REPORT No. 10

COLONY AND PROTECTORATE OF KENYA

MINING AND GEOLOGICAL DEPARTMENT

GEOLOGICAL SURVEY OF KENYA

GEOLOGY OF THE MIGORI GOLD BELT

AND ADJOINING AREAS

(WITH COLOURED MAPS)

by

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Digitally converted version

PLATE I

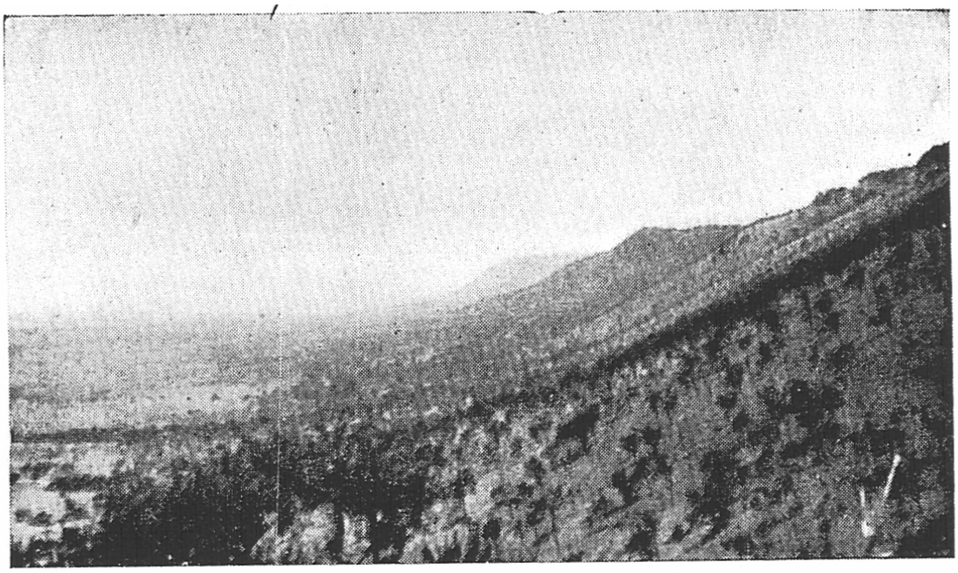

FIG. 1

View southwards along the Isuria Escarpment towards Kijarimweta. Tertiary phonolites at the top rest on mylonitized gneisses which form the slope. The Trans-Mara Plain below is underlain by the same phonolites, downthrown about 1,200 feet Qy the Isuria fault.

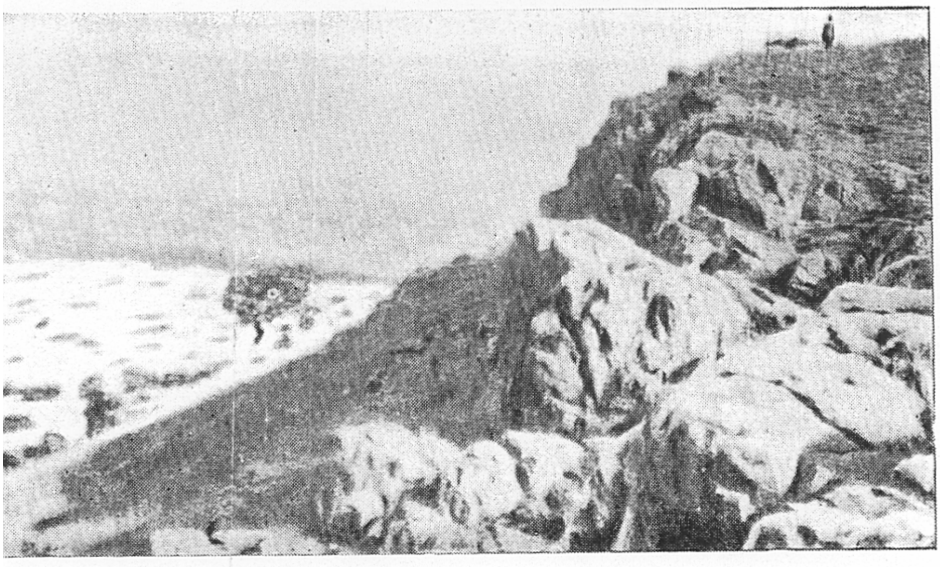

FIG. 2

Scarp of Kisii Quartzite west of Kilgoris. The slope below consists of basalts which form the lower part of the Kisii Series. The plains are underlain by the Kilgoris granite, on which the Kisii Series rests unconformably.

Frontispiece

FOREWORD

The fieldwork which led to the writing of this report was carried out by Dr. R. M. Shackleton between September, 1940, and September, 1942. The report was compiled immediately after the survey, but owing to war restrictions could not then be published. It has now been revised and brought up to date as far as possible.

The accomplishment of the work was made possible by a grant from the Colonial Development fund.

GEOLOGY OF THE MIGORI GOLD BELT

I-INTRODUCTION AND GENERAL INFORMATION

Introduction

The area described in this report owes its geological importance to a narrow zone of gold mineralization which runs through it in a general east-south-easterly direction. This zone lies mainly in the valley of the Migori (or Gori) River and is conveniently called the Migori Gold Belt. The Belt is situated about ten miles north of the Kenya-Tanganyika boundary, to which it is parallel. Its width can be taken as about three miles, and its length from near Karungu on Lake Victoria to the place east of Lolgorien where it finally disappears beneath younger lavas, is a little more than 50 miles. Throughout this length it is remarkably straight and regular. The chief object of the present work, which occupied a period of just over two: years, was to map the Gold Belt topographically and geologically in enough detail to serve as a basis for the further prospecting and development of the area. For this purpose a scale of 1: 25,000 was used, the field being covered by eight sheets. In addition, the surrounding country was mapped in less detail as far as the Tanganyika boundary in the south, eastwards to the Isuria escarpment, and northwards to a line from Nundowat to a point a few miles north of Suna, and thence eastwards and east-north-east to Abossi on the Masai-Kisii border. Maps of the whole area on a scale of I: 125,000 are provided with this report (PIs. III and IV in end folder). The eight sheets on a scale of 1:25,000 are published separately. They are referred to in this report as the Sectional Maps or by their numbers (I to VIII) in Roman figures.

Gold is believed to have been discovered in the area as long ago as 1904, but not in workable quantities. A Government geologist. Mr. Coates visited the district in 1909 and reported the widespread occurrence of gold in the streams and rivers but he was unable to locate payable ore-bodies. Not until 1922, when there was a minor rush of prospectors to the area, were workable deposits discovered. Production on a minor scale ensued: in 1926 it amounted to 667 oz. of unrefined gold, but by 1939 had risen to over 10,000 oz. per annum.

Maps

A strip of country along the Kenya-Tanganyika boundary is covered by the maps of the Anglo-German Boundary Commission which were issued in 1906. Sheets I and II cover part of the present area and form a strip about 12 miles wide on the Kenya side of the boundary. The accuracy of the maps diminishes away from the boundary and was inadequate for the geological survey of the Gold Belt. Part of the western end of the Belt falls within the 1: 250,000 Karungu Sheet South A-38/E published by the Ordnance Survey in 1916. Much of the country especially in the Lolgorien area was unmapped when the present survey was begun.

A secondary triangulation of the Migori Mining Belt was carried out for the Mining and Geological Department by Mr. C. T. Cogle, assisted by Mr. E. J. Butler of the Survey Department; the triangulation chart was published in 1934.

In the course of, the work use has also been made of various maps; plans and aerial photographs put at my disposal by Messrs. Macalder Mines, Ltd., Kenya Gold Mining Syndicate, Ltd., Ngiga Mining Co., Ltd., and Kenya Consolidated Goldfields: Ltd., to whom thanks are expressed. Maps and aerial photographs deposited with the Mining and Geological Department by Messrs. Watende Mines, Ltd., were also used.

Nature of the Country

Near Lake Victoria the country is dry and almost barren, with Euphorbia trees and 'little grass. Rainfall increases inland with the result that the vegetation changes. East of Suna and up to Lolgorien clumps of bush in waist-high grass result in a more park-like country, while between Lolgorien and Kilgoris and in the upper Migori valley there is much forest. The hills west of Ki1goris are open and grassy and support large herds of Masai cattle. Generally speaking the country is not difficult for geological mapping, and rock exposures are usually adequate, though largely confined to streams in the eastern parts of the area.

Access and Communications

In the early days access was from Nairobi. Heavy mining machinery had to be brought in by ox teams and lorry, over very bad roads. After the 1922-23 "gold rush" a road was constructed from Lolgorien to Mohoru, where a pier was built. Heavy machinery and stores now come from Kisumu by this route. The Tanganyika-Kisii-Kisumu road crosses the Lolgorien-Mohoru road at Suna and provides the best road access to the district. The rivers are not navigable except perhaps the Kuja below its confluence with the Migori.

Native Population

The whole area lies in Native Reserves; the western part being in the South Kavirondo Reserve, and inhabited by Jaluo, while a small area near Suna and Kahancha is the Watende Reserve; east of this is Masai Reserve. Labour on the mines is mostly Jaluo, with some Watende.

II-PREVIOUS GEOLOGICAL WORK

The first published account of geological work in South Kavirondo was by Dr. Felix Oswald, who in 1911 examined certain fossiliferous deposits near Karungu (Oswald, 1914)[*]. He made a collection of Miocene fossils for the British Museum and mapped in detail the deposits in which they occur. He also made a geological traverse from Karungu to Kisii and from there to Homa and Kendu. From the information gained he prepared a geological map of a large part of South Kavirondo, showing the post-Miocene volcanic rocks extending from Victoria Nyanza towards the Kuja River; a large area of quartzites in the Kisii Highlands east of Kisii; and in the lower country between the quartzite and the recent volcanics an area of schists, gneiss, amphibolite, dolerite, augite andesite and other ancient rocks the mutual relationships of which he could not determine in the time available. His tentative correlation of the Kisii quartzite with the Karagwe quartzites of Uganda was subsequently corrected by Wayland.

The next geological description of South Kavirondo, and the first to deal with the Migori Gold Belt, was by E. J. Wayland, then Director of the Geological Survey of Uganda, who in 1931, at the request of the Government of Kenya, made a geological reconnaissance through South Kavirondo (Wayland, 1931). At the time gold mining there was in the early stages; Wayland reported favourably on the geological setting and economic prospects of the gold-bearing veins which were being prospected, and recommended detailed' geological mapping of the area by a Geological Survey of Kenya, should one be formed. His own geological work was recorded in traverse notes and summarized in a provisional stratigraphical sequence. His oldest rock group (1) is termed "Crystalline Complex" and includes "G1 granite" (not remarked upon in the traverse notes) and amphibolites which were noted at many places, including Karungu where they underlie the Miocene sediments. In his next division (II) he included the Wire Hill felsites and the "Gori Conglomerate." The latter is described as an extremely ancient and much metamorphosed rock seen in the Migori River at the old Suna ferry. It is not clear which of the two conglomerates that are now known to occur there was meant. Murray-Hughes has since (1933, a, sketch map) used the term Gori Conglomerate for the boulder conglomerate, which is now referred to the Kavirondian System. In group III (Karagwe-Ankolean) were placed, some boulder conglomerates (Kavirondian according to present classification) which were seen elsewhere in South Kavirondo. In the same group he placed phyllites (Kitere phyllites), which were seen between Kisii and Oyugis. They were thought to overlie the conglomerate. His group IV, Bukoba Series; comprises the Kisii quartzites (whose similarity to the Bukoban sandstones was recognized) and some lavas which were discovered associated with quartzites. A dolerite sill in the Kisii Series was placed in Group V (Karoo). Group VI, the Miocene rocks, includes not only the Karungu Miocene deposits described by Oswald but also fossiliferous deposits associated with lavas and tuffs, which Wayland discovered on Rusinga Island and the mainland opposite. Groups VII, VIII and IX include the various post-Miocene sediments and volcanic rocks.

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[*] References to literature are quoted on page 59.

The general correlation of the sequence in the Migori area with those of other areas is shown in the following table:-

GENERAL CHRONOLOGY		NORTH KAVIRONDO	CENTRAL KAVIRONDO		SOUTH KAVIRONDO		MUSOMA TANGANYIKA TERRITORY
			SOUTH WEST QUADRANT	NW AND NE QUARDRANT	K.C.G. CONCESSION AREA	MIGORI AREA	
		W. Pulfrey (1936)	*W. Pulfrey (1938)*	*C. S. Hitchen (1936) (1937)*	*A. A. Fitch, C. D. Hallam and W. Edgeworth-Johnstone (1937)*	Present report	*G. M. Stockley (1936)*
	PLEISTOCENE					Plateau gravels	
TERTIARY	PLIOCENE				Homa and Ruri volcanics		
	MIOCENE		Volcanics and sediments of Uyoma		Gwasi volcanics	Gwasi and Isuria volcanics Karungu sediments	Utimbara Phonolitic suite
	? POST KARROO	Dolerites	Dolerites	Dolerites	Dolerites	Quartz-dolerites (D2)	Quartz- and Olivine dolerites
PALAEOZOIC	BUKOBAN	-	-	-	KISII SERIES 3. Andesites 2. Quartzites etc. 1. Basalts	KISII SERIES 3. Red felsites, Andesites and Rhyolites 2. Quartzites 1. Basalts	IOORONGONGO SERIES Shales, grits and quartzites with intrusives
PRE-CAMBRIAN	KAVIRONDIAN	Acid and basic dykes Ramogi syenite Mumias/Kanyaboli granite	Minor granitic intrusion. Intrusive dykes and bosses ranging from acid to basic in type Abiru granite Gb.? Asembo, Ndeda granites G	Biotite granite syenite and allied rocks. Lamprophyres Kanyaboli Kisama-Mumias Raualo — Granites Gb		Granites G2 and syenites S3	Acid dykes and lamprophyres Granites G3 and G4
		KAVIRONDO SERIES 2. Grits, sandstones and mudstones 1. Thin basal conglomerates		KAVIRONDO SERIES 3. Grits with pebble bands 2. Slates and mudstones 1. Grits and conglomerates	KAVIRONDO SERIES 1. Conglomerates; dioritic porphyrite	Kavirondo system 3. Conglomerates with dioritic porphyrite boulders 2. Dioritic porphyrite 1. Conglomerate	North Mara series Kuria volcanics
	NYANZIAN		Abom Tedo Bondo etc. — Granites Ga	Nyarodi granite Ga and granitized diorite	Kitere granite, pink granite and diorite Quartz porphyries and felsites (wire series)	Granodiorite and syenite (G2 Suite) Quartz porphyries	
	NYAZIAN	Greenstone	Dolerites and epidiorites	-	Dolerite (amphibolites)	Dolerites (D and epidiorites)	Basic intrusives
		3. Kadimo volcanics 2. Samia hills series volcanics and banded quartzites 1 Akarra "dolerite"	PRE-KAVIRONDO VOLCANIC SERIES 3. Basalts 2. Andesites 1. Rhyolites — With tuffs, agglomerates and conglomerates	PRE-KAVIRONDO VOLCANIC SERIES 3. Basalts and dolerites 2. Intermediate lavas 1. Rhyolites and sub-acid lavas, tuffs and agglomerates	GREENSTONE SERIES Acid and basic lavas with tuff and agglomerates	NYANZIAN SYSTEM 3. Slaty suite with Masara andesitic rocks 2. Graywackes and conglomerates 1. Basaltic group and dolerites (D1 part) (with banded ironstones in all three groups-	MUSOMA SERIES
		-	-	-	-	? Orthogneisses of Brannstrom Collin	Foliate Granites G2
	BASEMENT SYSTEM	Basement complex on N. Kitosh etc.	Rocks of Tedo and Kayamo Island etc.?	-	-	2. Quartzites of Lemeck Hills etc. 1. Schists and gneisses of Mara Valley and Isuria scarp.	Crystalline schist and gneisses of East Mara.

"Blackhall's" and "M.K. Reef" at Masara were found to lie in sheared porphyry and schist (it is not clear from the report to which division in the stratigraphical table these were referred). He showed that the veins occur in an ancient (? pre-Karagwe-Ankolean) zone of intense north-west-south-east shearing and mylonitization near a granite contact.

The petrography of the specimens collected by Wayland was described by Dr. A. W. Groves in an appendix to the report. Of particular interest in connexion with the present work are his demonstration, in a series of rocks collected at Blackhall's Reef, of a gradual transition from porphyry to slabby and slaty rocks, due to progressively intense shearing; the close similarity recognized between the granites, including the one near Masara, and the newer ("G2") granites of Uganda; and the recognition of angular grains of cassiterite among the heavy minerals isolated from the Kisii sandstone.

Another geological report (Kitson, 1934) on the area was submitted to the Government of Kenya by Sir Albert Kitson, who with Mr. R. Murray-Hughes as assistant, in 1932 made a series of reconnaissance traverses through Kavirondo. The results were recorded in the form of traverse notes with a short explanatory section. Kitson remarked (*ibid*., p. 7) "to the south of the Gori River the geological structure of the country and the evidences of gold . . . were sufficient to show its probable value as a mineral-bearing country."

In 1933 a pamphlet was published by the Mining and Geological Department on the Lolgorien area (Murray-Hughes, 1933, a). A geological sketch map shows a belt of undifferentiated slate, phyllite, and porphyry "favourable for prospecting" striking east-south-east across the map and narrowing east of Lolgorien to end near the Isuria escarpment. Along the northern side of the belt a strip of "Gori conglomerate" is shown and south of it granite. Recent phonolitic lavas were indicated north and east of Lolgorien. The north-east-south-west Isuria fault was shown with lavas resting on granites on the north-west side and lavas, gneiss and quartzite on the south-east side. The "banded ironstone" of Lolgorien Hill was discussed:

The Mining and Geological Department also published in 1933 a report (Murray-Hughes, 1933, b) summarizing what was then known of the geology of the western half of Kenya. On the map therein, the area east of the Isuria scarp, and also a narrow strip along the escarpment itself, were indicated as undifferentiated "Basement Complex." The Upper Division of the Basement Complex, consisting of greenstones, banded ironstones and allied sediments, was shown as occurring over a large area north of the Gori River, with younger granites south of it. Granite was also shown west of Kilgoris. Rocks of the Kisii Series, and Tertiary and post-Tertiary volcanics were also shown. The banded ironstone and associated rocks of Lolgorien, included in the Upper Basement Complex, were recognized as older than the conglomerates which were correlated with the Muva-Ankolean.

No subsequent work on the district has been published but an area of over a thousand square miles of South Kavirondo, immediately north of the area covere4 by this report, was mapped for Kenya Consolidated Goldfields, Ltd., by Hallam, Fitch, and Edgeworth-Johnstone (1936, 1937 and 1938). Much information relevant to the present work is contained in their, reports, copies of which were submitted to the Mining and Geological Department.

The various reports and maps covering areas in North and Central Kavirondo by Dr. C. S. Hitchen and Dr. W. Pulfrey (Hitchen, 1936, 1937; Pulfrey, 1936, 1938) deal with a rock succession and mineralization similar in many respects to that of the Migori area and represent the most detailed work so far done on the Goldfields Formations or western Kenya. They were accordingly referred to for purposes of comparison and correlation, as also was Mr. G. M. Stockley's account (Stockley, 1936) of the geology of the Musoma District which adjoins the Migori area on the south side of the Kenya-Tanganyika boundary.

Since this report was first written Mr. G. M. Stockley has proposed new names for some of the Systems (Stockley, 1943). The new nomenclature has been adopted here.

The correlation of the rocks of these various areas is tabulated on the folder opposite page 2.

III-SUMMARY OF THE GEOLOGY

The principal rocks seen in the district are grouped according to their age, thus:-

RECENT ANT PLEISTOCENE

Alluvium and' black valley clays (*mbuga*).
Lateritic Ironstone (*murram*).
Eluvial Deposits (rubble, etc.).
Plateau Gravels.

TERTIARY

Phonolitic Lavas of the Isuria Plateau, etc.
Gwasi Volcanics (nephelinite lavas and tuffs)
Lake deposits (sandstones, clays, etc.) (Miocene).

-great unconformity-

BUKOBAN SYSTEM. KISII SERIES. (Palaeozoic?)

3. Aridesitic Group.
2. Quartzites:
1. Basalts.

-great unconformity-

KAVIRONDIAN SYSTEM.

Boulder Conglomerates, etc., and associated porphyrites.

-unconformity-

NYANZIAN SYSTEM.

Pillow lavas, andesitic volcanic rocks, graywackes, conglomerates, shales and banded ironstone.

-inferred great unconformity-

BASEMENT SYSTEM.

Quartzites and gneisses.

Basement System

The oldest series of' rocks known in East Africa was formerly called in Kenya the Turoka Series arid in Tanganyika the Lower Basement Complex. Following the nomenclature recently proposed by Stockley (Stockley, 1943), these rocks are now referred to the Basement System. Rocks of this series form the Lemeck Hills where they consist of white quartzites, formed by the recrystallization deep in the earth's crust of ancient sandstone formations. Similar rocks are known to form many of the other hills in the western part of the Masai Reserve.

Along the Isuria fault-scarp there is a zone of mylonitized gneisses striking parallel to the fault line. These rocks also are regarded as belonging to the Basement system. The Migori Gold Belt must end west of this zone, somewhere under the lava sheet of the Isuria plateau.

The structure of the Basement System rocks of this area is unknown. The foliation, which coincides with the original bedding, dips at moderate angles; the dominant strike appears from scanty records to be between north-north-west and north-east. The rocks are highly metamorphosed.

Up to now no important gold mineralization has been discovered in the Basement System rocks of Kenya although traces of gold in streams draining them have often been reported. Prospectors working on these rocks should, however, be able to recognize commercially useful, occurrences of mica, optical quartz, graphite, magnesite asbestos and corundum, any of which might occur though the prospects cannot be regarded as particularly encouraging in this district.

Nyanzian System

All the gold so far produced in Kenya has come from areas either of Nyanzian or Kavirondian rocks which are, together, conveniently referred to as the "Goldfields Formation"

In the Migori Gold Belt most of the veins occur within a long narrow strip of Nyanzian rocks. These rocks are basic pillow lavas, andesitic volcanic rocks, conglomerates, graywackes, shales and banded ironstones. They are all strongly sheared, but the low grade of metamorphism indicates that, unlike the Basement System, they have not been recrystallized far' down in the earth's crust. This difference in metamorphism is the chief evidence of the greater age of the Basement System rocks, which are nowhere seen in normal contact with the Nyanzian.

The basic lavas are lumpy-weathering, bluish-green rocks, often showing pillow structure. Lavas with this structure look as if they consisted of pillow-shaped and sack-like masses of varying sizes pressed together (see Plate II, Fig. I). This structure often results when lavas of basic composition flow into water.

The andesitic volcanic rocks include lavas, contemporaneous intrusions and volcanic ashes (tuffs). They are grey rocks with abundant small whitish felspar crystals; they often show "tombstone" weathering and form a whitish dust on-the roads. They are thickest at the western end of the Belt.

The greywackes are perhaps the most widespread kind of rock in the Nyanzian System in this district. They include a variety of rocks, all, however, containing grains of quartz, usually in a dirty green matrix, and mixed with a good deal of felspathic ashy material. They represent a mixture of sand and volcanic ash, deposited in water.

The conglomerates are graywackes with scattered pebbles, seldom over an. Inch in diameter and mostly consisting of grey, red or black chert and jasper.

The shales are grey, bluish grey, sometimes silvery and phyllitic, sometimes black and graphitic, and represent variously altered muds. Every gradation from these finest-grained deposits to the graywackes and conglomerates occurs.

The banded ironstones (see Plate II, Fig. 2) are characteristic rocks made up of alternate bands of grey chert and brown or red iron oxides and hydroxides. They often outcrop as ridges or rock ribs.

All these various rocks outcrop in a strip, usually not much more than three miles wide, bounded to the south by the granite which intrudes them and to the north by the Kavirondian conglomerates and porphyrite. They generally dip southwards towards the granite; the oldest are the pillow lavas on the north side of the Belt. The andesitic volcanics are near the top of the visible succession.

Various intrusive rocks are closely associated with the Nyanzian volcanic rocks and are probably more or less contemporaneous with them. The commonest are dolerites (Older Dolerites), porphyrite (NAP on sectional maps), and quartz porphyry and felsite

Mineralization is not confined to anyone of these rock types but certain bands are more susceptible to it, notably shales and banded ironstones.

Kavirondian System

The Kavirondian rocks in this area are represented by boulder beds, felspathic grits and andesites, associated with an enormous mass of porphyrite which is probably mostly intrusive and. forms the hills which stretch from Goddiquach and Nyakune near Kuja, to Gwa a few miles north of Kahancha. The extraordinary boulder beds, often containing huge yet well-rounded boulders of granite, porphyrite and many other rocks, are easily recognized and characteristic (see Plate II, Fig 3), They are believed to have been swept down by torrents from scarps and mountain ranges which were being formed at that time

Structures in the Kavirondian rocks are obscure but although they must be unconformable with the Nyanzian rocks, they have themselves been faulted, folded and sheared, though less intensely than the latter.

The Granites

The largest mass of intrusive rocks in the district extends from the Gold Belt southwards to the Tanganyika boundary and beyond, and from Lake Victoria td the Isuria escarpment. Many thousands of feet of this granite and the formations into which it was intruded have been removed by erosion, and the Gold Belt now exposed lay far down on the northern wall of the granite mass, while south of this Belt no relic of the roof of the intrusion remains (see Fig. 4). The northern wall dips, surprisingly, at a steep angle southwards, so that the granite ac1ually overhangs the country rocks. Near the wall, the granite is strongly foliated. The intrusion itself is complex and was probably intruded during a long period of time. Boulders like the earlier marginal types occur in the Kavirondian boulder beds, which are however themselves intruded by another granite. The gold mineralizing solutions evidently came from the granite mass south of the gold belt, since the auriferous veins are concentrated near its contact. Another large granite mass south of Kilgoris, intrusive into the Kavirondian System, appears to have caused no mineralization; several small granite bosses in the gold belt are likewise non-mineralizing granites.

Later Dolerites

A series of conspicuous dolerite dykes is later than the granites.

Kisii Series (Bukoban System)

The massif known as the Kisii Highlands is a nearly flat cake of basaltic and andesitic lavas with subordinate tuffs, with a conspicuously outcropping hard quartzite bed in the middle of the succession. The rocks of the Kisii Series are later than the main period of gold mineralization although traces of gold are found in them at several places. Around Kilgoris the Kisii rocks have been tilted and faulted, with the result that the quartzite outcrop is repeated in several more or less parallel ridges.

Miocene Sediments near Karungu

In some insignificant looking gullies near Karungu are exposed a series of clays, silts, sands and conglomerates which have long been known to geologists for the interesting assemblage of bones and other fossils that have been found in them. The remains include those of *Deinotherium,* crocodiles, a giant tortoise, and freshwater and terrestrial shells. The fossils fix the age of the deposits as Miocene and show that they are old lake deposits probably laid down near the mouth of a large river. The rocks rest unconformably on Nyanzian pillow lavas and other ancient rocks; they are overlain by the nephelinite lavas and tuffs which cap Nundowat and the hills east of it.

The Gwasi Volcanic Series

The country north of Karungu is a rocky volcanic district. The rocks, which are dark grey lavas with abundant black augite crystals, and tuffs of similar composition, are known as the Gwasi Volcanic Series, after the district where they have their greatest development. The south-eastern fringe of these rocks reaches into the area covered by this report, but they must once have extended further south, since the scarp along the top of which they now end is an erosion feature. The eruption of these rocks-probably began in Miocene' times. Slides show them to be nephelinites and related types.

The Isuria Lavas

East of Lolgorien is another region of different lavas. They are blue-grey phonolites with half-inch long white or glassy sanidine felspar crystals and small greasy looking greenish-grey nepheline crystals. Lavas of this kind cover the Isuria plateau; they are found as far as Tarime and beyond, in Tanganyika, and in the Mara valley below the Isuria escarpment. These remaining patches are part of an originally continuous and large sheet, consisting of several separate lava flows. They flowed from the north-east, but the focus of eruption is not known. They have been broken by the Isuria fault and dropped down on its eastern side. The fault belongs to the Rift Valley system of fractures, though far from the Rift Valley itself.

At the base of the Isuria lavas, around Lolgorien, is a bed of gravel which cannot be more than a few feet thick: Where this gravel has been derived in part from the Goldfield Formations it may contain gold in workable quantities

Pleistocene and Recent Deposits

Since the time of the Isuria faulting and the tilting which accompanied it, the history of the region has been chiefly one of erosion. The effect of the faulting and tilting was to produce a fairly even slope from the Isuria escarpment to Lake Victoria with a few low hills which had remained above the lavas, and the big block of the Kisii Highlands standing out to the north. On this slope the Migori river system was initiated. The Mara river system draining the country east of the escarpment must have taken shape at the same time.

Widespread plateau gravels on a peneplained surface indicated that at one stage the-Migori valley had been eroded nearly to base level. The peneplained surface slopes towards the Lake, owing to further subsequent tilt, connected with a subsidence of the Lake region. Since then the Migori (and Kuja) have again been cutting downwards and now in several sections flow through narrow steep-sided valleys.

At some stage after the formation of the plateau gravels, the climate and drainage were such that lateritic ironstone ("murram") formed on the gentler slopes. The rocks at the surface were selectively decomposed, with the result that only a residuum of siliceous rocks resistant to lateritic weathering remained on the surface. To this we owe the fortunate concentration of quartz "rubble" near the reef outcrops. Of all the various rocks which must originally have been collected in the plateau gravels, the only ones now left are quartz, Kisii quartzite and jasper. The murram is in some places being eroded and is no longer forming, except perhaps in the dry area near, the Lake. Silt, a little sand, and less gravel have been deposited in recent times, particularly along the lower course of the Kuja, and on the flats between Kadem and Karungu. These recent alluvial deposits are probably thin.

Implements showing that man has inhabited the area for a long period of time can be found in many places, the older ones chiefly in river gravels and the more recent ones on the present land surface.

IV-DETAILS OF THE GEOLOGY: (I) THE OLDER ROCKS 1.

1 The Basement System (M)*

The oldest rocks recognized in East Africa have been referred to in Kenya as the Turoka Series, after the district where they were first described (Parkinson, 1913). They are paragneisses, quartzites, marbles and graphitic, micaceous, hornblendic and other schists, which are now included in the Basement System as defined by Stockley (Stockley, 1943).

Rocks of the types mentioned, particularly quartzites, are known to occur in the western part of the Masai Province.

Quartzites of the Lemeck Hills

A reconnaissance of the Lemeck Hills, near the Lolgorien-Narok road about ten miles east of the Mara Bridge, was made chiefly to compare the rocks there with those on the Isuria escarpment. The Lemeck Hills, where traversed, consist of massive whitish Quartzites, highly metamorphosed and with pegmatitic segregations. The foliation is parallel to the bedding, as is probably the case with most of the Basement System rocks. As a structure it is thus quite distinct from the cleavage, which is oblique to the bedding in the later Nyanzian and Kavirondian rocks. The reason for the difference is that the rocks of the Basement System were deformed at a greater depth in me earth's crust; there is, moreover, a complete difference in tectonic style. Strikes in. the Lemeck Hills vary considerably within short distances and in the short time available no structure could be elucidated.*

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* Symbols on the following pages are those used on the sectional maps. Those in heavy type are also used on the I: 125,000 maps, Pls. III and IV, but in most cases with a broader significance. Some of the symbols used could not reproduced with the type available; reference should be made to the maps

Basement System Rocks east of the Mara River,

More information about the Basement System in the western Masai area Was obtained by Mr. Brannstrom, a Government prospector. He saw quartzites on the hills around Loldobaith, east of the Mara River near the Tanganyika border. He also collected other types of metamorphic rocks. Microscope examination of the quartzites show them to be highly metamorphosed. Original grain outlines are obliterated by recrystallization of the quartz to a sutured mosaic. The even grain size in some slides suggests the original sedimentary character which is in any case obvious from the composition and structures seen in the field. Flakes of muscovite and greenish biotite in parallel orientation penetrate the quartz grains. The muscovite is conspicuous in the hand specimens and shows the direction of the foliation. The quartz in some of the rocks shows strain-polarization.

Less common types include *injection gneiss* (II.3),* consisting of pink leucogranite alternating with thinner streaks and folia of biotitic schist; a grey augen gneiss (II.9) with pink microline felspars; grey *quartz-microline-biotite* gneiss (II.11a); *granitoid gneiss* (II.15); a *garnetiferous mica schist* (II.12), and a *clinozoisite schist* (11.8). This is a typical assemblage of Basement System rocks, but the absence of marble and graphitic schist is noteworthy. One specimen (11.13) was of granite similar to the newer granites of the goldfields.

It appears that quartzites outcrop at intervals between the Lemeck Hills and the Loldobaith Hills, and that west of this north-north-east-south-south-west quartzite zone there are more variable schists and gneisses. This gneiss and schist series probably dips eastwards beneath the quartzites.

Strikes recorded by Mr. Brannstrom were chiefly (8 out of 11) between north-north-west-south-south-east and north-east-south-west. The prevailing dip was easterly. A strong lineation (a linear texture shown by elongation of minerals on the foliation surfaces and' due to rolling out during plastic flow) 'was seen' in several of the hand specimens.

Isuria Mylonitic Gneisses.

Along the Isuria escarpment beneath the lava cap, are a series of strongly foliated gneissose rocks, extending from below Kijarimweta Trigonometrical Station to the Lolgorien-Narok road west of the Mara Bridge, and probably beyond. The foliation along this strip is parallel with the escarpment, that is, north-east-south-west; the dips being south-east at about 45°. Slides of these rocks show that they differ from the Basement System rocks collected by Brannstrom particularly in being intensely mylonitized. This mylonitization must have affected the rocks when they were in a much less deep-seated environment than during the original regional metamorphism of-the Basement System rocks. It is essentially similar to the mylonization of the granite, and adjacent country rocks, along the southern margin of the Migori gold belt. A steeply pitching lineation is similar to that in .the Migori contact zone. It is obvious, however, that the mylonitized and granulitized rocks differ from any seen along the granite contacts in the, Migori Belt. The gneissose structure in the Isuria gneisses is due to the alternation of granitic, biotitic and muscovitic folia. The gneisses are sharply contorted, unlike any of the Nyanzian contact rocks. Their variability is notable. In thin sections the most significant point is the presence in them of smashed and shredded, but originally quite large plates of muscovite. This mineral is seldom seen in the Migori contact zone, and its presence strongly suggests that the mylonitized rocks belong to the Basement System. The: contact was obviously of a different kind from that between granites and Nyanzian rocks along the Gold Belt. There the contact is sharp and cleancut and very few granitic veins penetrate the country rocks, whereas in the case of the Isuria gneisses, the granite penetrated intimately into, them. Folia, veins and thick*

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* Numbers in brackets refer to specimens in the collections of the Mining and Geological Department, Nairobi.

sheets of pink granite are seen everywhere among the gneisses. This in itself suggests that the rocks with which the granite was here in contact were already foliated.

The absence of quartzites is not surprising since it appears from Brannstrom's traverse that gneisses and schists occur west of them.

It is concluded that the Isuria gneisses are of Basement System age and that they lie in a mylonitized granite contact zone. The contact is probably structurally similar to the one described at the eastern end of the central granite of Tanganyika in the Mpwapwa district (Temperley, 1938, pp. 17 and 18).

2; The Nyanzian System

The Succession

The Nyanzian System is clearly distinguished from the Basement System and although the two are nowhere seen in contact there is no doubt that the Nyanzian is the younger. Whereas the Basement System rocks have everywhere suffered fairly high-grade regional metamorphism, the grade of metamorphism of the Nyanzian rocks is'-mat characteristic of the chlorite zone or even lower. Shearing and cleavage are widespread but local.

The distinction of the Nyanzian from the Kavirondian is less immediately obvious, but mapping not only in the Migori Gold Belt but throughout the Kavirondo goldfields as well as in the Musoma district of northern Tanganyika, leaves no doubt that the two are separated by a major unconformity. Boulder conglomerates are particularly characteristic of the Kavirondian, especially in the southern part of the region; among the boulders are undoubted Nyanzian rocks. The Kavirondian rocks are on the whole less sheared than the Nyanzian but owing to the variable intensity of the shearing this cannot be used as a criterion to distinguish them.

The System comprises a series of lavas and tuffs alternating with sediments. In the Migori Gold Belt, which is a belt of strong compression and shearing, they generally dip steeply, and along most of the Belt towards the granite contact. Graded bedding and the relation of cleavage to bedding, prove that these southward dipping rocks are not inverted. Therefore, unless the Belt is traversed by unsuspected (though not improbable) strike faults, the youngest rocks must be those nearest the granite and the oldest those on the north side of the Belt. (In the Macalder area where the dip is to the north this does not apply.) Gradational contacts in many cases prove that the succession is unbroken; further, although as is usual in a volcanic sequence, lateral variation is rapid, some beds can be traced considerable distances along the strike, and it is possible to fit together a succession which applies to most of the area. This succession is indicated diagrammatically in Fig. I which shows the variation in thickness of the principal-rock groups as they are traced through the Belt, from Lolgorien to Masara. (The apparent slopes of the beds in the figure are not significant.)

It will be seen from this diagram that three principal groups can be distinguished, with subsidiary divisions most of which cannot be traced far.

The succession may be tabulated as follows:-

3. SLATY AND ANDESITIC GROUP. -Variable tuffaceous, silty and ferruginous slates, with the Makuru banded ironstones in the lower part, the Masara Andesitic Group near the top (in the west) and shales at various places and horizons.

2. GRAYWACKE GROUP.-Comprising graywackes, gritty andesitic tuffs near the top, conglomerates usually near the middle and a banded ironstone horizon near the base.

1. BASIC VOLCANIC GROUP. -Basic volcanic rocks, chiefly metabasalts and pillow lavas, with the banded ironstone group of Lolgorien Hill near the middle.

Study of .the 1: 25,000 maps, sheets II and III; will show that around Macalder Mine and east of it for several miles, the rocks dip away from the granite instead of towards it. This, however, does not result in the reappearance in reversed order of

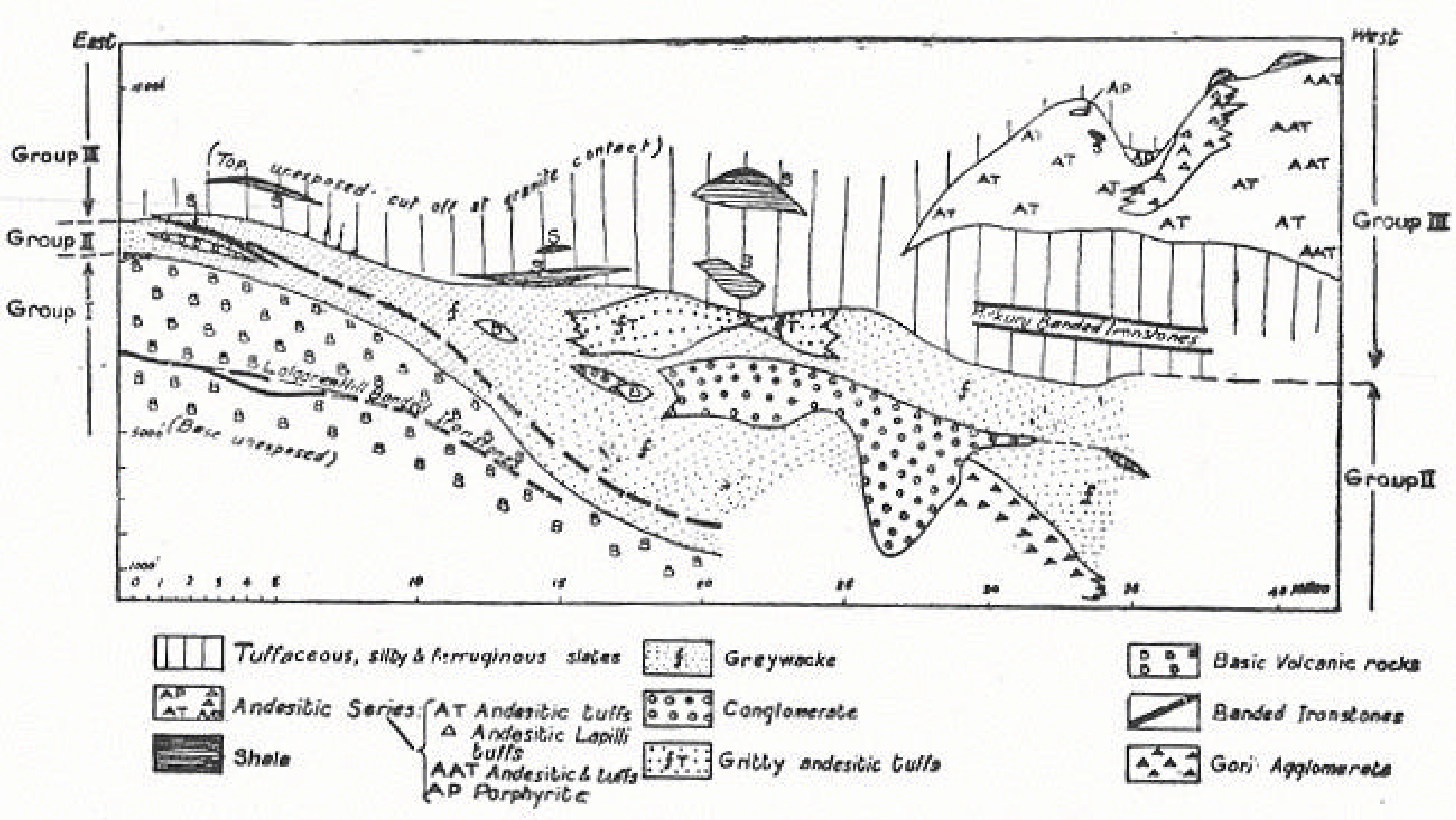

FIG. I

Diagram showing the lateral variation of the Nyanzian rocks through the Migori Gold Belt, from Lolgorien in the east to Aka1a in the west. The apparent dips of the surfaces arise from the exaggerated vertical scale and absence of a datum plane, and are not significant.

the rocks which occur to the south of it, as would be the case if the reversal were simply due to crossing the crest of an anticline. There must be strike faulting, separating these rocks from those to the south, but the position of the inferred fault or faults is uncertain. The succession in the immediate neighbourhood of Macalder Mine is:

(top) 3. Graywacke.

2. Banded ironstone.

1. Metabasalts and pillow lavas.

This sequence probably represents the top of Group 1 and the lower part of Group 2 of the general sequence set out above. The banded ironstone might represent the Lolgorien Hill banded ironstone since the group of basic volcanic rocks above that horizon seems to thin westwards, so that the ironstone comes nearer the graywackes. The rest of the rocks round Macalder Mine and east of it are more difficult to fit into the standard sequence and must for the present remain uncorrelated. The position of some felsitic and andesitic rocks north of Macalder Mine is particularly doubtful. Some banded ironstones further east might be correlated with the Makuru banded ironstones.

The great area of pillow lavas and metabasalts towards Karungu (Map, PI. IV) presumably belong to the Basic Volcanic Group (I).

North of Lolgorien, Nyanzian rocks reappear beyond a narrow belt of porphyrites and Kavirondian boulder beds. They are chiefly basic volcanic rocks and banded ironstones, evidently belonging to Group 1. The banded ironstone of the Longawone ridge is probably to be correlated with that of Lolgorien Hill; both thin out rather suddenly to the west in a corresponding manner.

The characteristic features of the various rocks are described below.

J. THE BASIC VOLCANIC GROUP

(NB) *(a) Basic Lavas*

The most characteristic rocks of the Basic Volcanic Group are pillow lavas. These are seen at intervals, from near Karungu in the west to the Lolgorien district in the east. Typical exposures occur by the Akala-Karungu road, immediately north of the alluvial plain; at Adiel Hill; and in the Migori River above and below the road bridge about six miles west of Lolgorien (see Plate II Fig. 1.). The pillow structure is clearly seen in some of the Macalder Mine diamond drill cores. Outcrops show a characteristic irregular lumpy weathering. The pillows vary in length from less than a foot to five or six feet, but are seldom more than a foot or two thick. The bigger ones bulge irregularly. The spaces between the pillows are filled with chlorite or calcite, but not, as is often the case elsewhere, by chert. Their edges, being chilled, are usually slightly harder than the interior and are also often marked by a concentration of varioles-paler green spherical structures about 1/8 in: in diameter due to radial growth of fibrous felspar crystals in the glassy lava. They are easily distinguished from vesicles (which also occur) by their characteristic dirty green colour, and the fact that they are often in contact or appear to have coalesced. The vesicles are about the same size as the varioles (1/8 in. or less), and are usually filled with dark green chlorite, or with calcite which is dissolved out on weathered surfaces leaving holes. Unlike varioles they are discrete and do not touch one another.

The pillow lavas are usually sheared. For this reason the method of distinguishing reversed from unreversed dip, which has been successfully used in many parts of the world, has not so far been applied in this district, but its possible use should not be overlooked. The pillow structure shows that the lavas flowed into, or under, water.

Other basic rocks which are thought to be lavas, rather than intrusions, occur particularly in the area covered by sectional sheet I, around Beacon "Q" and elsewhere. Some are vesicular; others are only mapped as lavas because of their fine-grained texture. All the basic lavas are greenish or bluish-green in colour; where not pillowy they have a blocky jointing.

Thin sections of the basic lavas are rather unsatisfactory because of the fine grain and universal alteration. The varioles are seen merely as more opaque patches and the groundmass is a dirty chloritic, calcitic and leucoxene-dusted material with crisscross or stellate narrow prisms, about 0.3-0.5 mm. long, of altered plagioclase. In some slides, minute sheaves of actinolite show the former presence of interstitial augite. The original composition of the felspars is uncertain; they are now oligoclase. The evidence of the slides, such as it is, suggests that the rocks were normal basalts. There is no evidence of an abnormally sodic composition which would imply spilitic affinities.

(b) Basic Tuffs (not distinguishable on maps)

These are rare among the basic lavas. One band about 100 feet thick was recognized beside the Migori River about I ¼ miles east of Masara Hill. It consists of greenish feebly banded rocks which are seen under the microscope to consist of small subangular grains of basic lavas (felspar microlites in a chloritized and calcitized base), bits of altered felspar, and small detrital quartz grains, in an altered matrix of chlorite, sericite, calcite and quartz. Graded bedding is distinct both under the microscope and megascopically. These features show that the rock is a water-lain and water-sorted deposit derived chiefly from basic volcanic sources, but with no features which prove it to be a true pyroclastic rock.

(c) Banded Ironstones (NBI, part)

A number of different beds of banded ironstone occur in the area. They are easily recognized, and, being hard, form conspicuous outcrops although the beds are actually thin (usually not more than 20 feet). They are useful marker bands in geological mapping.

Although the banded ironstones belong to several distinct groups, they are always essentially similar in lithology and presumably in origin and the description and discussion below applies to all of them.

The weathered rocks are the "banded ironstones" proper. Owing to their susceptibility to weathering the fresh rocks are only seen in underground workings and look quite different from their weathered equivalents. The only places where fresh banded ironstones have been seen in the Migori Gold Belt are at Macalder Mine and the Red Ray adit at Lolgorien. At Macalder Mine they are greenish translucent cherts, with a delicate, and sometimes slightly wavy banding shown by lines and stripes of magnetic -dust. The Red Ray rock is greenish grey, and the banding is less conspicuous.

Thin sections of these fresh banded ironstones show that they consist chiefly of microcrystalline to cryptocrystalline silica (chert) and minute rhombohedra of siderite (ferrous carbonate, $FeCO_3$). The latter are more or less uniform in size and are concentrated in bands. At Macalder Mines there is also some magnetite dust, probably formed from the siderite during the mineralization. No spherulitic or nodular structures, and no greenalite, were seen in the slides examined.

When weathered, the ironstones consist of alternating bands of greenish chert and reddish-brown ferric hydroxides (limonite). The bands are seldom more than ½-in. thick and usually about ¼-in. or less. Most of the cherty bands show delicate lines of limonite parallel to the main banding. It can sometimes be seen that a thick ferruginous band is associated with a thick band of chert. According to the accepted explanation for the formation of these rocks by co-precipitation of colloidal silica and ferric hydroxide, the ferruginous layer should be the lower one in such a pair, since ferric hydrosol is precipitated much more quickly than colloidal silica. This relationship has not been checked in the field but if established should be useful in elucidating structure in a mine such. as Macalder where banded ironstones are closely associated with the mineralization.

Thin sections of the weathered rocks from various places in the Lolgorien area show clearly that they are oxidized sideritic cherts. The siderite rhombs have been altered to microcrystalline gothite with preservation of their form.

Associated Rocks

On Lolgorien Hill the banded ironstones are associated with moderately coarse sandstones and graywackes. Ironstone bands, one up to ten feet thick, alternate with the sandstones. The contacts are sharp. At the eastern end of the Lolgorien ridge the Masai have scraped red material from an outcrop of hematitic slate which underlies the ironstone. This is like the "paint rocks" of the Canadian Ironstone formations.

A second banded ironstone, occurring at a higher horizon in the Lolgorien area, outcrops about three-quarters of a mile south of the Lolgorien ridge and can be traced some miles westwards; this, too, occurs among graywackes:

At Macalder Mine the banded ironstone lies on basic lava but is overlain by graywackes, and the numerous impersistent bands which run through Makuru and Nyabasawa Hills occur among ferruginous slates. Elsewhere in the area banded ironstones occur also among basic lavas, where their immediate association is often not known, but the evidence is at least not inconsistent with the supposition that in these cases they occur between the lava flows, even if they are not actually within sediments.

Origin

The origin of banded ironstone formations has been the subject of discussion for many years. It is certain from the nature and delicacy of the banding that they are of colloidal origin; the silica was evidently precipitated as a gel. The general association with waterlain sediments or with lavas whose pillow structure shows they flowed out under water, indicates that the banded ironstones were deposited in water. Detrital grains are, however, seldom seen in them, showing that the conditions which led to their formation were correlated with a practically complete œssation of normal sedimentation. Sharp junctions suggest that the change from normal sedimentation took place suddenly.

In most places the unweathered banded ironstone, unless metamorphosed, consists, as it does in the Migori area, essentially of siderite and microcrystalline silica. Many geologists have concluded, therefore, that these were the original minerals deposited. The uniform size of the siderite rhombohedra in the banded ironstones of the Migori area suggests that they were formed as a chemical precipitate. On the other hand the physio-chemical evidence, exhaustively discussed by Moore and Maynard (1929) is in favour, of the view that the iron was precipitated as ferric hydroxide. They conclude that assuming abundance of organic matter, cold water could have extracted and transported enough iron and silica from the great areas of basic igneous rocks exposed in pre-Cambrian time to build up even such: large deposits of banded iron and silica as occur in North America. The iron would be dissolved and carded as ferric oxide hydrosol and the silica as colloidal silica, both being stabilized by organic matter which would inhibit their co-precipitation.

Moore and Maynard suppose that the sols were eventually thrown down by the action of the electrolytes in the sea. Woolnough (1941) accepts this mode of transportation of the hydrosols but argues for deposition in isolated closed basins on a peneplained land surface rather than in the sea. Some writers have advocated precipitation by algae. If the iron was precipitated as ferric hydroxide, its alteration to siderite was probably the result of the decomposition of associated organic material.

Structure

The banded ironstones are commonly sharply contorted and broken by small faults whose throws are often only a fraction of a foot. These structures are appropriate to a rock consisting of alternating bands of brittle and softer material, which has been deformed by earth stresses. They are related to other structures of tectonic origin and are not due to contemporaneous slumping. The physical character of the banded ironstones probably also explains their frequent association with the mineralization. They tended to fracture easily and the fractures could be penetrated by the mineralizing solutions.

(d) Other Sediments within the Basic Lava Group

Thin bands of sediments occur among the basic lavas at various places but can seldom be traced far. A band of graywacke was mapped on scanty evidence south of the Longawone Range. The presence of such sediments shows that the basic vo1canic series must actually consist of many separate flows, some separated by sediments which indicate a long interval between the successive eruptions.

2. THE GRAYWACKE GROUP

The group comprises the following rock types: (a) Graywackes, (b) Gritty andesitic tuffs, (c) Conglomerates, (d) Banded ironstones.

(a) *Graywackes*. (Nf). -Probably the most widespread rock type in the Migori Belt is a cleaved and usually indistinctly bedded rock consisting of quartz grains and angular or subangular bits of felspar, scattered through a dirty greenish matrix which itself forms a considerable proportion of the rock. The quartz grains can always be seen with a lens, and nearly always with the naked eye. On the sectional maps the graywackes have been distinguished from various other associated rocks: conglomerates (NC) which contain pebbles in a similar matrix; a rather ill-defined group of various slaty rocks (Nt); shales (NS); and gritty tuffs (NT). Owing to the variability of all these rocks from bed to bed and from place to place, their separation is usually somewhat arbitrary; bands of graywacke are common in the shales and slaty rocks and bands of shale in the graywacke, and so with the others. Nor do the lines of separation necessarily or even probably correspond to time divisions; shales in one place may have been formed at the same time as graywacke or conglomerate elsewhere.

In thin sections, the graywackes are seen to consist of angular or subangular, but very rarely rounded quartz grains, and subangular altered felspars (usually now oligoclase), occasional chloritized flakes of biotite, and very rarely a few flakes of muscovite. There are also often grains of micro-crystalline quartzose material which may be altered acid lava, or possibly chert. A few grains were definitely identified as felsite containing quartz blebs. The grains lie in a matrix the chief component of which is sometimes sericite and sometimes chlorite; these minerals, which occur in minute flakes, more or less parallel throughout the rock, have been formed during the low grade metamorphism which the Nyanzian rocks have undergone. Other minerals, some or all of which are usually present in the base, are quartz, felspar, rutile, calcite and rarely biotite.

(b) *Gritty Andesitic Tuffs* (NTf).-Some rocks in the graywacke group are distinctly bedded and contain detrital quartz grains like the other graywackes, but contain much more felspar, and have a matrix which is not chloritic but yellowish or light grey. These rocks were evidently deposited while andesitic material was being erupted somewhere in. the vicinity and either the dust and felspar crystals fell as volcanic "ash" into the water in which the ordinary graywacke material was being deposited, or was washed down by rivers from the volcanic area and became mixed with the graywacke material. The result, whichever was the case, was a mixture of dust and felspars of andesitic origin, with the gritty mud which by itself formed the graywackes. It was thought at first that these gritty tuffs (or tuffaceous grits) should be correlated with the Masara andesitic rocks, but from the diagram (Fig. I) of the lateral changes along the Migori Belt, and from the maps, it can been seen that this is not so, if the correlations and grouping adopted are correct.

Microscopically, these rocks consist of an unsorted mixture of angular fragments and whole crystals of turbid altered plagioclase with fewer angular grains of quartz, and numerous fragments of altered andesitic lavas. In one slide, there were also pieces of a dacitic lava containing corroded quartz crystals as well as the usual plagioclase felspars. All the quartz grains might well have been derived from such dacitic lavas. Many appear to be corroded, or have crystal faces, or the irregular curved cracks typical of the quartz crystals in dacites. Some of the rocks may therefore be dacitic tuffs rather than gritty andesitic tuffs.

(c) *Conglomerates*. (NC).-About two miles north-north-east of the Kenya Gold Mining Syndicate Mine, there is a narrow zone of pebbly graywacke, which can be followed for a little over two miles eastwards. After a gap of nearly two miles, a similar conglomerate appears at the same horizon and north of Nyabasawa forms a distinct ridge. It is there about 300 feet thick, and is nearly vertical. About a mile east of Nyabasawa the lower, or northern, surface of this conglomerate zone suddenly swings round, across the end of the Migori agglomerate (NA on sectional maps), after running back as an embayment into the agglomerate mass, the contact follows an irregular north-easterly course to the dioritic porphyrite which, with the Kavirondian boulder beds presumably overlaps it unconformably. The upper contact of the conglomerate follows a more or less straight line across the area near Suna as shown on Sheet IV of the 1:25,000 maps. The width of outcrop of the conglomerate thus increases from about 200 yards to about I ½ miles, in a distance, measured along the: strike, of half a mile. Two miles east of the Suna dukas the conglomerate outcrop must narrow rapidly again, though the lower contact cannot be accurately located here owing to lack of exposures. Still further east the conglomerates again increase in thickness, until they have a width of outcrop of about half a mile on Maganana Hill, beyond this they pass into graywackes as suggested diagrammatically on the map. Other conglomeratic graywackes in the Kahancha area (Sectional Map V) are mapped as lenticular masses. Further east again near Lolgorien (Sectional Map VIII) there are two lenticular zones of conglomerate which are apparently at about the same horizon in the graywacke series as those further west. These lenses near Lolgorien are probably nowhere more than 50 feet thick.

The remarkably sudden swelling of the conglomerate outcrop at Suna is associated with some changes of strike which are unique for this goldfield, in which strikes are generally remarkably regular. Where the conglomerate passes across the end of the Migori agglomerate, the strike swings through 90° to a north-south direction; nearer the porphyrite, the dips and strikes are irregular. On the other hand in the Migori River south of the Suna Bridge the dips in the conglomerate are very regularly south-eastwards. The irregular strikes, and the transgression across the end of the agglomerate, are perhaps best explained by supposing that a thick mass of gravelly sand was deposited in a deep channel or valley cut across the end of a large pile of the agglomerate, and that the stresses set up at the irregularly transgressive contact caused some local buckling and perhaps faulting which emphasized and distorted the already anomalous contact. The irregularity of the present dips and strikes would thus be due partly to deposition on slopes and partIy to the local folding.

The pebbles in these conglomerates are well rounded and usually not more than an inch in diameter. Most of them consist of chert or jasper. Red jasper pebbles are particularly characteristic of the Suna conglomerates and those further west. The source of the jasper is not known. Grey and black chert pebbles are also common; a few whitish ones may be felsites.. Of 27 pebbles collected from the conglomerate near Lolgorien, five were of bluish chert, all of which were pyritized, the pyrite in some occurring as films and stringers along cracks, in others as cubes and pyritohedra. One of the chert pebbles was definitely banded. There is no doubt that these chert pebbles were derived from a banded ironstone horizon, in which pyrite had already been deposited. The other 22 pebbles were all igneous, and all were too much decomposed to be identified accurately but they were non-porphyritic, aphanitic rocks, dirty greenish-buff in colour. Quartz blebs were doubtfully identified in one pebble, suggesting a dacitic composition.

Small trial holes had been dug in the conglomerate near Lolgorien; why and with what results is not known.

(d) *Banded Ironstone* (NBl, part).-In the Lolgorien area, about t mile south of the Lolgorien Ridge, a banded ironstone occurs in the graywacke series. It can be traced westwards for about two miles, and after a gap, it reappears and can be traced a further two miles, to a point about half a mile south of the Migori bridge, six miles west of Lolgorien. Other small discontinuous outcrops of banded ironstones occur at about the same horizon as far west as the old saw mill site north of the small granite boss which is shown near the north-west corner of Sectional Map V. These banded ironstones are similar to those already described as occurring among the basic volcanic rocks in the lower part (Group I) of the Nyanzian succession. In the Lolgorien area they are often associated with small auriferous quartz veins such as those formerly worked by Mr. W. Rainbow. Some of the veins lie in a thin band of sheared sediments which divides the ironstones into two bands.

3. SLATY AND ANDESITIC GROUP

The following are the chief rock types included in this Group:

(a) Tuffaceous, silty and ferruginous slates (Nt);

(b) Banded Ironstones of Makuru (NBI) (Part);

(c) Masara Andesitic rocks (NAT, NAA, NAAT, NAP) (NA);

(d) Shales (Ns).

(a) Tuffaceous, silty and ferruginous slates (Nt)

This is a miscellaneous group, which includes a variety of rocks most of which were not precisely identified. The term "tuffaceous slates" is intended to apply particularly to a group of rocks which occur close to the granite in the Kenya Gold Mining Syndicate area. They are hornfelsed near the granite (see sectional maps) and are then hard, striped, greenish and grey flinty rocks. A little further from the granite, sericitic schists occur, and still farther away, platy kaolinitic slates in which there are often very thin dark shale films. These rocks are evidently tuffaceous, and they may be andesitic or rhyolitic dust tuffs. The more altered rocks nearer the-granite –were probably similar. They are associated with quartz porphyries which may be either intrusive sheets, or lavas. These tuffaceous slaty rocks of the Kenya Gold Mining Syndicate area extend from the Migori, south-south-west of Masara Mill, east-south-eastwards about ten miles along the strike, between the Masara Andesitic Group (c) which they overlie, and the granite which is in intrusive contact with them. Towards the Suna area they pass into silty slates.

Ferruginous slates are the predominant type in the zone which extends from Suna to the Masara-Kwere fault, between the Graywacke Group to the north and the Masara andesitic rocks to the south. The "ferruginous slates" are rusty-weathering argillites, soft and with a flasery, rather poor cleavage. In some places they appear to be kaolinized. They form the country rock of numerous impersistent-banded ironstones (the Makuru Banded Ironstones (b)) It is probable that the fresh rocks would be found to contain their iron largely in the form of siderite, as is the case with the banded ironstones.

Many of the rocks from further east which are included in this group are best described as silty slates. They are not well exposed and are extensively hornfelsed by the adjacent granite, but in many places are seen to be alternating slates, shales, flaggy shales and fine-grained cleaved graywackes.

(b) Banded Ironstones of Makuru (NBI part)

Among the ferruginous slates already mentioned there are numerous banded ironstones. These range from Nyabasawa Hill, west of Suna, through Makuru Hill, and westwards towards the Migori River, south of Masara Hill. They are lithologically similar to those already described, the only difference noticed being that in some of them the proportion of iron is much less; in these cases they are grey cherts, without the usual limonitic bands. Individual bands are less persistent and thinner than those in the lower Groups.

(c)Masara Andesitic Rocks (NAT, NAA, NAAT, NAP, NAA) (NA)

A group of andesitic volcanic rocks appears near Suna (Sectional map IV) and expands westwards to a thickness of over 1,500 feet at Akala (Sectional map II) where it is cut off by a fault which there separates the rocks of the Gold Belt from the granite. In the eastern part of their outcrop the andesitic rocks are mostly felspathic crystal tuffs.

The rocks may be distinguished from other andesitic groups as the Masara Andesitic Rocks, Masara being the area around the Kenya Gold Mining Syndicate Mine where they are developed in greatest variety.

In that area they include andesitic crystal tuffs, andesitic lapilli tuffs and contemporaneous porphyrite intrusions. Further west at Akala the series is a monotonous mass of rocks which include both andesites and tuffs. In the field these are here so similar that it has not been found practicable to separate them. Generally speaking the rocks are andesitic, but with distinct dacitic affinities. The rock types distinguished on the sectional maps are-

Andesite (NAA) Andesitic lapilli tuff Andesitic crystal tuff (NAT) Porphyrite (NAP)	} NA

The symbol NAAT implies andesites and tuffs, not mapped separately.

(i) *Andesite* (NAA).-Many of the rocks in the Akala area (Sectional Sheet II) are andesites. They are usually sheared and decomposed to a light greyish colour. A typical rock from the Kuja River one mile west-north-west of Masara Hill, is seen in thin section to consist of cloudy euhedral plagioclase' phenocrysts in a calcitized and sericitized base. Signs of shearing and fracturing are conspicuous. Another rock, similar in appearance, from the road near Macalder's wooden bridge over the Kuja, was found to contain corroded quartz crystals as well as the usual larger dusty plagioclase~ phenocrysts. The base, as in most of these rocks, is decomposed but was evidently felspathic. This rock is, therefore, a dacite. An andesite from the roadside ½ mile north of Akala *duka* contains dirty brownish biotite as minute flakes in the groundmass, and has probably been thermally metamorphosed.

(ii) *Andesitic lapilli tuff*- The lapilli tuffs can usually be recognized in the field by the form of their weathered outcrops, which are often spiky little crags with the irregular lumpy appearance characteristic of agglomerate outcrops. The lapilli and ejected blocks range up to six inches or so in size; they are paler than their matrix.

Thin sections show chips and crystals of felspars ranging from albite to zoned andesine, a few quartz grains, and lapilli of andesite or dacite, in a sheared base mainly composed of sericite and chlorite.

(iii) *Andesitic crystal tuff* (NAT).-These are tuffs of andesitic composition, consisting essentially of acid plagioclase crystals and chips with usually a few quartz grains, in a sheared sericitic base. Minute greenish-brown biotite flakes seen in some slides indicate metamorphism by the not far distant granites. The presence of sporadic quartz grains in the rocks suggests that dacitic rocks may have been erupted, though most of the ejected material was andesitic.

Particularly in the eastern part of the outcrop of these tuffs, bedding is sometimes distinct though never conspicuous. Slight sorting of the constituents is then noticeable in thin section.

(iv*) Porphyrites associated with the Masara Andesitic Rocks*.-Several lenticular sheets of porphyrite occur among the Masara Andesitic Rocks; their close petrological affinities with the volcanic rocks, and their occurrence among them, indicates that they are part of the same volcanic episode. They are probably contemporaneous intrusions.

The largest sheet forms the country rock at the Kenya Gold Mining Syndicate Mine at Masara. It is a grey rock with abundant whitish felspar phenocrysts up to a quarter of an inch in length; in the shear zones which traverse the mass, these felspars are smeared out to mere films, and the rock itself becomes a platy greenish-grey mylonite. "Blackhall's Reef" (Kenya Gold Mining Syndicate Mine)* occurs in a shear zone of this kind. Examples of the transition from the normal, rather feebly cleaved porphyrite, with the characteristic large felspars, to its mylonitic derivative with smeared-out felspars, can be collected from the spoil heap.

* K.G.M.S. Mine on maps.

Thin sections of the normal rock show cloudy altered plagioclase (oligoclase) in a fine-grained felspathic base with the usual alteration products. A slice of a rock from a smaller mass (not marked on the I: 25,000 map) close to Kenya Gold Mining Syndicate's "D.A. reef", showed that although very similar to the "Blackhall's" porphyrite, it differed in containing corroded quartz crysta ls and is thus a dacite. Another intrusion, also dacitic, occurs near the Migori about I 1/2 miles south of Masara Trigonometrical Station. (This also is too small to be shown on the map.) There is also a long narrow lenticular outcrop of the "Blackhall's" type porphyrite south of the small granite boss shown on Sectional Map III.

North of the junction of the Migori and Kuja Rivers (Sectional Map II) is a thick lenticular mass of porphyrite similar to the "Blackhall's" type. It was intruded into dolerites (now metamorphosed to epidiorites and hornblende schists) and lies structurally above the top of the Masara Andesitic Group, so it is perhaps slightly younger, but it is mapped under the same symbol and probably belongs to the same volcanic cycle. The rock contains white plagioclase phenocrysts (oligoclase) in a' dark grey altered base. It is strongly sheared throughout.

(d) Shales (NS)

Lenticular masses of shales occur particularly in the upper part of the Slaty and Andesitic Group (Group 3). They are normal grey-blue shales, surprisingly free from admixed tuff or silty material. Even a thin band within the Masara-Andesitic (1rnnp. east of Kenya Gold Mining Syndicate Mine, is free from ashy material. Microscopic examination of the shales which form the country rock of some of the Kahancha veins discloses only scattered silt grains in a predominantly argillaceous rock. Some of the shales are graphitic, particularly those in the band in which "No.5" and other veins occur at Kahancha. In some places near the granite contact they are phyllitic and in a few localities are metamorphosed to *knotenschiefer* or chiastolite slate. Generally, however, the shales are surprisingly little metamorphosed, even close to the granite. Near Kenya Gold Mining Syndicate Mine for instance, shale, apparently unaltered, occurs within 200 yards of the granite contact.

4. OTHER ROCKS, THE POSITION OF WHICH IN THE NVANZIAN SEQUENCE IS NOT KNOWN

(a) The Migori Agglomerate

An area about six miles long and a mile wide, west of Suna, immediately to the south of the dioritic porphyrite, is underlain by a very uniform kind of agglomerate or lapilli tuff. It is a dark irregular-weathering rock consisting of :pale angular lapilli and ejected blocks and occasional small bits of red jasper, in a dark chloritic matrix. It gives rise to the jagged and spiky outcrops typical of cleaved agglomerates. Bedding is rarely seen in the mass, though in a few places near its southern margin, steep dips towards the south were observed, suggesting that it underlies the graywackes which occur on that side. The conglomerate which cuts across the eastern end of the agglomerate mass (see p. 15) evidently also overlies it. On the other hand, at its western end the agglomerate seems to finger out into a series of badly exposed siliceous mudstones, which together with some banded ironstones and graywackes form a part of the anomalous northward-dipping area east of Macalder Mine. A slide of the agglomerate showed angular lapilli of andesitic type, containing altered plagioclase phenocrysts in a fine grained altered base containing matted felspar microlites. The matrix is chloritic and altered.

(b) Sediments west of the Migori Agglomerate outcrops

Cleaved mudstones, silicified mudstones, graywackes, and banded ironstones occur west of the Migori Agglomerate as. stated above. Some of the banded ironstones are typical, others are better described as cherts. One band, which can be traced at intervals for three miles, dips north-east. The associated mudstones are brownish-weathered blocky rocks, often only slightly cleaved; some are distinctly banded. They are included in the miscellaneous slaty group (Nt) on the sectional maps, without any implication that they are to be correlated with other rocks mapped under the same symbol. Graywackes in the same area are similar to those of the Graywacke Group.

(c) Felsitic andesitic and cherty rocks (NF) north of Macalder Mine

Still further west, some of the rocks mentioned above (sub-paragraph (b)), seem to pass into felsitic, andesitic and chert ' rocks. Among these rocks are andesitic tuffs, with distinct bedding; others are gritty. Another type appears to be a felsitic lapilli tuff, and rocks identified in the field as andesite, felsite, porphyrite and chert also occur. Exposures are not good enough, and too few; of the rocks have been determined microscopically, to differentiate them, nor has their relation to the rocks towards which they strike been determined. Westwards, they can be traced as far as the Kuja River on the other side of which there are porphyrites. An area of granitic porphyrite has been mapped separately among these rocks, but may extend further east than indicated on the map. It closely resembles the marginal facies of the dioritic porphyrite seen north of Suna. The limit of the "tuffs, felsites and andesites" (NT), as shown on the sectional maps is merely an envelope roughly defining the area in which these rocks are seen.

3. The Kavirondian System

The Kavirondian System is separated from the Nyanzian System by an angular unconformity, proving that a period of crustal deformation occurred during the interval between the deposition of the rocks of two systems. There is also in most. areas a well marked difference between the rocks that are included in the two systems. In North and Central Kavirondo the Nyanzian rocks are mostly volcanic while the Kavirondian are exclusively sedimentary. In the Migori belt in South Kavirondo sediments form a considerable part of the Nyanzian sequence, while large masses of igneous rocks occur associated with the Kavirondian rocks. Some of these are certainly extrusive. They are however easily distinguished from any of those of Nyanzian age. Two kinds of sediment are particularly characteristic of the Kavirondian, both here and elsewhere, in Kavirondo. These are the boulder conglomerate with large rounded boulders of granitic and other rocks (see Plate II, Fig. 3), and a grey felspathic grit. Shales also occur in the series, and some hornblende andesites that are regarded as lavas.

(a) The Boulder Conglomerates (KC)

These extraordinary and striking rocks consist of 'large and well-rounded boulders, sometimes as much as three feet in diameter, of a variety of rocks, among which granodiorite is conspicuous, in a felspathic gritty matrix. Usually they are not bedded, but occasionally a faint stratification can be seen. Cleavage is seldom obvious.

The following rocks have been identified as boulders in these conglomerates:

Granodiorite: G2
Porphyritic hornblende granite (or granodiorite): G2P
Foliated hornblende granite (or granodiorite): /G1
Foliated porphyritic hornblende granite (or granodiorite): /G2P
Diorite
Aplite: ap
Older Dolerite (fine-grained mottled type): Dl
Basic volcanic rocks, some vesicular: NB
Greenish graywacke or grit: Nf
Andesite (or porphyrite)
Dacite
Quartz porphyry: QP
Fine-grained hornblendic schist (Hornfels of contact zone)
Hornblende porphyrite or andesite: KA
Dioritic porphyrite: PDI
Red jasper
Black and grey chert
White vein quartz
Bluish-grey vitreous vein quartz

The rock groups from which these are believed to have been derived are indicated by the symbols which correspond with those on the maps.

The granitic rocks closely resemble those of the G2 granite suite. The large size of the boulders (a granodiorite boulder three feet in diameter in the conglomerate of Kobeia Hill is shown in the photograph Plate II, Fig. 3) proves that they cannot have been carried very far, and the general assemblage strongly suggests derivation from the G2 granites immediately south of the gold belt. The occurrence of fine-grained hornblendic rocks, like those near the granite contact there, adds weight to this suggestion.

Many of the other boulders are certainly derived from the Nyanzian series, notably the basic volcanic rocks, the graywackes, and probably the andesitic and dacitic ones. Others (Older Dolerites, quartz porphyry) must come from pre-Kavirondian intrusions.

Other boulders, of diorite porphyrite and hornblende andesite, may be derived from rocks that are themselves of Kavirondian age. Hornblende andesites are frequently seen in traverses across the conglomerate zones in the eastern part of the area. They follow the general strike of the conglomerates, and are often brecciated. The immediately adjacent' conglomerates also contain angular blocks of the same kind of rock so that it is difficult to see where one ends and the other begins. These hornblende andesites are evidently true lavas.

The dioritic porphyrite boulders are abundant in the boulder beds which cover a large area north of the River Kuja (Plate III), in the boulder beds west of the Kuja (about two miles north of Macalder Mine) and in those along the north side of the dioritic porphyrite mass near the old Kahancha-Kisii road. The conglomerates in the j first of these areas probably overlie the dioritic porphyrite. The relation in the second locality is doubtful. Those of the third area, when followed westward along the strike, are found to dip towards, and apparently under, the dioritic porphyrite. By postulating a strike fault separating this third conglomerate mass from the dioritic porphyrites south of it, it is possible to maintain that all those conglomerates, which contain dioritic porphyrite boulders, are younger than the porphyrite, which can then be regarded as intrusive into the earlier Kavirondian boulder beds. Otherwise, it is difficult to avoid concluding that the dioritic porphyrite is a mass of lavas, from which blocks are carried into boulder beds that were accumulating during the eruptions. For reasons discussed later, the dioritic porphyrite is thought to be intrusive, and the former interpretation is preferred.

(b) The Felspathic Grits (K,)

In the Kavirondian System there are some grey rocks, so homogeneous that, at first sight, they might be mistaken for andesites or porphyrites, but which can be seen on closer examination to contain abundant clastic quartz grains, as well as the felspars which are their chief constituent. Bedding is very indistinct, though occasionally cross-bedding can be seen. These rocks are not common in the Migori area, but occur in a few places, notably a few miles north of the Kuja, as shown on Sectional Map I (on which they are not differentiated from the boulder beds), on the same strike east of the Kuja, and in several other places shown on Sectional Maps VI, VII and VIII. Their presence is noteworthy because rocks of this kind are widespread in the Kavirondian Series of North and Central Kavirondo, and also occur in the equivalent North Mara Series of the Musoma district (Stockley, 1936). The typical felspathic grits of North and Central Kavirondo are apparently somewhat coarser and more obviously clastic than those found in the Migori area.

Microscope study of one of these felspathic grits showed that its material must have been derived mostly from granites and dioritic porphyrites. The disintegration of these rocks to felspathic sand was accomplished without much decomposition of their minerals since the felspars are still quite fresh, although the material must have been carried by rivers some distance to the place where it was deposited. The freshness of the felspars is consistent with the suggestion that they were deposited in cold climatic conditions (Hitchen, 1936, pp. 21-22).

PLATE II

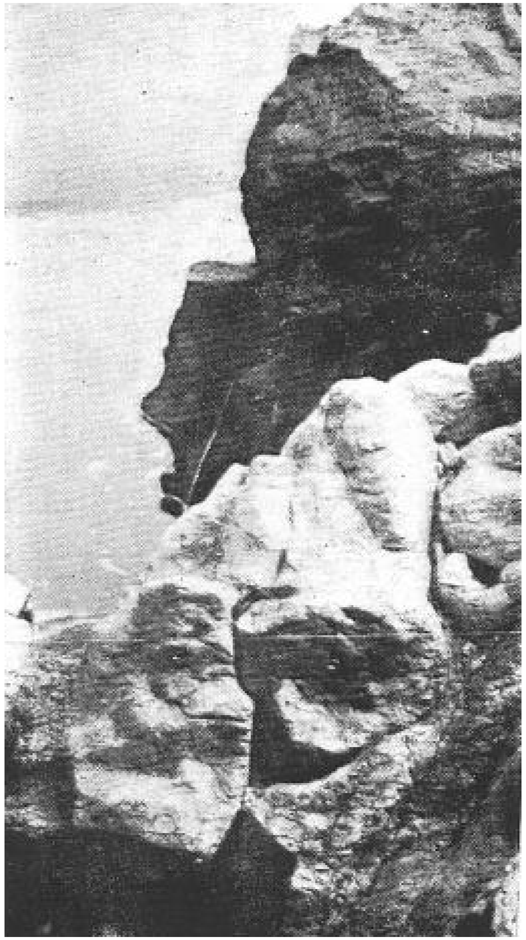

FIG. 1

Pillow-lava (Nyanzian System) by the Migori River, 6 miles west of Lolgorien.

FIG. 2

Folded Banded Ironstones (Nyanzian System) on Lolgorien Hill

FIG. 3

Boulder Conglomerate (Kavirondian System) on Kobeia Hill. The large boulder at the bottom is about 3 feet in diameter and consists of G2 type granodiorite.

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(c) Shales (KS)

Near the Migori River north of Lolgorien are some grey and blue-grey shales which are evidently Kavirondian in age since they occur among typical boulder beds and themselves sometimes contain scattered pebbles. Lithologically, they appear no different from the Nyanzian shales.

(d) Hornblende andesites (KS)

As has been mentioned, there are among the conglomerate~ in the eastern part of the area (see Sectional Maps VII and VIII) some hornblende andesites which are evidently lavas of Kavirondian age. They fire grey rocks with glistening black hornblende prisms. They were erupted in thin flows, the upper parts of which consisted of broken-up blocks. Angular blocks of the same easily recognized rocks are found in the associated conglomerates, as well as elsewhere in the conglomerates of that area. In bulk they form an insignificant part of the Kavirondian system, but arc interesting as showing that there was some volcanic activity during Kavirondian times (cf. Hitchen, 1936, p.14).

Structure and Thickness of the Kavirondian Rocks

No clear exposure of the base of the Kavirondian rocks has been found in the area. The variety of boulders in the conglomerates, derived from the Nyanzian system and the G. suite of granites, proves, however, 'that powerful deformation of the Nyanzian rocks must have occurred before the boulder beds accumulated. Further, the dips in the Kavirondian rocks and the associated flow-banded dioritic porphyrite are contrary to those in the Nyanzian rocks along part of the northern side of the Gold Belt. This indicates a structural break or unconformity as shown in the sections (Fig. 5). The form and relations of the patch of boulder conglomerate (containing the usual granite boulders), about three miles north of the Kenya Gold Mining Syndicate Mine indicate that it lies unconformably on the Nyanzian rocks there. A point established by the present work is that the Kavirondian boulder beds and other sediments are not here merely superficial patches lying on the older rocks, as was suggested by the geologists employed by Messrs. Kenya Consolidated Goldfields, Ltd. (Hallam, Fitch and Edgeworth-Johnstone, 1938, p. 7). Dips are often steep; the rocks have evidently been affected by strong folding and faulting.

The thickness of these Kavirondian sediments is unknown, since their upper limit is not exposed, but the boulder beds now seen in the area must in some places be several thousand feet thick.

Mode of origin of the Kavirondian sediments

The extensive and thick boulder deposits could only have been formed in a mountainous region. The large boulders must have been swept down from the mountains by powerful torrents and. rapidly accumulated in valleys or depressions at their foot. The mountains were probably formed during the period of intrusion of the G2 granites, when the Nyanzian rocks were first compressed, sheared, and folded. The surface expression of these movements may well have been a series of fold mountains with some considerable fault scarps.

4. Intrusive Igneous Rocks

The following rock types are recognized as intrusions among the older rocks:

PLUTONIC ROCKS

Older Granitic Suite.

Fine-grained grey gneiss (included in /G2)
Granodiorite and hornblende granites G2, 02P, /G2, /G2P
Syenitic facies (S2 and / S2) of the 02 granites

Younger Granitic Suite.

Porphyritic granite and related types G3P, G3, G3ap
Syenite S3

Acid.

Granite Porphyry GP
Aplite ap
Quartz Porphyry QP
Felsite F

Intermediate

Dioritic Porphyrite POI
Porphyrite of Masara andesitic group NAP
Porphyrite P

Basic

Older dolerites DI; coarse mottled type DIC; fine grained speckled type DIF
Younger dolerites D2

These rocks are briefly described below; their probable relative ages are indicated in the correlation table (Section VI).

PLUTONIC ROCKS: THE GRANITES AND RELATED INTRUSIVE TYPES

(a) Fine-grained grey gneiss.

Some fine-grained gneissose or streaky grey rocks were distinguished in the western part of the main granite area. It is doubtful whether they should be classified as separate intrusive group since they ate probably granitized basic rocks or contaminated granite. They are, however, fairly distinct and extensively developed. They have not been shown separately on the published maps.

Microscopically a typical rock (V, 18) of this group was found to consist of subhedral crystals of acid plagioclase (oligoclase) and some orthoclase, in a granular mosaic of quartz, microcline, and albite-oligoclase, with sub-parallel flakes of biotite, anhedral bluish-green hornblende, some sphene, and apatite. The most characteristic feature of the rock is its granulitic texture which is shown particularly by the simple shapes and even size (about 0.1 mm.) of the quartz grains. The foliation arises from the subparallel arrangement of the biotite flakes and a less rigid parallelism of the hornblende prisms.

A similar texture and constitution is seen in a slide (V, 11) of a grey fine-grained gneissose rock injected by veins of aplitic granite. The small grains of quartz are well exemplified in this rock. The field relationships at the locality where it occurs (Angoiche River bridge, on the Suna-Mohoru road) leave no doubt that the grey gneiss is here a granitized basic rock, and it is very probable that all the rocks of this type are hybrids in the G2 granites.

The older (G2) granite suite

Most of the large region of granitic rocks south of the Migori Gold Belt is mapped as G2 or Older Granite and it is believed that much of this mass is pre-Kavirondian in age, because boulders similar to the chief types distinguished have been found in the Kavirondian conglomerates. The boulders were probably derived from the upper parts' of the batholith, since removed by erosion, so that exact correspondence with the types now exposed is hardly to be expected.

(a) Granodiorite and hornblende granite G2

The most distinctive type of this widespread and variable group is a non-porphyritic granodiorite with a panidiomorphic or monzonitic texture. The rock consists largely of small stumpy well-formed oblong crystals of oligoclase 3 to 7 mm. long. They are white or greenish-white in hand specimens. Their matrix is a pink and grey mixture chiefly consisting of quartz, microcline and hornblende. The granodiorites do not usually outcrop very conspicuously. There is, however, a general tendency for more acid types (hornblende granites) to occur further from the contact and some of these are transitional towards the G3 type of granite. These types tend to give rise to rockier country, like that typical of the G3 Granites.

Microscopicaly the typical G2 granodiorites are seen to consist of about 50 per cent oligoclase, 15 per cent microcline, and 20 per cent quartz, the rest being chiefly hornblende, biotite and a little sphene.

The oligoclase crystals are usually feebly zoned, and clouded .by alteration products. Microcline and quartz are interstitial and anhedral. Incipient replacement of the cloudy oligoclase by c1ear microcline is sometimes seen as well as myrmekitic quartz-felspar intergrowths. The quartz sometimes shows slight strain-polarization.. The dark minerals are commonly associated in clots which probably represent incompletely assimilated basic material. Green hornblende, subhedral or spongy, is the principal dark mineral. It is usually associated with greenish-brown biotite, magnetite, apatite, and often epidote. Relics of colourless augite are occasionally seen in the hornblende.

(b) Porphyritic and sub-porphyritic hornblende granite (G2P)

In some zones in the G2 granite, poorly formed phenocrysts of microcline occur. These zones are separated in some places as G2P on the maps; Apart from the presence of the phenocrysts, which have a sub-parallel arrangement, the rocks are similar to the normal G2 granites.

(c) Foliated granodiorite IG,

Near the margin of the granite complex, along the south side of the Gold Belt, the granite is strongly sheared and foliated. This is a common feature near granite contacts. The shearing is usually parallel to the walls; this is believed to be the case here.

The foliated granodiorites contain small white plagioclase idiomorphs similar to those of the normal G2 granites. The foliation is seen in slides to be due to flow having taken place chiefly in the matrix between these crystals. There are lenticles of granular quartz and microcline, curving sinuously round the plagioclase idiomorphs. Dark streaks following the same flow lines consist of sub parallel biotite flakes and hornblende prisms. The oligoclase evidently crystallized early, and the remaining magma with these innumerable oligoclase crystals suspended in it, must have been forced .by the pressure from below to flow upwards as it was crystallizing. The movement evidently continued after crystallization was complete, resulting in some mylonitization. This final mylonitization was guided by the previously developed flow structures, and the plagioclase crystals largely escaped its effects. The shearing stress transmitted through the part crystallized, part viscous magma was such that the solid adjacent country rocks were themselves intensely sheared throughout a zone hundreds of feet thick. A conspicuous feature of the shearing both within the granite and in the adjacent sheared country rocks is a strong linear texture (lineation) due to the extension of the mineral particles along the direction of movement, which is shown by the pitch of the lineation to have been everywhere upwards and slightly eastwards.

(d) Augen-gneiss (/G2P)

Near the contact of the granite with the Gold Belt rocks, especially in the west of the area, foliated porphyritic granodiorites and augen-gneisses are found, and are typically exposed near the Migori Bridge on the branch road to Macalder Mine. They are essentially similar to the other foliated rocks in the marginal zone except that they contain conspicuous microcline porphyroblasts or augen.

(e) Marginal syenitic types (/S, and S2)

Near the margin of the G2 granite complex in the Lolgorien area, pink syenitic modifications occur near the contact. Within the marginal shear zone they are foliated and shown on the Sectional Map as IS,; where they extend beyond the shearing, they are shown as S2' A slide of one of the un-sheared rocks showed it to consist of acid oligoclase, orthoclase, microcline, chloritized biotite, and hornblende, with calcite, iron-oxide staining and other signs of alteration. A very small proportion of quartz is present.

Contamination, hybridization and xenoliths in the G2 granite suite

The main G2 granite mass south of the gold belt is distinctly more basic towards the contact and some assimilation of the country rocks has obviously occurred, though for reasons given below it is not thought that assimilation of the rocks along this contact, at the present level of erosion, has been on a very large scale. There are however, in the G2 granites in many places small basic xenoliths, or streaks and patches of more completely assimilated basic material. The least altered of the xenoliths consist of an aggregate of small blades of a slightly bluish-green hornblende, some greenish-brown biotite, magnetite, and epidote. They are fragments of dolerites or basalts that have been soaked by granitic fluids. The basification of the granite surrounding them is evident.

In a syenite exposed by the Migori River about six miles south-east of Kahancha, orbicular structures, the size of a hen's egg and consisting of alternating blackish and green shells, were seen. Microscope examination of one of them showed a core of quartz, calcite and a little green chlorite or serpentine, traversed by lines and streaks of granular magnetite, forming a pattern which suggested derivation from olivine. Outside this core was a shell of diallage partly altered to tremolite and actinolite, with some calcite, than a shell similar to the core, and outside this another diallage-tremolite-actinolite shell. This was evidently an ultra basic xenolith.

In the Geological Survey collection, there is an interesting rock (K 1103) collected near the Suna- Tanganyika road 8.7 miles south of the Migori River. It is medium grained, grey in colour, and consists of hypersthene with subordinate augite, andesine, and biotite and with interstitial orthoclase and quartz. There is some magnetite and a little bluish-green hornblende. This is probably a hornfelsed and slightly granitized dolerite inclusion in the granite.

Porphyritic granite and related types (G3)

Various leucocratic non-foliated granites, often with microcline phenocrysts, are grouped together as later (G3) granites. They form a number of separate outcrops which, although possibly connected to one mass in depth, differ lithologically one from another where they are now exposed.

These granites, particularly the coarser porphyritic varieties, tend to outcrop as enormous smooth rocks sometimes perched one on another and resembling the tors of the west of England, except for the absence of the strong system of flat joints which is usually conspicuous in the granites there. Because of this resemblance the G3 granites are often referred to as the tor-forming granites. The type is widespread in many parts of Africa; in Central Kavirondo it is included in the Gb granites (Hitchen, 1936; Pulfrey, 1936), and in Tanganyika it has been described as megalithic granite. It corresponds to the 'G4 type described by Grantham (Grantham, 1933). The tor-forming tendency is probably due to the relatively large proportion of microcline, which is one of the most stable of the felspars.

Although differing in some respects, the various G3 granites in the Migori area have certain features in common. They are not foliated or sheared. They are light grey granites with only a small proportion of dark minerals, which is perhaps to be correlated with a scarcity of xenoliths. There is usually a considerable amount of quartz, which, particularly in the coarser varieties, forms quite large anhedral grains. Often the rocks are porphyritic, with well-formed crystals of microcline, usually about an inch long. In some places the porphyritic types have an indistinct fluxional structure, shown by a rude parallelism of the phenocrysts.

The following masses consist of G3 type granites:-

1. *The Mohoru Mass*.-This forms the rocky Mohoru promontory and the Kadem Hills. The granite around Mohoru is a coarse light-grey granite with few phenocrysts. Near the end of the promontory, a slightly different type with a weak fluxional structure is probably a slightly altered intrusion. In the Kadem hills the predominant type is a finer-grained leucocratic granite (G3ap PI. III). East of the Mohoru mass, the same magma seems to have penetrated throughout the older granitic rocks, forming innumerable sheets arid dykes of leucogranite and aplite. Small pegmatitic segregations, with quartz cores, occur in the Mohoru granite.

2. *The Olassie Mass* is an irregular shaped mass of porphyritic granite (distinguished as G3p on PI. III) sometimes with fluxion structure. It forms the low hills along the Kenya Tanganyika boundary, from Olassie Trigonometrical Station westwards nearly to Mohoru Bay.

.3 The Gueribe Mass covers a large area from Gueribe Hill I the west to the lava-covered watershed south-east of Kijarimweta. The northern limit of this mass is not well defined. It is doubtful whether the coarse hornblende granite of Chilati Hill should be included with it, and more time would be needed to map its contact east of Chilati. It must extend into Tanganyika, as does the Olassie mass. The rock on Gueribe is a typical coarse G3 tor granite. Here, and eastwards to the Suna-Tanganyika road, the contact with the G2 granodiorites is easily located, both by the different nature of the rocks, and the form of their outcrops.

4. The Kilgoris Mass -Granite has been found to cover a large part of the country drained by the upper Migori. North of Lolgorien, it is intrusive into the Kavirondian boulder beds. On the west it extends to the foot of the escarpment formed by the Kisii Series which lies unconformably on it. The contact is complicated by faulting near Kilgoris and then runs out of the area mapped, east of Abossi Trigonometrical Station. Eastwards it extends almost to the Isuria escarpment, being intrusive into the mylonitized gneisses there. Further south it is covered by the Isuria lavas so that its relation to the granites south of the Gold Belt cannot be seen.

The granite is grey, or sometimes pink and not usually porphyritic, though typical porphyritic G3 type granites form Lokwaia Hill near the Isuria escarpment. Similar types may form the conspicuous granite tors (not visited) further north, near the Kilgoris-Mara Bridge track. Where this crosses the Migori River a distinctly foliated type of granite is exposed. The foliation strikes N. 30° E. and dips at 85° to the north-west.

5. The Angugo granite.-Only two exposures of this granite were seen, in the Angugo valley, where it underlies the Tertiary lavas. It seems to be a fine-grained non-porphyritic granite of G3 type.

6. The "Kisumu Reef" boss.-About two miles east of Kenya Gold Mining Syndicate Mine there is a small round area less than t mile in diameter, of fine-grained, non-porphyritic biotite granite. This is evidently the top of a boss, the magma having assimilated its way upwards through already sheared and steeply tilted Nyanzian rocks. It is the only G3 granite which can plausibly be related to any gold mineralization and even here the connexion is by no means certain, since the "Kisumu Reef", which is close to the boss and dips towards it, is also well within the zone of mineralization of the main G2 granite mass south of the Gold Belt. The boss forms a low round hill.

7. The Burira boss.-The hill of Burira (PI. IV and Sectional Map V) consists of rather fine-grained porphyritic non-foliated granite of G3 type. It is a boss, but is less regular in shape than the one near "Kisumu Reef"; tongues from it penetrate the slates and shales into' which it has risen. There is a distinct fluxional arrangement of the phenocrysts near its eastern contact. The contacts are shown on the ground by seepages of water, thrown out by the impermeable shaly and slaty country rocks.

8. The Rhino Camp boss. - This covers only a very small area near Rhino Camp (PI. IV and Sectional Map V), and is a fine-grained rock, containing well-formed phenocrysts. It appears to pitch eastwards, judging by the conspicuous contact metamorphism on that side. It is presumably the top of a boss.

Petrographical features of the G3 granites

In nearly all the G3 granites, the dark mineral is biotite, and the dominant felspar is microcline. The texture is granitic, and the grain size coarse or medium.

Quartz is always present and forms perhaps 20-30 per cent of the rock; it has sometimes slight strain-polarization. Orthoclase, in slightly cloudy anhedral crystals, is uncommon; more often, the potash felspar is a clear microcline. In the porphyritic rocks the phenocrysts are of microcline (perthitic?), and the plagioclase is albite, or faintly zoned oligoclase dusted with alteration products. It crystallized before the potash felspar, and is subhedral or euhedral. The biotite is a greenish-brown type, sometimes altered to a green hydrobiotite or chlorite with magnetite. Accessory minerals are sphene, magnetite, epidote, apatite and zircon (some brownish). Rarely there is a little hornblende. Myrmekitic quartz-felspar intergrowths are sometimes seen, and the} plagioclase has in some of the rocks been patchily replaced by microcline. Purple fluorite was seen in one of the Mohoru granites.

Syenitic modification of the 03 granites (S3)

Some hills north-west of Gueribe Trigonometrical Station consist of a non-porphyritic pink syenitic variety of the G3 granite. The rock differs from the ordinary G3 1 granites only in the proportions of the constituent minerals; quartz is present but less abundant, and microcline is correspondingly increased. Dark minerals are scarce.

Form, structure and age of the intrusions of G3 granites

While the intrusion of the para-tectonic G2 granites played an important part in the deformation of the rocks of the Gold Belt (see pp. 40 and 41), the G3 granites are essentially post-tectonic. The magma rose, not as the result of pressures forcing it up into higher regions of the crust, but by quiet assimilation. The G3 intrusions have not pushed aside the surrounding rocks; they replace them (see Fig. 4). In spite of this they are in this area seldom noticeably xenolithic*. The assimilation must have been complete and rapid, indicating perhaps both super-heat and concentration of volatiles. In the case of the G3 intrusions within the main G2 granite mass, the assimilated material would itself be granitic. The small bosses which occur in the Gold Belt are probably very steep-sided and there is no indication of a large mass of G3 granite immediately beneath the exposed gold belt.

The age of the Kilgoris granite is definitely post-Kavirondian since it is intrusive into the Kavirondian Series. This, the absence of boulders of G3 type in the boulder beds, and the post-tectonic character of these granites, makes it reasonably certain that 'the whole G3 suite is post-Kavirondian in age; this is in agreement with conclusions reached in North and Central Kavirondo.

In the Migori area mineralization does not seem to be associated with the G3 granites.

HYPABYSSAL ROCKS

(a) Granite Porphyry (GP)

Several small intrusions in the area consist of granite porphyry. The largest is a boss, which forms a hill about two miles east of Kahancha (shown as QP on Plate IV). It is a light grey rock with abundant phenocrysts of quartz, felspars and an altered ferromagnesian mineral, in a felspathic base.

Another lens-shaped intrusion, broken by a branch of the Kwere-Masara fault, occurs north of Macalder Mine. A thin section shows corroded and euhedral quartz crystals, large phenocrysts of albite-oligoclase, smaller ones of orthoclase, and a few thick flakes of chloritized biotite, in a felspathic base. A similar rock occurs as a marginal facies of the dioritic porphyrite, near Suna, and at a few other places not indicated on the map. North of Lolgorien, among the Kavirondian rocks, there is a large irregular intrusion of granite porphyry associated with porphyrites. This intrusion is in places sheared and contains auriferous quartz veins; it forms the footwall of the "Maghor Reef", the hanging wall being Kavirondian conglomerate. The rock contains quartz blebs, abundant kaolinized acid plagioclase, biotite or hornblende, and microscopic crystals of apatite and sphene in a quartzo-felspathic base. An irregular intrusion near Oganga I beacon (Sectional Map I) is strongly sheared and in part contact metamorphosed by the nearby granite. It contains quartz blebs, and phenocrysts of dusty oligoclase and biotite in a sheared base with small stumpy and ragged fe1spars, chlorite, calcite and sericite. Near its margins it passes into quartz porphyry from which it only differs in containing biotite plates and more felspar phenocrysts.

* In North and Central Kavirondo the equivalent Gb granites are on the contrary distinctively xenolithic, with large and numerous xenoliths, mostly basic. They are more hornblendic than the G3 granite of the Migori area.

(b) Aplite (ap)

There are innumerable sheets and dykes of aplite in the granitic; rocks east of the Mohoru G3 granite, and in the granites west of the Goldfields Formations. Eastwards they gradually become less numerous and beyond the Kwere-Masara fault, are only occasionally seen. There is every gradation from medium-grained leuco-granites such as form the Kadem Hills, to the fine-grained aplites of the thin dykes. Most of the dykes and sheets are parallel to the strike of the foliation of the G2 granite, but some are inclined at low angles, usually, towards the south-west. Many of them have a parallel arrangement of the minerals that is probably fluxional rather than tectonic in origin. They often weather to a pale pinkish colour.

It is understood that aplites of the above type are characteristically associated with the G2 granites in North and Central Kavirondo.

(c) Quartz porphyry (Qp).

Quartz porphyry dykes and sheets are numerous at the western end of the Gold Belt. The sheets occur particularly among the shales and slaty rocks near the granite; the largest is an irregular mass, with intricate tongues penetrating the shales in which it is intruded. It can be traced for nearly two miles, west of the Kwere-Masara fault. Usually the only mineral that can be identified in it in the field is quartz, which forms small-corroded crystals. The matrix is grey, except where it is sheared and hydro-thermally altered near some of the veins (e.g. Kenya Gold Mining Syndicate's "C.W. reef"), when it is a yellowish-white kaolinitic or sericitic phyllite, with scattered quartz blebs. Under the microscope the base is seen to be a micro-granular quartz-orthoclase mosaic, with flakes of sericite, green biotite (or hydrobiotite?), and in one slide, inky-blue chloritoid. The rocks are strongly sheared and evidently also metamorphosed by the granite which is quite close.

The quartz porphyry dykes form a small swarm across Akala and the area around Macalder Mine, and continue a few miles further south-westwards. They are usually only ten to twenty feet thick but a few are as much as a hundred feet thick. They often form distinct features on the ground. Some can be traced a mile or more along the strike. A characteristic feature of these rocks is the unusually large size of the quartz phenocrysts which are sometimes t in. in diameter. They are often well-formed bipyramidal crystals, some with a re-entrant "waist" due to twinning. Felspar and biotite crystals are often present. The dykes are intrusive into the Older Dolerites as well as into the Nyanzian rocks.

Towards Karungu, among the pillow lavas and metabasalts, irregular dykes of quartz porphyry are frequent. Quartz phenocrysts are sometimes absent; these quartz-free rocks are, however, otherwise similar and are therefore coloured similarly on the maps but distinguished by the symbol P.

(d) Felsites (F)

A few non-porphyritic siliceous dykes have been mapped as felsite (F).

(e) Dioritic, Porphyrite (POI)

The barren and rocky hill country between the Oyani River (north of the area mapped) and the Migori Gold Belt, and extending from Goddiquach and Nyakune in the west to Gwa near Kahancha in the east, is formed by a very uniform type of porphyrite. It is bluish-grey with abundant small whitish plagioclase felspars and usually either hornblende or augite or both. The plagioclase crystals are well shaped, oblong and three or four mm. long. The rock breaks off the outcrops as cuboidall blocks which are strewn down the steeper slopes. The apparent effects of weathering are very slight. Inside a pale weathered skin, only a few mms thick, the rock appears quite fresh. The weathered surfaces are sometimes rusty, sometimes greyish. Under the microscope, the felspar phenocrysts are seen to be zoned oligoclase, or less often, andesine. A colourless augite ($Z \Lambda c$ 42° +/- 1°; 2V large) is the commonest dark mineral and forms small phenocrysts; it is sometimes altered marginally to actinolite.

Phenocrysts of green hornblende, sometimes with a brown core, and biotite, often altering to chlorite, are usually present. Serpentinous pseudomorphs after a rhombic pyroxene were seen in one slide (Survey Coll. K987). Quartz is very uncommon but occurs as small blebs in one rock examined (V, 60). The base is cherty and micro-crystalline.

In the field streaky flow-banding is commonly seen. The streaks are lenticular, darker than the rock in which they occur, and not sharply defined. The dips in the porphyrite mass shown on the maps refer to this flow-banding, which, although sometimes varying rapidly in dip, and less markedly in strike, as usual with a flow-structure originating in a viscous magma is none the less regular enough to be used as an indication of structure.

Another structure less common than the flow-banding but not infrequent, is auto-brecciation. In some of the supposed auto-brecciated rocks (e.g. IV, 43), slides show fragments of the normal 'porphyrite, in a darker non-porphyritic matrix. There are cavities containing chalcedony and irregular strings and streaks of dirty dark chloritic and epidote-rich material (IV, 41). A curious feature is the sporadic occurrence of pebbles enclosed in the porphyrite. In the area mapped, these were only seen in one place (about 1 ½ miles south-east of the Suna-Migori bridge), where they were of black and grey chert. In the Kenya Consolidated Goldfields geological reports (Hallam, Fitch and Edgeworth-Johnstone, 1936-1938) dealing with the northern part of the porphyrite mass, the same feature is mentioned, but there the pebbles are of a variety of rocks including granite. The pebbles were presumably caught up from unconsolidated gravels or boulder deposits, and incorporated in the magma.

The mode of origin of the dioritic porphyrite has not been definitely established. The fine-grained microcrystalline base indicates rapid cooling, either of a lava or shallow intrusion. There are Kavirondian boulder beds below it, in it, and on top of it, and as has already been stated, in some of these boulder beds (supposedly those overlying the porphyrite) a large proportion of the boulders are of dioritic porphyrite, which must therefore have flowed over or among the boulder beds during the period of their deposition. If intrusive, some of the mass must soon have been uncovered by erosion, to yield boulders to the conglomerates. Although the mass must be several thousand feet thick, no tuffs have been found in it, which would be unusual in such a large mass of andesitic lavas. Although there are auto-brecciated zones, there is no suggestion either in the topography or the nature of the rocks that the mass consists of separate lava flows. It is remarkably homogeneous. The jointing too is regular, more like that of an intrusion than of lavas. The absence of vesicles again points to an intrusive origin. In one area, intrusive tongues of the porphyrite appear to penetrate among the underlying mudstones (see Plate III and Sectional Map III). Elsewhere the lower contact is regular, and although nowhere actually seen, must be sharp. The occasional presence of a thin marginal facies with quartz blebs suggests contamination at an intrusive contact.

The geologists employed by Kenya Consolidated Goldfields mapped the northern part of the porphyrite mass and regarded it as intrusive. On the other hand, specimens in the Geological Survey collection, collected north of the present area, and east of the Kenya Consolidated Goldfields' concession, appear to indicate an association of typical dioritic porphyrites with crystal tuffs composed of the same minerals as the porphyrites. During a visit to the Musoma District with Mr. G. M. Stockley, I was able to satisfy myself that the South Kavirondo porphyrite is in many respects identical with the Kuria Volcanic Series of the Musoma District (Stockley, 1936). It differs only in the general but not invariable absence of quartz phenocrysts and is strikingly similar n mode of weathering, nature of the flow-banding, and association with Kavirondian boulder beds (North Mara series), which contain boulders of the "Kuria volcanic" rocks. It may be remarked that although Mr. Stockley believed the Kuria rocks to be volcanic, no tuffs were found among them, and the evidence of their origin is as inconclusive its in the Migori District. For the present the South Kavirondo mass is regarded as a shallow intrusion. The rocks are described as dioritic porphyrites, following the geologists working on the Kenya Consolidated Goldfields' concession.

. Mineralization is absent from the whole mass of dioritic porphyrite and its margin is therefore regarded as forming the northern limit of the Migori Gold. Belt. Some large quartz "buck reefs" run through the mass near Suna, along a fault line, which is one of a widespread system of diagonal tear-faults. Cleavage is not seen in the porphyrite. Joints are clean and regularly spaced and follow several directions.

(f) Porphyrites associated the Masara Volcanic rocks (NAP)

These have been described in connexion with the volcanic rocks with which they are associated.

(g) Porphyrites (P)

Other porphyrites occur, which do not belong .to either of the above-mentioned types. They are grey, with felspar phenocrysts. The largest mass is associated with granite porphyry and Kavirondian boulder beds near Lolgorien (see Sectional Map VIII). Thin sections show large phenocrysts of oligoclase, smaller blades of hornblende, micro-phenocrysts of apatite and sphene and leucoxenized plates of ilmenite, in an andesitic base. The apatites and sphene have the same distinctive features as those in the granite porphyry and the two rocks are evidently closely related.

(h) Older dolerites (D1, DIC, DIF)

Two distinct groups of doleritic rocks are recognized in the area; the Younger Dolerites (D2) are post-Kavirondian; the Older Dolerites (D1. etc.) are Nyanzian in age, and are closely associated with the Nyanzian Basic Volcanic Group (NB) as can be seen on the maps. The Older Dolerites are shown to be older than the G2 granite by their metamorphism to hornblende schists and epidiorites near its contact. Elsewhere they have undergone the same low-grade metamorphism as the other Nyanzian rocks.

The appearance of the Older Dolerites in the field varies with their coarseness and degree of shearing. The most typical are fairly coarse ophitic dolerites (DIC) which have a lustre-mottling due to the plates of augite, 5-10 mm. in diameter, which enclose smaller chloritit ized felspar laths. These rocks are mottled black and green. Other finer-grained Older Dolerites (DI) are bluish-green, blocky, and difficult to distinguish in the field from meta basalts. The edges of most of these intrusions are sheared to a chloritic schist. It is sometimes possible to judge their coarseness of grain by the size of the whitish specks of leucoxene derived from ilmenite (of which skeletal relics can sometimes be seen in the leucoxene). In the lavas, the leucoxene specks are not larger than a pinhead and usually much smaller; in the dolerites they are usually about' 2: mm. or so in diameter. These leucoxene specks seem to remain, even when the rest of the minerals are unrecognizable owing to shearing. Leucoxene in a moderately altered dolerite can be seen in some of the Macalder diamond drill cores.

A fresher type of dolerite designated DIF (on Sectional Maps I, II and III) occurs in the middle of a thicker sheet of the coarse mottled type. At their contacts the two types are sometimes patchily mixed and were evidently contemporaneous. In spite of its fresh appearance, the fine-grained speckled type (DIF) is therefore classified with the Older Dolerites. It forms a useful marker band. Its discontinuous en échelon outcrops may be due to faulting, as it is certainly faulted by the Masara fault north of Macalder Mine.

Microscopically the older dolerites are seen to consist of plates of augite, spongily replaced by actinolite and chlorite and enclosing laths of plagioclase which in the coarser types are about I mm. long. Plates of leucoxenized ilmenite are always present; secondary minerals usually include chlorite, calcite and epidote. One of the Older Dolerites from Macalder Mine (IV, 20) and another (I, 19) from "Alpha Ray" (Lolgorien) were seen to contain a little interstitial quartz.

The Older Dolerites form sheet-like masses or sills. Although irregular in form, and in detail transgressive, the sheets generally follow the regional strike. No dykes of Older Dolerite have been recognized.

The nature of the hornblendic schists and epidiorites which are the result of the contact metamorphism of Older Dolerites near the granite is noted in the section (p. 43) dealing with the metamorphism. It may be remarked here that in some of the coarser epid iorites the original lustre-mottled texture of the rocks can stilt be recognized. The occurrence of sheets of the Older Dolerites among rocks which are believed to be higher in the Nyanzian sequence than the basic volcanic group, indicates that the basic magma was still being injected after the basic eruptions had ceased.

The existence of dolerites which were later than some of the granites but earlier than others is suggested by a specimen (K. 1120) collected about 12 miles south-southwest of Kahancha, from among the granites. It is a piece of dolerite, similar to that of the dykes which cut the G 2 granites, with the original ophitic structure clearly preserved, but on one side of the slide it is hornfelsed to a granular mosaic of augite, hypersthene, quartz and untwinned felspar.

(;) Younger Dolerites (D2)

Dykes of fresh dolerite are common throughout the Kenya goldfields, and are particularly numerous in the western part of the Migori area. The thicker dykes form strong features on the ground, standing up as ridges, or aligned small hills. They are easily seen on air photographs, either as ridges, or as dark bands among the paler granite outcrops, or by the larger trees which grow on them. Microscopically, these dyke rocks are seen to be ophitic quartz-dolerites. The augite is colourless or pale, and sometimes diallagic. Subordinate enstatite earlier in crystallization than the augite, was seen in one slide (V, 53). The augite is seldom replaced by actinolite and then only marginally. The felspar is zoned labradorite, which in the less fresh rocks is altered to oligoclase or albite. Plates of ilmenite occur. Quartz is always present either as small intergranular grains, or in micro-pegmatite, which, however, is usually scanty; evidently the residuum was not usually potassic enough to yield an appreciable quantity of fresh felspar. In the slide of one specimen (K. 2065) the effect of residual potassic fluids is seen in the presence of a little biotite. Another slide (K. 2074) showed that the felspar in the scanty micro-pegmatite was microcline, with very fine "cross-hatching."

The dykes must occupy fractures; they generally follow the strike of the country rocks, but in: some places take a direction' parallel to the diagonal tear faults for a short distance. Distribution of the Younger Dolerites near the Kwere-Masara fault might suggest that they have been displaced by it, but this distribution is evidently the result of injection of the dolerite magma into fractures that had themselves already been displaced by the fault. The presence of dykes along the Masara-Kwere fault shows that they post-date it. As some of the dykes cut the Kavirondian conglomerates and others occur in the dioritic porphyrites, this dolerite invasion must be post-Kavirondian. None of the dykes have been, seen in the Kisii Series of rocks, and their similarity to the post-Bukoban[*] quartz dolerites of Uganda (Groves, 1931) cannot be taken as proof of their similar age.

5. The Mineralization of the Older Rocks

From the economic point of view, mineralization in the Migori area implies mineralization with gold, or at most gold and copper. It is a process which gave rise to a system of veins, mostly of quartz, with, in some' places, a very small proportion of pyrite, arsenopyrite, chalcopyrite, and galena, and an even smaller proportion of gold. The geological aspect is considered here, the economic aspect in a later section.

MINERALOGY AND TEXTURE OF THE VEINS

The products of the mineralization may be broadly classified as:-

(1) Auriferous quartz veins, and other similar but non-auriferous veins.

(2) Auriferous; and pyritic impregnations.

(3) Massive sulphide replacement deposits (Macalder type).

(4) Barren white quartz veins ("Buck Reefs").

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[*]The Kisii and Bukoba Series are both regarded as belonging to the Bukoban System.

1. The auriferous quartz veins

These are the commonest and most characteristic products of the mineralization. Their quartz may be blue, grey, nearly black, or white. The blue, grey and blackish quartz is “greasy” or resinous and is usually found closer to the granite than the white quartz, which occurs more often in massive igneous rocks, and further from the granite. Most veins within the granite are white. Gash veins, dipping at low angles towards the granite, or steeply away from it, are often drusy, with small quartz crystals growing into the cavities. The blue and grey quartz veins usually follow shear lines which dip steeply towards the granite; the quartz in these veins is not drusy. Nearly all the veins in shales are of blue or grey quartz; the colour may be due to mineral inclusions or, more probably, to strain. The strained condition of the quartz is shown optically by undulose extinction and the slightly different extinction position of the adjacent needles or strips into which the crystal units have been fractured. The fractures are usually parallel to the crystallographic axis; they are also marked by lines of liquid-gas inclusions (vacuoles), imprisoned when the sub-microscopic cracks were healed. These are not confined to blue or grey quartz, which however does in the writer's experience, nearly always show these features whereas white quartz often does not.

Microscope examination shows that in nearly all the quartz veins the quartz first crystallized as a coarse mosaic of sutured grains; in most cases this first-generation quartz has been strained and fractured either by irregular brecciating cracks, or along more or less parallel planes. Along and near these fractures the quartz has been recrystallized to microcrystalline or very fine-grained second-generation quartz. In a few veins (Kahancha "No.5," Kenya Gold Mining Syndicate's "M.K.") slight tourmalinization has followed the fracturing. More often, pyrite or arsenopyrite has been deposited along the fractures. Pyrite cubes often replace the first-generation quartz; in poly one slide (K. 1955) was fracturing and brecciation of the pyrite observed; in this case the fractures through the pyrite were sealed with tine-grained quartz, itself slightly strain-polarized. The first-generation quartz is usually dusted with inclusions, many of them mineral (some rutile); the second-generation quartz is clearer, with fewer inclusions.

The brecciation of the first-deposited quartz, and its mineralization along these fractures, can sometimes be seen in hand specimens, as for instance, in the richer ore from the 'Kisumu Reef" (Kenya Gold Mining Syndicate), which consists of brecciated quartz, cemented by sulphides, chiefly arsenopyrite. Some cross-fracturing of the veins, followed by deposition of pyrite, usually in cubes, occurred after the gold mineralization. This is seen in the Kenya Gold Mining Syndicate Mine ("Blackhall's Reef"), where a number of small faults cross the vein. They are associated with pyrite but have no appreciable effect on the gold distribution (see Fig. 9).

Primary minerals found in the auriferous quartz veins include sericite (probably derived mostly from hydrothermally altered country rock); tourmaline (minute brownish or bluish prisms, sometimes visible to the naked eye, as in veins in the shales near the River Kuja west-south-west of Masara Trigonometrical Station); calcite (e.g. in "Black hall's Reef," Kenya Gold Mining Syndicate Mine, where it occurs as small nests in the quartz); ankerite; scheelite (identified by Wayland from Kenya Gold Mining Syndicate's "M.K." veins (Wayland,]93], p. 28»; siderite; chlorite (common); rutile as microscopic inclusions in quartz and probably derived from shaly country rocks; anatase? (microscopic crystals); epidote (not common in the auriferous veins though widespread in the area); purple fluorite (seen only in one vein near the "Kisumu Reef" granite boss); pyrite, both in cubic crystals and granular, in nearly all the veins and in wall rocks, particularly shales; arsenopyrite, also common; chalcopyrite, not uncommon and generally associated with high gold values; galena, probably wide spread in the primary zone; and gold.

2. Auriferous and pyritic impregnations

In a few gold occurrences in the area, quartz is absent or nearly so and the primary (unoxidized) ore is a pyritic impregnation. The most recently worked of these is Radford's Masara Mine ("Achar Reef") where the primary ore was a pyritic impregnation, with some arsenopyrite and low gold values, along an irregular shear in Older Dolerite (or basalt?). The oxidized portion of this vein was rich though patchy; the primary ore has not been worked. It is probable that gold values in occurrences of this kind in the Migori Belt would always be very irregular. The oxidized zone of such impregnations tends to be thoroughly decomposed, and gold liberated during weathering accumulates, the residual enrichment thus being, greater than in the case of quartz veins. This should be taken into account in estimating probable values in the primary zone of such deposits.

3. Massive sulphide replacement deposits

Only one massive sulphide orebody is known in the district. This is Macalder Mine ("No.9") of which a more detailed geological description is given in Section VI. The deposit consists of a branching series of lenticular sub-parallel veins each about 20 ft. in width and with a strike of over 1,000 ft. The primary ore is a fine-grained streaky granular aggregate of pyrite, pyrrhotite, chalcopyrite, magnetite, arsenopyrite, sphalerite (blende), and galena, with interstitial calcite. Fragments of greenish translucent cherty quartz with magnetic dust and siderite are enclosed in the ore and are derived from a "banded ironstone" associated with the veins. Chlorite is often plentiful near their margins.

Hand specimens of the ore give some evidence of the order of crystallization. Magnetite forms small elongated lenses and streaks in the other sulphides and seems to be the earliest of the metallic minerals. Pyrite crystallized next; sometimes large pieces of it are enclosed in the banded sulphides, and the banding flows round them. Chalcopyrite and pyrrhotite are evidently later as they often form veinlets traversing the streaky sulphide ore, which consists chiefly of pyrite, blende and magnetite. The chalcopyrite and pyrrhotite seem too to have been more mobile than the other constituents, and lire the chief minerals seen in the fractures in the enclosed fragments of banded ironstone.

A private report (by Krieger, American Metals Corporation) to Macalder Mines, kindly shown to me by Mr. W. P. Alderson, supplements these observations. From mineragraphic study (of a single specimen) he concluded that the para-genesis of the minerals in it was: pyrite, arsenopyrite, pyrrhotite, chalcopyrite, electrum, galena. He showed that the gold occurs in the form of electrum, a natural gold-silver alloy, and that it is closely associated with the galena.

The form and relations of the Macalder sulphide ore bodies indicates that they are replacements. Their contacts are sharp.

4. "Buck Reefs"

Besides the system of lenticular auriferous and non-auriferous quartz veins, already described, there is another system, the quartz veins of which do not contain more than traces of gold and differ from the auriferous veins in several respects, which indicate a different mode and time of origin. It is arguable that they should not even be included as "products of mineralization.”

These barren veins are popularly known as "buck reefs." They are white, or rarely slightly iron stained; and are described by prospectors as "hungry-looking." Some contain felspar (though none was seen in the slides examined) and no metallic minerals were observed. Their thickness is often considerable (for instance the "reef" running through Masara Hill must exceed 100 feet in thickness), and they have often been called quartz dykes. They traverse all the older rocks of the district, granites (G2 and G3), the Goldfields Formations, and Kavirondian porphyrites alike. They occur along fractures or fault lines, and particularly along a well-defined system of diagonal tear faults which is described below (p, 42). Examples of "buck reefs" in the area are those on the Masara-Kwere fault; those traversing the porphyrites near Suna; and a group crossing the gold belt in a fracture and flexure zone at Kahancha.

Microscope examination of a few slides of "buck reefs" showed the texture of the quartz to vary; microcrystalline, almost cherty quartz, coarse sutured mosaic, and subhedral to euhedral crystals with interstitial microcrystalline quartz, were seen in different slides. Sericitic shreds may represent felspar. Strain-polarization of the quartz is slight or absent.

The fact that these veins are not concentrated along a granite contact like the auriferous quartz veins; but traverse all the older rook indiscriminately, suggests a later and deeper origin; no actual proof of this has been obtained from contacts with auriferous veins, since no such contacts were discovered, but the following evidence is thought to leave no doubt ~that the "buck reefs" are younger than the mineralization.

1. At Kahancha (Sectional Map VI) two auriferous veins ("No.2") occur along thrust planes; their structures suggest that they were injected during or soon after the thrusting. The thrust planes and the veins have curved outcrops, having been twisted where they enter a transverse zone of flexure. "Buck reefs" occur along this zone of flexure.

2. "Alpha Ray" vein, at Lolgorien, is broken by faults, belonging to the diagonal tear-fault system. "Buck reefs" are (elsewhere) injected along the faults of this system.

3. The diagonal tear-faults, and the "buck reefs," traverse the G2 granites, which must therefore have been crystallized and solid at the time, whereas the auriferous reefs are concentrated near the granite contact in a manner which can only be due to residual fluids, which, escaping from the cooling magma deposited gold and its associated minerals in the adjacent country rocks.

4. The "buck reefs" are nowhere significantly mineralized. The traces of gold found in them are sporadic and apparently unrelated to the main gold mineralization.

5. The fracture system along which the "buck reefs" occur do not seem to have influenced the mineralization as they surely would have done if they had been in existence at the time of the 'gold mineralization.

6. The diagonal fractures are later than the maximum shearing whereas many of the veins are affected by it, or have structures indicating that they were formed while the compression was still operative.

The age of the gold mineralization relative to the "buck reefs" and tear faulting is of practical importance at Macalder Mine.

In the discussion of other aspects of the mineralization, which follows, the "buck reefs" are not included unless specifically mentioned.

NATURE OF THE ORE FLUIDS

The minerals deposited in the veins by the mineralizing fluids have been mentioned; other evidence of the nature of these ore fluids could be derived from a study of the alteration they have effected in the wall rocks, but without the support of chemical, analyses such evidence is too vague to be useful and is only briefly noted here.

In most of the wall rocks effects of shearing, and of metasomatism by the ore solutions, are superimposed or coincident. The shearing took place during the intrusion of a large mass of granite and was therefore certainly accompanied by notable migration of fluids. Its principal mineralogical effects were production of actinolite from augite, chlorite from various ferromagnesian minerals, oligoclase or albite from labradorite, and particularly of sericite. A bright green chlorite, quartz, sericite and pyrite, are the principal wall rock minerals attributed to metasomatism by ore solutions. At Macalder Mine, shearing of the wall rocks is by no means always notable even within an inch of the ore bodies and there the alteration of the wall rocks, which has resulted particularly in abundant calcite, and some bright green chlorite, must be mostly metasomatic. The fluorite and tourmaline occasionally noted in the veins indicate traces of fluorine and boron in the ore fluids. 'Sericitization in most cases must have involved addition of potash. Metasomatic albitization is not marked nor is albite recorded from the veins. This may be connected with the potash-rich nature of the residual granite fluids, indicated by the late-crystallized microcline and the replacement of acid plagioclase by microcline, in the granites.

The texture of the quartz suggests rapid deposition from fluids carrying a high proportion of silica, possibly in the colloidal form. The structures indicate injection under pressure. The composition of the fluids changed progressively and the evidence indicates that the gold was deposited at a late stage, when, the fluids had become less siliceous.

A discussion of the nature of the ore fluids from which the Macalder sulphide ore bodies were deposited is not attempted in this report, but it may be remarked that the veins are replacement deposits, that their banding is attributed to plastic flow and not to colloidal deposition, and that the temperature at which they were deposited was probably much lower than is sometimes assumed where pyrrhotite and magnetite are present.

ORIGIN OF THE ORE FLUIDS

From the distribution of the veins it is evident that the ore fluids were derived from the "granites." This is not proved but probable in the case of the Macalder sulphide ores.

LOCUS OF MINERALIZATION

The primary factors which determined the locus of the mineralization were the varying physical and chemical conditions near the contact of the mineralizing granite (or granites?) with the adjacent goldfields formations. The gold mineralization in the Migori Belt is' essentially confined to a zone extending probably not more than ¼ mile within the granite, and about three miles outside it. The following figures give the distance outside the contact of some of the principal veins:

Macalder No. 9 (Sulphide ore bodies)..13,000 ft.
Lolgorien (Kenya Consolidated Goldfields) "Maghor"..11,000 ft.
Radford (Masara Mine) "Achar Reef"..9,000 ft.
"Simba. Reef"-(Sectional Map V)..9,000 ft.
Lolgorien (Kenya Consolidated Goldfields) "Alpha Ray"..7,000 ft.
Macalders No. 18..6,000 ft.
Kahancha "Carlos"..5,000 ft.
"Allenby Reef"-(Sectional Map V)..4,500 ft.
Kahancha "No.5"..4,500 ft.
Kahancha "Prancis"..4,500 ft.
Macalders No.3..4,000 ft.
Kenya Gold Mining Syndicate "Kisumu Reef" (from main granite contact;
very close to "Kisumu Reef" boss)..4,000 ft.
Macalders No.14..3,000 ft.
Lolgorien (Kenya Consolidated Goldfields) "Caldwell"..3,000 ft.
Kenya Gold Mining Syndicate's "M.K."..2,500 ft.
Kenya Gold Mining Syndicate's "Steel's"..2,500 ft.
Kahancha "HomeStead"..2,500 ft.
Lolgorien (Kenya, Consolidated Goldfields) "Blue Ray"..2,500 ft.
Kahancha "No.2”..2,000 ft.
Kenya Gold Mining Syndicate's "Black hall's"..1,000 ft.
Kahancha "Sagire”..just inside the granite contact

It is worth noting that the Macalder Mine sulphide ore bodies (No. P) and the pyritic impregnation at Radford's Masara Mine, are among .the most distant from the granite. This, and the tendency for the blue and grey quartz to occur in the veins nearer the granite, and the only signs of zoning noted.

The principal secondary factor, which determined the distribution of the veins within this broad mineralized zone, was evidently the structure. This is discussed below.

MINERALIZATION IN RELATION TO STRUCTURE

All the veins may be presumed to occur in fractures. Some of these are faults. Since, however, there are in the area far more fractures than veins, and since the fractures are in any case more difficult to locate and trace than the veins, this knowledge is of little or no practical value in prospecting, and the statement that a particular vein lies in a "shear zone" is often meaningless. There are however, certain horizons that, for structural rather than mineralogical or chemical reasons, arc particularly liable to carry veins. A shale horizon at Kahancha (see Sectional Map VI) is one such, and the brittle and invariably fractured banded ironstones another. Knowledge of these and other similar relationships which can be read from the sectional maps should materially help further prospecting, particularly in the more neglected areas where outcrops are scarce.

It is probably the case that owing to the structural homogenity of the Migori Gold Belt, generalizations are more likely to be possible than in other fields in Kenya.

STRIKE AND en Échelon PATTERN

The majority of the veins are nearly, but not quite parallel to the strike of the rocks in which they occur, and most of them dip towards the granite. The only vein of any economic importance that makes a high angle with the strike is Macalder's No. I which was not accessible for examination as the workings are not in use.

Although the veins strike nearly parallel with the country rocks, the slight divergence which they constantly exhibit is very important. Throughout the belt, the veins diverge to the left, from the country rock strike (see sectional maps). On the other hand, the strike of vein systems, or groups of veins, is usually almost coincident with the country rock strike. Thus any single vein system consists of a series of veins arranged en échelon and the overlap of the units which form the en échelon group is right-handed. The meaning of this is shown by the diagram (Fig. 2).

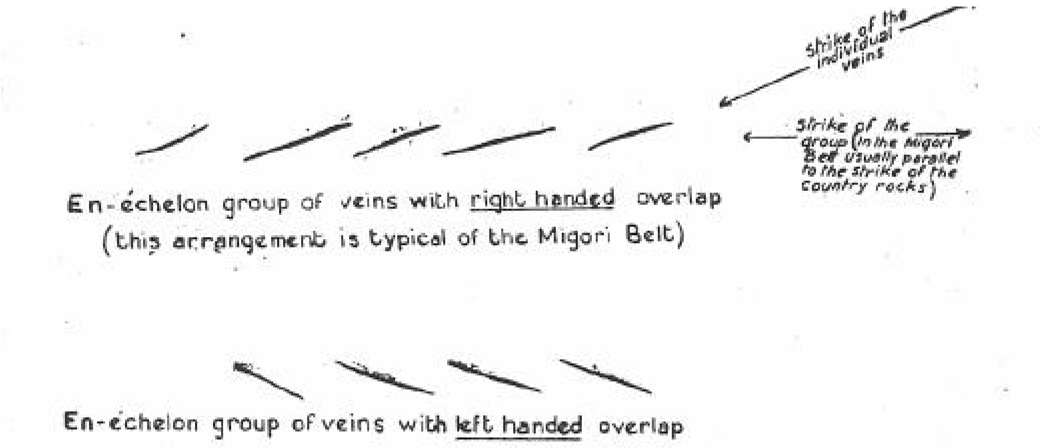

FIG. 2

En échelon arrangement of veins.

Its practical importance is obvious; if a vein pinches out, the correct place to prospect for another vein of the same system is not to be found by following the line of the original vein; it will be slightly to the right of this line. The same applies to underground development.

It is probable, though not proved, that a similar en échelon arrangement obtains in a vertical sense. In flat or gently dipping veins, such as "Steel's" (Kenya Gold Mining Syndicate), a new vein might be expected to come in below. In the steeper systems the arrangement is still unpredictable but the possibility of parallel but vertically en échelon veins should be borne in mind, where shallower veins are bottomed.

CORRELATION OF VEIN THICKNESS WITH CHANGES OF DIP

A point which should be watched in any large mine is the relation of very slight changes of dip of the vein, to the width, and mineralization. In veins on reversed faults, thickening should occur with decrease of dip; in tensional (normal) faults, the thickest portions of the vein should be the steepest. This arises from the size of the openings produced. It is suspected that the former relationship obtains in the Migori belt; this should not, however, be assumed. It is evident that such a relationship if established would be of considerable value in predicting ore thickness from diamond drill sections, at a mine such as Macalder. It may be noted that "Steel's Reef" (Kenya Gold Mining Syndicate) thinned, and gold values decreased, as it flattened downwards; "Blackhall's" Reef (Kenya Gold Mining Syndicate) which steepness slightly on the lower levels (see Fig. 9, ii and iii), at the same time tends to become thinner, and less auriferous downwards. The same may be the case at "Maghor" (Kenya Consolidated Goldfields, Lolgorien)~ Generalization is at present not justified, but careful correlation of data should be worth while. The significant changes of dip may be very slight.

NATURE OF CONTROLLING FRACTURES

The fractures in which the veins' occur are of various kinds. Some, notably most of those near Kahancha, are thrust planes; excellent examples, with several feet of balled and crushed rock below the soles of the thrust planes, are to be seen in the workings along the two veins near the European quarters at Kahancha Mine. These thrusts are along the bedding, or make a low angle with it. The beds immediately above the thrusts appear quite undisturbed, in striking contrast to those below. A lamprophyre sill a few inches thick follows one of the thrusts, indicating that these or connected fractures extend to great depth. "Blackhall's Reef" (Kenya Gold Mining Syndicate) lies in an intensely sheared porphyrite but no definite single controlling fracture is recognized; the vein often seems to diverge slightly to the left of the direction of the shear planes. Probably, however, this vein follows a reversed fault. "Kisumu reef" (Kenya Gold Mining Syndicate) lies in a fault marked by a thin layer of gouge, and dips at about 500 towards the adjacent granite boss. "Steel's Reef," occurring in a still flatter fracture, is probably not on a fault. The veins at Macalder Mine dip north-north-east at about 60° and certainly follow faults, but whether they are normal or reversed is doubtful. Slickensides in the ore and walls pitch steeply north-north-east, but the direction of' movement could not be determined from them. It is probably true to say that the majority of the fractures in which the veins of the Migori Belt occur were produced by shear and not tension.

FOLDING OF VEINS

It is doubtful whether any of the veins are folded, though of course dips vary. An unusual hooked vein at Kenya Gold Mining Syndicate (Fig. 3) recalls some ptygmatic quartz veins in metamorphic rocks described by H. H. Read (1931, pp. 110-111), who showed that their form was not due to intricate folding but to their injection along irregularly curved fractures. The same explanation probably applies here. Another curious structure is seen in the "M.K." vein (Kenya Gold Mining Syndicate). This is a comparatively narrow vein, generally less than a foot thick, which swells and constricts regularly both in a vertical and horizontal sense. The vein thus consists of flattened ovoid masses, a foot or two in diameter. This is reminiscent of boudinage* structure, and like it, probably occurs when a thin brittle bed, lying in more plastic country rocks, is pressed and squeezed into partly separated lumps, instead of flattening uniformly. Whether this is the case or not, the structure clearly indicates deposition before or during deformation.

FAULTING OF VEINS

Many of the veins are crossed by fractures, most of which cause no perceptible displacement, and are zones of close jointing rather than faults. They usually make a good deal of water, and are more or less at right angles to the veins. Fractures of

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* French-*boudin,* a sausage.

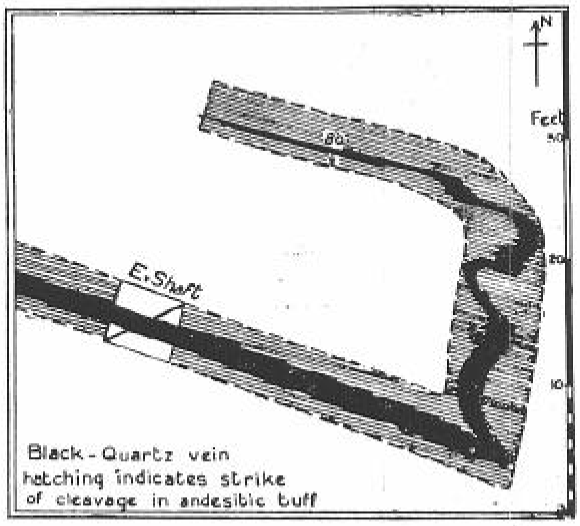

FIG. 3
Sketch plan of the eastern end of "Boundary Reef" (K.G.M.S. Mine) on the first (26ft.) level.

this kind are well seen at Kenya Gold Mining Syndicate ("Blackhall's Reef"). . True faults displacing the veins are uncommon; the best examples are in the "Alpha Ray" vein at Lolgorien, which is displaced by several parallel diagonal tear-faults. These belong to the north-east-south-west group and therefore have a left-handed throw. Knowledge of the direction of the throw to be expected, according to the direction of the fl4ull (p, 42) might save wasteful driving in the wrong direction in such cases.

PITCH OF "PAY SHOOTS"

The gold mineralization is severely localized, usually in the form of "shoots" within the veins. The number of mines in which these shoots have been followed far- enough down in the primary zone to reveal the direction and angle at which they pitch, is very limited. At "Blue Ray" (Lolgorien) the shoots pitch eastwards; at Kahancha No.5 they pitch eastwards at about 70°, in the Kisumu Reef they pitch eastwards; in Blackhall's reef (Kenya Gold Mining Syndicate) they are poorly defined but appear to pitch steeply west (see Fig. 9); "Big Blow" (Kenya Gold Mining Syndicate) is a vertical shoot. Data from Macalder are as yet insufficient to decide the direction or angle of pitch. These few facts warrant the suggestion, in a district of such tectonic homogeneity, that the prevailing pitch may be found to be eastwards.

SIZE AND SHAPE OF ORE BODIES AND SHOOTS

The granite mass south of the Gold Belt has been deeply eroded and the rocks now exposed in the Migori Gold Belt originally lay thousands of feet down the side of the batholith. Such a situation is usually considered to imply not very large, and characteristically lenticular veins and is regarded as less favourable than regions nearer the roof. The Migori belt on the whole conforms to this generalization. The ore bodies are strongly lenticular, and not very large. Macalder "No.9" is an exception in this and other respects.

The following approximate figures give some idea of the visible lengths of strike of the veins (not pay-strike) at surface:-

"Alpha Ray" (Lolgorien) .... 2,000 ft.
"Blue Ray" (Lolgorien) .... 2,000 ft.
"Maghor" (Lolgorien) .... 1,100 ft.

"No.5" (Kahancha)..300 ft.
"Homestead" (Kahancha)...2,000 ft.
"Blackhall's Reef" (Kenya Gold Mining Syndicate)................................1,000 ft.
"M.K." (Kenya Gold Mining Syndicate) ....300 ft.
"Waterbuck" (Kenya Gold Mining Syndicate).......................................1,300 ft.
"Steel's" (Kenya Gold Mining Syndicate)..800 ft.
Macalder "No.9"...1,300 ft.
Most other veins that have been worked in the area are shorter.

Widths of these veins are usually less than four feet, though at Macalder "No.9" the average width is of the order of twenty feet. The vertical extent of the veins is unknown since few have been bottomed; Blackhall's reef is strong at 650 ft. vertically below surface. It is, however, to be expected that the veins will be lenticular in vertical as in horizontal section, though the vertical rate of thinning is probably less than that in a horizontal direction.

DATE OF THE MINERALIZATION

It is probable that mineralization continued for a considerable period of time and it may have been repeated. The principal facts which have to be taken into account in dating the mineralization are:

1. Auriferous veins, apparently all belonging to the one system of mineralization, occur in the G2 granite, the Nyanzian rocks, and the Kavirondian rocks.

2. This mineralization appears to be confined to a zone along the G2 granite contact.

3. The post-Kavirondian G3 granites do not, in this area, seem to have produced appreciable mineralization.

4. The quartz in the vein5 has often been severely strained and sheared.

5. The veins are probably later than the impression of the cleavage.

6. The veins are earlier than the diagonal tear-faulting and earlier than the "buck reefs."

The fact that the mineralization appears to derive from the supposedly pre-Kavirondian G2 granite suite and yet affects the Kavirondian rocks introduces an obvious difficulty. The most likely explanation of this seems to be that some or all of the G2 granite complex was in fact intruded during the pre-Kavirondian earth movements, and its upper parts were uncovered by erosion, and provided boulders for the Kavirondian sediments, before the main part of the batholith, deeper down, had crystallized. If so the continuance of the mineralization long into the Kavirondian epoch would be explained.

It may be suggested that the reason the G3 granites -have not in this area produced notable mineralization is that they have for the most part assimilated their way up through the earlier G2 granites from which the gold' had already been expelled in the mineralizing solutions. The only G. granite mass which has perhaps given rise to some gold mineralization is the Kisumu Reef Boss, which rose, presumably by assimilation into a zone of Nyanzian rocks that already contained auriferous veins.

6. Structure and Metamorphism

STRUCTURE OF mE OLDER ROCKS

It has been shown that throughout a wide region of which the present area is only a small part, the older rocks can be separated into three Systems: The Basement, Nyanzian and Kavirondian. The rocks of each, so far as is yet known, form a continuous sequence of deposits, separated from each other by structural and metamorphic breaks which indicate that between the long and relatively quiet periods of their deposition, there were periods, perhaps briefer, when the rocks of the region were strongly folded and compressed. Three periods of crustal deformation or orogenesis can thus be distinguished:

1. Post-Basement orogenesis.
2. Post-Nyanzian phase } Kavirondian orogenesis.
3. Post-Kavirondian phase }

The last two deformations are tentatively grouped as phases of one orogenesis for reasons given later.

1. Post-Basement orogenesis

The present work touched only the edge of a large area of Basement System rocks, and that only cursorily. Information gained from traverses made by Mr. Brannstrom, Government Prospector, through the country east of the Mara River has been used to supplement the data collected on my own hasty traverses there.

Strikes recorded by Mr. Brannstrom were mostly between north-north-west and north-east, and dips were eastwards. The measurements, presumably taken on the foliation, may be assumed to represent also the dip of the bedding, with which, in these rocks, the foliation appears to coincide. Rock distribution suggests that a line separating quartzites from gneisses runs approximately north-north-east-south-southwest across the district east of the Mara. If so, the strike of both major and minor structures may follow approximately this direction. Lineation was seen in several of the specimens collected by Mr. Brannstrom. It is evidently the type characteristic of high-grade regionally metamorphosed rocks, that is, parallel to the strike of the minor folds and at right angles to the direction of movement. The bedding-plane foliation, regional lineation, and regional metamorphism are believed by the writer to indicate a type of tectonics in which the viscous drag of the deeply buried crustal rocks by the subcrustal material resulted in plastic flow, the flow planes corresponding generally with the bedding planes. In this way cumulatively very large movements evinced by the lineation can be reconciled with the lack of foliation or cleavage transverse to the bedding, and the general simplicity of the major structures.

2. The Kavirondian orogenesis (Post-Nyanzian and post-Kavirondian phases)

The degree of unconformity between the Nyanzian and Kavirondian series gives a measure of the intensity of the orogenic movements that occurred in the interval between them. In the Migori area this unconformity is believed to have been an angular one; in North and Central Kavirondo it was, judging by the published maps (see Hitchen, 1936, 1937 and Pulfrey, 1936, 1938), probably less marked. The nature and intensity of the post-Kavirondian deformation can, theoretically, be discovered from the structures of the Kavirondian rocks. In practice, structures in the Kavirondian rocks of this area are difficult to eluc idate and most of the structural information comes from the gold belt in which the Nyanzian rocks have been affected by both post-Nyanzian and post-Kavirondian deformations. Post-Kisii Series movements were so mild in comparison with .the earlier deformations that their effects on the older rocks can be ignored.

The two deformations, post-Nyanzian and post-Kavirondian, are regarded as phases of a single orogenesis for which the term Kavirondian orogenesis is here used pending the adoption of a more suitable term. The reasons for so regarding them are, first, that so far as can be seen in Kenya, they affected the same region; second, that the folds and other structures produced show that in both, the crustal pressures acted in more or less the same direction; third, that the structures produced are broadly speaking of the same type-folds, varying from open to tight or isoclinal, strike faults, usually steeply inclined, and shearing, also steep or moderately steep, and varying greatly in intensity. The delayed ("hangover") mineralization (p. 38) which suggests the presence of a granite mass remaining as a magma long into Kavirondian times also indicates close connexion between the two phases. The frequent practical difficulty of distinguishing their effects is also an argument for associating them.

The Post-Nyanzian Phase

(a) The structures of the G granite contact zone

In the Migori belt the characteristic feature of the post-Nyanzian orogenic phase is the syntectonic intrusion of a large mass of granodiorite magma. This magma, generated presumably during an early stage of the movements, was forced up and behaved as an "active" mass, transmitting the orogenic stresses to' the "passive" Nyanzian rocks. The structures are those associated with intrusion tectonics.

The evidence for these assertions is found in the west-north-west--east-south-east zone of intense shearing and deformation which follows the contact of the G2 granite from one end of the Migori belt to the other. For up to a mile or so on either side of the contact, all the rocks are intensely sheared, and have a strong lineation. This lineation or linear texture is seen as a parallel elongation of the mineral particles on the shear surfaces, on which they are both flattened and drawn out. This structure, spread as it is through a rock mass more than a mile thick, must indicate a total movement of many miles. It is obvious that the granite has moved upwards relative to the rocks of the gold belt. The lineation, everywhere through the gold belt, pitches steeply down the foliation or shear surfaces; the pitch is slightly towards the west, indicating that the granite was pushed upwards and also a little eastwards. This lineation is quite different in origin from the regional lineation characteristic of the Basement System rocks; the latter is at right angles to the direction of movement and is due to the rolling out and elongation of the crystal grains by rotation during plastic flow; the local post-Nyanzian lineation is associated with cataclasis and is parallel to the direction of movement. It is thus essentially similar to slickensides on a fault plane.

Microscopically the zone is characterized by widespread mylonitization and sericitic or chloritic shear planes.

The contact of the G2 granite with the Nyanzian rocks presents some interesting, and, by implication, unusual features; these are: -

1. It follows a nearly straight course for about fifty miles.

2. It is almost concordant; that is to say parallel to the strike of the country rocks.

3. It is knife-sharp and there is little sign of assimilation of the adjacent country rocks by the magma.

4. The contact lies in the zone of intense shearing and lineation described above; both granite and country rocks are involved; the structures indicate that the granite has moved upwards (and slightly eastwards) over the country rocks.

5. The country rocks are hornfelsed and thermally metamorphosed near the granite.

6. The greater part of the contact is unfaulted although in some places it has parted and there has been some slight movement along it.

7. The country rocks consistently dip towards the granite, but less steeply than the foliation or cleavage which also dips towards the contact; in many cases the southward-dipping beds are proved by graded bedding to be unreversed.

8. The dip of the foliation, assumed to be parallel to the contact, indicates that the contact itself is inclined southwards; the granite overhangs the gold belt.

9. The granite mass extends many miles to the south and shows no roof pendants.

The contact is almost certainly parallel to the foliation; the beds dip towards this contact, where they must end abruptly against the granite. The rock mass in which they were formerly continued has disappeared; the straight contact and insignificant granitization of wall rocks there' Seems inconsistent with the view that the missing mass has been assimilated in the granite. The only explanation which seems to correlate the facts satisfactorily is that as the granite magma was squeezed upwards the overlying rock mass gave way, probably along a straight pre-existing fracture, and the rock mass south of the fault was lifted as a roof on the rising magma, while the rocks on the north side of the fault formed the wall of the intrusion (see Fig. 4).

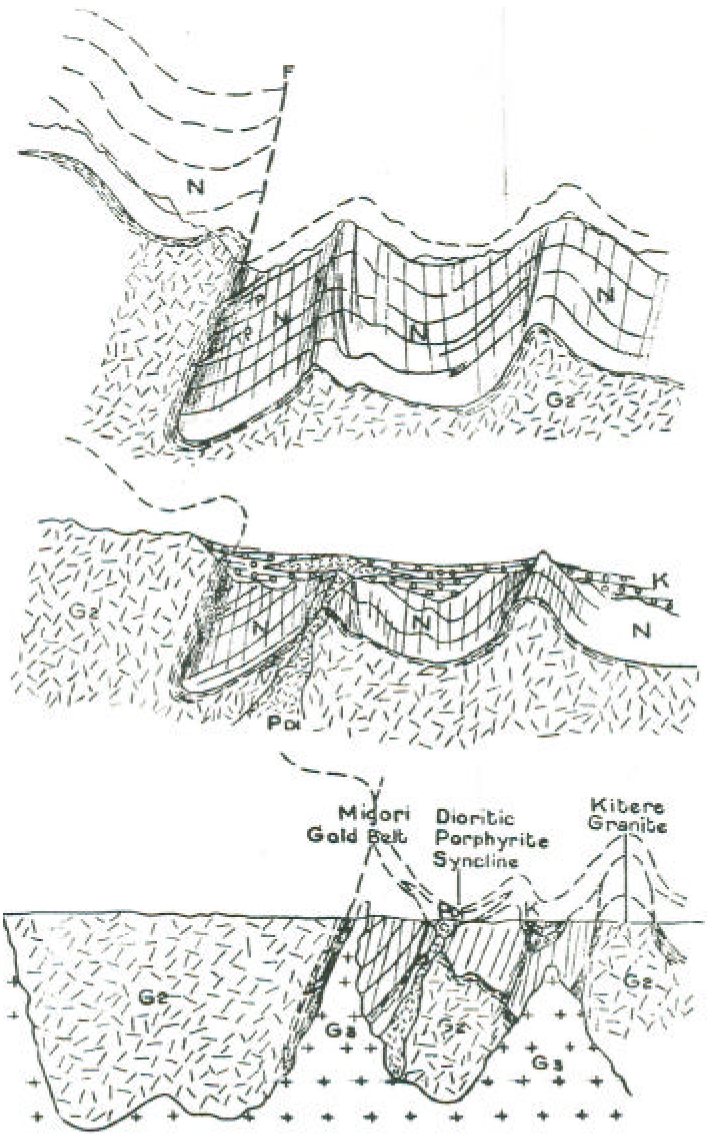

FIG 4

Serial sections across the Migori Belt. The sections, which are not to scale, are intended to show the structural development of the southern part of Kavirondo. They represent a zone about 30 miles wide between the Tanganyika Boundary in the south, and Kitere in the north.

Section I (beginning of the Kavirondian Period). The Nyanzian rocks (N) have been folded (in the post-Nyanzian orogenic phase) and the syntectonic granites (G) injected into them. Erosion has already lowered the fold-mountains and exposed the granite.

Section II (end of the Kavirondian period).- The Kavirondian boulder beds (K) lie on the eroded surface of Nyanzian rocks (N) and Granites (G). The mass of dioritie porphyrite (Pm) shown within the Kavirondian boulder beds, is thought to have been partly intrusive, partly extrusive.

Section III (present day).-The zone has been further compressed, ruptured and sheared during the post-Kavirondian orogenic phase and the post-tectonic granites (G3) have risen by assimilation through the deformed rock masses. Prolonged erosion bas reduced the region to its present condition.

To face page 40

As the granite magma was forced upwards, under a hydrostatic pressure sufficient to lift the roof regions bodily upwards, it would at the same time exert an equal pressure on the wall rocks; this was perhaps the first stage in the compression of the Nyanzian rocks of the gold belt. As the viscosity of the magma increased as a result of crystallization, hydrostatic pressure on the walls would gradually be superseded by viscous drag and this, in turn, by shearing,. At this stage, the marginal shearing and production of lineation would chiefly occur. At this stage also, the less cohesive horizons in the wall rocks, sloping down towards the contact, would tend to be dragged open. To this is attributed the fracturing in the shale horizons which later formed channels for the mineralizing solutions. Perhaps at the same time the small thrusts along the bedding planes, seen near the granite at Kahancha, were formed.

A way from the granite contact, the localized shearing and lineation gradually die away, and structures characteristic of the Nyanzian rocks over a wider region can be seen.

(b) Structures ill the Nyanzian rocks of the gold belt

(i) *Folding.*-In the gold belt nearly all the rocks dip towards the granite; the dips are normal, not reversed, and there is no large scale repetition by strike faulting.

This southerly dip of the large mass of rocks along the gold belt must have been induced by the post-Nyanzian deformation, since the Kavirondian rock mass lying unconformably on it dips in the opposite direction, to the north. Presumably, the southward dipping Nyanzian rocks form the southern limb of a major anticline whose axis is concealed under the later Kavirondian porph yrites and conglomerates. In the east of the area, folding can be recognized in the Nyanzian series, north of the zone of Kavirondian rocks. The folds are broad and open. It seems therefore that folding in the post-Nyanzian phase whose of simple character, the wavelengths of the resultant folds being measured in miles. Minor folding, restricted to incompetent rocks such as shales, or layered and brittle ones such as the banded ironstones, is not infrequent. Tight, almost isoclinal folds of small amplitude are deduced in the greywackes at Macalder Mine from diamond drill cores.

(ii) *Cleavage*.-True slaty cleavage is nowhere strongly developed; many of the rocks are sheared rather than cleaved, and the shearing varies rapidly in intensity. Cleavage which is the result of flattening rather than simple shear probably occurs in some of the silty slates. In the shales near the granite, slip has taken place along the lamination and the extreme result is phyllitic rather than slaty. Probably most, but not all of the shearing and the production of the poor slaty cleavage took place during the post-Nyanzian phase.

The strike of the shearing and cleavage in the gold belt is generally parallel to the granite contact and the dips are towards the contact; where the beds dip towards the granite, the dip of the cleavage is steeper than that of the beds.

.(iii) *Faulting*.-The only faults that can be referred to the post-Nyanzian phase are the small thrusts along the bedding planes at Kahancha. Other strike faults of the same age doubtless exist.

Easterly disappearance of post-Nyanzian structures:.-An interesting point is the complete absence of any trace of the structures mapped through the gold belt (and in particular of the contact shear zone), on the Isuria escarpment which is only a few miles east of Lolgorien, where the gold belt structures pass under Tertiary lava sheets. The Isuria fault is a Tertiary or Pleistocene structure with a downthrow to the east, but it occurs within a zone of intense mylonitization of much earlier date. From the similarity of this mylonitization to that along the G2 granite contact south of the gold belt, this powerful shear-zone is thought to have originated during the Kavirondian orogenesis. It affects rocks referred to the Basement System, and appears to b~ earlier than the Go granites. It may represent a zone along which Basement System rocks have been thrust up against the Nyanzian granites. A steep lineation indicates that the direction of movement was upwards towards the north-west; the shear planes dip south-east. Whatever the exact age of this shear zone, the absence of any trace of the structures of the gold belt in the rocks of the escarpment is remarkable. The mylonitization could hardly have obliterated all of them completely, nor have they been recognized among the Basement System rocks east of the Isuria shear zone. It is suggested in explanation, that the whole shear zone, strike faulting and compression of the Migori gold belt was confined to the rock masses above the granite batholith, which perhaps is a vast sheet between the Basement and later rocks. This would account for the general distribution of the goldfields formations of East Africa -isolated areas surrounded by granite and apparently nowhere in normal contact witl1 the Basement System tocks. It is in any case certain that the gold belt does not reappear in the Isuria escarpment or in the country to the east of it.

The post-Kavirondian Phase

(i) Folding.-The great mass of the Kavirondian dioritic porphyrite and boulder beds is interpreted as a deep synclinal structure, the southern limit of which is replaced by a fault at the eastern end. The whole structure is considered to lie unconformably on the Nyanzian rocks; since, along much of its southern margin, the Nyanzian rocks dip in the opposite direction to the Kavirondian. The observations of dips, on which this interpretation is based are recorded on the maps, and the interpretation of the structure is shown in the accompanying sections (Fig. 5).

The post-Kavirondian structures include broad folds, and considerable strike faults. The evidence for these strike faults is partly the occurrence of drag-folds close to some of them, partly the impossibility of otherwise constructing a consistent and reasonable stratigraphical sequence. Shearing is seen in the Kavirondian rocks, particularly in the east; true cleavage has not been noticed. The strike of folds, strike faults, and cleavage is the same as that of the post-Nyanzian structures, that is, approximately west-north-west-east-south-east. The main synclinal structure through the porphyrite mass appears to be complementary to an uplift of the granite region south of the gold belt.

(ii) G3 granite intrusion.-After the end of this second, post-Kavirondian, phase of the Kavirondian orogenesis, or as it was declining, the G3 granites assimilated their way upwards into the folded rock masses. They are essentially post-tectonic.

(iii) Diagonal tear-faults.-Probably the latest structures that can be referred to the Kavirondian orogenesis are a series of diagonal tear-faults. These faults follow two directions roughly at right angles and making angles of about 45° with the general strike of the rocks. Drag structures, affecting vertical shearing, near small-scale faults of this system, shows that the displacement is horizontal. The displacement on the north-north-west-south-south-east group is always right-handed, that is to say on crossing such a fault the strata will be found to have been displaced to the right; the displacement on the other, east-north-east-west-south-west group, is always left-handed. The, two sets represent directions of maximum shearing stress at a late stage in the deformation. They are each at about 45° to the direction of maximum compression, which was north-north-east-south-south-west. Displacement along these faults varies from a few inches up to nearly a mile on the Masara-Kwere fault. Many are marked by "buck reefs".

M.ETAMORPHISM

, Three types of metamorphism have affected rocks in the area; the Basement System shows high-grade regional metamorphism; the Nyanzian rocks, and perhaps some of the Kavirondian, show a very low-grade regional metamorphism and also, near the granite contacts, a local contact metamorphism.

The regional metamorphism of the Basement System is apparent from the complete recrystallization of the quartz in the quartzites to a sutured mosaic, or a coarse granular mosaic with parallel muscovite flakes penetrating the grains. There is no trace of the original clastic grain outlines. A highly metamorphosed pelitic rock is represented by a garnetiferous mica-schist; and a clinozoisite schist probably represents either a metamorphosed basic rock or an impure limestone. Biotitic gneisses, injection gneisses, and pegmatitic segregations in many of the rocks also indicate a high grade of metamorphism.

The low-grade regional metamorphism of the Nyanzian and perhaps to a slight extent of the Kavirondian rocks is shown by the widespread chlorite, sericite and actinolite. Older descriptions of the rocks as schists, and of the sheared pillow-lavas as amphibolite give an exaggerated idea of the degree of regional metamorphism which is of low grade

Near the main granite contact south of the gold belt, and to a less extent near the other granite contacts, contact metamorphism has produced biotite-bearing and hornblendic hornfelses from sediments and tuffs, hornblende schists and epidiorites from the older dolerites and various other metamorphic types. The hornfelses are blocky, hard, flinty rocks with pronounced banding and usually a green or grey colour. Microscope examination shows the more greenish types to consist essentially of a microcrystalline mosaic of quartz and alkali felspar with minute subparallel blades of green hornblende (actinolite) distributed throughout; banding is shown by varying proportion of hornblende. Another hornblendic hornfels from within a few yards of the granite contact, near Kenya Gold Mining Syndicate Mine, shows micro-granular quartz-felspar bands, alternating with bands of matted actinolite, subordinate quartz, and granular sphene. There are also in this rock some coarser irregular patches of green hornblende, quartz and. microcline, which are evidently due to the soaking-in of granitic material. Other hornfelses, some of which have a purplish tinge, contain minute parallel biotite flakes as well as, or instead of, the actinolite blades, Microscopic rutile needles are often seen in the hornfelses, but not in the more hornblendic bands, in which granular sphene takes their place.

Rocks which in the field appear unaffected by contact metamorphism often show its effects microscopically by the presence of minute flakes of biotite. In other places it is shown by a blocky type of jointing.

A *knotenschiefer* was seen in section to contain altered euhedral chiastolites in a schistose (pelitic) matrix.

The contact metamorphosed older dolerites are glistening green hornblendic schists or fine to coarse-grained epidiorites.

IV-DETAILS OF THE GEOLOGY: (II) THE YOUNGER ROCK

1. The Kisii Series (Bukoban System)

DISTRIBUTION

The Kisii Series is named from the Kisii Highlands, a block of high country east of. Kisii township. * The hills rise to over 7,000 ft. and consist chiefly of volcanic rocks with a conspicuous quartzite group in the middle of the Series. The rocks dip at low angles and rest unconformably on the older Nyanzian and Kavirondian rocks. The southern part of the Kisii Highlands extends into the area covered by this report. Behind a few small outlying hills (such as the one two miles north of the road, mid~ way between Kahancha and Lolgorien), the ground rises steeply as a dissected scarp, the top of which is formed by the conspicuous Kisii quartzite. The main quartzite escarpment is breached by the upper Oyani River behind Keyan; from there it runs southwards for about four miles, then bends eastwards, passing close beneath the trigonometrical station Mwita, beyond which it bends northwards again to pass out of the Masai Province a mile or so to the west of the Kisii-Masai border market of Nyangusu. Then owing to repetition by faulting, the contact of the Kisii series-here no longer marked by a scarp-swings back east of Nyangusu, towards Kilgoris; there, owing to more faulting, two ridges run out from the main massif, and stop suddenly as promontories in an expanse of low country which is underlain by the Kilgoris granite. These two ridges, Losoaiyet and Oloolomisimis, are due to the Kisii quartzite, tilted westwards at about 30° and repeated by faulting. The quartzite finally runs out of the district at Abossi Trigonometrical Station (the area between Kilgoris and Abossi is not included on the maps published with this report).

* Kisii is the administrative centre of South Kavirondo; it lies outside the area covered by this report.

The scarp mentioned is an erosion scarp, quite different from the straight fault scarps so familiar in Kenya. Along its southern front, ridges and spurs form discontinuous subsidiary scarps. Dark rock outcrops forming level or gently sloping lines along the escarpment are the outcroppings of lava flows. The quartzite scarp is remarkably level along the southern front near Mwita. Climbing up to it, one expects to see a level plateau behind. Instead there is a basin-shaped grassy hill region, dissected by a fan-like system of valleys and surrounded by a narrow rim, the crest of which lies just behind the actual quartzite scarp. The quartzite dips gently inwards towards the basin. From the summits on the rim one appreciates at once the very even summit level of the whole Kisii Highlands massif, which is obviously a dissected remnant of a peneplain, the level of which would now b~ about 7,200 ft.

SUCCESSION

The succession in the southern part of the Kisii Highlands is:-

3. Upper: Red felsites, andesites and rhyolites (thickness considerable),

2. Middle: Quartzite (approximate thickness 50-450 ft.).

I. Lower (b) Non-porphyritic basalts (approximate thickness 1,000 ft.).

(a) Porphyritic basalts (approximate thickness 0-600 ft.).

Lower Division: Basalts

(a) *The Porphyritic Basalts* (BBp).-An easily recognized porphyritic basalt is the lowest member of the Kisii Series. It weathers to brown-skinned blocks on which the small narrow white plagioclase crystals, about 4-6 mm. long, are conspicuous; there are generally some small subspherical vesicles. The fresh rock is grey or greenish-grey speckled, by the white felspars, which show lamellar twinning and are often in groups.

Thin sections show that the felspars range in composition from albite to oligoclase. Augite forms ragged micro-phenocrysts, subophitic plates, intersertal granules or feathery and comby skeletal crystals in rocks of different textures. Vesicles are filled with chlorite (or celadonite?) and calcite. The groundmass is altered and was probably glassy. The texture is seriate. Specific gravities were determined as 2.87 and 2.85 for two typical specimens. This basalt is recognized from near Nyangusu, around the southern front of the escarpment to within a few miles south-east of Sekawa. It is not seen under the Losaiyet, Oloolomisimis or Abossi quartzite ridges. No intercalated tuffs were seen, but the presence of a series of flows is evident from the form of the outcrops.

(h) The Non-porphyritic Basalts (BBp).- The main part of the hills and scarp-slope below the quartzite consists of numerous flows of a non-porphyritic vesicular basalt Most of the vesicles are filled with chlorite concentrically banded; some have chalcedonic cores. The fresh rocks are greenish-grey and weather to small cuboidal blocks. Flows are probably mostly 10-50 ft. thick, with highly vesicular tops. Tuffs are insignificantly developed.

Slides show that the felspar in these rocks is oligoclase, or even albite-oligoclase. Pyroxene is abundant. Some specimens from near Kilgoris are coarser than most lavas but their mode of occurrence, closely associated with highly vesicular rocks that are certainly effusive, indicates that they too are lavas. These coarser rocks are seen in slice to consist of oblong oligoclase felspars up to 2 mm. long, and unusually long and narrow pyroxenes. In one slice (1.75) the pyroxene was identified by its rather low optic axial angle as a pigeonitic variety, in others it is a normal augite. Intersertal brownish material, distinctly birefringent and with a fibrous structure, is probably an altered glass, though the possibility that it is altered analcite was considered. The pyroxenes do not, however, suggest that the rocks have alkali affinities; on the contrary, they seem to be a normal basaltic suite. The oligoclase felspars are probably derived by alteration from more basic plagioclase: Specific gravities of typical specimens were determined as 3.00, 2.81 and 2.74.

Middle Division: Kisii Quartzites (BQ)

A bed of quartzite about 100 feet thick forms a regular rock Cage along the top of the main escarpment, and its upper surface forms a rock terrace along which one can walk for several miles near Mwita Trigonometrical Station and elsewhere (see Frontispiece). There are in some places lower indistinct scarps of quartzite down to about 450 ft. below the top of the main scarp. The main quartzite is persistent and nowhere thins away. It is a hard light grey or white rock, often yellow, purplish, or pink-stained by iron oxides. It is well bedded, sometimes current-bedded, and commonly ripple-marked; the wavelength of the ripples .at a typical exposure was 1 ½ in.; their amplitude ¼ in. Magnetite is often concentrated in streaks and bands, particularly in the current-bedded quartzites. Jointing is locally strong.

Under the microscope the quartzite is seen to consist of rounded grains, with distinct outlines, cemented by quartz in optical continuity with the grains. Nearly all the grains are of quartz, some of which shows strain-polarization; a few are of micro-crystalline cherty quartz. The sand was well graded, and in any particular rock the grain size is fairly uniform. In a slide of a typical specimen the mean diameter of the grains was measured as 0.3 mm., the grade of medium sand; some beds are coarser. Some of the grains are traversed by lines of liquid-gas inclusions which indicate fracturing later than the cementation since the lines pass through several grains. The heavy mineral assemblage of the quartzites has not been investigated, but in specimens collected by Wayland from near Kisii, Groves (Wayland, 1931, appendix by Groves, p. 54) identified cassiterite (angular), zircon, biotite, iron ores, muscovite, garnet, tourmaline, anatase, amphibole, and diopside. This assemblage was compared with that of the Bukoba Sandstone.

The relation of the Kisii Quartzite in the area to the banket and quartzite at the base of the Kisii Series in the Sotik district is unknown, but it is possible that they are at the same horizon, since the basalts below the quartzite appear to be thinning in that direction and may disappear entirely in the intervening and unmapped 25 miles between Abossi and the Sotik "banket" area.

Upper Division: Red felsites, andesites and rhyolite (BA)

Everywhere in the area the quartzite is overlain by a characteristic red felsite. It forms soft brick-red or slightly purplish-red blocks with green specks. At the base, where it overlies the quartzites, it has a strong platy structure, and is slightly vesicular. This red felsite is apparently a lava but must be very thick, and no tuffs or indications of separate flows can be seen in it.

On a traverse from the Kilgoris-Romashawa-Chemagel road south-eastwards to Nagweni (a little north of the limit of the published map) other volcanic rocks; apparently overlying the red felsite, were seen. They included a pinkish weathered' vesicular andesite, a coarse grey andesite evidently forming a fairly thick flow, and a grey rhyolite with drawn-out vesicles. Andesitic lapilli tuffs are associated with these rocks.

Microscopically the red felsite is found to contain chloritized phenocrysts of a potash felspar which has the cross-hatching and crystal form (modified by corrosion) of anorthoclase. These phenocrysts, which are the green "spots" seen in the hand specimens, lie in a very typical groundmass; it consists of quartz and felspar (? orthoclase), the latter occurring as minute close-packed laths, poecilitically enclosed in quartz. The texture approaches that of a micrographophyre. There are also very abundant small chloritic pseudomorphs, the form of which suggests that they may represent hornblende. Typical specimens of the red felsite were found to have specific gravities of 2.59 and 2.68.

A vesicular andesite (I. 82) was seen to have slightly corroded oligoclase micro-phenocrysts in a felspathic base. The groundmass felspar appears to be acid plagioclase, and some of it occurs as tufts of delicately curved microlites. Secondary minerals include leucoxene after ilmenite, granular sphene, and plentiful chlorite.

Another coarser and fresher grey andesite (I. 85) consists of oblong and tabular crystals of acid plagioclase, varying in length from I mm. downwards, closely packed in a dusty felspathic base, whose felspar is largely plagioclase. Some of the groundmass is indistinctly spherulitic. The specific gravity was determined as 2.70.

A rhyolite (I. 86) containing long drawn-out vesicles filled with chalcedony was seen in section to be a glass divitrified to a brownish patchy quartzose mosaic. The specific gravity of this rock was found to be 2.68.

2. Tertiary Sediments and Lavas

MIOCENE SEDIMENTS OF KARUNGU (TMi)

The Miocene deposits near Karungu were carefully investigated and described by Oswald (Oswald, 1914) and no further work has been done there in connexion with this report, beyond plotting the occurrences on the map.

The beds are exposed in a series of gullies at Nira (Ngira) and Kachuku; and at several places under the volcanic rocks at Nyagwena (Nagwena). Oswald divided the deposits into three Series:-

3. Upper Series.-Grey and brown clays and shales, containing very few fossils.

Beds of sandstone are of rare occurrence. Average thickness 70 ft.

2. Middle Series.-Variable red and grey clays with white sandstones in the lower half. Average thickness 30 ft.

1. Lower Series.-Buff-coloured sandstones and torrential gravels (containing *Deinotherium*) passing down (at Nira) into clays and sandstones. Average thickness 55 ft.

Travertinous beds occur at intervals throughout the whole thickness. The fossils collected by Oswald include remains of *Deillotherium*, rhinoceros, a giant tortoise, crocodile, and freshwater and lacustrine shells (op. cit.).

DISTRIBUTION

In addition to the exposures noted by Oswald, a few more indications of the presence of Miocene marls or clays have been noticed during the present survey, enabling their distribution to be more precisely plotted. At several places, marked on the sectional map (I) there are short, conspicuous outcrops of a cellular yellowish laterite. The form and position of these outcrops indicates that they are not superficial deposits on the present land surface, as is the recent lateritic ironstone (murram), but are the outcrops of a bed that passes into the sloping ground where they occur. They are therefore presumed to be Miocene in age and if so, must have been formed on the Miocene land surface. No exposures of the beds presumed to overlie the laterites were seen near them. Lithologically these supposed Miocene laterites are appreciably different from the recent laterite ("murram") in that they are yellow rather than reddish, more homogeneous, and more cellular; their concretionary structure is more distinct.

The lower boundary of the Miocene deposits has been drawn to pass immediately beneath these laterite outcrops. Its form indicates a gently undulating surface beneath the Miocene deposits.

Conditions of Deposition

A quartz-ironstone breccia, and perhaps the basal red clay, described by Oswald, and the laterites mentioned above, are evidently weathering products formed on the sub-Miocene land surface. The rest of the Miocene deposits are fluvio-lacustrine. Since the deposits become notably thinner even in the four miles from Nira to Nyagwena, which. at the same time certain beds at the bottom disappear altogether, and the deposits themselves become coarser, it is clear that the shore and the source of the deposits lay to the east. The character of the fossil fauna shows that the shore line cannot have been distant.

The mention of augite crystals in several of the coarser beds indicates that volcanic activity had already begun somewhere in the region.

SUB-VOLCANIC GRAVELS AT LOLGORIEN

The Isuria lavas east of Lolgorien are different from those overlying the Mi0gene beds near Karungu, but for reasons discussed later (p. 52) the surface on which they rest is thought to be part of the same Miocene land surface which underlies the Miocene sediments and Gwasi volcanic rocks at Karungu. Immediately beneath the Isuria lavas, around Lolgorien, there is evidence of a gravel bed which may therefore be Miocene in age. The presence of this gravel is shown by the great numbers of small well-rounded quartz pebbles which are found on the slopes everywhere beneath the lava scarp in the Lolgorien area. On Larumbas ("Alpha Ray") Hill there is a small outlier of lava resting on Nyanzian meta-basalts and meta-dolerites, which are penetrated by an auriferous quartz vein ("Alpha Ray" vein). This vein outcrops slightly below the lava on the southern scarp slope. Above the outcrop is auriferous rubble, with quartz pebbles and slightly rolled bits of banded ironstone. The latter rock does not occur in situ on Alpha Ray Hill. Two adits driven under the lava outlier to try to find the veins from which this gold was shed disclosed none, and it is inferred that it was derived from the unexposed sub-volcanic gravel. The land surface on which the gravel rests was much more mature than that of the present day and conditions would be more favourable for the concentration of alluvial gold. The possibility therefore of the occurrence of workable "deep leads" in some of these gravels deserves investigation.

The pebbles are almost all of quartz, and slides of a few show these to be vein quartz. No pebbles of either the Kisii or Basement System quartzites were seen, so that the source of the gravels remains to be determined.

THE GWASI VOLCANIC ROCKS (TB)

The volcanic rocks overlying the Miocene deposits near Karungu and forming the country north thereof lie at the fringe of a volcanic region which seems to have had its centre at Kaksingeri, in the Gwasi area after which the rocks have been named. The rocks are lavas, agglomerates and tuffs. The lavas are dark grey rocks with black augite crystals, and have been shown by microscope examination to range from nephelinites to basalts.

Relation to the underlying Miocene sediments

According to Oswald, the lavas flowed over an eroded surface from much of which the Miocene deposits had already been removed by denudation. He thought the valleys of Kitama and Kikongo were eroded before the eruptions of the lava~ which then flowed down and filled them. The present work, admittedly cursory in this area, tends rather to suggest that the base of the lavas is a fairly even though tilted surface. Further, at Gotmagungu, where there is a continuous exposure from agglomeratic tuffs of the volcanic series down into the Miocene sediments, there is np unconformity but on the contrary a transition, with alternating sediments and tuff beds. The actual contact was not seen elsewhere by the writer.

Petrography

Slides of the volcanic rocks were studied by Goldschlag (1912), Oswald (1914) and Groves (appendix to Wayland, 1935). Those in the collection of the Geological Survey of Kenya have been examined during the present work. From these it is possible to get a preliminary idea of the range of variation in the lavas of this area.

Nephelinites were identified by Goldschlag from near Karungu, and by Oswald from Nira Hill. In some the nepheline is anhedral, in others it forms minute euhedral crystals. A rock collected a few miles from Migori on the Karungu road (K. 962) is a nephelinite with phenocrysts of augite and nepheline. Olivine nephelinite, differing from the other nephelinites in containing micro-phenocrysts of olivine, forms the peak of Nundowat. It was described by Oswald (1914, p. 142) as containing large diopside phenocrysts, serpentinized olivines, a few flakes of biotite, anhedral nepheline, small augites, magnetite granules, rare leucite, and altered glass (?).

Other rocks (K. 957, K. 958, K. 961) in the collections of this Department from near Migori on the Karungu road (a few miles north of the limit of the area mapped during the present work) are phonolitic tephrite. They consist chiefly of small prisms of pale greenish augite microlites and ragged laths of acid oligoclase, a few small flakes of biotite, abundant small crystals of magnetite, possibly some sanidine, and probably some anhedral nepheline, as well as a little clear glass. Specimen K. 963, from the same locality is similar but contains also minute euhedral nephelines, and altered micro-phenocrysts of olivine. This is a phonolitic basanite. Groves (Wayland, 1935, appendix by Groves, p. 44) described a rock said to be typical of the rocks between Homa and Karungu. It consisted of large phenocrysts of a pale augite, in a fine-grained base formed of minute pyroxene needles, interstitial felspar and iron ore. The felspar was thought to be a basic plagioclase, and the rock therefore classified as a basalt. The above rocks have obvious features in common, notably the large phenocrysts of augite, which are usually diopside, sometimes with an outer shell of aegirine-augite and sometimes a faintly purplish and titaniferous variety. Probably the apparently wide range in alkalinity suggested by the presence in some slides of plagioclase with no nepheline, in others of nepheline with no plagioclase, would be less striking were the composition to judged from chemical analyses.

Like most of the Tertiary and post-Tertiary volcanic rocks of Kenya, this is a soda-, rich suite. As a whole it shows interesting resemblances to the Ngong basalts (Sikes, 1939, pp. 18-20).

THE ISURIA LAVAS (TPh)

Distribution

East of Lolgorien is the Isuria plateau, which is underlain by Tertiary phonolitic lavas. The Western edge of the lava sheet is a wooded and rocky scarp with an irregular course more or less following the contours; it is a normal erosion scarp. The eastern edge of the plateau is a steep and straight fault scarp nearly a thousand feet high.

The lavas outcrop along the crest of this escarpment from Oloololo southwards to the Tanganyika boundary (and beyond). North of Oloololo a small outlier was noted near the Lolgorien-Mara bridge road. West of the plateau edge. near Lolgorien, other small outliers of the lava occur, on Natakili Hill, on Larumbas ("Alpha Ray") Hill, where the outlier is only about five hundred feet long, on a small hill about ¼ mile east-south-east of Larumbas, and about a mile south of Natakili and on another hill ("F. 53"), where only a few square yards of lava remain.

Below the Isuria escarpment, the Mara River meanders across rolling grassy plains. Descending the Isuria escarpment on the road from Lolgorien to Mara bridge, the Isuria fault is crossed about three miles before the bridge is reached. At the fault the granitic gneisses of the scarp slope give place to Tertiary lavas, which are then seen in frequent outcrops down to the Mara bridge. The lava outcrops in the river below the bridge, and further eastwards, continues to the foot of the Lemeck Hills, which stood out above the flood of lava. Traversing the country cast of the Mara, Mr. Brannstrom, Government Prospector, saw lavas on the Lorogoti plains, and on both sides of the Mara River between Moggone and Omarti Hill.

Looking down on the plains and the Mara valley from the edge of the Isuria escarpment, it is apparent that the hills around Moggone are formed of flat-lying lavas. An irregular scarp feature, running across the plains, appears to indicate the southern edge of the lava sheet. This feature is suggested on the Boundary Commission Map, Sheet II, by the closer spacing of the form lines at about 5,150 feet. Beyond this feature, towards the Tanganyika boundary, a number of small hills could be seen which are evidently capped by lava outliers.

From these observations, it can safely be concluded that the whole plain, from the Isuria fault eastwards to the quartzites hill of Lemeck and Loldobaith, and southwards to the irregular scarp mentioned, consist of lavas. These lavas are the same type as those of the Isuria plateau and are obviously part of the same sheet faulted down east of the Isuria fault line.

The occurrence of outliers beyond the present extent of the Isuria sheet shows that the lavas must once have extended further west and north than they now do. Similar lavas have been mapped (Stockley, 1936) around Tarime and below the Utimbara scarp in Tanganyika. Evidently, therefore, these lavas once flooded a large area. The extent of their subsequent erosion can be judged from the degree of isolation of the lava outlier on Natakili Hill near Lolgorien. From the orientation of the sanidine crystals it appears that the Isuria lavas flowed from the north-east. Their northward extent is unknown.

The presence of at least three lava flows is evident from the step-like terraced slope of the eroded edge of the lavas between Kijarimweta and Oloololo. No tuffs were seen. The lavas must have been very fluid and probably flowed out rapidly but quietly, and without explosive eruptions, from fissures.

The top of the lava sheet is everywhere eroded so that its original thickness is~ unknown. On the Isuria plateau it must exceed 450 feet; on the road from Lolgorien to Mara bridge, the drop from the first lava exposures to those in the Mara River is several hundred feet and in this section neither top not base are seen. On Oloololo at least 450 feet of lavas must be present.

Nature of the lavas

The Isuria lavas consist of a very uniform type of dark bluish-grey phonolite, ~containing conspicuous glassy or white-weathered felspar crystals, usually about half an inch long, and smaller greenish-grey nephelines. Some have a few vesicles. The crystallinity of the groundmass is usually evident from its glistening appearance.

Under the microscope phenocrysts of glassy felspar and nepheline are seen in a holo-crystalline (?) base consisting of small euhedral nepheline crystals, small prisms of aegirine, some with cores of aegirine-augite, sub-ophitic kataphorite, deep brown cossyrite, a few small isometric crystals of a felspathoid (? sodalite or leucite), abundant specks of magnetite, small crystals of apatite, together with abundant thin laths of clear simply-twinned felspar. Scarce micro-phenocrysts of olivine are optically negative and must be a ferriferous variety; some of them are altered at the core to a brown mineral possibly gothite, and marginally to a brownish-green mineral with the optical properties of bowlingite. A few larger (early) micro-phenocrysts of pyroxene are diopside. The interstitial matrix is a transparent isotropic substance with very low refractive index and no cleavage. It is perhaps analcite. In other slides the matrix has been replaced by a colourless mineral with undulose extinction and refractive indices below those of nepheline it is probably a zeolite,

Both porphyritic and groundmass felspars appear to be sanidine. Their refractive indices are below 1.525, the optical axial angle is small, and the optic axial plane is parallel to 010.

The conspicuously porphyritic texture and mineral composition, especially the presence of olivine and the absence of biotite, indicate that these rocks should be compared with the phonolites of Kapiti type described by Campbell Smith (1931, p. 238). They differ, however, from the rocks described by him in having sanidine instead of anorthoclase.

The comparison of the Isuria lavas with the Kapiti phonolites and of the Gwasi volcanic rocks with the Ngong basalts suggested that the Isuria lavas may be older than the Gwasi rocks.

3. Pleistocene and Recent Deposits

Pleistocene rocks are poorly represented in the area; the deposits which occur are classified as: -

4. Alluvium and black valley soils.

3. Lateritic ironstone ("murram").

2. Residual deposits ("rubble").

1. Plateau gravels.

1. PLATEAU GRAVELS

Gravels are widely distributed on flat or gently sloping surfaces considerably above the present level of the Migori and Kuja Rivers, and for many miles on either side of their present courses. Most of the pebbles are of vein quartz and Kisii Quartzite; a few are of banded ironstone and other siliceous rocks. All are well rounded, more particularly towards the west, where also coarse quartz sand occurs with the gravels. These gravels and sands were derived from the east and north-east and were carried down by the precursors of the present Kuja and Migori Rivers and spread over gently sloping surfaces. Subsequently, during the period of lateritic ironstone formation, air but the siliceous pebbles were decomposed and removed in solution. Thus, the present gravels are merely an "insoluble residue" of the original gravels. Those that now remain seldom exceed a foot in thickness.

The levels of the surfaces on which the gravels rest are noted in a succeeding section in corinexion with the recent tectonic and physiographic evolution of the area. the age of the gravels has not been proved, though it was suspected that some of the pebbles had been broken by human agencies and might be implements of a pebble-tool culture. ' ,

The distribution of the gravels has not been plotted on the maps (except on Sectional Map II) but observed occurrences have been indicated by a symbol. More recent boulder gravels consisting of large well-rounded boulders of a greater variety of rocks than occur in the normal plateau gravels, are seen at various places on terraces much nearer to the present river level than those on which the plateau gravels lie.

2. RESIDUAL DEPOSITS ("RUBBLE")

The deposits which are included under this heading are regarded as having accumulated mostly at the same time as the lateritic ironstone was being formed. They consist of angular or very slightly rolled pieces of siliceous rocks, chiefly vein quartz, more or less in situ. It is probable that almost all this material has come from rocks that have been weathered away since the formation of the plateau gravels, which, it is supposed, were laid down on a peneplained surface that had probably been swept clean of earlier soils and residual deposits. Two tyres of the subsequently formed residual deposits can therefore be distinguished, those that are residual from rocks decomposed beneath the plateau gravels and those residual from rocks eroded during the dissection of the gravel covered peneplain. The latter type of residual deposits lie on the slopes of valleys cut below the level of the gravels and are spread a little way down the slopes from the outcrops whence they are derived. The former are essentially in situ, and evidently, since they are residual from the greater thickness of rock, they give rise to the larger "rubble" deposit for a given width of reef. There is no reason to believe that any of these residual deposits have been derived from veins that now outcrop on the downhill side of them; they may however have been derived from veins on the uphill side that have now been entirely eroded away. Many of them are of considerable value where derived from auriferous veins and much gold has been won from them. The Kenya Gold Mining Syndicate has set a good (and profitable) example in their systematic sampling and exploitation of such deposits.

3. LATERITIC IRONSTONE ("MURRAM")

Lateritic ironstone, popularly known as murram, is found on most of the gentler slopes in the district, at various levels, and on nearly all kinds of bed rock except the Tertiary lavas, on which it is only occasionally seen. It is a cellular and concretionary lateritic ironstone similar to that well known over much of East Africa. In this area it is seldom over ten feet thick and usually less. Quartz veins are sometimes seen in it, having remained more or less in their original attitude, while the adjacent country rock has been decomposed and removed and lateritic ironstone deposited in its place. From this it is obvious that the ironstone has grown downwards by replacement as well as, presumably, upwards by deposition of material at its upper surface.

The age of the lateritic ironstone is not known except by analogy with other areas where it has been proved to have been formed at two or more periods in the Pleistocene. The fact that it occurs at many levels from the Lake shore to the highest hills, does not in itself prove that it was formed at different times on a series of different peneplains. It rather appears as a mantle on a recent surface which differed only slightly from that of to-day. The ironstone is now being eroded, and many of the streams have cut down a little way below the surface on which it was deposited.

Obsidian tools, of Wilton or later types, are very common throughout the district; they lie on the surface of the murram none were seen actually it.

4. ALLUVIUM AND BUCK VALLEY SOIL

Below the junction of the Kuja and Migori Rivers, are extensive deposits of alluvial silt, with lenses of sand, and, near water level, layers of gravel. Further up these rivers smaller alluvial patches occur.

In the flat-bottomed valleys which drain the drier parts of the area, there is a deposit of "black cotton soil" which is partly alluvial in origin and which, for ease in mapping, is not separated from true alluvium. A layer of calcareous concretions ("kunkar") is often present beneath this black soil. As elsewhere, these black soils are characteristic of badly drained areas.

4. Structure of the Younger Rocks and Physiographic Evolution of the Area

Since the deposition of the Kisii Series, the structural history of the area is largely one of comparatively gentle tilting and warping, which can be elucidated as much from the geomorphology as from the folds, faults and other structures of the rocks. Structural and physiographic development are therefore treated together here.

The principal stages that have been distinguished in this development are:-

Period	Processes and Events	Results
1. Pre-Kisii………	Erosion	Sub-Kisii surface
2. Post-Kisii…..…	Warping, tilting and faulting	Structures in the Kisii rocks
3. Mesozoic…….	Peneplanation	"Kisii Highlands Peneplain" (P1)
4. Miocene?……..	Uplift (or lowering of base level of erosion) followed by peneplanation.	(Erosion levels [p2] and [p3])(Sub-volcanic Peneplain [p4].) Sub-volcanic gravels and sediments.
5. Miocene?……..	Eruption of Isuria and Gwasi volcanic rocks, followed by deposition of gravels	Isuria and Gwasi volcanic rocks: Gravels near Utimbara scarp (Musoma district)
6. ?……………….	Faulting and westward tilt	Isuria fault
7. ?……………….	Initiation of Migori drainage and erosion to base level	Plateau gravels on faintly terraced surface (P5)
8. ?……………….	Westward tilt causing rejuvenation of the Migori.	Narrow incised Migori valley, cut down below plateau gravel surfaces.

Correlation of these stages with those elsewhere is not yet possible. Some Pleistocene deposits in the Karungu area, which were examined by Mr. E. J. Wayland, Dr. C. S. Hitchen and the Rev. Archdeacon Owen, following the discovery of human remains by the latter at Nira (Ngira), were not re-examined during the present work.

1. THE SUB-KISII SURFACE

It can be seen, along the southern side of the Kisii massif, that the earliest of the lavas flowed over a surface of moderate relief; in some places the lavas clearly flowed into valleys, as is apparent from the varying levels of the base as shown on the maps. (Plate IV and Sectional Map VII). These variations in levels are not due to subsequent folding.

2. STRUCTURES IN THE KISII ROCKS

The structures in the Kisii Series rocks are comparatively simple. The western block consists of a shallow asymmetrical syncline, trending approximately north-south. At its southern end the rocks pitch northwards, at two or three degrees. East of this fold the dips steepen but as a result of several strong faults throwing against the dip, the same beds are repeated in parallel fault blocks. The faults must die out rapidly southwards, since there is no sign that they reach the Gold Belt. From the topography

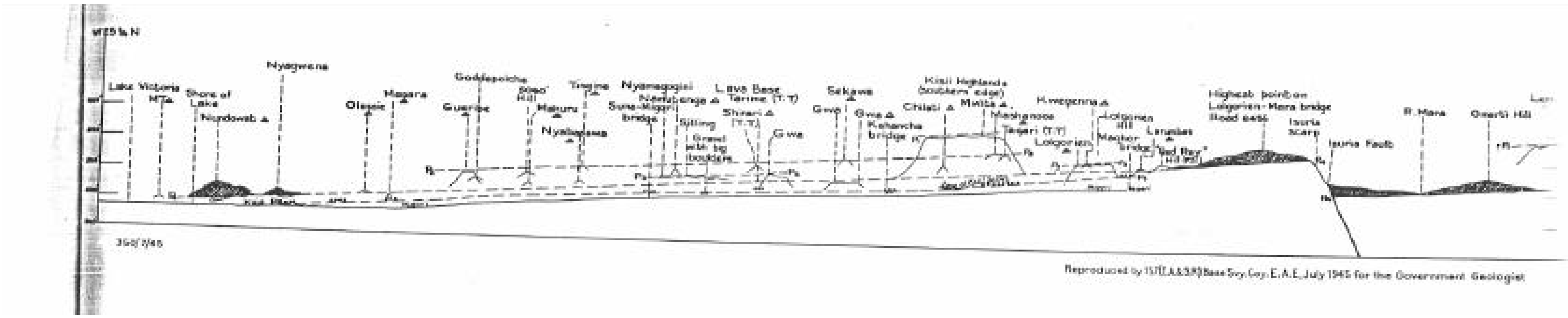

FIG. 6

Profile along the Migori Valley to show erosion levels

The profile is projected on to a line through Masara and Larumbas trigonometrical stations. The erosion levels indicated are:

p1 Kisii Highlands Peneplain (Cretaceous ?).

p2 and p3 Intermediate erosion level.

p4 Surface on which the Miocene sediments and volcanic rocks rest (Sub-Miocene Peneplain).

P5 Surface on which the plateau gravels rest (End-Tertiary Peneplain).

The lowest line in the profile represents the Migori River thalweg from Maghor Bridge, north of Lolgorien to near Lake Victoria.

The Tertiary volcanic rocks are cross-hatched, Miocene sediments are stippled and the plateau gravels are shown by small circles. Vertical scale ten times the horizontal.

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it is obvious that the fault blocks of Kisii rocks are cut off by cross faults to the south, where the quartzite ridges end abruptly and give place to granite, but the actual arrangement of this fault system could only be elucidated by the discovery of many more exposures.

Regarding the age of these structures all that can be said is that they must be earlier than the Kisii Highlands Peneplain, which is itself much older than the Sub-Miocene Peneplain.

3. THE "KISII HIGHLANDS PENEPLAIN"

The even summit level of the Kisii Highlands clearly indicates that the massif is a dissected relic of an old peneplain (Pl on diagram, Fig. 6). It is the highest and oldest erosion level and can be seen from the diagram to stand about 1,300 feet above the level of the base of the Miocene volcanic rocks. The Lemeck Hilts rise to about the same height above the lava base and signs of the same peneplain wilt probably be found there. There is no evidence to show the age of the Kisii Highlands Peneplain. 11 may be Cretaceous.

4. OTHER EROSION SURFACES (P2 AND Pa) BELOW THE KISII HIGHLANDS PENEPLAIN, AND THE SUB-MIOCENE PENEPLAIN (P 4)

Below the "Kisii Highlands Peneplain" there are relics of erosion surfaces at various lower levels. The summits on the Mara-Migori watershed near the Tanganyika boundary rise about 600 feet above the lava base and some of the dioritic porphyrite hills, and Mashanooa Hill, perhaps represent the same surface (P 2). The Lolgorien and Longawone ridges and the remarkably even surface of the dioritic porphyrite, between Namutenga and the Suna-Kisii road probably belong to another erosion surface (P 3) about 250 feet above the lava base.

The surface on which the lavas rest provides a datum to which the levels of the other surfaces can be referred. Mapping, particularly in the Lolgorien area, shows that the base of the Isuria lavas is an even surface, evidently a well-developed peneplain, from which there rose low residual hilts ranging in height from the Lolgorien banded ironstone ridge 300 feet above the plain, to the hills of the Kisii rocks which rose some 1,300 feet above it. The flatness of the surface is also evident from the wide extent of the comparatively thin lava sheets. As can be seen from Fig. 6 this sub-volcanic surface slopes gently towards the Lake (the slope being about I in 150), and if projected in that direction it meets the corresponding surface beneath the Gwasi volcanic rocks of the Karungu area. It is therefore believed that these two volcanic Series were erupted on the same surface; this does not, of course, prove that they were erupted simultaneously, but only that their eruptions occurred during the same erosion stage. The level of the lava base at Tarime, projected on to the line of section fits in well, although the mapping there (Stockley, 1935, map), indicates that the sub-volcanic surface is less regular than on the Kenya side of the boundary.

The sub-volcanic surface is Miocene in age. The Miocene sediments appear to occur in hollows in this surface.

5. THE ISURIA AND GWASI VOLCANIC ROCKS AND GRAVELS NEAR UTIMBARA SCARP

After the eruption of the Isuria lavas there was an appreciable interval of quiescence, since quartz gravel occurs on the lava surface, close to the edge of the Utimbara fault scarp, south-west of Tarime. (These gravels were noticed during a visit to that area with Mr. G. M. Stockley.) It therefore seems that the eruption of the Isuria lavas was not closely connected with the faulting.

6. THE ISURIA FAULT

The Isuria fault, in the area mapped, has a downthrow to the east of about 1,200 feet. It outcrops within a zone of mylonitized gneisses in which the shear planes dip east-south-east at moderate to steep angles. If the position of the fault in this shear zone, at the present level of erosion, is not a coincidence, the fault must also be inclined east-south-east and it is therefore a normal fault. The fault scarp is in part deeply dissected. It is not certain that all the movements took place in one stage; a second movement may have occurred at the same time as the second tilt, i.e. after the formation of the plateau gravels.

7. THE PLATEAU GRAVELS,

The cycle of erosion which followed the Isuria faulting led to the deposition of the Migori and Kuja plateau gravels. These gravels are spread over a surface (P5.) which slopes very gently inwards towards the present Migori valley. The surface can, in places, particularly near Suna, be seen to consist of a series of wide terraces each five or ten feet lower than the one above. It is evident that the surfaces on which these wide sheets of gravel were spread must have been formed by a river far more mature than the present-day Migori. The gravels, from Lolgorien to Akala, lie between 350 and 200 feet below the sub-volcanic level *(see* Fig. 6), and with an approximately similar gradient, namely 1 in 150. It seems certain that they were laid down in a mature valley with a lower gradient than at present. Therefore at least some of the westward tilt which affects all the older erosion surfaces occurred after the deposition of these gravels.

The surface (P5) on which the plateau gravels rest is correlated with the End-Tertiary Peneplain of other areas of East Africa.

8. INCISED MIGORI VALLEY

The final westward tilt evidently rejuvenated the whole of the westward-flowing portion of the Migori, with the result that it incised the narrow valley in which it now flows. The river is generally about 200 feet below the plateau gravel surface. This more or less uniform lowering of the valley is quite different from the result that would have followed a lowering of Lake level, instead of the postulated tilt.

The tilt was presumably connected with some subsidence or down-warping in the Lake Victoria basin. A similar lake-wards tilt of comparatively recent date is also observed in Central Kavirondo.

V-ECONOMIC GEOLOGY

The geological aspect of the mineralization of the older rocks has already been discussed. The following section contain notes on the geology of the principal gold mines, and on the mineral resources other than gold.

Gold

DETAILS OF MINES AND PROSPECTS

(a) Macalder Mines. Ltd.

Various deposits designated by numbers and lying in the Akala and Masara Hill areas, have been located, developed and in some cases mined by Macalder Mines, Ltd. Their positions are shown on Sectional Map II. The most important has proved to be "No.9" which is now known as Macalder Mine.

"No. 3."-This is the most north-westerly auriferous deposit of any value known in the Gold Belt. It consists of two principal veins, parallel and about 100 feet apart, with various smaller veins. The principal veins strike about 1400, dip south-west at about 550 and are traceable along the strike for about 1,500 feet. They consist of bluish quartz and occur in grey and black, sometimes graphitic, slates or cleaved mudstones. In a few places these rocks are indistinctly banded, when their dip is seen to be south-west, apparently at the same angle as the veins. A short distance east of the workings, quartz porphyry is exposed, and similar rocks form the country rock of a small vein about t mile to the north-west of the principal veins on about the same strike. The quartz porphyry probably lies only a little below the principal veins.

A diamond drill hole (No.2) was put down to intersect these veins but the cores have unfortunately been mislaid. A considerable amount of underground work has been done on the prospect with encouraging results, but work is at present stopped on his and most other prospects, while attention is concentrated on "No. 9." The underground workings were consequently inaccessible during the present survey.

"No. 29" is a quartz vein or veins in altered andesitic rocks.

"No.2" vein is also in sheared and kaolinized or sericitized andesitic rocks near the top of the Andesitic Group. It follows the strike of the country rocks and is one of a series occurring at approximately the same horizon, which is evidently an unimportant zone of weakness. Further south-east this zone includes a shale horizon.

No. 1."- This vein cannot now be satisfactorily observed at the surface; considerable underground work was done and much of the payable ore stopped out. The country rock is a fine-grained hornblendic schist, derived from the metamorphism of older basic rocks. The apparent strike of the vein, approximately north-east, is unusual for the area.

"No. 8" and "No. 18."-Both of these are quartz veins in andesitic rocks; they occur on the same strike about a mile apart, and belong to a series of veins which follow the general strike of the country rocks from near the Masara-Kwere fault to the Kuja and west of it. No. I8 is considered the more promising. The country rocks there are much altered and are probably andesitic tuffs.

"No.9" (*Macalder Mine*) *see* Fig. 7 and Fig. 8.-The mine is situated about t mile north-west of Masara Hill. The ore bodies are a branching series of lenticular veins extending over a distance exceeding 1,200 feet and following a general north-west-south-east direction. The veins, which are frequently 20 feet or more in thickness, consist of massive banded sulphides. Down to a depth of about 120 feet from the surface the primary sulphide ore has been oxidized to a mass of auriferous iron oxides or gossan. At the base of the gossan there is a thin zone of secondary copper enrichment.

The country rocks are meta-basalts, banded ironstones and graywackes. In the vicinity of the ore-bodies these rocks have a complex structure which is best appreciated from the plan (Fig. 7) and section (Fig. 8). It is believed that the apparently numerous banded ironstone horizons are in fact one bed, repeated by folding and faulting. The general dip of the rocks is towards the north-north-east.

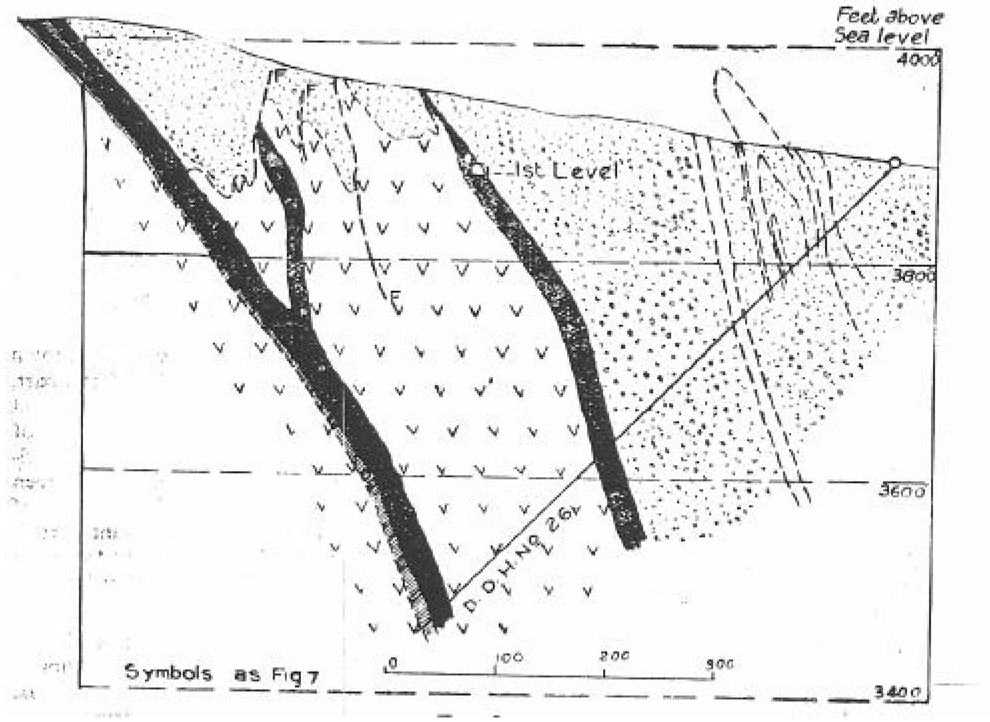

FIG 8
Geological Section, Macalder Mine.

The section is on the line of diamond drill hole 26 (see Fig. 7). The isoclinal fold in the graywacke series is inferred from the attitude of bands in which graded bedding was seen in the cores.

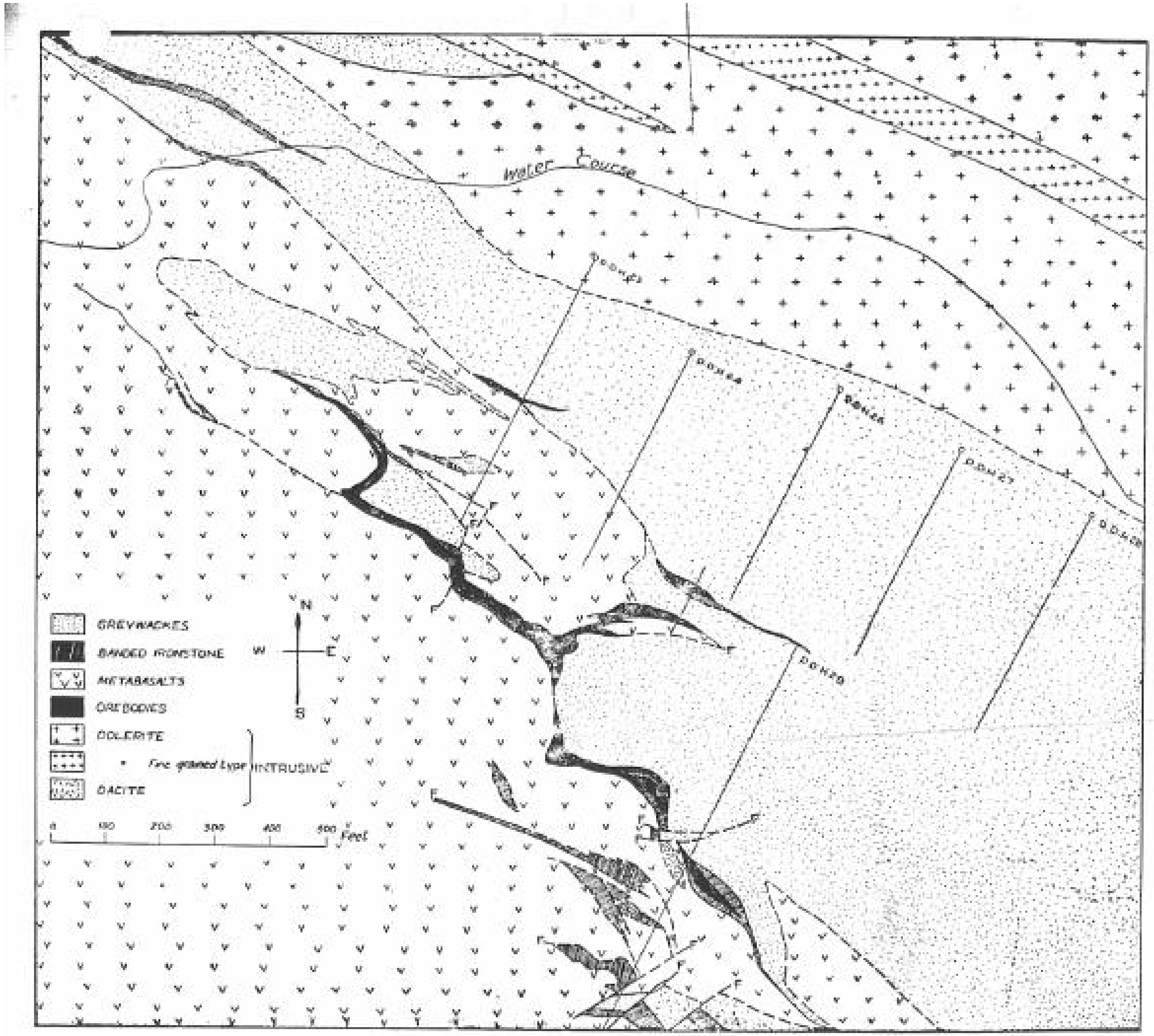

FIG 7

Geological plan of the area around Mavcalder Mine.

The banded ironstone outcrop shown are thought to repsresent a single band, separated by faulting. The orebodies are replacements. The disposition was controlled by faults and the metabasalt-greywacke contact

To face page 54

Towards the eastern end of the vein system, a mass of graywacke outcrops at the surface, but is known from underground workings and diamond drill sections .0 be underlain by meta basalts. The nature of the under-surface of the mass is suggested in the section (Fig. 8), but its exact form is speculative. It is, however, clear that this graywacke cover pitches eastwards.

Other areas of graywacke occur west of the large mass. Their presence is due mainly to strike faulting, but possibly in part to folding.

The veins are generally inclined towards the north-north-east at varying angles. Deeper in the mine, the dip of the veins is steadier, at about 60" to the north-northeast. It will be seen from the map that the veins tend to occur at the graywacke metabasalt contacts and that in nearly all cases they are associated with lenticles or sheets of banded ironstone, which are supposed to occur normally at this contact. Diamond drill holes show that at the depth of the proposed fourth level, the northern or "C" vein occurs on or near the metabasalt-graywacke contact, but that the other principal vein (here regarded as the "A" or southern vein of which "8" is a branch) lies within the meta basalts, about 200 feet below their contact with the graywackes. It is, however, still associated with banded ironstone. It is believed that the veins occur along faults.

There is little doubt that these ore bodies were formed by replacement. This is apparent from the way in which irregular tongues penetrate into the country rocks, as well as from the general form of the vein system.

The character of the primary ore has already been described (see p. 32 above). An analysis of a composite sample of the sulphide ore from a cross-cut on the third level is given below:

Pb	0.89
Cu	3.83
	Tr
As	0.52
Sb	0.03
Fe	32.29
AI.O.	3.27
TiO	Tr
Mn	0.18
Zn	5.13
Co	0.26
Ni	Tr
Ca	5.60
MgO	0.97
SiO	9.89
S	25.70
CI	Tr.
CO2	7.23
H,O-	0.49
Te	Nil
Au	3.5 dwt. per ton
Ag	3 oz. 2 dwt. per ton

(Analyst: Miss A. F. R. Hitchens, Chemist and Assayer, Mining and Geological Department.)

It should, of course, be understood that this analysis is intended to show the nature of the ore and not its average composition.

The zone of secondary enrichment between the primary sulphide ore and the overlying gossan is thin and impersistent. Close to the base of the gossan, malachite, azurite and cuprite occur and below this there is a rapid transition to the sulphide ore, which at the top is soft, and in the drives, covered with a deposit of melanterite, Bornite occurs sporadically immediately above the sulphide ore

The gossan is a cavernous mass of iron oxides and hydroxides, with satisfactory gold values, which, it is interesting to note, were rather low close to the surface. The mineralogy of the gossan has not been investigated but can approximately be deduced from the composition of the primary ore.

A mill with a capacity of 150 tons per day is now treating the gossan ore which is being worked in large open-casts. The primary ore will require flotation and smelting.

(b) "Masara Mine" (Radford's)

This mine is now dosed down. The production was mainly from a vein known as "Achar Reef," which was worked by a complicated system of holes. The vein occurs in a meta-dolerite (or meta-basalt) and had a surface pay strike of 300 feet, which at the 100-foot level had diminished to 100 feet. The dip is variable and the fracture in which the vein occurs is evidently an irregular and minor structure. The primary ore, where exposed in the mine, was a narrow impregnation of pyrite and arsenopyrite with ill-defined walls. Copper minerals were not seen. The oxidized zone was a soft yellowish altered rock, passing gradually down into less altered material. The gold values in this oxidized zone were high. The "Clive Reef" diverges at a low angle from the "Achar Reef" and is a pyritic white quartz vein with low and patchy gold values.

(c) Kenya Gold Mining Syndicate. Ltd.[*]

This company has worked a number of quartz veins and rubble deposits in the Masara area. Those recently or now worked include "M.K.", "Blackhall's Reef" (Kenya Gold Mining Syndicate Mine), where the mill is situated, and "Kisumu Reef." "Steel's," now abandoned, yielded in the past some rich ore.

"M.K."-The "M.K. Reefs" are situated about three miles north-west of the Kenya Gold Mining Syndicate Mine. Two parallel quartz veins, about 50 feet apart, are present, the one to the south being the more important. They strike 120° and dip steeply south-south-east. Although having only a short strike-about 500 feet-and a pay strike which is much less, the vein has yielded a useful quantity of rich ore for several years. It varies in width in a remarkable manner, swelling and constricting in both vertical and horizontal directions, resulting in ovoid swellings varying from a few inches up to several feet in diameter. The width of the vein seldom exceeds 12 in.

Mr. E. J. Wayland identified scheelite from the "M.K." vein (Wayland, 1931, p. 28).

The country rock at "M.K." is a cleaved and chloritized andesitic lapilli tuff with no perceptible bedding. The veins appear to follow the cleavage.

"Steel's Reef."-This vein lies about one mile north-west of the Kenya Gold Mining Syndicate Mine; it is no longer worked. It can be traced for about 1,000 feet and values were payable at surface along a large part of this length. The strike is nearly east-west, and the dip is southwards at from 25° to 40°; it tends to decrease downwards. The vein was explored to about 120 feet vertically below the surface, but stoping was not carried below 100 feet down the dip, as values gave out. Other veins on either side of "Steel's Reef" form, together with it, an en échelon group. The veins occur in feebly bedded andesitic crystal tuffs.

"Black hall's Reef" (see Fig. 9) is the vein at the Kenya Gold Mining Syndicate Mine and was the earliest to be mined in Kenya. It is a strong vein of whitish quartz; traceable at the surface for over 1,000 feet; the strike is about 110° and the dip south-south-west at about 80°. The vein varies up to about five feet in width but is somewhat lenticular. It diminishes irregularly or dies out altogether towards both eastern and western ends of the levels. Downwards its length becomes less in successively lower levels. The payable portion of the vein, now largely stoped out, formed a wedge-shaped area, within which definite shoots were not well defined. The axis of the wedge as a whole seems to pitch steeply westwards. The reef is now being explored below the bottom of this payable wedge, in the hope of discovering another similar body.

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[*] .Since this report was written, K.G.M.S. properties have been transferred to Messrs. Masara, ltd.

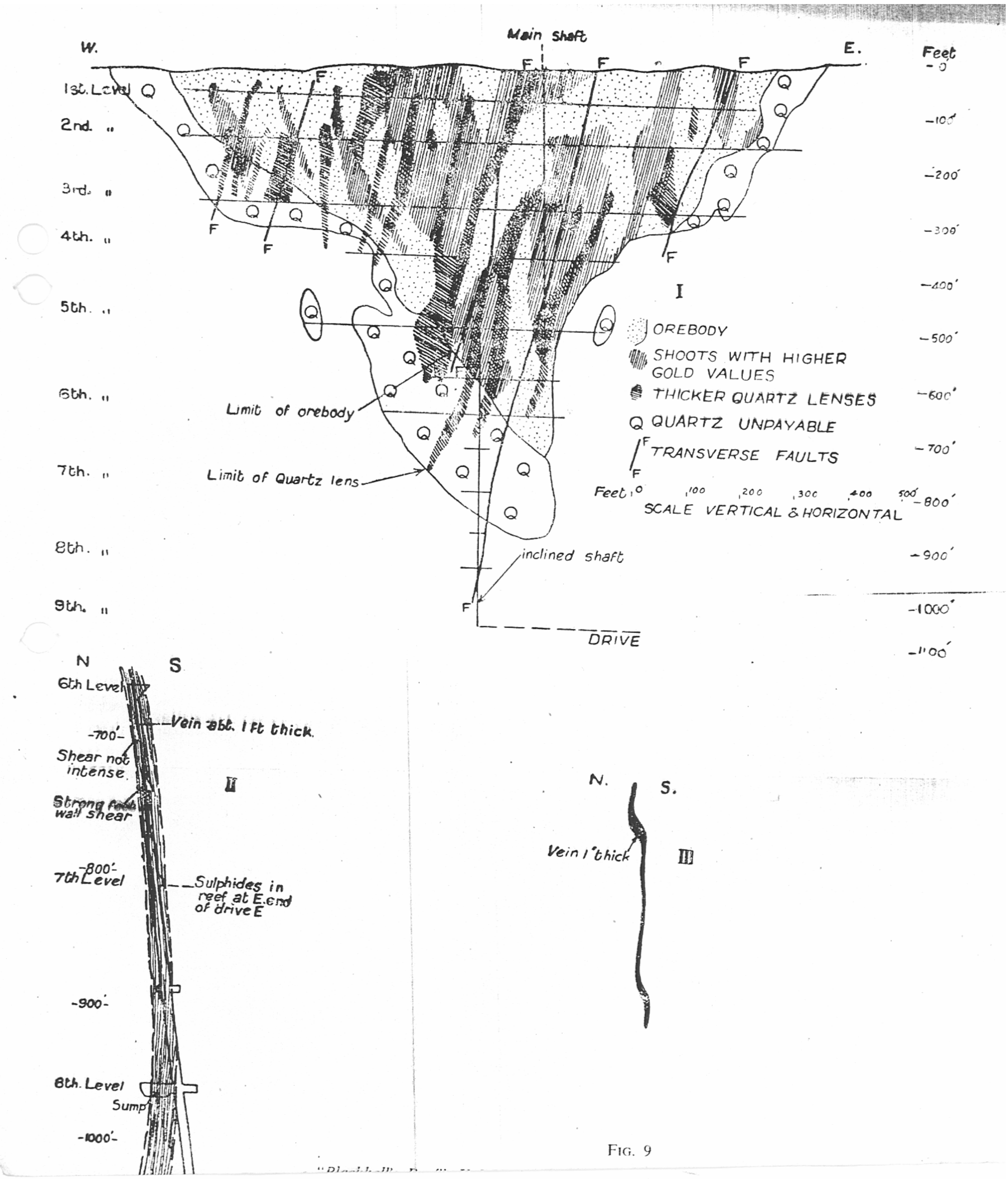
Main Shaft
W.
E.
Feet
-0
1st. Level
2nd. "
3rd. "
4th. "
5th. "
6th. "
7th. "
8th. "
9th. "
-100'
-200'
-300'
-400'
-500'
-600'
-700'
-800'
-900'
-1000'
-1100'
F
Q
I
OREBODY
SHOOTS WITH HIGHER GOLD VALUES
THICKER QUARTZ LENSES
Q QUARTZ UNPAYABLE
TRANSVERSE FAULTS
Feet 0 100 200 300 400 500
SCALE VERTICAL & HORIZONTAL
Limit of orebody
Limit of Quartz lens
inclined shaft
DRIVE
N
S
6th Level
Vein abt. 1 ft thick.
-700'
Shear not intense
II
Strong foot wall shear
-800'
7th Level
Sulphides in reef at E. end of drive E
-900'
8th. Level
Sump
-1000'
N.
S.
Vein 1" thick
III

FIG. 9

The vein follows a complex shear system through massive porphyrite, and the shearing is usually strongest in the footwall of the vein. Shear zones are in many places seen to diverge at a law angle to the right from the main shear, which seems not to be a single fault, but a web-like group of anastomosing or en échelon shear zones. This shearing was very intense and has resulted in the transformation of the normal blocky porphyrite into an almost slaty mylonitic rock in which the original porphyritic felspars are flattened and smeared out to films on the shear surfaces. Everywhere the shear surfaces show the strong steeply pitching lineation which is typical of the contact zone of the main granite mass.

The vein is crossed by a number of shatter zones or faults with little or no displacement; these frequently trend about north-east-south-west and are nearly vertical. A little late pyrite has been deposited in their vicinity but appears to be unrelated to gold distribution.

Minerals noticed in the vein include calcite, chlorite, pyr ite and a little chalcopyrite.

"Kisumu Reef."-This was formerly known as the Kisumu Prospecting Syndicate Mine and has been worked on a small scale for some years, during which time some very rich ore has been obtained from it. It is situated about two. miles east of Kenya Gold Mining Syndicate Mine near the main road. It is a quartz vein fallowing a, well-defined fault marked by a narrow seam of pug. The strike is about 80° and the dip some 50° to the south. The quartz is brecciated and heavily mineralized with arsenopyrite and pyrite. The higher gold values are restricted to rather small shoots which pitch eastwards. This is one of the few mines in the area where good gold values are obtained from outside the vein in silicified rock which is difficult to distinguish from the unaltered country. The country rock is an andesitic crystal tuff.

(d) Rhino Syndicate

About midway between Suna and Kahancha several veins were formerly worked by this Syndicate; the principal of them, called "Allen by Reef," is about ¼ mile south of the main road (see Sectional Map V). It is an en echelon group of quartz veins in distinctly banded silty mudstones.

(e) Ngiga Mining Co., Ltd. (Kahancha Mine) (see Sectional Map V)

Various properties in the neighbourhood of Kahancha which were originally discovered and developed by Major B. F. Webb some years ago and subsequently worked by Watende, Ltd., are now operated by the Ngiga Mining Co.., Ltd. The principal veins are known as "Carlos" (East and West), "No.. 2," "Homestead," "Sagire" "Francis" and "Freda".

"Carlos East" and "Carlos West" (about two. miles west of Kahancha).-Neither of these veins can now be examined as the workings are flooded. They occur in graphitic shales, and are pyritic quartz veins striking about 120° and dipping south-west at about 45°. They are probably arsenical. The workings at Carlos East extend to about 120 feet vertically below the surface.

"No. 5."-This is at Kahancha about ½ mile north of the Company's office and mill. It is a lenticular quartz vein in the same zone of crushed graphitic shales as the Carlos veins and "Homestead" further east; it strikes about 80° and dips south-south-east at about 55 °. The quartz is pyritic and contains arsenopyrite and the shales near the vein contain plentiful pyrite, but payable gold values are can fined to the quartz. The vein occurs in a steep thrust plane, and as usual with veins in shales, is lenticular and influenced by various faults and changes of structure. It was evidently injected while movements were still taking place. The gold occurs in two well-defined shoots, one an either side of the main shaft. They pitch eastwards, the western one at about 70° and the eastern one at about 60°. Their breadth is not great-about 30 to 50 feet-but they do not appear to be narrowing downwards and the values in the lower levels are enough to. encourage further exploration. The eastern shoot has not yet been intersected at the third level.

"No. 2."-Two veins near the European quarters at Kahancha are known as "No.2." They follow a curved course on the ground owing to the twist which has affected the rocks on the line of the Kahancha "buck reefs," and their outcrops are about 400 feet apart. Both the veins follow strong thrust planes, beneath which several feet of the rocks are crushed and rolled into ball-like masses, while above, they are little disturbed. The thrust planes are almost parallel with the bedding which dips at from 25° to 35° to the south-west. The veins are usually less than a foot thick, and values are low. The controlling structures must continue to considerable depth. A few inches above one of the thrusts there is a lamprophyre sill. The country rocks are slightly hornfelsed blocky and banded fine-grained sediments.

"Homestead: This is a quartz vein in a strong thrust fault in dark shales. The strike of the vein is about 135° over some 1,800 feet, but values are low.

"Francis."- This is another quartz vein in dark shales, and is probably similar in character to "No.5." The workings, which are now flooded, extend about 150 feet below the surface. The vein generally strikes 145° over about 1,000 feet and dips at 70° to the south-west.

"Freda."-This is the name now used for a number of veins formerly known as the "Gori rubble." They are situated about two miles east of Kahancha, above the right bank of the Migori, and are a series of lenticular quartz veins in silty shales and greywackes.

"Sagire".-This promising vein has only recently been discovered. It is about a mile south-south-west of the Company's office and lies just within the granite contact in strongly' sheared granitic rocks. It is the only worked vein in this Gold Belt that occurs in the granite. The vein has been proved for over 1,500 feet; it strikes about 100° and the dip is southwards. The quartz is a platy white variety with brownish films and often contains visible gold.

(f) "Balman Mine" (formerly "Rainbow Mine")

The principal vein of those formerly worked by Mr. Rainbow is the "Vim Reef", about one mile south of Lolgorien Hill. It is a pyritic quartz vein associated with banded ironstone; the pay strike is perhaps 400 feet with widths up to 18 inches and interesting values. Other small veins were also worked.

(g) Kenya Consolidated Goldfields, Ltd. (Lolgorien)

This Company holds a number of properties in the neighbourhood of Lolgorien, the principal being "Blue Ray", "Alpha Ray", "Maghor", "Caldwell" and "Red Ray".

"Blue Ray".-This is situated about a mile south of Lolgorien Post Office; the mill is adjacent to it. The vein strikes 94° over nearly 2,000 feet. A small pay shoot occurred at the eastern end but the principal values were found further west in a shoot which pitches eastwards at about 50°. The lower limit of this shoot is quite sharply defined and regular whereas the irregularity of the upper limit suggests that the mineralizing solutions followed a channel near the lower limit of the shoot and deposited the gold in subsidiary shoots spreading upwards more or less vertically from the main channel.

The vein lies in a thin wedge of shales and greywackes between two masses of basic rocks which are probably fine-grained meta-dolerites or possibly meta-basalts. The wedge of sediments tapers eastwards and disappears towards the eastern end of the mine.

"Alpha Ray". - This is a thin nearly vertical yellowish-white quartz vein with a strike of 100° over about 2,000 feet, occurring in meta basalts. Several north-east-southwest tear faults shift the vein towards the left. The vein is never very wide, probably averaging about 8 in. in the payable sections, but values are good and the reopening and development of its eastern sections should yield interesting results.

"Maghor".-This is a small mine situated about one mile north of Lolgorien Post Office. The vein is of quartz, and strikes l00 over about 1,000 feet. It occurs at the contact of a granite porphyry, forming the hanging wall, and Kavirondian boulder beds, forming the footwall. The vein dips south-south-west and probably follows a fault

"Caldwell".-This vein, nearly a mile west along the strike from Blue Ray, has not been worked for some years and little information concerning it could be obtained. It appears to have a strike varying from 90 to 100 over about 2,000 feet, and is a quartz vein, apparently in meta dolerite, but sediments may occur.

"Red Ray".- This is a quartz vein in the Lolgorien Hill banded ironstone horizon, about two miles east-south-east of Lolgorien Post Office.

(h) All Gold Mines, Ltd.

Various small reefs have been intermittently worked by this Company and its predecessor, Kanji Naranji, but no vein has been developed and proved payable for mining. Most of the gold obtained has been from surface workings. The veins are mostly associated with the Lolgorien banded ironstone horizon and are one to two-and-a half miles east-south-east of the Lolgorien Post Office. Other veins are in meta-dolerite.

(2) RESIDUAL AND ALLUVIAL OCCURRENCES

Residual gold deposits comprise the "rubble" deposits which are well known to workers in the field and require no further mention here. They are referred to on p. 50.

Alluvial occurrences are of two types, neither of which has yet been proved to be workable. The first is the sub-volcanic gravel of the Lolgorien area, which, it is believed, may contain payable gold values on Larumbas, and possibly elsewhere. These sub-volcanic gravels deserve careful prospecting. The second type of alluvial occurrence is in the recent alluvium. This is not considered promising, although no systematic testing of the Lower Kuja flats has been done.

2, Other Mineral Resources

Apart from the copper and other base metals in the Macalder sulphide are bodies, the only proved mineral resource of the area is the gold deposits, and during the present work no discoveries of any other minerals likely to be of importance were made. The only occurrence of a non-precious mineral noted as deserving investigation was one of barytes. Angular pieces of this mineral up to 6 in. in length were seen embedded in the base of the murram, in a pit a short distance west of the road junction at Kahancha. It is white and is not seen to be associated with any other mineral, but in view of its rarity in the goldfield and its common association with lead-zinc deposits elsewhere, this occurrence, which must be almost in situ, should be investigated.

VI-REFERENCES

Goldschlag, M., 1912.-"Beitrage zur Kenntnis der Geologie and Petrographie Ostafrikas I", *Centrallblatt f. Min*., pp. 567 and 593.

Grantham, D. R., 1933.-"Classification of Tanganyika Granites." Ann. Report for 1932, Geol. Div., Department of Lands and Mines, Tanganyika Territory. Government Printer, Dar es Salaam.

Groves, A. W., 1931.~"The Dolerite Dykes of Uganda." Ann. Report for 1930, Geol. Surv., Uganda. Government Printer, Uganda.

Hallam, C. D., Fitch, A. A., and Edgworth-Johnstone, W., 1936, 1937 and 1938.-Unpublished Geological Reports on parts of South Kavirondo, submitted to the Mining and Geological Dept., by Messrs. Kenya Consolidated Goldfields, Ltd.

Hitchen, C. S., 1936.-"Geological Survey of No.2 Mining Area, Kavirondo." Interim Report and Map of the north-west Quadrant. Report No.4, Mining and Geological Department, Kenya. Government Printer, Nairobi.

1937.-"Geological Survey of No.2 Mining Area, Kavirondo." Interim Report and Map of the north-east Quadrant. Report No.6, Mining and Geological Department, Kenya. Government Printer, Nairobi.

Kitson, Sir Albert E., 1934.-"Geological Reconnaissances in Kavirondo and other Districts of Kenya." (Final Report.) Government Printer, Nairobi.