively prospected by the Department in 1942. The work was abortive, however, and no crystals of piezo-electric or optical value were discovered. Occasional crystals have been found in other veins in the district, but no occurrences of economic value have come to light.

Pyrite

East African Industries Ltd. ((50) *and* (87) *of Fig.* 3).—This concern, incorporated in April, 1949, and controlled by Government and the Colonial Development Corporation, prospected massive pyrites bodies at Bukura and Akwirangi while holding exclusive prospecting licences over those areas. In the case of the Bukura prospect (50), the exclusive prospecting licence covered an area of 296 acres and included the gossanous body prospected in 1933 by the Yala-koa Syndicate and, under option, by the Swedish Mines Syndicate. One shaft was sunk to 160 ft., but at that depth was abandoned due to flooding with water and running sand. Three diamond drill-holes were also sunk but only one of these, to a depth of 440 ft., gave any useful information. The pyritic body was passed through between 263 ft. and 347 ft. and showed a sulphur content ranging between three per cent and forty-six per cent. The average grade was considered to be too low for the economic production of sulphur and all activities on the prospect ceased in April, 1951. The Akwirangi prospect (87) was also abandoned in April, 1951, when an adit, driven a distance of 250 ft. into the hillside through weathered Kavirondian mudstones, struck the still oxidized pyritic body at about 100 ft. below the summit of the ridge (A.H.).

The gossans at Bukura traverse the divides about seven miles south-west of Kakamega, and give rise to marked bluffs and hog-backs that stand up from the gentle south slope of the Sioka valley. One section of the gossan zones extends more or less continuously over a distance of 4,500 ft. eastwards from the River Yaanamakour. The gossans are the oxidation products of pyritic members of a mudstone succession in the Kavirondian System and include solid ironstones, cellular ironstones, quartz-ironstone breccias, mudstones in all stages of impregnation by iron hydrates, and silicified mudstones.

During the prospecting in 1933, when gold was being sought (*see* Ann. Rep. Mining and Geological Department for 1934, p. 28), two bore-holes were drilled, two shafts sunk and an adit driven. The bore-holes intersected the primary sulphide ore-bodies lying below the gossan over the following widths.

	Total inclined depth	Inclination of borehole	Sulphides, true width	Vertical depth at which sulphides were struck
	feet			
Borehole No. 1 ..	300	45°	5·9 and 12 ft.	231 and 264 ft.
Borehole No. 2 ..	266	45°	15·0 and 29·3 ft.	between 152 and 196 ft.

The sulphide bands were found to consist variably of pyrite, pyrrhotite, and mixtures of the two minerals, with varying proportions of intercalated mudstone. Analyses of material obtained from the cores are given in the table below.

ANALYSES OF DRILL-CORE SAMPLES FROM BORE-HOLES IN THE BUKURA PYRITIC LODES

	per cent	per cent	per cent
SiO_2	6·19	5·67	5·22
Al_2O_3	1·24	0·80	0·16
Fe	53·69	43·22	47·83
S	34·65	46·18	37·15
As	tr.	tr.	tr.
Cu	tr.	nil.	nil

Anal. A. F. R. Hitchins.

In the adit and in the cross-cut from the main shaft the following gossan widths were recorded:—

	gossan width
adit	6 ft. and 17.5 ft.
cross-cut	6.6 ft. and 26.4 ft.

A sulphide ore-body was also found in the workings of the Bukura Mine and was examined by a cross-cut in 1943. Analyses of two samples indicated 33.76 and 25.41 per cent of sulphur content with traces only of arsenic.

3. Water-supplies

The area is extremely well watered, annual averages varying between 60 and 75 in. of well distributed rainfall in different parts of the quarter-degree area. As a result of this and the close network of permanent rivers and streams, it is seldom that water-supply difficulties are encountered, though many of the streams are highly polluted in this thickly populated area. No bore-holes have been sunk in the area and few wells are known, most of the inhabitants drawing their water direct from the streams or springs.

4. Building Materials

Easily dressable building stone is not known in the area. The Basement System rocks, the granites, the Kavirondian grits and conglomerates, the Nyanzian volcanics and the Tertiary volcanics are all too hard to attract the attention of the local builders. Spoil from the mine dumps has in some areas been used for rough walling and laterite block buildings are common in certain parts of the district. The granites are used locally, roughly dressed, as millstones operated by crude water-wheels.

Most native dwellings are of the wattle and daub variety but there is an increasing local industry in the production of burnt bricks and roofing tiles, often of reasonably good quality. Brick-making material is widespread in the area and it is seldom that one traverses a distance of more than two or three miles without seeing smoking kilns. With proper mechanical equipment there is no doubt that high class bricks and tiles could be produced in many localities.

Good, coarse, building sand is available in most of the rivers draining the Basement System and granite areas, and to a lesser extent the Kavirondian grit areas.

5. Possibilities of the Area

The economic potentialities of the newly-mapped portion of the area from a mining point of view would appear to be confined to the possibility of discovering further gold-bearing quartz veins or massive, probably low-grade sulphide impregnations. Fig. 3 indicates the portions of the area already intensively prospected and it is considered unlikely that any *large* new finds will be made in those parts of the district, nor are the areas underlain by the Maragoli and Mumias granites and the Basement System rocks likely to yield gold deposits of economic value.

There remain, however, two areas underlain by Kavirondian and Nyanzian rocks which, from the records available, do not appear to have been prospected in any great detail. They are (*a*) the area between the Khayega–Kaimosi road and the Mumias granite contact and (*b*) the area east of Malaba to the foot of the Nandi Scarp. Area (*a*) lies almost entirely within the Kakammega Forest Reserve and is difficult of access. Detailed prospecting here would necessitate line clearing and deep pitting or augering through the heavy soil cover. Area (*b*) is in more open country but again the soil cover is generally deep. There is, however, in both areas a fairly close network of streams, the panning of which should prove of value in any search for gold-bearing quartz veins.

VII—RECORDS OF UNDERGROUND BOREHOLES

1. Records of Underground Bore-holes, Rosterman Mine

Depth From ft.	To ft.	*D.D.H. No.* 17
		Drilled from the 240-ft. level, Horst Reef, at −70° on a bearing of 180°. Logged by Rosterman Gold Mines Ltd.
0	388	Coarse-grained diorite with numerous bands of fine-grained rock. Calcite stringers occasionally seen.
388	465	Finer-grained diorite. At 465 ft. 15.7 dwt./14 in. in quartz and 1.0 dwt./14 in. mineralized channel.
465	485	Coarse-grained diorite.
485	502	Finer-grained diorite with calcite stringers.
502	569	Coarse-grained diorite with calcite vein at 568 ft.
569	595	Coarse-grained broken diorite.
595	609	Fine-grained broken diorite.
609	699	Coarse-grained diorite.
699	715	Fine-grained diorite. 42 dwt./10 in. at 707 ft.
715	1,035	Coarse-grained diorite with occasional bands of finer-grained rock. 6.7 dwt./4 in. channel, 1.0 dwt./10 in channel, and 33.8 dwt./4 in. quartz at 863 ft.
1,035	1,167	Coarse-grained diorite.
1,167	1,717	Coarse-grained diorite with bands of fine-grained rock. 17 dwt./26 in. quartz, 30 in. diorite, and trace/26 in. quartz at 1,167 ft.

Bottom of Bore-hole.

D.D.H. No. 24

		Drilled from the 180-ft. level, Horst Reef, at −47° on a bearing of 180°. Logged by Rosterman Gold Mines Ltd.
0	500	Coarse-grained diorite with bands of fine-grained rock.
500	1,015	Coarse-grained diorite with calcite stringers.

Bottom of Bore-hole.

Assay results from this bore-hole were traces at 230 ft., 426 ft., 439 ft., 470 ft., 500 ft., and 860 ft.

D.D.H. No. 36

Drilled from main south cross-cut, 500-ft. level, at −55° on a bearing of 180°. Logged by Rosterman Gold Mines Ltd.

Depth From ft.	To ft.	
0	441	Coarse-grained diorite.
441	467	Probably andesites.
467	694	Coarse-grained diorite.

Bottom of Bore-hole.

Assay results from this borehole were traces at 327 ft., 567 ft. and 694 ft.

D.D.H. No. 37

Drilled from the 580-ft. level, Horst Reef, at −70° on a bearing of 160°. Logged by Rosterman Gold Mines Ltd.

0	190	Coarse-grained diorite.
190	274	Fine-grained diorite.
274	310	Fine-grained broken rock, may be volcanics.
310	606	Bands of finer-and coarser-grained diorite.
606	902	Coarse-grained diorite.

Bottom of Bore-hole.

Assay results from this bore-hole were Tr./2 in. at 371 dt., Tr./48 in. at 464 ft., Tr./1 in. at 606 ft., Tr./1 in. at 703 ft., Tr./24 in. at 782 ft.

D.D.H.s Nos. 41 to 51 drilled at various points along the 6th level in the No. 1 Foot-wall Reef were logged by Hitchen in 1938.

D.D.H. No. 41

Depth From ft.	To ft.	
0	15	Coarse-grained diorite.
15	21	Inclusions of volcanics—andesites (?)
21	37	Coarse-grained diorite.
37	41	Broken core—coarse diorite.
41	43	Coarse diorite.
43	46	Broken core—coarse diorite.
46	71	Coarse-grained diorite.
71	95	Coarse-grained diorite with small inclusions of vocanics.
95	96	Reef. Trace/13 in.
96	97	Diorite.
97	99	Reef matter. 0.9 dwt./33 in.

Bottom of Bore-hole.

D.D.H. No. 42

0	28	Coarse-grained quartz diorite.
28	31	Coarse-grained diorite with inclusions of volcanics.
31	32	Reef.
32	44	Fine- and coarse-grained diorite with inclusions of volcanics—main volcanic contact not far distant (?)

Bottom of Borehole.

D.D.H. No. 43

This borehole passed through medium-grained diorite for the whole of its length of 63 ft.

D.D.H. No. 44

This bore-hole passed through medium- to coarse-grained diorite for the whole of its length of 77 ft.

D.D.H. No. 45

Depth From ft.	To ft.	
0	6	Volcanics.
6	8	Biotite porphyrite intrusion.
8	11	Volcanics and fine-grained diorite.
11	13	Fine-grained diorite.
13	20	Altered volcanics—basalt.
20	24	Fine-grained diorite (contaminated).
24	25	Volcanics.

Note: D.D.H. No. 45 very mixed—no coarse diorite—evidently on volcanics-diorite contact. Rendered complex by assimilation and intrusions of biotite porphyrite.

Bottom of Bore-hole.

D.D.H. No. 46

0	4	Diorite—somewhat contaminated.
4	12	Inclusions of porphyritic andesite, matrix of which is aggraded to a biotite porphyrite type. Relics of original phenocrysts of hornblende and felspar.
12	27	Diorite—somewhat contaminated.
27	33	Andesites (?).
33	34	Andesites aggraded to biotite porphyrite as above.
34	35	Reef. 6-in. channel gave 9.6 dwt. and 6-in. quartz gave 30.5 dwt.
35	56	Volcanics—andesites aggraded to biotite porphyrite as above.

Bottom of Bore-hole.

D.D.H. No. 47

0	6	Coarse-grained diorite with inclusions of volcanics.
6	30	Coarse-grained diorite.
30	69	Coarse-grained diorite with some inclusions and signs of brecciation.

Bottom of Bore-hole.

D.D.H. No. 48

No log.

D.D.H. No. 49

0	14	Coarse-grained diorite.
14	18	Diorite with inclusions of volcanics.
18	19	Reef.
19	20	Fine-grained diorite.

Bottom of Bore-hole.

Depth From ft.	To ft.	*D.D.H. No.* 50
0	8	Volcanics partly aggraded to biotite porphyrite.
8	14	Basalt in process of aggradation—biotite being developed.
14	15	Reef.
15	16	Basalt.

Bottom of Bore-hole.

D.D.H. No. 51

This borehole passed through andesites for the whole of its length of 57 ft.

Details of twenty-five of the bore-holes logged by the writer have been plotted on the underground plans accompanying this report. Records of others logged but not plotted are given below. They are arranged in groups according to the level from which they were drilled.

SEVENTEENTH LEVEL

D.D.H. No. 255

Depth From ft.	To ft.	Drilled from No. 17 level at −55° on a bearing of 180°. Co-ordinates of collar 661 S. 667 W.
0	18	Diorite porphyrite.
18	36	Dark grey andesite.
36	44	Fine-grained diorite.
44	47	Andesite with quartz stringers.
47	142	Coarse-grained diorite with relics of andesite scattered throughout. Diorite fine-grained marginally.
142	145	Andesite with diorite veinlets.
145	193	Andesite.
193	317	Alternations of fine-grained diorite and diorite porphyrite. Diorite 193-204, 214-215, 218-258, 284-317 ft.
317	362	Andesite.
362	443	Igneous breccia.
443	448	Diorite porphyrite.
448	477	Igneous breccia.
477	499	Porphyritic andesite.
499	727	Igneous breccia.
727	729	Fine-grained andesite.
729	755	Igneous breccia (brecciated and silicified diorite?).
755	784	Hornblende andesite.
784	960	Kavirondian conglomerate. Fault gouge at 959 ft.

Bottom of Bore-hole.

Depth From ft.	To ft.	D.D.H. No. 259
		Drilled from No. 17 level at −55° on a bearing of 180°. Co-ordinates of collar 616 S. 450 W.
0	50	Diorite porphyrite.
50	92	Fine- and coarse-grained diorite with andesite xenoliths.
92	100	Microgranite dyke.
100	106	Diorite porphyrite.
106	177	Fine- and coarse-grained diorite.
177	182	Altered andesite.
182	184	Diorite porphyrite. Andesite felspathized on contact.
184	247	Coarse-grained diorite.
247	275	Diorite porphyrite.
275	315	Fine-grained diorite.
315	375	Diorite porphyrite.
375	379	Fine-grained andesite.
379	384	Coarse-grained diorite.
384	429	Diorite porphyrite.
429	679	Fine- and coarse-grained diorite.
679	728	Fine-grained andesite.
		Bottom of Bore-hole.

Assay results from this borehole were: Tr./50 in. at 95 ft., Tr./6 in. at 571 ft., Nil/2 in. at 575 ft., Tr./8 in. at 618 ft., Tr./6 in. at 671 ft. and Tr./58 in. at 673 ft.

D.D.H. No. 263

Drilled from No. 17 level at −55° on a bearing of 170°. Co-ordinates of collar 661 S. 666 W.

0	12	Diorite porphyrite.
12	33	Fine-grained volcanics. Fault gouge at 27 to 29 ft.
33	328	Fine- to coarse-grained diorite with occasional small relics of andesite. Fault gouge at 36 to 37 ft.
		Bottom of Bore-hole.

D.D.H. No. 264

Drilled from No. 17 level at −34° on a bearing of 180°. Co-ordinates of collar 616 S. 694 W.

0	21	Diorite porphyrite.
21	57	Medium-grained diorite.
57	63	Diorite porphyrite.
63	96	Coarse-grained diorite, finer-grained on margins.
96	105	Diorite porphyrite.
105	280	Alternating fine- and coarse-grained diorite.
280	317	Fine-grained andesite, lightly altered.
317	337	Fine-grained diorite.
337	448	Diorite porphyrite with relics of fine-grained volcanics.
448	645	Kavirondian conglomerate.
645	680	Fine-grained diorite.
680	810	Kavirondian conglomerate with 6 in. dyke of porphyritic biotite microgranite at 782 ft.
		Bottom of Bore-hole.

Assay results from this core were: Nil/12 in. at 469 ft. and Tr./2 in. at 694 ft.

Nineteenth Level

D.D.H. No. 262

Depth From ft.	To ft.	
		Drilled from No. 19 level at −55° on a bearing of 139° 30′. Co-ordinates of collar 325 S. 634 W.
0	8	Fine-grained andesite.
8	115	Alternating diorite porphyrite and fine-grained diorite. Diorite at 43-69, 73-91 and 112-115 ft.
115	124	Fine-grained andesite.
124	440	Alternating fine- and coarser-grained diorite.
440	610	Core missing.

Bottom of Bore-hole.

Assay results from this bore-hole were Tr./3 in. at 39 ft. and Tr./9 in. at 112 ft.

Twenty-First Level

D.D.H. No. 248

Drilled from No. 21 level at −55° on a bearing of 180°. Co-ordinates of collar 70 S. 55 W.

0	53	Alternating fine- and coarse-grained diorite.
53	55	Fine-grained andesite.
55	294	Alternating fine- and coarse-grained diorite with a 6 in. relic of andesite at 144 ft.

Bottom of Bore-hole.

Assay results: Tr./10 in. at 234 ft. and Tr./3½ in. at 272 ft.

D.D.H. No. 268

Drilled from No. 21 level at −54° on a bearing of 20°. Co-ordinates of collar 915 S. 340 W.

0	239	Alternating fine- and coarse-grained diorite with small andesite relics prominent at 128 ft.

Bottom of Bore-hole.

Assay results: Tr./27 in. at 164 ft.

D.D.H. No. 275

Drilled from No. 21 level at −55° on a bearing of 200°. Co-ordinates of collar 1160 S. 420 W. This bore-hole passed through Kavirondian conglomerate for the whole of its length of 52 ft.

D.D.H. No. 276

Drilled from No. 21 level at −40° on a bearing of 200°. Co-ordinates of collar 1120 S. 420 W. Only Kavirondian conglomerate was seen in this bore-hole which had a length of 120 ft.

D.D.H. No. 270

Drilled from No. 21 level at −34° on a bearing of 200°. Co-ordinates of collar 914 S. 340 W.

Depth From ft.	To ft.	
0	31	Medium- and coarse-grained diorite.
31	72	Fine-grained andesite.
72	88	Fine-grained diorite.
88	103	Fine-grained andesite.
103	147	Diorite porphyrite.
147	202	Coarse-grained diorite with occasional relics of andesite.

Bottom of Bore-hole.

Assay results: Tr./19 in. at 94 ft. and 0.4 dwt./7 in. at 106 ft.

D.D.H. No. 322

Drilled from No. 21 level at +45° on a bearing of 200°. Co-ordinates of collar 1115 S. 420 W.

From ft.	To ft.	
0	87	Kavirondian conglomerate.
87	94	Porphyritic microgranite dyke.
94	99	Kavirondian conglomerate. Considerable pyrite.

Bottom of Bore-hole.

D.D.H. No. 323

Drilled from No. 21 level at +55° on a bearing of 15°. Co-ordinates of collar 1115 S. 420 W. This bore-hole penetrated Kavirondian conglomerate, with considerable sulphide dissemination, throughout its length of 100 ft.

D.D.H. No. 312

Drilled from No. 21 level at −60° on a bearing of 180°. Co-ordinates of collar 58 S. 460 W.

From ft.	To ft.	
0	416	Diorite porphyrite.
416	448	Fine-grained diorite.
448	525	Fine-grained andesite.
525	630	Fine-grained andesite with many veinlets of diorite.
630	694	Diorite porphyrite. Quartz stringers at 690 to 692 ft.
694	752	Alternating fine- and coarse-grained diorite.
752	753	Inclusion of andesite.
753	768	Medium-grained diorite.

Bottom of Bore-hole.

D.D.H. No. 291

Drilled from No. 21 level at −55° on a bearing of 170°. Co-ordinates of collar 405 N. 403 W.

From ft.	To ft.	
0	153	Fine-grained andesite, highly sheared to 73 ft.
153	155	Patches of diorite porphyrite in andesite.
155	161	Fine-grained diorite.
161	367	Fine-grained andesites with veinlets and patches of diorite.
367	382	Fine-grained diorite.
382	394	Core badly broken and recovery only 40 per cent, in diorite porphyrite. Clayey material at 394 ft. may be fault gouge.
394	496	Core missing.

Assay results: Tr./8 in. at 291 ft., Tr./6 in. at 292 ft., 1.1 dwt./8 in. at 293 ft., Tr./2 in. at 297 ft., and 0.8 dwt./7 in. at 329 ft.

D.D.H. No. 321

Depth From ft.	To ft.	
		Drilled from raise 560 w. ex No. 22 level at −45° on a bearing of 20°. Co-ordinates of collar 1115 S. 540 W.
0	28	Fine-grained volcanic material with tiny veinlets and tongues of diorite.
28	30	Medium-grained diorite.
30	34	Fine-grained volcanic material as above.
34	90	Coarse-grained diorite.

Bottom of Bore-hole.

D.D.H. No. 287

Drilled from winze 445 W. ex No. 21 level horizontally on a bearing of 270°.

Co-ordinates of collar 1060 S. 445 W.

0	35	Coarse-grained diorite with occasional andesite inclusions.
35	97	Diorite, darker than the normal types. Many andesite inclusions which are penetrated by tongues and veinlets of the diorite.
97	103	Fine-grained andesite. Fault gouge at 103 ft.

Bottom of Bore-hole.

D.D.H. No. 282

Drilled from winze 445 W. ex No. 21 level at −45°, on a bearing of 180°. Co-ordinates of collar 1066 S. 435 W.

0	35	Coarse-grained diorite.
35	39	Fine-grained andesite with diorite veinlets.
39	74	Kavirondian conglomerate.

Bottom of Bore-hole.

TWENTY-SECOND LEVEL

D.D.H. No. 265

Drilled from No. 22 level horizontally on a bearing of 190°. Co-ordinates of collar 135 N. 318 W.

0	6	Fine-grained diorite.
6	28	Diorite porphyrite.
28	45	Fine-grained diorite.
45	49	Coarse-grained diorite.
49	69	Diorite porphyrite.
69	167	Fine- and coarse-grained diorite in alternating bands with occasional andesite relics.
167	173	Diorite porphyrite.
173	176	Fine-grained andesite.
176	200	Fine-grained diorite.
200	217	Fine-grained andesite.
217	283	Fine-grained diorite with relics of fine-grained volcanics. From 217 ft. onwards the core is badly broken and recovery only 40 per cent.

Bottom of Bore-hole.

Depth		
From ft.	To ft.	*D.D.H. No.* 289
		Drilled from winze 445 W. ex No. 22 level horizontally on a due north bearing. Co-ordinates of collar 970 S. 445 W.
0	6	Coarse-grained diorite.
6	16	Fine-grained diorite.
16	70	Fine-grained andesite with occasional tongues of coarse-grained diorite.
70	81	Fine-grained diorite.
81	83	Coarse-grained diorite.
		Bottom of Bore-hole.
		D.D.H. No. 302
		Drilled from No. 22 level at −42° 30′ on a bearing of 180°. Co-ordinates of collar 1063 S. 660 W.
0	50	Kavirondian conglomerate, heavily mineralized at 31 to 33 ft.
		Bottom of Bore-hole.
		Assay results: Tr./14 in. at 22.5 ft., Tr./5 in. at 24 ft., 2.0 dwt./3 in. at 31.6 ft. and 1.3 dwt./14 in. at 32.9 ft.
		D.D.H. No. 303
		Drilled from the same point as D.D.H. No. 302 but at −42° 30′ on a bearing of 0°.
0	8	Kavirondian conglomerate.
8	10	Diorite porphyrite.
10	50	Kavirondian grit and conglomerate with considerable sulphide banding. Core looks rather sheared from 40 ft. onwards.
		Bottom of Borehole.
		TWENTY-THIRD LEVEL
		D.D.H. No. 313
		Drilled from No. 23 level at −30° on a bearing of 180°. Co-ordinates of collar 920 S. 600 W.
0	18	Diorite porphyrite.
18	60	Very coarse-grained diorite.
60	63	Fine-grained diorite.
63	126	Diorite porphyrite.
126	171	Fine-grained diorite.
171	190	Diorite porphyrite.
		Bottom of Borehole.
		D.D.H. No. 318
		Drilled from winze 445 W. ex No. 23 level at +50° on a bearing of 340°. Co-ordinates of collar 740 S. 440 W.
		This bore-hole was drilled through fine- and coarse-grained diorite, with occasional andesite relics, for its whole length of 48 ft. Three inches and five inches of quartz were present at 6 ft. and 24 ft. respectively.

2. Records of Certain Diamond Drill-holes, Kimingini Mine

Certain bore-holes sunk at the Kimingini property were logged by Hitchen in 1937. Their positions are shown on Figs. 9 and 21, and the logs are summarized below,

D.D.H. No. 3

Depth From ft.	To ft.	
		Drilled from the surface at −76° on a true north bearing.
0	100	Felspathic grits.
100	313	Mudstones.
		Bottom of Borehole.

D.D.H. No. 4

Drilled from surface at −80° on a true north bearing, in slaty mudstones or mudstones for its whole depth of 282 ft.

D.D.H. No. 6

Drilled from surface at −81° 25′ on a true north bearing, in alternating slaty mudstones and felspathic grits over a total depth of 385 ft.

Cores from Bore-holes Nos. 1, 2 and 5 were not available for examination.

U/G. D.D.H. No. 1

Depth From ft.	To ft.	
		Drilled from No. 1 level horizontally on a bearing of 354° 40′ from NX. 51 E.
0	95	Altered basalt.
95	105	Altered porphyritic basalt.
105	120	Altered metamorphosed hornblende porphyrite.
120	224	Altered basalts.
		Bottom of Borehole.

U/G. D.D.H. No. 7

		Drilled from No. 2 level horizontally on a true south bearing from E.D. 42 S.
0	20	Coarse felspathic grit.
20	345	Altered basalts.
345	405	Felspathic grits and slaty mudstones. Coarse grit at 345 ft.
405	534	White quartz reef.
		Bottom of Bore-hole.

Kampala Syndicate Bore-holes

D.D.H. No. 1

Drilled from surface at −50° on a bearing of 350°, in felspathic grits and slaty mudstones for a total depth of 180 ft.

D.D.H. No. 2

		Drilled from surface at −80° on a bearing of 170°.
0	415	Sheared felspathic grits and slaty mudstones.
415	493	Felspathic breccia—volcanic origin (?).
493	515	Crushed and altered quartz dolerites.
		Bottom of Bore-hole.

YALA KOA BORE-HOLES

D.D.H. No. 2

Depth From *ft.*	To *ft.*	
		Drilled from surface vertically.
145	150	Altered dolerite.
292	297	Altered dolerite.
345	351	Altered porphyrite or porphyritic lava.
467	471	Slaty band.
489	493	Sheared felspathic grit.

Note.—Only part of the above core was retained and No. 1 D.D.H. core was not available.

The logs of U/G. D.D.H.s Nos. 8, 9 and 10 are as shown in Fig 21.

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