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**MINISTRY OF ENVIRONMENT AND NATURAL RESOURCES**

**MINES AND GEOLOGICAL DEPARTMENT**

**GEOLOGICAL SURVEY OF KENYA**  
**Preliminary Report on the Geology of the**  
**No. 1 Area, North and Central Kavirondo**

WITH TWO MAPS

by

**WILLIAM PULFREY, M.Sc., Ph.D., F.G.S.**  
**Assistant Geologist**

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PRELIMINARY REPORT ON THE GEOLOGY OF THE  
No. 1 AREA, NORTH AND CENTRAL  
KAVIRONDO.

By WILLIAM PULFREY, *M.Sc., Ph.D., F.G.S.*

I.—INTRODUCTION AND GENERAL INFORMATION.

The area described in this report, the geology of which is shown on the accompanying maps, is Area No. 1 of the five divisions of Western Kenya suggested by Sir Albert Kitson in a report to the Government in 1933 ((12), p. 12),\* and re-defined in Government Notice No. 169 of the 3rd March, 1934. The boundary follows the Kenya-Uganda border from Sio, on Lake Victoria, northwards to the River Totogananga, where it turns along the river to the Mbale-Malakisi road. It continues eastwards along the road to Kimilili, and then south on the Kakamega road to the River Nzoia, which it follows downstream to a point north of Niahumbe T.S.† The boundary here turns to the south on a line through Niahumbe and Akarra T.S.s to the Yala-Otodo confluence, where it deviates in a south-westerly direction to the head of Kadimo Bay; and thence by the shore of Lake Victoria to the Sio River.

The greater part of the area is included on the Mumias' Sheet (North A36/W) of the 1:250,000 War Office map printed in 1916, whilst the Kadimo area, in the south, is part of the Karungu Sheet (South A36/E). The topography of the maps which accompany this report is based on a map, on the scale of 1:125,000, prepared from aerial photographs taken in 1933 by the Aircraft Operating Company of Johannesburg for Messrs. Tanganyika Concessions, Ltd. The field work involved in obtaining the geological data was undertaken in March and April of the present year. During the work, Sir Robert Williams and Co., Kisumu, on behalf of Tanganyika Concessions, Ltd., kindly allowed the writer access to what aerial photographs and prospectors' maps of the area were available at their Kisumu office.

Owing to the necessity for a rapid survey, it has not been possible to make a detailed examination of the area. An attempt was made, however, to cover as much ground as possible in the time available, and to arrive at a conception of the

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\* Numbers (1) to (23) refer to literature listed on pages 30 and 31.

† T.S.(s) = Trigonometrical Station(s).

geology as a whole. With this aim, the area north-east of a line through Malaba and Kalera, consisting mainly of granite, was left entirely untouched. On the remainder of the area, a greater part of the time was devoted to the extra-granite country, though the granite contact was examined in detail in Ugenya, Marach, and along parts of the River Kami (Wamia).

To complete the present work it has been necessary to abstract a small amount of detail from earlier maps. Thus the approximate north boundary of the Mumias' Granite has been taken from a map prepared by Mr. R. Murray-Hughes, and in places which the writer was unable to visit, the assumed contact on the southern margin has been fixed by reference to prospectors' maps. A few dolerite dykes have also been inserted from prospectors' field maps.

As Dr. C. S. Hitchen, Acting Government Geologist, had recently completed the survey of the north-west section of the No. 2 Area (11), he undertook the reconnaissance of Western Alego, which adjoins it. The area north-west of the River Nzoia and the Kadimo area were examined by the writer.

The area is fairly well supplied with roads, though access to large portions may often be had only by use of paths. The Kadimo and Alego areas are readily accessible by roads from Yala and Luanda. The area north of the River Nzoia can be approached by two road bridges, one near Mumias' on the Kakamega-Busia road, the second (Nzoia Bridge) east of Ukwala, on the Yala-Busia road. The Marach-Samia area is isolated from the Busia-Nambare area by the River Sio, which is spanned by one bridge only, nine miles south-east of Busia.

The nearest European shops are at Yala and Kisumu. Reliable supplies can be obtained from Indian shops at Busia, Asembo and Mumias', while limited supplies of goods are also stocked by shops at Kadimo, Sio and Nambare. Petrol and oil supplies can be obtained at Busia, Mumias', Yala, and Asembo.

The area, with the exception of parts of Samia and Kadimo, has a fairly accessible and constant water supply. Timber is not abundant, and whilst there is sufficient for domestic purposes, fuel for mining purposes will have to be brought in from other areas. There is almost no timber suitable for the support of shafts and underground workings, and timber for that purpose will have to be imported into the area.

### *Acknowledgments.*

The writer's thanks are due to Mr. E. J. Wayland, Director of the Geological Survey of Uganda, for his kindness in allowing him to co-operate with Dr. K. A. Davies, a member of his staff, to whom the writer is greatly indebted for conducting him round the Busia area, and for very helpful discussion on the rocks of the No. 1 Area and Eastern Uganda.

### II.—PREVIOUS WORK IN THE AREA.

No detailed work had been done in the No. 1 Area until recent years. Elliott and Gregory in 1895 (9) referred briefly to the area, indicating a Karagwe-Ankolean age for the quartzites and associated rocks of the Samia Hills. Later Hobley produced a geological map of Kavirondo, including the No. 1 Area, but the map cannot at present be traced.

In 1921 Gregory (10) described "Karagwe-Ankolean sediments" in the Samia Hills as "folded into a syncline, at the base of which occur the ironstones around Berkeley Bay" (p. 44), and mentioned the occurrence of "gneiss" in the Samia Hills and along the River Sio (p. 122).

In 1929, O. H. Odman published a paper dealing with the geology of North and Central Kavirondo (18). He noted the general lack of regional metamorphism, and remarked on the uniform strike and steep dips of the Kavirondo Series. He noted the lithological differences between the Samia Hills Series—"banded ironstones, shales and greenstones," folded on north-east axes and broken by many small transverse faults—and the Kavirondo Series. He regarded his Kavirondo Series (the Samia Hills Series plus the Kavirondo Series of the present report) as of Karagwe-Ankolean age, considering the Samia Hills Series as a different facies of the Kavirondo Series, and separated from it by a drag fault pulling to the north. He believed his Kavirondo Series to be an intermediate facies of the Karagwe-Ankolean, between an east and south-east volcanic series, and western, exclusively sedimentary series of that age.

In addition, Odman described the rock types occurring in the area, including the Alego volcanics, the volcanic conglomerates of Kadimo, the normal Kavirondo Series, the Samia Hills Series (especially the quartzites), and the granites. He considered the Mumias' Granite as correlative and consanguineous with the Maseno Granites.

Mr. E. J. Wayland, Director of the Geological Survey of Uganda, in travelling from Busia to Mumias' in 1930, noted the occurrence of granite and the roof-pendant east of Okwara T.S. ((23), pp. 6-7 and 23).

In 1932, Sir Albert Kitson made a rapid reconnaissance of North and Central Kavirondo, and in a statement by the Government ((13), subsequently reprinted in (14), p. 3) gave a brief description of the geological features of the No. 1 Area. He noted the presence of gneisses and schists of the Basement Complex along the Malakisi-Kimilili-Broderick Falls road, and roughly delimited the Mumias'-Akure Hills granite mass, considering it to be a complex intrusion with possibly small roof-pendants resting on it. The area south of the granite he believed to be occupied by Karagwe-Ankolean sediments cut by minor intrusives. He also mentioned the presence of several gold-bearing quartz reefs and veins.

In the following year the Government published Report No. 3 of the Geological Survey (17). This dealt with the whole of Western Kenya, but references were made to the No. 1 Area. The rocks of the Samia Hills, described as quartzites, sericite schists, banded magnetite quartzites, jaspilites and greenstone schists with altered igneous and pyroclastic rocks, were considered to resemble lithologically the Upper Basement Complex of Tanganyika. Murray-Hughes also believed that the rocks of the roof-pendant might be of similar age.

In the Annual Report of the Mining and Geological Department for 1933 ((15), p. 21), Murray-Hughes described a "gold-bearing quartzite" near Busia. He considered the gold to derive from small and impersistent quartz veinlets in the quartzite.

In 1934 Sir Albert Kitson's final report on Kavirondo was published (14). Observations on the No. 1 Area were not included in the report, as the area was then held under exclusive prospecting licence by Tanganyika Concessions, Ltd. In descriptions of road-traverses, however, Sir Albert mentioned the occurrence of biotite-hornblende granite along the Alego-Luambwa road (pp. 10-11), lavas at Usangi (Kadimo), and gritty conglomerates and slates near the head of Kadimo Bay (pp. 14-15).

The Annual Report of the Mining and Geological Department for 1934 made no mention of the No. 1 Area, except that geological work was being carried out by Messrs. Tanganyika Concessions, Ltd.

The most recent publication was a paper by Dr. K. A. Davies in 1936 (8), in which he gave an account of the succession in South-Eastern Uganda, and suggested correlations with adjacent parts of Kavirondo.

### III.—TOPOGRAPHY.

Topographically, the area may be divided into four distinct types :—

1. The major granite areas.
2. A peneplain, underlain in part by sediments of the Kavirondo Series, extending from Busia, through Nambare, Sega and Ukwala to Luambwa, and in part by the volcanic series of Kogwong and Kadimo.
3. The Samia Hills, and Usangi in Kadimo.
4. The Yala Swamp Area.

The granite country, with the exception of the Akure Hills, is essentially part of the peneplain, but it is characterized by the presence of tors, and locally by widespread bouldery outcrops of granite. The Akure Hills and Ramogi are "granitic" masses forming residual hills standing up out of the peneplain. The peneplain is a distinctive area, marked by low, flat divides of an approximately uniform height, and often capped by laterite (Map II). It is evident in the Kadimo area east of the Ramogi-Usangi residual hills, though it is broken by the Akarra Ridge in South Alego.

The Yala Swamp, a papyrus area broken by irregular water channels and occasional small lakes and grassy islands, lies roughly between a line from the mouth of the River Nzoia to Lake Kanyaboli and the northern limits of the Kadimo area. Little is known of the area except that river gravels have been found at considerable depth below present swamp levels.

Parts of the No. 1 Area are drained by perennial streams. In Samia, South-West Ugenya, and Kadimo, however, most of the streams are intermittent, flow depending on heavy rains. The three main rivers of the area, the Nzoia, Sio, and Malaba, have remarkably parallel courses, running from north-east to south-west, which, however, in North Kitosh, is replaced by a radial arrangement of their feeders, flowing from a centre on Mount Elgon. The parallel courses of the main streams are closely at right angles to the Nandi Escarpment in the Broderick Falls district, and may perhaps be ascribed to a south-westerly tilt of the area normal to the fault-escarpment.

The smaller rivers are rarely clean-flowing streams, and usually flow through papyrus or reed marshes, which are acting

as sediment filters, leading to the silting up of the valleys. The River Sio, cutting through its alluvial deposits, occupies a wide mature valley, and is bordered by marshes or flats over the greater part of its length. The River Nzoia has cut deeper into its flood-plain, and along part of it excellent exposures are to be found. Though wide flats occur along part of its course, long stretches have no alluvials worthy of mention.

The divides are mantled by thick soil deposits or crusts of laterite. As far as these surface deposits are known, they are indicated on Map II. The laterite crust varies considerably in thickness: it may be one to two feet thick, whilst thicknesses up to fifteen feet have been seen in the Busia area.

Access to areas lying between the roads is usually tolerably easy in the Ugenya-Wamia-Marach areas, owing to the sparseness of the bush and the frequency of shambas. The Samia Hills are more difficult of access owing to coarse scree, covered by tall grasses, and in places by thick thorn bush. The hills are most easily examined in the early months of the year when the natives are burning the vegetation.

Thorn bush is an obstacle in parts of Kadimo and Alego. The Ramogi Syenite mass can be reached easily, but work on the hill itself is impeded by a growth of dwarf forest.

#### IV.—SUMMARY OF GEOLOGY AND GEOLOGICAL SUCCESSION.

A concise idea of the geology and history of the area may be given by the following succession:—

- |                               |   |  |
|-------------------------------|---|--|
| Recent and Pleistocene        | { | 14. Fluctuations of level: modern denudation and partial destruction of laterite.            |
|                               | { | 13. Formation of laterite.   |
|                               | { | 12. Peneplanation.   |
|                               | { | 11. Intrusion of <i>Dolerites</i> and allied dykes.  |
| Age unknown in the No. 1 Area | { | 10. Local shearing.  |
|                               | { | 9. Intrusion of <i>Acid</i> and occasional <i>basic dykes</i> : incidence of quartz veining. |
|                               | { | 8. { Intrusion of <i>granites</i> .  |
|                               | { | { Intrusion of <i>Ramogi Syenite</i> .   |
| Pre-Cambrian                  | { | 7. Uplift and folding.   |
|                               | { | 6. Deposition of sediments of the <i>Kavirondo Series</i> .                                  |
|                               | { | 5. Folding and faulting—probable unconformity.   |
|                               | { | 4. Intrusion of <i>Akarra Dolerite</i> .   |
|                               | { | 3. { Formation of <i>Quartzite-volcanic</i> suite of the <i>Samia Hills Series</i> .         |
|                               | { | { <i>Volcanics</i> of Kadimo.  |
|                               | { | 2. Time lapse—folding and regional metamorphism.   |
|                               | { | 1. <i>Basement Complex</i> of North Kitosh and Malaba.                                       |

It is believed that the succession may be correlated with those of other East African areas in the following manner:—

EASTERN UGANDA (K. A. Davies, (8), 1935)	No. 1 AREA	No. 2 AREA (C. S. Hitchcock, (11), 1936)	MUSOMA, TANGANYIKA (G. M. Stockley, (20), 1935)	SARAGURA, TANGANYIKA (F. B. Wade, (22), 1934)
Masaba Dolerites.	Dolerites.	Dolerites.	Dolerites.	Dolerites.
Acid and sub-acid plutonic intrusions.	Mumias' } Granites Kanyaboli } Ramogi Syenite	Kisama } Granites Kanyaboli }	Younger Granites (G3 and G4).	Granites.
Bulugwe Series in part ?	Kavirondo Series (sediments).	Kavirondo Series (sediments).	North Mara Series (sediments, regarded as Muva-Ankolean).	—
—	Akarra Dolerite	Akarra Dolerite.	—	—
Bulugwe Series in part (sedimentary, regarded as Karagwe-Ankolean) ? Rocks of Sigulu Island (eastern part) (banded ironstones, altered igneous rocks, etc.).	Samia Hills Series (volcanics and banded quartzites) Kadimo Volcanics.	Andestic Volcanic Suite.	?Kuria Volcanics Musoma Series (volcanics, banded ironstones, quartzites, etc., regarded as pre-Karagwe-Ankolean).	Upper Basement Complex (banded ironstones, tuffs and greenstones).
Tira Dolerites. Lunyo Granite.	— — Basement Complex of North Kitosh.	— — —	— — —	— — —
			Basement Complex with foliated granites.	

## V.—DETAILS OF GEOLOGY.

### 1.—BASEMENT COMPLEX.

Rocks of the Basement Complex, of different type and probably of different age from the members of the Samia Hills Series which is also regarded as part of the Basement Complex, are believed to occur in North Kitosh. The area was not visited during the present survey, but specimens of hornblende gneiss and schist were collected and recorded previously by Sir Albert Kitson ((14), p. 3), who regarded them as part of the Basement Complex.

An area of altered sediments occurs around Malaba Station and the Lower River Malakisi. Whilst they bear some resemblance to rocks of the Kavirondo Series of the Nambare-Busia area, they show a degree of metamorphism which is not seen there, and it is probable that they should rather be included with the Basement Complex. In the Malakisi valley the sediments are light grey, sandy, heavily micacised types, whilst at Malaba they are poorly schistose sandy rocks containing abundant small prisms of a black shining mineral. Under the microscope the black mineral proves to be hornblende. The rocks are siliceous and granular, and one example (I/68)\* contains abundant fragments of felspar, including microcline and orthoclase. Microscope examination indicates that these rocks are metamorphosed sandy sediments, originally chloritic, and which may with justification be called hornblende and mica schists.

### 2.—THE SAMIA HILLS SERIES.

The major area occupied by this series extends from the Yala Swamp, through Samia and Bukhekhe, to South-western Marach, and it is here that the typical succession of acid and sub-acid lavas, tuffs and agglomerates, banded quartzites and ironstones, occurs. South of the Yala Swamp, the Kadimo area consists almost entirely of members of this series, including lavas, tuffs, agglomerates and volcanic conglomerates, but lacking the quartzites of Samia; whilst the area between the River Yala and Lake Kanyaboli is occupied by volcanic members of the series. A small triangular area, east of Busia, is also considered to consist of rocks of the Samia Hills Series. The boundary shown on the map is entirely hypothetical, but it separates a series with quartzites, shales and "porphyries", from sediments which, in the opinion of the writer, represent the later Kavirondo Series.

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\* Numbers prefixed by the letter "I" refer to specimens in the museum of the Mining and Geological Department, Nairobi.



Fig. 1.—Banded Quartzites, Nambuku Hills.



Fig. 2.—Quartzite Breccia, Nambuku Hills.

*Age and Correlation.*—In the Busia area, the quartzite series (Bulugwe Series of Uganda) is believed by Dr. K. A. Davies to be equivalent to the Karagwe-Ankolean of Western Uganda ((8), p. 32), and he inclines to correlate the Bulugwe Series of Busia with the rocks of the Samia Hills. The writer finds it difficult to accept the correlation of the latter with the Karagwe-Ankolean. On lithological grounds, it is preferable to compare the Samia Hills Series with the Musoma Series of Tanganyika, which are Pre-Karagwe-Ankolean in age. The Musoma Series includes acid and basic lavas, tuffs and agglomerates, and siliceous banded ironstones which are considered to be altered lavas and tuffs ((20), p. 15; (21), pp. 11-17). The Kuria volcanics of Musoma, comprising lavas and intrusive porphyries, may also represent in part the Samia Hills Series as it occurs in Kadimo and Alego. In addition, the Upper Basement Complex of the Sanza area ((22), p. 5), with acid and sub-acid tuffs, greenstones, greenstone schists and tuffs, and banded ironstones (which F. Oates (*loc. cit.* p. 32) regards as altered members of the acid volcanic series), though it is somewhat more metamorphosed, apparently resembles the Samia Hills Series.

On these grounds, the Samia Hills Series is regarded tentatively as the equivalent of the Upper Basement Complex of other parts of East Africa, correlating with the Musoma Series and the Sanza banded ironstone-greenstone series in Tanganyika.

Dr. K. A. Davies has pointed out that a series including highly cleaved and altered igneous rocks with interbedded ironstones occurs on Sigulu Island, west of Port Victoria. This series he considers as differing considerably from the Bulugwe Series of Busia, and probably correlating with the Samia Hills Series. This again would seem to support the view that the Samia Hills Series may be of Pre-Karagwe-Ankolean age.

*The Quartzites.*—The quartzites vary little throughout the Samia Hills. They grade from dense, massive, fine-grained white or grey quartzites, through dense grey and white banded quartzites, to banded ironstone quartzites, which consist of fine or coarse interbandings of quartzite and limonite (Fig. 1). Brecciation is a fairly constant feature, and may be seen on most of the hills. Typically, the breccias consist of fragments of banded quartzites, up to an inch or more in length, cemented in a siliceous or limonitic matrix (Fig. 2).

On most of the hills, one quartzite horizon only is seen, but at several localities—Port Victoria, Ndima, Samia, etc.—two or three distinct horizons occur, whilst there are two well-separated horizons in the Busia area. It is probable that more than one horizon occurs throughout, but that the second or other horizons are covered by talus.

Microscopic examination of the quartzites yields little information concerning their origin and derivation. Specimens examined all appear in thin slice to be alternating bands of fine and coarse quartzite with variable amounts of impregnation of the bands by hydrated iron oxides. However, a specimen from Lugulu (I/150), though quartzitic, shows traces of replacement of a former texture, but which is not sufficiently characteristic to lead to a determination of the original rock. Whatever their original nature, however, these rocks may at present with justice be called "banded quartzites". Odman ((18), p. 87) has suggested that they arose by rythmical deposition of iron hydrates and silica, considering the iron to be derived from ferruginous springs active after the period of volcanicity which gave rise to the lavas and tuffs of the series.

Stockley ((21), pp. 18–19) has recently given an account of banded quartzites and ironstones occurring in the Musoma area of Tanganyika. Some he can prove to be normal sediments, but among the banded ironstones and jaspilites of the Musoma Series (Upper Basement Complex) he has observed gradual transitions from acid lavas to banded ironstones. These types were formed only in Pre-Muva-Ankolean times.

The writer is inclined to believe that the Samia Hills quartzites represent profoundly altered acid lavas and tuffs. On the Nambuku Hills felsitic tuffs were observed to contain angular lumps of banded quartzites. This would appear to indicate that the quartzites were altered to the form we now know within the volcanic period, and probably that they represent non-sequences of considerable duration.

*The Ironstones.*—True ironstones, distinct from the so-called banded ironstones, are associated with the quartzites in the hills south of Sio. Gregory ((10), p. 44) described them as siliceous phosphatic ores, occurring in pockets at the base of the quartzites. The only lens seen during the present reconnaissance occurs on the south-east flank of Lugulu Hill, where, however, it is at the top, not at the base of the quartzites. The ore is a reddish-brown to inky blue rock, consisting mainly of limonite, with siliceous streaks and patches, and which, in the field, one might consider to be a highly ferruginized member of the

volcanic series. In thin slice (I/151) it is seen to consist of highly cellular limonite (the cellules filled by quartz) with occasional dense schlieren of limonite and coarse quartz lenses.

*Volcanic Rocks of the Samia Hills Area.*—The volcanic sequence includes acid lavas, andesitic lavas (porphyries of previous observers), a small proportion of basic lavas, tuffs, and agglomerates. Most of these rocks, except the rhyolitic lavas of the Wanga area and some of the volcanics of Marach, are usually deeply weathered, and have taken on pinkish or pale to dark mauve-purple colours which are distinctive of the series. The Marach volcanics usually have a green tint, due to the presence of chlorite, readily distinguished from the greys and browns of the sediments of the Kavirondo Series a little farther east.

Acid lavas are probably the most common, and occur throughout the hill ranges. The rhyolites of the Wanga-Ndima area are dense creamy-grey or dark grey siliceous rocks, often of a semi-flinty nature (obsidians). Small felspar phenocrysts can often be detected in them, and, in some, small quartz phenocrysts. Dark grey types containing rather abundant quartz phenocrysts (e.g. north-east of Wanga) might readily be confused with re-crystallized grits of the Kavirondo Series. On weathered crags, flow banding is occasionally seen, though in the unweathered rock it can be traced only with difficulty. On Lugulu Hill coarsely vesicular rhyolites (I/152) occur among other lavas. They are black felsitic rocks (weathering to pale chocolate felsitic types) with scattered vesicles, up to one-third of an inch in diameter, now containing spongy limonite with quartz fillings on two sides.

Many of the acid lavas can be described only as devitrified glasses, but some are more typically rhyolitic. One from near Wanga Hill (I/110) contains abundant phenocrysts of orthoclase and acid plagioclase, together with occasional quartz phenocrysts, in a fine-grained quartzo-felspathic matrix, containing also small felspar prisms. There is no original ferromagnesian mineral, which is now represented by clouds of small crystals of fibrous actinolite.

The other lavas of the Samia Hills appear, in the field, to be mainly of andesitic type. When unweathered they are dense grey rocks with abundant felspar phenocrysts, and in more acid types (dacites) with quartz phenocrysts in addition. Under the influence of weathering they become more obviously porphyritic, and with greater alteration and weathering many

become almost unidentifiable, and in the field can be recognized only as "highly altered felspathic rocks". In many cases microscopic examination yields little information of value in identification.

Dacites from near Rumbeye are found to contain tabular oligoclase-andesine felspar phenocrysts and irregular quartz blebs, set in a coarse devitrified glass. Ferromagnesian minerals have been replaced by actinolite (?). Many of the lavas of South-West Marach probably belong here, but are usually so altered that exact identification is not possible. They are usually highly calcitized, with large irregular vesicles and gashes of calcite (I/173, River Ookwak). Normal round vesicles also occur in some specimens.

Basic lavas are comparatively rare. Altered basalts were mapped on the Nambola Hills, north-east of Luambwa, and what may be a spilite type was noted in the River Luwenya (Marach). A curious rock, tentatively described as a "lava conglomerate", was observed in the upper River Sifuyu, a little west of the basal conglomerate of the Kavirondo Series. This rock contains "pebbles" of coarse-grained gabbroic rocks in a slightly vesicular basaltic matrix. It may represent the brecciation of an intrusive rock during extrusion of the lava, or perhaps the enveloping of pebbles after the lava had reached surface.

The tuffs of finer grade present a difficult problem. It is probable that many of the rocks described as tuffs in the field are actually altered lavas, but as microscopic examination gives little help in identification they are tentatively considered as tuffs. They are fine-grained, usually soft, buff or pinkish rocks, occasionally containing traces of broken felspar crystals or vesicles.

Good examples of crystal tuffs occur on the Nambuku Hills; one (I/134) contains abundant angular quartz grains and ghosts of sericitized felspars in a matrix of quartz, felspar and sericite. A second example (I/143) contains coarse lumps of acid lavas as well as sub-angular quartz grains.

No basic tuffs have been observed.

The finer tuffs grade into coarse tuffs and agglomerates. Examples of coarse tuffs occur on the grassy hillock north-east of Wanga Hill. They are greyish-green rocks, containing abundant small iron-stained fragments of various types of lavas. The agglomerates are of essentially similar constitution but of coarser grade.

Associated with the normal volcanics of the Samia Hills occasional mudstone-like rocks have been noted near Port Victoria and Nambuku. They are fine-grained grey or greenish-grey parti-cleaved rocks, which on first examination might be considered as pelitic facies of the Kavirondo Series. Under the microscope the Nambuku rock, however, appears not to be a sediment, but a profoundly altered lava.

*Volcanic Rocks of the Kadimo Area.*—In the Kadimo area the volcanics are, as a rule, less altered than those of the Samia Hills. They include various types, ranging from acid to basic—obsidians at Usangi, dacites and andesites over most of the area, and basaltic types near Ramogi.

The obsidian is a dense, flinty, grey or pale purple-brown rock containing scattered felspar phenocrysts. On weathering it takes on a more whitish floury appearance, though still hard, and has a reddish or yellow-brown crust. Under the microscope it is seen to be a completely devitrified glass enclosing traces of primitive felspar laths and only rarely true felspar phenocrysts (I/235).

The intermediate lavas are dense light to medium grey rocks with more or less abundant felspar phenocrysts, and occasionally, e.g. at the southern end of the Nsori Peninsula, containing calcite vesicles. At certain localities, andesitic breccias, probably auto-breccias in origin, occur within the lava sequence. Most of the intermediate lavas fall into the dacite-andesite groups, with oligoclase-andesine phenocrysts set in micro-granular matrices. Original ferromagnesian mineral rarely remains, and calcite and chlorite are frequently present as alteration products.

More basic lavas were observed only near the eastern margin of the Ramogi Syenite, where a type approaching basalt occurs. It is a dark heavy rock with bright yellow and rusty brown weathering tints. It contains a fair proportion of original augite in irregular crystals (I/250).

On the Nsori Peninsula and west of Kadimo there are extensive developments of volcanic conglomerates. Whilst they are not unlike the conglomerates of the Kavirondo Series, they are interbedded with the volcanic series, and are in part agglomeratic, and the writer prefers to consider them as penecontemporaneous conglomerates of the volcanic series. Agglomerates are also present, and may be seen north-north-east of Kadimo, on the edge of the Yala Swamp.

The conglomerates range from very coarse rocks (I/260; full of well-rounded pebbles, mainly of volcanic rocks and acid intrusives, but with occasional granite pebbles, in a gritty felspathic matrix, to dark-coloured gritty rocks containing scattered pebbles (I/262). The latter, which occur at the north end of the Nsori Peninsula, are in thin slice quartzose tuffs containing pebbles of variolitic lavas.

In addition to the coarser pyroclastics, medium-grained crystal tuffs occur in the Nsori Peninsula. One (I/237), south-east of Usangi, contains a large proportion of angular quartz grains. The Nsori tuffs are similar (I/259), and contain angular quartz grains, fragments of altered felspar, and pieces of altered lavas.

*The Volcanics of South Alego.*—The volcanic rocks of this area are a direct continuation of those of the No. 2 Area ((11), p. 14). They comprise andesites of types similar to those of the Kadimo area.

### 3.—THE KAVIRONDO SERIES.

The Kavirondo Series is developed in three parts of the No. 1 Area. The largest area stretches through Ugenya and Marach to the Nambare-Busia area. A small area in western Alego is also occupied by representatives of this series. A considerably larger area occurs as a roof-pendant on the Mumias' granite, east of Nambare. The boundary of this area has not been mapped on the ground, and as it has been reported that sediments similar to those which have been examined also occur further east in the Sio Valley, the roof-pendant may prove to have a more elongate shape and a considerably greater extent than is shown on the present map (I).

*Age of the Series.*—Here, as with the Samia Hills Series, there is some difficulty in arriving at the age and correlation of the series. Dr. K. A. Davies, correlating it with the Samia Series of Eastern Uganda ((8), p. 35), considers that the Kavirondo Series may be in part post-granite, and to be correlated with a later date than the Karagwe-Ankolean. As far as the writer has seen, however, the Kavirondo Series is pre-granite. In addition, as a whole, the Kavirondo Series bears a close resemblance to the North Mara Series of the Musoma area in Tanganyika, which are considered by Stockley ((20), p. 9, (21), pp. 17-19) to be of Muya-(Karagwe-) Ankolean age.

The correlation of the Kavirondo Series with the Karagwe-Ankolean would seem to be upheld by the findings of the Kigoma Geological Conference ((1), p. 12), but as unanimity of

opinion cannot yet be obtained, it is preferable to use the term "Kavirondo Series", a name originally used by Odman ((18), p. 83) to include the Samia Hills Series and the present Kavirondo Series, but recently re-defined and restricted by Hitchen ((11), p. 8), and not Karagwe-Ankolean (or Muva-Ankolean) as has been done in previous reports on the Kavirondo.

*The Kavirondo Series of Western Alego.*—The sediments occurring in the area west of Lake Kanyaboli appear to be mainly of siltstone and sandstone type.

*The Main Belt.*—On the whole, except for good sections in the River Nzoia, the series is poorly exposed. The sediments rarely show on the divides, except in road cuttings or drains, and the majority of outcrops are to be seen along valley bottoms, especially at path crossings and cattle watering-places.

Along the River Nzoia a fairly continuous interbanding of grits and sandstones with mudstones, and occasional pebble bands, occurs. In the remainder of the area, the predominating facies is a fine-grained one; grits are rare, and conglomerates very rare.

A dense, massive, dark grey conglomerate (I/203), containing abundant rounded pebbles, many of a fine-grained igneous rock, occurs in the River Safu, three miles north-north-east of Segá Mission. The conglomerate is impregnated with pyrite, and it is probable that it is in contact with the granite.

A second conglomerate occurs in the dry valleys five miles west of Ukwala. This is a massive, dense, hard rock with abundant poorly rounded pebbles, which resemble the acid lavas and banded quartzites of the Samia Hills Series. The matrix of the pebbles is a felspathic grit. On its composition and location (lavas of the Samia Hills Series occur a little farther west), this conglomerate may perhaps be considered as the basal facies of the Kavirondo Series in this district. The actual unconformity is not, however, exposed, and throughout the remainder of the suggested boundary of the Series basal facies have not been seen.

Grits and sandstones occur in the Rivers Nambare, Kami and Merekwi. In the latter river, thermal metamorphism by the granite has converted them into biotite-grit hornfelses. The Nambare grit is a sheared, weathered buff rock, felspathic and tuff-like in appearance. A more typical Kavirondo Series grit occurs near the south-east head of the River Kami. It is a dark blue-grey rock with abundant small quartz porphyroblasts

in a dense recrystallized matrix (I/231), and resembles many of the finer grained grits of the No. 2 Area ((11), p. 11), and the south-east Kakamega district ((19), p. 30). The sandstones have essentially the same characteristics as the grits, except that they are more fine grained.

Microscope examination indicates that true grits (i.e. with grain size greater than 2 mm.) are rare, and strictly speaking most of the arenaceous sediments should be called sandstones. As usual in this series they are variously felspathic, and show little sign of sub-aqueous attrition. Nearer the granite, chlorite and sericite of the original sandstones have reacted to form biotite under the influence of the heat of the granite.

Mudstones have been observed more frequently than the coarse sediments. They are usually blocky, buff or khaki weathering rocks, sometimes poorly cleaved. When unweathered they are grey or dark blue-grey fine-grained rocks. Banding occurs, e.g. in the Nzoia mudstones, but is not a common feature.

The sediments of the north-western part of the Kami drainage are closely allied to those described above. They are usually somewhat weathered, but gritty and mudstone types can be readily distinguished. Near the bridge on the Lukolis road, normal Kavirondo dark blue-grey blocky mudstones occur, and in the same area blocks of typical grits comparable with that described above (I/231) can be found on the surface.

At many places in the main belt of sediments an interbanding of coarse and finer sediments occurs. Such interbanding appears to be a characteristic feature of the Kavirondo Series.

*The Kitosh Roof-pendant.*—The sediments of the roof-pendant were examined only in the River Sio and the River Walawatsi, in the west and south-west. As would be expected, they show evident signs of thermal metamorphism, and the grits and sandstones have been converted into biotite-grit and sandstone hornfelses. In the north-east tributary of the Sio, east of Okwara, cleaved grey sandy mudstones with abundant flakes of secondary mica occur as well as sandstone hornfelses.

*Metamorphism of the Kavirondo Series by the Granites.*—The metamorphic aureole is narrow, and the effects of the intrusion of the granite into the sediment are, as a rule, feeble. Alteration is best seen along the River Merekwi, where induration, the formation of biotite hornfelses, and the occasional intense soaking of granitic fluids into the sediments, yielding

hornblende granulites, occurs. A less intense stage is seen in the Kitosh roof-pondant, where felspathic grits have been converted into biotite grit hornfels. At the bridge over the Sio on the Nambare-Mumias' road an actinolite grit hornfels was also found, but it is possible that it owes its peculiar mineral constitution to emanations from the large dolerite dyke which cuts the roof-pondant thereabouts. In hand specimens the grit hornfels differ from the unaltered grits in that they are harder and more dense, and that recrystallization has often produced a crude resemblance to quartz porphyries.

Obvious changes in the finer sediments, other than induration, are uncommon. The development of spots, due to the incipient formation of new minerals, has been seen along the Rivers Nzoia and Safu (I/7, I/10, I/14), but is rare. The formation of abundant small mica flakes, which accompanies the spotting, also occurs where no spots are seen, affording evidence of the hydrothermal alteration of the sediments.

#### 4.—THE INTRUSIVE IGNEOUS ROCKS.

##### (a) *The Akarra Dolerite.*

The Akarra dolerite is a hard, fine-grained black rock, which forms, in the No. 1 Area, the western extension of the Akarra Ridge. It has recently been described by Dr. C. S. Hitchen ((11), p. 19), who considers that it is intrusive into the Pre-Kavirondo volcanic series.

##### (b) *The Granites and Allied Types.*

*Distribution.*—Granites occupy almost the northern half of the area, though it is to be doubted that they represent one intrusion only. Several rock types are involved, and it is considered that a complex of intrusions, probably not of very different ages, may be present. The northern contact of the granites, between Broderick Falls and the River Malakisi, has not been examined during the present work, and the boundary shown on the map is tentative only. The southern boundary, though actual contacts are not well exposed, can be readily followed from the River Kisama to the upper River Safu, whilst along the River Merewi contacts are in places well exposed. Further north-west contacts can be seen in the upper and middle River Kami. Although, where the margin is visible, the contact appears to dip steeply, it seems that in some places, e.g. north of Ukwala, north-east of Busia, and in north-east Marach, it may slacken considerably and even rise, resulting in small cupolas, which in the cases mentioned have been cut into by streams.

The granites of the north-western part of the mass, in the Akure Hills district, appear to differ in type from those farther east; they are usually leucocratic muscovite-bearing varieties, whereas the eastern types are mottled biotite or hornblende-biotite varieties.

The second largest granite mass of the district is almost unrepresented in the No. 1 Area. It occupies a large area in the Samia Province of Eastern Uganda, south of Busia, but in the No. 1 Area apparently occurs only in the upper River Sango, the contact following the Kenya boundary very closely.

The Kanyaboli Granite, occupying the greater part of Northern Alego, lies north-east of the Yala Swamp. Contacts are not exposed, but a close approximation to the margin may be obtained in the River Nzoia.

South of the Yala Swamp, no granites are known, but the area on and around the Ramogi Hills is occupied by rocks of syenitic affinities, occurring apparently in a boss-like mass.

*Age of the Granites and Allied Types.*—Exact determination of the age of the granites is not possible. The granites of the Mumias'—Akure area are intrusive into the rocks of the Kavirondo Series, whilst the Uganda Granite is probably of a similar age (*cf.* Davies (5), p. 22). The Kanyaboli Granite has not been seen to cut the Kavirondo Series, but in the River Nzoia the sediments nearby are contact altered, and the granite appears to be Post-Kavirondo Series, and probably of the same age as the Mumias'—Akure granites.

The Ramogi Syenite cuts the old volcanic series, but as no sediments of the Kavirondo Series occur in the area a closer approximation to dating cannot be obtained. It is, however, as fresh and unaffected by stress as are the main granites of the area, and on mineralogical constitution it may be correlated with the granites.

*The Mumias'—Nambare Granites.*—Though the granites of the main mass exhibit several variations, the average type is a medium- to coarse-grained biotite variety, usually porphyritic. The phenocrysts are, apparently non-consequentially, abundant or scattered, large or small. Occasional facies, e.g. on the River Kalera north of Mumias', are composed almost entirely of large felspar phenocrysts. Such types are also marked by the presence of large blocks of more basic rocks; the whole being considered as a type of intrusion breccia.

In thin slice an example of the normal granite from the east slopes of the River Safu, near Segá Mission, is seen to be a typical biotite granite with abundant zoned plagioclase crystals.

In addition to the biotite granites, other varieties, apparently closely related to them, occur at several places. Four miles north of Nambare the granite is a dark grey mottled hornblende variety enclosing numerous cognate xenoliths, rich in hornblende. The granite on the road at the head of the River Ruwumbu (I/46) is also a hornblendic variety, though the hornblende is almost all secondary. Other hornblende varieties occur near Jinga (I/188) and three miles east of Muanda. In these the hornblende appears to be a primary mineral. They are also characterized by the presence of large crystals of sphene, a feature of less acid granites.

Locally, coarse types with gneissose texture have been noted, e.g. near Jinga, north of Mumias', and near Muanda, but on the whole are rare.

Along the River Merekwi, in North-East Marach, various marginal facies are found. They include normal granites and more basic rocks, some of which appear to have been formed by the intrusion of a later more acid member of the igneous suite into basic earlier members, resulting in brecciation and hybridization. Near the native bridges on the Muanda track, an adamellite occurs (I/50). It is a grey fine-grained rock with abundant small feldspar phenocrysts, which in thin slice is found to contain abundant small prisms of a feebly pleochroic hornblende, and small cloudy feldspar phenocrysts. The matrix tends to be granular, consisting of feldspars and a small proportion of quartz grains. Aplitic granites and porphyritic biotite (actinolite) granophyres (I/78) also occur in this part of the area.

In addition to the granitic types, more basic diorite-hybrid types, related to the appinites, occur. One (I/47) is a dark grey, moderately coarse rock, rich in hornblende and cut by granite veins. A second example (I/51) is very coarse grained, crowded with large hornblende crystals in a rather sparse fine-grained diorite-like matrix.

A totally different marginal facies, a biotite hornblende porphyrite, is developed in the Nzoia Valley, about one mile west of its confluence with the Kisama Valley. This rock, which can be seen cutting and invading grits of the Kavirondo Series, is dark blue-grey, mottled with white feldspar phenocrysts and small dark ferromagnesian crystals. In thin slice it

is found to contain as phenocrysts occasional resorbed quartz crystals, abundant zoned acid plagioclase and anorthoclase, biotite, and less abundantly hornblende. Occasionally the biotite and hornblende are intergrown. The matrix is a fine-grained quartz-felspar mosaic. The porphyrite is of acid type, and closely related to the neighbouring granites.

Very few pegmatites were noted in the area. A big example was mapped, however, about one mile south-west of the Nzoia-Kisama confluence. It apparently consists only of coarse crystals of quartz and felspar associated with much smaller crystals of a yellowish-white mica.

*The Kami Area.*—The granites of the north-western part of the area have not been examined in detail. That of the upper Kami, north-west of Nambare, is a fine-grained, light grey biotite variety (I/229), which in thin slice is found to be a biotite granite porphyry, not a true granite. In the middle Kami, north-east of Busia, marginal types occur in addition to normal granites, and include fine-grained grey or dark grey biotite granophyres (I/81, I/83), which merge into quartz diorites and microgranites.

*Small Granite Bosses.*—The small granite boss in the River Gaula, though of somewhat different type, is regarded as a cupola rising from the continuation of the main granite mass. It is (I/31) a medium-grained grey non-porphyrific biotite hornblende granite. Marginally the boss is represented by a quartz hornblende diorite (I/30).

Other small bosses are exposed in the River Walupe, north-east of Busia. The southernmost is a porphyritic biotite granite, whilst the northern, which has been seen only during pitting, is apparently a granite porphyry.

*The Budama Granite (Uganda).*—The Budama Granite occupies a large area south-west of Busia, but it appears to dive underground soon after crossing the colonial boundary. A marginal facies only, a leucocratic muscovite type, has been seen in the No. 1 Area, in the upper River Sango. Davies ((6), p. 21) has described the Budama granites as biotite varieties, sometimes carrying secondary hornblende, and with abundance of anorthoclase feldspars.

*The Kanyaboli Granite.*—The Kanyaboli Granite has been seen by the writer only on its northern margin. At the contact in the River Nzoia it is a moderately coarse black and greenish-white mottled rock containing abundant biotite (I/15).

In thin slice it is found to be a biotite actinolite variety. The granite from the dry valley south-west of Niahumbe T.S. is medium grained, not unlike the Nzoia rock, but less rich in dark minerals (I/122). This again is a biotite actinolite variety. The biotite is an unusual type, pleochroic from pale yellow-brown to a deep plum-red tint, which has not been observed in other granites from the No. 1 Area. The feldspars include a small proportion of microcline, and interstitial microgranophyre is also present.

*The Ramogi Syenite.*—The Ramogi Syenite complex occupies a small area, north of Lake Saru, in Kadimo. The main mass is a striking rock composed mainly of long lathy feldspars, which on weathered surfaces give an appearance of coarse felting, and containing scattered biotite and hornblende crystals, with occasional bright blue or purple grains of an unidentified mineral (I/241). Locally the rock is porphyritic (I/242), and sometimes contains rather large (up to one-eighth of an inch) pyrite cubes. Marginally on the east, and at places in the interior of the mass, a medium-grained black and white mottled variety occurs, which is much richer in biotite than the coarser type (I/247, I/249). On the east flank of the hills there are also syenite aplite intrusions (I/243) and coarse pegmatites. The pegmatites (I/244, I/246) appear to consist only of biotite and feldspar.

Under the microscope the Ramogi Hill Syenite is seen to be coarse grained with large crystals of micro-perthite and some acid plagioclase feldspar. There are large clots of a deep green, almost non-pleochroic hornblende, with scattered biotite crystals along the edges of the clots and occasionally inside them. No quartz was seen in the slices examined.

The marginal variety contains abundant, comparatively large, squarish crystals of an intensely pleochroic biotite, whilst a non-pleochroic hornblende is much scarcer. The matrix is essentially feldspathic, somewhat altered, and consisting mainly of microperthite and orthoclase, but with a proportion of acid plagioclase crystals.

*Miscellaneous Diorites.*—These rocks are classified here for convenience, as they are of coarser grade than the usual more basic intrusives, and appear in some cases to occur in non-dyke-like forms. An example occurs in the west tributary of the River Merekwi, a little south of Aduya's (I/79); it is a medium-grained rock with abundant stumpy oriented prisms of feldspar. Ferromagnesian mineral occurs in small scattered

clots. Microscope examination shows the rock to be a quartz diorite, with abundant zoned plagioclase crystals, and roughly equal proportions of biotite and hornblende.

Other examples occur in the rivers near Bujumbo. One (I/175) contains veinlets of a woody fibrous light grey hornblende mineral.

(c) *The Sio Porphyries.*

The Sio porphyries are known only near Sio on Berkeley Bay, and possibly on the Nangosia-Luambwa road, about two miles west-south-west of Rumbeye. The porphyries at Sio are mainly very weathered, but a little east of the jetty less altered rock occurs; it is light grey with small quartz phenocrysts in a fine-grained siliceous matrix (I/105). In thin slice it is found to be a typical quartz porphyry, and it is probably a marginal facies or a related intrusion of the Mjanji Granite which occurs two miles to the north-west.

The Rumbeyt occurrence has not been mapped in detail. It is very similar to the Sio rock, and in thin slice is a typical quartz porphyry.

Both porphyries are intrusive into the Samia Hills Series.

(d) *Acid and Intermediate Dykes.*

Dykes of acid and intermediate composition have been observed rarely. Near the granite contact at Aduya's, granitic apophyses may be seen cutting the contact sediments, and sediments at Malaba and in the River Malakisi on the Busia-Malaba road are also cut by fine-grained muscovite granite veins.

The only other acid dykes observed are a pink granite porphyry, occurring as surface blocks two miles north-west of Ukwala, and a grey granite porphyry dyke, about 30 feet wide, in the River Gaula.

An andesitic dyke or sill, a dark grey fine-grained sandstone-like rock, was observed in the River Safu, east of Sega Mission.

(e) *Basic Dykes and Allied Types.*

Basic dykes of several types occur throughout the area, but are most frequent in the main belt of the Kavirondo Series and in the Kanyaboli Granite. As a rule they show at surface giving outcrops of rounded boulders or crags, and often support a coarser vegetation than the surrounding area. Strikes

vary considerably, but range about north-west and north-east, though almost east-west strikes are not unknown. As a rule, the length of mappable strike is small.

In the field the basic dykes may be divided into several types; all are dark, heavy and tough rocks, but with other distinguishing characteristics :—

1. Fine-grained types, including basalt-like rocks in thin dykes (I/217, River Ruwumbu), dyke selvages (I/158, River Siyoga), and fine-grained epidiorites (I/92, I/185).
2. Fine or coarse felted types, comparable with normal dolerites (e.g. I/53, Sio Bridge; I/9, River Safu; I/90, River Merekwi, etc.).
3. Types with scattered or abundant greenish-white or white felspathic clots (I/77, River Merekwi; I/73, Sio Bridge).
4. Porphyritic types, containing few or abundant feldspar phenocrysts (I/60, south-east of Okwara; I/5, River Ugege).
5. Coarse-grained "diorite" types. Many of these are probably epidiorites, but in the field appear as hornblende rocks with diorite texture.
6. Coarse epidiorite types, usually characterized by an abundance of large or small secondary hornblende crystals (I/161, north-east of Samia; I/12, River Gaula, etc.).

In addition to these dolerite types, a gabbro was observed in the Nambola Hills, and a lamprophyre in the River Siyoga, two and a half miles west of Ukwala.

Omitting the gabbro and the lamprophyre, the basic dykes are doleritic, varying from almost unaltered ophitic dolerites, with abundant pyroxene, through types with the pyroxene partly replaced by actinolitic amphibole, to those in which the pyroxene has been completely replaced by amphibole. There is little justification for considering them as of different ages. With the exception of rare diorites, they are dolerites which have suffered uralitization, from a minor to a complete degree, and even when the pyroxene has suffered little change, the feldspars are often considerably altered. Accordingly all the dykes (with one exception described below) grouped as "doleritic" are considered of the same age, on a broad scale, post-granite.

The post-granite dolerites of Kavirondo have commonly been found to be quartz-bearing types. This is so too in the No. 1 Area, though in some cases the quartz appears to be secondary. Interstitial microgranophyre was observed in two dykes only—in I/32, a partly altered dolerite in the lower River Siran, and in the large dyke east of Nambare (I/59).

An unusual type, which may be pre-granite, can be described only as an actinolitic greenstone (I/92, River Merekwi). It is a dark grey fine-grained rock with matted texture and a rather waxy appearance; in thin slice it consists of very abundant plumose actinolite with interstitial recrystallized feldspar.

*The gabbro* of the Nambola Hills is of doubtful age, but it may perhaps be correlated with the dolerite dykes. It is a coarse, dark grey rock, with long, lathy, matted feldspars, occurring as a mass not a dyke. In thin slice it is seen to contain large crystals of augite, some of which have been replaced by fibrous actinolite. The feldspar, a basic plagioclase, occurs in coarse prisms.

*Lamprophyre* was found in one locality only, in the River Siyoga, west of Ukwala (I/159). It is a dark grey, medium-grained rock, with abundant, comparatively large, shining black crystals of a ferromagnesian mineral. In thin slice the black mineral is found to be colourless augite, partly (and sometimes completely) replaced by coarsely fibrous actinolite. Petrologically this rock would perhaps be classed with the spessartites. In age it may be more closely allied with the few "late-granitic" acid dykes than with the doleritic suite.

*Diorites*.—True diorites are rare. An example occurs in the River Oukwak (I/175); it is a medium grey rock with matted texture. In thin slice it is found to be somewhat altered, and the hornblende is in part replaced by chlorite. The feldspars have suffered sericitization, and secondary epidote occurs in crystals and crystal clusters, associated with the hornblende. A second diorite occurs near the Nzoia Bridge. It contains abundant lathy crystals of a feebly pleochroic hornblende, and a large proportion of somewhat altered plagioclase feldspar in stumpy prisms. The hornblende appears to be primary.

The diorite dyke, north of Mbwewa's, contains abundant hornblende, which, however, is often fibrous and may be secondary. The feldspars, nevertheless, though somewhat altered, appear to consist of oligoclase-andesine plagioclase,

and the rock may be conveniently classed with the diorites. It contains a fair proportion of interstitial microgranophyre and some quartz.

#### 5.—QUARTZ VEINS.

Few quartz veins of any size have been observed in the area examined. Quartz stringers and veinlets occur, as usual, in the sandy and occasionally in the pelitic members of the Kavirondo Series. A large blue quartz cuts the sediments in the upper River Kami. A sample of the quartz was crushed and panned, but no free gold was obtained. A quartz vein is also known to occur a little south of the eastern head of the River Walupe,  $2\frac{1}{2}$  miles east of Busia. The vein is not exposed at surface, but samples were obtained from spoil heaps round an old shaft. These were panned, with the following results: (a) An apparently non-pyritic blue quartz yielded a small tail of gold and a fair proportion of sulphides; (b) A pyritic quartz yielded a heavy tail of sulphides, but no visible gold.

Poor exposures and shortage of time have probably led to many quartz veins being overlooked, and one may be confident that, with search and excavation, other quartz veins will be discovered.

#### 6.—ALLUVIALS, ETC.

Some indication of the nature of the alluvial deposits has already been given in the section on topography. On the whole, in the extra-granite areas, the streams flow through marshy flats with little dry alluvium. Certain streams, however, have suffered rejuvenation, and in them, over considerable lengths, the alluvials have been eroded and the streams are now cutting into their rock beds. This applies to the tributaries of the River Saka and to much of the River Nzoia.

The state of the area indicates two or more fluctuations of level within recent times. It may be considered that the following cycle has occurred:—

4. Final partial rejuvenation;
3. Aggradation and formation of alluvials;
2. Major rejuvenation;
1. Primary aggradation;

with possibly many more minor fluctuations which at present cannot be correlated.

Traces of the primary aggradation still exist in a few places. High level gravels, approximately on the 4,000 feet contour on the divide near Ukwala, probably correspond with

gravels occurring at Niahumbe and Ogunja, south-east of the Nzoia. The larger part of the alluvial deposits corresponding with these gravels have been removed, presumably at the rejuvenation consequent on the rise of the Nandi Escarpment. The maximum phase of rejuvenation is perhaps represented by river gravels which have been found at depths of over 100 feet below the present surface of the Yala Swamp.

## VI.—TECTONICS.

Omitting Recent and Pleistocene fluctuations, it appears that three periods of earth movement, the latest very slight, must be considered :—

3. Post-granite.
2. Post-Kavirondo Series—pre-granite.
1. Post-Samia Hills Series—pre-Kavirondo Series.

A definite decision whether the Samia Hills Series and the Kavirondo Series are separated by an unconformity cannot at present be made. What appears to be a basal conglomerate of the later series occurs in the River Sifuyu, but elsewhere no distinct boundary between the two series has been discovered. That the Samia Hills Series is considerably older than the Kavirondo Series seems borne out by the fact that the former series appears to be more intensely folded than the latter, and due to forces acting from different directions than those which affect the Kavirondo Series.

The folds in the Samia Hills strike about north-east-south-west, with axes pitching steeply to the north-east. There are two complementary folds, marked by the chains of hills; on the north-west there is an anticline with steeply dipping limbs, and on the south-east a syncline, which, however, has suffered inversion, so that it is isoclinal in form, both limbs dipping steeply to the south-east. There is a distinct packing of the folds at the turning points in the north-east and the south-west, and a marked gape in the central area away from the turning points. It is suggested that this may be due to torsional stress.

In the No. 1 Area little is known of the structures in the Kavirondo Series, but in the areas east of Alego and Ugenya the series appears to be folded along east-west axes. A later orogeny must naturally have affected an earlier one, probably by an intensification of folds and by shearing, and it is probable that the forces which led to the folding in the Kavirondo Series initiated intensification of folding and perhaps a torsional effect in the Samia Hills.

It seems that the granite masses have been drawn into the major synclinal areas in the Kavirondo Series, and to have avoided the tight folds of the earlier Samia Hills Series. The intrusion of the granites has apparently deranged the previous fold-lines, with the result that the contact rocks have been rotated, so that their strikes are now parallel to the contacts. This is especially noticeable round the granite lobe in Ugenya.

*Faulting.*—In an area which is so poorly exposed as the No. 1 Area it is not possible to trace faults in many parts. In excavation and mining, however, it is to be expected that numerous faults will be found.

In the Samia Hills many faults can be traced breaking the continuity of the quartzite bands in the Samia Hills Series and giving rise to steps in the alignment of the hills. The effect of the faulting can be seen from almost any point on the hills. The majority of the faults strike west-north-west and north-north-west, though occasional north-east fractures are known. The faults cannot be traced beyond the limits of the steep hills. The nature of the faulting is not readily determinable, but it is considered that they are tension, not thrust, faults. If the hypothesis of torsion put forward above should be sound, it is more probable that they are tear faults.

The northern end of the fault which has given rise to the Nandi Escarpment runs into the area, with a west-north-west strike, near Broderick Falls. It is apparently a tension fault, with a downthrow to the west of several hundred feet.

*Cleavage.*—Owing to the paucity of exposures in the Kavirondo Series, few observations on cleavage were made. In the River Sia, the tributary of the River Kami flowing from Mbwewa's, cleavage was found to strike north-north-east. Four miles to the south, in a tributary of the River Sio, it was determined as about north-west. In both cases the cleavage strike is at a large angle with the strike of the bedding. In Ugenya the cleavage follows the bedding more closely, and in some cases it may be difficult to determine which feature is being dealt with.

## VII.—ECONOMICS AND MINERAL RESOURCES.

During the present reconnaissance actual search for gold by excavation and panning was not practicable. Examining the area on the surface only, the number of quartz veins or gashes found is disappointing, and those that have been seen do not yield encouraging results.

Only two vein systems are known to have been opened up in the area. One, a quartz vein, stated to lie in felspar porphyry, was discovered in 1934 near the east head of the River Walupe. It was proved by trenching over a strike of about 500 feet, and by means of a shaft was followed to a depth of 50 feet. The vein thinned downwards, and values were not encouraging. It is believed that at the time of the discovery, quartz containing various sulphides, including galena, was recovered from this vein. The quartz left around the shaft is a blue glassy variety, some of it carrying pyrite.

Veins and gashes of quartz have also been found near the River Amali, a tributary of the Rover Sio, but apparently excavation showed little of value.

As far as is known, only small gold values have been found in the Samia Hills area.

Dr. K. A. Davies, who has prospected and mapped intensively in the area around Busia, believes that gold can be expected to occur only in a comparatively narrow belt around the granite contacts. The width of the belt will naturally depend on the steepness of dip of the contact. At Busia it appears to be of the order of two miles, though in the Ugenya district it may be considerably wider. The Kitosh roof-pendant would naturally be included in the list of "likely" marginal areas, and it is interesting to note that E. J. Wayland ((23), p. 6) suggested several years ago that the valley near Watende might repay prospecting.

In Eastern Uganda, Dr. Davies' work appears to show that the greater part of the gold has been shed from porphyries marginal to the granite ((8), p. 35). In the No. 1 Area marginal porphyries have not as a rule been observed, and it is believed that gold found in soil and gravels has been shed from quartz veins or stringers, correlated in time with the late stages of the granite intrusion.

Though pyrite is commonly found in certain rocks of the area, e.g. in many of the basic dykes, in certain parts of the Samia quartzites, and in the rare conglomerates of the Kavirondo Series, the writer considers it unlikely that any low-grade ores of workable extent will be discovered. Auriferous bodies found will probably be quartz veins or shear zones associated with quartz veins.

No indications of precious metals other than gold have been seen in the area, though prospectors have reported the presence of occasional platinum grains in the gravels of the

River Walupe. The Geological Survey of Uganda ((6), pp. 50-51) records that small grains of a silvery mineral have been obtained from clayey gravels at six to seven feet depth in the lower reaches of the same river. Tests showed it to be platinum with a small percentage of rhodium.

Traces of copper, in the form of malachite and azurite stains, have been observed in the volcanic rocks of Samia, but it is probable that they are of academic interest only.

The only other metallic mineral worthy of note is the Samia ironstone. Gregory ((10), p. 44) records that the ore near Berkeley Bay was found to contain "41, 43 and 62 per cent or iron". It is improbable that these ores are of economic value. During the present survey a pocket of the ore was mapped on Lugulu. It is of small surface extent, and probably impersistent in depth.

As no excavation has been carried out, little but guesses could be made at the value of the alluvials. Alluvials, which may prove workable, occur in the valleys of western Wamia, but the writer has no knowledge of the alluvials elsewhere. It is highly improbable that the alluvial deposits of the Yala Swamp are workable. Gravel bands, rich enough in themselves to be worked under suitable conditions, will be a hopeless proposition owing to the great thicknesses of unprofitable overburden.

#### VIII.—PROSPECTING AND HEALTH.

It is perhaps not unreasonable to issue a warning to prospectors that searching for gold in the No. 1 Area will be an arduous task. Little of value is exposed, and reefs will only be found by careful loaming and pitting along valleys in which auriferous alluvials are found. At many localities deep soil cover may be expected, and very often on the divides a thick crust of hard laterite, through which it is a difficult and costly task to dig. Blasting may quicken the work, but it is worthy of note that around Busia it has been found that there may be a more indurated upper layer of laterite covering more incoherent lateritic rubble, and that in blasting the harder crust is left unbroken.

The soil and laterite completely mask the solid geology, and where there is laterite normal quartz float cannot be expected. Nevertheless, Dr. Davies finds that over quartz veins he can usually discover a breccia-like rock consisting of quartz fragments in a limonitic laterite matrix. In prospecting, such indications should be carefully searched for.

Examining the alluvials, owing to the prevalence of marshy valleys, will often be a difficult task, and it seems that some form of augering or drilling may be necessary in many cases.

*Health.*—About the rainy seasons anopheline mosquitoes are liable to be prolific in certain areas, and reasonable precautions should be taken against malarial infection. Around the edges of Lake Victoria, the Yala Swamp and Lake Kanyaboli, tsetse flies are found and necessary precautions should be taken against them when working in those areas. Prospectors are advised to obtain two pamphlets,\* issued by the Medical Department, dealing with suitable precautions against mosquitoes and tsetse-fly.

No water in the area can be trusted, and boiling and filtering is necessary for all potable water. Many streams are believed to be infected with bilharzia larvæ, and it is advisable to wear gumboots when working in marshy ground or in streams.

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