

SOUTHERN RHODESIA  
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No. 51

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The Geology of the  
Miami Mica Field  
(URUNGWE DISTRICT)

*by*  
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Dissertation submitted for Degree of  
Doctor of Philosophy of Rhodes University.

## PREFACE

The detailed geological survey of the country described in this bulletin commenced in 1953 and was completed in 1956 with the mapping of 1,480 square miles of country. Information is supplied on 227 mines which produced mica alone or both mica and beryl, and 134 mines which produced only beryl. In addition, wolfram, gold, graphite, kyanite and rutile deposits and mines are described. Mineral outputs are given up to end of 1959.

The field mapping and writing of the bulletin is entirely the work of Mr. Wiles.

Mapping of the Field has established that, with a few exceptions, a metamorphic control has operated in the development of economic sheet mica and has led to the conclusion that very many of these pegmatites are composite bodies which have derived their material from two sources: one metamorphic and the other igneous. This conclusion was arrived at after a detailed petrographic investigation of the metamorphic rocks.

The map at the end of this bulletin was drawn by Mr. A. H. Barrie and the diagrams are largely the work of Mr. D. O. L. Levy.

Chemical analyses are by Messrs. A. J. Radford and E. Golding and were made in the Geological Survey Laboratory.

Some of the photographs are by H. J. Cotterel of the Geological Survey while the remainder were taken by the Planning and Technical Services of the Federal Ministry of Home Affairs (formerly the Federal Information Department).

It gives me pleasure to acknowledge the assistance and facilities offered the Department by mining men and residents in the district.

F. L. AMM,  
*Director.*

Geological Survey Office,  
Salisbury.

20th September, 1961.

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PLATE I



Prizing a book of mica from the Owl Mine pegmatite.

Photo: R.D.K.H.

# The Geology of the Miami Mica Field

(URUNGWE DISTRICT)

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## Part I — GENERAL GEOLOGY

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### INTRODUCTION

THIS BULLETIN deals with the main mica mining areas of Southern Rhodesia which are situated in the recently constituted district of Urungwe. The area which is towards the extreme north of the Colony was previously a portion of the Lomagundi District.

The accompanying map covers approximately 1,500 square miles of country, with the township of Karoi near its centre, and has the following limits:

29°30' and 30°00' east longitude.

16°30' and 17°00' south latitude.

The main road from Salisbury to Chirundu and on to Northern Rhodesia passes diagonally across the map in a north-westerly direction dividing it into two approximately equal parts.

The farms, located mainly in the centre of the district, are served by good roads, but the deeply-dissected marginal areas, to the north and south-west, in which most of the mica mines are situated, contain only bush tracks.

The geology in the eastern sector has been plotted on topographical maps compiled from aerial photographs by the Department of Federal Surveys. The base maps for the remainder were made by the Air Survey Company of Rhodesia Limited, and are a portion of the large area mapped by them on contract to the Federal Government in connection with the Kariba Hydro-electric Scheme.

The nearest railway siding is at Lion's Den, 22 miles from the point where the main road leaves the southern edge of the map. The route of a proposed rail connection from Lion's Den through to Kafue in Northern Rhodesia has been surveyed. It closely follows the line of the main road, but it is doubtful whether the connection will be made in the immediate future.

The mapped area can broadly be divided into three portions on the following basis:

- (1) Mining in the dissected northern sector.
- (2) Farming in the flatter country straddling the main road.
- (3) Native Reserve in the lower lying south-western sector.

As a whole the district is healthy and pleasantly habitable but at one time tsetse-fly (*Glossina morsitans*) was widespread. In bulletins of the former Southern Rhodesia Government Entomological Section of the



Agricultural Department, it is stated that after the rinderpest epizootic in 1896, the nearest point inhabited by the fly was in the Tchetchenini area. Tchetchenini itself is a dominating ridge just east of the Angwa River some two miles outside the north-eastern boundary of the map. The fly occurred in an isolated patch along a tributary of the Reko-miche River in the north of the area. Between 1905 and 1910 a few specimens of the fly were encountered towards the north-west. As the game increased and spread so did the fly and it was decided to stem its advance by the unpopular measure of game reduction aided by the erection of extensive game control fences.

Shooting of game as a control measure commenced, in what is now the Urungwe District, in 1931, at which time the fly occupied a large portion of the north-west sector of the area covered by the map, and had advanced to within a few miles of Miami Village.

Since that time there have been repeated outbreaks which have been controlled by the methods previously mentioned together with insecticide spraying.

As long ago as 1901 a pioneer, Jack Carruthers (1)\* reported the presence of muscovite mica in the area between the Zambezi and the Angwa rivers, but it was not till 1919 that the first mica was mined. The country was wild and abounding in game. Apart from the condition of the country, many of the prospectors had a difficult time due to lack of experience in this new type of mining as well as in the marketing of the product. This early activity was centred on the town of Miami which was then able to support two hotels. Many and interesting are the stories relating to those times.

As there were no roads but only tracks, the prospectors walked the 70 miles from Sinoia to Miami. On the way it was easy to live off game which was unaccustomed to the rifle. The natives, being friendly, would proffer gifts without expectation of payment. The donkey was used as a pack animal, as it was able to withstand tsetse-fly better than the horse or ox.

B. Lightfoot (2) has recently drawn attention to the first description of the mica deposits in 1920 by the late H. B. Maufe (3) with particular reference to Maufe's great personal efforts to keep the Field going. In 1921, Maufe went to India to get what information he could on mica mining and preparation. He returned with samples of the tools used and the mica gradeograph. Copies of the latter were in great demand but the miners were apparently not interested in the tools.

For the following reasons the full potential of the area was not realized.

- (1) Mining practice was poor.
- (2) The miners submitted samples to the overseas buyers, of a grade and quality in excess of what they could supply and consequently fell into disrepute.

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\*Numbers in parenthesis (1), etc., refer to list of references at end of the bulletin.



- (3) Rail charges were excessive as they were based on the samples submitted rather than on the less valuable consignments eventually shipped.

The mines were mainly shallow open workings on "reefs" that in many cases, would not be looked at today. Nothing was known about the zoning of pegmatites and it is obvious from the low "cuttability" of much of the early-mined mica that it was striated core-material. Whereas today approximately 10 per cent. of the mica mined is boxed for the market, in the early 1920's less than 2 per cent. was marketable.

Beryl, which is a by-product of the mica mines and is also found in pegmatites that do not contain payable mica, came into prominence in the early 1950's when beryllium was required in the atomic industry. Current prices do not encourage beryl mining and production is falling away.

The small village of Miami is now little more than the headquarters of the Police and District Native Commissioner and it seems likely that this latter department will shortly be moved to Karoi, a township that was surveyed in 1947. Karoi is the business centre of a thriving tobacco-growing district which has been built up largely by ex-servicemen under a land settlement scheme started in 1946. There were, however, a few farms such as Nassau Estate in existence long before that date. Karoi is experiencing a boom initiated by the Kariba Hydro-electric Scheme. The 1951 census gave a return of 43 Europeans and 166 non-Europeans and by 1956 the numbers had increased to 150 and 360 respectively.

An early subdivision of land known as Masterpiece Farm was surveyed in 1924. It is situated a little over ten miles north-east of Miami in a rather poor farming area. It appears soon to have reverted to Crown land and is now occupied solely by natives.

There are still a number of natives living in the area to the north of Masterpiece and Miami. The main concentration, however, is in the extreme north-east of the map in the area known as Kazangarare. These natives will all be resettled in the Urungwe Reserve during 1960, as soon as land can be made available.

Evidence that the marauding Matabele frequented these parts is still to be found. Even in the highly dissected Angwa Valley area to the north-east many peak-like features show such evidence of former occupation as pottery, grinding-stones, bones and iron-slag. Evidence of iron-smelting is widespread throughout the district. Iron occurs in small quantities in many of the pegmatites and it was presumably gleaned from this source.

The average rainfall map of Southern Rhodesia for the 30 years ending in June, 1951, showed that Karoi and Miami lie in an area having an average annual rainfall of between 32 and 36 inches. The margins of the mapped area have between 28 and 32 inches. The wettest months are from December to March, when average monthly falls of the order of eight inches occur. In recent years falls of up to 50 inches per annum have been recorded locally in the Miami area. Many farms here readily become waterlogged due to their low relief and poor

drainage, and when this happens the tobacco crops suffer far more than in dry years. In some of the vleis farmers have successfully grown rice to augment native rations.

The area of this bulletin falls within the 70 degree Fahrenheit mean annual temperature belt with maximum temperatures reaching 90 degrees in summer.

European farming practice is progressive. The district has been declared an Intensive Conservation Area. Farm lands of even gentle slope are contoured and earth dams, both large and small are ubiquitous. The township of Karoi has an earthen dam with a capacity of 310,000,000 gallons.

In the district there are many boreholes which have yielded excellent supplies of water, but there have also been numerous failures. The schists and gneisses are poor aquifers, and for this reason sites have to be carefully selected.

The main Salisbury-Chirundu road has been realigned and when completed will probably replace the Bulawayo-Livingstone road as the main national road to the North. The first road to Chirundu down the Zambezi Escarpment was constructed by the late Captain Whitby as a telephone route.

The district as a whole is well timbered though, in the farming areas, a great deal of timber has been removed in order to open up arable land. Some 29 varieties of "Highveld" trees can be identified. First in order of abundance is probably the mafute (*Brachystegia boehmii*) followed by either mahobohobo (*Uapaca kirkiana*) or umnondo (*Burkea africana*). In the immediate environs of Miami Village the muhacha (*Parinari curatellaefolia*) is a conspicuous and decorative tree with its tall, straight stem and dense, regularly rounded crown. "Lowveld" trees make their appearance in the west and extreme north-east where the Zambezi Valley and Angwa Valley vegetation fingers its way into the dissected edges of the "Highveld" plateau. The tree which so conspicuously heralds the presence of "Valley" vegetation is the baobab (*Adonsoni digitata*).

## PHYSICAL FEATURES

### *Topography*

In its broadest sense the belt of country bordering the main road, with an altitude which averages a little over 4,000 ft. may be regarded as an outlier of the "Highveld" plateau of the Colony which lies to the south-east. As one looks south-east from the trigonometrical beacon on Chirangwe Hill, a feature  $1\frac{1}{2}$  miles north of the point where the main Chirundu road leaves the northern edge of the map, one is struck by the plateau-like nature of the country. From here, Urungwe Hill, from which the district takes its name, can be seen 12 miles to the east and, like Chirangwe, is also  $1\frac{1}{2}$  miles north of the northern edge of the map. Urungwe Hill, and the hills farther north, stand up very prominently from the plateau with characteristic *inselberg* appearance.



Marginally this upland is strongly dissected by tributaries of the Zambezi River which are deeply incised as a result of the formation of the Zambezi Trough. As examples, there are the deep Mkwiche Gorge, the head of which enters the map in the extreme north-central area, and the steep Angwa Valley escarpment in the north-east with a fall of more than 1,000 ft. to the river. Farther south the Angwa passes through the deep, narrow Darwin Gorge. Where it leaves the extreme north-east corner of the map the altitude is approximately 2,200 ft. The highest point in the area is Chumburkwe with an altitude of 4,556 ft. There is, therefore, a maximum relief of over 2,300 ft.

A few of the higher points, now nearly all sites of trigonometrical beacons, were presumably low monadnocks on the "Highveld" plateau and mostly owe their existence to the resistant nature of small quartz or pegmatite dykes which are found on their summits. The area is well served with trigonometrical beacons, there being 3 primary and 17 secondary stations.

#### *River System*

All the rivers which drain the area are tributary of the Zambezi River, which flows in an arc, forming the northern and part of the western boundary of the Urungwe District.

The eastern sector of the area is drained by the Angwa River and its tributaries, which from north to south are the Mkwiche, Mpofu, Miami and the Mlichí, to mention only the larger ones. To the north is the Rekomiche River and its tributaries. By far the major portion of the area drains into the Naodsa River which flows in a westerly direction.

The east-flowing subsequential tributaries of the Angwa River show in their own tributaries a most marked adjustment to structure, even in the smallest detail. This is also apparent in the other rivers of the area but is not so well marked in the gneisses as in the mica-schists.

The main rivers of the area, the Rekomiche, Naodza and Angwa are consequential to the Zambezi River, following the development of the broad Zambezi Trough which started in pre-Karoo times, but which reached its maximum development in post-Karoo times.

There are some classic examples of river capture among small tributaries of the Mkwiche River just outside the map, and within the area piracy is imminent. In the north-central area the deeply incised headwaters of the Mkwiche River come to within less than 200 yards of one of the broad, shallow, vlei-like tributaries of the Rekomiche.

The main rivers in the area do not always flow throughout the year but they have large perennial pools. The Rekomiche rises in flat farming country where it forms broad vleis which are always wet. Soon after these vleis are burnt out — which is an annual occurrence — fresh green grass springs up forming good early grazing.



## PREVIOUS GEOLOGICAL WORK

H. B. Maufe (3) produced the first published account of the geology of the mica deposits, which was issued in 1920. The report was an optimistic one and must have provided a stimulus to prospecting. However, it is obvious that little or no field work was done and that the geological information must have been obtained from visits to mining properties. There have followed from time to time unpublished reports on various mines and claims by mining concerns and members of the Southern Rhodesia Geological Survey. The earliest unpublished geological report was made by the engineer of the Anglo-American Rhodesian Exploration Company before Maufe visited the Field.

In April, 1929, S. C. Morgan, of the Southern Rhodesia Geological Survey, produced an unpublished report entitled "A note on the Miami Mica Field". Only a few lines were devoted to the geology of country rock which was described as a quartz-biotite-gneiss.

B. Lightfoot followed this up in October, 1929, with a long road-traverse by car through the Lomagundi District (which then also included the area now known as Urungwe). His unpublished report was entitled "The Lomagundi Puzzle". The traverse was carried out with the declared intention of seeing—

- (1) if there were any obvious exposures which would clear up the problem;
- (2) if suitable areas existed in which mapping could be carried out, with some hope of profitable results.

The problem was that of trying to find a correlation between the definite Lomagundi System in the Sinoia area and the variously metamorphosed and granite-invaded pelitic sediments to the west (the Piriwiri series of Molyneux). This traverse was obviously not very successful for no conclusions were drawn.

The first geological sketch-map of a portion of the Field was made in 1943 by R. Tyndale-Biscoe. Copies of the map, prepared in the Geological Survey Office, have been in great demand with miners and prospectors in the area. In addition to the map, Tyndale-Biscoe produced an unpublished short report on the geology and notes on some of the mines.

In November, 1950, J. J. Frankel published a paper in the *South African Journal of Science* on "Flattened Tourmaline Crystals in Muscovite from Miami".

In 1955 a "Mica" pamphlet, produced by R. Tyndale-Biscoe, was issued by the Southern Rhodesia Geological Survey. This is No. 11 of a Mineral Resources series.

A. M. Bensusan (4) a mining engineer, while consultant to Rhodesia Mica Mining Co. Ltd., produced a paper on various aspects of mica mining in Southern Rhodesia which stimulated some interesting discussion.

TABLE OF GEOLOGICAL EVENTS

| Approx.<br>age in<br>million<br>years | Geological<br>age |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
|---------------------------------------|-------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 200                                   | PALEOZOIC         | <p>TROUGH FAULTING — Formation of a wide <i>graben</i> in which the Zambezi River now flows. In the depression, Triassic, Jurassic and Cretaceous sediments were deposited. This occurred north of the mapped area but a complementary series of regional faults developed within it. Movements continued well into post-Karoo times.</p> <p>UPLIFT AND EROSION — Up-doming along the line now occupied by the Zambezi River causing a southerly pitch of the metamorphic zones.</p> <p>UPLIFT AND THRUSTING — Remnant klippen of low-grade schists, of a type similar to those found in the east of the area, now rest on paragneisses of the same formation on the south-west.</p> |
| 600                                   |                   | <p>SUBMERGENCE — Deposition of Sijarira sediments. These are now preserved just south of the area mapped.</p> <p>ISOSTATIC READJUSTMENTS — Basic dykes following the advent of tension. Temperature sufficiently high in country rocks to accelerate retrograde trends resulting in meta-dolerites as a final phase in the dying regional metamorphism. Initiation of erosion cycle.</p>                                                                                                                                                                                                                                                                                             |
|                                       |                   | <p>LATE OROGENIC PHASE — Increased mobility as a result of granitization, leading to the intrusion of granite. In the main mining areas these intrusions take the form of stocks and bosses with much related pegmatite. Mica- and beryl-bearing pegmatites belong here.</p>                                                                                                                                                                                                                                                                                                                                                                                                         |
|                                       |                   | <p>OROGENIC PHASE — Deep depression of part of the formation. Some basic intrusions. Regional metamorphism followed, producing the amphibolite facies over a wide area, with attendant metasomatism reaching out from a granitization core. Soda followed by potash. Some uneconomic pegmatites.</p>                                                                                                                                                                                                                                                                                                                                                                                 |
|                                       | PRECAMBRIAN       | <p>PRE-OROGENIC METAMORPHISM (THERMAL) — Caused by rising temperatures following depression, intense folding and burial of the mass. This was a period of static recrystallization with the development of large cordierite and chialtolite crystals. Some quartz veins.</p>                                                                                                                                                                                                                                                                                                                                                                                                         |
| 2,000                                 |                   | <p>SEDIMENTATION OF PIRIWIRI SYSTEM — Predominantly argillaceous sediments with narrow arenaceous hands and calcareous lenses. Calcareous rocks more extensive at the top of the system. Apparently deposited under very cold lacustrine conditions.</p>                                                                                                                                                                                                                                                                                                                                                                                                                             |



## OUTLINE OF THE GEOLOGY

The area of country herein described is a metamorphic classic of Southern Rhodesia and is sufficiently large to include the complete granite cycle.

The Piriwiri System and its metamorphism forms the main subject of the geological section of this bulletin. The relationship between these rocks and the Lomagundi System has long been a puzzling one and the Piriwiri has until recently been considered to be the upper series of this system. The Piriwiri succession is here regarded as being older than the Lomagundi System and in this bulletin it is elevated to the status of a system. It consists of many thousands of feet of sediments which, in the lowest metamorphic areas, are predominantly phyllites with subordinate arenaceous bands. These latter may form many very thin beds occurring in rapid alternation or occasionally thicker beds that are more widely spaced. Because of the close folding, and overfolding, it has not been found possible to give thicknesses of the main mass of the pelitic sediments.

Slaty graphitic rocks occupy the north-east corner of the area mapped, where the regional dip of the sediments changes from westerly to easterly, indicating that they belong to the upper part of the system and that the phyllites belong to the lower part. The slaty appearance of the upper group, even when occurring in a zone of high metamorphism is due, apparently, to the resistance to change offered by them as a result of their graphite content, unless they are highly aluminous as well.

J. G. Stagman (5, p. 5) believes that thrusting has taken place along the line of these graphitic rocks—the Graphitic Slates farther south—and for this reason the relationship between the Piriwiri System and the Lomagundi System is not clear stratigraphically. On account of this, the writers of all earlier geological reports on the Lomagundi District regarded the Piriwiri System as being an upper Lomagundi Series.

A. M. Macgregor (6, p. 40) did, however, report that “west of Sinoia the Arenaceous series of the Lomagundi System is folded in open folds having dips of up to 66 degrees, but the overlying, argillaceous beds are contorted into small recumbent folds, the graphitic beds behaving as a lubricant between the two kinds of folding”.

A. J. C. Molyneux (7) appears to have introduced the name Piriwiri series but it was not used in the two latest publications dealing with these rocks. It was reintroduced by Stagman (5) as a pre-Lomagundi series, of unknown age, which includes an upper Graphitic Slate Group and a lower Phyllite Group. The writer's investigation of the Piriwiri rocks has been in an area where their correlation with other formations is not possible. Reconnaissance work east of the Angwa River was inconclusive. The writer has in consequence been led to accept Stagman's correlation, which has much to support it. Nevertheless the “Lomagundi Puzzle” must be regarded as largely unsolved.

The Piriwiri phyllites extend for some 80 miles south of the area mapped, occupying several thousand square miles of country in which there are widespread traces of copper mineralization. In discussing the



more highly metamorphosed derivatives of these pelitic rocks and their distribution, Macgregor (6, pp. 41, 42) says that "garnetiferous schists and gneisses extend eastwards along the Zambezi Escarpment and form the Rusambo Mica-field, situated near the Portuguese border and north of the Mazoe River". This, however, is not an established fact since much of the work in this area has been of a reconnaissance nature. Continuing, he states that "South-westwards from Miami the gneisses pass under the younger sediments, but they probably reappear as the gneiss of the Wankie Tin-field".

Since these rocks mapped belong to a single system it has been decided to produce a metamorphic map based on isograds drawn to embrace the various index minerals. These lines serve, not only to illustrate the broad structure which would not have been so apparent if the map had been based on stratigraphy alone, but they indicate isogradic zones which can be correlated with the system of metamorphic facies used by Turner and Verhoogen (8). For the detailed description of these rocks the appropriate headings employed by them have been used.

Macgregor (6, p. 40) speaks of a "scarcely perceptible" increase in the metamorphism of these rocks when followed northwards along the strike but this has not been borne out by detailed mapping. The Angwa River, which flows from south to north and, for the most part, just within the eastern margin of the map, would appear to follow some major structural line. As this line is passed, when travelling from east to west, there is a sudden increase in the metamorphism which rises in a regular sequence. In the southern section the metamorphism rises and falls as higher and lower parallel zones, which pitch to the south, are passed over.

There is still clear evidence of geothermal metamorphism over a wide area, upon which regional metamorphism with its concomitant metasomatism has been superimposed. No deep-seated granite intrusion is envisaged as the cause of the earlier thermal effects. They are believed, rather, to have been caused by rising temperature following folding and the deep sinking of a great area of these rocks preceding the truly orogenic phase. Thus a static recrystallization ensued which resulted in the development, primarily, of cordierite and chiastolite crystals with the latter attaining, on occasion, very large proportions. The later derived regional metamorphic minerals, such as kyanite and muscovite, frequently form perfect pseudomorphs after cordierite and chiastolite (Plate III). These pseudomorphs suggest that much of the folding which has taken place was initiated before the growth of the first thermal metamorphic minerals thus supporting Read's (9) contention that "Regional metamorphism, therefore, has little to do with stress or folding deformation — it is largely an affair of permeation by metasomatising solutions". He regards regional metamorphism as "inexplicable when detached from granitization".

Metasomatism has clearly been operative in the higher zones of regional metamorphism here. During the advancing stages of this metamorphism rock changes proceed from a largely iso-chemical recrystallization to one in which reactions assume an allochemical character;

the change-over becoming megascopically apparent when the amphibolite facies is reached. However, only when the highest grade of this facies, the sillimanite-almandine subfacies, is attained does metasomatism reach a maximum, and by the continuation of the process succeed in completely transforming and granitizing the rocks. Thus, in the area mapped, a sequence of rocks developed ranging from phyllites through various types of mica-schist to granitic gneisses and finally to a metasomatic gneissic granite. The granitization process started with a predominantly sodic metasomatism and ended as a largely potassic one.

Four granites have been recognized. They have been divided into two groups and classified as synkinematic and late-kinematic types. The two late-kinematic granites are believed on good evidence to be the mobilized products of the gneissic synkinematic granite. The origin of the other synkinematic granite, which is porphyroblastic, can be traced back in the field through biotite-gneiss to amphibolite.

The whole petrographic study builds up to the regional setting in which the granites and pegmatites have their origins, since the purpose of the investigation was concerned primarily with the economic pegmatites. It will be clear to any student of metamorphism that Read's (10) "Plutonic Series" is well represented here.

The pegmatites are of two origins, the one magmatic and the other metamorphic or metasomatic. These may occupy separate structures or be combined in what the writer refers to as composite pegmatites. The economic mica-bearing pegmatites are so distributed as to reveal definite metamorphic control whereas the beryl-bearing ones are clearly of igneous origin, and related to the intrusive plugs of late-kinematic biotite-granite. An abundance of these pegmatites, in the absence of any nearby granite mass, is indicative of a sub-outcropping cupola of migma-magma.

Basic intrusions of two ages occur throughout the area, the older type, now epidiorite, is clearly of pre-metamorphic age. The younger meta-dolerite, was intruded late in the metamorphic or orogenic cycle while rock temperatures were sufficiently high to produce some marked regional metamorphic effects. It follows from this that these latter dykes, where they occur in low metamorphic zones, have the appearance of more normal dolerites.

The major structural features have both a local and regional significance. Well after the main metamorphism and in pre-Karoo times, presumably about mid-Paleozoic, there was a shallow orogenesis which resulted primarily in nappe thrusting. Some purely dynamic effects and slight retrograde metamorphism may be associated with this movement.

## METAMORPHIC FACIES

As implied in the foregoing outline of the geology, the map has been divided into a number of metamorphic zones by drawing isogradic lines based on the main index minerals produced by the regional metamorphism in the pelitic sediments.

These zones fit naturally into the various facies and subfacies as described by Turner and Verhoogen (8) and are used as headings for the various rock descriptions.

The lowest grade is dealt with first and descriptions follow in order of increasing metamorphism. This is possibly a reversal of the normal procedure but since the rocks were, to some extent, mapped in this order, it is felt that it is really the most convenient method of tracing the changes which have taken place.

The writer, who started the investigation with a magmatic bias, ended up convinced that no truly magmatic granite need be invoked to explain the observed metamorphic sequence.

Some compositional variations in the rocks have been strongly emphasized by the metamorphism. Alumina-rich sediments have given rise to striking development of aluminosilicates. The impure calcareous rocks have been converted to calc-silicates which are always conspicuous due to their resistance to both weathering and granitization. Within areas of synkinematic para-granite, these rocks and to a less extent the older basic dykes, form "resisters".

Of great interest is the marked evidence of an earlier geothermal metamorphism upon which regional metamorphism has been superimposed. This earlier metamorphism was widespread but in the higher regional zones only faint and, at times, uncertain traces of it have survived.

In the sections which follow, rocks of the Piriwiri System with minor basic intrusions, are traced through the various grades of regional metamorphism to the stage where, by various metasomatic processes, they are converted to para-gneisses and granites.

## I. GREENSCHIST FACIES

### THE NON-CALCAREOUS SEDIMENTS

#### *Lithology and Distribution*

The group of rocks which is embraced in this classification is that having the lowest grade of metamorphism in the area covered by this investigation. It comprises a series of argillaceous rocks with subordinate arenaceous and calcareous bands. The main rock type is a phyllite.

No subdivision of this facies was made on the map since poor exposures in some areas have not allowed of such detail to be mapped with any degree of accuracy. However, in the specimens collected, two subfacies can be identified and these are described under separate sub-headings in the petrographic section.

The phyllites occupy some 60 square miles of country in the south-east of the area from where they form northerly protruding tongues, bordered by the next higher grade zone.

In the extreme south-east the dips are rather flat and, locally, even horizontal. The direction of dip of both the bedding and the foliation is generally easterly here but becomes westerly at a distance of some



five miles from the margin of the map due to isoclinal overfolding. High-angle, westerly dips are generally maintained over the greater part of the total area. On Mani Mlichí Farm, west of the main road, a westerly dip of 80 degrees was measured.

The narrow arenaceous bands among the phyllites serve to elucidate the structure and indicate the frequent coincidence of bedding and foliation in most areas. These bands are variable in thickness and frequency of occurrence. A rapid alternation of bands is often seen with the layers varying in thickness from less than an inch to many feet. The wider beds are characteristic, fine-grained quartzites with micaceous partings. On occasion, however, the bedding is oblique to the metamorphic foliation, and at one locality on Springbok Heights Farm the direction of bedding and foliation are normal to one another. When the two are coincident their average strike is between north and north-north-east.

Some 17 miles west of the south-east corner of the map a number of arenaceous bands can be traced striking north 25 degrees east through the farms Springvale and Springbok Heights. These reveal that the country here has been thrown into a tight isoclinal fold dipping west.

Small pegmatite dykes, quartz reefs and, less frequently, epidiorite dykes have been emplaced along the contacts between the arenaceous bands and the phyllite at many points. Possibly due to the tendency for shearing or fracturing to take place along such contacts, natural channels were provided for the dykes and reefs.

Puckering can be observed in some of these phyllites, a feature which becomes more marked and widespread as they become more coarsely micaceous with advancing metamorphism.

The phyllites are lustrous, dove-grey to greenish-grey rocks which, on weathering become buff, pink, red or yellow. The derived soils are normally poor, thin, and reddish brown but their colour is influenced to some extent by the nature of the drainage. In the broad, open vleis leaching has given rise to very pale or white soil in which small termite mounds form a conspicuous feature.

The arenaceous rocks which are variable in texture and composition are frequently dark grey, weathering to pale grey. Some are coarse grits but more commonly they are highly micaceous and schistose.

Large, well-formed porphyroblasts of cordierite and chiastolite or, more accurately, pseudomorphs after these minerals, are often made conspicuous by differential weathering. On Lazy Five Ranch, 5½ miles west from the south-east corner of the map is an exposure of phyllite which is weathered to a yellow colour and has a lustrous appearance due to an abundance of sericitic mica. In the matrix "shimmer" aggregates of muscovite form pseudomorphs after andalusite. These aggregates have rhombic cross-sections with macro axes of up to half an inch. A mile east of this occurrence are exposures of a lustrous grey phyllite which is packed with porphyroblasts of both biotite and altered cordierite (Plate II).

The phyllites are frequently rich in magnetite and in places large haematite crystals occur as pseudomorphs after pyrite.

PLATE II



Porphyroblasts of cordierite and biotite in a lustrous grey phyllite. Crown land east of Lazy Five Ranch and  $1\frac{1}{4}$  miles east of south of Mlechi trigonometrical beacon. One-third natural scale.

Photo: H.J.C.



Occasionally graphitic sediments are found interbedded with phyllites. The most conspicuous exposure is a graphitic quartzite which has a strike of 2,500 yards and forms, for part of its strike, a conspicuous ridge on Kankombe Farm. On this ridge faulting has taken place along the line of strike and boulders of quartz-breccia rich in graphite are exposed. It would seem that some hydrothermal redistribution of the graphite has occurred.

A large number of specimens were collected, but few of the pelitic ones were suitable for detailed study. Along the main rivers, erosion by attrition exposes fresh specimens, but elsewhere the rocks are usually too weathered for sectioning. The arenaceous rocks, however, usually provide specimens fresh enough for microscopic study.

As mentioned earlier, petrographic study has clearly indicated two metamorphic subfacies among these rocks and these are used as sub-headings in the petrographic descriptions which follow.

#### *Petrography of the Pelitic Rocks of the Muscovite-Chlorite Subfacies*

Slide 16210\* is from a specimen collected on Litombo Farm, half a mile south-south-west of Nascot trigonometrical beacon. The rock has a marked schistosity and muscovite and chlorite predominate over the quartz and are segregated into narrow bands. The muscovite and chlorite are in part intimately intergrown. The chlorite is the ferri-ferous variety diabantite. Magnetite is abundant and there is a little apatite and tourmaline. Along the river forming the northern boundary of Travios Farm, the rocks appear somewhat schistose and are rich in small magnetite crystals. In thin section (16211) the rock differs from the Litombo Farm specimen in being much richer in muscovite and having much coarse magnetite which is confined to the chlorite-rich zones as crystals up to 1.2 millimetres across. Very small granules of epidote occur throughout. Tourmaline is more abundant, the largest prisms being 0.15 millimetres long.

Traced downstream the rocks again become more phyllitic in appearance. Though much finer grained they have the same mineralogical composition. Some pale quartz-rich streaks represent what may be the original bedding direction, while at 32 degrees to this line is the foliation direction marked by the elongation of muscovite and chlorite.

#### *Petrography of the Non-Felspathic Arenaceous Rocks of the Muscovite-Chlorite Subfacies*

These rocks may be defined as quartz-schists as they are composed mainly of quartz but there is also a fair amount of chlorite, often with muscovite intergrowths. Magnetite occurs in globular form and there is a little epidote and tourmaline.

#### *Petrography of the Felspathic Arenaceous Rocks of the Muscovite-Chlorite Subfacies*

Rocks of this group are slightly felspathic quartzites which become, in places, meta-arkoses. A fresh specimen collected in the Mlichi River on Travios Farm reveals, in thin section (16212), interlocking

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\*Numbers of specimens and slides kept in the Geological Survey collection.



quartz grains with a fair amount of clear albite-oligoclase feldspar. Streaky chlorite is scattered throughout and serves to show the direction of foliation. A few hypidiomorphic magnetite crystals, often associated with epidote, attain a size of 0.6 millimetres. Tourmaline crystals 0.4 millimetres long are coarser than those found in the more schistose rocks. A little muscovite is present.

Two other sections were examined; one from a specimen collected on the rock-dump at the Kent Gold Mine and the other from a bend in the Mlichí River where it forms the northern boundary of Kan-kombe Farm. These two are similar in appearance but contain a little graphite.

#### *Petrography of the Pelitic Rocks of the Biotite-Chlorite Subfacies*

Bordering the higher almandine garnet zone the rocks of this subfacies have conspicuous biotite porphyroblasts arranged with their cleavage planes usually normal to the foliation but where shearing has occurred the biotite has been rotated into oblique positions.

South of the old barns on Litombo Farm, near the northern end of the long strike of the graphitic quartzite, the phyllite has abundant small biotite porphyroblasts which have a preferred orientation. Here the cleavage planes of the biotite are approximately parallel to what appears to be a direction of secondary stress. The rock is puckered along this plane and the biotite books are also conspicuously puckered (Fig. I, Slide 16273) resulting in the development of secondary twinning.

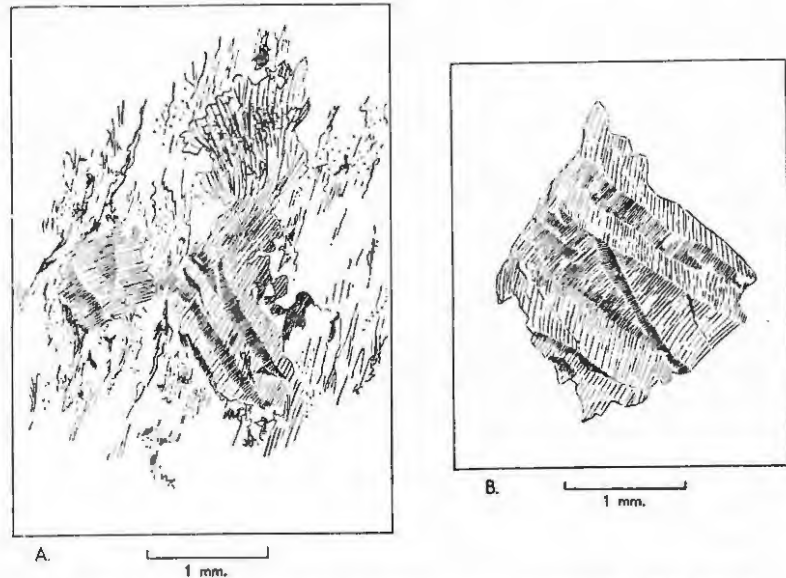


Fig. 1. Secondary twinning in biotite produced by puckering (Slide 16273)  
Litombo farm

In thin section (16273) quartz and muscovite occur in about equal proportions forming a ground-mass in which are occasional lenticular aggregates of quartz and abundant biotite porphyroblasts. During their growth, the porphyroblasts have pushed the minerals of the matrix aside so that they now curve round them. Numerous quartz inclusions with some magnetite occur in the biotite. On the average the longer axis of the biotite measures 2.5 millimetres.

Other occurrences in this zone are more highly silicious than the one described though, megascopically, they appear equally lustrous. The terms meta-siltstone or quartz-mica-phyllite are apt names. They all contain abundant idiomorphic, microscopic garnets of a grey to pale-green colour. Panning of a specimen produced a large amount of magnetite but not enough of the garnet for a specific gravity determination. Its refractive index, however, is that of spessartite, a variety of garnet belonging to this subfacies.

Slide 16213 from a specimen collected in the bed of the Angwa River, four miles from the southern edge of the map, has a ground-mass of quartz and muscovite with the former predominant. Partly chloritized biotite occurs as small irregular aggregates. There is a little fine, scattered epidote and a few tiny idiomorphic tourmaline crystals. Another specimen (Slide 16274) collected almost six miles to the south-west contained the same mineral assemblage but in different proportions.

Slide 16214 was prepared from the specimen shown in Plate II. The large porphyroblasts of cordierite seen in the hand specimen do not feature in this thin section. The biotite books measure seven millimetres and the completely sericitized cordierite crystals twice this amount. Narrow quartz-rich bands, parallel to the foliation, traverse the slide at intervals of about 1.5 millimetres while at 80 degrees to this direction are chlorite-rich bands. Magnetite, in rod-like crystals is orientated parallel to the foliation and tends to be concentrated in the quartz-rich bands. A few tourmaline crystals up to two-millimetres long lie parallel to the magnetite rods.

#### *Petrography of the non-Felspathic Arenaceous Rocks of the Biotite-Chlorite Subfacies*

A narrow arenaceous band on Sable Ridge farm is traceable for two miles. Thin section 16215, from a specimen taken at a point 1.9 miles south-east of the homestead, is a fine-grained biotite-schist exhibiting only the faintest, closely spaced banding, produced by parallel streaks of biotite alternating with quartz-rich bands composed of irregular interlocking grains. Epidote occurs in granular form as bands and aggregates. Carbonate occurs in similar fashion. Sphene, tourmaline and magnetite are accessory, with the last present only as a single idiomorphic crystal. Fine specks of graphite are peppered throughout the slide. No muscovite was detected.

Two miles south-east of the occurrence just described is a rock (Slide 16275) having a somewhat leached appearance. It differs in having a number of narrow dark bands rich in biotite that are not metamorphic differentiates but compositional variations in the bedding. The section

has no calcite, muscovite, sphene or graphite, but there are more magnetite, a little epidote and larger tourmaline crystals, which measure up to 0.07 millimetres.

The graphitic quartzite (Slide 16276) has a little biotite and muscovite and some crystals of sphene. The quartz grains are interlocking except where separated by graphite which occurs both as a disseminated dust and as black, smudgy patches.

#### *Petrography of the Felspathic Arenaceous Rocks of the Biotite-Chlorite Subfacies*

Thin-section 16216 is from a specimen collected on Sholah Park Farm, 1,300 yards north-north-west of the south-eastern corner beacon, where it outcrops at a fork in the drainage. The specimen has a finely banded appearance. It is a grey, even-grained rock composed predominantly of quartz with some rather indeterminate sodic plagioclase. Shreds of secondary muscovite are included in the feldspar but there are also a few discrete plates. A fair amount of epidote and small scatterings of biotite, magnetite and tiny tourmalines occur.

Three and a half miles north-west of the last-mentioned exposure is a banded quartzite (Slide 16277) of similar appearance but with only the faintest parallelism of constituents. In addition to the quartz is some fresh untwinned oligoclase. Muscovite is present as large plates while biotite occurs both as disseminations and ill-defined bands. Accessory minerals are chlorite, magnetite, tourmaline and zircon.

#### THE CALCAREOUS SEDIMENTS

The calcareous rocks are not abundant and usually occur as narrow bands and lenses in the arenaceous rocks.

Their metamorphism is interesting in that they form calc-silicates exhibiting a higher grade than would be expected in this facies. This must be attributed to the effects of the earlier thermal metamorphism. It would appear that regional metamorphism has not been intense enough or of sufficient duration to produce very noticeable retrograde changes in this rock type.

They form tough, compact rocks which are fresh immediately below a very thin, yellow-brown, weathered surface. Owing to their resistant nature these rocks are sometimes found on surface as small round boulders in the absence of other exposures.

Two specimens were collected for detailed study from exposures two and half miles apart and, judging from the general direction of strike they are probably from the same stratigraphic horizon. The calc-silicate bands are paler than the enclosing arenaceous rocks and have the general appearance of granitic dykes. Slight compositional variations across the bedding of these calc-silicate rocks gives them an overall heterogeneous appearance.

The specimen from Arden Farm is a fresh, very compact, mottled-grey rock. The matrix is fine grained and the mottling is due to porphyroblasts and aggregates of mafic composition. All the minerals in



the rock are anhedral. In thin section (16217) the texture is both granoblastic and poikiloblastic. The poikiloblasts are large, irregular, green hornblende crystals with sieve structure. They have the pleochroism: X = yellow-green, Y = olive-green and Z = dark green.

The hornblende has numerous conspicuous pleochroic haloes which are produced by inclusions of sphene, present as abundant granules and irregular patches up to 0.6 millimetres in diameter. There are a few, pale pink, sieve-textured garnets the largest of which measures three millimetres across. Other minerals present in small amounts are biotite, muscovite, clinozoisite and calcite. All these comprise only 30 per cent. of the rock, the bulk of which is composed of a granular, interlocking mosaic of quartz and labradorite.

The other specimen was collected to the north on Springbok Heights Farm. The two are in many respects similar but there are some important differences. This second specimen is finer grained and has a higher percentage of mafic minerals.

In thin section (16218) the most striking difference is that, in place of the plagioclase feldspar, there is an abundance of microcline. There is neither garnet nor biotite, but clinozoisite is abundant and there is an appreciable amount of tremolite in broad, sieve-textured, irregular crystals. In contrast to the first section the sphene is, in a degree, idiomorphic, darker coloured and pleochroic. Green hornblende is the most abundant single constituent. There is a little apatite.

## II. ALBITE-EPIDOTE-AMPHIBOLITE FACIES

### THE NON-CALCAREOUS SEDIMENTS

#### *Lithology and Distribution of the Pelitic Rocks of the Chloritoid-Almandine Subfacies*

More simply stated the rocks of this group are garnetiferous mica-schists. In these rocks most or all of the constituent minerals are coarse enough for megascopic identification.

The rocks of this subfacies occupy some 70 to 80 square miles of country in the east-central and south-eastern portions of the map. To the south they tongue into the lower facies while from the north, tongues of a higher grade of metamorphism extend into them and they have been invaded by granite stocks. On the west this subfacies is terminated by granite.

In the area of San Michele Farm the simple metamorphic trend is somewhat disrupted. The staurolite-kyanite subfacies is absent and the parallel-striking sillimanite schists and gneisses are truncated by the garnetiferous mica-schists which also tongue into the gneisses north-east of Karoi Township where they are in part migmatized. It would appear from this that the regional metamorphic trend can, on occasion, miss a beat and that here kyanite and staurolite were not developed, the latter probably owing to lack of iron in the original sediment.

In addition to this main area of outcrop there are schists of the same grade in the Urungwe Native Reserve where they occur as isolated klippen resting on the gneisses and granite. Soil cover obscures the actual

contacts, but since the gneisses and the granite concerned are metamorphic derivatives of the schists, nappe thrusting must be invoked to explain the observed facts. To the south J. G. Stagman\* has mapped an extensive mass of Lomagundi system rocks which have been thrust over both the Piriwiri system gneisses and the younger Sijarira System.

The main minerals of the schists of this facies are quartz, muscovite, biotite and garnet. Varying proportions of these minerals in the rocks reflect original compositional differences. The most conspicuous megascopic difference between rocks of this and those of the lower grade is the increased coarseness of the micas which give them a glistening and markedly schistose appearance. The garnets vary from tiny and inconspicuous crystals to large and very prominent ones.

Half a mile south-east of the "I Wonder" rutile claims, very large garnets protrude from the schists or are strewn about in the rubble. One weighed 13 ounces (Plate III).

In this zone, as in the lower zone, evidence of the earlier thermal effects are widespread. There are aggregates of mica which are pseudomorphs after chiastolite and there is some completely sericitized cordierite. It seems likely, too, that some garnet development was initiated during the earlier thermal metamorphism and that they have merely increased in size during the following regional metamorphism.

The sericitized thermal metamorphic index minerals mentioned are best preserved at a point about a mile south-east of the Mlichí trigonometrical beacon near the south-east corner of the map. Chiastolite crystals measuring two and a quarter inches long and one and a quarter inches across, and cordierite crystals one and a quarter inches by half an inch were found here.

Coarse "shimmer" aggregates of muscovite after chiastolite, having the same form and dimensions as those just described were found standing out on the weathered surface of the schist, less than a mile south of where the large 13-ounce garnet was found.

Near the extreme north-east corner of the map the country rises steeply from the bed of the Angwa River to give rise to the feature known as Denda. The rocks in this area are graphitic and of slaty appearance, nevertheless, half way up the hill is a narrow band of rock which is rich in somewhat fibrous kyanite. Nearby float contains fragments having biotite porphyroblasts of up to five millimetres across. These rocks indicate a marked local compositional variation and reveal that kyanite can occur in both the amphibolite and albite — epidote — amphibolite facies. (See p. 21.)

The *arenaceous rocks* of this zone differ little in appearance from those of the lower group. A specimen collected on the farm Springbok Heights has the fine compositional banding previously noted. The biotite-rich bands are more readily eroded than the remainder of the rock and thus outcrops have developed a fluted appearance.

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\*Personal communication.

PLATE III



(i)



(ii)



(iii)

- (i) Garnet weighing 13 ounces from half a mile south-east of the "I Wonder" rutile claims. Actual size.
- (ii) Cordierite (completely sericitized) from two miles south of the Angwa-Mlichi confluence. Actual size.
- (iii) Kyanite pseudomorph after chistolite, Masterpiece Farm. Actual size.

Photo: H.J.C.



Some of the arenaceous bands are graphitic as is the schist on occasion. This was most noticeable on Leconfield and Moyale farms.

*Petrography of the Rocks of Pelitic origin of the  
Chloritoid-Almandine-Subfacies*

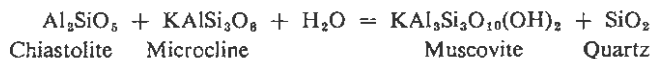
Not many of these schists were found to be suitable for sectioning but the coarse metamorphic minerals could be sectioned individually or examined in crushes.

The garnets are always fresh but the chiastolite and cordierite porphyroblasts are always altered. Were it not for the occasional discovery of mica aggregates with well-preserved crystal outlines, the cause of some of the queer-looking mica concentrations might be very puzzling.

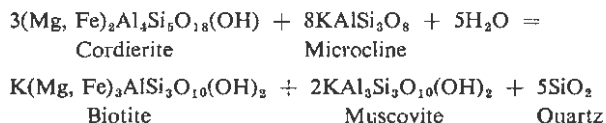
The complete absence of chloritoid is noteworthy. This may be accounted for by the absence of sufficient stress or some compositional deficiency, such as lack of alumina after the muscovite had crystallized, in areas where the mineral would normally be expected.

The large garnets mentioned in the lithological section have the composition, almandine 30 per cent., spessartite 70 per cent. They contain abundant small quartz inclusions.

The development of muscovite from chiastolite, following the superimposition of regional metamorphism on the earlier thermal metamorphism, could be a retrograde step. If at the time of the formation of the chiastolite, some microcline was generated from the potash available in the rock, and it will be recalled that abundant microcline was present in one of the calc-silicate specimens in the facies previously described, then it would follow that as a result of the second metamorphism the chiastolite and microcline could react to produce muscovite as illustrated by Turner and Verhoogen (8, p. 447):



On the same page they give an equation to show how cordierite can be converted to muscovite and biotite.



In the facies which follows some metasomatic addition of potash seems to be indicated but it is not certain that this has happened here.

Slide 16219 was cut from a well-foliated specimen displaying marked puckering and studded on the surface with "shimmer" aggregates after andalusite. The slice which was cut parallel to the foliation, shows an abundance of muscovite plates enclosing small quartz crystals. There is some chloritized biotite and chlorite replacing garnet. Magnetite is scattered throughout. There is one patch measuring eight millimetres across, composed of fine aggregated muscovite.

Slide 16220 is of a finely micaceous schist with aggregates of quartz having rhombic outline. In addition, abundant magnetite crystals stand

out on the weathered surface. In the slide the aggregates are seen to be composed of quartz and muscovite with some biotite and shreds of chlorite. These are also presumed to be pseudomorphs after andalusite. They have the characteristic concentrations of biotite surrounding them such as is found round this mineral when, during growth, it has been able to clear itself to some extent of inclusions. The magnetite occurs in two generations with the larger crystals having a cubic form, probably after pyrite. The few small prismatic tourmaline crystals have orientations both normal and oblique to the foliation, which suggests that they are post-stress minerals of metasomatic origin. No garnet appears in the slide but it can be identified in the specimen.

Well within this garnet zone one finds bands of schist which carry no garnet but have biotite porphyroblasts in abundance, due to a compositional deficiency such as low alumina.

About a mile east-south-east of spot height 3701 on Janetville Farm some andalusite porphyroblasts were dug out of the schist. They measure an inch and a quarter in length and only show sericitization along cleavages and cracks (16221). They probably developed before the regional metamorphism and represent a metastable association.

#### *Petrography of the Rocks of Arenaceous Origin in the Chloritoid-Almandine Subfacies*

In thin section (16222) a specimen of the normal arenaceous rock from Springbok Heights Farm reveals only the faintest evidence of schistosity. But for the sub-parallel arrangement of the disseminated biotite shreds, up to 0.5 millimetres in length, the texture might be described as granulitic and the rock named a micaceous quartzite. There are a few muscovite flakes which attain a length of 1.2 millimetres. Other accessory minerals include oligoclase, garnet, epidote and a few specks of pyrite.

On Mafalo Farm a north-striking graphitic quartzite band can be traced for 2½ miles. Apart from quartz and graphite there is only a little tourmaline (16223).

Other specimens of arenaceous rock from a wide area all contained a scattering of graphite. They are somewhat foliated and predominantly quartzose with varying proportions of sericite, biotite, garnet and magnetite. Tourmaline crystals are as usual very small and few in number.

#### THE CALCAREOUS SEDIMENTS IN THE ALBITE-EPIDOTE-AMPHIBOLITE FACIES

Calc-silicate rocks of two distant types occur in this zone and belong to the *actinolite-epidote-hornfels subfacies* of the above facies.

Near the boundary between Buffalo Downs and Springbok Heights farms, at a point 900 yards north-east of the trigonometrical beacon named Mica, a narrow lenticular band of mottled grey hornfels has weathered into small spheroidal boulders having a thin yellowish brown "skin" beneath which the compact rock is fresh and tough. This rock is almost identical in appearance with the specimen (16217) from

PLATE IV



Porphyroblasts of Rutile in a Matrix of Tremolite. "I Wonder" rutile claims (two-thirds natural scale).

Photo: H.M.C.



Arden Farm in the lower green-schist facies. The only apparent megascopic difference between specimens is the slightly more schistose tendency of the rock in this group.

In thin section (16224) large, irregular, green, hornblende and hypidiomorphic garnet crystals appear in a mosaic of quartz and labradorite. There is some pyrite and a little sphene and clinozoisite.

The second type is largely monomineralic and is exemplified by the host-rock of the rutile on the "I Wonder" claims (Plate IV). This is an attractive, greenish-grey amphibolite which is, in places, coarsely crystalline and exhibits a monoclinic fabric symmetry. In the matrix rutile occurs as porphyroblasts, glomeroporphyroblastic clusters and also as lenticular concentrations. The amphibole is tremolite and the whole mass is conceivably the metamorphic equivalent of a silicified dolomite. The rutile is clearly authigenic, but some of the other constituents may be later hydrothermal additions. It will be noted that many of the calc-silicate rocks in the higher zones contain appreciable titanium in the form of sphene.

In many of the prospect trenches on the rutile claims there is much sugary, cellular quartz either alone or mixed with tremolite. Some of it carries specks of rutile or veins of haematite. The latter is largely of secondary origin, derived from the oxidation of pyrrhotite. One specimen collected from the Miami River bed was rich in pyrrhotite and contained a crystal of brown apatite, an inch in length, and much micaceous talc.

### III. AMPHIBOLITE FACIES

In this facies two subfacies have been distinguished and each has been divided into two zones which have been separately mapped as follows:

- (1) Staurolite-kyanite subfacies—
  - (a) Staurolite zone;
  - (b) Staurolite-kyanite zone.
- (2) Sillimanite-almandine subfacies—
  - (a) Sillimanite-schists;
  - (b) Sillimanite-gneisses.

#### STAUROLITE — KYANITE SUBFACIES

The two zones while being in part divisions of the same general strike of the sedimentary formation, may indicate the possibility of some slightly progressive metamorphism. Francis (11, p. 355) points out that "In the Dalradian, staurolite appears before kyanite in advancing grade, but they are soon found together". He notes that in other areas the two zones are indistinguishable and that kyanite can exist at lower grades than staurolite. A local example of this has been noted in the occurrence of kyanite in the chloritoid-almandine subfacies at Denda Hill.

Although a variation in the grade of metamorphism is possible, a much more likely explanation of conditions in the area being described, is that the presence or absence of excess potash is the influencing factor if the assumption is true that kyanite is more susceptible to the presence of additional potash than is staurolite. There are indications that the additional potash may have been metasomatically derived. In support of this suggestion is the fact that the staurolite zone here is in closer proximity to plugs of intrusive granite than is the staurolite-kyanite zone. Furthermore, the staurolite zone has been invaded by considerably more pegmatite dykes than the zone in which the kyanite appears.

However, it must be borne in mind that if there was a variation of potash content in the original sediments, thermal metamorphism would still have caused development of chiastolite in both zones. In the potash-rich zone microcline would be an associated mineral which, on the advent of regional metamorphism, would react with the chiastolite to produce muscovite. In the absence or deficiency of microcline the metamorphism would result in the development of kyanite pseudomorphs after chiastolite. (See formulae on page 19.)

In a discussion of the petrography of the sillimanite-almandine sub-facies mention will be made of how potash could be made available for metasomatic addition to a lower subfacies.

#### *Lithology and Distribution of the Staurolite Zone*

The rocks are coarse micaceous schists which are often conspicuously studded on weathered surfaces with large staurolite crystals that are usually idiomorphic and commonly exhibiting the characteristic penetration twins. However, in the area some 4½ miles south-east of Miami the staurolite forms large, poorly developed crystals. One measured 9 inches long and 4.5 inches in cross-section. Such large crystals are usually full of quartz inclusions and appear to be associated with tiny quartz veins. They give the impression of having grown too rapidly to have had the opportunity of clearing themselves of inclusions.

In the absence of exposures in some areas, concentrations of staurolite frequently occur as rubble.

Large well-developed staurolite crystals occur in the vicinity of Magugisi Hill and on Mafalo Farm near the eastern margin of the map. Elsewhere crystals are smaller and may be quite inconspicuous or even microscopic.

Staurolite, without kyanite, occurs in two tongue-like areas in the south-eastern quadrant of the map and they are separated by rocks of the lower grade, garnet zone. Just to the west of this is an isolated area of staurolite-rocks completely surrounded by garnetiferous schists. In all, this zone occupies some 92 square miles.

Conspicuous evidence of the earlier thermal metamorphism is still widespread as shown by the presence of mica pseudomorphs after chiastolite and cordierite. Just west of the Angwa River, less than 1.5 miles from the eastern margin of the map and two miles south of the Angwa-

Mlichí confluence, the weathered surface of the schist is studded with sericitized cordierite crystals having very nearly perfect hexagonal outlines (Plate III). Some of these crystals measure over 1.5 inches across.

Fairly large and completely sericitized andalusite crystals appear conspicuously on weathered surfaces of the schists on Moyale and Nyomgoma farms and, indeed in most parts of this zone. Frequently, however, coarse mica aggregates are found which clearly pseudomorph chialstolite. (See chemical formulae on page 19.) On Mafalo Farm a mica aggregate after chialstolite was collected. It is studded with small garnets and has a fresh staurolite crystal eight millimetres long, embedded parallel to the *c* axis of the original chialstolite.

On the Garahanga-Moyale farm boundary, 1,400 yards from the north beacon of the latter, large chialstolite crystals have recrystallized to form muscovite aggregates which enclose tiny fresh staurolite granules. One exposure on Garahanga Farm revealed "shimmer" aggregates of muscovite after chialstolite, variously orientated and forming divergent crystals up to 16 inches in length.

A single porphyroblastic andalusite crystal four inches long was dug out of a somewhat silicious schist in a tributary, 1.5 miles north-west of the Nyomgoma-Mwala farm dam. It seems to be somewhat anomalous in this setting and will be referred to again in the petrographic section.

Several specimens were collected from a weathered outcrop on Mafalo Farm a little south of the Domo road. This rock is so massed with small 5-millimetre garnets that it has a specific gravity of 2.9. In spite of the fact that there are more garnets than anything else in the rock there is still evidence of the earlier thermal metamorphism which produced radiating crystals of chialstolite now apparent only as lines of coarse muscovite aggregates.

On Crown land, 3.5 miles east of the "I Wonder" rutile claims the surface of the schist is studded with tabular garnets having perfect hexagonal outline and measuring 1.5 inches in cross-section. These can be chipped off like scales and appear very much like the cordierites in cross-section. Their composition is given in the petrographic section.

The only discovery of kyanite was made on the ridge above the Sylvia Mine some 4.25 miles south of Miami Village where it occurs as pseudomorphs after chialstolite in synkinematic quartz reefs. Some muscovite also occurs with the kyanite in the pseudomorph. It would appear that there was not enough potash to convert all the chialstolite to mica.

The arenaceous rocks do not differ in appearance to any notable extent from those of the lower facies.

#### *Petrography of the Rocks of Pelitic Origin in the Staurolite Zone*

The coarsely micaceous character of these rocks renders them unsuitable for sectioning and they have had to be studied piecemeal. Similarly, variations in composition of the original rocks can be detected by the presence or absence of certain minerals or their varying abundance.



Bands rich in staurolite are found adjacent to bands in which this mineral is completely lacking. Sometimes the concentration of staurolite in a narrow band serves to define bedding in highly foliated rocks. Even in this zone bands of rock can be found in which biotite porphyroblasts occur without either garnet or staurolite. The earlier thermal metamorphism has emphasized compositional variations by producing concentrations of cordierite and chiastolite, which are now transformed.

Some staurolite crystals contain inclusions of both biotite and small idiomorphic garnets.

A specimen (16225) collected two miles north of Magugisi trigonometrical beacon is a coarsely micaceous rock in which the small staurolite crystals are wrapped in muscovite foliae. Garnet and biotite are also present and there is a fair amount of oligoclase. It seems probable that the felspar has been derived from a pegmatitic source. Felspar has been observed in the schists adjacent to some pegmatites.

A specimen from 1.75 miles east of Magugisi is of similar mineral composition. The garnets, which reach a cross-section size of half an inch, are larger than the more abundant staurolite crystals. In this locality there is a band of schist two feet wide which carries neither staurolite nor garnet. A thin section of this schist (16226), which was cut parallel to the foliation, reveals muscovite and quartz as the main constituents with flakes of biotite up to one millimetre in length scattered throughout. There is an appreciable amount of coarse hypidomorphic magnetite and a little evenly distributed oligoclase. The few tourmaline crystals present are larger than those found in the rocks of the lower facies.

Thin section (16227) was prepared from what was originally a fairly large chiastolite crystal. It was collected from a point 0.75 miles south-west of the north-east corner beacon of Garahanga Farm. It is composed of muscovite in which is set numerous small fresh staurolite crystals having a sub-parallel orientation. Some shreds of chlorite after biotite are intergrown with muscovite but there is also a little residual biotite. Accessory are fine magnetite, minute tourmalines and quartz. The staurolite and biotite owe their presence here to the impurities present in the original chiastolite.

In one of the altered cordierite porphyroblasts collected 5.25 miles north-west of the south-east corner of the map, quartz and sericite predominate but a yellow-brown chlorite is fairly abundant (Section 16228).

Section 16229 is from another cordierite crystal; this one being one of the large, nearly perfect pseudo-hexagonal crystals from the same vicinity as that shown on Plate III. Large plates of quartz are set in a sericitic groundmass, some of which has crystallized into larger shreds of muscovite. There are several crystals of biotite, brownish-green in colour. The largest of these measures 1.4 millimetres across. A fair amount of bluish-green chlorite is also present. Magnetite occurs in two generations. There are only a few crystals which attain a length of one millimetre, but there is much fine globular iron ore scattered throughout. A few garnets and tourmalines are present and there is a

single crystal of sphene. The biotite and the secondary chlorite are full of tiny birefringent needles orientated mostly in two directions at about 60 degrees to one another and which may be rutile.

On the assumption that there has not been extensive change in the total composition of these porphyroblasts during the later metamorphism and also to give some confirmation that the original mineral was indeed cordierite, a partial analysis was made which gave the following results:

|     | Per cent. |
|-----|-----------|
| FeO | 3.96      |
| MgO | 4.62      |
| CaO | trace.    |

J. P. Allchin (Chemist)

The andalusite crystal from 1.5 miles north-west of Nyogoma-Mwala dam was sectioned (16230). As contrasted with the andalusite in section (16221) from the garnet zone this crystal is quite unaltered, is very much larger and is full of inclusions of muscovite, biotite, quartz, and abundant magnetite. In addition a tiny quartz vein cuts across the section. The country rock is highly micaceous. Muscovite predominates, but there is also much biotite. Magnetite occurs in two generations and there is a little garnet, plagioclase and tourmaline.

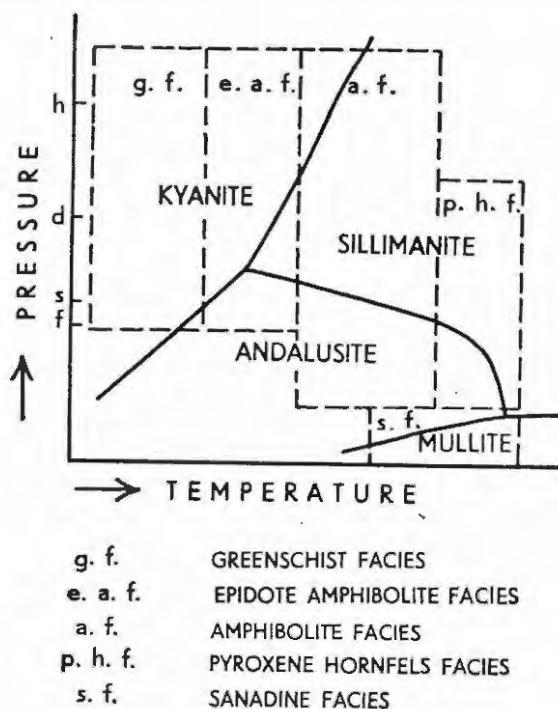


Fig. 2. The stability relation of kyanite, sillimanite, andalusite and the physical conditions of the metamorphic processes. (After Akiho Miyashiro, 1949.)



The critical conditions for the development of andalusite in this subfacies are given by Miyashiro (12) and are illustrated diagrammatically in Fig. 2. A similar representation is given by Francis (11, p. 361). In explanation of this state of affairs Turner and Verhoogen (8, p. 456) state that "rocks that correspond to a transition facies between the cordierite-anthophyllite and the staurolite-kyanite subfacies are marked by a paragenesis that combines the critical minerals of both groups. Such are the andalusite-biotite-schists and andalusite-staurolite-biotite-schists of Banffshire in the north-eastern part of the Scottish Highlands." The andalusite is clearly in equilibrium with its surroundings and is not the result of polymetamorphism. Only this one andalusite crystal could be found.

A determination of the tabular garnets with hexagonal outline, which were mentioned in the lithological section, showed them to have the composition: Grossularite 55 per cent., andradite 45 per cent. This tends to confirm that they may be pseudomorphs after cordierite.

#### *Petrography of the Arenaceous Rocks of the Staurolite Zone*

These rocks have their counterparts in the lower metamorphic grades which differ little in mineralogical composition and appearance from those of the Staurolite Zone.

A specimen (16231) collected 2.25 miles east-north-east of Magugisi, differed from a specimen collected 10.5 miles to the south-east only in containing a little epidote. These rocks are banded garnetiferous and felspathic quartzites with muscovite, biotite, magnetite, tourmaline, sphene and, on occasion, a little apatite. The feldspar is oligoclase.

The rock from 2.75 miles north-north-east of the south-east corner beacon of Nyamapipi Farm is similar in appearance to the rock in the garnet zone 4.75 miles to the north-east of it. Quartz aggregates with rhombic outline occur as apparent pseudomorphs after small andalusite crystals (Slide 16232).

#### *Lithology and Distribution of Rocks in the Staurolite-Kyanite Zone*

As in other zones pseudomorphous relics of the earlier metamorphism can still be identified over a wide area. Perfect pseudomorphs of kyanite after chiastolite (Plate III) along a narrow belt more than eleven miles long, makes it necessary to revise one's ideas regarding "stress" and "anti-stress" minerals, for it would appear that in the regional metamorphism here temperature and hydrostatic pressure were the prevailing factors.

H. H. Read (9, p. 18) has pointed out that "the division of metamorphic minerals into 'stress' and 'anti-stress' types has no foundation in the field. All so-called stress minerals occur in non-stress environments, and all so-called anti-stress minerals occur in stress environments; stress and anti-stress minerals frequently occur together". Tilley (13, p. 97) on the other hand has stated that "kyanite remains one of the few minerals which still merit description as 'stress-minerals'. However, he does mention that "kyanite might be generated without the



incidence of stress." Akiho Miyashiro (12, p. 301) in "A note on stress-minerals" states that "it is the purpose of the present paper to criticize the hypothesis of 'stress-minerals' proposed by Alfred Harker to make it clear that it is unnecessary to use such a concept, and to attempt the explanation of metamorphic rock characteristics by regarding temperature, pressure (hydrostatic) and concentration of components as the only essential factors controlling metamorphism. Petrological and physico-chemical considerations do not show the necessity of Harker's hypothesis of 'stress-minerals', in the present writer's view."

In parts of this zone, notably towards the north-east and east a cursory glance at the rocks would suggest that the metamorphism is rather low, but on closer inspection kyanite is found to be widespread. In addition, staurolite occurs in two localities; one in the Angwa River 1.25 miles south-south-east of Katsuke Hill and the other the same distance north-north-west of it. In the absence of staurolite, the critical assemblage oligoclase-actionolite-garnet which was found to occur near the extreme north of the map where the staurolite-kyanite zone borders the lower almandine zone, was used to assist in drawing the isograd.

It is clear that the rocks in this area of the map belong to the upper Graphitic Group of the Piriwiri System. Some of these graphitic rocks are highly aluminous while others contain little or no alumina. The most notable alumina-rich graphitic sediments are those which form the narrow belt, over eleven miles long, which starts just south of the Mpofu River, 1.25 miles east of the Judy Mine, strikes south through the eastern sector of Masterpiece Farm, crosses the Angwa River, just north of its confluence with the Miami River, and leaves the eastern margin of the map a mile north of where the Angwa River itself does.

Apart from this belt it would seem, on the whole, that graphite acts as a deterrent to metamorphism by preventing recrystallization in many of the rocks. It was at times difficult to know where to draw the isograd separating the kyanite-staurolite and garnet zones. Some compositions of these rocks result in the absence of all index minerals, and as already pointed out, kyanite can occur in the almandine zone. Beyond the graphitic rocks to the west and north-west, on the other hand, kyanite and staurolite occur in coarse mica-schist. These minerals occur together but are also locally segregated. There is no area of any extent free of staurolite which could be mapped as a separate kyanite-muscovite subfacies.

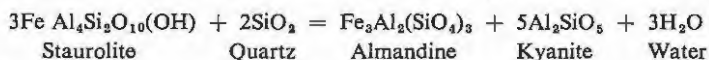
The main staurolite-kyanite zone occupies some 80 square miles in all. However, in the area of para-gneisses towards the mid-west, on the farms Pumula and Maora, there are outcrops of kyanite-schist. Owing to rather poor exposures the relationship of the schist to the gneiss is obscure but it is conceivable that it is a *klippe*. A number of scattered *klippen* occur in the Urungwe Reserve to the south-west.

The arenaceous rocks are micaceous and foliated meta-arkoses of varying grain size. A specimen collected just east of Masterpiece Farm is a pink grit, while another collected five miles to the north in the Mpofu River is dark-grey and fine grained. Some of these rocks are highly micaceous and still others are graphitic.

*Petrography of the Rocks of Pelitic Origin in the  
Staurolite-Kyanite Zone*

It is clear from the literature that there will have to be some revision of the concept of the amphibolite facies so that uniformity is established. It would appear that the presence or absence of staurolite from a zone in which it could occur with kyanite is determined largely by the percentage of ferrous iron in the rock. If this is so, then the presence of staurolite in the absence of kyanite cannot be taken as evidence of a lower metamorphic grade and two subfacies are called for.

Turner and Verhoogen (8, p. 454) once claimed that "staurolite appears to be stable over a narrow, limited range of temperature. At the boundary between the zones of staurolite and kyanite, almandine-kyanite becomes a stable association at the expense of staurolite.



"The plagioclase-muscovite-kyanite-almandine-quartz assemblage now takes the place of the two assemblages that would contain staurolite at the slightly lower temperature . . ." As we will see presently they later dropped this concept.

On the basis of the equation given above Francis (11, pp. 354 - 357) proposes splitting Turner's Staurolite-kyanite subfacies into two, namely:

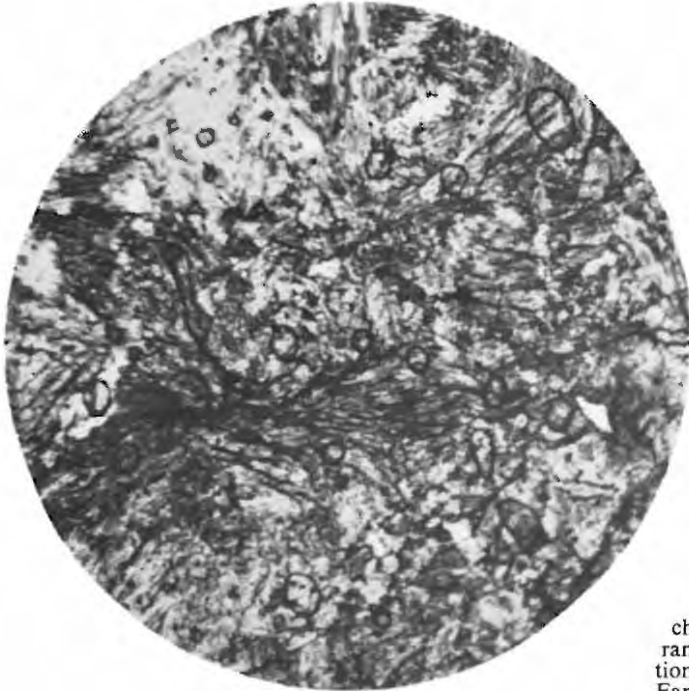
- "(1) *The Staurolite-Quartz Subfacies*. For rocks isograde with stable assemblages of these two minerals, lying in the highest part of the epidote-amphibolite facies; and
- (2) *The Kyanite-Muscovite Subfacies*. For rocks isograde with stable assemblages of this pair, without staurolite, lying in the lower part of the amphibolite facies."

He has warned that since kyanite has such a wide stability range its mineral associations "must be taken into account if it is to be used in a restricted (zonal) way as in the kyanite zone of Barrow. It is not even sufficient to define the zone by the occurrence of kyanite in pelitic rocks." On page 355 he points out "that kyanite persists beyond staurolite in rising metamorphism, thus the exit point of staurolite rather than the entry point of kyanite is significant and should define the lower limit of the kyanite zone."

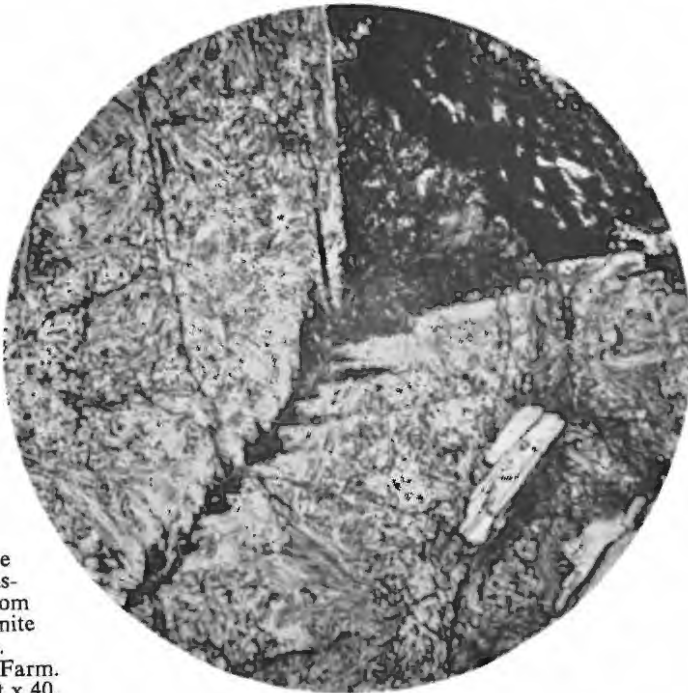
The suggestion made by Francis was later heeded by Fyfe, Turner and Verhoogen (14, p. 230) in so far as the acceptance of the second subfacies goes. They state that "the writers here accept the kyanite-muscovite-quartz subfacies erected by Francis (1956) to cover rocks of the kyanite zone of progressive metamorphism. The paragenesis is the same as for the staurolite-quartz subfacies (Figs. 103, 104) except that staurolite is absent."

We find, too, in the next section that the sillimanite-almandine subfacies can be split into two subfacies. Finally Francis (11, p. 366) gives a table of index minerals and critical assemblages for regional trend lines.

PLATE V



A. Kyanite  
crystals after  
chiasfolite, with  
random orienta-  
tion. Masterpiece  
Farm. Ordinary  
light x 40.  
Photo: H.J.C.



B. Part of the  
original chias-  
folite cross from  
a perfect kyanite  
pseudomorph.  
Masterpiece Farm.  
Ordinary light x 40.  
Photo: H.J.C.





These coarse, highly micaceous rocks are unsuitable for sectioning. The graphitic rocks, on the other hand, usually contain little mica and provide suitable specimens for sectioning.

The host rock of the long narrow aluminous belt striking through Masterpiece Farm is poorly resistant to weathering and forms no exposures on high ground. The line of strike is marked by rubble formed of kyanite pseudomorphs after chiastolite. Many perfect crystals can be found and some weigh as much as 15 pounds. In some river sections, on the other hand, where erosion has taken place the matrix forms a fresh, tough rock.

A specimen (16233) collected 1.25 miles south-east of the Angwa-Miami confluence, in the bed of a tributary, is a compact black rock which has conchoidal fracture and fresh surfaces glistening with biotite. In the matrix are set large pseudomorphs of kyanite after chiastolite which occur in places, as radiating crystals almost six feet in length. In thin section the rock is seen to consist of a fine-grained mosaic of quartz crystals bespeckled with graphite which gives the rock its black colour. There are porphyroblasts of brown biotite up to two millimetres across. There is some irregular magnetite, a few crystals of staurolite measuring up to 0.4 millimetres and some shreds of muscovite of the same size.

A section of one of the perfect pseudomorphs of kyanite after chiastolite from Masterpiece Farm was prepared. It reveals a mass of kyanite needles and blades grouped in divergent clusters which have all orientations (Plate V.A.).

Another section contains part of the original chiastolite cross (Plate V.B.) and due to the orientated crystallization of kyanite blades, it has taken on a form rather like a toy Christmas tree. At the base of the "stem" the "branches" form an inverted "V" having an angle of 89 degrees which is equal to the interfacial angle between the prism faces of the original chiastolite. "V"s of decreasing size, but the same orientation occur one above the other forming the taper of the "tree" and the whole terminates rather like a barbed shaft. In other words it has the appearance of a cross-section of cone-in-cone algae. Stress has certainly played no part in the development of this structure which has clearly been controlled by composition related to crystal structure of the original mineral.

In detail, the main "V", which may be described as an isosceles triangle, has at its apex graphite which has contaminated the adjoining kyanite crystals, while parallel to the base is a band composed of biotite and quartz.

Some kyanite pseudomorphs were collected which were far more coarsely recrystallized and contained some blue, bladed kyanite crystals measuring as much as 1.25 inches in length. A mile north-east of the Judy Beryl Mine on the hairpin bend in the Mpofu River is an exposure of kyanite in a graphitic rock in which the kyanite does not appear to be pseudomorphous. The matrix differs from the material described above in possessing no staurolite and in having a somewhat schistose appearance (Slide 16234). There is also less graphite. The kyanite is markedly poikiloblastic and the inclusions are mainly quartz.

There is a small area some 12 square miles in extent in the north-eastern part of the zone, between the Mpofu River and Kazangarare native village, in which kyanite occurs in small bladed crystals in black graphitic schists. In part these rocks are phyllitic in appearance and where kyanite is absent give the impression of belonging to a very low grade of metamorphism and one is consequently surprised when one discovers kyanite. Compositional variations control the presence or absence of kyanite. For instance, in a rock (Specimen 16281) which is a quartz-biotite-schist, original pelitic partings are represented by planes carrying orientated small kyanite plates. In addition to quartz and biotite the enclosing rock carries muscovite in flakes up to 2.5 millimetres long as well as a little untwinned oligoclase feldspar (Slide 16281).

But for the presence of some staurolite in these graphitic rocks just west of the Angwa River at a point one mile south-south-east of Katsuke Hill, a larger area of these graphitic kyanite-bearing rocks would have been included in the almandine zone in the north-east corner of the map.

The feature Boromininga, a little over a mile due west of the Mpofu-Angwa confluence is composed of a black, slaty looking rock in which occur some narrow, black, bladed crystals of kyanite measuring up to two inches in length so arranged as to produce mullion structure. Their black colour is due to included graphite. The crystals of kyanite are set in a fine-grained graphitic quartz-biotite matrix. In some of the surrounding rocks, on this feature, small bladed kyanite crystals occur with a somewhat talcose-looking chlorite which forms flakes of up to five millimetres across. This chlorite is pale green to almost colourless but is darker in places due to included graphite. It was identified as the variety of clinochlore known as leuchtenbergite (Slide 16235).

Also in this belt of graphitic rocks is the dark-grey amphibole-bearing rock mentioned earlier. Tiny sub-parallel actinolite needles are set in a fine-grained matrix of quartz and oligoclase. The latter is not readily distinguishable from the quartz as it is neither turbid nor twinned. Magnetite occurs in irregular grains which are coarser than most of the other minerals in the rock. Two microscopic garnets occur in the section (Slide 16278).

Proceeding west from the area of graphitic rocks described above one comes to a prominent escarpment which rises well over 900 ft. from the bed of the Manyenza River, and forms the approximate boundary between the graphitic rocks and the coarse kyanite-staurolite-bearing, mica-schists. Kyanite claims were once held in this area, the mineral being screened from the soil and river sands.

A specimen (16236) collected on the north bank of the Dete River, a mile south of the northern edge of the map and 2.75 miles north-north-west of the Judy Mine, has conspicuous kyanite and staurolite crystals protruding from the weathered surface. Individual crystals measure up to an inch in length, but these minerals themselves tend to occur in elongated concentrations as much as six inches long and suggest original concentrations of an alumino-silicate such as chiastolite crystals. Foliation planes in the schist are rich in muscovite and biotite



and are separated by quartzo-felspathic lenses carrying biotite. The felspar is oligoclase. Tiny garnets occur mainly as inclusions in the kyanite and staurolite. The rock itself is beginning to take on a somewhat gneissic character.

On the south bank of the Dete River, opposite the locality of the specimen described above, the rock (Specimen 16279) carries blades of kyanite up to an inch in length but no staurolite could be found. The garnets here are larger and suggest the conversion of staurolite as indicated in the equation on page 32. Felspar, too, is more in evidence, being more coarsely crystalline.

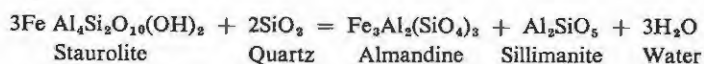
Three miles south of this area on the banks of the Mpofu River the rocks are somewhat similar to those on the Dete but here the kyanite is quite clearly recrystallized from original chiastolite and occurs with a certain amount of fine muscovite.

As one proceeds upstream along the Mpofu to the tip of the granite stock one finds that the kyanite has been metasomatically altered to albite-oligoclase porphyroblasts by emanations from the granite. These felspar porphyroblasts are crowded with inclusions, the largest of which are quartz, biotite and magnetite with the last mentioned reaching one millimetre in size. The quartz, which occurs in globules and irregular bands and aggregates, shows that resorption has taken place to a marked degree. The quartz bands and lenses have the same orientation as those in the host rock and indicate a somewhat helicitic texture in the felspar. In marked contrast to the larger inclusions are the swarms of idiomorphic to hypidiomorphic muscovite and magnetite crystals. The muscovite which occurs as small rhombs and pseudohexagonal plates is orientated in three directions parallel to crystallographic directions of the felspar host in typical saginitic structure. Irregular and larger muscovite plates of an earlier generation are present. Other included minerals are garnet, tourmaline and idiomorphic staurolite. Twinning of the host plagioclase is only faintly in evidence. In addition there has developed a pseudo-twinning caused by gliding as a result of stress applied too slowly to cause rupture.

A thousand yards upstream aggregates of fine-grained kyanite needles, resembling sillimanite, occur as protrusions on the surface of the schist and measure six inches by three inches. They are clearly derived from earlier chiastolites. These kyanite clusters contain abundant biotite crystals up to four millimetres across and there are also a few small garnets, staurolites and magnetite. The kyanite needles exhibit a marked degree of parallelism, a feature not observed in the perfect pseudomorphs to the east on the other side of this belt. Shearing has taken place but it did not produce the kyanite; it merely orientated it and gave it a fibrous form with parallel ribbands of quartz. In the kyanite itself are occasional shreds of muscovite. Larger muscovite plates occur intergrown with the biotite.

This last specimen (16280) was collected from very near the eastern boundary of the sillimanite zone. The fibrous character of the kyanite at this junction makes it difficult to distinguish it from the fibrolite, but the presence of staurolite in the schists is a useful, though not infallible,

guide as sillimanite and staurolite have been found to occur together along this boundary. Turner and Verhoogen (8, p. 457) mentioned such a combination as a state of disequilibrium and the following equation is produced:



In this equation the right-hand assemblage is the stable one in the next higher grade, which is the sillimanite-almandine subfacies.

Not all the kyanite can be megascopically identified with certainty but its presence is usually suspected from the mineral assemblage. Since the isogradic lines have been drawn to embrace megascopically identified index minerals it is not surprising to find a specimen from within the staurolite zone which contains microscopic kyanite.

Slide 16237 was prepared from a specimen collected three miles north-east of Magugisi Hill. The weathered surface of the rock here has many protrusions which suggest that chistalite prophyroblasts once existed. Complete recrystallization has taken place to produce an equigranular texture made up predominantly of kyanite and quartz with, here and there, a granule of staurolite. Magnetite is evenly distributed. Biotite occurs in flakes up to 2.5 millimetres and there is a little muscovite and tourmaline.

#### *The Petrography of the Arenaceous Rocks of the Staurolite-Kyanite Zone*

Four specimens from different localities were collected for sectioning and all were found to contain a high percentage of microcline feldspar. The question which presents itself is how much is merely recrystallized clastic material and how much, if any, owes its presence to metasomatic additions of potash. The occurrence of feldspar here supports the contention that it also recrystallized in the pelitic rocks of the earlier hornfels facies from clastic material, but during the superimposed regional metamorphism it reacted with the andalusite (chistalite) to produce muscovite, according to the equation given on page 19.

A specimen collected in the bed of the Ruquere River, 1,100 yards east of Masterpiece Farm has, in section (16238) a gneissic structure with a somewhat microporphyroblastic texture due to the development of one-millimetre microcline crystals. Quartz is less abundant than the feldspar, and biotite with sub-parallel arrangement occurs throughout. Accessory minerals are muscovite, garnet, sphene and apatite.

On high ground some 800 yards to the north-west is a coarse-grained felspathic rock which is typical of the hill-forming sediments in this area. The large amount of microcline present has given the rock a pinkish colour. The microcline is distinctly porphyroblastic (Slide 16239). The quartz occurs as irregular interlocking grains of variable size which form about half the rock. Biotite is present in only small amounts, but secondary chlorite is abundant. Muscovite plates with sieve texture, having cross-sections up to 2.5 millimetres are irregularly distributed. There is a little iron oxide and a crystal or two of rutile.

Some six miles to the north of the last-mentioned locality is a rock (16240) of similar mineralogical composition and, in addition, a little plagioclase. The abundance of micas gives it a rather schistose appearance. Magnetite occurs as small disseminated globules and hypidomorphic crystals (Slide 16240).

Not all the arenaceous rocks contain microcline. One (Specimen 16281) mentioned in the previous section dealing with the pelitic rocks, which carried a thin kyanite-bearing band or film, has a texture which might qualify it for either section. In addition the actinolite-bearing rock mentioned at the end of the last section might be regarded as arenaceous or included in the following calcareous section.

#### *Calcareous Rocks in the Staurolite-Kyanite Zone*

Once again these calcareous rocks are present only in small amount, but they provide an interesting variety of types ranging in colour from white through green to brown. Their textures, too, are very variable and it is evident that their compositions ranged from nearly pure calcareous limestone to those carrying various proportions of magnesium and pelitic material. The metamorphism of some of these rocks illustrates the process of de-dolomitization by recrystallization.

At 1.2 miles south-east of the Angwa-Mpofu rivers confluence a narrow band of white marble, two feet wide, is exposed on the slope of a hill where it occurs interbedded in black slaty graphitic rocks. In the specimen collected was a vein of coarse siderite. The marble itself (Slide 16241) is composed of calcite with, in places, a few small un-twinned felspar crystals.

Near the west bank of the Angwa River, 1.25 miles south of Katsuke Hill, is a black garnetiferous calc-silicate rock occurring as a narrow band. Just below this band kyanite and staurolite crystals can be seen in the schist. The calc-silicate rock (Slide 16242) is composed predominantly of sieve-textured hornblende crystals one millimetre long, in parallel arrangement. The pleochroism is, X=yellow-green, Y=olive-green, Z=dark green. Next in order of abundance is small granoblastic quartz poikilistically enclosed in the amphibole but interlocking where in contact. Only a portion of a sieve-textured garnet appears on the margin of the slide but garnets are fairly numerous in the hand specimen and measure as much as half an inch in diameter. Sphene and apatite are accessory.

On Masterpiece Farm, 0.75 miles south-west of spot height 3,740, is an exposure of dark-green actinolite-rock and 1.5 miles south-east of it is a larger exposure of the same rock which has magnetite conspicuously apparent in hand-specimen. In thin section (16243) the specimen from Masterpiece Farm is virtually monomineralic. It is composed of pale-green actinolite with only a speck of magnetite. This rock would appear to be slightly more ferriferous than the host rock of the rutile on the "I Wonder" claims, a rock described in the albite-epidote-amphibolite facies.

Some five miles south-south-east of the above occurrence is a white talcose rock outcropping in the bed of the Miami River at its confluence with the Angwa River. The full width of this band is not



exposed. In thin section (16244) talc and oligoclase feldspar are the predominant constituents and are present in about equal proportions. Accessory minerals are vesuvianite, rutile and pyrrhotite. The vesuvianite is pleochroic from colourless to yellow-green and occurs as inclusions in the plagioclase from which it appears to have been derived.

About 0.75 miles to the north-west of the Miami-Angwa confluence is an exposure of very impure black graphitic limestone which contains abundant large porphyroblasts of tremolite. It is black in hand-specimen due to an abundance of included graphite. The surface is heavily iron-stained. Lenses and veins of calcite traverse the rock. In addition there are opaque bands of graphite. Talc, pleochroic from colourless to pale yellow, occurs in bent plates measuring 0.6 by 0.4 millimetres.

In the coarse mica-schists, eight miles to the north-west, one finds narrow pure white lenses, a few inches wide, of tremolite with a little oligoclase feldspar. The coarsely micaceous schists in this area carry a fair amount of tremolite which suggest that the muds from which they crystallized were somewhat calcareous. It would appear that the narrow bands are exudation veins produced by the metamorphism in the same way as the sillimanite-rich veins are produced in the higher zone.

#### SILLIMANITE-ALMANDINE SUBFACIES

This is the zone in which economic mica occurs. The rocks, which were originally predominantly pelitic sediments, reveal quite a variety of alteration and have been divided broadly on the map into schists and gneisses, though the division is not always clear-cut. Gneisses occur in the schists and vice versa, but the division serves to show up the trend of the metamorphism.

The subfacies is one where metasomatism has been conspicuously operative and the gneisses merely mark an advanced stage in the transformation. The sillimanite is in a sense relict as in the *faserkiesel* gneisses. It is the sillimanite which readily causes the fixation of migrating alkalies, and perfect pseudomorphs of muscovite after sillimanite can be found in the schists adjacent to pegmatites and occasionally in the pegmatites themselves. More discussion on these changes and processes is given in the section on pegmatites.

#### *Lithology and Distribution of the Sillimanite-Schists*

A zone of sillimanite-schists extends in a narrow belt for over 22 miles and strikes roughly north and south. Where it leaves the northern edge of the map the zone is three miles wide and is bounded on the east by the kyanite-staurolite zone and on the west by the sillimanite-gneisses. From here it extends south through Miami Village, where it is five miles wide, and ends on San Michele Farm 0.75 miles north of the Miami River at a point which forms the focus of four zones. Over half this distance it borders the staurolite zone where the two minerals can be found in association as mentioned on page 32. This would presumably be a point where pressures were very high and

temperatures moderate to fairly high. It is quite certain that specimens could be found farther north containing sillimanite, kyanite and staurolite.

Sillimanite and kyanite occur together in the mica-schist on Chatigera Hill on the western margin of the map five miles south of the north-western corner.

The first indication of the presence of sillimanite in the schists is the appearance of small quartz lenticles which, on careful examination are found to contain sillimanite needles. This is the *quartz sillimanitisé* of Barrow (15, pp. 337-345). It should be noted that Barrow used the term synonymously with *faserkiesel* but that Sanders (16, pp. 144-151) used the term in the sense of the mineral being relict.

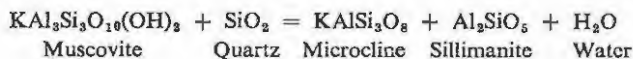
The *quartz sillimanitisé* lenticles are resistant to weathering and stand out on the weathered surface of the schist producing a jagged appearance so that the presence of sillimanite in the rocks can be presumed even at a distance from them. In areas of poor outcrops, these lenticles form a fairly abundant rubble in the soil. Sometimes the lenticles are not so highly silicious, and porphyroblastic aggregates of almost pure, silky sillimanite fibres are found.

There are rocks, however, where the sillimanite is evenly distributed as a felt of fibres in segregated bands, and others where the sillimanite is present only as fine hair-like inclusions in the biotite.

Garnets may or may not be present, but in some of the segregated lenses of sillimanite, irregular garnets of up to two by one and a half inches in diameter are quite abundant. These lenses are very like the tremolite-garnet lenses mentioned in an earlier section. One such sillimanite-garnet band occurs a mile south-west of the Ruby Valley Mine and 8.5 miles north-north-east of the Grand Parade Mine and will be discussed in the petrographic section. In this rock the sillimanite occurs as discrete films and plates of fibres which are in part wrapped round the numerous coarse garnets. Quartz, free of sillimanite, can be seen between the films. Some feldspar and muscovite are also present. Elsewhere in the schists where there are concentrations of sillimanite fibres, they have associated parallel sillimanite-free quartz veins. In this sillimanite zone the part played by quartz in the distribution and segregation of the mineral is apparent. The role of quartz as the medium of transport of elements and molecules will be discussed in the section on pegmatites.

Francis (11, p. 357) has noted that "the first sillimanite is often in quartz veins and segregations, and transporting fluids are easily visualized in the sillimanite zone."

In the northern portion of the sillimanite-schist zone are some quite extensive areas which are very coarsely micaceous and in which sillimanite is absent. In such areas muscovite is more abundant than biotite. It is presumed that higher pressures and lower temperatures than the average were prevalent, so that in the equation given below the left-hand rather than the right-hand assemblage was the stable one:



In these coarse sillimanite-free schists garnets may or may not be present. Because of their physical characteristics the micas tend to give the impression of being more abundant than they really are by obscuring the quartz and feldspar. In cross-section the other minerals are clearly seen between the mica foliae. An abundance of fine-grained tourmaline is present in some of the schists and is clearly of metasomatic origin.

Near the northern edge of the map the rocks of the belt become in part, more gneissic owing to an increase in the percentage of feldspar, but mica is still very conspicuous.

Apart from the main belt of sillimanite-schists, similar schists again make an appearance in the north-west of the area where a group of mica and beryl mines, known as the Urungwe East Group, is situated. These schists occur in small amount with the sillimanite-gneisses and have not been differentiated from them. This area will, therefore, be described under the heading of sillimanite-gneisses.

The *arenaceous rocks* in the zone are quartz-biotite-gneisses, usually without feldspar or garnet. Where local granitization has taken place around small granite intrusions they often remain as "ghost structures" in the granite.

#### *Petrography of the Sillimanite-Schists*

The first feldspar to make its appearance in these schists is oligoclase which, in the main, is a product of soda metasomatism and it will be demonstrated in the sections which follow that this element has preceded the main influx of potash. The first potash, however, which is available for feldspar formation comes from the schists themselves. When temperatures became sufficiently high a reaction is started which is virtually the silicification and dehydration of muscovite and results in the formation, following the ideal formula, of microcline and sillimanite (page 35).

Francis (11, p. 359) notes that there are well known areas "in the eastern United States in which rising metamorphic grade produces the stable assemblage sillimanite-muscovite before the assemblage sillimanite-potash feldspar". On the following page he proposes to group the three pairs andalusite-muscovite, sillimanite-muscovite and kyanite-muscovite in the kyanite-muscovite subfacies. The petrology of this process is discussed in more detail under the heading of sillimanite-gneisses, which rocks provide better thin sections for detailed study.

At the sillimanite grade of metamorphism a sufficiently high "energy level" has been attained to cause a greater mobility of ions thus permitting granitization processes to operate with far-reaching results. In the schists, granitization is more local and is, for the most part, attendant on late kinematic granite intrusions and on emanations from granites which do not always appear at the surface.

The large garnets which occur in the differentiated bands, rich in sillimanite, in the area south-west of the Ruby Valley Mine gave, after careful cleansing, the composition, as deduced from their physical properties, as follows:



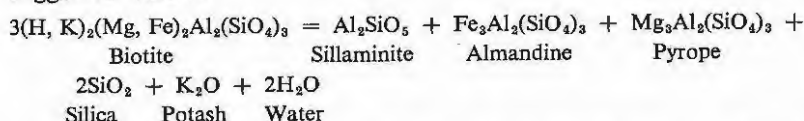
- (a) Almandine 50 per cent., pyrope 27 per cent., andradite 23 per cent. For comparison the garnet in the mica-schist a mile south-west of the above has the composition:
- (b) Almandine 61 per cent., pyrope 26 per cent., andradite 13 per cent.

From Dana's "Textbook on Mineralogy", fourth edition, using the analyses given for the various pure end members, the compositions of these two garnets are calculated as follows:

|     | SiO <sub>2</sub> | Al <sub>2</sub> O <sub>3</sub> | Total iron oxides | MgO | CaO |
|-----|------------------|--------------------------------|-------------------|-----|-----|
| (a) | 38               | 17                             | 29                | 8   | 8   |
| (b) | 38               | 19                             | 31                | 8   | 4   |

The significant differences are in the lime and alumina contents.

The metamorphic differentiation of biotite in gneisses rich in that mineral is well known. Under a favourable set of physical conditions biotite can be replaced by sillimanite and a phase in this reaction is suggested below:



The percentage of almandine in this theoretical garnet is 55 which, it will be noted, is the average almandine content of the two garnets mentioned above.

In the schists south and south-west of the Catkin Fly-chamber, sillimanite is abundant. Exudation has operated to produce sillimanite concentrations in the form of bands, lenses and even quite large dyke-like bodies. The last mentioned are quartz-sillimanite masses.

A specimen of nearly pure sillimanite rock from the track-side 1.25 miles south-west of the chamber is seen, in section 16245, to consist of a mass of sillimanite fibres in parallel, divergent and sheaf-like forms with a subordinate amount of biotite and muscovite. The sillimanite is replacing the muscovite and biotite.

It is clear that at this degree of metamorphism many mineral transformations take place, their variety and complexity depending on compositional variations. In this way elements which cannot be fixed locally migrate to produce metasomatic changes elsewhere. Such regrouping can release both potash and soda as will be illustrated in later sections. These abstractions, which take place in the hotter metamorphic environments, yield considerable quantities of material which can be trapped under favourable circumstances to contribute to pegmatite formation, especially of the economic mica-bearing pegmatites.

#### *Lithology and Distribution of the Sillimanite-Gneisses*

These gneissic rocks form a broad zone striking north from Karoi Township and are bounded by the sillimanite-schists on the east and the granitic gneiss on the west. In addition to this main belt, sillimanite-gneisses occur in the north-west of the area as large isolated, irregular, relict rafts in a sea of para-gneisses in which the sillimanite has dis-

appeared and granitization has been carried appreciably further. Boundaries are gradational and difficult to determine. The colour scheme on the map has been arranged to try to indicate at a glance the gradational nature of most contacts and to try to avoid an impression that the sillimanite-gneisses represent outliers. Permeation has already advanced to a considerable degree in the sillimanite-gneisses which are, in reality, migmatites. Broadly, these isolated patches of gneisses occur as follows: An irregular body extending several miles both west and south of the Catkin Fly-chamber. A four-mile long, north- to south-striking belt, south of the Catkin Fly-chamber; another smaller one striking east-north-east from the Poll and Parrott mines; north of this a larger, irregular body stretching from the Blyvooruitsig Mine to beyond the Locust Mine, and there are several others. The mica and beryl mines are situated mainly in these rocks and have collectively been named the Urungwe East group to distinguish them from the West and main Miami groups of mines.

The effects of potash metasomatism are part of the migmatitic process and can be seen everywhere. In these gneisses, granite and pegmatite form concordant bodies which frequently outcrop when the host rock does not. Such terrain gives the impression of being composed entirely of granite. A closer examination reveals that the outcrops are related to parallel bands of granite and pegmatite.

It can frequently be observed, at good exposures of gneiss, how the rock was in the process of being converted to pegmatite by the continued growth and coalescence of microcline porphyroblasts. A similar state of affairs was noted in Greenland by Hans Ramberg (17, p. 198) and he states that "some pegmatites are merely clusters of felspar porphyroblasts in gneiss or schists and all gradations can be found between single porphyroblasts and large pegmatite bodies". There are exposures within the township of Karoi and elsewhere which match this description exactly. Fairly large irregular masses of pegmatite and coarse granite have been formed in the gneiss in a way that might be likened to the spread of a mould. In some of these granitic pegmatites, patches of relict sillimanite can sometimes be found. The gneisses, too, have all gradations between sillimanite-mica-schist and granitic gneiss. In the rocks which approach the latter the sillimanite can be found only with difficulty in an occasional lens or band.

Sillimanite-gneisses, the typical rocks of the main Miami Mica Field are well exposed in the dissected country north-west of Miami Township in the area of the Berea and Spider mica mines. These rocks have a very crumpled appearance. The granitic fractions have formed into granulose lenticles conspicuously ringed with sillimanite and biotite, and also a little muscovite.

As the sillimanite-schists became converted to gneisses by migmatization there must have been a significant temperature increase. More and more muscovite became converted to sillimanite and microcline, and biotite consequently became more conspicuous though not necessarily due to any increase in the percentage of the mineral in the rock. In some rocks, however, biotite does seem to have increased and this



seems only reasonable. As granitization progresses the percentage of biotite present becomes reduced so that some sort of "basic front" would seem to be operative and it would increase the percentage of biotite in the rocks ahead of the process. The potash from the dissociated biotite contributes to the increase of feldspar in the rocks becoming granitized, while iron and magnesia are liberated and removed.

In the belt of country between Karoi Township and the Last Hope Mine to the north, potash feldspar is again much in evidence. Microcline porphyroblasts, large and small, scattered or numerous to the extent of virtual pegmatitization, are present. Here too, contorted sillimanite-gneisses contain an abundance of pegmatite in small lenses, knots and veins. Some patches of a square foot or more are composed of almost pure microcline feldspar. On the weathered surfaces of such rocks quartz-sillimanite lenticles are often conspicuous.

In an area of otherwise poor exposures, five miles north-west of the Last Hope Mine, in the Rekomiche River, is a large pavement of sillimanite-gneiss. Abundant porphyroblasts of microcline are present and the mineral also occurs in small lenses and knots many inches in diameter. The whole mass is not far removed from being a granite in composition, and nearby are small patches which are, in fact, metasomatic granite.

About nine miles a little west of north of Miami Village are exposures of fine-grained, contorted, biotite-gneiss in which sillimanite occurs as porphyroblastic patches. In these patches the sillimanite is orientated in parallel fibres and appears, under the lens, to be quite free of quartz. The sillimanite is resistant to weathering so that natural exposures have very ragged surfaces. Sillimanite fibres are also disseminated throughout the biotite-rich bands.

#### *Petrography of the Sillimanite-Gneisses*

In thin section (16246) the rock from the Berea Mine shows no microcline feldspar. It is composed of albite-oligoclase feldspar and quartz with subordinate biotite. In this matrix are set the lenticular sillimanite aggregates which attain lengths of up to seven millimetres. In the centre of these aggregates the fibres are colourless, but they become a greenish brown peripherally, where the encasing biotite is clearly undergoing some dissociation to produce additional sillimanite.

The sillimanite-gneiss from nine miles north of Miami (Slide 16247) contains sillimanite which is more acicular than hair-like in habit. The small, somewhat bladed, crystals attain a millimetre in length. Some of these splay out into fibres giving the impression that the small blades are pseudomorphous after kyanite. Some of the biotite contains sillimanite inclusions but much of it is free of this mineral. Quartz is abundant in this rock and there are a few flakes of muscovite of 2.5 millimetres long. Potash feldspar makes its appearance in the form of anorthoclase, both in the matrix and as porphyroblasts.

Oligoclase feldspar occurs as one of the main constituents. The presence of anorthoclase rather than microcline is apparently due to the temperature having been lower in this particular locality. The sillimanite



is pseudomorphous after kyanite and the presence of quite large muscovite flakes suggests that the temperature of dissociation of muscovite, according to equation given on page 35 was not attained. This argument is substantiated by the work of Bowen and Tuttle on artificial melts, referred to by Turner and Verhoogen (8, pp. 94-95). Phase diagrams of the system  $\text{NaAlSi}_3\text{O}_8$ — $\text{KAlSi}_3\text{O}_8$  are reproduced which show a two-felspar field, following a single-felspar field, at a lower temperature. The conclusion is drawn that "mutual replacement of K + and Na + ions is limited in alkali felspar crystallizing within at least the lower part of the range of magmatic temperatures". It would appear that, under certain conditions of metamorphism, the same behaviour also holds good and it may be possible to use the presence of anorthoclase as a temperature index.

The sillimanite-biotite-gneiss from the Grand Parade Mine has, in part, a *lit-par-lit* structure near the intrusive potash-granite. Apart from the narrow bands of granite, there are anorthoclase augen two inches in length. The main constituents of the rocks are quartz, oligoclase, anorthoclase and biotite with subsidiary sillimanite, muscovite and magnetite. A few specks of apatite and sphene are also present (Slide 16248).

The sillimanite-gneiss in the area of the Last Hope Mine, nearly six miles south-west of the Grand Parade Mine, carries small garnets a millimetre in diameter. Hair-like sillimanite crystals occur as clusters in quartz and in some of the biotite, but there is also unaltered brown biotite which is free of inclusions. In this rock, quartz is abundant. The feldspars are oligoclase and anorthoclase, but the latter is present only in small amount. Muscovite is a subsidiary constituent, while sphene occurs only as a few specks.

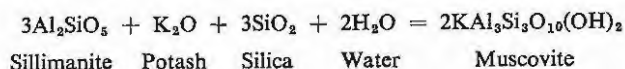
Muscovite porphyroblasts are, in some localities, a conspicuous feature in the gneisses near or in contact with granite, as the product of wet potash metasomatism. The original sillimanite has fixed the available potash, to produce muscovite. Some of the more highly granitized rock has round muscovite porphyroblasts which average about six millimetres in diameter. Some of the more irregular flakes measured as much as 17 millimetres across. These are distinct from the large books of mica, many inches in length, which have been found in some of the coarse mica-schists.

Some 0.75 miles north-east of the Garnet Mine, mica porphyroblasts occur in the gneiss between two small granite masses. The groundmass is composed predominantly of quartz and biotite but with appreciable muscovite and oligoclase felspar. Anorthoclase occurs as sparsely distributed porphyroblasts. There is no discrete sillimanite, but it does occur in small amount in some of the muscovite where it is orientated parallel to the prism and pinacoidal directions.

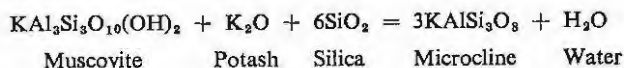
The granite gneiss (Slide 16252) outcropping 800 yards north-east of the Garnet Mine is similar to the para-gneisses in the west. There is much oligoclase felspar with poorly defined twinning. Microcline, biotite and quartz are present in abundance. There are some shreds of muscovite and a little apatite and sphene.

*Discussion:* It is presumed that in rocks of this type the anorthoclase developed before the intrusions of the granite, during the advancing metamorphism which caused the dissociation of the muscovite and the development of sillimanite. Similar reasoning would seem to indicate that the earlier feldspathization, with the development of the oligoclase, took place at a lower temperature before the formation of the sillimanite and potash feldspar from muscovite. The presence of sillimanite in the mica porphyroblasts cannot, in this setting, be regarded as the incipient stage in the epitaxial replacement of muscovite by sillimanite and must, therefore, be an exsolution phenomenon.

Continued granitization leads to the formation of abundant microcline and the gradual elimination of sillimanite, which is followed by a marked reduction in the amount of both micas. These developments are brought about by the process of potash metasomatism. The conversion of sillimanite to muscovite can be observed to have taken place on the margins of the pegmatite in many of the mines. Here muscovite has replaced sillimanite. This is a local phenomenon indicating a retrograde process which can be illustrated by the following equation:



Progressive metasomatism with rising temperature gradually eliminates the muscovite as follows:



An early stage in the advancing metamorphism of rocks of this facies is illustrated by a study of the muscovite. This reveals that some sillimanite is actually formed from the mica, in addition to that formed from staurolite or the inversion of kyanite. Also that this formation of sillimanite can take place without the development of potash feldspar or elimination of the mica from which it is derived. This takes place by a change in the chemical composition of the mica. Thus if "white" mica is regarded as a combination of the three end members muscovite, phengite and Fe<sup>+++</sup>-muscovite (17, p. 268), then a change in composition will be reflected in changes in their proportions. An abstraction of alumina to form sillimanite results in an increase in the percentage of phengite, the alumina-poor mica.

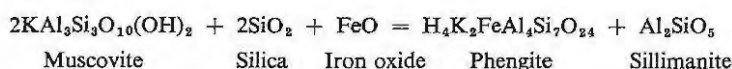
The muscovite porphyroblasts in the gneiss containing a little sillimanite (Specimen 16249) were found, by optical methods, to have the following composition: Muscovite, 33 per cent.; Phengite, 50 per cent.; Fe<sup>+++</sup>-Muscovite, 17 per cent. The composition of the mica in a specimen (16250) which contains far more sillimanite is as follows: Phengite, 80 per cent.; Fe<sup>+++</sup>-Muscovite, 20 per cent.

For comparison the composition of mica in the granite gneiss which contains no sillimanite gave the following result: Muscovite, 65 per cent.; Phengite, 25 per cent.; Fe<sup>+++</sup>-Muscovite, 10 per cent.

From the ideal formulae of the three end members, the composition of the micas listed was calculated as follows:

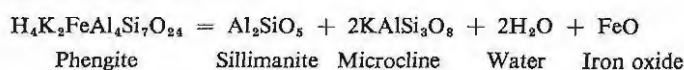
|                                    | Spec. No. 16251<br><i>No sillimanite<br/>per cent.</i> | Spec. No. 16249<br><i>Little sillimanite<br/>per cent.</i> | Spec. No. 16250<br><i>Much sillimanite<br/>per cent.</i> |
|------------------------------------|--------------------------------------------------------|------------------------------------------------------------|----------------------------------------------------------|
| K <sub>2</sub> O . . .             | 11.6                                                   | 11.5                                                       | 11.3                                                     |
| Al <sub>2</sub> O <sub>3</sub> . . | 33.6                                                   | 29.1                                                       | 24.5                                                     |
| SiO <sub>2</sub> . . .             | 46.3                                                   | 47.5                                                       | 49.2                                                     |
| FeO . . .                          | 2.2                                                    | 4.3                                                        | 7.0                                                      |
| Fe <sub>2</sub> O <sub>3</sub> . . | 1.9                                                    | 3.2                                                        | 3.7                                                      |
| H <sub>2</sub> O . . .             | 4.4                                                    | 4.4                                                        | 4.3                                                      |
|                                    | <hr/> 100.0 <hr/>                                      | <hr/> 100.0 <hr/>                                          | <hr/> 100.0 <hr/>                                        |

These figures illustrate that, with advancing metamorphism, the significant change undergone by the mica during the development of sillimanite is the abstraction of alumina and the relative increase of silica and iron. An ideal formula for this metamorphic change could be as follows:



The sillimanite-rich specimen (16250) shows that biotite may also contribute. A plate of phengite-rich mica measuring 5.5 millimetres across is full of hair-like sillimanite, orientated parallel to the main crystallographic directions. Most of the slide consists of interlocking quartz grains averaging 0.3 millimetres, which are well laced with sillimanite fibres. There are also some small plates of colourless mica. Oligoclase feldspar is sparse. A segregation of biotite with some magnetite occurs in one part of the slide. No potash feldspar was seen in the slide and possibly none was produced at this degree of metamorphism. The formula on page 35 showing muscovite giving rise to microcline and sillimanite, applies to the complete dissociation of the mica. The conversion of muscovite to phengite and sillimanite does not necessitate the formation of potash feldspar.

The second stage in the production of sillimanite from mica can be considered to be as follows:



Thus the first stage is a virtual silicification and the second stage a dehydration and elimination of the mica.

Pegmatites intrusive into sillimanite-bearing rocks cause, on their walls, a reversal of the mica to sillimanite reaction considered above and specimens have been collected with pseudomorphs of mica after sillimanite. As is to be expected this is an alumina-rich mica with much of the muscovite molecule and little of the phengite molecule. Similarly the mica forming the "shimmer" aggregates, after chiastolite, has a high percentage of the muscovite molecule. Its composition is as follows: Muscovite, 80 per cent.; Fe<sup>+++</sup>-Muscovite, 20 per cent.



Compare this with the mica in specimen 16250 which has 80 per cent. phengite and none of the muscovite molecule.

The irregular granite mass in which the Garnet Mine is situated contains granitized and partly granitized schist inclusions as well as similarly altered margins. Sillimanite-gneiss can be traced into gneissic granite with unchanged dip and strike. The gneisses in the vicinity of this granite have developed large microcline porphyroblasts. While microcline can be produced at the expense of the mica in the schists and gneisses without metasomatic additions of potash, the more extensive development of this feldspar during granitization must involve metasomatism which also eliminates the sillimanite. The higher temperature then operative, results in potash feldspar rather than muscovite, but some biotite could be produced. The addition of potash to the right-hand assemblage of the last equation shown above would result in biotite.

When the theoretical composition of this muscovite is compared with the calculated compositions of the micas given earlier in the table on page 42 there would appear to be an anomalous state of affairs but this can be quite readily explained. This muscovite has an optic angle of 33 degrees and a mean refractive index of 1.598, the properties of mica containing the following molecular proportions: Muscovite, 10 per cent.; phengite, 70 per cent.; Fe<sup>+++</sup>-Muscovite, 20 per cent. This gives the following theoretical composition for the mica:

|                                          | <i>Per cent</i> |
|------------------------------------------|-----------------|
| K <sub>2</sub> O . . . . .               | 11.4            |
| Al <sub>2</sub> O <sub>3</sub> . . . . . | 25.9            |
| SiO <sub>2</sub> . . . . .               | 48.6            |
| FeO . . . . .                            | 6.1             |
| Fe <sub>2</sub> O <sub>3</sub> . . . . . | 3.7             |
| H <sub>2</sub> O . . . . .               | 4.3             |
|                                          | <hr/>           |
|                                          | 100.0           |
|                                          | <hr/>           |

Compare the alumina content given above with that of the three specimens mentioned earlier. One might have expected it to have been nearer to that of specimen 16251 than of specimen 16250. There is, however, a notable mineralogical difference between the two paragneisses 16251 and 16252. The former has no microcline while in the latter this feldspar is abundant. It would thus appear that the alumina once extracted from the mica does not again re-enter it on granitization under normal circumstances, but that the sillimanite formed in this way goes to the formation of microcline under the temperature conditions prevailing in the granitization atmosphere.

Investigations along this line might prove of value in determining the origin of granitic rocks.

The muscovite in the pegmatites of this area is highly aluminous. In this respect an analysis of waste muscovite from the Hendren Mica Mine, eight miles north-west of Miami is of interest.

|                                          | <i>Per cent.</i> |
|------------------------------------------|------------------|
| SiO <sub>2</sub> . . . . .               | 45.32            |
| Al <sub>2</sub> O <sub>3</sub> . . . . . | 35.28            |
| Fe <sub>2</sub> O <sub>3</sub> . . . . . | 4.82             |
| Na <sub>2</sub> O . . . . .              | 0.70             |
| K <sub>2</sub> O . . . . .               | 10.02            |
| H <sub>2</sub> O . . . . .               | 4.15             |
| TiO <sub>2</sub> . . . . .               | 0.20             |
| MnO . . . . .                            | 0.02             |
|                                          | <hr/>            |
|                                          | 100.51           |

MgO, CaO, S nil.

Analyst: E. Golding.

## AMPHIBOLITES

The rocks considered under this heading may not belong to the Piriwiri System although they have been subjected to the same metamorphism. Their origin poses a problem, the solution of which will have to be sought outside the area herein described.

The two possibilities that present themselves are that they may be the metamorphic derivatives of marls and are, therefore, para-amphibolites or else that they are metamorphosed lavas and consequently ortho-amphibolites.

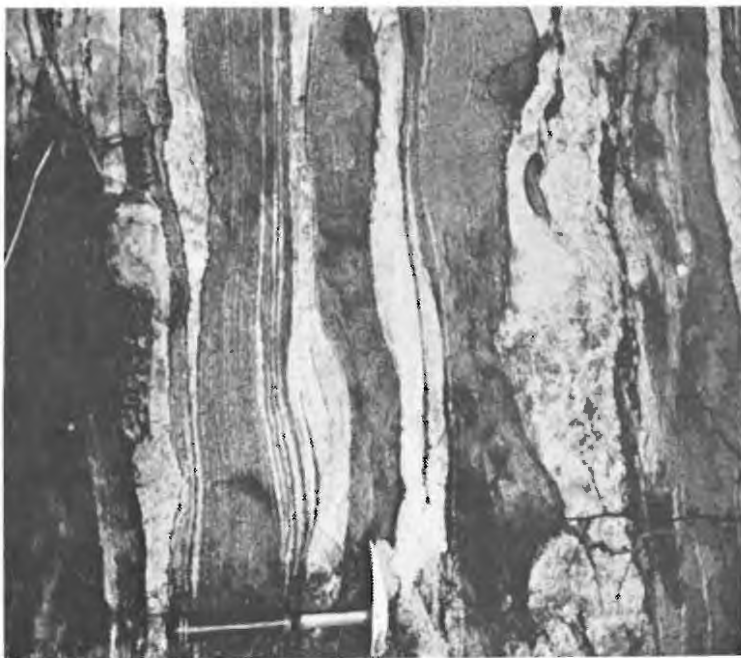
Undoubted Deweras System lavas do occur half a mile beyond the eastern margin of the map. This is approximately one and a half miles east of the Mpofu-Angwa river confluence and the lava there is a fine-grained epidiorite. When, therefore, a quite extensive area of hornblendic rocks and their metasomatic equivalents are found apparently overlying Piriwiri gneisses, the possibility of their being derived from Deweras lavas is suggested.

Some reconnaissance to the north-west, beyond the limits of the map, revealed an extensive area of hornblende-bearing rocks, which are plainly calc-silicate-hornfels. They appear to be a continuation, with somewhat changed facies, of the amphibolites which form the topic of this section. Within the amphibolite sheet itself are small exposures of undoubted calc-silicate rocks such as anthophyllite-schist, garnetiferous diopsidic rocks as well as marble which will receive detailed description in a later section. There is, therefore, stronger support for these amphibolites being of sedimentary origin but because there is an element of doubt they are not described with the other calc-silicate rocks, which latter are most likely very much younger.

*Lithology and Distribution*

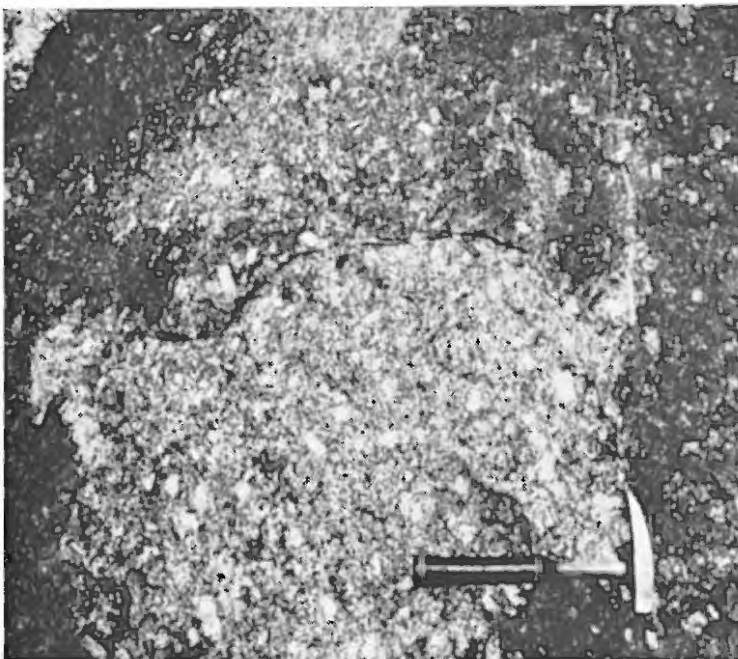
Only some 12 square miles of an extensive area of hornblendic rocks occurs in the north-western sector of the map where the Sinoia-Chirundu road leaves it. These rocks occur on the farms Omega, Chiuwa, St. Mawes, Childerley and Pendennis as part of a continuous sheet. In addition there is a small, isolated patch to the south on Rekomitje "A" Farm. Undifferentiated bands of hornblendic gneiss and amphibolite occur in the gneisses farther to the south. Some of these may have originated as minor basic intrusions of pre-metamorphic age.

PLATE VI



A. Migmatized amphibolite, Rekomiche River.

Photo: J.W.W.



B. Porphyroblastic biotite-gneiss, two miles north-east of  
Chimba trigonometrical beacon, Urungwe Reserve.

Photo: J.W.W.



In the absence of exposures, the presence of hornblendic rocks is heralded by a change in the colour of the soil from the pale sand of the granitic gneisses to a chocolate-red soil of rather sandy texture due, to some extent, to extensive migmatization.

The continuous extent of these rocks is occasioned by their nearly horizontal attitude. Good exposures reveal extensive migmatization (Plate VI. A.). This metataxis has resulted in conspicuous metasomatism on the margins of the granitic bands which is more marked where these are pegmatitic. Here potash metasomatism has converted the hornblende to biotite to distances of up to a foot or more on either side of the granitic bands. Relict lenses of hornblendic rock may be found in the biotite-gneiss. Thus clear evidence is provided to show how an amphibolite can be transformed into a biotite-gneiss. The sequence of rock types in this event is amphibolite, biotite-hornblende-gneiss, biotite-gneiss, pegmatite. The large area of biotite-gneiss occurring to the south, and which has been formed in this way, is described in the following chapter.

The bands of granite, due to contamination, often carry appreciable epidote, hornblende and magnetite in addition to their normal feldspars and quartz. Similarly the pegmatite often contains lens-like concentrations of biotite derived from incorporated hornblende.

Within the main mass of amphibolite there are also some larger intrusions of pale granite and inliers of granite-gneiss which, in the absence of exposures, are shown up by patches of paler soil.

#### *Petrography*

A specimen (No. 16253) of the amphibolite from St. Mawes Farm revealed some tendency to parallelism of its main constituents, the hornblende and andesine-labradorite. Quartz and sphene are accessory. The sphene occurs mainly as inclusions in the amphibole where it gives rise, on occasion, to marked pleochroic haloes (Slide 16253). The hornblende is the dark complex variety. Three and a half miles away and just west of the point where the main road leaves the northern edge of the map a specimen (16254) was collected which is very rich in hornblende. Magnetite is abundant and there is a little plagioclase and quartz.

The different effects produced by granite and pegmatite can be clearly seen. The uncontaminated granite is a pale rock composed of albite and microcline in nearly equal proportions with quartz in smaller amount. Ferromagnesian minerals constitute a very small percentage of the whole. Assimilated mafic material results in a gneissic hornblende-granite rich in epidote. A little garnet, biotite and magnetite are also present.

The "wetter" pegmatite produces the metasomatic effects already noted, namely the conversion of hornblende to biotite and the conversion of calcic plagioclase to sodic plagioclase.

A hybrid rock from Chiuwa Farm is composed of oligoclase, epidote and diopside with some sphene and apatite. The epidote forms large crystals, some of which show twinning. Diopside forms pale green crystals up to two millimetres across which become duller green on uranalitization.

#### IV. PERMEATION GNEISSES (AMPHIBOLITE FACIES)

In the explanation on the map the term permeation has been used to embrace the sillimanite as well as the granitic gneisses. The sillimanite-gneisses have already been described so that the heading here given is used in a more restricted sense than that used by Read (18) and Cheng (19). Read used the term "to denote those injection rocks arising from the soaking and permeation of country rocks by juices from the injecting magma".

The rocks described under this heading embrace a group in which metasomatism has progressed to the stage where, in those of pelitic origin, sillimanite has been eliminated. In these rocks, too, the percentage of micas has been greatly reduced during the process of alteration from schist to gneiss. This system has been adopted for simplification in mapping and description. Regional metamorphism proceeded in a normal sequence through the various grades up to the amphibolite facies at which stage a "wet" metamorphism or metasomatism moved outwards from a "focus" of granitic activity (10, p. 4.).

Under the broad heading given above are two main groups. They have been classified as *granitic gneisses* of variable texture and composition which have approached the end product of granitization of rocks of pelitic origin, and *biotite-gneisses and schists* which have been derived from hornblendic rocks, presumably calc-silicate rocks, by a predominantly potassic metasomatism.

For the most part the granitic gneisses may be described as migmatites even though conspicuous banding is lacking. Cheng (20) attributed the absence of banding in rocks of pelitic origin to the fact "that the invading liquor easily soaked through and was readily incorporated and fixed, no chance being offered to the fluid to concentrate and then crystallize along certain zones". On the other hand the hornblendic rocks, which gave rise to the biotite-gneisses, first became markedly migmatized (see Plate VI A) but as metasomatism proceeded the banding disappeared and a conspicuous porphyroblastic texture developed (Plate VI. B).

#### GRANITIC GNEISSES

##### *Lithology and Distribution*

These gneisses are distributed over some 500 square miles in the western half of the map. To the east they grade into sillimanite-gneisses while to the north-west sillimanite-gneisses form large, irregular, relict rafts in the granitic gneiss which may be locally quite micaceous. The mica mines of the Urungwe East Group are located mainly in the sillimanite-gneiss. Calc-silicate rocks of variable composition are widespread in this area which, together with remnants of basic intrusions, form the "resisters" of Read (19).

To the south the gneisses grade imperceptibly into para- or synkinematic granite so that it is no easy matter to decide where to draw the geological boundary separating them.

It must be evident that in a mass of pelitic gneisses undergoing migmatization or permeation, variations in the degree of alteration must occur in such widely distributed rocks. In the area shown as granitic gneiss are patches better described as granite and there is also much pegmatite, while in the granite to the south there is much that could be described as granitic gneiss. In other words, the synkinematic granitization process reveals various stages in the development of "granite" as defined by Vladi Marmo (21, p. 431).

The rock types include fine-grained pinkish gneiss, which is migmatitic in part, and grey gneisses that are richer in biotite and frequently porphyroblastic as a whole or along well-defined broad bands. In some, the gneissic structure is strongly developed. In others a further stage in the granitization has resulted in rocks of a more homogeneous character but which still retain a definite streakiness.

A narrow belt of coarsely porphyroblastic gneiss 6.5 miles in length strikes south-west from the main road on Rekomitje "A" Farm through the Makore Hills. This belt has been differentiated from the surrounding granitic gneiss and there is clear evidence of structural control. This coarse gneiss strikes parallel to the Chipapa River and to the grain of the country. The rock is strongly gneissic with marked parallelism of the abundant, tabular, idiomorphic feldspars. The individual feldspar crystals measure up to an inch or more in length and show clearly developed Carlsbad twinning. Where plastic flow has taken place the closely spaced feldspars follow the lines of banding and retain, for the most part, their sub-parallel arrangement. Occasionally crystals have been rolled out of alignment and have become lodged with their long axes oblique and even normal to the banding. In such cases they have become rounded or augen-shaped.

Bands of similar porphyroblastic gneiss, not differentiated on the map, occur two to three miles farther south-west along the same line as the Makore gneiss and outcrop in the prominent hills east of the Catkin Mine across the Naodsa River. Here, however, the porphyroblasts are sparser and augen structure is more common. Three miles south-east of the Catkin Mine the coarse granitic gneiss is also only sparsely porphyroblastic. However, small porphyroblastic zones and bands are widespread throughout the granitic gneiss.

Apart from the collectively large amount of concordant granite and pegmatite in the granite gneiss, which is related to the migmatization process, there are younger discordant granitic intrusions. One such is well displayed in the quarry 1.5 miles north-east of the Makore trigonometrical beacon where the country rock is granitic gneiss and dark grey granulitic calc-silicate rock.

It seems likely that much of the older granitic material is of metasomatic origin. An occasional ideal exposure allows one to trace the gneiss along the strike into granite and finally pegmatite. Some quite



large irregular masses of pegmatite have clearly formed *in situ* and give the impression that the pre-existing rocks have been stewed in a granitizing "juice". There is so much evidence in the literature to prove granitization, that further elaboration will not be given here.

Late in the granite cycle when the rocks had developed sufficient mobility, forceful injections of granitic material took place.

Just east of the Lynx Mine, some three miles west of the Makore beacon, is a small area in which are some highly folded gneisses with much mica along the well-developed foliation planes. Where steeply dipping the rocks form large mica-spangled exposures. They have a very different appearance from the earlier-mentioned granitic gneiss due to the abundance of muscovite which is rather rare in the latter. Muscovite and biotite are present in about equal proportions and the absence of feldspar porphyroblasts is noteworthy.

The finer-textured granitic gneisses occur in an area east and west of the main road to Chirundu some 20 miles north of Karoi Township. The mica in these rocks which appears, in hand specimen, to be mainly biotite, occurs in a very fine state along the foliation planes which are closely spaced so that banding is not apparent except where there has been *lit-par-lit* development. These types are in strong contrast, megascopically, to the coarsely crystalline mica-spangled gneisses from the Lynx Mine area. In some of the finely banded gneiss occasional feldspar augen attain dimensions of 2.5 by 0.5 inches and reveal twinning. Lenses and veins of fine-grained quartz are often seen bearing both concordant and discordant relationships to the gneiss and some are ptlygmatically folded.

#### *Petrography*

Twenty-four specimens collected over a wide area were sectioned and examined in detail. They all contain virtually the same mineral assemblages but in different proportions. The textures are crystalloblastic in the main but, where well developed, the large microcline porphyroblasts tend to become idioblastic. The mineral constituents are quartz, oligoclase, microcline and biotite. With the exceptions mentioned in the previous section, muscovite is present only in small amount and is often mainly of secondary origin.

In the various thin sections either quartz or feldspars predominate. In the common grey gneiss the predominant feldspar is a somewhat turbid oligoclase but in the porphyroblastic varieties microcline may equal the plagioclase in amount or even predominate.

Some of the microcline occurs interstitially but the bulk is of late origin and has made room for itself by replacing the plagioclase. Related to this replacement process was the development of myrmekite, an intergrowth of vermicular quartz and plagioclase. It is most commonly seen at the contact of the microcline and plagioclase where the vermicular quartz has dendritic appearance branching towards the microcline. Read (19, p. 121) has described a myrmekite as having the form of "cauli-

flower-shaped protuberances projecting into the potash felspar from an oligoclase base, but sometimes entire crystals of myrmekite are enclosed in the orthoclase".

Cheng (20, p. 140) has devoted almost a page to the description of myrmekite and its origin. He supports what appears to be the generally accepted view that myrmekite is produced as a result of the replacement of potash felspar by oligoclase. He then goes on to explain the possible origin of the replacing plagioclase. As in the case with the gneisses described in this section, Cheng found that "in all the migmatites and granitic rocks, *whenever both oligoclase and orthoclase* (microcline in Urungwe) are present, the former is seen to have been replaced and reabsorbed by the latter while both have been corroded and replaced by quartz". Cheng believes that part of the soda and lime released by the replacement of oligoclase by potash felspar "furnished most, if not all, of the material needed for building up the myrmekite" which then in turn replaced the orthoclase. The vermicular quartz in this secondary plagioclase is interpreted as being the excess silica released as a result of the new replacement.

From the careful examination of the myrmekite and microcline relationships in a number of the Urungwe slides there would at first appear to be much evidence that does not support Cheng's view. In many occurrences where microcline and myrmekite are in contact, it is not clear which is replacing which and several instances were seen where the microcline was clearly replacing the myrmekite. This apparently anomalous state of affairs can be explained quite simply if it is appreciated that both types of replacement must have been going on simultaneously. For vermicular quartz to develop by the replacement of microcline by plagioclase the latter should, according to the theory advanced, have a smaller percentage of silica in its composition than the former. A determination of the felspar in these gneisses by universal stage methods revealed a plagioclase of average composition  $Ab_{80}$  which contains about one per cent. less silica than the microcline, thus allowing free silica to be formed on replacement of the latter by the former. The quartz enclosed in the secondary plagioclase is not always vermicular in form but is, on occasion, of micrographic appearance.

Clear evidence of myrmekite replacing microcline is shown in Figure 3a drawn freehand from a thin section (16282) of one of the gneisses viewed under the microscope. Figure 3b is a drawing prepared from slide 16255. Here plagioclase is being eaten back by the microcline leaving gaunt fingers of once included quartz as relict projections into the replacing felspar. At the bottom of the figure myrmekite forms a sharp contact with the same microcline porphyroblast but elsewhere on the margins of this crystal, which is six millimetres long, the myrmekite exhibits an intrusive relationship similar to that shown in Figure 3a. Globular patches of myrmekite are also found included in the microcline. Twinning in the secondary plagioclase of the myrmekite has been eliminated.

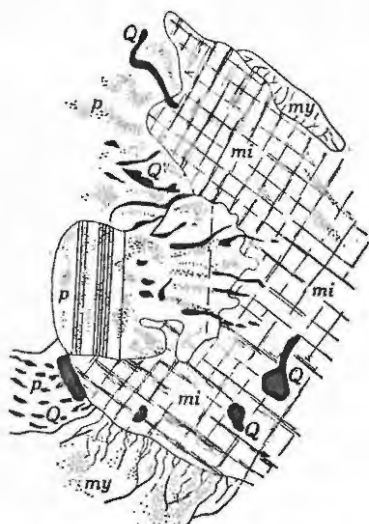


Fig. 3a

1 mm.



Fig. 3b

1 mm.

#### Explanation

- |                                     |               |               |                                   |             |
|-------------------------------------|---------------|---------------|-----------------------------------|-------------|
| Q Quartz                            | p Plagioclase | mi Microcline | my Myrmekite                      | m Muscovite |
| a. Microcline replacing plagioclase |               |               | b. Myrmekite replacing microcline |             |

Turbid relict plagioclase occurs in the microcline with elongated form and is arranged in a sub-parallel or *en echelon* manner. In this way, by replacement, structures are formed which resemble patch perthite. The turbidity of the plagioclase in these gneisses, where a predominantly potash metasomatism is being superimposed on a lime-soda metasomatism, is due to sericitization. Clear rims tend to form in the plagioclase where it is in contact with microcline. For the most part the myrmekite is not as turbid as the primary plagioclase though the two appear to be of identical composition.

The volume composition of slide 16255 described above, and from which Figure 3b was prepared, is given in the table on page 69 together with an analysis of the specimen from which the slide was prepared.

Discrete muscovite plates are often present where there is a good development of myrmekite. In one notable thin section (Slide 16256) muscovite crystals, the longest of which is 0.8 millimetres, are orientated in two main directions at 61 degrees to each other. These directions are parallel to the prismatic cleavage of the microcline porphyroblast (see Figure 4a). The muscovite plates are mainly in the myrmekite but in places they extend beyond it into the microcline. This indicates that the replacing myrmekite has a preferred orientation based on that of the microcline and both extinguish almost simultaneously. It will



be observed that even the enclosed plagioclase crystal and marginal biotite have directional orientations as though the later microcline had been built on them. The enclosed plagioclase has a clear rim and shows some evidence of resorption. Thin section 16255 provides a good example of replacing microcline taking on an orientation related to the plagioclase. This is illustrated in Figure 4b. Both extinguish together and the twinning lamellae are in continuity. Such perfect pseudomorphs are not always apparent and it is clear from a glance at figures 3a and 3b that more than one mutual orientation is possible between the feldspars.

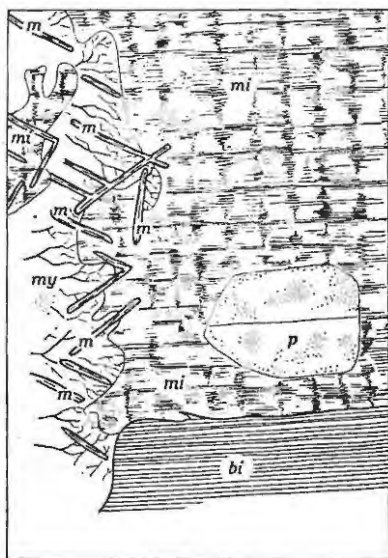


Fig.4a

1 mm.



Fig.4b

1 mm.

#### Explanation

| Q  | Quartz                                                                             | p | Plagioclase | mi | Microcline | my | Myrmekite                                                                       | m | Muscovite |
|----|------------------------------------------------------------------------------------|---|-------------|----|------------|----|---------------------------------------------------------------------------------|---|-----------|
| a. | Myrmekite replacing microcline with development of orientated secondary muscovite. |   |             | bi | Biotite    | b. | Microcline replacing plagioclase and taking the same orientation as the latter. |   |           |

The orientated muscovite plates mentioned above would appear to owe their origin to the release of potash from the microcline during its replacement by the myrmekite.

In the mica-spangled gneiss (16251) just east of the Lynx Mine there is a complete absence of microcline since the physical conditions were such as to cause muscovite to crystallize in its stead. It is assumed that high pressure and a lower temperature gave rise to a wetter metamorphic environment locally. The absence of myrmekite is another notable feature. The plagioclase, which is  $Ab_{80}$  is limpid by comparison with the plagioclase in microcline-bearing gneiss. It is as though all the sericite has been extracted to contribute to the formation of the muscovite. Individual muscovite plates measure as much as 4.5 millimetres in cross-section. Quartz is the predominant mineral and some

of it occurs as grains rounded by corrosion in the muscovite. Muscovite and biotite are present in about equal proportions and are sometimes intergrown. No obvious replacement of plagioclase by muscovite could be detected. A few garnets appear in the slide.

From optical data the composition of the white mica is: Muscovite, 65 per cent.; Phengite, 25 per cent.; Fe<sup>+++</sup>-Muscovite, 10 per cent.

In some of these gneisses there are relatively broad bands containing garnet or both garnet and sillimanite. Where present, hornblende serves to indicate the virtually complete digestion of some basic material by granitization.

#### BIOTITE - GNEISSES

##### *Lithology and Distribution*

These biotite-gneisses have been derived from amphibolite by a predominantly potassic metasomatism. To the north of the main area of outcrop are the parent hornblendic rocks which have already been described under the heading of amphibolites.

Biotite-gneiss forms the predominant rock type over an area of some 50 square miles in the south-western corner of the map. Similar gneisses occur in small amount in the area of granitic gneisses and are presumably derivatives of small basaltic intrusions. They have not been differentiated on the map from the main gneiss. The granitic gneiss itself carries biotite but in far smaller percentage.

The biotite-gneisses are dark grey to blackish rocks which give rise to a reddish-brown soil.

In summing up the general processes which have taken place in these rocks some recapitulation will be necessary. The mafic rocks, being more resistant to granitization than the pelitic schists, reacted differently. At first they became markedly migmatitic (see Plate VI.A). The pegmatite bands produced especially noticeable metasomatic effects on their margins, converting the hornblendic rock to biotite-schist and gneiss. Through contamination the granite bands became enriched in epidote, hornblende and magnetite with occasional lenticular concentrations of biotite. The hornblende under these conditions sometimes recrystallized into coarse aggregates.

Lime was liberated from the hornblende during this metasomatism and as it progressed the plagioclase, too, yielded up lime and became less calcic. Some of this liberated lime contributed to the formation of the epidote concentrations.

The continuation of the metasomatic processes leads to the complete elimination of all hornblende. With increased plasticity the migmatitic banding disappeared and the rock became homogeneous. With a further increase in granitization there is a gradual elimination of biotite, and this itself liberates material which contributes to further microcline production and porphyroblastic growth. The last stage with resultant mobility leads to the formation of a coarse porphyroblastic granite.



In the coarse biotite-gneisses there may be found occasional small lenses or concentrations of biotite which formed during the migmatization.

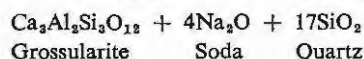
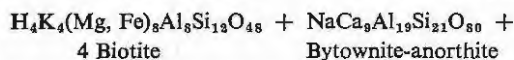
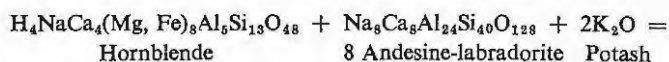
E. Ackerman (Leipzig) produced a paper, apparently as yet unpublished, on "The Problems of the Mkushi Gneiss on the north-west Margin of the Rhodesian Block" in which he discusses "biotite gneisses of problematical origin". He has not entered into petrographic detail but from his general description there seems to be much similarity between the Mkushi gneisses and those of Urungwe although there has, as yet been no attempt at correlation. In both areas these rocks have been granitized *in situ* by predominantly potassic "solutions".

### Petrography

Four specimens which have been selected to illustrate as far as possible the metasomatic processes which take place during the conversion of amphibolite to biotite-gneiss are described here.

Specimen 16257 from 1.5 miles west of Magunge is a dark-grey rock devoid of banding and having a granoblastic texture. Biotite is conspicuous on the fresh surfaces while the weathered surface is dull and pock-marked. The predominant mafic constituent is brown biotite enclosing much ilmenite. In addition some of the biotite plates reveal well-developed sagenitic structures due to hair-like crystals, possibly of rutile, occupying crystallographic directions in the mica. Pale olive-green hornblende occurs in small amount as aggregates interspersed with some quartz and plagioclase. In places some of the amphibole has clearly been replaced by biotite. There is a fair quantity of pale-pink garnet forming irregular crystals of up to four millimetres in cross-section. It is idiomorphic towards the biotite and is also full of inclusions of ilmenite and some quartz. Apatite is a fairly abundant accessory. Plagioclase constitutes 40 per cent. of the rock and is a limpid bytownite in contrast to the andesine-labradorite of the amphibolites. Quartz is present in small amount and microcline, which is so conspicuous and abundant elsewhere, is completely lacking. It would appear that the metasomatically derived microcline makes its appearance only after the complete elimination of the hornblende and then forms conspicuous porphyroblasts (see Plate VI.B). The first potash additions are therefore taken up in the conversion of the amphibole to biotite.

In the earlier stages of this granitization process some of the lime released from the hornblende goes to produce a temporary calcification of the plagioclase and some into the formation of garnet. The following formula has been worked out to fit the observed fact:





Soda is made available in the process and unless some local physical conditions induce it to move on, the newly constituted calcic plagioclase is soon reduced to or enveloped in a more sodic variety as is revealed in the next specimen collected from immediately north-west of Mahororo store, a point five miles west-south-west from Magunge. This rock has conspicuous porphyroblasts of plagioclase feldspar, and again microcline is absent. The crystals are idiomorphic where uncrushed, and measure as much as an inch in length.

In thin section (Slide 16256) the plagioclase encloses much fine granular epidote. The feldspar is a medium andesine, and one of these porphyroblasts encloses a turbid, more calcic plagioclase with a clear rim marking the contact between the two. The replacement or conversion of the more calcic plagioclase to an andesine results in the separation or exsolution of lime in the form of epidote while the excess alumina and absorbed potash goes into the formation of muscovite. This mica is fairly abundant and occurs partly surrounding some of the plagioclase or is concentrated along fractures within it. The tendency for epidote to be included and muscovite to be largely excluded from the plagioclase suggests that in the incipient stages of sodification or alteration, sericitization preceded saussuritization. Aggregates of quartz are fairly abundant and a few granules of sphene occur.

Microcline first makes its appearance as a replacement of plagioclase. In much of the gneiss, microcline feldspar forms rectangular to augen-shaped porphyroblasts measuring as much as two inches and more in length. In this type of rock two compositions of plagioclase are present. That included in the microcline is a turbid albite-oligoclase while the discrete plagioclase is a medium andesine,  $An_{38}$ . In thin section (16258) in which no porphyroblast or portion of one was included, abundant andesine was the only feldspar present. The feldspar is clear and contains inclusions of epidote and muscovite. Some of the larger crystals show fracturing and bending of the twin lamellae. Quartz is subordinate to feldspar in the slide and is strained. Both predominate over the biotite which again shows well-developed sagenitic structure. Sphene and apatite occur in fair abundance with the biotite, and ilmenite, so conspicuous in one of the slides described earlier, is wanting.

A thin section was prepared of one of the microcline porphyroblasts in this rock. In one part, albite-oligoclase forms a selvage to the microcline. The former contains much micrographic quartz and the whole has presumably been derived in the same way as the myrmekite in the granitic gneiss. Within the microcline some very turbid included plagioclases have borders containing micrographic quartz. It is clear that in the mineral transformations which take place as a result of changed physical conditions, some elements are temporarily redundant but manage to find a place locally by metasomatic replacement or formation of new minerals while others are compelled to migrate. A knowledge of these metamorphic processes is necessary in any consideration of the origin of the pegmatites which are related to this environment. The potash which has been operative in transforming the amphibolite to biotite-gneiss is conceivably of metamorphic origin. The addition of

potash to rocks of the composition here considered initiates a soda metasomatism which itself assists in the sodification of the plagioclase. This process releases lime which goes towards the formation of more epidote, sphene, garnet and apatite if local conditions allow. Conditions can occur which produce a local abstraction of certain of these released substances and, if not fixed by metasomatic reactions elsewhere, they may go to the formation of vein minerals or become part of the substances contributing to pegmatite formations.

Misch (22, p. 238) has noted that there are two chief chemical types of granitization, one of which produces a predominantly soda metasomatism. He remarks that soda metasomatism seems "more easily able to attack basic rocks". It would appear from the study of Urungwe amphibolites that it is the potash which is the prime transformer and that the effects of soda are secondary.

#### CALC-SILICATE ROCKS

##### *The Almandine-Diopside-Hornblende Subfacies*

Because of some reasonable doubt as to origin of the amphibolites, which may belong to this group, they were separately described in an earlier chapter. The rocks included here are of small local extent, but of wide distribution. They, nevertheless, form a most varied and interesting group of usually fresh, tough rocks which provide ideal specimens for detailed study. Because of their variable compositions and the interesting minerals they contain more than 50 thin sections were prepared and studied.

##### *Lithology and Distribution*

The rocks of this group are easily recognizable in the field and they tend to form conspicuous exposures in areas where the enclosing gneisses do not outcrop. Where massive, they form low dyke-like ridges, but more usually occur as piles of rounded boulders. The tendency is for these rocks to resist deep weathering and differential solubility sometimes produces a fluted structure. Compositional variations of the bedding layers are accentuated by the metamorphism so that a collection of boulders in any one exposure may have a heterogeneous appearance. Some may contain abundant large garnets, some may be pale and highly felspathic; others dark grey and have the appearance of epidiorite or amphibolite.

Those rocks, containing appreciable amounts of diopside, amphibole, or other mafic constituents, form dark reddish-brown soils which contrast strongly with the paler sandy soils of the gneisses.

The trend of some of the narrow calc-silicate bands and lenses is often highly folded or contorted and serves to show up the bedding of the gneisses.

There are some irregular masses of tremolite-rock mainly along the eastern margin of the biotite-gneiss which would appear to have some special significance. Some are associated with garnetiferous mica-schist and therefore both of them, like the other irregular masses of schist

further south, are *klippen*. Tremolite-actinolite-schists do, however, occur in bands in the gneiss. It will be noted that these rocks are composed of the very elements which are removed from rocks rich in ferromagnesian minerals on granitization. The thought which presents itself is that some such rocks might arise as an excretion from granitized hornblende rocks such as have been described earlier. Elsewhere in the district quartz reefs have been found which carry much actinolite and magnetite. Some epidote concentrations were found which were clearly by-products of the metasomatism of basic rocks.

In some of the granitic gneisses, which might be mistaken by some as orthogneisses, are many small bands or lenses of calc-silicate rock which constitute typical "resisters" and serve to show the sedimentary origin of the enclosing gneiss. There are some gneisses which originally contained only a small percentage of calcic material. On Foliot Farm there is a massive diopsidic rock which displays, in part, an injection banding and in which some of the pyroxene forms coarse aggregates with individual crystals up to two inches in length. Just north of the area mapped diopside crystals were seen measuring as much as eight inches in length. In the main, the rocks are compact and granular and have generally resisted migmatization. Banding in most cases is due to compositional variations though on occasion some permeation has taken place.

The rocks exhibit a wide variety of colours which include speckled, dirty-white, pale-green, mottled brown weathering to a dark chocolate-brown, and all shades of grey up to a dark grey.

At a point 3.75 miles south-west of where the Chirundu road leaves the northern edge of the map is a small rocky kopje strewn with boulders. Banding of these rocks cannot be seen *in situ*, but compositional variations in the original mass is exhibited by the variation in the mineral assemblages seen in different boulders. Elsewhere some compositional variations were seen *in situ*. A white, partly silicified marble, flecked with green, overlies a dark grey to blackish fine-grained calc-silicate rock at a point 1.75 miles north of where the Naodsa River leaves the western edge of the map. The dark rock has given rise to rounded boulders which are strewn on the slope of the hill. Similar gradations were seen elsewhere.

Some of the calc-silicate rocks are so highly silicious that they are virtually quartzites. The mafic constituent in many cases is diopside which is inconspicuous when fresh. However, the presence of only a little pyroxene in the rock results in quite a deep reddish soil. One such quartzite occurs as a ridge striking north-east from Kasiga River a little over a mile west of where it leaves the edge of the map. It is overlain by a pale calc-silicate rock which grades upward into a dark grey amphibolite. Some of these amphibole-rich rocks are almost identical with epidiorites.

#### *Petrography*

The minerals present form an impressive list. One mineral or another may predominate locally depending on the original composition, while others are always accessory. This list includes diopside, tremolite, acti-



nolite, hornblende, plagioclase which varies in composition from albite-oligoclase to bytownite-anorthite, quartz, carbonates, garnets, epidote, scapolite, sphene, chlorites including antigorite, microcline, muscovite, biotite, magnetite, ilmenite, pyrite, pyrrhotite and apatite.

Any one of the following minerals may give rise to a virtually monomineralic rock: tremolite, actinolite, carbonate, diopside and epidote.

A number of specimens was collected from the rocky kopje 3.75 miles south-west of where the Chirundu road leaves the northern edge of the sheet. One of these is composed predominantly of epidote and due to the parallelism of the somewhat prismatic crystals, a weak foliation is apparent. A very little diopside is present and there are small lenticular concentrations of sphene with a little associated magnetite. Calcic plagioclase occurs in the slide (16259) and is interspersed with, and partly replaced by, epidote. The plagioclase is untwinned and the grains all extinguish simultaneously so that there is either a single poikiloblastic crystal or else the structure is pseudo-poikiloblastic, an effect produced by the preferred orientation of a number of individual grains. Pale-yellow irregular garnets of less than a millimetre in cross-section are scattered throughout the slide.

Another specimen from the same kopje is a garnet-plagioclase-hornfels in which the garnet constitutes a third of the rock. The plagioclase is bytownite-anorthite and both minerals have small inclusions of epidote, sphene, quartz and ilmenite.

In some of the garnet-rich specimens, individual crystals of this mineral attain half an inch in diameter and are of a deep red colour. The garnet from specimen 16260 has the composition  $\text{Gr}_{80}\text{An}_{30}\text{Al}_{10}$ . Another specimen (16261) collected from the same rock mass as the previous one has a slight compositional banding. In one band, hornblende and in the other, diopside is the predominant mafic constituent. Together they constitute about 50 per cent. of the rock. At least part of the amphibole is uraltic. The plagioclase is bytownite-anorthite. No quartz is present in thin section. A little sphene is scattered throughout.

Small, round boulders shed from a narrow calc-silicate band occur on the track to the Catkin Mine, half a mile south of the Lynx Mine. This rock has a similar mineralogical composition to that just described but the compositional variations found in the other rock-mass are absent here. Diopside forms large sieve-textured porphyroblasts and calcic plagioclase constitutes 30 per cent. of the rock. The hornblende, diopside and plagioclase are peppered with small granular sphene crystals. A little apatite and quartz are also included.

Specimens of calc-silicate hornfels on Foliot Farm are composed predominantly of diopside with individual crystals measuring as much as two inches in length. The associated plagioclase is andesine-labradorite and in addition there is a fair amount of scapolite. Some exposures have been injected by highly potassic granite and pegmatite veins. One narrow pegmatite band is composed of almost pure microcline.

A good exposure of calc-silicate rocks occurs on high ground 1.75 miles north-east of the Catkin Mine. An actinolite-schist containing

much sagenitic iron ore grades into a somewhat massive rock composed of actinolite, diopside, andesine and garnet with much magnetite (Slide 16386). The garnet is clearly of reaction origin formed at the expense of both the amphibole and the plagioclase. Where the two minerals are in contact, the garnet occurs as irregular to hypidiomorphic, corona-like selvages separating them (Figure 5). This reaction has thrown out excess iron, derived from the actinolite molecule, as magnetite which frequently forms vermicular structures in the garnet. Coalescence of this magnetite produces irregular masses of the mineral, but in one instance a crystal was seen idiomorphic towards the garnet.

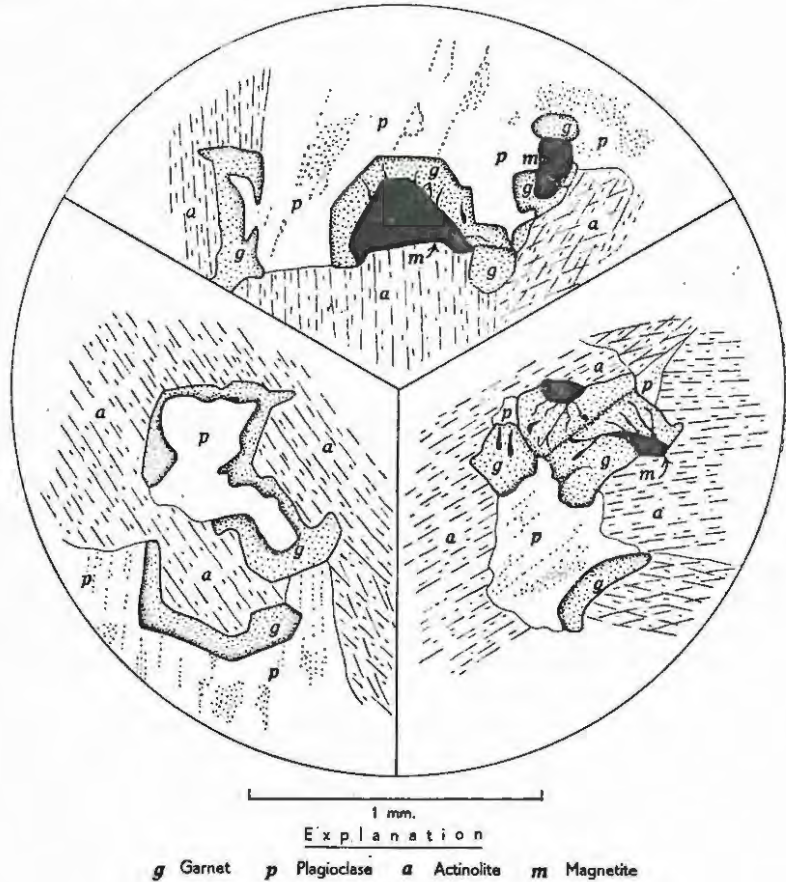


Fig.5. Reaction garnet in calc-silicate rock

(Slide 16386)

The garnet is unsuitable for specific gravity determination because of the numerous specks of magnetite included in even the smallest grains. The refractive index is 1.79 which is the same as that of the garnet mentioned earlier and, therefore, it seems reasonable to assume that this garnet, too, is largely grossularite. Finally there is the body of calc-silicate rock near the western edge of the sheet, 1.75 miles north of the Naodsa River which has some points of interest not seen in the

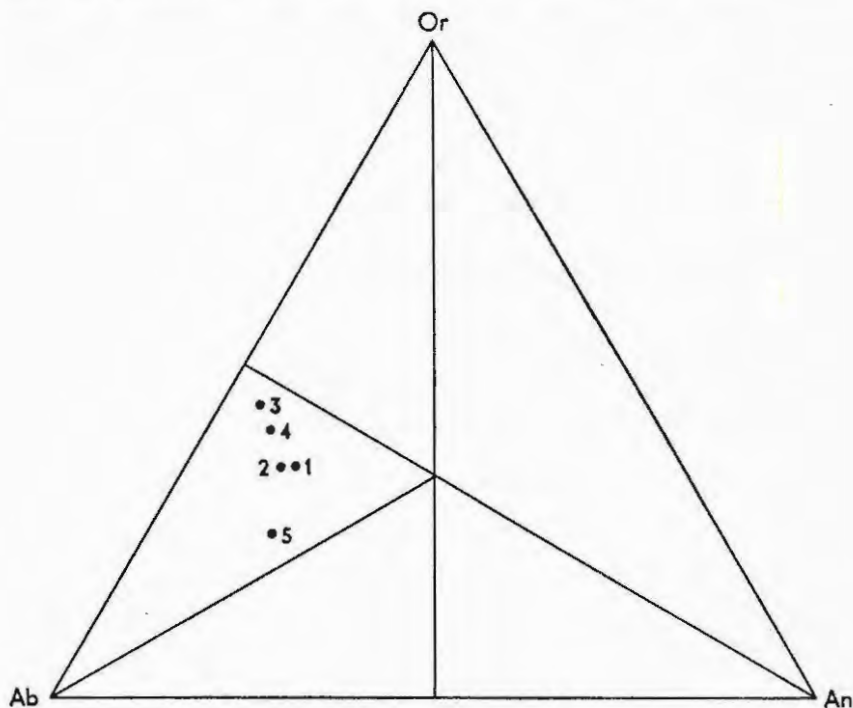
other exposures. Here there is a diopsidic band rather similar to that in the rock described immediately above but instead of grading into an actinolite-schist it grades into an ophicalcite.

### GRANITES

Field relationships have led to the classification of the granites into four types which have been grouped under the two main headings Synkinematic and Late-kinematic.

The two synkinematic granites are of very distinctly different appearance. They occur in the same metamorphic environment and are clearly of granitization origin, but they have been derived from rocks of initially very different chemical compositions.

The late-kinematic granites are intrusive and comprise a gneissic biotite-granite, which is sometimes porphyroblastic, and occurs as stocks or bosses, and a muscovite-granite which occurs as a belt intrusive into the phyllites in the east and into the synkinematic granite in the



- |                            |                     |
|----------------------------|---------------------|
| 1. Granitic gneiss         | Analysis No. 60/4   |
| 2. Biotite-granite         | Analysis No. 60/6   |
| 3. Gneissic granite        | Analysis No. 60/5   |
| 4. Muscovite-granite       | Analysis No. 60/114 |
| 5. Porphyroblastic granite | Analysis No. 60/7   |

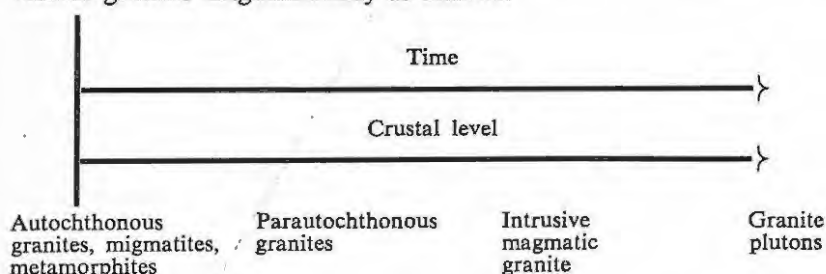
Fig.6. Triangular diagram to show composition of the granites



west. Petrographic studies reveal a genetic relationship between the late-kinematic granites and the gneissic granite derived from the pelitic sediments. This correlation is also to some extent borne out by the analyses given in the Table on page 68 but it is even more clearly seen in Figure 6 where all five rock types have felspar compositions which plot in the soda-granite field, but form three distinct groups. Thus the two late-kinematic granites are conceivably mobilized products of a granitization granite. The difference between the two intrusive granites is due to the different degrees of metasomatism which the parent rock type underwent prior to mobilization. This is not inconsistent with the description given under these group headings by Vladi Marmo (21) in his classification of the Precambrian granites.

Two granitic episodes have taken place. The earlier mainly sodic episode was followed by a later one as a result of additions of potash. This potash mobilized some of the earlier formed granite in which much replacement of plagioclase had occurred. This period of potash metasomatism also gave rise to some highly potassic granitic dykes.

The synkinematic granites have been described variously in recent publications as para-granites, diffuse granitization granites and autochthonous granites. Read (22, p. 410) illustrates the relationship of the various granites diagrammatically as follows:



These various granites make up his "Granite Series".

#### SYNKINEMATIC GRANITES

##### THE GNEISSIC GRANITE

In the field this rock can be seen to grade into the granitic para-gneiss and it is no easy matter to decide where to draw the geological boundary separating them. In tracing the gneiss to the south it is found to become more homogeneous in appearance and streaky rather than banded.

The granite of this type is often coarse grained to almost pegmatitic in part. Much is also relatively fine grained, but where sectioned, this was found to be due to crushing.

Good exposures in the form of large boulders and dome-like masses occur in the more broken country on Peveril Place Farm, but in the flatter country farther to the east the exposures are poor.

In the gneiss there is often much that could be called granite and vice versa, a state of affairs only to be expected in these metasomatically derived rocks.

### *Lithology and Distribution*

This granite occupies an area of some 90 square miles towards the south-western portion of the map. The necessarily arbitrarily drawn boundary between granite and parent granitic gneiss is an irregular one but the granite has a regular western contact with the porphyroblastic granite. This western contact meets the southern edge of the map at a point 11.75 miles east of the south-western corner. Owing to lack of exposures the eastern boundary of this granite with the intrusive granite is obscure.

Chisumba Hill, on which is situated a beacon forming the meeting point of the boundary lines between Crown land to the north, European farm land to the east and native reserve to the west, occurs near the northerly tip of the granite mass. Here, as elsewhere in areas of good exposure, there are bands of relict gneiss some of which are calc-silicate "resisters". Plastic flow or local mobilization of the para-granite causes some of this relict material to assume the appearance of xenoliths.

Irregularly distributed porphyroblasts occur along occasional coarse bands in this predominantly gneissic granite. Some of the larger relict areas of gneiss are distinctly migmatitic.

In the vicinity of the drift over the Siwa River, which latter forms the boundary between Lancaster and Derepat farms in the south-central area of the map, the mixing of this granite with the intrusive granite is clearly in evidence, and both are cut by pegmatite veins.

### *Petrography*

Microscopic evidence, as well as the chemical analyses and calculations, indicate a clear relationship between this gneissic granite and the two late-kinematic intrusive granites.

Analysis No. 60/4 is of a sample represented by specimen 16255 which is a granitic-gneiss occurring in the middle of Nyamabidzi Farm on the indicated geological boundary between the granitic gneiss and the gneissic granite. Since the boundary is gradational this analysis is also indicative of the composition of the gneissic granite at this point. It will be seen, too, that there is a very close similarity in composition between this gneiss and the intrusive biotite-granite from the Grand Parade Mine area given in analysis No. 60/6.

A specimen of this gneissic granite from Naba Estate (16262) was collected from a point about 0.75 miles north of Naba trigonometrical beacon. This is 5.25 miles east-south-east of the locality of the specimen 16255 of granitic gneiss mentioned above and very near the contact with the intrusive muscovite-granite. The analysis of this granite is No. 60/5. It will be remembered that potash metasomatism was active as a late transforming factor in the granitic gneiss and gneissic granites and it is not surprising, therefore, to find an increase in the percentage of potash in a direction away from the main mass of gneiss and near the muscovite-granite of somewhat similar composition (Analysis No. 60/114). It is, therefore, presumed that the gneissic granite, on mobilization, was able to give rise to two types of intrusive granite which are related to the degree of metasomatic alteration of the parent material.

The gneissic granite is petrographically similar to the granitic paragneiss. The most interesting feature in this granite is the replacement relationship between the two feldspars, with myrmekite as a frequent associate. In some specimens the plagioclase, oligoclase, is more abundant than in others. Where plagioclase is abundant the microcline is present in the form of porphyroblasts and its replacing nature is in no doubt. Some of the potash feldspar is perthitic. In the large microcline crystals, which are nearly always fresh, plagioclase occurs in ragged relict form, or as ghostlike turbid patches. The inclusions of plagioclase have clear rims in contact with the microcline.

On the roadside near the boundary between Derepat and Pa Denga farms is a small exposure of a spotted, somewhat massive granite having a dirty white to fawn colour. Thin section 16263 shows it is clearly a variant of the gneissic grey granite and provides a rather excellent example of replacement of plagioclase by microcline. The small amount of mafic material which causes the spots consists of aggregates of biotite. This rock was originally a xenomorphic-granular mass of plagioclase and quartz with the former predominant and of larger grain size. The rock is now highly potassic and has a most interesting association of feldspars. It differs from the porphyroblastic or microporphyroblastic types, in which the microcline is formed by both replacement and accretion, in that the microcline tends to form almost perfect pseudomorphs. In almost every microcline crystal the original plagioclase forms partial rims, ghost patches or irregular wisps which reveal that the form of the earlier plagioclase is unchanged. No myrmekite occurs in the slide and it is apparent that appreciable soda, as well as some lime and alumina, must have been liberated by this replacement. This small granite mass is presumably mobilized gneissic granite.

Biotite in varying but small amount is present in all the granite. Hornblende is present only where granitization of mafic rocks has taken place and where the effects of the later potash metasomatism have not been appreciable.

#### THE PORPHYROBLASTIC GRANITE

Just as the grey gneissic granite can be traced back to its origin from pelitic sediments, so can this one be traced back to its basic origin through biotite-gneiss to amphibolite. The analysis (60/7) shows a slightly higher lime content than the other granites which is reflected in a higher anorthite content in its norm. Both these synkinematic granites are, therefore, truly of metasomatic origin.

#### *Lithology and Distribution*

This granite occupies an area of some 35 square miles and forms a tongue-like protuberance with its roots near the south-west corner of the map and extending from the native reserve in a north-east direction across parts of the farms Sandra, Oribi Park, Marshlands and Pompey.

Starting off in the biotite-gneiss and advancing toward the porphyroblastic granite there is a clear gradational change. With advancing granitization the rocks generally become paler in colour as the quantity



of biotite diminishes. At first there are large scattered felspar porphyroblasts which become more numerous as granitization proceeds. Their rectangular outline and marked parallel arrangement are initially a characteristic feature (Plate VI). Mobilization tends to eliminate the directional properties so that eventually the rock takes on the appearance of a porphyritic granite, but with rather more biotite than the other granites.

It is a medium-grey rock with a coarse, though not altogether uniform texture, owing to the irregular size and distribution of the microcline porphyroblasts. These reveal a simple twinning in hand specimen and occur as hypidiomorphic laths which are frequently more than an inch in length, occasionally two inches or more. Concentrations of biotite with muscovite form lenticles of an inch or more in length in some of the coarser exposures. For analytical purposes, and for the determination of the volume composition, one of the finer-grained specimens was selected (Analysis No. 60/7).

Some small dyke-like masses of grey gneissic granite occur intrusive into the biotite-gneisses and the porphyroblastic granite.

#### *Petrography*

The large microcline porphyroblasts have a microperthitic structure and like the microcline in the gneissic granite show marked evidence of having replaced the plagioclase. The plagioclase sometimes remains as irregular relics and turbid patches which merge with the clear surrounding potash felspar. Some myrmekite is also present.

In the matrix of the rock a medium oligoclase predominates. Crushing of the groundmass is much in evidence and the larger plagioclase crystals, which are of the order of three millimetres in length, have a rather augen-like appearance with bent twin lamellae and strain shadows. The plagioclase is frequently full of inclusions of muscovite which sometimes forms quite large irregular plates. Muscovite also occurs partly surrounding some of the plagioclase, as concentrations in quartz and in association with biotite. Quartz occurs as blobs and lenticular concentrations with sub-parallel arrangement giving a rather gneissic appearance in thin section, but this is not really apparent in hand specimen. The biotite, too, occurs in sub-parallel streaks which tend to curve round some of the larger plagioclases. With some of the biotite there is a little sphene.

It would appear that the main crushing took place before the growth of the microcline porphyroblasts since fragments of plagioclase and quartz often occur partly replaced and surrounded by microcline. The potash felspar shows some fracturing but it is not as severe as that exhibited by the plagioclase. Carbonate occurs as a fracture-filling in places.

Complex metasomatic replacements have taken place to produce this final granite phase from an amphibolite. The collection of a great many specimens over a wide area would have been necessary to follow step by step all the changes which have occurred, but it is clear that additions of silica, soda, potash and water were made and that these

caused the elimination of much iron, magnesia and lime. Some of the changes which resulted in the conversion of amphibolite to biotite-gneiss were discussed in an earlier section. It is thought that the abundance of muscovite is due largely to the excess of alumina released from the plagioclase by metasomatism. Elimination of much of the earlier formed biotite would also make additional potash available in the rock.

#### LATE-KINEMATIC (INTRUSIVE) GRANITES

In addition to the large-scale granitization which has operated to produce the granites and gneisses already discussed, there were superimposed local effects around the small masses of intrusive granite in the schists and gneisses. These plugs were rich in volatiles as is evidenced by the abundance of pegmatite which has given rise to many beryl and mica mines in the surrounding country.

The extent of this local granitization was dependent on the metamorphic grade of the country rock and the attitude and physical characteristics of the granite. Some granite, and this seems to apply only to the smaller intrusions, arrived on the scene somewhat chemically impotent; conceivably as a low temperature, extensively crystallized mush. The pegmatites themselves can sometimes be observed to have caused quite local granitization beyond their terminations. This is discussed in a later section on pegmatites.

It will be recalled that in the description of the kyanite-staurolite zone mention was made of the metasomatic conversion of kyanite to albite-oligoclase on the margin of a granite boss. This late-kinematic granite, which is exposed nine miles north-east of Miami, is the same as that at the Grand Parade Mine of which an analysis (No. 60/6) appears on page 69. It is interesting to note that a granite which carries an equal percentage of soda and potash produces effects attributable to a soda metasomatism along its margins. This illustrates once again that soda has a greater mobility than potash.

#### THE BIOTITE-GRANITE

##### *Lithology and Distribution*

This is a gneissic granite which contains only a very small percentage of muscovite and is in places porphyroblastic. It occurs as a number of bosses of small areal extent which give rise to the pegmatites constituting the ore-bodies of the main mica and beryl mining areas. These intrusions are concentrated mainly in the zone of sillimanite-gneiss. Owing to local granitization effects, contacts are often rather diffuse but wherever they can be observed, the schists and gneisses dip steeply away from the granite. This is most noticeable in the granite intrusive into sillimanite-schist, two miles east of the Grand Parade Mine and in another of similar size and form, 7.25 miles north-east of the same mine.

It will be noted that a number of these intrusions are ovoid in form with their longer axes parallel to the strike of the schist formations. There is a mass of tourmaline-bearing pegmatite and included gneiss

on Ruwanzi Ranch which has this form and association. Numerous beryl-bearing pegmatites occur peripherally. The conclusion is drawn that this pegmatite mass represents the cupola of an unexposed granite boss. The intrusion of this mass has caused a big swing in the trend of the foliation of the country rock. Unexposed granite is also suggested at shallow depth by the occurrence of beryl-bearing pegmatites several miles away to the south and south-east. In his unpublished report on the geology of portion of the Lomagundi Mica Fields, R. Tyndale-Biscoe (1943) states that "the impression is gained that the granite underlies the whole area with a highly irregular surface of protrusions and hollows, and that these exposed granite masses represent some of the protrusions".

Numerous, narrow, tourmaline-bearing pegmatite veins cut the granite north-north-west of the Grand Parade Mine. West of both the Grand Parade and Akata mines are exposures of the porphyroblastic phase of this granite.

### *Petrography*

The analyses already referred to show a very close similarity between the clearly intrusive biotite-granite here considered and the granitic gneiss. Certain petrographic similarities between the biotite-granite and the gneissic granite, which latter is derived from the granitic gneiss, also emerge. While the C.I.P.W. symbol classes both these granites, and the muscovite-granite, as dosodic, a glance at Figure 5 will reveal that they are not far removed from being sodipotassic.

Whereas the microcline in the gneissic granite is of replacement origin, it has the appearance of an original constituent in the normal biotite-granite. In the porphyroblastic phase of the biotite-granite, however, which is of small extent, the large microcline crystals were formed after the main mass of the rock had crystallized and are presumably of deuteric origin.

Thin section 16264, was prepared from a specimen collected 600 yards north-west of the Grand Parade Mine. Its chemical and volume compositions are given in the Table of Analyses. The calculated mesonorms of this and the other granites agree well with their determined volume compositions. There is in places a little evidence of microcline replacing plagioclase as well as myrmekite replacing the microcline. It is conceivable that this state of affairs was inherited from the parent gneiss and was preserved in the mobilized product. On the other hand, late potash activity has been operative in some parts of this granite. The microcline is clear, with xenomorphic granular to interstitial texture. The oligoclase is often inconspicuously twinned and is only patchily turbid. Owing to the gneissic character some thin sections are richer in biotite than others and for the volume determination a section was cut normal to the banding. Muscovite is intergrown or associated with the biotite and there is a little apatite.

A porphyroblastic variant of this granite was collected at a point 1,000 yards west of the Grand Parade Mine where there are very good exposures. As is usual, simple twinning can be seen in the large micro-



cline crystals in hand specimen. In thin section (16265) the microcline porphyroblasts reveal inclusions of all the mineral constituents of the rock, including the earlier formed microcline. One of these larger microcline crystals has, at one point, a little marginal myrmekite.

#### THE MUSCOVITE-GRANITE

##### *Lithology and Distribution*

This is, for the most part, a fine-grained pale-grey, massive granite which weathers white. A local coarse-grained phase is found in the proximity of pegmatite intrusions. Muscovite is often quite strongly in evidence and is most conspicuous in the weathered and coarser rocks. Biotite is present but is subordinate to muscovite, whereas in the other granites and para-gneiss the reverse is the case.

The granite occupies a narrow south-striking belt some six miles in width and 11.5 miles in length due south of Karoi Township. It outcrops about half a mile south of Karoi at its most northern extremity, where it is in contact with sillimanite-gneiss. On the west it is intrusive into granitic gneiss and gneissic granite, whereas on the east it has invaded the garnetiferous schist and the phyllite.

A feature of this granite is the abundance of inclusions of schist, gneiss and gneissic granite.

The contact between the muscovite-granite and the gneissic granite is rarely exposed so that the line which has been drawn between the two is largely conjectural. A mixture of the two granites can be seen on Derepat Farm near the drift over the Siwa River. The gneissic granite is clearly invaded by the massive granite and the former is also cut by a discordant pegmatite.

Some minor granite intrusions which occur in the gneiss are described in this section.

##### *Petrography*

The chemical analysis and volume composition of a specimen of this granite shows its affiliation to the more potassic variant of the gneissic granite. However, specimens collected over a wide area reveal quite a variation in the percentage of the two feldspars as is only to be expected since such changes also occur in the gneissic synkinematic parent rock.

An impression gained from a study of some sections of this granite was that it was intruded as a mass containing a high percentage of already crystalline plagioclase and biotite. A specimen (16266) collected near the north-east corner of Pa Denga Farm revealed that here the rock is composed predominantly of plagioclase. This feldspar has a vaguely rolled appearance and some crystals show fracturing or bending of twin lamellae. There is little more than a trace of interstitial micro-

cline and the quartz, which constitutes some 10-20 per cent. of the rock, is partly interstitial and partly aggregated. There is more muscovite than biotite, and a single small irregular garnet is present. A feature of all the granites is the presence in the feldspars of small round quartz grains, which are corroded remnants included during their earlier porphyroblastic development.

Another specimen which contains a large percentage of microcline was collected a mile north of the last-mentioned occurrence. This exposure is on the boundary between Derepat and Runnimeede farms about a quarter of a mile north of the south-west corner beacon of the latter. The composition of the rock appears in the Table of Analyses as No. 6/114. The largest crystal in the slide is a roughly oblong oligoclase 4.5 millimetres long, containing a few inclusions of rounded quartz grains as well as some muscovite, epidote and carbonate. With the exception of the quartz, the inclusions are of secondary origin. The mica, which has formed from sericite, is somewhat concentrated towards the outer edges of the crystal, while fine granular epidote with some carbonate occurs along certain twin lamellae towards the middle of the crystal. This indicates an originally, more calcic, central portion. The plagioclase shows a little marginal replacement by microcline. The other plagioclase crystals are similar but do not give any indication of zoning or crystal outline. The clear microcline has formed both by replacement and interstitial crystallization. The muscovite is again more abundant than the biotite. Some flakes are bent and others form sieve-textured plates up to 0.7 millimetres in length. This mica is pleochroic from pale yellow to colourless and is an alumina deficient variety. From optical data the following composition was calculated: Phengite, 55 per cent.; Muscovite, 36 per cent.; Fe<sup>+++</sup>-Muscovite, 9 per cent. The quartz occurs as stained interlocking aggregates.

This granite, as well as the biotite-granite, has been intruded following metasomatic additions of potash to a once predominantly plagioclase-rich para-gneiss.

The minor intrusions of granite which occur cutting the para-gneisses have very variable compositions, even in the same locality.

A road quarry near the Makore trigonometrical beacon has opened up a mass of grey, diopsidic calc-silicate rock which is traversed by an irregular branching, granite dyke. The granite is plagioclase-rich with much quartz, only a small amount of microcline and a little myrmekite. Some granulation is apparent in the slide (16267) and the plagioclase lamellae are often bent. A pegmatite in the same quarry is composed almost entirely of microcline and quartz.

An exposure of porphyroblastic granitic gneiss, 500 yards west of the quarry, is cut by a narrow granite dyke which is composed of microcline and quartz with much myrmekite. The small amount of turbid plagioclase is relict and exhibits clear rims in contact with the microcline (Slide 16268).

# TABLE OF ANALYSES

## CHEMICAL ANALYSES

| <i>Specimen No.</i>            | 16255  | 16264  | 16262  | 16269  | 16270 |
|--------------------------------|--------|--------|--------|--------|-------|
| <i>Analysis No.</i>            | 60/4   | 60/6   | 60/5   | 60/114 | 60/7  |
| SiO <sub>2</sub>               | 71.47  | 72.90  | 75.54  | 74.41  | 72.09 |
| Al <sub>2</sub> O <sub>3</sub> | 14.48  | 14.56  | 11.86  | 13.54  | 15.65 |
| Fe <sub>2</sub> O <sub>3</sub> | 0.84   | 0.49   | 1.47   | 0.47   | 0.46  |
| FeO                            | 2.08   | 1.98   | 1.65   | 1.31   | 1.67  |
| MgO                            | 0.79   | 0.54   | 0.30   | 0.29   | 0.11  |
| CaO                            | 1.93   | 1.67   | 0.76   | 1.32   | 2.11  |
| Na <sub>2</sub> O              | 3.70   | 3.70   | 3.60   | 3.81   | 4.33  |
| K <sub>2</sub> O               | 3.50   | 3.60   | 4.40   | 4.33   | 2.60  |
| TiO <sub>2</sub>               | 0.41   | 0.36   | 0.32   | 0.21   | 0.29  |
| MnO                            | 0.04   | 0.03   | 0.03   | 0.03   | 0.02  |
| P <sub>2</sub> O <sub>5</sub>  | 0.13   | 0.17   | 0.05   | 0.08   | 0.07  |
| H <sub>2</sub> O —             | 0.05   | 0.10   | 0.02   | 0.10   | 0.04  |
| H <sub>2</sub> O +             | 0.63   | 0.44   | 0.21   | 0.17   | 0.41  |
| TOTAL                          | 100.05 | 100.54 | 100.21 | 100.07 | 99.85 |
| SPECIFIC GRAVITY               | 2.673  | 2.644  | 2.655  | 2.650  | 2.677 |

Analyst: A. J. Radford

## NIGGLI MOLECULAR NORMS

| <i>Specimen No.</i> | 16255  | 16264  | 16262  | 16269  | 16270  |
|---------------------|--------|--------|--------|--------|--------|
| <i>Analysis No.</i> | 60/4   | 60/6   | 60/5   | 60/114 | 60/7   |
| Corundum            | 1.59   | 2.77   | —      | —      | 2.39   |
| Orthoclase          | 20.80  | 21.20  | 26.55  | 25.80  | 15.75  |
| Albite              | 33.70  | 33.50  | 32.75  | 35.35  | 41.30  |
| Anorthite           | 8.65   | 6.50   | 3.37   | 5.90   | 9.75   |
| Quartz              | 27.99  | 30.63  | 33.06  | 29.25  | 27.43  |
| Apatite             | 0.29   | 0.59   | 0.10   | 0.29   | 0.29   |
| Ilmenite            | 0.56   | 0.56   | 0.44   | 0.34   | 0.44   |
| Magnetite           | 0.84   | 0.67   | 1.53   | 0.51   | 0.51   |
| Wollastonite        | —      | —      | 0.12   | 0.32   | 0.34   |
| Enstatite           | 2.20   | 1.56   | 0.90   | 0.78   | 0.34   |
| Ferrosilite         | 3.38   | 2.02   | 1.18   | 1.46   | 1.80   |
| TOTALS              | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 |



## NIGGLI VALUES\*

| Specimen No. . . | 16255  | 16264  | 16262  | 16269  | 16270  |
|------------------|--------|--------|--------|--------|--------|
| Analysis No. . . | 60/4   | 60/6   | 60/5   | 60/114 | 60/7   |
| si . . . . .     | 346.00 | 376.10 | 451.00 | 454.10 | 430.40 |
| al . . . . .     | 41.28  | 45.20  | 41.01  | 47.61  | 41.94  |
| fm . . . . .     | 20.34  | 15.17  | 17.71  | 9.52   | 9.32   |
| c . . . . .      | 10.17  | 9.29   | 4.07   | 9.89   | 13.62  |
| alk . . . . .    | 28.19  | 30.34  | 30.52  | 32.96  | 35.13  |
| k . . . . .      | 0.38   | 0.39   | 0.45   | 0.42   | 0.29   |
| mg . . . . .     | 0.28   | 0.29   | 0.16   | 0.27   | 0.11   |
| qz . . . . .     | 133.15 | 154.74 | 299.32 | 222.30 | 208.32 |

\* The gneiss (16255) approaches the composition of a soda rapakivitic magma type.

The granites are not far removed from normal alkali-granite magma types.

## MESONORMS

| Specimen No. . . | 16255  | 16264  | 16262  | 16269  | 16270  |
|------------------|--------|--------|--------|--------|--------|
| Analysis No. . . | 60/4   | 60/6   | 60/5   | 60/114 | 60/7   |
| Corundum . . .   | 0.83   | 2.17   | —      | —      | —      |
| Muscovite . . .  | 4.20   | 2.10   | 1.20   | —      | 8.33   |
| Microcline . . . | 12.35  | 16.70  | 23.60  | 23.65  | 8.00   |
| Albite . . .     | 33.70  | 33.50  | 32.75  | 35.35  | 39.30  |
| Anorthite . . .  | 7.55   | 6.50   | 2.50   | 5.90   | 9.75   |
| Quartz . . .     | 30.88  | 32.42  | 34.29  | 30.37  | 30.51  |
| Biotite . . .    | 8.17   | 4.79   | 3.36   | 3.44   | 2.87   |
| Apatite . . .    | 0.29   | 0.59   | 0.11   | 0.29   | 0.29   |
| Sphene . . .     | 0.84   | —      | 0.66   | 0.49   | —      |
| Magnetite . . .  | 0.84   | 0.67   | 1.53   | 0.51   | 0.51   |
| Ilmenite . . .   | —      | 0.56   | —      | —      | 0.44   |
| TOTALS . . .     | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 |

## VOLUME COMPOSITIONS

| Slide No. . .    | 16255 | 16264 | 16262 | 16269  | 16270 |
|------------------|-------|-------|-------|--------|-------|
| Analysis No. . . | 60/4  | 60/6  | 60/5  | 60/114 | 60/7  |
| Muscovite . . .  | 4.2   | 1.4   | 1.0   | 6.5    | 5.7   |
| Microcline . . . | 12.5  | 16.8  | 25.0  | 23.9   | 8.3   |
| Oligoclase . . . | 41.3  | 42.9  | 32.5  | 33.2   | 48.2  |
| Quartz . . .     | 31.7  | 32.3  | 36.5  | 31.8   | 30.5  |
| Biotite . . .    | 9.2   | 6.4   | 3.3   | 4.4    | 7.3   |
| Apatite . . .    | 0.3   | 0.2   | —     | —      | —     |
| Sphene . . .     | 0.2   | —     | 0.7   | 0.2    | —     |
| Magnetite . . .  | 0.3   | —     | 1.0   | —      | —     |
| Garnet . . .     | 0.3   | —     | —     | —      | —     |
| TOTALS . . .     | 100.0 | 100.0 | 100.0 | 100.0  | 100.0 |

| <i>Specimen No.</i> | 16255 | 16264  | 16262 | 16269  | 16270 |
|---------------------|-------|--------|-------|--------|-------|
| <i>Analysis No.</i> | 60/4  | 60/6   | 60/5  | 60/114 | 60/7  |
| Corundum . . .      | 1.33  | 1.53   | —     | —      | 2.12  |
| Orthoclase . . .    | 20.50 | 21.13  | 26.13 | 25.58  | 15.57 |
| Albite . . . . .    | 31.44 | 31.44  | 30.39 | 33.01  | 36.68 |
| Anorthite . . . .   | 8.90  | 7.51   | 3.34  | 5.84   | 9.73  |
| Quartz . . . . .    | 29.70 | 32.46  | 35.16 | 31.62  | 31.50 |
| Apatite . . . . .   | 0.34  | 0.68   | 0.14  | 0.34   | 0.34  |
| Magnetite . . . .   | 1.16  | 0.83   | 1.89  | 0.70   | 0.70  |
| Ilmenite . . . . .  | 0.40  | 0.76   | 0.16  | 0.46   | 0.61  |
| Diopside . . . . .  | —     | —      | 0.33  | 0.71   | —     |
| Hypersthene . . .   | 5.96  | 3.78   | 1.99  | 2.05   | 2.15  |
| TOTALS . . . . .    | 99.71 | 100.12 | 99.98 | 100.31 | 99.41 |

\* These all have the same symbol I.4.2.4. Lassenose and plot as soda granites (see Fig. 5).

## SHAND SYMBOLS

Symbols "XOp $\beta$ L" apply to specimen Nos. 16255, 16264 and 16270.

Symbols "XOm $\beta$ L" apply to specimen Nos. 16262 and 16269, but both are very nearly peraluminous.

## Locality:

- 16255 — Granitic gneiss. From the centre of Nyamabidzi Farm.
- 16264 — Biotite-granite. 600 yards north-north-west of the Grand Parade Mine.
- 16262 — Gneissic granite. Naba Estate, 0.75 miles north of Naba trigonometrical beacon.
- 16269 — Muscovite-granite. On Derepat and Runnimede farm boundary, 0.25 miles north of south-west corner beacon of Runnimede.
- 16270 — Porphyroblastic granite. Pompey Farm, 600 yards north-east of home-stead.

## PEGMATITES

This subject embraces more fascinating and controversial genetic aspects than any so far discussed in this bulletin. It is included at this point since it forms the culmination of all the metamorphic processes described.

Pegmatites in general vary greatly in structure and mineral assemblage depending on the type of granite from which they have been derived. They are a source of a great variety of minerals which, because of their mode of crystallization, frequently reach large proportions.

The types which occur are mica- and beryl-bearing pegmatites which differ appreciably in mineralogy and structure from the lithium- and tantalum-bearing pegmatites intrusive into gold-belt rocks and their adjacent granites.

It is clear that the mica-bearing pegmatites, more than all others, must be interpreted in the light of the established "*Plutonic Series* (9, pp. 3-5), therefore if one is concerned with an explanation of the source material of the constituent minerals their study cannot be divorced from an investigation of the metamorphism.

A great deal has been written on pegmatites without much attention to their environment and, where the authors have had a magnetic bias, these pegmatites have been regarded simply as differentiates from intrusive magmas.

Richard H. Jahns (24) has provided an excellent summary of pegmatite investigations to date with a comprehensive bibliography. With regard to source and mode of emplacement all the various theories advanced can be classified under three main headings as follows: A. Aqueous theories; B. Igneous theories; C. Metamorphic theories.

As is often the case where multiple theories have been advanced relative to any investigation, it is found that the ultimate truth does not lie wholly with any one of them.

### *Distribution*

Mapping has revealed a close relationship between the granite plugs and many of the large economic pegmatites. A glance at the map will indicate the tendency for the mines to be clustered around these plugs. Where there is a concentration of pegmatites in the absence of any local granite it may confidently be assumed that granite occurs at no great depth beneath the surface.

The granite plugs occur in different metamorphic environments and in this connection an important observation can be made. While beryl-bearing pegmatites have a wide distribution the economic mica-bearing pegmatites are more restricted, and reveal, in so far as the mica is concerned, clear evidence of metamorphic control. There are, of course, exceptions but the mica mines tend to be confined to the amphibolite facies of regional metamorphism where sillimanite-bearing schists and gneisses have developed, or where sillimanite is relict in areas of more advanced metasomatism. These facts are illustrated on Plate



VII, and the question immediately arises as to what contribution, if any, the country rocks make to the formation of mica in certain pegmatites.

### *Origin of the Pegmatites*

In the early days of mica prospecting in the district the more experienced miners seemed to have been aware that there was some relationship between the nature of the country rock and the mica content of the pegmatites. The favourable country rocks were referred to by some as "kindly schists", and the intruded pegmatites, if rich in mica, were called "mellow".\* R. Tyndale-Biscoe (25) after mentioning Southern Rhodesia mica occurrences, notes that the mica-bearing pegmatites usually occur "cutting gneisses and schists which are themselves usually highly micaceous. Since this applies in general to mica-fields all over the world, it seems probable that the formation of large 'books' is in some way connected with the nature of the country rocks". Farther on, after raising the question as to why the concentrations of mica in pegmatites are not more uniform if the wall-rocks have contributed in part to their mica content, he states that "There is, at any rate, no escape from the almost universal association of pegmatites containing commercial mica with micaceous country rocks and this is too common to be fortuitous."

Cameron *et al.* (26) have also noted that "sheet-mica-bearing pegmatites have been cited as one example of a relationship between mineralogic types of pegmatite and the composition of the enclosing wall-rock". They mention the exceptions to this state of affairs and caution "that no sweeping generalizations are justified by present knowledge".

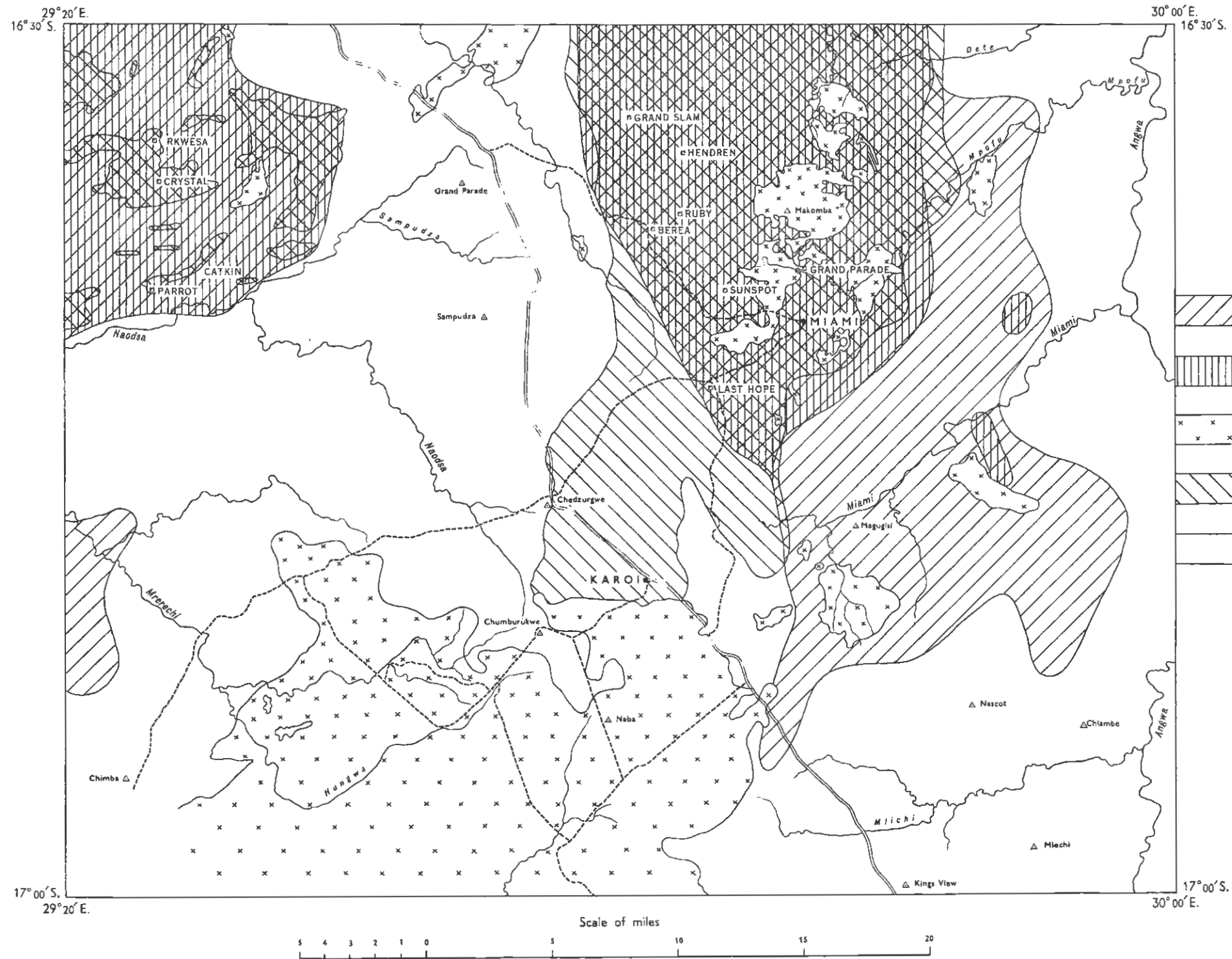
Hans Ramberg (17) found a relationship between the localization of pegmatites and regional metamorphism. He found, too (p. 188) that pegmatites, especially large ones, are relatively rare in the granulite facies but that in the amphibolite facies (or the high epidote-amphibolite-facies) the largest number, as well as the largest bodies, of pegmatite are to be found. In addition, he noted that muscovite is generally absent or rare in the granulite facies.

The present writer regards the uncertainties, expressed by some investigators as to whether contributions are made to pegmatites by the metamorphic country rocks, as being due to the concept that if material is incorporated, it must come from the actual rocks enclosing the pegmatite by a process akin to assimilation. This idea might naturally be held by those having a purely magmatic concept of pegmatite origin. Just as the early French concept of granitization was discredited for a while in favour of the magmatic postulates of the German school, so we may find, in the light of proved metasomatic transformations, a swing in the favour of one or other of the metamorphic theories.

By a process of differential pressure or squeezing, material may be secreted from the zone of active metasomatism and migrate to produce replacements elsewhere, or accumulated material may be forcibly in-

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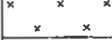
\*Mr. N. A. Tatham (personal communication).



MAP SHOWING THE METAMORPHIC  
CONTROL OF ECONOMIC MICA,  
MIAMI MICA FIELDS.

Geology by J.W. Wiles

Explanation

-  Beryl Areas
-  Mica Areas
-  Granite
-  Sillimanite-bearing rocks
-  Phyllites and granitic para-gneiss

jected into suitable structures. In addition, material capable of secretion may be drawn off by transient pegmatitic fluids from greater depths and thus added to the bulk composition of the injection. Later it may be segregated again in some rest position by differential crystallization. This dual source of material will be referred to again later in this section. It would appear that the metamorphic rocks can constitute at one point, namely within the granitic gneisses or granulites, a zone of abstraction from which material can move to another point, in the sillimanite zone, which we can call the zone of shear, fracture or emplacement. This latter zone can also yield by plastic flow or rheid deformation to smaller stresses of long duration. In addition this is the zone of local physical incorporation and possible assimilation.

The type of structure will determine how much material is enclosed as xenoliths but the character of the pegmatite will determine the extent of assimilation. Inclusions are usually larger and more abundant in concordant pegmatites. The size of the pegmatite and the environment in which it is emplaced will largely determine its physical potential. From the extent and nature of the wall-rock alterations, as well as from the internal structure of the pegmatite, one can derive some idea of the physical state of the pegmatite on injection.

Concentrations of economic mica are frequently found around the larger inclusions in mica-bearing pegmatites and one may infer from this that the inclusion, especially when it is highly micaceous and coarsely recrystallized, is the source of this mica. However, it seems more likely that the chilling effect of the inclusion provided local nuclei around which the mica books developed from material which came in with the pegmatite. Of course one might point out that it is not the inclusion, derived more or less *in situ*, that makes the significant contribution to the pegmatite composition, but the material incorporated at much greater depths where palingenesis is more likely to be operative. This is approaching one of the metamorphic theories of pegmatite formation but the frequent absence of pegmatite "roots" would seem to militate against the concept of a locally large migrating mass of igneo-aqueous material capable of incorporating and transporting blocks of country rock. One can, however, conceive of some material being derived from the country rocks by a less spectacular process. Cheng (20) believes that just after their release from the parent magma the pegmatites will be at their highest temperature and thus chemically most active. At this point he assumes that they will be able to digest appreciable quantities of material from the invaded rock. The acceptance of this type of wall-rock contribution does not necessitate the adherence to any one theory of granite origin, as the magma might equally well be primary, or the end product of granitization.

The writer contends that many of the Miami pegmatites, but more especially the majority of mica-bearing ones, are composite bodies whose substance may be regarded as having been derived from two sources, the one igneous and the other metamorphic. The material derived from the former may contain varying quantities of assimilated country rock while the latter will be the material secreted from the extensively meta-



somatized gneisses. The latter is the main source of the economic mica. The term composite is used not only in connection with the two sources of material, but also in connection with the structure. It will be explained in a later section that the ideally zoned mica pegmatites are composed of two assemblages which on occasion formed separate pegmatites.

Wegmann and Kranck (see 27, p. 10) have interpreted some pegmatite dyke as parts of granitizing solutions that crystallized in open spaces in the rocks. As already mentioned, very many pegmatites in different parts of the world have been found to be isolated bodies of rock without traceable "roots". This would appear to be a strong argument in favour of their development by metamorphic processes but it is not infallible. Barth (see 24, p. 1065) as well as others have cited this "as evidence for nourishment by diffusion rather than by moving fluids"

In addition to the regular pegmatites which have so far been mentioned, there are pegmatites in the Miami area which have been formed by replacement. Some of these form large irregular masses and are a phase of the general permeation of the country rock by granitizing solutions. The development of pegmatite by continued porphyroblastic growth has received mention in the description of the sillimanite-gneisses. Jahns (24, p. 1065) draws attention to the fact that Barth, Ramberg and others have reported a similar state of affairs. The process is referred to as "Porphyroblastic, or concretionary growth at the expense of solid rock" and may result in augen and "certain larger masses of pegmatite that generally are fringed by concentrations of mafic minerals".

In furtherance of the contention that important contributions have been made to pegmatites by secretions from certain metamorphic zones, it will be necessary to review, to some extent, the processes which have operated in the metamorphic rocks. These have already been described in some detail (pp. 41-43, 48-55).

By virtue of their composition the pelitic sediments are very susceptible to metamorphic changes. In the lower grades of regional metamorphism the changes are, in a broad sense only, isochemical, but as metamorphism proceeds and the higher grades of the amphibolite facies are attained, both physical and metasomatic additions are made. It is possible to trace the evolutionary trend of a certain type of siliceous vein from the zone of quartz reefs to the zone of pegmatites. The observed mineral variations can be related to changes which have taken place in the country rocks. Such "reefs", if not derived wholly from the same source, contain some secretions or tapings from a local source. In other words, a series of dyke-like bodies has been found, often of quite large proportions, individuals of which were in phase with their surroundings at the time of their formation. Anomalous minerals in this type of fracture-filling are often clearly traceable to later metamorphic effects. What may have been a simple trend of mineral zoning related to metamorphic environment has, in places, been obscured by intrusions of granite and pegmatite.

From careful field observations it has become apparent that silica plays a vital role in the rock transformations which are initiated by metamorphic processes. With comparatively low metamorphism it would appear that silica can become the collector and vehicle for transportation of various elements which, in the form of silicates, play their part in porphyroblastic development.

The pelitic sediments with their hydrated minerals must be able to yield up a large quantity of water on metamorphism. It is suggested that, at about the mesograde of regional metamorphism, this water from the sediments, in the form of superheated steam, can form a solution of almost pure silica which is a highly mobile and chemically active interstitial fluid that operates through the pore-spaces in the rocks in a way similar to the residual liquor in a crystallizing magma. The chemical activity of this fluid would increase with increasing metamorphism.

In the low-grade metamorphic rocks where shearing and fracturing have taken place, quartz veins and reefs are ubiquitous. In depths below the activity of meteoric waters the pore-fluid referred to would be available as secretions to fill the fractures. From this simple case we can jump for a moment to the high metamorphic zones where there are available within the rocks more complex substances which would fill the tension fractures with pegmatite. A basic dyke (amphibolite) in the granitic para-gneiss which outcrops in the Catchiro River, north-east of the Catkin Mine, provides an example of this. The dyke which is 3 ft. wide developed, on shearing owing to its competence, a number of parallel tension joints which became filled with pegmatite in lenticular form (Fig. 7). The largest of these lenticles is 36 in. in

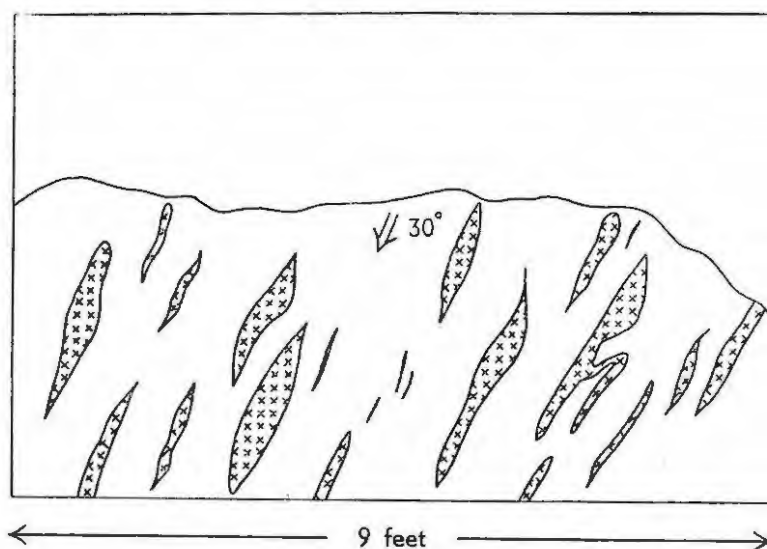
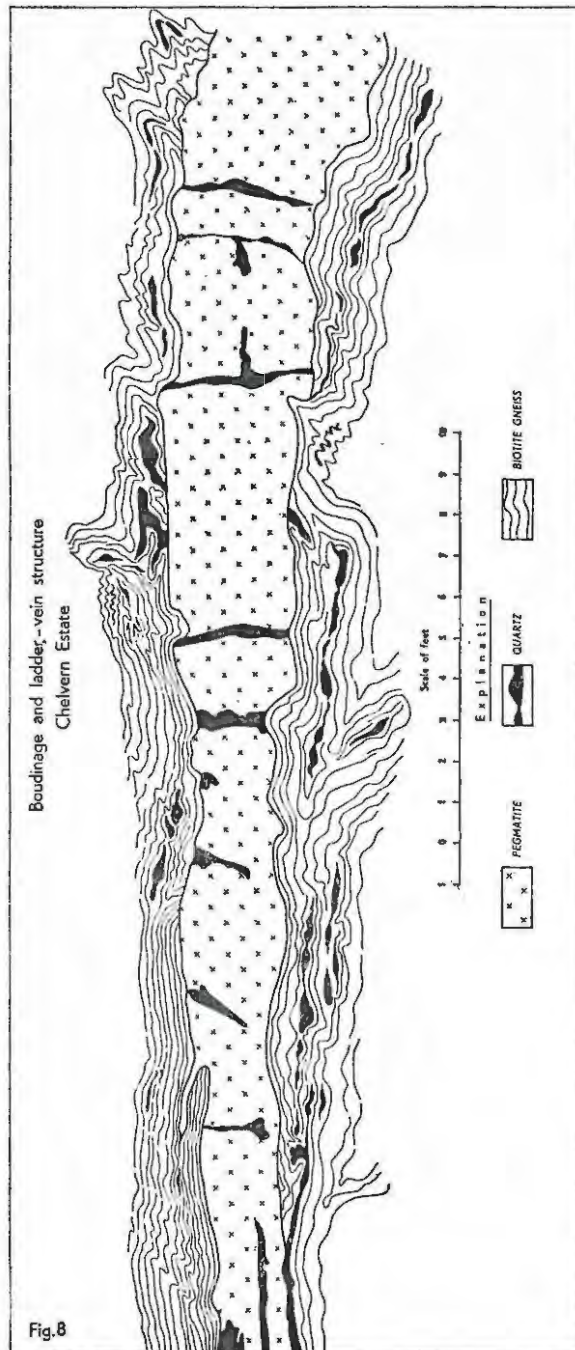


Fig.7. Lenticular pegmatite-filled tension fractures in amphibolite in the Catchiro river north-east of the Catkin Mine

length and 4 in. wide. The pegmatite is composed predominantly of quartz and albite with some hornblende and secondary biotite. These pegmatite-filled tension cracks make an angle of between 40 - 45 degrees with the direction of foliation of the rock. With falling temperature pegmatite again gives way to quartz as a fracture filling (Fig. 8). Of





course it would be difficult or impossible to tell with pure quartz filling whether the material was derived locally, from deep-seated hydrothermal solutions or from near surface. Some of the hydrothermal quartz veins can actually be traced back to pegmatites. The true secretions are, however, confined bodies without traceable connections with no obvious source of supply other than pore-spaces or sub-microscopic channels in the host rock.

In considering the siliceous pore-liquor once again, it seems reasonable to assume that as metamorphism proceeds and a higher energy level is reached, it will be capable of taking up various elements and transporting them, either to growing porphyroblasts or into fractures when these are present.

From the order of development of the common metamorphic minerals it would appear that iron and magnesium are among the first elements to be transported. Aluminium, too, would appear to be an element having a high degree of mobility. Lapadu-Hargues (see 27, p. 16) lists the ions as K, Ca, Na, Mg, Fe in order of increasing mobility.

Where large porphyroblastic index minerals appear in the schists they are often associated with quartz veinlets. Some large porphyroblasts are of course virtually aggregates of quartz and a silicate mineral. Staurolite, on account of its dark colour, revealed this most noticeably. Small staurolite crystals are idiomorphic and rather pure, but where physical conditions and the composition of the host rock were favourable some fine, granular quartz-staurolite aggregates were formed which measure as much as 9 x 5 inches. The weathered surfaces of these schists have large irregular lumps of quartz-staurolite aggregate standing out from the surface. Some large irregular garnets were also seen to be aggregates of both garnet and quartz. Concordant quartz veins in sillimanite-rich rocks have been observed having border concentrations of sillimanite. The *quartz sillimanitised* of Barrow (15) is another example of this association of quartz with a silicate mineral. In a coarsely micaceous schist of the amphibolite facies, books of mica which measured as much as five inches in cross-section were observed linked to tiny quartz veins. No pegmatite was anywhere apparent.

By a process akin to greisenization great masses of sillimanite-gneiss became converted to a coarsely crystalline rock composed predominantly of muscovite and quartz with biotite and a little tourmaline. Numerous quartz-muscovite veins traverse this rock type. They are very rich in mica and in the larger bodies the books measure many inches across. Many have been prospected and some have even yielded economic sheet mica. It is clear that this muscovite has been derived locally and that the veins are segregations from the rock. A pegmatite intruded into such a rock at the time of metamorphism would draw off this quartz and muscovite. Here there would be an actual physical addition of mica molecules to the pegmatite, but it is believed that in most segregations only the elements, or some of the elements, necessary to produce mica are added.

Not only is quartz intimately mixed with the index minerals of regional metamorphism but it also occurs similarly with the chialtolite and cordierite of the earlier thermal phase in this district.

These details of porphyroblastic development have been given as a prelude to the mention of similar associations, though in somewhat different proportions. Strong fracture fillings have in similar fashion derived most, if not all, of their substance from locally secreted material. In harmony with their environment quartz "reefs" carry the appropriate index mineral or minerals. These include the following types: quartz-chiastolite, quartz-kyanite (very coarsely bladed), quartz-sillimanite, quartz-garnet-sillimanite, quartz-kyanite-sillimanite, quartz-tremolite (with a little oligoclase) and quartz-muscovite. The chiastolite in the first-mentioned type was inverted to kyanite which latter formed perfect pseudomorphs. Some muscovite is usually present with the kyanite and sillimanite. It will be appreciated that reefs rich in alumina would readily fix any available alkalis to form either muscovite or albite or both. Therefore such a reef secreted during the amphibolite grade of metamorphism could, when metasomatism becomes operative, be converted to resemble an intrusive pegmatite.

It is clear from field observations that secretions do occur and range from pure quartz to pegmatite. Thus when pegmatites of magmatic origin occupy structures in high-grade metamorphic rocks, secreted material from a reasonably local source, as well as elements which are drawn off in transit must be added to their bulk composition. Should suitable structures occur in the metamorphic rocks of the high-grade amphibolite facies, in the absence of reservoirs of pegmatite, they could be filled entirely by material evolved from the rocks. This state of affairs was also envisaged by Wegmann and Kranck (27, p. 10). The material once collected could be injected, by squeezing, so that an abstraction from one point could become an intrusion at another.

The material capable of secretion is at first exogenetic but as metamorphism proceeds endogenetic additions are made. It is the source of this latter material which is the subject of such controversy. Temperature must be the prime factor in liberating certain substances and differential pressure would provide the motive power. It is conceivable that reactions once started could be maintained and even caused to spread to cooler horizons by exothermic reactions.

It was mentioned on page 36 how sillimanite was derived from muscovite by a process akin to dehydration. This process liberated potash, silica and water. In the rocks studied these liberated substances were absorbed locally to form new minerals such as microcline, but it seems likely that under different physical conditions migration could occur to produce potash metasomatism elsewhere. By a similar process, biotite liberates potash, magnesium, iron, etc. It has been shown (pp. 53, 54) how addition of potash to a mafic rock liberates soda as a first step and how later as granitization proceeds, lime, magnesia and iron have been eliminated. The amount of material which has to be removed from the rock undergoing granitization will depend, naturally, on its original composition. The elements not needed in the formation of granite can be removed for collection by pegmatite in transit or, in its absence, for accumulation in favourable structures.



Thus to summarize, mineralogical transformations resulting from changes of metamorphic environment liberate elements which may be taken up locally or with increasing metamorphism be made to migrate.

With advancing metamorphism and the attainment of higher temperatures and pressures, which are not altogether controlled by depth, the rocks pass from the amphibolite facies through the granulite facies to the eclogite facies. The amphibolite facies is the "wet" facies in which granitization by metasomatic processes takes place, while the eclogite facies is conceived of as the hot, "dry" facies in which pegmatites are relatively rare. It seems reasonable to suppose that the "wet" substances have been derived from the deeper metamorphic zones where they were redundant.

H. H. Read (23, p. 412) in discussing Ramberg's work on the gneiss complexes of Neo-Nygaard and Berthelsen in Greenland states that "According to Ramberg, no magma of paligenetic or anatectic origin was involved, the operative process being a metasomatism brought about by the migration of elements, preferentially squeezed out from the deep granulite facies and moved upward to give the granitization of the shallower amphibolite facies".

Field work in the Lower Sabi Valley of Southern Rhodesia supports the above contention. The writer mapped an area of Precambrian rocks in the Ndanga District which had attained the granulite facies of metamorphism and which included some rocks with charnockitic affinities. Pegmatites were rarely seen. It seemed quite certain at the time that the main mass of leucocratic rocks were of sedimentary origin. Later W. H. Swift\* of the Southern Rhodesia Geological Survey mapped these same rocks farther north where they were found to be more granitic in appearance and gave the impression of being ortho-gneisses.

Finally, brief consideration will be given to the source of the magmatic fraction of the composite pegmatites. In the "wet" environment of the para-gneisses in the amphibolite facies, mobility is attained: first plastic deformation, but with continued metasomatism a *migma-magma* capable of forceful injection results. It is contended that the intrusive granite of the Miami Mica Field was derived in this fashion. This end product of granitization would on crystallization and differentiation release much pegmatitic substance, and this is a characteristic of the granite plugs. A neomagma on the other hand would presumably be drier. In the section on wall-rock alterations it will be pointed out how some economic mica may be produced from the wall-rock mica by the introduction of mineralizers and heat from an intrusive pegmatite. The growth of fairly large books of mica in mica-schist has already been mentioned.

#### *Wall-rock Structures*

As far as these are concerned the economic pegmatites may be divided into two categories — those which bear concordant relationships to the country rocks and those which are discordant. In local mining parlance the concordant pegmatites are referred to as "gashes" to dis-

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\*Personal communication.



tinguish them from the discordant dykes which are referred to as "true-fissures". While the use of the term "gash" is understood on the Field, it will be realized that this is a novel application of a geological term which already has several definitions.

There was at one time a prejudice against the so-called "gashes" on the grounds that they were of less persistent dip and strike than the "true-fissures" but this contention is not well-founded. It is true, however, that while the discordant pegmatites tend to have a regular width, the concordant types tend to be more markedly lenticular or to exhibit pinch and swell structures. A pegmatite many feet in width may very suddenly pinch to little more than a narrow fissure, but the pegmatite may just as suddenly "make" again. In some old mica mines which have been reopened it has been found that work in one direction or another had been terminated on a pinch. Later work beyond such structures revealed the pegmatite continuing as strongly as before (see Becket Mine.)

There is a tendency for concordant pegmatites to be more common in the highly micaceous schists where they have a strong tendency to form spurs or offshoots. Some pegmatites which were reasonably strong bodies in depth have been found to form numerous branches near surface. The concordant pegmatites are not always simple dilations within the schist. Some have been found to occupy low-angle thrust planes which show strong evidence of wall-drag. Discordant bodies of pegmatite have been emplaced along tension fractures or normal fault planes. A pegmatite may, on the other hand, be concordant at one point and discordant at another owing to folding in the schist. Some multiple control structures may be formed in this way. In addition to the actual fracture, which controls the emplacement, following the foliation in one place and transgressing it at another, the main pegmatite may have numerous spurs or branches controlled by the foliation planes.

Some discordant pegmatites strike with the foliation but dip at a different angle. Others when viewed only marginally appear to be concordant owing to a superimposed foliation caused by post-pegmatite movement. In the absence of positive evidence of stresses within the pegmatite this marginal foliation might be interpreted as the product of forcible injection.

Most pegmatites of economic importance form very sharp contacts with the wall-rocks (Plate VIII). Post-pegmatite movement is often localized along this contact. There are pegmatites, however, which have made room for themselves by replacing their walls and have thus widened out from narrow fissures. Where this state of affairs was definitely established the pegmatites were barren and presumably older than the economic pegmatites. There are also pegmatites of replacement origin which appear to occupy no definite structures. These are the large, irregular, highly potassic masses which have clearly replaced the schists and left the arenaceous bands in their original attitudes where they form the well-known "ghost structures". These pegmatites, too, are of no economic importance and are presumably related to some concealed magmatic source.

PLATE VIII



Border zone of the Locust Mine pegmatite forming sharp contact with gneiss. Four-tenths natural scale.

Photo: H.M.C.

### *Wall-rock Alterations*

The nature and extent of any contact alteration would appear to be contingent on a number of factors, among the most important of which are the attitude of the pegmatite, its mineralogical composition and temperature of emplacement.

Additions of material to the wall-rocks have often been made. Abstractions, if these have been made locally, are less easy to detect.

The alteration of wall-rocks was more noticeable in the concordant pegmatites than in the discordant ones. The reason for this is that in the former the parallel foliation planes form a better trap.

Where notable alteration of the hanging-wall has taken place this may result in a troublesome state of affairs for mining operations. It can produce what miners on the Field call a "false hanging-wall" which may be as much as two feet thick. If this false hanging-wall is not secured or broken away with the pegmatite it may lead to large slabs of rock falling away later. One such wall-rock was found to be composed of a granular mass of quartz and tourmaline with some biotite. Beyond these zones the wall-rock was found to be coarsely micaceous. Where the country rocks are rich in sillimanite much of the muscovite has clearly taken the place of the sillimanite. This indicates that addition of potash has been made, which if not derived from the pegmatite itself, may have come from or have been augmented by potash released from the false hanging-wall as a result of replacement reactions taking place there. The replacement of mica by tourmaline would release potash. In certain of the mica mines described in the economic section of this bulletin (see p. 123) it was noted that muscovite and tourmaline can be mutually exclusive. Concentrations of fine-grained tourmaline may be found in wall-rocks, even where the pegmatite itself carries very little tourmaline.

The schist bordering some pegmatites may be coarsely recrystallized for distances of up to a foot or more from the contact. Such rock is composed of mica and quartz, with the former the more conspicuous even when not predominant. This state of affairs has been induced by the influence of trapped volatiles or mineralizers which were at a reasonably high temperature and produced a type of greisenization. Small offshoots on the prolongation of some large, concordant, mica-bearing pegmatites have been found to contain concentrations of economic mica in surprisingly large books and this can be traced to the same cause.

The formation of biotite-schist at the expense of amphibolite on the margins of pegmatite veins or dykes has received earlier mention.

### *Age of the Pegmatites*

This subject can be approached from two different aspects. Firstly, there is their actual age as near as can be determined by scientific methods, and secondly the age relative to the orogeny which initiated the whole metamorphic cycle.

Actual ages of pegmatite formation were determined by both the lead-age distribution and the potassium/argon methods. For the former,



radioactive columbo-tantalite from the Rita Mine, six miles north of Miami Village, was used, while for the latter muscovite from the Catkin Mine, 22 miles west of Miami, was employed.

The information here given was supplied to the writer in personal communications from A. M. Macgregor in 1954.

J. D. Louw of the National Physical Laboratory at Pretoria, determined the age of the columbo-tantalite as 477 million years, but it should be pointed out that he complained of the specimen being far too small and that it contained too little lead. Using Louw's analyses, Arthur Holmes recalculated the age to be about 680 million years.

The argon age of the muscovite was determined in Toronto, Ontario, as 520 million years, but Macgregor stated that those concerned were not satisfied with the determination and had requested more material. In confirmation of the Catkin pegmatite age is a new preliminary determination of 530 million years based on muscovite from the Esquire Mine. The material was collected by Arie Poldevaart, Professor of Geology (Petrology), Columbia University, in 1959, and submitted to Professor Kulp's group at Lamont Observatory.

During field work in 1954, the writer identified the mineral betafite in a pegmatite which was being mined for beryl. Macgregor was advised of the discovery and samples were sent away by him, but it is not known what the outcome of the investigation was.

Although there is no close agreement in the ages derived by the two methods, they do serve to indicate a general age for the pegmatites and therefore the metamorphism.

Secondly there are pegmatites of at least two ages, each conceivably belonging to a group which marks a distinct episode in the metasomatism. As far as can be determined the older group is of no economic importance. The pegmatites are unzoned and composed of plagioclase and quartz with some tourmaline. It would appear, therefore, that they belong to the earlier period of soda metasomatism. They frequently reveal evidence of granulation and a sketch has been made of one on Chelvern Estate which gives a perfect illustration of *boudinage* or pinch and swell structure with the resulting tension joints filled with quartz to give a ladder-vein structure (Fig. 8).

The younger group, which includes the economic pegmatites, frequently contains abundant microcline. It belongs to the later potash phase of metasomatism. Underground in some mica mines pegmatites of this group have been found cutting older pegmatites almost at right angles, but in one instance a spur reef rich in mica was found to end up against an older barren pegmatite which was occupying the same structure.

The older pegmatites have been markedly affected by the orogeny, but the younger group only occasionally or not at all. This younger group is post-metamorphism in age as is evidenced by the effects on the sillimanite in the wall-rocks. The intrusive plugs of granite which came in at the same time have also left their imprint on the metamorphic minerals. Locally, movements were still taking place, involving folding and thrusting. These movements have resulted in the development of

PLATE IX



A. Muscovite book from the Miami Mica Field bent to an angle of 55 degrees. (Half natural size.)



B. Bent beryl crystal from the Miami Mica Field. (Natural size.)

Photo: H.M.C.

a secondary foliation on the margins of some pegmatites, and the crushing of the component minerals, or are reflected in the buckling of mica books and the bending of beryl crystals assisted by gliding on the basal plane (Plate IX). In addition, some pegmatites have been truncated by thrust faulting. Possibly the most spectacular evidence of post-pegmatite movement is provided by what is thought to be the overturning of a pegmatite as surmised from the position of the mica shoot. If only one mica shoot forms in a zoned pegmatite, it is more usual for it to form on the hanging wall side. When, therefore, as at the Majestic Mine there is a shoot on the foot-wall side only it may be assumed that overturning has taken place. Here there has been some crushing of the feldspar and buckling of the large books of mica. It seems likely that the plane of this pegmatite has been turned through as much as 80 degrees (see Majestic Mine).

This, and the other evidence, serves to date the pegmatites as late-kinematic.

*Classifications.* There is as yet no universally accepted system of classification of pegmatites and when their complexity is considered the reason is apparent. However, where it can be applied the system based on internal structure is one which appears to be receiving much popular support.

Jahns (24, p. 1048) summarizes the trends as follows: "Pegmatites and bodies of pegmatites have been variously classified in terms of form, size, relationships with the enclosing rocks, mineral and chemical composition, texture, internal structure, presumed origin and mode of development, and combinations of these features". He then gives the composite classification for bodies of feldspathic pegmatite suggested by Girsburg in 1928.

If a successful genetic classification were possible it might aid prospecting and lead to the discovery of undisclosed mineral concentrations. It has been a common practice, especially with beryl not to prospect a pegmatite unless there are surface indications of the mineral even when an adjacent and apparently genetically related pegmatite has yielded beryl. It is possible that some of these pegmatites might contain sub-outcropping mica shoots or pockets of beryl. Of course the low price of beryl in the past has discouraged exploration in depth.

For mining purposes pegmatites might be broadly classified into mica-bearing, beryl-bearing and barren types. In this respect the presence of a strong quartz core is regarded as a favourable indication of the possible presence of beryl. However, some pegmatites initially mined for beryl have later yielded economic mica, while many pegmatites mined for mica have also produced beryl.

L. R. Page *et al.* (28, p. 7) consider that some sort of system based on both mineralogy and structure is desirable. Adopting this approach many pegmatites fall into two broad groups which may be labelled the simple and the complex, the former homogeneous and unzoned, the other heterogeneous and zoned. It may be necessary with some pegmatites to indicate a third type by using a term based on a mixture of the above-mentioned terms. Thus in addition to unzoned and zoned, one



might add simple zoned where the pegmatite would be homogeneous in so far as the quartz and feldspars are concerned but yet have, in part only, a wall zone concentration of mica.

In their excellent and comprehensive publication on pegmatites Cameron *et al.* (26) have filled the need as they put it "for a stable but flexible classification and terminology of pegmatite units, so that descriptions can be as clear as possible and genesis and other problems can readily be discussed". Many of the pegmatites of the Miami Mica Field can be very well classified under this system and the terminology will be used in the detailed descriptions of the different units in the zoned pegmatites. For this reason a brief description of their system, in their own words follows:

"The lithologic and structural units found within pegmatite bodies differ in mineralogy or texture, or both. Three basic types of units are distinguished and are defined as follows:

1. *Fracture fillings* are units, generally tabular, that fill fractures in previously consolidated pegmatite.
2. *Replacement bodies* are units formed primarily by replacement of pre-existing pegmatite, with or without obvious structural control.
3. *Zones* are successive shells, complete or incomplete, that reflect to varying degrees the shape or structure of the pegmatite body. Where ideally developed they are concentric about an innermost zone or core. Some concentric units, however, are not zones but belong in the categories above".

These units and their general relationships are diagrammatically illustrated in Figure 9. The following zones have been proposed:

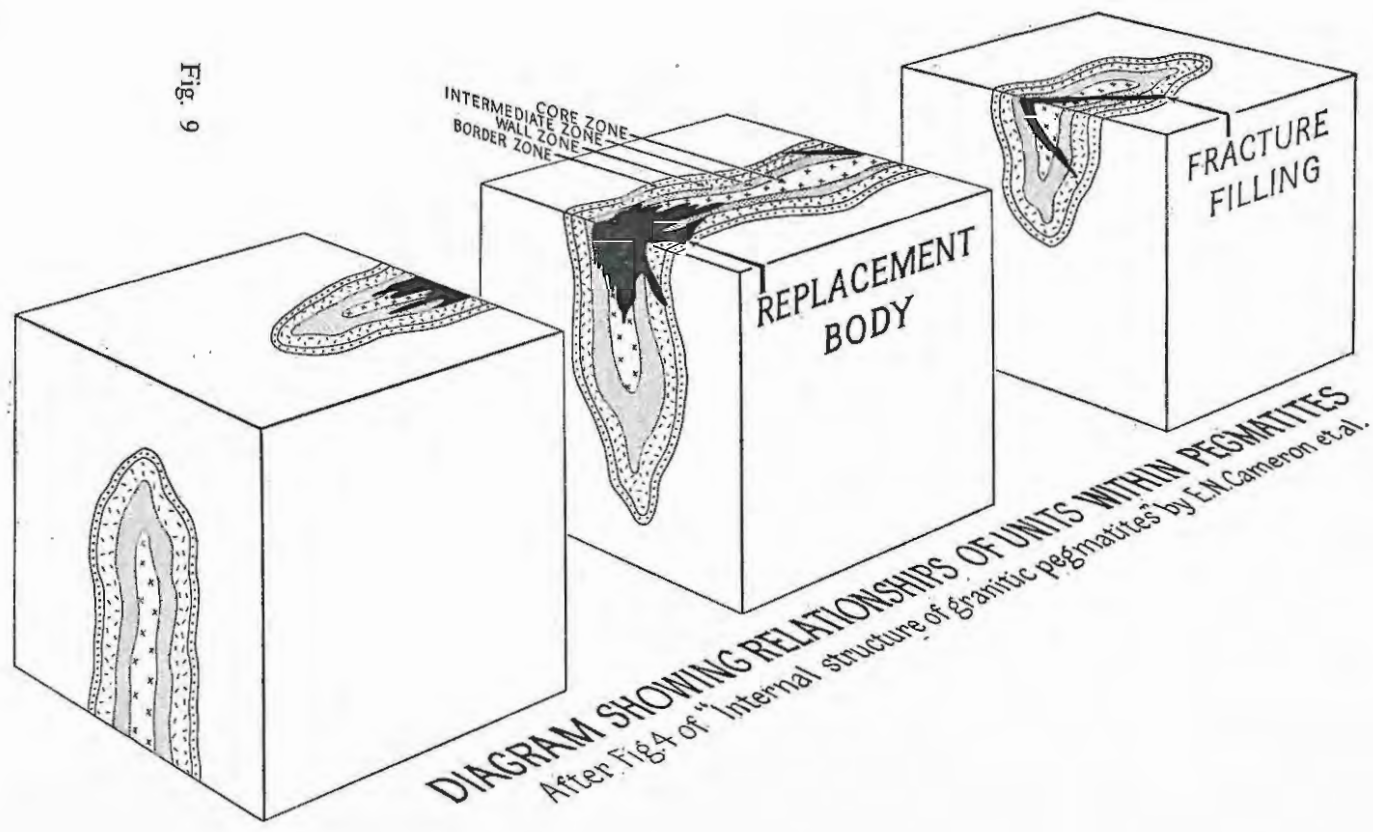
1. Border zones
2. Wall zones
3. Intermediate zones
4. Cores.

The mineralogy and significance of these zones, where they apply to the mica- and beryl-bearing pegmatites of the Urungwe District, will be discussed. The large, irregular, barren replacement pegmatites and the *lit-par-lit* pegmatites of the migmatites, whose margins are gradational into the gneiss and are mainly, if not altogether, formed by replacement, will not be described.

As a generalization one might say that the economic mica (sheet or book) occurs in the wall zones while beryl occurs in the core or core-margins, but there are many exceptions. But for one of the only two lithium-bearing (amblygonite) pegmatites recorded in the district, and an occasional mica pegmatite, the outer intermediate zone is of no economic importance.

The BORDER ZONES in mica pegmatites usually differ only texturally from the wall zones. In other words, they are merely the outer selvages of the pegmatite which in the intrusive types may be regarded

Fig. 9



as chilled margins. On the one side they tend to form knife-edge contacts with the country rock while on the other, in the absence of mica shoots, the contacts are gradational.

Mineralogically the border and wall zones are frequently identical but on occasion the former may contain tourmaline in appreciable amount while the latter may have little or none. The whole border zone is seldom more than a few inches wide. In some simple pegmatites the only zoning, if it can be called zoning, has been the development of border zones and the composition is the average of the pegmatite.

The WALL ZONES, as already stated, are generally the most productive of mica, but there are exceptions which will be discussed later.

#### *Mica-bearing Zones*

Few pegmatites are vertical, so that where mica-bearing zones are developed on both sides of the pegmatite the one, quite naturally, is referred to as the foot-wall zone and the other as the hanging-wall zone. In most pegmatites the wall zones if "ideally developed" envelope the intermediate zones and the core, and where these latter thin out, the wall zones if present, come together before they too, with the pegmatite as a whole, also terminate. Where the wall zones carry mica this joining leads to a local concentration of mica which simplifies mining (see Hendren V Mine). Too often, however, the end of the core heralds the termination of the pegmatite which then carries much smaller books of mica than previously.

Mica concentrations in the wall zones may occur as well-defined "shoots" with a definite pitch, and if their direction can be ascertained early enough this is of great value in planning mine development. Shoots may be disconnected, or united only by a narrow leader, and the character of one wall is not necessarily reflected in the other. Economic mica may not be present at all on one of the walls. Under normal circumstances, if mica occurs on one wall only, it will be on the hanging-wall. If mica is found on the foot-wall only, it may sometimes be presumed that overturning has taken place. There are, of course, alternative explanations. In one pegmatite a hanging wall mica shoot was observed to turn into the foot-wall over a short length of strike and then to return to the hanging-wall. It is felt that this temporary migration of the mica shoot was caused by convection.

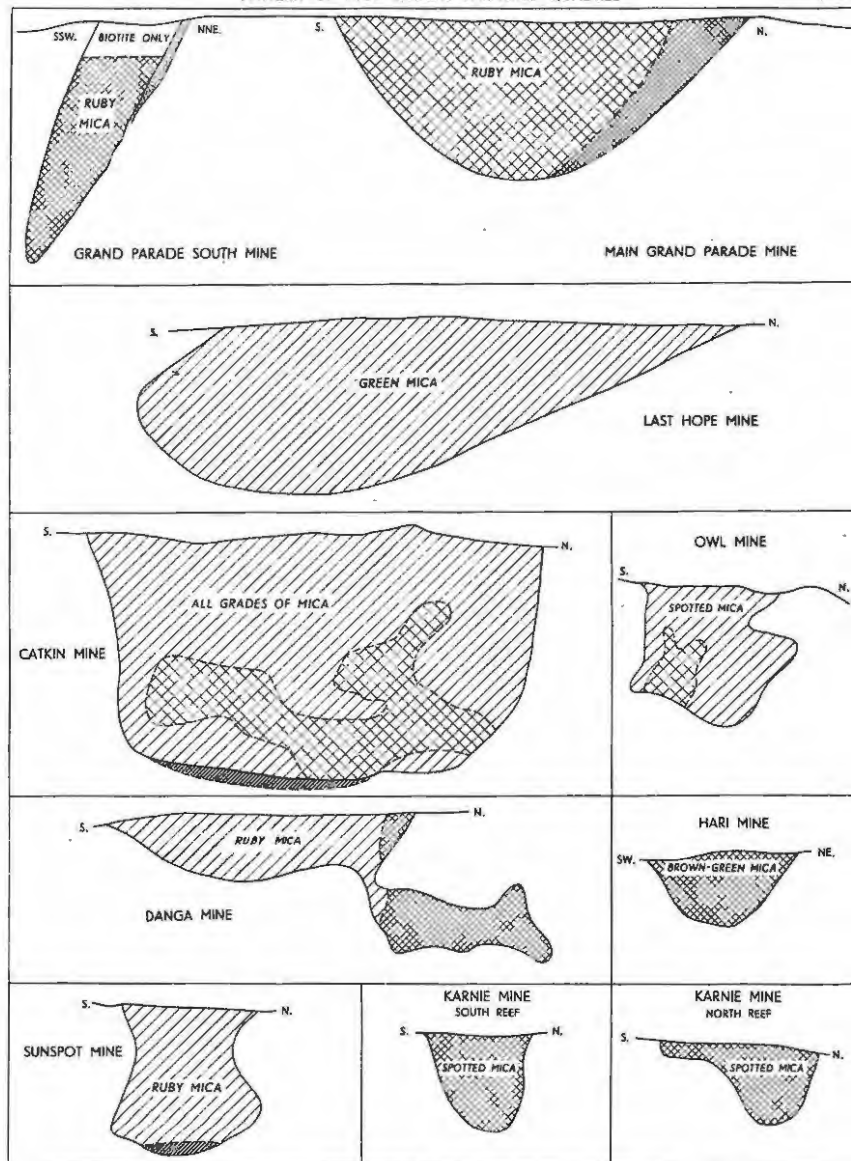
In the absence of "shoots", the concentrations may bear some relationship to the form of the pegmatite as at the Piper Mine. Plate X illustrates some of the patterns of mica concentrations found in a few of the better-known mines of the Miami area.

Equal development of mica on both walls of a pegmatite indicate identical rates of crystallization and therefore of cooling. This state of affairs is most likely to develop in vertically dipping pegmatites. In a closed system, as the inclination lessens, conditions should favour hanging-wall development of mica at the expense of the foot-wall. In nature, however, conditions are seldom simple or ideal and factors which may upset ideal developments are, convection, thickness, multiple injection



PATTERN OF MICA SHOOTS SHOWING QUALITIES

Plate X



Scale of feet 150 0 100 200 300

Explanation

- |                      |            |                    |
|----------------------|------------|--------------------|
| MICA ON HANGING WALL | TOURMALINE | MICA ON BOTH WALLS |
| MICA ON FOOTWALL     | EPIDIORITE | MICA THROUGHOUT    |

which would produce zonal disruption, and composition. Later movements may have changed the initial inclination of some pegmatites and assessment of the dip at which, under ideal or simple conditions, mica forms on the hanging-wall only (for a given thickness) is impossible. It would seem that the thicker pegmatites are more likely to carry mica on both walls than are the thinner ones. The Last Hope pegmatite has a dip of 50 degrees, and over the productive area, it averaged 5 ft. in width, with payable mica developed on the hanging-wall only. However, at the bottom of the mine the pegmatite widened to 12 ft., but the sparse concentration and small size of the mica in the hanging-wall rendered mining in depth uneconomic. What is of interest, however, is that some reasonably large, though sparse, books have developed along the foot-wall which may indicate the start of another shoot there.

The Piper Mine pegmatite which dips at 55 degrees, carried mineable mica on both hanging- and foot-walls. This pegmatite, though markedly lenticular, was on the average very much wider than the Last Hope body and at one point attained a width of 15 ft. Another difference is that the Piper pegmatite is a typical example of a zoned pegmatite, while the Last Hope pegmatite is rather simple and is zoned only in so far as the mica is concerned.

These facts serve to indicate that no simple answer can be given regarding the control of mica shoot dependent on the attitude of the pegmatite.

A notable feature of the mica in zoned pegmatites is the orientation of the books. The tendency is for mica to be orientated with its cleavage plane perpendicular to the walls. The C crystallographic axes, therefore, lie in the plane of the shoot, but with all orientations in this plane. The mica shoot as a whole may therefore be said to have an axial fabric symmetry. The mica books which crystallize with this orientation are relatively thin, but may have a large basal section (e.g. 18 x 24 inches).

On the Locust Mine, some books of mica have a greater thickness than basal section. Mica of this type is known as the "thick book" or "C" type. The latter name has been given because the major development or growth has been in the direction of the C crystallographic axis. The development of this type of book would appear to be controlled also by orientation. Where the thick book type of mica was found it was orientated, not with its C axis in the plane of the shoot, but at a large angle or even perpendicular to it. It is clear that the crystallization of the mica begins on the outer margin of the zone and that growth is inwards, in the direction of increasing thermal gradient. Thus, the tendency for the C axis to be orientated in the direction of the thermal gradient has led to the major growth being in this direction. The same orientation perpendicular to the walls has also been observed in both beryl and tourmaline crystals.

In the ideal mica pegmatites the felspar of the wall zone associated with the mica shoot is a sodic plagioclase which, where determined, was albite-oligoclase. Quartz is present in variable proportions. In the absence of a mica shoot the wall zone may be composed of quartz,

plagioclase and some small muscovite. The zone may be a few inches or several feet wide. This assemblage may constitute an intermediate zone where an economic mica shoot is developed but this depends on the size of the mica books. If the books are large, and orientated, they may reach from the border zone inwards, so that an intermediate zone of quartz and plagioclase with small mica does not exist. Where the zone carrying plagioclase is wide, or the mica books in the shoot relatively small, then an outer intermediate plagioclase-bearing zone is present. It will be seen from this that these two zones, and others in the pegmatite, can merge to form a single zone. Or, in the absence of a mineral such as mica, which virtually constitutes a zone, one zone can become eliminated and its place taken by another. This merging is referred to by Cameron *et al* (26, p. 43) as "telescoping", and will be discussed later. Pegmatites are seldom ideally developed or symmetrical in either transverse or longitudinal section. No purpose will be served here in describing the many variations or eccentricities. Concentrations of mica can occur in more than one type of zone in a pegmatite or in one zone in one pegmatite and a different zone in another.

#### *Crystal Habits and Imperfections of Muscovite*

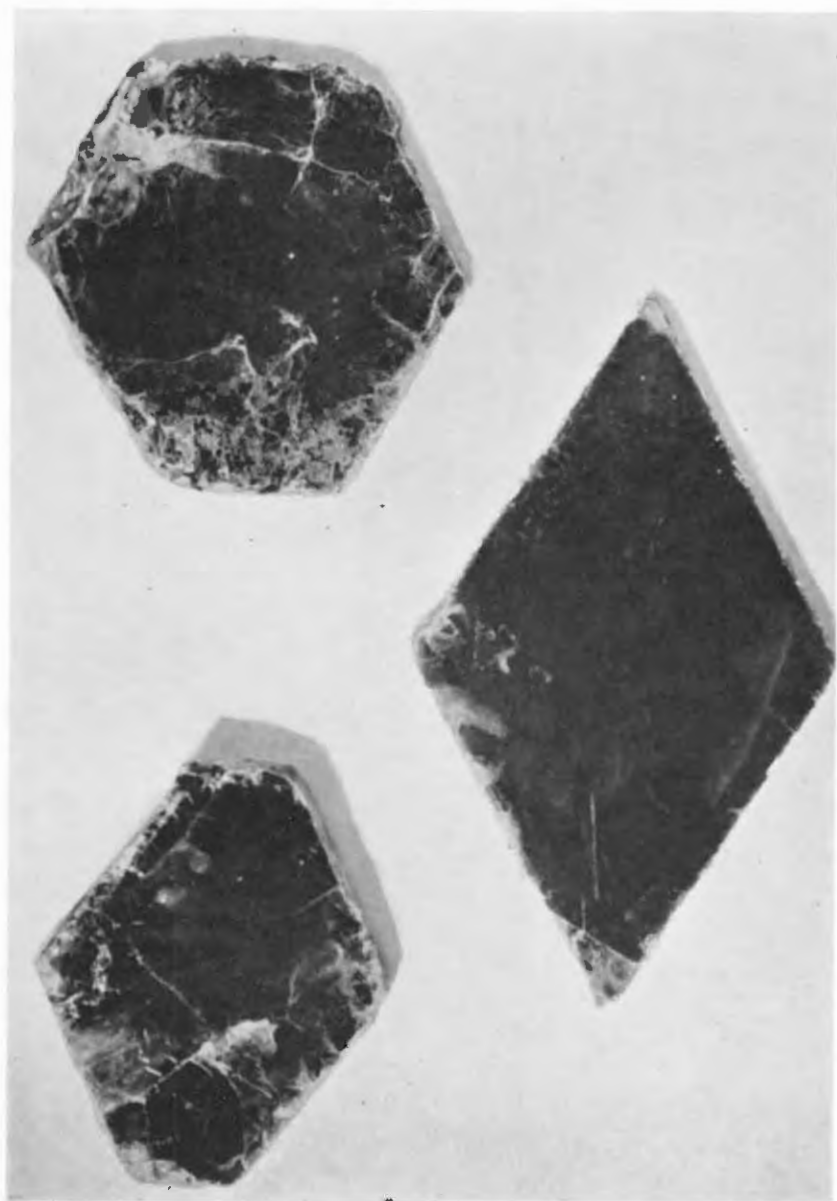
This section deals with the variations in habit of muscovite when it crystallizes in the different zones or in unzoned pegmatites. Certain structural imperfections which are the effects of chemical or mineralogical environment are also discussed. Some of the imperfections which are here considered can also be brought about by external forces where the mica initially crystallized under ideal physico-chemical conditions.

Ideally developed mica crystallizes in a base of plagioclase with quartz. In such surroundings the mica crystallizes before the other minerals. In the ideally zoned pegmatites the mica books in the wall zones tend to have rhombic or pseudo-hexagonal outlines (Plates XI). Usually the more perfect the crystal, the higher is the percentage of sheet mica which can be cut from it. In most pegmatites a 10 per cent. average cuttability is considered high. In the early days of mica mining on the Miami Field the overall average cuttability was a little over one per cent.

Mica which crystallizes in a base of microcline or in the quartz of the core is wedge-shaped (see Plate XII A) with a herring-bone, "A" or fish-tail structure. This type of structure also forms on the cleavage planes of flat books but is referred to as "flat-A" as opposed to the "wedge-A" mica. On the Field, all mica rendered valueless as sheet mica due to the development of "A" structures throughout is referred to as fish-mica or just "fish" by the Africans. The "wedge-A" books do not split along the cleavage planes without tearing and the mica is then referred to as being interleaved or of the tangle-sheet type and cannot be used for sheet mica. Concentrations of large wedge-shaped mica crystals, sometimes many feet in length, may form intermediate zones, as illustrated in Fig 11A, assemblage 4. Where this has happened, microcline or perthite usually forms an inner intermediate zone with quartz as the core. Frequently these two zones have been telescoped to produce a mixed core of irregular quartz masses and



PLATE XI



Similarly orientated muscovite crystals from the Ruby "B" Mine showing relative development of prism and clinopinacoidal faces. Half natural scale.

Photo: H.J.C.

PLATE XII



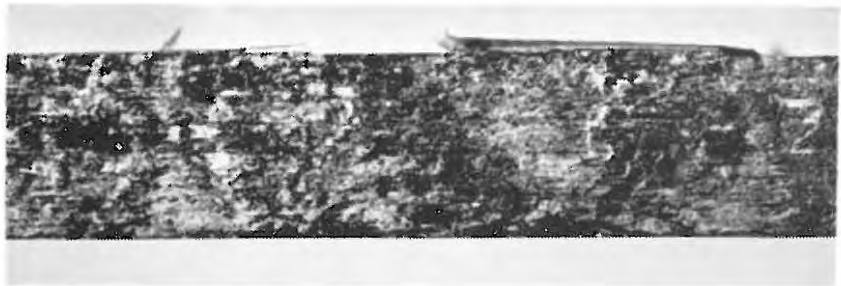
A. Wedge-shaped muscovite book from the Pearl Mine. Side view  
three-tenths natural scale.

Photo: H.J.C.



B. Front view of A, showing herring-bone structure.

Photo: H.J.C.



C. Cross section of normal book of muscovite suitable for sheet mica.  
Berea Mine.

Photo: H.J.C.

large microcline crystals. In such cases the mica zone concentration may have become disrupted and occur partly on the margins and partly in the core around the large microcline masses. Where the mica forms a zone on the margins of a microcline core it is referred to as a core margin zone. The mica of this zone may have formed by replacement.

Sometimes the telescoping of zones may be carried farther so that the plagioclase becomes mixed with the microcline, and the mica books then occur partly in plagioclase and partly in a base of mixed feldspar. The large books of mica in the mixed feldspars are severely broken by movement, or by the effects of the later microcline crystallization, into many pieces of variable size so that only much smaller sizes of sheet mica are available from what were large books. If much microcline is present the same state of affairs may be found in a homogeneous pegmatite which carries disseminated mica. Where only fragmentation of the mica has taken place there may yet be much of sufficient size to be economic, but more often than not many books or parts of books have developed such a waviness or become so striated along secondary cleavage directions that interleaving results. Then there is so much wastage that the pegmatite might not be worth mining unless it can produce a high-quality ruby mica.

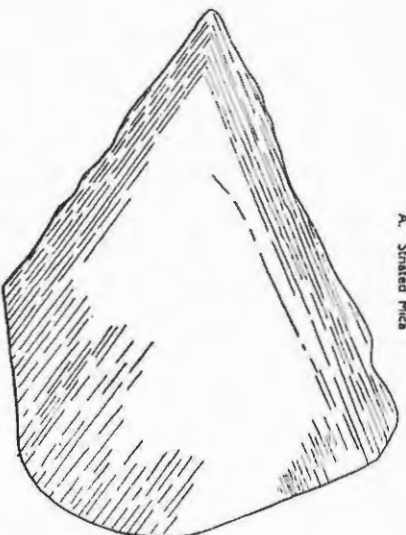
When prospecting, therefore, the presence of much microcline is an unfavourable indication unless it occurs as a distinct zone apart from the plagioclase and mica.

The identification of the two types of feldspar is sometimes quite easy even for the layman. The plagioclase is frequently white while the microcline or perthite is pink. In addition, and the only really sure indication, the plagioclase polysynthetic twinning may be detected in reflected light on one of the cleavage surfaces, with or without a hand-lens, while the microcline shows fine but discontinuous spindle-shaped lamellae. The perthite may have megascopically detectable strips or veins in nearly parallel arrangement with very fine, disrupted, lamellae almost perpendicular to them. Perthite from the core zone of the Bold Beryl Mine reveals both these sets of lines quite clearly under a lens, so that a cross-hatching is apparent on the main cleavage planes. The two feldspars are shown, as they appear megascopically, on Plate XIII.

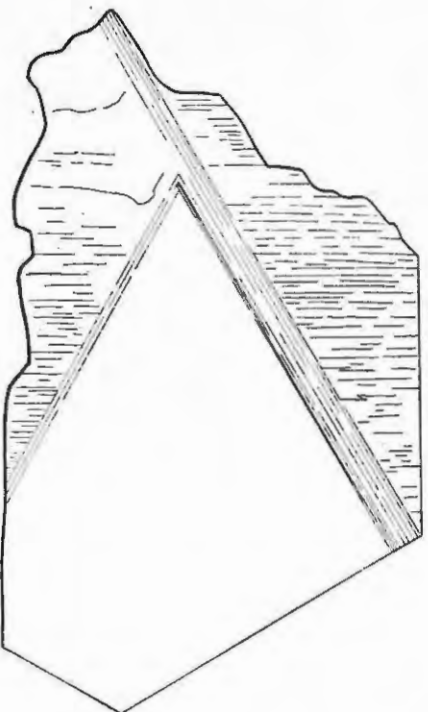
On the idealized plan of a pegmatite marked A on Fig. 11 the positions of the two possible mica shoots are illustrated as assemblages 2 and 4. Some pegmatites exhibit a modified form of this state of affairs. They may carry only a single shoot in which some of the mica exhibits the form found in the one zone, and some the form of the other. Such a mica concentration occurs as an outer intermediate zone with the normal books wholly in the plagioclase on the inner side of the wall zone, while the striated books occur on the margin of the quartz-microcline core. Unless the books on the core margin are actually imbedded in microcline they will not show the wedge-shape illustrated in Plate XII A, in which the mica is strongly interleaved. They will, on the other hand exhibit striations, A-structure, or so-called reeves, but if not too strongly developed will not cause interleaving thus allow them to be readily split along cleavage directions.



A. Striated Mica



B. Striated Mica



C. Ruled Mica Book showing orientations of rulings

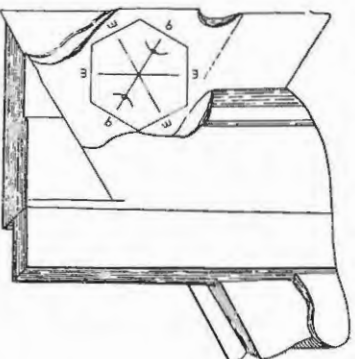


Fig 10. Showing common defects in sheet Mica

PLATE XIII



A. Albite from the Early Bird Mine showing polysynthetic twinning.  
Natural size.

Photo: H.M.C.



B. Microcline-perthite from the Bold Mine showing albite interlamination.  
Natural size.

Photo: H.M.C.

If the striations are in two sets they make an angle of 60 degrees to one another on the basal cleavage planes. In some instances such structures traverse the whole book, which is then valueless for sheet mica, but in others cuttable mica is found in the interior of some books in the V between the striations (Fig. 10). Where books are large, fair sizes of mica can be cut, but there is a very large percentage of waste. Since the same number of striations do not traverse the whole book it is clear that as the book was growing, both in length and cross-section stresses were variable.

Books have been found with three sets of striations, two parallel to the prism faces, and one parallel to the clino-pinacoid. In such books, where the striations are marginal, quite large sizes of sheet mica are available (Fig. 10b).

There are three other directions, at 60 degrees to one another, along which the mica books can be damaged by stress. These are glide planes or secondary cleavage planes which are inclined at 67 degrees to the plane of the cleavage (Fig. 10c) and form, on the cleavage planes, traces which are parallel to the ray lines of the so-called pressure-figure. The effect of the development of these glide planes, is often only to reduce the size of cuttable mica. The planes are sharp as though cut with a razor-blade, and the mica splittings look as though they have been deliberately cut in this way. Only a few planes may be developed in one direction to produce broad strips, but they can be so numerous that thin parallel fibres result. These planes may not pass through the whole thickness of a book and may affect only the margin or a portion of a large book giving the appearance of its having been split inwards for certain distances. Usually little or no displacement has taken place along these planes. Where they do not traverse the full thickness of a book it would appear that the plane developed during the early growth of the book.

The striations referred to above are not to be confused with the geometrical patterns produced by rows of spots or films of iron, manganese or biotite which follow the same crystallographical directions.

#### *The Beryl-bearing Zones*

The majority of pegmatites mined primarily for beryl are short lenticular bodies, usually with well-developed quartz cores. Owing to its resistant nature the quartz forms a conspicuous outcrop and some of the larger pegmatites give rise to prominent small kopjes. The outer zones of the pegmatite may not be exposed but the quartz of the core differs from the usual run of barren quartz reefs in containing one or more of such minerals as micas, tourmaline, apatite or beryl. The presence in the pegmatite of beryl may be deduced on occasion from the preservation in the core of casts of crystals which have since disappeared.

Where there is a strongly developed quartz core there is usually an inner intermediate or core margin zone of microcline or perthite. With this potash feldspar there may be a dissemination of biotite which characteristically forms broad laths up to six feet or more in length. The frequent concentrations of wedge-shaped, striated, muscovite associated



with this felspar has been mentioned. The telescoping of inner zones with the quartz of the core is common, so that many cores are of a mixed character.

There is one "pegmatite" worthy of specific mention here and that is the one which constituted the ore body of the B.H. Mine. This was found to be little more than a high temperature quartz reef, carrying beryl and a very little associated felspar which was too decomposed for identification but which was presumably microcline. There was no tourmaline to be seen, but a concentration of small muscovite mica books occurs in the quartz at one exposed contact with the sillimanite-bearing, micaceous schist, wall-rock. The mica gives the impression that it was recrystallized from the schist as a result of the high temperature hydrothermal effect produced by the intrusion of the quartz. This quartz is presumably the squeezed-off core material from some deeper-lying pegmatite.

In the strongly zoned pegmatite of the Lion Hill Mine long beryl crystals were seen having several orientations. Crystals which occurred wholly in a matrix of perthite were aligned both in the plane of the zone and obliquely to it. One crystal, however, which was over three feet long, was orientated perpendicular to the dip and strike of the zones. It commenced crystallization in perthite of the core margin zone and extended well into the quartz core where it was sheathed in felspar. The crystal was a little bent at the junction between the two zones and had a very gradual taper from the quartz towards the felspar. This particular taper appeared to be not a termination but more of a gradual diminution in cross-section of the hexagonal prism. Terminations in beryl are rare but crystals have been found, some of large proportions, which have high-order hexagonal pyramids.

Beryl does not occur only with what may be regarded as the core assemblage minerals but is also found on occasion in plagioclase in relatively simple pegmatites. However, in some mica-pegmatites which are composed predominantly of plagioclase and quartz, beryl may occur in a "blow" with quartz and microcline.

Because of the rather low value of beryl, many of the so-called mines were little more than shallow rubble workings where free beryl crystals were picked up almost at surface or gleaned from among large quartz boulders derived from the core. Little information could be gained as to the structure and composition of these pegmatites. Where mining has been undertaken, this has been mainly of an opencast nature to a shallow depth, over varying lengths of strike. Beryl tends to occur in concentrations known as pockets and when one such pocket has been mined out the working is usually abandoned. If the price of beryl were to increase substantially it is certain that many of the old workings could again yield beryl profitably.

Other beryllium minerals identified from these beryl-bearing pegmatites are chrysoberyl, phenacite, hurlbutite, euclase and herderite. Apatite is a common associate of beryl and sometimes forms concentrations of large crystals which prospectors have on occasion mistaken for beryl. Other phosphates which have been identified include arroja-

dite, triplite, triploidite and sarcopside. Amblygonite was found in two pegmatites, only one of which was mined; here the mineral occurred with white quartzose-looking beryl on the margins of a quartz core. Large iron-rich garnets sometimes occur and may weigh many pounds.

Tourmaline may or may not be present with the beryl. Sometimes it occurs as large black (schorl) crystals nine inches or more in diameter. When present it is usually in the quartz. In an area of small tourmaline-rich pegmatites a single crystal of cassiterite was found. Topaz is not common and was only seen in one pegmatite.

Tantalo-columbite occurs in small amount in many pegmatites and is often radioactive. Microlite has been identified from one pegmatite. Betafite and euxenite, uranium-bearing niobates possibly of secondary origin, occur with tantalo-columbite in several pegmatites. A dark-brown uraniferous mineral which was found with beryl in one pegmatite was investigated by the United Kingdom Atomic Energy Division and is thought to be a new mineral of primary origin. A bright-yellow, secondary uranium mineral forming a film on triplite is probably autunite.

Magnetite may form occasional large masses. Galena, cerussite, native bismuth and bismutite are occasionally found. Epidote and vesuvianite have been identified on many waste dumps. Another conspicuous secondary mineral forming on triplite is strengite. Wolframite, which has been mined from tourmaline-bearing quartz reefs, was also found in one pegmatite.

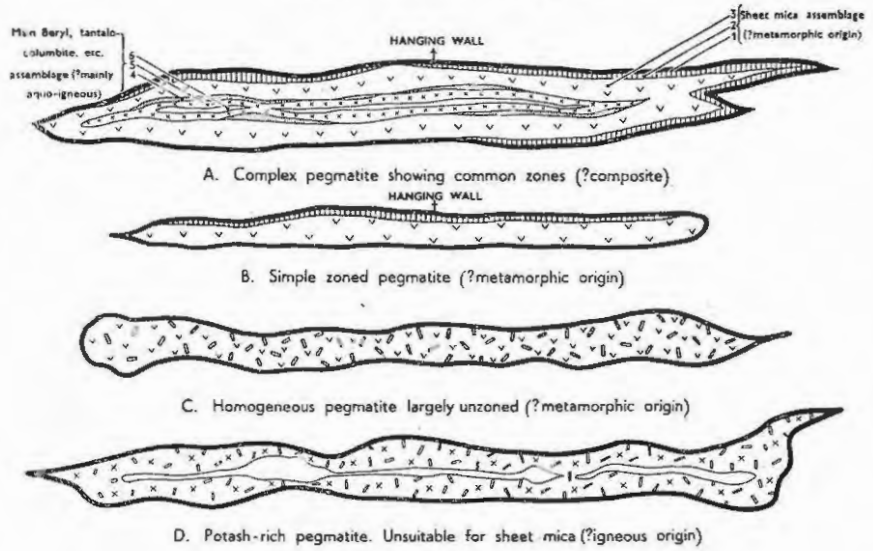
This list is not altogether a complete one but it includes all the more interesting minerals.

### *Origin of Zones*

In considering the phenomenon of zoning in pegmatites, a structure brought about primarily by mineral differentiation as the result of fractional crystallization, the sources of material and their different times of arrival on the scene must be borne in mind. Under ideal conditions a clear pattern emerges, but the frequent disruption of this pattern shows that the factors often varied.

Field observations have revealed that most, if not all, of the mica-beryl-bearing pegmatites of the Urungwe District can be placed in one of three main groups, each of which may or may not reveal some measure of zoning. Taken as a whole there are two distinct assemblages which can occur as separate injections or be united in one pegmatite body. It is this state of affairs, as well as the availability of material, which has led the writer to conceive of the possible composite nature of at least the mica-pegmatites. The observed facts are diagrammatically illustrated in Figure II. The first diagram in this Figure (labelled A) is a complex or ideally zoned pegmatite of the type which can contain economic block mica and beryl and it is regarded as composite. Some pegmatites having this mineral assemblage may show little, if any, evidence of zoning. If we take the ideally zoned pegmatite apart we can derive from it two distinct types of pegmatite both of which are common on the Mica Field. These are shown as types B and D. Type C is of

# IDEALIZED PEGMATITE PLANS



## Explanation

- |   |  |                          |                                                                                  |
|---|--|--------------------------|----------------------------------------------------------------------------------|
| 1 |  | BORDER ZONES             | { Tourmaline-quartz-mica-plagioclase                                             |
| 2 |  | WALL ZONES               | { Sheet mica with quartz-plagioclase                                             |
| 3 |  | OUTER INTERMEDIATE ZONES | { Quartz-mica-plagioclase                                                        |
| 4 |  | INTERMEDIATE ZONES       | { Concentration of striated and fishtail mica                                    |
| 5 |  | INNER INTERMEDIATE ZONES | { Microcline or perthite with quartz, beryl etc.                                 |
| 6 |  | CORE ZONE                | { Mainly quartz, some microcline, micas, beryl, tourmaline etc. possibly present |
|   |  |                          | Sheet mica-quartz-plagioclase                                                    |
|   |  |                          | Uneconomic mixed micas in perthite or microcline and quartz                      |

Fig.11



the same mineralogical composition as B, but is not zoned. Modifications of types B and D may be found in the same pegmatite but occupying, for the most part, opposite ends of the same structure (see Karnie Mine, p. 147).

At this stage it is well to consider briefly the three generally accepted "principal possibilities for the origin of the zones" as given by Cameron *et al* (26, p. 99) and see how far they are applicable to the structures observed in the economic pegmatites of the Urungwe District. The three possibilities are as follows:

(1) Development by crystallization of pegmatitic magma *in situ*. Pegmatitic liquid is injected into a chamber and undergoes fractional crystallization. Reaction of crystals and rest-liquid is incomplete, and successive crops of crystals are deposited against the walls until the chamber is filled. Successive zones of contrasting composition result. The zones develop in what might be called a "restricted system", a system closed to the extent that nothing is added to it from the source of the liquid between the time of the original injection and the end of zone development, but open to the extent that material may escape during crystallization, and reactions between the pegmatite and its walls may take place.

(2) Development by successive deposition in an open system. The space occupied by a zoned pegmatite represents part of a channel along which pegmatite solutions travel. Progressive changes in temperature, pressure, and composition of the solutions cause deposition of successive layers of contrasting composition.

(3) Development in two stages: (1) a magmatic or epimagmatic stage during which pegmatitic solutions were injected and crystallized to massive pegmatite (or aplite) in a restricted system, and (2) a hydrothermal stage (or pneumatolytic and hydrothermal stage) during which solutions passing through the pegmatite effected successive replacements in an open system. If the solutions followed the walls of the pegmatite body, peripheral replacement of the pegmatite might result, yielding a unit enveloping a core of unreplaced pegmatite. Further waves of replacement might result in a pegmatite consisting of several shells.

Cameron *et al* are in favour of the first of these three possibilities and their arguments put forward to support the contention can certainly be substantiated by many Urungwe examples. There are, however, many exceptions that would appear to indicate that the system is not always a closed one for the whole of the crystallization period.

If a closed system is in operation how can concentrations of mica in two distinctly different zones in one pegmatite, or in one zone in one pegmatite and in a different type of zone in another pegmatite of essentially similar total mineralogical composition be explained? It cannot be explained on the basis of rhythmic crystallization as the result of changed critical conditions, since the mica of the two zones is formed in entirely different chemical environments. Or why should mica development appear to be inhibited in one zone of crystallization where it is normally found and yet crystallize in another later-formed zone? An explanation on the basis of the phase rule may be sought but this encounters difficulties. The most logical and simplest explanation would appear to be that the mica in these two zones is from different sources, one metamorphic and the other magmatic, but formed by replacement.

The time of arrival of the material at the site of crystallization influences the structure. If all the material from both sources arrives at the same time, the effect will be of crystallization in a closed system. If the material from an igneous source is later than the crystallization of the wall zone mica, which is presumed to be of metamorphic origin, then a second mica shoot may crystallize and various replacements may be effected.

The telescoping of zones, producing in some pegmatites the almost complete jumbling up of all the minerals present into a somewhat homogeneous body, is in many instances clearly not the result of external movement during crystallization. A pegmatite might be homogeneous up to a point, and still show some traces of incipient zoning. Such pegmatites may contain large perfectly flat books of muscovite (e.g. Lynx Mine) in spite of their confused appearance, which suggests that multiple injection, possibly together with some convection, is the cause of the disrupted zoning. Perhaps in some such conditions, metamorphic or metasomatically derived material may arrive after the first injection of igneous material. Many possible variations suggest themselves.

In all zoned pegmatites, crystallization clearly starts on the margins of a pegmatite and extends inwards. The orientation of mica books and occasionally of beryl and tourmaline crystals supports this view. It suggests that growth has taken place in the direction of the increasing thermal gradient and that for this part of the crystallization, at any rate, the system has been a closed one.

The Karnie Mine North Reef pegmatite suggests that crystallization of the mica has taken place in an open system. The pegmatite which was unzoned, averaged about 18 in. in width and yet books of mica were extracted which measured as much as 4 in. in thickness and 17 x 24 in. along the plane of the cleavage. For such large books to grow in such a narrow pegmatite they had to lie with their cleavage planes in the plane of the pegmatite which is an orientation at right angles to that normally found in zoned pegmatites. So orientated they were able to grow in the direction of migration of material.

It would appear from what has been said that pegmatites can be found which exhibit crystallization under three different sets of conditions; a closed system, one allowing multiple injection of material, and an open system.

One of the most significant factors supporting the formation of zones by fractional crystallization in "a restricted system" according to Cameron *et al* (26) "is the fact that material of an inner zone may extend outward along fractures into an outer zone or even beyond it into the wall rock, whereas the reverse is not true". In two instances in the Urungwe District (Mica View and Locust mines) evidence was found which, if not contradicting the above statement, at least supports the contention that material from two sources is present in the average complex mica-pegmatite. In the two pegmatites, fracture fillings in the core zone were composed of a mica-quartz-plagioclase-pegmatite similar to that found in the outer zones. One of these veins even showed a mica concentration on one wall similar to that in the main wall zone

PLATE XIV



A. Basal view of muscovite crystal. Seven-tenths natural scale.

Photo: H.J.C.



B. Prismatic view of same muscovite crystal A, showing bending as a result of forces set up by replacement of the albite matrix by microcline.

Photo: H.J.C.



pegmatite. Owing to the nature of the mining operations it was not possible to trace these fracture fillings beyond the core. It is conceivable that the pegmatite as a whole is cut by such veins and that the material is of extraneous origin. It will be remembered that pegmatite material of essentially the same composition was found filling tension cracks in an amphibolite (Fig. 7) and the inference is that such pegmatitic material was available locally within the metamorphic rocks for secretion into suitable structures.

The wall zone material of some pegmatites, consisting of mica-quartz-plagioclase, has been found, on occasion, to extend as narrow longitudinal veins well beyond the main mass of pegmatite. The absence here of microcline or perthite, which occurs in the core or core margin of the body, suggests that there was never a homogeneous mass of pegmatite filling the structure, and which crystallized in a closed system. Rather, it would seem, was there injected material from two sources, with a potash-rich fraction, presumably magmatic, arriving later than the material of the veins.

The difference in habit between mica which crystallizes in a plagioclase matrix and that which crystallizes in a microcline or perthite matrix has already been discussed. If then, as was found in a prospect near the Piper Mine, there is a rich wall zone mica shoot in a matrix of potash feldspar in which the books, though badly broken or bent and interleaved (Plate XIV) have nevertheless had marked pseudo-hexagonal or rhombic outlines, it can be assumed that crystallization took place in a base of plagioclase and that this feldspar was later completely replaced by microcline. This could take place in a normal sequence of events with the residual potash-rich liquor replacing the already crystalline outer zones. It is unusual and suggests that hot potash solutions arrived late and were presumably more chemically active than a normal potash-rich residuum which had crystallized in a closed system. It is believed that the breaking up or buckling of the mica books under such circumstances is due to an increase in volume of the pegmatite. Potash has almost twice the atomic radius of soda and replacement of the latter in the feldspar molecule must cause expansion with consequent stresses and strains.

More common than the wholesale replacement of one feldspar by another is a local replacement or displacement caused by the dilatation of the quartz-microcline core zone whereby an outer mica-quartz-albite zone is locally interrupted and core material reaches to the walls.

Beryl and its associated minerals so frequently occur with a microcline-quartz assemblage and economic block mica with plagioclase that it is suggested that the mica-albite-pegmatite is mainly of metamorphic or metasomatic origin whereas the potash-rich assemblage is of igneous origin. This may be a bold statement and there are unquestionable exceptions, but evidence has been given in support of this contention both in this section on pegmatites and in the description of the metamorphic rocks.

Finally, the nature of the fracture may control the amount of metamorphic substance drawn in. A shallow fracture, of whatever character, may be filled entirely with metamorphic material, whereas a deep

fracture may contain a high percentage of igneous matter. Under certain conditions, therefore, a tension fracture is likely to contain more material from a metamorphic source than a tight shear containing forcibly injected igneous matter. This contention is borne out by the Karnie pegmatites which are described in the mining section (see Fig. 15).

#### MINOR BASIC INTRUSIONS

These rocks, which occur throughout the area, and have been variously affected by the metamorphism, fall into two distinct groups as follows:

- (i) The meta-dolerites which are post-kinematic but have been affected by the dying metamorphism. Temperatures were still sufficiently high in the area in which they are found to cause appreciable acceleration of retrograde stages but not of sufficient duration to allow too complete a breakdown.
- (ii) An older group which are pre-metamorphism in age and have suffered changes commensurate with the grade of metamorphism of the area in which they occur. The majority of these rocks may be classified as epidiorite.

The *meta-dolerites* form dykes intrusive into the para-gneisses in the vicinity of the western group of mica mines. They follow the same structural trends as the epidiorites.

The intense clouding of the feldspars and the abundance or schiller inclusions of magnetite in the pyroxene, together with the abundance of biotite and hornblende, has made most of these rocks quite black. For the size of the dykes they are rather coarse grained, which has resulted from their slower than normal cooling due to the relatively high temperature of the rocks into which they were intruded.

They vary in the proportions of their felsic and mafic contents, and some have appreciable hortonolite. The original doleritic texture remains, but corona structures are a conspicuous feature around the mafic minerals which have not been completely replaced to form mixed mineral aggregates. All have developed varying amounts of secondary garnet.

The abundance of magnetite, together with the unusual presence of hortonolite in some of these small dykes, suggest that they are a late differentiate of some large body of mafic magma.

Two representative slides are worth brief descriptions. One (16271), prepared from a specimen collected 150 yards north of the southernmost beacon of Rekomitje "A" Farm, contains garnets and yet the clouded andesine crystals still exhibit their original form but occasional crystals show reaction embayments. The clouding serves to show up zoning by being more intense in the calcic cores while the margins are often clear. This is most conspicuous in the slide (16283) from a dyke near the Ruby Mica Mine. Much of the original pyroxene, which was augite, has been extensively replaced and recrystallized. The relict pyroxene is almost black due to the abundance of "schiller" inclusions of magnetite and it has coronas of hornblende and biotite with the

latter clearly a replacement of the former. This replacement is patchy and in some parts of the slide there are concentrations of biotite. One irregular sieve-textured crystal of biotite measured 1.5 millimetres in length. Small granular garnets are present in various parts of the section and are the product of interaction between the plagioclase and mafic constituents. This garnet is presumably similar in composition to the corona lime-rich garnet described in some of the calc-silicate rocks from this area.

Where all original pyroxene has completely disappeared there are mafic aggregates in which the constituent minerals, formed as a result of the breakdown of the pyroxene and contributed to by some of the plagioclase, are hornblende, biotite, epidote, vesuvianite, garnet and magnetite. The magnetite which forms fairly large irregular masses towards the middle of each aggregate, is the coagulated product of the schiller inclusions so conspicuous in the original pyroxene. Apatite is quite abundant as prisms up to 0.6 millimetres.

A slide (16272) is from a specimen collected from a dyke a mile south-south-east of the Grand Parade trigonometrical beacon and a mile west of the main North Road. The rock is coarser and darker than that previously described, in spite of the fact that it carries more abundant plagioclase. As a whole it shows less alteration though it occurs in the same environment. This may be a result of its larger dimensions and the position of the specimen selected.

The pyroxene is almost again black due to the abundance of "schiller" inclusions but has little or no corona development, although a crystal or two have completely altered to biotite with a core of magnetite. There is as much hornblende as pyroxene and the former has narrow double coronas consisting of an inner colourless antigorite and an outer green chlorite. Some of this chlorite has been altered to biotite. There is a very small development, in part incipient, of tiny garnet granules and an almost equally small amount of epidote.

The plagioclase is very much like that in the first slide but at one or two places there is a little very inconspicuous, patchy replacement of the turbid plagioclase by a clear and more sodic felspar. Bordering the mafic constituents, but included in the plagioclase, are small replacing vermicular clusters of a mineral with a high refractive index which is presumably garnet. Their apparent anisotropic character is due to their small size which permits them to occupy different levels in the plagioclase which latter produces interference colours. There is an appreciable amount of apatite with the mafic minerals.

R. Tyndale-Biscoe collected a number of specimens from these dykes in 1943 (see page 6). Those that were sectioned appear in the Southern Rhodesia Geological Survey slide collection as Nos. 10425, 10426, 10440, 10443 and 10444.

The *older basic intrusives* occur as both dykes and sills throughout the area mapped, and range from epidiorites through amphibolites to hornblende-gneiss. Then they finally lose their identity on conversion to biotite-gneiss in the areas of extensive metasomatism. The more altered types are indistinguishable from similar products derived from meta-amphibolites.



In the extreme north-east of the area there are a number of sills which serve to show up the nature of the folding in the schists. One such sill occupies the centre portion of Masterpiece Farm.

In the phyllites the dykes have suffered little or no change of texture, and are not far removed from meta-dolerites. They have clearly been derived from quartz-dolerites. The plagioclase is so highly saussuritized as to be indeterminable but has not lost its original form and the interstitial quartz is still undisturbed. The pyroxenes have gone completely but their original form is sometimes suggested by vague coronas of hornblende. In the centre of such coronas is a conglomeration of epidote, hornblende and ilmenite. Ilmenite is also scattered throughout the rock. Apatite is quite abundant in some of the dykes.

Progressive metamorphic changes result in some recrystallization of part of the very turbid original plagioclase to a clear albite-oligoclase with which aggregates of epidote are associated. Brown biotite sometimes makes its appearance in appreciable amount as a replacement of hornblende.

In the almandine zone more extensive recrystallization occurs, resulting in almost complete destruction of all original forms and texture. Most of the feldspar is a clear, secondary, sodic plagioclase.

In the staurolite-kyanite zone one of the dyke rocks (Slide 16284) collected was a poikiloblastic amphibolite with hornblende crystals an inch long. The groundmass is composed of granular, untwinned or inconspicuously twinned, clear oligoclase and some quartz. Abundant prismatic hornblende crystals have a parallel arrangement. There is also an aggregate of sphene crystals.

Similar types of rock in the same zone are often fine grained and non-porphyroblastic.

As the higher grades of metamorphism, with attendant metasomatism, were attained, these basic rocks underwent changes similar to those of the para-amphibolite and more basic calc-silicate rocks already described.

## STRUCTURE

The structure of the area is not simple but a general picture will have been gained from what has been written in the previous sections.

Late Precambrian orogeny resulted in a synkinematic metamorphism in which predominantly argillaceous sediments attained various degrees of alteration, resulting in the development of phyllites, mica-schists, sillimanite-para-gneiss, granitic para-gneiss and para-granites. A structural continuity has been found to exist between the metamorphic rocks and the synkinematic granites, thus indicating their metamorphic replacement origin. The late-kinematic granites, on the other hand, show strong evidence of forcible intrusion and have locally influenced the dip and strike of the metamorphic rocks.

Isostatic readjustment initiated an erosion cycle and in the ensuing eras the region retained a certain mobility. Periodic subsidence caused relatively shallow, possibly landlocked, basins of deposition to form,

in which the Lomagundi, Sijarira, Karroo and probably Cretaceous rocks were deposited, in that order, and subsequently removed by erosion.

The north-east-trending regional faults are tension fractures which have been operative throughout this period, with the latest movements taking place in post-Karoo times. It was movements along this system of faults which gave rise to the Middle Zambezi Valley. Gair (29) has called this structure "a huge asymmetrical faulted syncline floored with Karroo rocks and lying about 2,000 ft. below the main Rhodesian Plateau". He also mentions that it has been referred to as a rift valley.

A southerly pitch of the various metamorphic zones is revealed by the plotted isograds which are shown on the map at the end of this bulletin. These indicate that uplift has taken place along the zone now occupied by the Middle Zambezi Valley. This uplift produced the tension necessary to initiate trough faulting. Subsidence was clearly going on in Karroo times to allow the thick accumulations of sediments there. Lambert (30) has drawn attention to the increase in metamorphism of the Lower Katanga rocks towards the Zambezi on the Northern Rhodesian side of the Valley. He states further that "the mid-Zambezi and Luangwa valleys can be demonstrated to be along a north-east-trending upwarp." He dates the beginning of this uplift as late Precambrian.

In late Precambrian to early Paleozoic times, nappe-thrusting took place from the east and was initiated in the area of Graphitic Slates of the Piriwiri System which lie approximately along the line of the Angwa River. This caused rocks of a lower grade of metamorphism to come to rest on high-grade gneisses farther west. In most instances the gneiss is representative of the high-grade metamorphic product of the overlying *klippe*.

It seems likely that an unconformity exists between the undoubted Piriwiri rocks and the amphibolite and its metasomatically derived product the biotite-gneiss. The solution to this problem lies outside the area of the map, where these rocks have a wide distribution. The porphyroblastic biotite-gneiss, which is exposed in the extreme west of the area, constitutes the main rock type at the Kariba Dam.

The picture which emerges is that of a dissected peneplain on which are displayed the truncated roots of the pre-Cambrian mountains. Before the later intrusion of the granite the axes of all the folds were parallel with a north to south strike. This resulted in a series of tight, inclined, isoclinal overfolds with generally steep westerly dips. Attitudes have become rather "wild" in the granitic para-gneisses due to the effects of plastic flow.

In the schists and phyllites the bedding planes are usually in correspondence with the foliation directions but there are exceptions which have been mentioned. When examined in the field the rocks show much evidence of lineation which, together with the dips and strikes of fracture cleavages, so conspicuous in the narrow, interbedded arenaceous bands, reveal the direction of pitch of the folds. These directional trends are often confirmed by strong lines of puckering in the mica-schists.

The continued activity along the main north-east-trending fault direction over many hundreds of millions of years is borne out to some extent by the basic dykes. Those which are clearly of pre-metamorphic age occupy certain directions which have been followed by the later meta-dolerites intruded during the dying phase of the metamorphism. While the many thousands of pegmatites in the main mica and beryl areas include some having random orientation controlled only by purely local structures, the majority are controlled by the two major structures, namely the foliation directions of the schists and gneiss and a direction of faulting related to the main regional trend.



## Part II — ECONOMIC GEOLOGY

### INTRODUCTION

A BRIEF HISTORY of the early days on the Mica-field has been given in the introduction to Part I of this bulletin.

The Miami and Phoenix mines were in production in 1919 and in the following year there were 14 working mines.

An exception to the early run of pegmatites was the Grand Parade, first pegged by Small, which was so rich that in spite of ignorance and poor mining practice it was a highly profitable proposition. It produced "ruby" mica and has probably been one of the richest mica mines in the world. The claims were taken over by J. Goldberg, a leading hotel-keeper in Salisbury, who went to live on the mine and opened a store there. It was not long before the improvident local miners were bartering mica for goods. The London buyers soon expressed dissatisfaction over some of the outside mica which was introduced under the name of Grand Parade. The mine finally struck a water fissure and did not survive the slump of the 1930's. However, it was reopened a year or so later and continued in production for many years.

During the slump, mica mining was brought to a virtual standstill, though a few mines struggled along.

World War II and the strategic value of mica led to a revival of interest in the Field, but now the miners were no longer left to their own devices. The Government took an active interest and qualified technical assistance was made available to advise on both the mining and the marketing of the product. Mica is a mineral ideally suited to "small-working", but it was the marketing that always caused the difficulties, and it would seem, in so far as Southern Rhodesia is concerned, that the market has usually been a buyer's one, and producers had to contend with more cheaply produced Indian mica.

By the end of the war few operators remained and in the following years the majority of the mines and claims of any consequence became the property of G. Paterson & Sons. In 1955 Paterson sold out to F. F. Chrestien & Company, the world's leading mica buyers, who formed a subsidiary mining company known as the Rhodesia Mica Mining Company Limited. The advent of new capital on the Field, combined with the high prices being paid for mica, gave a temporary stimulus to mica mining. No new discoveries were made and activities were confined to reopening old properties; some proved satisfactory but the mica qualities were on the whole inferior. Their scattered locations and the small sizes of the pegmatites, coupled with the rising costs of production began to make it appear that the venture was not altogether an ideal one for the company scale of operations. Ruby mica was fetching very high prices but the company's ruby-bearing pegmatites were apparently all exhausted.

In 1957 the Company decided on a policy of somewhat drastic retrenchment. The labour staff was cut and much equipment disposed of by public auction.

Soon only two of the Company's mines remained in operation and it was decided that these should again be made to operate on a "small-working" basis, paying their own way.

During this time the amount of mica being produced from other sources within the area of the bulletin was of little or no consequence.

Before the end of 1958 all the Company's properties in the district had ceased production and in April, 1959, they decided to discontinue all mining activity in Africa. The company had by this time become incorporated in Associated Electrical Industries Limited, so that once again their F. F. Chrestien Rhodesian interests became confined to mineral buying. Rhodesia Mica Mines Limited were dissolved in October, 1959.

Early in 1959, owing to the establishment of a new mica buyer, the New Africa Mica Company Limited, with an office and cutting-shed in Salisbury, a stimulus was given to mica mining. The activity of this company, which was incorporated in Tanganyika, was short lived and it virtually ceased activities in Southern Rhodesia in April, 1959, as it was felt that the cost of maintaining an office and staff was not justified by the small amount of mica coming in for cutting and grading. The Company, whose head offices are in the United States of America, hoped to encourage producers to ship their sheet mica direct to them there. It would seem, however, that F. F. Chrestien & Company are once again to enjoy the monopoly of mica buying in Southern Rhodesia, at least in so far as the "small man" is concerned since he cannot afford to wait for his money.

Suitable African "miners" are being assisted and encouraged by F. F. Chrestien & Company to glean mica from the old workings and claims held by the Company. For a time this will bring in a little mica but it is a system which will never realize any potential the Field may yet have.

It must be borne in mind that this survey was undertaken long after the "hey-day" of mica mining when the great majority of the mines were already closed and inaccessible. What there was to be seen of many pegmatites on surface or in shallow prospect workings raised questions that could only have been answered by reopening them. Many of the mines, too, had been closed without reports or plans, so that frequently the structure of the pegmatites could only be presumed from the nature of the material on waste rock dumps and an occasional poor exposure.

Because of the usual patchy nature of the mica mineralization it should be noted that mining levels average about 50 ft. apart on the incline.

The early miners and prospectors were not familiar with the relationship of economic mica to the zoning and composition of the pegmatite, so that in some instances much useless work was done while in others it was inconclusive. Some pegmatites were abandoned because the mica was found to be buckled and striated, but frequently such work was confined to the core zone where these features are normal, whereas the interesting wall zones often remained unprospected.

Of interest to future prospectors will be the fact that two pegmatites which were unpayable at surface were opened up to form the valuable mines known as the Grand Parade South Prospect and the Sunspot. Work on other pegmatites, which include the Catkin and Locust mines, proved the occurrence of disconnected mica shoots. On the Dunga Mine there were two shoots connected by only a very small mica-bearing zone (Plate X). On the Hendren VI pegmatite a small, but rich, sub-outcropping mica shoot was found purely by chance long after the pegmatite had been mined for its beryl content.

These few examples serve to suggest that, in the past, many pegmatite workings may have been prematurely abandoned. In recent years by far the greater percentage of mica from the Urungwe district and elsewhere in Southern Rhodesia has come from the mines which have been successfully reopened. Price increases and the demand for smaller sizes of all qualities of mica might make it possible to reopen mines which were at one time proved uneconomic. Prejudice against spotted mica in the past has led to some rich pegmatites being poorly exploited with only the larger books being extracted. Poor mining practices also led to the closing of some workings which were still in good mica.

Not one of the mines is deep by Indian standards and none has reached a vertical depth exceeding 450 feet. On a number of mines, of which the Grand Parade and Last Hope are particularly noteworthy examples, the pegmatites continue strongly below the lowest workings where the mica shoots were bottomed, so that it would seem that if suitable structures exist, further shoots must occur in depth. Where such pegmatites yielded a high quality mica a drilling programme is clearly justifiable. Although the size of mica books cannot be determined in this way the structure and composition of zones may be obtained and this may prove a valuable guide.

Detailed pegmatite investigations have been carried out in many parts of the world, chiefly since the cessation of the major mica mining activity in the district. There is thus a wealth of information to draw on should sufficient stimulus be provided for further exploration of the Field.

During the mining of mica, beryl was also found. Mention of beryl was made in 1923 in a report on the Grand Parade Mine. At first it was regarded on the Field merely as a curiosity, some of the more attractive and well-formed crystals finding occasional use as door-stops or book-ends. The bulk of the crystals were discarded with the rock waste. When, therefore, following the discovery of beryl on the Bikita Tin Fields in 1949, and its demand as an ore of beryllium, there was a minor beryl "rush" to the Mica Field directed firstly at the old mica mines.

In recent years beryl production has also greatly decreased. The fall-off in the number of producers has been occasioned more by the low price of the ore than by a depletion of reserves. Many of the so-called beryl mines were little more than shallow rubble workings. Production ceased in many cases when it became necessary to excavate or to do any "dead" work. The patchy nature of many of the deposits has not



improved matters. It has been a rule, too, that unless beryl is found in the rubble or in the outcrop, not to touch even promising looking pegmatites.

A number of interesting minerals found in the pegmatites of the Urungwe district have been listed on page 92. However, the only other mineral, apart from mica and beryl, which is present in economic quantities in the pegmatites is colombo-tantalite, often radioactive, which is obtained as a by-product of beryl mining.

Early in 1952 wolframite was discovered on three of the "K" farms (farms allocated under a Land Settlement Scheme for ex-Servicemen) situated some 12 miles east of Karoi Township. The farms are Moniak (K.64), Garahanga (K.65) and Moyale (K.70). The discovery naturally caused much excitement among the local farmers who rushed to prospect and peg large areas of their farms. The mineral was found in small amount on some neighbouring farms and on Crown land (see Plate XVII) but the main occurrence was found to be on Garahanga Farm where numerous blocks of claims known as "Honey" were staked. The mineral occurrences which are all related to a single structural unit, were generally known as the Honey Wolfram Belt by the syndicate which was later formed to work them systematically and get the best possible extraction. The economic deposits were largely eluvial and the calculated tenor of the rubble was not realized by extraction, and mining operations ceased in 1957.

The values of declared mineral outputs from within the boundaries of the map accompanying this bulletin is summarized below.

| <i>Mineral</i>              | <i>Value<br/>£</i> |
|-----------------------------|--------------------|
| Mica . . . . .              | 1,112,136          |
| Beryl . . . . .             | 141,897            |
| Wolfram . . . . .           | 33,211             |
| Tantalo-columbite . . . . . | 1,111              |
| Gold . . . . .              | 794                |
| Graphite . . . . .          | 406                |
| TOTAL . . . . .             | <u>£1,289,555</u>  |

## MICA MINING

Because of the possibility of faulting, or the sudden disappearance of economic mica from a pegmatite, it became a well-founded rule to develop a pegmatite by following the mica down and not to do initial regular development, such as vertical shaft sinking, until the extent of payable mica was known. Usually, as much mica as possible was first extracted by opencast methods. In many of the small mines stoping and development went on hand in hand.

Inexperience or lack of capital, combined with the difficult nature of some of the mica-schists or occasionally highly decomposed pegmatite, led to the loss of mica and forced closing due to collapsed or dangerous ground. Wherever possible, much use was made of local timber. Experience showed that wall-rocks were more difficult to

support when the pegmatites were concordant than when they were discordant and for this reason the latter type were preferred, though the value of the mineralization is not dependent on the structural relationship of the pegmatite to the country-rock.

On the larger mines, when stoping commenced the waste was packed underground and a layer of thatching-grass was spread over it before each blast to act as a marker so that no unnecessary sorting of waste resulted after the blast. It is usual for the mica to break away cleanly from the enclosing rock on blasting. The large books which are exposed, but remain in position on the walls or in the face, are carefully prized out to avoid damage (Plate I).

In the early days most of the development was done with the aid of "hammer-boys", but the advent of portable compressors made it possible to use light jack-hammers even in rugged country. A coal-drill was successfully used in some highly decomposed pegmatites, as at the Akata Mine for example. Drilling through large books of mica is both difficult and wasteful and holes are pointed, as far as possible, to avoid this. To reduce the possibility of blasting damage to the mica, 40 to 60 per cent. ammon dynamite was used by the Rhodesia Mica Mining Co. Ltd. In addition gelignite primers, standard Brickford fuse and aluminium detonators were employed.

It is by no means an easy matter to assess the value of mica in a pegmatite. Owing to the tendency to remove, if it can be done without damage to the books, whatever mica is exposed along the drives and in the face after a blast, a valuable pegmatite may not reveal much in the drives. It is necessary, however, to keep records of some sort and it is normally a good rule that production from development should cover the development working costs. An effective and rather simple plan was worked out by the mine management of the Rhodesia Mica Mining Co., which provided figures for insertion on the mine plans so that they took on somewhat the appearance of gold-mine assay plans. These figures gave the average weight of cut mica per foot advance, taken over 15 feet. In this way, concentrations of mica or the position of shoots could be readily detected. This method also helps to eliminate the possibility of a false assessment being made in sections where there may be concentrations of imperfect mica.

#### MUSCOVITE

In the section on pegmatites on page 88 certain imperfections in muscovite have been considered. These were primarily the physical effects of environment which result either in so damaging the mica that it is of no use for sheet purposes or reducing the maximum sizes which can be cut from a book. It is intended here to mention other physical characteristics of muscovite which do not affect its property of free splitting. The habit of well-formed mica books is illustrated in Plate XI, but in most pegmatites where large books of cuttable mica are found, all gradations may be seen between those with crystal forms and those with very irregular outlines.

Mica differs from most minerals mined in that its value for sheet mica depends entirely on its physical characteristics.

Owing to its eminent basal cleavage, when undistorted, the mica splits readily into thin flexible and elastic lamellae of uniform thickness, or films of less than 0.001 in. which are often perfectly flat. Good books of mica, even when they can be measured in feet, may yield perfect reflections on fresh cleavage surfaces, and objects viewed through the splittings show no sign of distortion. Any departures from this perfect physical state, and they are common, reduce its quality and market value. The fact that so much of each and every book is damaged in some way, accounts for the relatively low percentage which can be cut into sheets. Whenever books are split and cut into sheet mica, therefore, there are always large accumulations of waste which can be used for stamping into washers or processed in some way.

### *Inclusions*

The actual physical inclusion of pegmatite minerals in the mica books is commoner in some pegmatites than in others. These minerals are often physically buried in the mica during its growth so that when the books are split many holes may appear in the sheets. Quartz may occur in crystal form or as plates forming "windows" in the splittings. Tourmaline crystals are frequently flattened and orientated in several directions parallel to the crystallographic directions of the mica. This is well illustrated in a book from the Rae Mine which is reproduced as Plate XV. Biotite is often intimately intergrown with the muscovite and appears to be common in ruby mica. Crystals of muscovite may be found in biotite or vice versa. A thin mica splitting may be composed partly of muscovite and partly of biotite revealing a change in composition of the mica during its growth.

### *Spotting*

Muscovite may be clear or marked by small inclusions to a varying degree. Those producing spotting are of a very thin platy character and occur in the thin mica foliae. They do not cause perforation or reduce the cuttable size of the mica but merely affect its quality. Such mica is known as spotted. Black spots are due to magnetite or haematite and they may be so numerous that the mica becomes almost black. Red spotting, which results in an inferior quality softer mica, is due to haematite or goethite.

The iron oxide inclusions often have a very interesting appearance. Individual specks may have an hexagonal or rhombic form related to the symmetry of the mica. Sometimes the specks have a regular skeletal to dendritic appearance with the numerous branches orientated parallel to the rays of the percussion figure of mica. The density of spotting may vary along the different planes of cleavage so that it is sometimes possible to obtain lightly spotted or even clear sheets and films from a quite densely spotted book. In addition to the forms of the individual specks, the inclusions as a whole may be arranged in geometrical patterns conforming to the traces of the crystal faces or axes. These lines of inclusions cross in three directions in the plane of the cleavage and have an hexagonal symmetry which gives the mica a tartan-like appearance. On occasion a book of mica has grown to fair size before spotting has taken place so that there has developed a clear hexagonal centre portion between the orientated rows of inclusions.



PLATE XV



Orientated flattened tourmaline crystals in muscovite books from the Rae Mine. Four-tenths natural scale.

Spotting is sometimes caused by tiny streaks or scales of biotite which may be black or shades of brown. These may appear as spots, mottling, or a very regular, closely spaced ruling having the mica symmetry. In effect this produces a crystal zoning like that of the iron oxides already mentioned.

### Stains

Apart from spotting, the colour of otherwise clear mica is spoiled by staining which may be of either primary or secondary origin. The former is found at any depth and the latter at or near the surface.

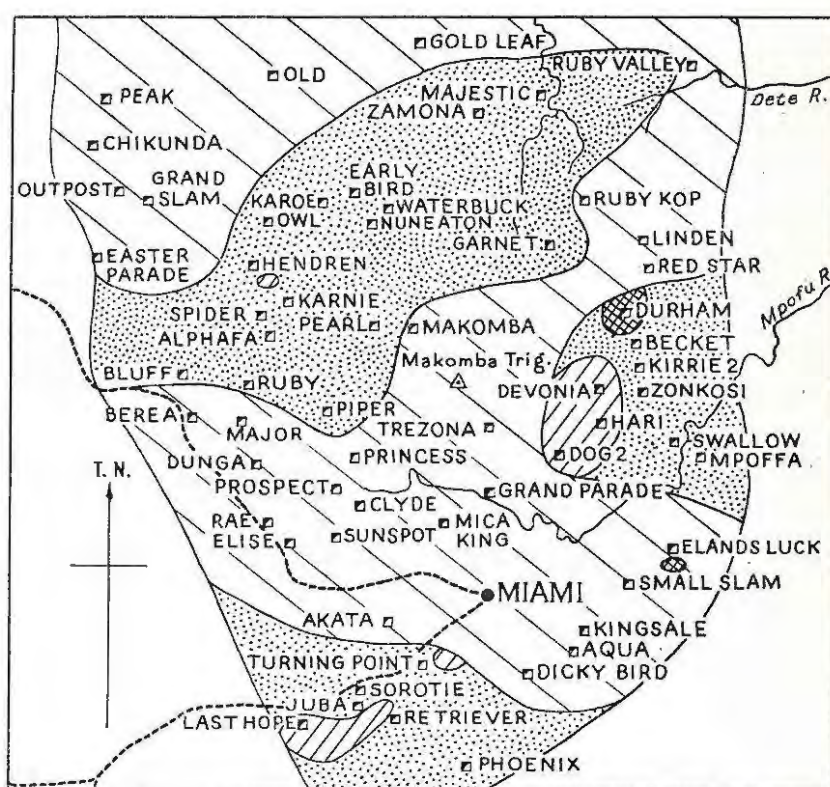
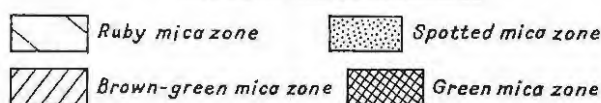


Fig.12. Distribution of mica qualities on the main Miami Mica Field

### Explanation



Scale 1:250,000

Primary stains appear as small, green or reddish-brown spots which on the Miami Mica Field are referred to as "sunspots". These are apparently haloes surrounding radioactive specks. Tiny bubbles of air or gas can produce a stained effect. Tiny scales of biotite or chlorite produce a green stain which, because of its colour, is referred to as a "vegetable stain".

Secondary stains may be due to mud, iron or manganese oxides, true vegetable matter or air creep. Air creep is due to air which enters the sheet from the edge and is often caused by trimming the mica with dull or blunt shears. This defect can sometimes be removed by squeezing or careful splitting.

*Colour* is a property which greatly affects the marketability of mica. The best prices are paid for ruby-coloured mica, though mica of another colour may have the same dielectric properties. The reason is that it is not possible to test each piece of mica purchased, and while mica of one colour may be as good as another, ruby mica maintains a high consistency while other colours are often variable.

On the Miami Mica Field mica is classified under four main colour headings as follows: (a) Ruby; (b) Green; (c) Brown-green, and (d) Spotted.

The spotted mica may be of any colour and a pegmatite which carries spotted mica may also yield a percentage of clear mica. The Catkin Mine, for instance, is reported to have yielded spotted, brown-green and ruby qualities.

The distribution of the various qualities of mica on the main Miami Mica Field is illustrated in Fig. 12.

In actual practice muscovite occurs in great variety of colours and in the South-eastern United States more than 75 different colours were identified.

#### MICA PREPARATION

The preparation of mica in the sheds has changed little in the last 40 or more years. The equipment is simple but mica requires repeated handling. Grading which is a visual art requires a great deal of training and experience.

Each of the four main colour groups is divided into a number of qualities and each quality into as many as 12 or 13 sizes depending on how large the sheets are, and how small a size is saleable. There are more than 200 categories into which the mica can be sorted.

A table of classifications and prices per pound of mica is given below. While the prices are subject to change, the relative prices of the different grades and qualities is likely to remain unaltered and they are therefore given as a guide.



# TABLE OF CLASSIFICATIONS AND PRICES

F. F. Chrestien & Co. Ltd.

## PURCHASE RATES FOR MICA DELIVERED GRAND PARADE DEPOT, MIAMI

Effective from 1st January, 1960

### RUBY

| Grade        | C.S.S. | F.S.  | G.S.  | S. "A" | S. "B" | H.S. | D.S. |
|--------------|--------|-------|-------|--------|--------|------|------|
| OOXX Special | 356/-  | 327/- | 251/- | 190/-  | 121/-  | 72/- | 46/- |
| OOX Special  | 327/-  | 285/- | 213/- | 161/-  | 107/-  | 62/- | 42/- |
| XX Special   | 285/-  | 237/- | 180/- | 133/-  | 92/-   | 52/- | 36/- |
| X Special    | 237/-  | 204/- | 150/- | 111/-  | 76/-   | 45/- | 30/- |
| Special      | 194/-  | 175/- | 138/- | 93/-   | 60/-   | 36/- | 27/6 |
| No. 1        | 166/-  | 135/- | 104/- | 62/-   | 41/-   | 24/- | 17/3 |
| 2            | 138/-  | 114/- | 86/-  | 42/6   | 29/6   | 18/- | 12/- |
| 3            | 124/6  | 101/3 | 71/3  | 36/3   | 20/9   | 12/- | 8/6  |
| 4            | 104/-  | 81/3  | 58/9  | 30/3   | 18/-   | 9/3  | 6/6  |
| 5            | 66/6   | 53/6  | 39/9  | 24/-   | 14/9   | 6/6  | 4/-  |
| 5½           | 41/6   | 36/3  | 29/3  | 16/6   | 10/3   | 4/-  | 2/9  |
| 6            | 19/9   | 18/-  | 15/6  | 9/-    | 5/9    | 2/9  | 1/-  |

### BROWN/GREEN AND SPOTTED

| Grade        | B/G<br>1st Q. | B/G<br>2nd Q. | Sptd.<br>1st Q. | Sptd.<br>2nd Q. | Sptd.<br>3rd Q. | Sptd.<br>3rd INF |
|--------------|---------------|---------------|-----------------|-----------------|-----------------|------------------|
| OOXX Special | 249/6         | 180/-         | 26/-            | 22/6            | 20/-            | 16/3             |
| OOX Special  | 225/3         | 145/6         | 24/-            | 20/-            | 17/6            | 14/6             |
| XX Special   | 201/-         | 107/6         | 22/-            | 17/6            | 15/-            | 13/-             |
| X Special    | 164/9         | 72/9          | 19/6            | 15/-            | 13/9            | 11/6             |
| Special      | 119/9         | 52/-          | 17/6            | 13/6            | 12/-            | 11/-             |
| No. 1        | 80/-          | 38/-          | 15/3            | 12/3            | 10/-            | 10/-             |
| 2            | 69/3          | 29/7          | 13/9            | 10/9            | 9/3             | 9/3              |
| 3            | 59/-          | 20/9          | 12/-            | 10/-            | 8/-             | 8/-              |
| 4            | 48/6          | 17/3          | 10/-            | 8/4             | 6/-             | 6/-              |
| 5            | 31/-          | 13/9          | 5/6             | 4/3             | 3/-             | 2/10             |
| 5½           | 22/6          | 11/-          | 3/9             | 2/9             | 2/-             | 1/9              |
| 6            | 11/-          | 6/3           | 1/9             | 1/4             | 11/-            | -/8              |

### THINS

| Grade        | F.S. | G.S. and<br>Brown/Green | Spotted<br>Thick | Thin |
|--------------|------|-------------------------|------------------|------|
| OOXX Special | 24/- | 20/6                    | 6/9              | 6/1  |
| OOX Special  | 24/- | 20/6                    | 6/9              | 6/1  |
| XX Special   | 24/- | 20/6                    | 6/9              | 6/1  |
| X Special    | 24/- | 20/6                    | 6/9              | 6/1  |
| Special      | 24/- | 20/6                    | 6/9              | 6/1  |
| No. 1        | 22/6 | 18/9                    | 6/2              | 5/6  |
| 2            | 19/- | 16/2                    | 5/6              | 4/11 |
| 3            | 15/8 | 13/3                    | 4/9              | 4/3  |
| 4            | 12/- | 10/4                    | 2/-              | 1/9  |
| 5            | 9/-  | 7/7                     | -/10             | —    |
| 5½           | 6/3  | 5/-                     | —                | —    |
| 6            | 3/6  | 2/11                    | —                | —    |

Subject to Alteration Without Notice

Red Spotted valued at 10 per cent. below Standard 3rd. Q. price.

Clear/Green 1st Q. valued at 15 per cent. below Brown/Green 1st Q. price.

Clear/Green 2nd Q. valued at 15 per cent. below Brown/Green 2nd Q. price.

Explanation — For grades see gradeograph in folder at the end.

C.S.S. = Clear and slightly stained. F.S. = Fair stained. G.S. = Good stained.

S. "A". = Stained "A". S. "B". = Stained "B". H.S. = Heavy stained. D.S. =

Dense stained. Thins = sheets having a thickness of less than 0.008 in.



Africans. The method of preparation can best be followed by reference to the flow diagram. (Shown in this bulletin as Fig. 13.)

"Splitting" or "rifling" is a straightforward operation carried out with a knife blade or flattened wire nail. Sheets having a thickness of less than 0.008 in. and known as films or thins are treated separately.

"Marking" requires considerable experience, and the marker is always the most skilled member of the team.

"Cutting" or "trimming" is done with 15-inch shears having one handle mounted in a heavy wooden block. For ruby mica, sickle trimming is sometimes adopted. This method, traditional in Bihar, has certain advantages in that blemishes can be cut out on a curve, so leaving a greater area. Some users prefer the chamfered edge which results from the sickle cut.

"Cleaning" also involves sorting into qualities; the ability to differentiate between the various specifications demanded by the buyers comes only with long practice. One or two pin-head specks, barely visible, may reduce a sheet by one or two qualities. The classification is by colour, clearness, degree and type of staining, hardness and flatness.

The mica is sorted into grades or sizes by checking each piece against a standard template which is known as an Indian gradeograph. A copy appears in the folder at the end.

The final product is carefully packed in wooden boxes lined with heavy waterproof "tobacco" paper. The boxes are generally 19½ in. by 12 in. by 4½ in. and carry 50 lb. of a particular specification.

The whole process of mica preparation demands ample light and accommodation, while cleanliness of the sheds is essential. Shallow wicker baskets are used throughout, being the most suitable receptacles for the mica sheets during the cutting and grading.

#### MARKETING — GRADE AND VALUE

The producer has the alternatives of selling outright to local buyers or consigning through agents to warehouses in London, when a proportional advance payment is usually made. Most Rhodesian block mica finds its way to London, where it is said to be bought largely on the reputation of the producer, which reputation, once gained, has to be guarded.

Market prices for the various qualities and grades alter considerably, and there is no straight-line relationship between the successive grades of a particular quality. Scarcity value and supply and demand are all reflected in price structure, which is, however, largely controlled by the users.

Several writers have commented on the seemingly most unscientific visual method of classification, successful though this may be in indicating the dielectric strength of the material—the intrinsic reason for its demand in the electrical industry. Nevertheless it appears strange that such quaint terms as "thick thins" and "over over extra extra specials" should survive.

Methods of electrical testing not open to the producer are, of course, employed by the users, and most rigidly applied, the object generally being to ascertain how cheap a quality can be used for a particular job with absolute reliability. An international commission has been sitting for several years with the object of standardizing mica qualities.

A small proportion of the sheet mica is cut to particular shapes in the mica shed as and when there is a demand (mainly from South Africa). Washers of various sizes are mechanically stamped out of what would normally be discarded material, and such things as domestic iron elements are cut to pattern by a guillotine or press from large spotted grades.



A problem that arises in mica preparation during marketing is when to sacrifice size for quality. The rule of thumb employed is to cut only if by the loss of one grade quality can be improved by two classes.

## USES

The following list of uses is given by Robert D. Thomson (31, pp. 13, 14).

Sheet mica, as single pieces split from crystals or as composite pieces in a built-up form, is an important material to the electronic and electrical industries. Block mica is used in manufacturing transmitting and receiving tubes, high-temperature steam-gauge glass, diaphragms, compasses, and as an insulator in electrical equipment. In the electronic field, most of the block mica is consumed as bridges and spacers in radio and television tubes. Usually more stained quality block is used for tube manufacture than any other quality. Lower qualities of block mica, including punch mica, are used mainly as electrical insulators in household appliances such as electric irons, toasters, and water heaters; in incandescent lamps; fuse plugs; and other electrical appliances.

Film mica is used in capacitors (condensers) that hold or store an electrical charge. Mica is useful in capacitors because it can be split into thin sheets, has a high dielectric constant and low power factor, is resistant to high temperatures and can be fabricated easily. Certain capacitors, especially those used in high voltage and high frequencies can be made only from mica. Film mica for capacitors must be fairly flat, must split to close tolerances and be of the higher qualities (stained or better).

Mica splittings are used in manufacturing built-up mica by heating, pressing, and trimming alternate layers of splittings and a binder (shellac, alkyl, or silicone resin). Products cut or stamped from sheets of built-up mica are used mainly as an insulating material in electric motors, generators, and transformers.

In peacetime, the emphasis is placed on mica usable in radio and television tubes, household appliances, heavy electrical equipment, and, to a lesser degree, capacitors. Civilian consumption requires large quantities of the lower quality sheet mica and demand for the highest qualities is not excessive. However, in times of emergency and stockpiling, demand for high-quality mica suitable for essential military applications increases tremendously. From all indications, sheet mica, especially of the higher qualities, will be in high demand for many years to come.

Large quantities of scrap or waste mica are available on dumps all over the Miami Mica Field. With the exception of an occasional contract for small tonnages of this material it has not been worth while shipping. It is hoped that one day a local industry will be built up that will find a use for this material. Powdered mica can be used in the manufacture of paints and paper, as a lubricant and as an absorbent of nitro-glycerine and disinfectants. It can be used as an insulator for packing of boilers and steam pipes; for decorative purposes to produce frosted effects on toys and stage scenery. It is used in the motor trade for rubber filling; in the building trade in patent tar-roofing and ornamental stucca. There are other reported uses such as in the annealing of steel, in calico printing and sizing, in lithographing, etc.

## STATISTICS OF MICA PRODUCTION

From the start of mica mining in 1919 until the end of 1959, when the amount of mica being produced from the area was negligible, the 227 mines and mine groups referred to in the text produced 3,326½ tons

of cut and boxed block mica which was sold for £1,105,541. In addition 1,590 tons of waste mica has been sold for £6,595. Assuming that 10 per cent. of the mica mined has been cut, and this is a generous assumption, then there must be about 30,000 tons of readily accessible mica waste on dumps within the area. At the average price paid for waste mica in the past this is worth well over 75,000 pounds.

The contribution of the mines and groups of mines to the total output is summarized below:

| Group                                                         | No. of mines<br>in group | Mica<br>produced |              | Per cent. of<br>total No. of<br>mines | Per cent.<br>of total<br>output |
|---------------------------------------------------------------|--------------------------|------------------|--------------|---------------------------------------|---------------------------------|
|                                                               |                          | tons             | lb.          |                                       |                                 |
| Mines with total mica<br>output of over 500<br>tons . . . . . | 1                        | 596              | 245          | 0·4                                   | 17·9                            |
| From 50 to 500 tons . . . . .                                 | 12                       | 1,895            | 552          | 5·3                                   | 57·2                            |
| Under 50 tons . . . . .                                       | 214                      | 835              | 203          | 94·3                                  | 24·9                            |
| TOTALS . . . . .                                              | <u>227</u>               | <u>3,326</u>     | <u>1,000</u> | <u>100·0</u>                          | <u>100·0</u>                    |

The single producer over 500 tons is the Grand Parade Mine, but it must be remembered that this figure includes mica from the Eland's Luck, Clyde, Catkin and Mica King mines as well, possibly, as mica bought by Goldberg from "down and out" prospectors. The most striking feature of the figures given above is that 75 per cent. of the mica produced has come from just under 6 per cent. of the mines. This comprises the following 13 producers in order of decreasing output: Grand Parade, Catkin, Beckett, Last Hope, Zonkosi, Hendren, Turning Point, Karnie, Owl, Locust, Miami, Sunspot, Danga. Of all the single pegmatites on the Field the Catkin has probably produced the biggest tonnage of cut mica. There are 11 mines in the lowest group which produced between 20 - 50 tons and in order of decreasing output they are: Kirrie, Ova, Rae, Hari, Eland's Luck, Early Bird, Ruby, Sorotie, Devonian, Mica King and Red Star. Twenty-four mines, therefore, produced the bulk of the mica.

#### THE MICA MINES

*Abigail Mine* (see *Hari Mine*).

*Adder Mine* (see *Piper Mine*).

The *Aionis Mine* locality is given as 11 miles south-east of the Native Commissioner's camp at Urungwe. This could be one of several camps and the mine may well be outside the area of this bulletin. Much of the early mining information is as vague as this.

The mine produced 1 ton 1,946 lb. of mica valued at £172 between 1927 and 1928.

The *Akata Mine* is situated 2½ miles west-south-west of Miami Village on Strathyre Farm.

The pegmatite, which is not more than 6 ft. wide, strikes north-north-west and has an easterly dip of 58 degrees at the surface, but steepens up at a shallow depth. The pegmatite has an apparent length of 400 ft. and bears a discordant relationship to the enclosing schist which is surrounded by granite.

The workings comprised 100ft. of open-casting to an average depth of 15 ft., 135 ft. of driving at the 82-ft. level off an inclined shaft, and 70 ft. of driving at the 106 ft. level. The pegmatite is highly decomposed and the hanging-wall schist had to be timbered. A small amount of stoping was undertaken above the first level. The mica here is sparse and, though of ruby quality, proved barely payable. The values were very slightly better on the second level but were really not worth mining under such difficult conditions.

From 1952-4 the mine produced 1 ton 548 lb. of ruby mica valued at £1,082. (See also under beryl.)

*All Rich Mine (see Ruby Kop Mine).*

The *Almo Mine* is situated a mile south-south-west of the Grand Parade Mine. There are in this vicinity a number of small, shallow, open workings on small pegmatites which strike in many directions. These are rich in quartz and microcline with biotite in fair abundance. Some ruby mica is intergrown with the biotite and there are also small, broken, discrete books. These pegmatites seem most unpromising. In 1923, 1,000 lb. of mica was produced and sold for £125.

The *Alphafa Mine* is half a mile south-west of the Karnie Mine and seven miles north-west of Miami Village.

The pegmatite strikes very nearly north and south and dips east at 60 degrees. Its relationship to the country rock is a discordant one. The underground workings are inaccessible. The portion mined can be seen to narrow rapidly towards the north but it is still wide in the south. It appears to have been typically zoned with, in places, a quartz core. The mica has apparently occurred as a hanging-wall shoot at surface but it is believed that below surface a foot-wall shoot was also mined. As is usual in concentrations of this sort, the mica appears to have exhibited fair crystal form, and a higher-than-average cuttability was probably obtained which is a common feature when this occurs.

The pegmatite has been mined open-cast over 340 feet of strike as well as underground. There are remains of several hanging-wall inclined shafts and a vertical shaft. There is no plan of the workings, but the fairly large amount of waste rock indicates that quite extensive development or stoping has been done.

The mica shoots are believed not to have been exhausted and the property may be worth reopening.

About 100 yards east of the main workings is a parallel pegmatite which, because of a strong quartz core, has given rise to a small ridge. On it there has been some surface prospecting and a shallow inclined shaft sunk. Much microcline is to be seen and muscovite books, which are of fair size, are frequently broken and striated.

Production from the mine is recorded for the years 1921, 1925-6 and 1936. In all, 9 tons 1,153 lb. of spotted mica were boxed and sold for £2,372.

The *Also Claims* are situated  $6\frac{1}{4}$  miles west of north of Miami Village.



A short lenticular pegmatite striking approximately north-north-west has been mined to a shallow depth at its northern end. The pegmatite appears to have been emplaced along the contact between granite and schist with the latter forming the hanging-wall.

No production has been recorded under this name.

*Althea Mine* (see *Miami Mine*).

The *A.N.D. Mine* is reported to be in the Urungwe East Group of mines, about five miles east of the Julia Mine. The Julia Mine is about a mile outside the western margin of the map and about four miles south-west of the Locust Mine. Between 1952-3 it declared 161 lb. of mica valued at £29.

The *Aqua Mine* is a little south of the Kingsale Mine and two miles south-east of Miami Village.

The mine is appropriately named, for it is almost in a vlei and when visited the old workings contained water right to the surface.

There is an approximate *en echelon* arrangement of five pegmatites in this area, three of them on the old Aqua, and perhaps Grand Prix, claims and two on the Kingsale Claims.

In an unpublished geological report on the Lomagundi Mica Field dated 6th September, 1943, R. Tyndale-Biscoe reports that the Aqua "dyke or dykes dip at rather low angles eastward. The commercial mica has, as usual, a patchy distribution in short shoots along the strike. At one point it is concentrated along the hanging-wall over a width of about six inches, in such a manner as to suggest strongly that its origin is closely connected with the highly micaceous country rock."

The mine produced in 1930, 1943-6 and in 1948, during which period 13 tons 204 lb. of boxed mica fetched £20,647.

The *Ardua Mine* is situated nine miles north-north-west of Miami Village on the steep western bank of the Karoe River.

A younger mica-bearing pegmatite striking east and dipping steeply north cuts at right angles across an older barren pegmatite. The younger pegmatite has a strong quartz-microcline core and has been mined open-cast along the hanging-wall over 60 ft. of strike to a maximum depth of 15 ft. A small adit has been put in 12 ft. below the open workings but has revealed little of interest.

This ruby-bearing pegmatite has no recorded production under the name of Ardua.

The *Beckett Mine* is situated  $4\frac{1}{2}$  miles north-east of the Grand Parade Mine and six miles east-north-east of Miami Village.

This pegmatite was one of the very earliest pegged on the Field and has had many operators. Its main production came during the years it was part of the Goldberg organization. After lying dormant for about six years the mine was successfully reopened in 1955 in spite of adverse verbal reports.

Workings: The pegmatite has been mined to the 5th level at a vertical depth of 144 ft., with two winzes still in pegmatite some 25 ft. below this. The biggest level is No. 4 at a depth of 111 ft. It is 450 ft. long and

extends for about 180ft. into the Zonkosi Claims. Because of the multiplicity of small rich spur reefs branching upwards at a relatively shallow depth, the ground was gouged out from surface to a depth of 80 ft.

**Pegmatite:** The main Beckett pegmatite is the middle one of three concordant, *en echelon* pegmatites striking north-north-west and having a westerly dip. The south-eastern pegmatite is on the Zonkosi 5 block. The Beckett pegmatite is 90 ft. on the hanging-wall side of it and overlaps it to the north-west. The third pegmatite bears much the same relationship to the Beckett pegmatite as it does to the Zonkosi 5, but it carries smaller mica and has not been mined.

The Beckett pegmatite is virtually a simple or unzoned body with disseminated books of spotted quality mica. Locally, the mica books formed 50 per cent. or more of the pegmatite and there was a tendency, in some places, for the mica to concentrate towards the hanging-wall. Books measuring 16 by 11 in. in the plane of the cleavage were commonly found. Apart from the muscovite the pegmatite is composed predominantly of albite-oligoclase. Quartz occurs interstitially or in veins. Microcline is difficult to find and it has been seen in small amount intergrown with plagioclase. At one point an individual crystal was seen associated with a little beryl and a large mass of magnetite which must have weighed many hundreds of pounds. Green apatite was observed at various points. Tourmaline is rare and only a few small crystals were seen. A feature of the schists in this area is their richness in muscovite.

The pegmatite averages about 7 ft. in width but at several places pinches to 12 in. or less. On occasion it was little more than a channel. These constrictions are very local and the pegmatite opens up again as quickly as it pinches.

A strong foot-wall spur, striking parallel to the main pegmatite and branching upward from it on the third level, was developed and stoped in places. A hanging-wall spur on the third level was not followed.

The Beckett pegmatite, like the Zonkosi 5, has a characteristic found in many of the pegmatites on the Field. The mica shoot or concentration was at the northern end of the strike and the pegmatite was mined almost to where it pinched out in this direction. At the south end of the workings the pegmatite continues into the face as a wide unpayable body. The payable section of the Beckett pegmatite seems to have been a flat, southerly pitching shoot.

**Structure:** The channel of the Beckett is interesting in that, while the pegmatite is a concordant one, it does not appear to occupy a simple dilation fissure. Apparently considerable movement took place along a fault-plane before the emplacement of the pegmatite and there was a small amount of post-pegmatite movement. The pegmatite appears to have been emplaced along a strike-thrust fault which had drag-folding developed in the overthrust or hanging-wall block. As a result the foot-wall of the pegmatite is a plane surface while the hanging-wall has frequent bulges.

Post-reef movement, which is most evident in the northern portion of the mine, has resulted in deeper weathering here. This is reflected in a reddening of some of the mica which is then of inferior quality.

Outputs: The mine first produced in 1920 and then again from 1925-9, 1946-8, 1950-3 and 1957-9. Some Beckett outputs have been declared with Zonkosi blocks. The Beckett records give 278 tons 587 lb. of cut mica valued at £70,987.

The *Bee Mine* is situated less than a mile south-south-west of the Beckett Mine and it also produced spotted quality mica. There is little to be seen at surface now other than some shallow surface workings and collapsed shaft collars. There appear to be two *en echelon* pegmatites striking 355 degrees (magnetic) and dipping west with the foliation of the enclosing schists. The northern pegmatite is the stronger of the two.

Outputs have been declared with the Zonkosi blocks.

The *Berea Mine* is situated seven miles north-west of Miami Village.

The underground workings were inaccessible but appear to have been quite extensive. The mine produced a rather poor ruby mica as the outputs indicate. The abundance of microcline which is to be seen on the dumps, may have been the cause of damage to the mica.

There are two lines of workings which may be on branching or separate pegmatites. The main workings are on a discordant body of pegmatite striking north and dipping east at between 50 and 60 degrees. The apparent surface strike is about 300 feet. Five inclined shafts are spaced at about 75-ft. intervals along the line of strike. With the exception of the southernmost one they have collapsed to form large shallow craters. There are in addition three vertical shafts. The most northerly is 60 ft. on the hanging-wall side of the outcrop and lies between Nos. 1 and 2 inclines; the second is 30 feet from the hanging-wall between Nos. 2 and 3 shafts; the third is 30 feet in the hanging-wall and almost opposite No. 5 incline.

Some plagioclase can be seen on the dumps associated with small muscovite books that have good crystal forms. Microcline is the predominant mineral and there is also much biotite. It is assumed that there was a weak hanging-wall mica shoot which yielded only small mica. Larger books of broken mica may have come from the microcline, intermediate or core zone. Some of the mica, unsuitable as sheets, has been punched into washers as is evidenced by waste cuttings.

On the foot-wall of the main workings is a concordant pegmatite or spur which strikes north-east with an apparent steep south-easterly dip. There is over 900 ft. of surface strike. If it does branch from the main pegmatite, the junction will be in the neighbourhood of No. 3 inclined shaft. This pegmatite has a quartz core with an intermediate or core margin zone rich in microcline and carrying biotite and buckled and broken ruby mica. Some plagioclase felspar on the waste dump at the vertical shaft suggests that there is a weak wall zone or border zone.

The country rock is a sillimanite-gneiss with porphyroblasts, veins and lenses of microcline.

The mine produced from 1924-7 and again in 1929. In all, 5 tons 1,159 lb. of boxed mica fetched only £1,161.



The *Betty Hill Mine* locality is given as  $1\frac{1}{2}$  miles north-west of the Mormond Hill Mine which is on Ruwanzi Ranch, eight miles south-east of Miami Village. It produced 153 lb. of mica in 1952 valued at £30. (See also under beryl.)

The *Betsy Mine* is  $4\frac{1}{2}$  miles north-north-west of Miami Village and in 1952 produced 584 lb. of mica valued at £100. The ground appears to have been gone over later for beryl but there is no output under this name.

The *Betty Ver Mine* is reported to be about five miles north-east of the Julia Mine, which would place it a little over a mile north-east of the Locust Mine. In 1955 it declared 293 lb. of cut mica valued at £39. (See also under beryl.)

The *Blue Jay Claims* are  $1\frac{3}{4}$  miles south-south-west of the Rkwesa Mine and five miles north-west of the Catkin Mine.

Two pegmatites have given rise to small features. The main workings are on the one nearest the river. It strikes north and south for 200 ft. and has an almost vertical dip. There is a little open working and two shafts, 30 ft. apart, on the east side. The exposed pegmatite is rich in quartz and microcline with biotite and fish-tail ruby mica.

The other pegmatite has 100 ft. of surface strike and an easterly dip. It has much the same characteristics as the first but there is a more well-defined quartz core.

There is no record of any output under the name of Blue Jay.

The *Birthday Mine* is reported to be five miles north-west of Miami Village and a part repegging of the Dee Bee Claims. An old claims plan indicates the Birthday Claims as being a mile north-east of the Major Claims. In 1926 it produced 74 lb. of cut mica valued at £3.

The *Birthday Gift Mine* is on Kachichi Farm  $1\frac{1}{2}$  miles south-west of Miami Village. There is a small open working revealing nothing of interest. In 1953 it declared 23 lb. of cut mica valued at £8. (See also under beryl.)

The *Bluff Mine* is on Crown land  $7\frac{3}{4}$  miles north-west of Miami Village and 700 yards north-east of the north-east corner beacon of Mahuti Farm.

There are two pegmatites which are roughly *en echelon*. The more southerly one strikes 250 degrees (magnetic) and has a northerly dip. Shallow open workings for mica extend for 270 ft. along the hanging-wall of a quartz core which was later blasted away at one end in a search for beryl.

The pegmatite is rich in spotted-quality mica which borders a microcline-rich core margin zone. The mica is very striated and buckled. Plagioclase appears in the rubble from the trench and presumably came from the wall zone which may have carried some better mica.

The second pegmatite is 120 ft. north of the other. Shallow workings reveal 270 ft. of strike. The main open working is 75 ft. long on the south-east side of a core zone which is rich in buckled and broken biotite books up to two feet in length. Magnetite occurs along the edges

of some of the biotite as well as in the quartz of the core. The pegmatite has a maximum width of six feet and appears to dip towards the other pegmatite at 45 degrees.

Some work on the foot-wall of the pegmatite has revealed much quartz and microcline with muscovite, biotite and tourmaline. The muscovite which can be seen in the core zone is smaller than the biotite and is partly intergrown with it. It is hopelessly buckled, broken and interleaved.

Mica was produced in 1924, 1944 and 1952 which totalled 1,749 lb. valued at £139. (See also under beryl.)

The *Blyvooruitsig Mine* is situated  $4\frac{1}{4}$  miles north-north-west of the Catkin Mine.

There are two pegmatites here with the main working on a vertical, 20-ft. wide, north-striking body. There is 150 ft. of trenching along the middle of the pegmatite to a maximum depth of about 15 ft. This reveals a wide core zone of microcline with subordinate quartz. On either side of the core is an intermediate or core margin zone three feet wide, which is rich in albite and quartz in graphic intergrowth. Muscovite is disseminated throughout these zones and it is much broken and intergrown with biotite.

On high ground 390 ft. north-west of this working is an east to west striking pegmatite which dips south. There is some trenching within the pegmatite and on the foot-wall side at the west end. The pegmatite is similar to the other but appears to carry even less mica.

There have been six annual declarations of mica outputs between 1948 and 1958 amounting to 2 tons 486 lb. of cut ruby mica valued at £1,774. (See also under beryl.)

The *Bul Bul Mine* is situated almost in the middle of a watercourse, half a mile south-south-west of Kapiri Hill and five miles east of Miami Village. There was little to be seen of the pegmatite from which in 1944 and 1948 a total of 2 tons 1,860 lb. of cut mica was produced at a value of £965.

*Burnley Mine* (see *Esquire Mine*).

The *Bynx Mine* locality is given as about a mile south-west of the Lynx Mine which puts it 22 miles north-west of Karoi Township. There are some shallow workings on several pegmatites in this general vicinity, but there was nothing that appeared to warrant further investigation.

In 1935-36 it produced 1 ton 1,164 lb. of cut mica valued at £319.

The *Caesar Mine* is reported to be  $2\frac{1}{2}$  miles north-west of Miami Village. It declared a single output in 1928 of 143 lb. of cut mica valued at £22.

*Carmine Mine* (see *Mica King II Mine*).

The *Catkin Mine* is situated 20 miles north-west of Karoi Township.

History: At the time of this survey the mine workings were inaccessible but the writer later had the opportunity of visiting the site in the company of N. A. Tatham who managed the mine and was the last man underground before it was finally closed. Much of the information here given was obtained, on the site, from Tatham.

Apart from being a most interesting pegmatite in many respects, it turned out to be both the richest concentration of mica per foot of pegmatite, as well as the largest working on the Field.

The pegmatite was discovered by a prospector named Jack Etkins about 1922 and it was apparently a fabulous sight. Mica books were found protruding from the ground, waist high, along the line of strike. Etkins sold the claims to J. Goldberg, who then owned the Grand Parade Mine, for about £150. The first books were taken on donkey to Miami for cutting.

The country abounded in game and buffalo were shot for native rations. Tsetse-fly, too, was widespread. It was thus that the hardy donkey was used both for transport and, it is believed, in operation of the first improvised hoist. Lions apparently attacked and killed the donkeys on one occasion during a hoisting operation. Later a steam-hoist was used, and oil-engines employed for pumping and compressors.

From 1926 to 1930, the mine produced an average of 38 tons of cut and boxed mica per year. In addition to this it is believed that much of the mica was declared with Grand Parade Mine mica.

In May, 1945, the mine was transferred to H. Tevis and Partners, Ltd., and in August of that year it was bought by G. Paterson and Sons. Paterson reopened the mine by sinking an inclined shaft in pegmatite which carried little mica. Later, as a result of driving and cross-cutting, this pegmatite was found to be a spur.

Workings: The underground workings extend over some 700 ft. of strike and to an inclined depth of 400 ft. or more at an angle of about 40 degrees. There are two inclined shafts, 360 ft. apart at surface, which have been sunk on pegmatite except for the first 100 ft. where they are in the foot-wall of the body. A mine plan prepared by Tatham reveals that the developed areas of the mine have been largely stoped. He has, however, indicated some areas on the foot-wall of the pegmatite which are intact and may be worth mining if the condition of the ground permits.

Pegmatite: A discordant relationship exists between the para-gneiss and the pegmatite which strikes approximately north-east and dips south-east at an average angle of about 40 degrees. The pegmatite narrows in the north-east end of the workings and is still 15 ft. wide where work has been discontinued at the south-west end. The hanging-wall contact with the gneiss is an almost perfect plane surface from which the pegmatite breaks away cleanly. However, wall-rock alteration, which has been caused by emanations from the pegmatite, has resulted in the development of a false hanging-wall which can cause dangerous falls (see p. 81). The foot-wall is irregular, a feature caused, apparently, by minor drag-folding (see Beckett Mine, p. 118). It is clear that the pegmatite occupies a fault plane. J. G. Stagman, of the Southern Rhodesia Geological Survey, visited the mine in October, 1947, and in an unpublished report mentions that "There are a number of strike faults with steep dips which are opposed to that of the pegmatite. The most westerly (i.e. nearest surface) has a considerable throw



and the mica concentration thins out in its neighbourhood, no doubt due to drag along the fault plane. The throw of the others is small, being only a few feet, and in each case the reef is down-thrown to the east". One such fault at the bottom of the north incline has displaced the reef into the foot-wall. A fault 40 ft. south of the south incline on the 1st and 2nd levels has displaced the pegmatite 20 ft.

The pegmatite is zoned and carried both hanging- and foot-wall concentrations of mica which were worked as separate bodies where the pegmatite was wide. A plan of the mica shoots is given on Plate X. Quartz forms an irregular core in places about half-way between the shafts, elsewhere the core is a mixture of quartz and large microcline crystals which are bordered by small, radiating crystals of herring-bone mica. Tourmaline, biotite and beryl also occur. At the bottom of the mine, as at the Rae, Piper and Hendren V mines, muscovite gives way to a concentration of tourmaline.

The quality of the mica varied from north to south. At the northern end of the mine the mica was all spotted but towards the southern end a proportion of clear ruby mica was cut.

Like so many of the mines on the Field the pegmatite persists after the mica-shoot has terminated and it is still an open question whether a further disconnected shoot exists in depth.

Output: The returns given below are in addition to the mica which has been declared with the Grand Parade Mine outputs. The mine operated from 1926-30, 1945-49 and 1954-55. In all, 368 tons 181 lb. of cut and boxed mica were sold for £83,284.

The *Celtic Mine* is reported to be 12 miles north of Miami. If this is a track distance, it is possibly just within the northern boundary of the map. In 1925 it declared 960 lb. of mica valued at £74.

The *Chengetai Mine* is reported to be on Crown land, two miles north of the Rkwesa Mine. In 1953 it declared 146 lb. of cut mica valued at £58. (See also under beryl.)

The *Chigwara Mine* locality is given merely as the Urungwe Mica Fields, East Group. It produced in 1944-45 when a total of 1,536 lb. of mica fetched £308.

The *Chikunda Mine* is on Crown land, 12 miles north-west of Miami Village and a mile north-east of the south-eastern corner beacon of Protea Farm.

The pegmatite is a discordant one striking east and west with the foliation of gneiss, across the spur of the hill, but dipping steeply north across the foliation.

The pegmatite has been benched into the side of the hill, and trenched to a shallow depth along the hanging-wall side of a quartz core which attains a width of eight feet. The exposed surface strike measures 150 ft. A crystal of beryl measuring 18 in. in length was seen embedded in the core and there is also some tourmaline and muscovite. The hanging-wall contact of the pegmatite was not seen due to rubble in the trench,

but there was presumably a small wall zone concentration of mica. On the foot-wall there is evidence of a very weak concentration of small mica books.

Outputs include mica from the Grand Slam Mine which quite possibly exceeds the weight cut from the Chikunda Mine where not much work has been done. In 1943-44, 2 tons 436 lb. of mica were sold for £1,403.

The *Chip Mine* is 10½ miles north-north-east of Miami Village and a little more than a mile north of the Owl Mine.

An underground plan of the workings, dated January, 1948, indicates a single, stepped drive 135 ft. in length connected to two inclined shafts with No. 1 shaft continuing a farther 45 ft. below the level. The pegmatite which strikes approximately east and dips north at 85 degrees has been trenched along the strike for 90 ft. It appeared to be composed of a almost homogeneous mixture of feldspar and quartz with very striated, lightly spotted mica. It is evident that only small sizes of mica were cut.

In 1947-48, 1 ton 175 lb. of mica were cut, valued at £485.

The *Clyde Mine* is situated in the south-west corner of Mapofu Farm, three miles north-west of Miami Village.

There are two pegmatites of very different character on the claims. They are over 800 ft. apart, are not quite parallel to one another, and dip towards each other.

The pegmatite on the west strikes 200 degrees (magnetic) and dips east. When visited, the workings had all collapsed and were full of water. It is believed to have been mined to about 100 ft. in depth on a very narrow unzoned pegmatite which carried disseminated ruby mica. It is said to have been a small-scale replica of the Sunspot Mine which is 1,500 yards away to the south-west. The pegmatite can be seen to pinch to small proportions in the north and to widen to the south, where it carries a high percentage of microcline. The pegmatite continues south beyond the last shaft but is probably unpayable. Its relationship to the gneiss is a discordant one

There is a plan of the workings on the eastern pegmatite dated April, 1949. Here there is a wide, lenticular concordant body striking 210 degrees (magnetic). It dips west at about 50 degrees at the surface, but flattens to 30 degrees at 75 ft. on the incline. There is an exposed surface strike of 270 ft. This pegmatite, unlike the other, is strongly zoned and has a well-developed quartz core, but the whole body of pegmatite is reported to have pinched out at a comparatively shallow depth. At the 90 ft. level there was a loop drive over 100 ft. of strike on the hanging- and foot-wall of the core. There was a shorter drive 30 ft. below this and the payable wall zone mica, which was of a high-quality ruby, was stoped to the surface.

The core of the pegmatite has since been prospected for beryl. Many fragments of which could be found on the rock dump, but there is no record of production.

The two Clyde pegmatites yielded 12 tons 1,030 lb. of cut ruby mica from 1948-51 and it was sold for £11,829. However, some mica from here has been declared with the Grand Parade Mine.

The *Coreen Mine* is on Crown land near the north-western edge of the map, four miles north of the Rkwesa Mine.

Little can be seen of the structure of the pegmatite in the open working and the two shafts are full of water. It would appear to be a wide, lenticular body with a nearly vertical dip and a surface strike of about 150 ft. The rock dump carries abundant microcline and quartz but there is some albite with graphic quartz. Biotite is also present. It would appear that the muscovite is disseminated in a largely unzoned pegmatite. There is a relatively large waste mica dump of striated and interleaved material. Some of the mica is of ruby quality and some has a fine dusty spotting.

The mine was operated in 1943-44, and 1948 when 1 ton 869 lb. of mica fetched £562.

The *Cork Mine* is reported to be five miles north-east of Miami Village, and is one of the Beckett-Zonkosi system of pegmatites which were rich in disseminated, spotted mica. All outputs with the exception of one were declared with Zonkosi outputs. In 1946 it declared 1 ton 500 lb. valued at £195.

The *Corolanty Mine* locality is given in the records as merely the Miami Mica Field. In 1920 it declared 604 lb. of cut mica valued at £55.

The *Cough Drop Mine* is reported to be seven miles north of Miami Village. In 1926 it declared 6 tons 610 lb. of mica valued at £860. It seems certain that this mine is now known under some other name.

The *Crystal Mine* is on Crown land 25 miles north-west of Karoi Township and 400 yards east of the Mica View Mine.

The mine owes its name to the vuggy nature of the pegmatite which allowed the growth of crystal aggregates of quartz and albite with tourmaline. Some of this quartz is believed to have been tested for its piezo-electric value but there is no record of any sale.

There is little or nothing to be seen of the pegmatite *in situ* owing to the inaccessibility of the workings. They indicate a short north to south surface strike of 150 ft. The disposition of two vertical shafts on the west side of a short, shallow open-cast working suggest a steep westerly dip. On the rock dump albite is the predominant felspar.

In 1937 the mine declared 544 lb. of ruby mica valued at £26 which suggests very small sizes or poor quality.

The *Cynthia Mine* claims adjoined the Makakutzi (342) block on the south-west side and the mine is presumably one of several old small workings situated  $3\frac{3}{4}$  miles south-west of Miami Village. In 1920 it declared 720 lb. of cut mica valued at £45.

The *Danga (Dunga) Mine* is situated  $5\frac{1}{2}$  miles north-west of Miami Village on Crown land.



**Workings:** An underground plan dated April, 1949, reveals a total of 800 ft. of development on strike, down to a maximum depth of 320 ft. in the northern sector. Surface prospecting has exposed a continuous strike of over 1,000 ft.

There have been three periods of operation under a number of different operators. The first period commenced in 1920 when the centre portion of the strike was mined from outcrop. The second period is believed to have been between 1943 and 1946 when the southern sector was mined, and the third and last period between the years 1946 and 1949 when the sub-outcropping shoot at the northern end of the pegmatite was extracted. This second shoot appears to have been discovered somewhat by chance and to have yielded as much mica as the outcropping shoot.

**Pegmatite:** J. G. Stagman, of the Southern Rhodesia Geological Survey, was able to visit the underground workings in October, 1947. He noted that the dip of the country rocks is opposed to that of the pegmatite and that the drag of the rocks shows that it occupies a normal fault fissure. At the southern end of the workings the pegmatite is very wide and a cross-cut 88 ft. in length did not reach the foot-wall. Immediately north of the main shaft the pegmatite is only a few feet wide and it continues narrow to the northern end of the mine.

The pegmatite is reported to consist of hard, pink felspar (composition not given), quartz and mica with accessory tourmaline. The mica is a clear ruby. It would appear that in the wider portion of the pegmatite, approximately south of No. 1 sub-incline, the mica occurs as a hanging-wall shoot but that the mica in the sub-outcropping northern shoot is disseminated throughout the narrow pegmatite (See Plate X). Where the mica occurs on the hanging-wall of the pegmatite it is probably of the simple zoned type as mentioned on page 84. The mica mined was hard and clear and is reported to have had the highest dielectric strength of any mica on the Miami Field which had been tested to that date.

Once again this pegmatite follows the pattern of many others and one feels that there must still be further mica shoots in depth if the pegmatite persists, as it gives every indication of doing.

**Output:** Production figures are given for the years 1920-2, 1925, 1930, 1936-7, 1945-9 and total 50 tons 147 lb. valued at £25,889.

The *Dan-Y-Graig Mine* is reported to be about six miles east of Kapfundi Hill, which would place it about  $5\frac{1}{2}$  miles south-south-west of the Catkin Mine. In 1953 it declared 466 lb. of cut mica valued at £166. (See also under beryl.)

The *Darkness and Dawn Claims* are located  $5\frac{1}{2}$  miles north-west of the Catkin Mine. A small amount of work has been done on three unpromising looking pegmatites. Two of the pegmatites bear discordant relationships to the gneiss and the other is concordant. All are zoned, with strong quartz cores but do not have wall-zone mica shoots. The small amount of ruby mica which they carry is broken and striated and is typical of mica that is associated with core margin zones, rich in microcline and biotite.

In 1947-8, 525 lb. of cut mica realized £139.

The *Day Dawn Mine* is reported to be seven miles north of Miami Village. In 1928 it produced 867 lb. of cut mica valued at £55.

The *Dee Bee Mine* is said to be a part repegging of the Birthday Mine which is recorded earlier as being five miles north-west of Miami Village. An old claims plan shows the Birthday Claims as being a mile north-east of the Major Mine. In 1931 it declared 1 ton 391 lb. of cut mica valued at £106.

The *Dennis Mine* is reported to be 1,500 yards north-east of a point three miles north of the Catkin Mine on the Catkin Fly-gate road. It produced in 1952-3 when 346 lb. of cut mica fetched £107.

The *Devonia Mine* is on Crown land, five miles north-north-east of Miami Village and  $1\frac{1}{4}$  miles south-west of the Beckett Mine.

The pegmatite strikes north-east and dips to the south-east at an angle which varies between 30 and 34 degrees. In the drives it has a variable width of between three and four feet but attained as much as seven feet in some of the stopes. It is of the simple or harmonious type, composed predominantly of albite with subordinate quartz. No microcline was seen underground. It carries green-brown mica which is disseminated throughout the pegmatite with an occasional tendency for a concentration to form towards the hanging-wall. But for the quality of the mica it is reminiscent of the Beckett pegmatite. Sporadic books were seen measuring as much as 14 in. in the plane of the cleavage. Judging from the amount of work done and the large waste-dumps of mica, there must have been some better concentrations of mica near surface. Tourmaline is present in the pegmatite and this may be increasing in depth in reverse proportion to the mica which is a state of affairs recorded in many pegmatites.

The pegmatite bears a discordant relationship to the schist. It has been emplaced along a fault-plane along which there has been post-pegmatite movement. In places there has been some local shearing of the schist parallel to the pegmatite which gives it a semblance of concordance. In addition there are some small scale pinch and swell structures and rolling of the pegmatite. These may be attributable to later movements. Some crushing has clearly taken place as a result of this movement and has damaged some of the mica books.

The pegmatite has been mined down to about 160 ft. on the incline. At this depth the pegmatite has become uneconomic due to bad ground and the sparseness of mica books. At the north-east end of the drive on the bottom level, small "mussel" mica occurs and may herald the termination of the pegmatite. At the other end of the drive the pegmatite passes through a pre-pegmatite epidiorite dyke which has resulted in a change of dip and strike.

The mine produced from 1922-8 and in 1956-7 giving a total of 24 tons 1,478 lb. of cut mica valued at £5,488.

The *Dicky Bird Claims* are on Crown land  $1\frac{1}{4}$  miles south-east of Miami. There are some shallow open workings on several rather barren-looking microcline-rich pegmatites.

The claims produced in 1941 and 1945, when 1,296 lb. of cut mica realized £405.

The *D.L. Mine* claims are on Crown land  $2\frac{3}{4}$  miles east of the Rkwesa Mine and  $5\frac{1}{2}$  miles west of north of the Catkin Mine. In 1959, these claims were re-registered as the Mica King Claims, which is unfortunate because there were Mica King Claims already in existence a little south of the Grand Parade Mine at Miami.

There are several unpromising-looking zoned pegmatites on the claims. They are fairly wide, lenticular bodies with short strikes.

The main workings are on a pegmatite with a north to south strike of 165 ft. and an easterly dip. The irregular, shallow, open workings reveal a quartz core with core margin microcline carrying biotite and sparse, small, books of ruby mica which is striated and broken. There is a shallow vertical shaft from which no development has been undertaken.

Less than 100 yards to the south-west is a pegmatite which forms a small feature. It is wide but has a north to south strike of only 130 ft. and dips east. It has a strong quartz core and a small amount of prospect work has been done on either side of it. Once again microcline and biotite are much in evidence.

The third pegmatite is a little south-east of the main working. It is rather like the other two but carries some tourmaline in addition to biotite and striated muscovite.

In 1945 the D.L. declared 1,113 lb. of cut mica valued at £311 and as the Mica King, 238 lb. valued at £18 in 1959.

The *Dog Mine* claims are  $1\frac{1}{2}$  miles east of the Grand Parade Mine. There are a number of pegmatites on the claims but only two have produced mica.

The Dog Mine is an open-cast working, 40 ft. long and 14 ft. deep, on a concordant pegmatite in a watercourse. When visited there was no pegmatite exposed. A prospect trench 240 ft. long can be seen 180 ft. south of the Dog. Several small pegmatites were intersected. To the north-west of the Dog open working is a wide-zoned pegmatite in which a shallow shaft has been sunk. This revealed little of interest and no development work was done.

The Dog II Mine is 400 ft. north-west of the Dog Mine. A little development has been done from an inclined shaft on a narrow pegmatite which strikes with the foliation of the schist but dips across it to give a discordant relationship. Some good, fairly large, clear, green-brown mica was taken from the pegmatite at surface. In the workings the ground is bad and the pegmatite looks most unpromising.

The Dog Claims produced from 1951-4 and in 1956-7, yielding a total of 1 ton 198 lb. of cut mica valued at £713.

The *Doon Mine* is reported to be ten miles north-west of Miami Village and three miles north-west of the Berea Mine. It was operated in 1926-7 and produced 1,768 lb. of cut mica valued at £36.

The *Doreen Mine* locality is vaguely given as a few miles south-west of Miami Village. An old claims plan, dated 1924, shows that the Doreen Claims adjoined the Makukutsi Claims on the south-east. It seems probable, therefore, that the Doreen has since been repegged as the Simba Mine.



The Doreen was worked from 1920-4 and declared 2 tons 1,464 lb. of cut mica valued at £506.

The *Dunga Mine* (see *Danga Mine*).

The *Dungusha Mine* is four miles north-east of Miami Village. An east to west striking, zoned, pegmatite was mined open-cast to a shallow depth for its beryl content. One very large quartz crystal with a good termination was seen lying free in the working. In 1952, 20 lb. of mica were sold for £9. (See also under beryl.)

The *Durham Mine* is  $6\frac{1}{2}$  miles north-east of Miami Village and half a mile north-west of the Beckett Mine.

The old inaccessible workings suggest that there are either two *en echelon* pegmatites, or a single one which has suffered small displacement as the result of transverse faulting. The pegmatites are concordant bodies striking north and dipping steeply west. The country rocks are the highly micaceous northern extension of the Zonkosi-Beckett belt which gives rise to rather bad ground. Together the two discontinuous open workings constitute a long strike, but there was nothing to be seen of the pegmatite.

The mica is green and of little value as sheet mica because it is highly striated and interleaved. It is reported that herring-bone, wedge-shaped books as large as "door frames" were extracted. Green mica is valued for grinding to a powder as it produces a desirable colour which spotted and ruby mica apparently do not. The form of the mica suggests that it occurs as a core margin zone in a matrix of microcline. (See page 88.)

Some sheet mica has been cut from this pegmatite but the low prices suggest either small sizes or inferior quality or both.

Production was from 1923-6 and in 1946-7 when 3 tons 552 lb. of cut mica were sold for £820.

The *Early Bird Mine* is  $8\frac{3}{4}$  miles north-north-west of Miami Village. An appreciable amount of mining has been carried out on two pegmatites.

The main pegmatite bears a discordant relationship to the porphyroblastic sillimanite-gneiss which is very similar in appearance to the rocks in the vicinity of the Hendren Claims, two miles to the south-west. The strike of this pegmatite is 350 degrees (magnetic) and the dip is to the east. It can be traced on surface for 500 ft. Only the surface could be inspected at the time of the visit. At the southern end of the strike the pegmatite carries only small mica, with good crystal forms. There is shallow open trenching at first on the strike, but 230 ft. north of the start of the pegmatite is the first inclined shaft and there is a vertical shaft 40 ft. on the hanging-wall side of it. There is a second caved inclined shaft, 150 ft. north of the first. Continuous open work on the pegmatite extends for a further 100 ft. north of this second inclined shaft, and the pegmatite continues beyond.

The nature of the pegmatite at the northern end is similar to that at the Alphafa Mine. Abundant, well formed mica books are set in a quartz matrix with subordinate albite. There is a little tourmaline and a lump of magnetite. Some microcline-perthite was seen on the rock

dump at the first inclined shaft. This shaft has been sunk on the hanging-wall of the pegmatite where there is evidence of a wall zone mica shoot. Books of mica exposed in the shaft top measured eight inches in the plane of the cleavage. The gneiss at this contact is enriched in secondary muscovite.

This first pegmatite, which carries a good-quality spotted mica, is believed not to have been worked out and may be worth reopening. Underground work ceased in 1928 when over  $7\frac{1}{2}$  tons of cut and boxed mica were sold. All later work is believed to have been done near the surface.

The second pegmatite mined is on the west side of the main pegmatite, 105 ft. from its northern end. It strikes 35 degrees (magnetic) and at surface has a south-easterly dip of 30 degrees. There is 150 ft. of continuous trenching along the strike. The pegmatite is wide, but the full width was not exposed. A hanging-wall mica shoot was mined here and was stoped to surface at one point where the workings were seen to be full of water. Some surface trenching has been undertaken on the foot-wall side of the pegmatite. Underground mining has been from a vertical shaft sited near the northern end of the surface workings which suggests a possible pitch to the shoot.

The pegmatite on the waste dump from the hanging-wall working consists of albite and quartz containing appreciable amounts of tourmaline. The specimen of feldspar showing good polysynthetic twinning, and reproduced on Plate XIII, was collected here.

The claims produced from 1926-8, and in 1944, and 1946-7 when a total of 29 tons 293 lb. of cut mica realized £4,591.

The *Easter Gift Mine* is on Haslemere farm half a mile south-west of the Last Hope Mine.

Two approximately parallel zoned pegmatites, with strong quartz cores, were mined open-cast to shallow depths for mica, and later were found to contain beryl.

The eastern pegmatite which strikes north and south has an apparently vertical dip. Shallow trenching was undertaken on both sides of a wide, milky, quartz core. Waste-fill and decomposed pegmatite make a study of the structure impossible. There is probably a microcline-rich core margin, but it is not known whether any wall zone mica existed. Both feldspars can be identified on the rock dump. The mica seen was striated and of a sooty looking appearance but the mine apparently produced ruby qualities.

The pegmatite to the west is similar in most respects and has also been prospected on both sides of the quartz core which is fairly rich in striated mica.

The mine produced from 1945-7 when 2 tons 1,844 lb. of cut mica fetched £1,088. These figures indicate that better mica was mined than can be seen at present in the pegmatites.

The *Easter Parade Mine* is in the eastern sector of Lot "1" of The Ridges Farm, and  $10\frac{3}{4}$  miles north-west of Miami Village.

The mine is in a flat, soil-covered area and the pegmatite which is very wide does not outcrop. Surface trenches and shafts extend over 230 ft. of east to west strike and indicate a southerly dip. The pegmatite is clearly very much longer than the extent of the workings for at the eastern end it is 45 ft. wide, while at the western end a cross-trench 33 ft. in length is still in pegmatite at both ends.

From what can be seen of the pegmatite, there is a wide core zone of microcline and quartz with much biotite in laths that on occasion exceed two feet in length. The muscovite in this zone is of ruby quality, but is broken and striated. There are apparently wall zones of plagioclase, quartz and mica, but no hanging-wall concentration of mica. Some sort of a shoot appears to have developed on the foot-wall, however.

The extent and depth of the underground workings is not known. There are two shafts 40 ft. apart, but no connection can be seen between them. The eastern shaft appears to be only about 15 ft. deep. Some work which may be the top of a small stope has been done from the western shaft to within 10 ft. of the surface.

The mine produced 5 tons 1,677 lb. of ruby mica valued at £3,260 in 1944-5. This includes the outputs of the Redwing Mine.

The *Eclipse Mine* locality is given vaguely as the Miami Mica Field. It produced a little cut mica each year during the period 1926-9 which totalled 2,060 lb. valued at £157.

The *Egg Mine* (see The *Zamona Mine*).

The *Eland's Luck Mine* is  $3\frac{1}{4}$  miles east-by-north of Miami Village.

R. Tyndale-Biscoe (25, p. 3), who was able to examine the mine before it closed, noted that the pegmatite is "unusual in apparently having the form of an undulating sheet, with knobs and protrusions on its upper surface. The distribution of mica is highly irregular, being found to have a tendency to be concentrated alongside quartz blows, of which there are many." Apparently in one part of the mine the full thickness of the pegmatite sheet was not discovered as the mica was merely mined from the top of the body.

The main workings yielded rather small-size books of high-quality ruby mica. This was compensated for, in a measure, by the high percentage cuttability of the splittings, which were usable right up to the edges. This suggests that the books had fair crystal forms. Biotite, which is almost always associated with ruby mica, was comparatively abundant.

The sillimanite-mica-schist walls formed very bad ground and for this reason much of the overburden was stripped. This resulted in the formation of two large, deep open workings. Because of the soft ground all mining was done without the use of explosives. The largest open working is between 40 and 50 ft. deep and 150 to 200 ft. across. To the north-north-west of this large quarry is another large hole over a flat pegmatite and the two workings were connected by drives. Also a 300 ft. adit was driven from the east to connect up with the main open working.

In addition to the flat pegmatite there are, in the near vicinity, many small concordant pegmatites which have been prospected by shallow trenches.



The sub-outcropping nature of the main flat pegmatite suggests that in the vicinity there may be others which could be found by drilling.

The Eland's Luck Mine was an early pegging on the Feld. It started production in 1921 and the last output was in 1958, but in between there were long periods when the mine was dormant. The last output of any consequence was in 1946 and the small production since then has been mainly on tribute. Much mica from here has been declared with the Grand Parade Mine, but its own declared output amounted to 31 tons 1,150 lb. valued at £8,075.

The *Elise Mine* is  $4\frac{1}{2}$  miles west-by-north of Miami Village on the north-eastern boundary of Pitlochry Farm.

The Elise pegmatite is believed to have been a replica in miniature of the Rae Mine pegmatite which is 700 yds. to the north-west. They have similar dips and strikes and clearly occupy related fractures so that they probably have a common source of material.

When the site was visited, all workings were completely inaccessible and no pegmatite could be seen *in situ*. The strike appears to be 56 degrees (magnetic) and the dip north-west. There is evidence of a collapsed vertical shaft 36 ft. on the hanging-wall side of the pegmatite. The schist from the shaft is highly micaceous, and it is penetrated by quartz veins that are rich in tourmaline and small books of muscovite.

The mine produced in 1943-4, and 1951, when a total of 5 tons 1,299 lb. of cut mica realized £2,891. (See also under beryl.)

The *Emerald Mine* locality is given merely as Urungwe East Group, and it might not be in the area covered by this bulletin. In 1924 it declared 2 tons 1,450 lb. of cut mica valued at £223.

The *Esquire Mine*, a repegging of the Burnley Mine, is  $1\frac{1}{2}$  miles south-east of Miami Village. Little could be seen of the pegmatite in the small, inaccessible underground workings. The Burnley together with the Unknown Mine produced in 1926-7, and 1944 when 1,410 lb. of cut mica fetched £121. The Esquire produced in 1952-3 when 80 lb. of cut ruby mica sold for £25.

The *Eurythmic Mine* claims are  $3\frac{3}{4}$  miles north-east of Miami Village and a quarter mile south of the Eland's Luck Mine.

Several pegmatites have been mined on the claims and outputs are given under three different claim numbers. Immediately north of the Miami to Masterpiece Farm track is a fairly large open-cast working which was full of water when the mine was visited. The schists here strike 240 degrees (magnetic) and dip steeply in a south-easterly direction. The pegmatite is believed to be a flat-lying body like that of the Eland's Luck Mine. This pegmatite is reported to have produced good-quality green mica, but was sparsely mineralized.

On the opposite side of the track, and 200 yards south of the first working, there has been some mining of a steeply dipping pegmatite which is nowhere exposed. About 700 yds. south-east of the first working, there are some fairly widespread, shallow, surface workings on high ground on what appears to be a flat-lying pegmatite, but there was virtually only rubble to be seen.

The various claims produced in 1943-4, and 1946 yielding a total of 8 tons 1,116 lb. of cut green mica valued at £4,022.

The *Fishtail Mine* is on Cheti Farm  $4\frac{1}{4}$  miles north-west of Miami.

There is a shallow open working over a short north striking pegmatite which dips steeply east. There is a collapsed hanging-wall shaft and another which was full of water on the foot-wall side of the pegmatite. The mica which could be seen was of ruby quality but was striated. The rock dump has both feldspars but microcline seems preponderant. There is also some tourmaline and biotite.

A little south of these workings several small pegmatites have been prospected, but they revealed nothing of value.

The mine produced in 1945-6 when 7 tons 1,490 lb. of cut mica realized £3,601.

The *Foil Mine* is reported to be three miles north of Miami Village. It produced in 1926 and 1930 when a total of 382 lb. of cut mica were sold for £50.

The *Fowler I Mine* is reported to be six miles south of Miami Village. In 1920 it produced 750 lb. of cut mica valued at £94.

The *Freak Claims* are on Crown land,  $1\frac{3}{4}$  miles south-east of the Rkwesa Mine and five miles north-north-west of the Catkin Mine.

The pegmatite is a wide, lenticular body with a strong quartz core. It has an overall north to south strike of about 100 ft. and an easterly dip of 52 degrees. Water was seen in an inclined shaft at about 30 ft. down where there was some development in both directions. Concentrations of wedge-shaped, core-margin mica is associated with some biotite. There was no evidence of any wall zone mica and it would appear that no cuttable mica was found. No production is recorded.

The *Garnet Mine* is  $7\frac{1}{2}$  miles north-by-east of Miami Village.

The underground workings are inaccessible as all the shafts have collapsed. There is over 750 ft. of trenching on the strike of the reef, which is 175 degrees (magnetic) with an easterly dip. The pegmatite actually continues on surface beyond the trenching. Near the northern end of the strike a spur branches off into the foot-wall.

The nature of the pegmatite and mineralization cannot be discerned in the trenches but good-quality spotted mica can be seen on a nearby waste dump of mica.

There is a pegmatite a little to the south-west which has a long east by north strike and a southerly dip. It has been prospected by means of an inclined shaft which had collapsed.

The Garnet Mine produced first in 1920-1 and again in 1929, and from 1945-7. In all 13 tons 1,649 lb. of cut mica were sold for £4,354.

The *Gem Mine* is on Crown land, 13 miles north-west of Miami Village and three-quarters of a mile north of the eastern beacon of Protea Farm.

The pegmatite has a strong quartz core which has given rise to a small feature. It strikes at 127 degrees (magnetic) and dips to the south-south-west. The ground falls away steeply at the west-north-west

end of the strike and here the core has been gouged out over a distance of some 30 ft. and to a maximum depth of 25 ft. From the bottom of the open cut there is a short drive of a few feet. The quartz core, which is 9 ft. wide at surface, has disappeared and the drive is in microcline of the core margin zone. This drive is connected with a collapsed adit from the south-south-west. There is in addition a fair amount of shallow surface work along 235 ft. of strike. Beyond the last surface working to the east-south-east the pegmatite takes a slight northerly turn and can be traced for a further 200 ft.

There are some shallow surface workings on two other pegmatites to the east. The three pegmatites are spaced about 600 yds. apart.

Much of the mica extracted from the main pegmatite was fish-tail, core-margin material of ruby colour. Some spotted mica cuttings seen on surface were presumably mined elsewhere. Inferior amethystine quartz was seen on the waste dump and may have been the reason for the name and —unless beryl was sought— why so much of the quartz core was extracted.

The mine produced in 1943-4 when 833 lb. of cut mica were sold for £291.

The *Gift Mine* locality is given merely as on Crown land, Miami. In 1953 it produced 69 lb. of cut mica valued at £26.

The *Gleam Mine* locality is given only as the Urungwe Mica Fields, East Group. In 1925, it declared 1 ton 658 lb. of cut mica valued at £80.

The *Gold Leaf Mine* is on Crown land, 11 miles a little west of north of Miami Village.

A pegmatite, striking east and dipping south at 80 degrees, has been open-cut into the side of the hill for 75 ft. and to a depth of 10 ft. This work reveals that ruby mica has been mined from the foot-wall of the pegmatite. A shaft has been sunk just west of the open working. In 1952 the mine declared 1,533 lb of cut mica valued at £480.

The *Goy Mine* is 2½ miles east of Miami Village.

Nothing is to be seen of the pegmatite *in situ* as it is decomposed at surface and strikes almost along the middle of a vlei. Shallow discontinuous trenching and an old, vertical shaft reveal an east-north-east strike and an east-south-east dip. Only the eastern end appears to have carried payable mica.

It produced in 1922 and 1924-5 when 1 ton 1,276 lb. of ruby mica were cut and sold for £403.

The *Grand Parade Mine* is on the north bank of the Mpofu River, two miles north of Miami Village.

History and development: The mine produced ruby mica of the highest quality. The official records of production unfortunately, include outputs from some other ruby-bearing properties, but even taking these into consideration, the mine produced a tonnage of mica which would be worth several million pounds at today's prices. The classified mica production figures for a three month's test period in August, September and October, 1923, are available. Substituting the purchase rates quoted



by F. F. Chrestien Co. Ltd., for mica effective from 1st January, 1960, the value of this three months production would have been £82,876. This price does not take into consideration 5 tons of thins and half a ton of 1½-inch mica discs.

Not long after the formation of the Federation of Rhodesia and Nyasaland, when the Federal Prime Minister, Sir Roy Welensky, was on a visit to Karoi, Mr. N. A. Tatham\*, then manager of Rhodesia Mica Mining Co., was able to discuss the Mica-field with him. Sir Roy said that many years ago he had been a carpenter on the Grand Parade Mine where he had made the shooks for the mica boxes. He remembers the large books of clear ruby mica from the mine being placed in the sun against the outer wall of the very long cutting shed to dry out before being split. Some of these books stood as high as he did and it was common to cut extra special sizes in perfectly clear mica.

The claims were reported registered in 1919, and named after the horse that won that year's Derby. However, the outcrop on which the main workings are now situated was not discovered until the following year. Like other virgin discoveries large books of mica were found, apparently, protruding from the ground. J. Goldberg, who was then an hotel-keeper in Salisbury, acquired the claims in August, 1920, and came to settle on the mine.

In August, 1921, C. A. B. Colvile, Inspector of Mines, issued a report on the mine. It had been open-cut to a depth of 15 ft. along 450 ft. of strike and had yielded 6 tons of clear, cut mica. Winzes were being sunk to connect with a 35 ft. level stope-drive. Cross-cuts had revealed that the foot-wall of the pegmatite also carried good mica. A vertical shaft had been sunk to a depth of 65 ft. and a cross-cut to the pegmatite had revealed a good concentration of very large books of clear ruby mica. The ground was so soft and the pegmatite so decomposed that all this work was done without the aid of explosives. It is believed that the pegmatite was eventually mined to a depth of 90 ft. before explosives became necessary. At the time of Colvile's visit the shed was cutting 4 cwt. of mica a day from the development work alone. This was all clear ruby mica with a good proportion of Nos. 1, 2 and 3 sizes as well as some specials. The mine was making a considerable amount of water.

During the last third of 1923, G. W. Williams, mining engineer, made a detailed study of the mine. At this date the vertical shaft had cut the pegmatite at 90 ft. from surface. Here there was a drive 430 ft. in length. Above this level the hanging-wall mica shoot had been stoped out right to the surface leaving numerous large pillars. Good mica still persisted in both faces. A 125-ft. level had been driven 360 ft. At the northern end the pegmatite was 4 ft. wide and carried large books of mica throughout. Four winzes below this level all revealed large mica books.

A 175 ft. level was reached by means of a 75 ft. cross cut from a new single-compartment vertical shaft which eventually cut the pegmatite at

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\* Personal Communication.

a depth of 230 ft. The average size and quality of the mica was reported to have shown an improvement at this level. A drive was run 40 ft. north and 60 ft. south off a winze 40 ft. below the 175 ft. level, but work was temporarily discontinued because of water and ventilation difficulties. The pegmatite averaged  $4\frac{1}{2}$  ft. in width in this winze and the level driven off it reportedly carried the best mica values in the mine.

In an attempted evaluation of the mine Williams discounted all the mica remaining above the 90 ft. level, and based his calculations on proven mica values below this. Working on an estimated average of £400 per ton, he arrived at a figure of over £200,000 as the value of the mine. At this time about 6 per cent. of the mica was marketable and he estimated that the mine could be run at an annual profit of £50,000.

It is believed that following Williams' investigation, Goldberg refused a company offer of £100,000 for the mine.

Williams was clearly unimpressed by the mine lay-out, for he wrote that "it just sort of happened along, more by good fortune than design." The pegmatite was so rich in high-quality mica that "it was quite impossible to avoid making very substantial profits."

The mine became the property of Hugh Tevis and Partners in March, 1942, and they operated it until the middle of 1945. During this period they produced a little under 107 tons of mica valued at £80,403.

In June, 1945, G. Paterson and Sons purchased the Grand Parade Mine, together with the Beckett, Catkin, Dunga, Eland's Luck, Hari, Kingsale, Rae and other properties, from Hugh Tevis and Partners. The purchase price of some £22,500 was paid for by the mica won from the Grand Parade South Prospect Mine.

By the time Patterson took over the main Grand Parade Mine the hanging-wall mica shoot had been completely developed. This shoot attained a maximum depth of 260 ft. with the form shown on Plates X and XVI. There were, however, large hanging-wall pillars to be extracted and the foot-wall mica shoot, which did not conform altogether to the form and position of the hanging-wall shoot, was still not completely mined out in the upper central and bottom portions of the mine. In addition, some work was done in pegmatite outside the limits of the shoot in the hope that a further shoot would be revealed. This included driving south beyond the limit of the hanging-wall shoot on the 230 ft. level for a distance of 345 ft. In this drive the pegmatite was 25 ft. wide in one cross-cut.

**Pegmatite:** The Grand Parade pegmatite is emplaced along a discordant fracture which strikes true north with the foliation of the gneiss but dips east across it at angles varying between 45 and 53 degrees. For the most part the body is typically zoned with a quartz core and hanging- and foot-wall mica shoots. Pegmatite widths are of the order of 10 ft. and more. Where the pegmatite was less than about 6 ft. wide the inner zones disappeared and it carried mica more or less throughout with enrichments towards the walls. Williams reported that at the 125 ft. and 175 ft. levels the pegmatite averaged  $5\frac{1}{2}$  ft. but varied from 2 ft. to 12 ft. or 15 ft. in width. In the winze below the 175 ft. level the peg-

matite was 4½ ft. wide with mica throughout, the largest books being on the hanging-wall. From these books some extra special sizes were cut.

The pegmatite can be traced for over 2,000 ft. and the hanging-wall mica shoot, which has a surface strike of 630 ft., occurs near the southern end of it. In a note on the Grand Parade Mine dated September, 1943, R. Tyndale-Biscoe writes: "The reef at the north end becomes gradually narrower and is finally reduced in width to five or six inches. The north end of the 145 ft. level drive exposes a sloping surface of granite with a sharp contact against the pegmatite in marked contrast to the irregular contact of pegmatite and schist. The bottom of the north incline shaft has also gone into the same granite." On a plan he shows the projected granite to gneiss contact as likely to occur at a depth of about 250 ft. below deepest point of the mica shoot. To explain the irregular contact between the pegmatite and the schist, he states that "The country rock (mica-schist) has its cleavage planes dipping in the opposite direction to the pegmatite, i.e. westerly, and the pegmatite sends small shoots out along the cleavage planes, resulting in an irregular indented contact." It will be noted that the country rock has been described both as a mica-schist and a gneiss. The reason is that the wall-rock is in fact a *lit-par-lit* gneiss which along the contact has been enriched in muscovite so that quite locally it could be called a schist.

In the mine the pegmatite is undisturbed but for a small reverse fault which outcrops as shown in Plate XVI. It has caused a small surface displacement of the strike while underground its maximum effect is illustrated in Fig. 14.

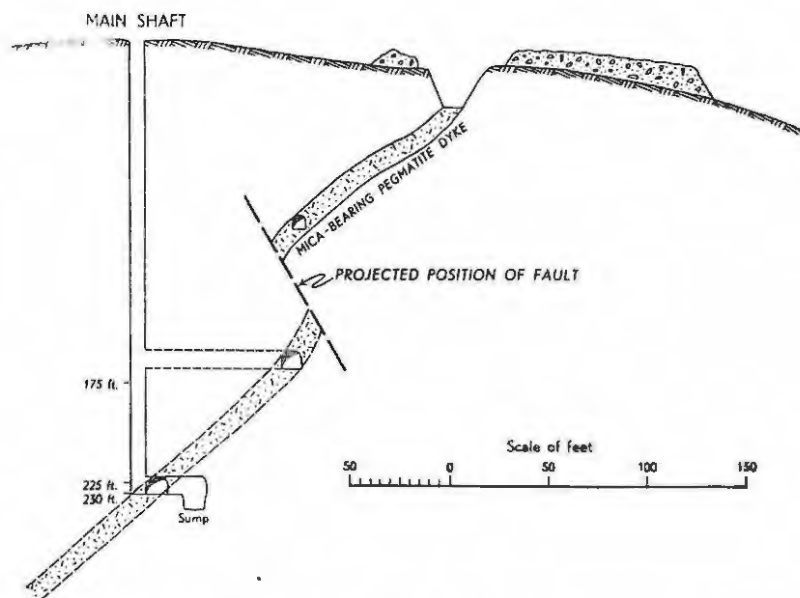


Fig 14. Cross-section of the Grand Parade Pegmatite



This fault has, however, a hinge-like displacement which varies from about 40 ft. to zero before the main shaft cross-cut.

The *Grand Parade South Prospect Mine* is on a pegmatite which was believed to have been the faulted southern extension of the Grand Parade pegmatite, but this was disproved by development.

This pegmatite is remarkable in several respects. Besides being the deepest mica mine on the Field, attaining a vertical depth of 440 ft., the form of the shoot (see Plates X and XVI), the short strike and narrow widths, and the high tonnage of valuable mica produced are an unusual combination of factors.

The pegmatite has an easterly dip of 52 degrees which is the same as that of the Grand Parade, but it strikes 25 degrees east of north instead of almost north and south (magnetic). The pegmatite did not outcrop and was picked up in a cross-cut from a shallow vertical shaft which was put down to try and find a southern extension to the Grand Parade pegmatite. The pegmatite where discovered, was narrow and carried a high concentration of biotite with only an occasional book of muscovite, so was abandoned. It was later reopened by G. Paterson and Sons under the management of N. A. Tatham, who kept a detailed record of development. A two-compartment inclined shaft was sunk and a first level at 50 ft. was driven to connect with the old working. Shaft sinking was continued but it was soon decided that unless the values improved, the working would be abandoned. However, at 60 ft. there was an improvement. Muscovite books of fair size were discovered and in places there was less biotite. While driving north on the upper levels an epidiorite dyke which is probably pre-pegmatite in age, was encountered but later faulting along it had displaced the pegmatite some 10 ft. into the foot-wall on the second level. The amount of displacement decreases in depth. The dyke and fault almost mark the northern edge of the shoot which had a payable strike of about 110 ft. on the 2nd, 3rd and 4th levels. Below it gradually shortened and ended just short of the 8th level at an incline depth of 430 ft.

On the 3rd level the biotite had practically disappeared at some 40 - 50 ft. north of the incline, and mica books yielded some specials which were valued at 55s. 9d. per pound. Between the 4th and 5th levels, where the shoot was only payable for 90 ft. and the pegmatite not much over 3½ ft. wide, 7 tons of cut mica which averaged about £1,000 per ton was produced. Production was at one stage at the rate of about 1 to 1½ tons of crude mica per day.

The northern edge of the mica shoot virtually marks the northern extremity of the pegmatite which narrows rapidly, but carries mica in smaller and smaller books right to the end. The shoot extends a little south of the inclined shaft, but was apparently left intact so as not to disturb the shaft. Unpayable pegmatite continues south of the shoot and soon becomes rather dissipated into spurs. In the shoot the mica occurred throughout the pegmatite which was of the simple type, composed predominantly of plagioclase.

The mica from the South Prospect was declared with that from the Grand Parade and was valued at about £70,000.

After this experience with a biotite-rich pegmatite, biotite was looked upon as a favourable indication. However, work was later done on the Biotite pegmatite just north-east of the South Prospect but no muscovite of any consequence was found. Two other pegmatites known as the Prospect and Thorntree, which occur nearby, were also thoroughly investigated. A pegmatite 90 yd. north-east of the Main Shaft on the Grand Parade Mine carries small books of good quality, ruby mica and was opened up to a depth of 60 ft. This pegmatite may be worth re-investigation. (See also under beryl.)

The *Grand Parade II Mine* is 500 yd. north-north-west of the main Grand Parade Mine. There are two sections here (see Plate XVI) which may be *en echelon* pegmatites or a single pegmatite displaced by a fault. Both strike a little east of north and dip east. They have each been trenched for some 240 ft. The workings in the northern sector are the deepest and there are a couple of old shafts here. Little can be seen of the pegmatite *in situ* and little is known about the workings.

The *Grand Parade III Mine* is threequarters of a mile north-by-east of the Grand Parade Mine. Here there is a long, narrow, shallow open-cast working in granite country. The pegmatite strikes north and dips at 60 degrees to the west. It has been prospected along about 200 ft. of strike and to a maximum depth of 10 ft. Much of the pegmatite is under water. At the northern end it is three feet wide and there is evidence of a quartz core at both ends. Apparently it yielded good ruby mica at surface, but in depth the mica became buckled.

With the Grand Parade group of mines are outputs from the Eland's Luck, Clyde, Catkin and Mica King mines. Production was during the following years: 1920-27, 1929, 1930, 1932, 1933, 1942-46, 1949, 1951-55, when a total of 596 tons 245 lb. of block mica realized £250,194. In addition, 250 tons of waste mica were sold for £987. (See also under beryl.)

The *Grand Prix Mine* is reported to be two miles east of Miami Village and the workings presumably adjoin those of the Aqua. Some outputs have been declared with those of the Aqua. The early outputs, in 1927-28, were declared separately and amounted to 1,717 lb. of cut mica valued at £165.

The *Grand Slam Mine* is on Crown land, 10 $\frac{3}{4}$  miles north-west of Miami Village.

There are three reasonably large pegmatites on what were presumably Grand Slam claims. Two of these, 200 yd. apart, have been mined for mica. They are *en echelon*.

One pegmatite was presumably on the block of claims registered as No. 1625 and the other on No. 4632. The former was repegged as the Radnor 2 and later as the Mazurka but there has been no production under the latter name. These mica mines are not to be confused with the Grand Slam beryl workings on Collingwood Farm, 15 miles south-east of Miami Village.

The northern mine is on a discordant pegmatite striking 35 degrees (magnetic) and dipping in a south-easterly direction. It can be traced

on surface for 375 ft., but the workings are confined to 150 ft. of strike at the north-eastern end. Development has been from five shafts. There are hanging- and foot-wall inclined shafts and a vertical shaft. A sixth shaft was started just south of the main workings but was stopped at a shallow depth and there is no development off it.

From what can be seen the pegmatite is a microcline-rich body attaining a width of over 20 ft. From the rock dump it would appear that a quartz core was present at the northern end and normal zoning may have been present giving rise to weak wall-zone mica shoots.

Just north of these workings is a pegmatite which has been excavated for beryl to a depth of 5 ft. along 18 ft. of a wide quartz core. It is exposed for 300 ft. on a strike of 60 degrees (magnetic) and it dips to the south-east.

The second Grand Slam mica working is about 200 yards south of the first working. This pegmatite has an exposed strike of 600 ft. and is structurally similar to the first. There is an eccentric quartz core at the north-east end where the hanging-wall has been trenched along 60 ft. of strike and to a maximum depth of 12 ft. In the absence of quartz, microcline forms the core zone.

A vertical shaft has been sunk at a point 26 ft. on the hanging-wall side of the open working. Judging from the small size of the waste dump at this shaft there has been little development from it, so no mica shoot of any consequence was found. It is clear that not much mica was produced from this pegmatite. From the outputs given it appears that this is the pegmatite that was later repegged as the Radnor.

The total output from the two workings amounted to 1 ton 1,209 lb. valued at £1,072. Productions were declared in 1924, 1943 and 1945. The production in 1924 of 150 lb. of mica valued at £10 probably came from the southern pegmatite.

The *Guinea Fowl Mine* is  $4\frac{3}{4}$  miles west-north-west of Magunge administrative centre in the Urungwe Native Reserve.

A microcline-rich pegmatite striking 353 degrees (magnetic) and having a steep easterly dip can be traced on surface for 200 ft. There is an abundance of poor fish-tail ruby mica. The workings consist of shallow marginal pits which are mainly in rubble from the pegmatite. The mine is clearly of little value and production in 1952 amounted to 25 lb. of cut mica valued at £11.

The *Halsmere Mine* is reported to be on Crown land, five miles north-east of the Catkin Mine, but in relationship to the reported locality of the Masokira Mine it would appear that there is an error of direction and that the locality should read five miles south-west of the Catkin Mine. In 1954 it produced 32 lb. of cut mica valued at £14.

The *Hari Mine* is  $3\frac{1}{4}$  miles north-north-east of the Miami Village and a little north-west of Chitenje Hill.

Two parallel pegmatites have been worked on the claims and are known as the Hari I and Hari II mines. The latter is just a little west of the former and nearer the river. Nothing could be seen of the pegmatites *in situ* but the nature of the workings indicates that they strike north-



east and dip south-east at something over 60 degrees. The mines were very wet and the pegmatites which were much weathered in the upper levels are in highly micaceous schist that gives rise to difficult ground. Both pegmatites were mined to a vertical depth of about 100 ft.

The mica, which was a high quality brown-green, was, for the most part, disseminated throughout the pegmatites with an occasional tendency for a hanging-wall concentration to develop. The mica books were apparently large, but very broken and only small sizes could be cut. In addition they were often striated and contained numerous inclusions of quartz. The striations were frequently more pronounced on one side of the book than on the other.

The pattern of the Hari I mica shoot is given on Plate X.

An appreciable amount of work has been done on two other nearby pegmatites, the one west of and the other south-west of the two main pegmatites. It is not known whether these were on the Hari claims.

Two Hari blocks have included the old Abigail block for which separate outputs amounting to 2 tons 1,008 lb. of cut mica valued at £142 were declared in 1927-8. The Hari blocks, excluding the Abigail outputs, have produced 32 tons 1,907 lb. of cut mica valued at £12,165. These figures are the total of nine outputs declared between 1925 and 1953, with no production in the 1930s.

The *H. B. Mine* is on Crown land, five miles north-east of Miami Village. In 1953 it declared 112 lb. of cut mica valued at £22. (See also under beryl.)

The *Hendren Mine* claims occupy a large area situated some eight miles north-west of Miami Village. There are at least 12 pegmatites which have produced mica and a number of small ones which have produced beryl.

The Hendren and Hendren I claims adjoin each other on the east and west respectively, and the Karoe River runs through the eastern sector of the Hendren block. On the western bank is a pegmatite striking north and dipping east at 58 degrees. Its relationship to the gneiss is a discordant one. The pegmatite, which is a plagioclase-rich body, has been trenched for 150 ft. into the slope of the hill. For the first two-thirds of this distance the trench is on the hanging-wall side of the pegmatite, and in the remaining third of the trench the whole of the pegmatite, which is 12 ft. wide, has been quarried. The quality of the mica is a clear, brown-green.

To the west-south-west of this working another fairly large pegmatite has also been mined open-cast. It strikes a little east of north with the foliation strike of the gneiss, but the dip of the pegmatite is to the east and is opposed to the dip of the gneiss. This working occurs south-south-east of the old mine house. There is 140 ft. of continuous trenching to a maximum depth of about 25 ft. and the pegmatite has been prospected along 400 ft. of strike. There is a large mica waste dump of rather buckled mica which appears to have come from a hanging-wall concentration in the pegmatite.

North of the last-mentioned working is another large pegmatite striking north by east and dipping east. At its southern end it gives rise

to a small hill and an adit has been driven on strike right through the hill on a bearing of 20 degrees (magnetic). The northern exit from the adit is on a steep hill slope leading to a river. Another adit has been driven on the pegmatite from the river side, well below the first adit. It goes in a southerly direction along the hanging-wall of the pegmatite and a cross-cut extends to the foot-wall.

The pegmatite in this southern section has a wide, microcline-rich core with plagioclase margins, and sparse, densely spotted mica with good crystal form. Pegmatite can be traced north for quite a distance and it may be part of a continuous dyke. A dolerite dyke in the river will cut the pegmatite if it is continuous. Wide pegmatite, with a quartz core and microcline-rich margins, continues up the hill slope north of the river. There is some mica on both walls but more open-cast work has been done on the foot-wall than on the hanging-wall side. Farther up the hill another dolerite dyke, 50 ft. wide, appears to cut the pegmatite. Pegmatite continues beyond the dyke and, if it is the same body, it has been displaced 160 ft. to the west of the line of strike of the southern outcrop. North of this dyke the pegmatite has a quartz-microcline core zone and the hanging-wall has been trenched for 180 ft. In the foot-wall of this pegmatite, at the northern end of the working, is another pegmatite with a strong quartz core. This pegmatite strikes north-west. The core zone has been mined for beryl and trenched for mica along 60 ft. of strike on the north-east side of the body.

Continuing north-west on the line of strike of this pegmatite is yet another pegmatite which dips east giving rise to a hillock. It has been trenched along the hanging-wall side and at the south end is a steep inclined shaft. There is more than 450 ft. of surface strike and at its northern end a quartz core has been mined for beryl. About 100 ft. north-west of this point, another pegmatite forms a hillock where there is a collapsed adit. From here, eastwards across the valley on high ground are two pegmatites which have been prospected by trenches.

The Hendren II Mine is about 700 yds. north-west of the Hendren I Mine. The pegmatite is a discordant body striking north-east. It has a variable north-westerly dip of the order of 70 degrees which decreases in depth. It is a zoned body, 9 ft. wide, with a quartz-microcline core at the south-western end. There is a little core margin fish-tail mica and the outer intermediate zones are of mica-quartz-plagioclase. Some 60 ft. along the adit drive from the south-west end, a hanging-wall mica shoot has been stoped to the surface over some 160 ft. of strike right to the adit exit at the north-east end which is at the 40-ft. level. At the south-west end of the strike is another adit which is really an Australian winze for the first 45 ft. The foot-wall of the pegmatite carries a little mica near the south-west end but it is not known whether this ever developed into a workable shoot.

There is a plan of the mine dated November, 1952. It shows that the pegmatite has been mined down to the 165-ft. level and from the stoping pattern it appears that the hanging-wall mica shoot had a form rather similar to the Danga mica shoot shown on Plate X, except that the "foot" of the Hendren shoot is more regular and points to the south-west. On the 125-ft. level the shoot is 180 ft. long. Another adit put in

from the north-east at about the 100-ft. level was clearly made without reference to a plan. It has gone through over 130 ft. of schist and has struck a valueless cross-pegmatite at a point almost below the upper adit entrance.

On top of the hill the main pegmatite has a prominent quartz core which has been prospected for beryl. No. 1 inclined shaft, 20 ft. deep, has been put down on the foot-wall side of this core but does not connect with the main working. This hill has two high points and the second is also occupied by a pegmatite which has the same dip and strike as the main pegmatite and is almost on the same line. They are, however, possibly different pegmatites and they are not connected by development. No. 2 inclined shaft on this second feature is almost 500 ft. south-west of No. 1 Incline on the main working. An Australian winze has been put in from the south-west and attains a depth of about 70 ft. The pegmatite has been stoped above this as far as the No. 2 Incline, 180 ft. from the start of the adit.

Several pegmatites have been prospected in an area about half a mile to the north and north-north-west of the Hendren II Mine. These may be on the Hendren III and IV blocks. One has been prospected for beryl but the other two are mica workings. These two mica-pegmatites are *en echelon* on a strike of 230 degrees (magnetic) but they dip in opposite directions. The larger of the two is on the northern bank of the river and dips south-east at 55 degrees. The exposed pegmatite is only three feet wide and has a narrow quartz core.

The Hendren V Mine is half a mile south-west of the Hendren II Mine and has been the most recently worked pegmatite. It is a concordant and markedly lenticular body, typical of many pegmatites which occupy similar structures. It is in many respects an ideally zoned pegmatite and for this reason it will be treated in more detail.

The strike is from north-east to south-west and the dip is to the north-west. The angle of dip of the pegmatite on the 2nd level is 54 degrees. The mica-shoots, from an economic consideration, can be regarded as sub-outcroppings. There is a strong hanging-wall shoot and a rather weak foot-wall shoot which was only payable over a small area on the 2nd level, north-east of the inclined shaft. The hanging-wall mica books were biggest where the pegmatite was widest and became unpayable when the width of the pegmatite decreased to five or six feet. A mica book was seen which measured 25 by 12 in. in the plane of the cleavage.

At the cross-cut, south-west of the inclined shaft on the 2nd level, which is presumably near the mid-point of the pegmatite, the body is 25 ft. wide. The details of the zoning in this ideal cross-section, from hanging-wall to foot-wall, are as follows:

- (1) A border zone of a few inches composed of albite-oligoclase, quartz, small muscovite books and tourmaline.
- (2) A hanging-wall zone of about two feet in width composed largely of muscovite books, in a base of albite-oligoclase and quartz,



oriented with their cleavage planes at right angles to the wall. Tourmaline is also present and is often included in the mica. There is more quartz than plagioclase.

- (3) An outer intermediate zone of albite-oligoclase, quartz and small muscovite.
- (4) Another intermediate zone, some 6 in. wide, of wedge-shaped, herring-bone muscovite. The inner intermediate zone of microcline is missing at this point so that the muscovite is embedded in the margin of the quartz core.
- (5) A milky white quartz core 9 ft. wide. Seven inches from the quartz hanging-wall is a beryl crystal, 2 in. across. Six feet in from the hanging-wall is a large crystal of microcline surrounded by the quartz core. The quartz core is not continuous, and elsewhere in the mine microcline constitutes the core. In all, 40 lb. of blue beryl (translucent aquamarine) was extracted from the core in this cross cut.
- (6) Large crystals of microcline form a core margin, on inner intermediate zone, on the foot-wall side of the quartz core. This zone is 3 ft. wide and also contains a little albite-oligoclase. Some of the potash feldspar examined was perthitic.
- (7) A narrow, middle intermediate zone of wedge-shaped, herring-bone muscovite in the margin of the potash feldspar.
- (8) An outer intermediate zone composed predominantly of pink albite-oligoclase. Quartz and small muscovite occurs here as on the hanging-wall side. No microcline was observed.
- (9) A narrow foot-wall mica shoot which here was unpayable. In the matrix is albite-oligoclase, quartz and tourmaline.
- (10) The foot-wall border zone differs from the hanging-wall border zone by being richer in tourmaline.

Plagioclase specimens from the two border zones and the two outer intermediate zones were examined optically and chemically, but no zonal variation in composition could be detected.

On the second level, about 20 ft. east of the inclined shaft, the core and core margin zones have pinched out and the hanging- and foot-wall zones have come together to form a pegmatite 18 ft. wide which virtually carried payable mica throughout so that the whole width of the pegmatite could be mined. The pegmatite narrowed rapidly, however, and this happy state of affairs did not persist for long. The mica shoot has a short workable strike and the bottom of the inclined shaft, which is not many feet below the 3rd or 150-ft. level, is apparently the end of the mica-shoot at this point. Appreciable tourmaline makes its appearance in the wall zone and the impression is gained that the end of the pegmatite is not far removed. The structure of this pegmatite is similar to the Piper Mine pegmatite in many respects (see Fig. 18). Just west of the bottom of the shaft the tourmaline goes out and large mica books come in again, indicating a flat pitch of the mica shoot to the south-west. The form of the hanging-wall shoot is elliptical with the long axis in the direction of strike. The Piper shoot may also

have had this form but the upper half of the shoot has been truncated by the erosion surface. The mica produced was classified as second-quality, spotted.

A feature of this pegmatite which has also been observed in other concordant pegmatites, is the presence of what is known on the Field as a "false" hanging-wall. It has been produced by the alteration of the wall-rock and it results in large slabs of the hanging-wall rock breaking away if not secured or removed during stoping operations. In the Hendren V Mine this false wall is 20 in. thick in the centre of the mine and is composed of granular quartz and tourmaline with some biotite. Beyond this wall the country rock is highly micaceous (see p. 81). The very regular, smooth hanging-wall is presumably a fault plane so that the pegmatite would appear to occupy a normal, strike fault structure.

Workings: This pegmatite can safely be regarded as having been exhausted. The main level was No. 2 with a payable strike of about 90 ft. and the bottom of the mine is only about 10 ft. below the 3rd or 150-ft. level. While the quality of the mica was not very good nor the average size large, it was the concentration of mica that made the mine payable.

The Hendren VI Mine is parallel to the Hendren V but dips in the opposite direction and is 140 yds. north-west of the latter.

This pegmatite has a strong quartz core and was first mined for beryl. However, after the reopening of the Hendren V, a small sub-outcropping, hanging-wall mica shoot was found purely by chance. It only had a short strike and was bottomed at 12 ft.

The Hendren VII Mine is about 700 yds. north-north-west of the Hendren II Mine.

The workings are on a discordant pegmatite striking north and dipping east at 40 degrees. They consist of a shallow trench on strike at the north end and a timbered inclined shaft at the south end. Between these two there is a vertical shaft on the hanging-wall of the pegmatite. About midway along the surface strike there is an oblique pegmatite which is possibly a spur off the main body. It has a wide quartz-microcline core zone which carries biotite. The main pegmatite has a similar core. Albite can be seen on the rock dump and the indications are that a hanging-wall mica shoot, having spotted quality mica, has been worked. The surface strike is of the order of 300 ft. and at the south end it appears to meet a beryl-bearing pegmatite.

To the south-east of this mine are two microcline-rich pegmatites carrying striated core mica.

Output: The pegmatites have yielded largely spotted mica but some brown-green quality has also been produced. Some mica from the Pet and New Prospect mines has been declared with the Hendren. Production was started in 1921 and ceased in 1956 with a 12-year break from 1932 to 1943. Nor was there any production in 1922 and 1953. A total of 167 tons 824 lb. of cut mica, valued at £52,348 was produced during this period. In addition 546 tons 436 lb. of waste mica was sold for £1,563. (See also under beryl.)

The *Highlander Mine* locality is given vaguely as the Miami Mica Field. It produced 2 tons of mica in 1920 valued at £500.

The *Hopefontein Mine* is reported to be three miles north-east of Miami Village. In this locality there are a number of old shallow prospect workings on small pegmatites within and just south of Chigangas Farm. The mine produced 85 lb. of cut mica in 1926 valued at £9.

The *Horwood Mine* is reported to be four miles east of Miami Village. In 1923 it produced 1 ton 1,640 lb. of cut mica valued at £207.

The *Ingiri Mine* is reported to be seven miles north-north-east of Miami Village and is presumably one of the many shallow pegmatite workings which occur between the Beckett and Red Star mines. In 1948-9 it yielded 1,025 lb. of cut mica valued at £125.

The *Isabel Mine* is  $11\frac{1}{2}$  miles a little east of north of Miami Village. A small discordant pegmatite striking north-east was trenched to a shallow depth for beryl, but it also yielded 24 lb. of cut mica valued at a little over £1 in 1954. (See also under beryl.)

The *Jam Mine* is reported to be 14 miles north-west of Miami Village. In 1943-4 it declared 1 ton 977 lb. of cut mica valued at £892.

The *Jan Mine* is  $6\frac{1}{2}$  miles north-west of Miami Village.

The workings are on a discordant pegmatite dipping east. It has been trenched continuously along 500 ft. on a north to south strike. The pegmatite itself can be traced on surface for over 600 ft.

There are two collapsed inclined shafts about 60 ft. apart. One is near the northern end of the trench, where there is also a vertical shaft which was full of water.

The true structure of the pegmatite could not be ascertained but it seems likely that a hanging-wall shoot was mined near the northern end of the strike. About 70 ft. from the northern end of the pegmatite there is evidence of a foot-wall concentration of small mica having fair crystal form, but the books are much broken and contain inclusions of various minerals. Except for this exposure there was little other evidence of zoning and most of the felspar identified was microcline. However, spotted mica of fair average size is reported to have been produced.

About 180 ft. west of the southern end of the Jan strike is another pegmatite which forms the crest of the hill. It has a quartz core and marginal microcline which contains large striated muscovite books. Large books of biotite are also present and are often intergrown with the muscovite.

There were two productions, the first in 1921 and the last in 1944, which totalled 5 tons 847 lb. valued at £1,433. (See also under beryl.)

The *Jill Mine* is reported to be on Crown land, adjacent to the Dan-Y-Craig Mine on the west. In 1954 it produced 143 lb. of cut mica valued at a little less than £57. (See also under beryl.)

The *Jo Mine* is on Crown land, four miles east of Miami. It has been mined essentially for beryl but in 1953 declared 12 lb. of mica valued at £6. (See also under beryl.)



The *J. J. Mine* locality is given vaguely as a few miles south of Miami Village. An old claims plan shows the J.J. Claims as adjoining the Phoenix 315 block on the west, just west of the old Miami to Sinoia road. It is quite probable that this mine was repegged as the Top Hat Mine. There was a single output of mica in 1921 of 1 ton 240 lb. valued at £280.

The *Joke Mine* is reported to have been three miles north of Miami Village. In 1927 it produced 1 ton 823 lb. of cut mica valued at £96.

The *Juba Mine* is  $3\frac{1}{2}$  miles south-west of Miami Village and  $1\frac{1}{2}$  miles a little north of east of the Last Hope Mine.

The pegmatite is parallel to the Sorotie pegmatite and about 250 yards south of it on high ground on the opposite side of the water course or river. The workings have collapsed and are much overgrown, but from what can be seen the pegmatite is similar to that on the Sorotie. The strike is east and west, and it dips south. A nearby pegmatite at the top of the hill has a quartz core and has been prospected for beryl.

In 1945 the mine produced 4 tons 361 lb. of cut mica valued at £736. Some was also declared with the Mica View Mine outputs.

The *Kabanga Ikona Claims* were  $4\frac{1}{2}$  miles north-east of Miami Village. There is a small open working just north-east of the Hari Mine but, according to records, the claims have never been registered.

The *Karere Mine* is reported to be seven miles south-east of Manyangau kopje. If these directions are correct the mine must be on the northern edge of the bulletin map, north of the Peak Mine which is 13 miles north-west of Miami Village. It is essentially a beryl working but in 1953 it declared 11 lb. of cut mica valued at less than £2. (See also under beryl.)

The *Karnie Claims* are seven miles west-north-west of Miami Village, and about a mile south-east of the Hendren II Mine.

There are a number of pegmatites on the claims and their structural relationships are indicated in Fig. 15.

The economic mica-bearing pegmatites are all discordant bodies with a northerly trend and an easterly dip but those which are of little consequence as mica producers are east to west trending, concordant bodies. These have strongly developed quartz cores which carry a little beryl. It would seem that the beryl-bearing, concordant pegmatites have been intruded in the direction of shearing whereas the discordant ones occupy a conjugated system of tension fractures. All these pegmatites are presumably of the same age, but it is thought that those occupying tensional directions have drawn in a greater percentage of metamorphic material.

Only two of the pegmatites were of much consequence and these are known as the Main North Reef and the Main South Reef. The patterns of the mica shoots in these two pegmatites is illustrated on Plate X.

There is little to be seen of the Main North Reef at surface as it has been stoped out along 255 ft. of strike. The underground workings were inaccessible at the time of this investigation. At the southern face of the open working the pegmatite is 3 ft. wide and has an easterly dip

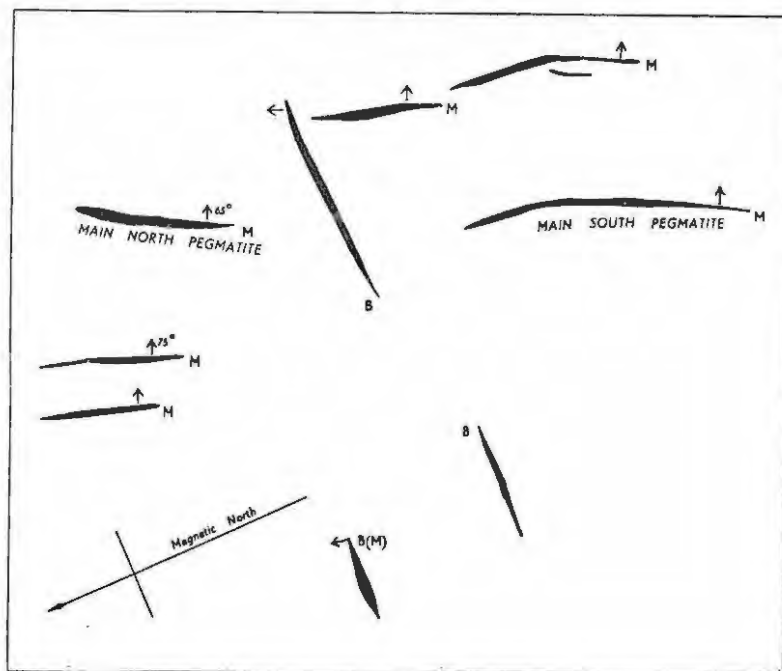
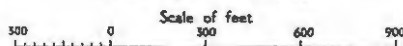


Fig.15 Illustrating trend of the Karnie pegmatites

B = Beryl, M = Mica



of 65 degrees. It is composed predominantly of quartz with a little felspar and small mica on the hanging-wall. In the lower workings, however, the pegmatite was reported to have averaged only about 18 in. in width and to have carried very large books of good quality, spotted mica throughout. In the shoot here the dimensions of the mica books, in the plane of their cleavage, often exceeded the width of the pegmatite. These books were orientated with their cleavage direction in the plane of the pegmatite. The small amount of rock waste on the dump is due to both the narrowness of the pegmatite and the fact that mica constituted a very high percentage of the whole.

This pegmatite was worked during two distinct periods. During the first period, which closed in 1931, the opencast work was done and an adit level was driven in from the northern end of the strike and reached a maximum depth from surface of about 45 feet. At this depth the mica shoot seems to have weakened somewhat. The second period was during 1952-3 when three levels, 30 ft. apart, were driven below the adit level on what was, to some extent, a second shoot with a shorter strike than that in the upper working. The pegmatite persists at the bottom of the mine where a winze below the bottom level is out of payable mica.

The mica shoot in the Main South Reef pegmatite had a maximum strike of about 170 ft. and was mined down to about 150 ft. Like the other pegmatite it was very rich in mica and there were some large

sizes. However, there was an appreciable amount of red spot which reduced its quality. The mica apparently occurred throughout the pegmatite in the area of the shoot and the matrix was certainly plagioclase-rich. The rock waste contains an abundance of plagioclase-though some microcline was identified. Lumps of a plagioclase-rich border zone with adhering wall-rock were noted. In the prospect pits on the strike of the pegmatite, immediately south of the large open working, the character of the pegmatite has undergone a marked change. Here it is mainly massive microcline with only a little quartz and mica, and it continues in this form for about 240 ft. south of the main open cut. It would certainly seem as though the structure was filled with material from two sources which arrived independently.

Pegmatites have been prospected to the east and north-east of the Main South Reef, but they look most unpromising. They are mainly microcline-rich with disseminated, broken and striated mica books. In one trench, however, there appears to have been a small hanging-wall mica concentration.

The pegmatite parallel to the Main North Reef and 200 ft. west of it has been mined open-cast to quite an appreciable depth. In 1956 the workings were cleaned out and a pegmatite 4 ft. wide with an easterly dip of 73 degrees was revealed. It was unzoned and carried rather small, disseminated, spotted mica. It was considered sub-economic by the Rhodesia Mica Mining Co.

The concordant pegmatite 150 yds. south-west of the last is a zoned, lenticular body typical of many beryl-bearing types. It has a short strike but is over 50 ft. wide. There is a quartz core, and a microcline-rich core margin with much large, wedge-shaped muscovite typical of this type of pegmatite. At the western end the hanging-wall of the pegmatite has been prospected for mica, and east of this beryl has been mined, though none has been declared under the name Karnie.

During 10 years of operation between 1925 and 1957 the Karnie Claims produced a total of 132 tons 1,104 lb. of cut mica valued at £16,358.

The *Karoo Mine* is  $8\frac{1}{2}$  miles north-north-west of Miami Village on the east bank of the Karoo River and about a mile east of the Owl Mine.

A zoned, concordant pegmatite striking 85 degrees (magnetic) and having a northerly dip of 65 degrees has been trenched for about 330 ft. to where it pinches out on the steep western slope of the valley. About 20 ft. below the trench a short adit has been driven, but it does not connect with any of the shallow winzes in the open cut.

There is a hanging-wall shoot of small, hard, flat, ruby mica books. The quartz-microcline core carries biotite and the large, broken and striated mica books on the waste dump have probably come from this zone.

In 1943 the mine declared 349 lb. of cut mica valued at £131.



The *Karoo Mine* is reported to be eight miles north-west of Miami Village. The map reveals a number of unnamed workings on pegmatites of little value in this area. In 1931-2 it declared 2 tons 847 lb. of cut mica valued at £304.

The *Kathie Mine* is reported to be eight miles north of Miami Village. In 1927-8 it produced 1,438 lb. of cut mica valued at £75.

The *Katsanga Claims* are on Foliot Farm, nine miles north-west of Miami Village.

A concordant pegmatite striking north and south across a water course and dipping west, has been quarried at both ends. It is a zoned pegmatite and the work done has been in the core zone which carried biotite, small striated ruby mica and tourmaline. Of interest is the presence of plagioclase in the quartz of the core. The dumps appear to have been turned over in search of beryl.

This property has been held for seven years but there is no record of any production.

The *Katsuru Mine* is reported to be seven miles north of Miami Village. In 1945 it declared 1,096 lb. of cut mica valued at £226.

The *Kerrycroy Mine* is reported to be five miles north-east of Miami Village. This is in an area which has subsequently been worked for beryl and this mine has, very likely, been reregistered under a different name. In 1925 it declared 1,295 lb. of cut mica valued at £90.

The *Kingsale Mine* is two miles east-south-east of Miami Village.

Two north-striking pegmatites which dip east are situated in close proximity and are very nearly on the same line of strike.

The North Reef pegmatite was first worked in 1921 and became a well-known producer of ruby mica. Some of the early produced books are reported to have been the biggest found on the Field and one yielded over half a ton of prepared sheet mica. The mine closed down in 1930 after all developed mica had been stoped. An attempt to reopen it soon afterwards failed on account of bad ground and it lay dormant for about 22 years.

Workings: The mine was reopened in 1952 by sinking an inclined shaft at 48 degrees well on the foot-wall side of the pegmatite. This shaft attained a vertical depth of 113 ft., and a cross-cut of 60 ft. towards the pegmatite encountered a foot-wall spur. This was driven on for 50 ft. exposing the whole of its strike. At this level a drive of 60 ft. was put in on the main pegmatite and two cross-cuts were put through to the foot-wall. A short raise entered the old workings. The old outcrop workings reveal a total strike of 135 ft.

Pegmatite: The pegmatite is typically zoned. It has a quartz core and there were both hanging- and foot-wall mica shoots. When the mine was reopened the main production came from the small rich spur but some also came from remnants of the foot-wall shoot.

Near the northern end of the drive on the 113 ft. level the mica shoot was found to end abruptly and the drive continued in pegmatite. Careful examination revealed that the Kingsale pegmatite abuts on an older barren pegmatite which occurs on the same line of structure.

The foot-wall spur branches off just south of this contact. At the contact a winze was sunk to a depth of 10 ft. below the drive, where a pre-pegmatite epidiorite dyke was encountered. This caused a tightening or constriction of the fracture resulting in a change of strike and pinching of the pegmatite. At the southern end of the drive on the 113-ft. level the pegmatite pinches and ends. From this drive a cross-cut has been put in 45 ft. into the hanging-wall and is all in pegmatite. It was again found that there is pegmatite of two ages. The first 9 ft. of the cross-cut are in Kingsale pegmatite, but at this point there is a strong strike fault which has cut off the mica-bearing pegmatite and has brought a barren pegmatite into juxtaposition. This barren pegmatite can be seen in another cross-cut farther south. Here the Kingsale pegmatite has already pinched out and the fault is in mica-schist with the barren pegmatite at the end of the cross-cut. This pegmatite contains a little yellow beryl, but there has been no declared output.

Faulting: The nature of the faulting is illustrated in Fig. 16.

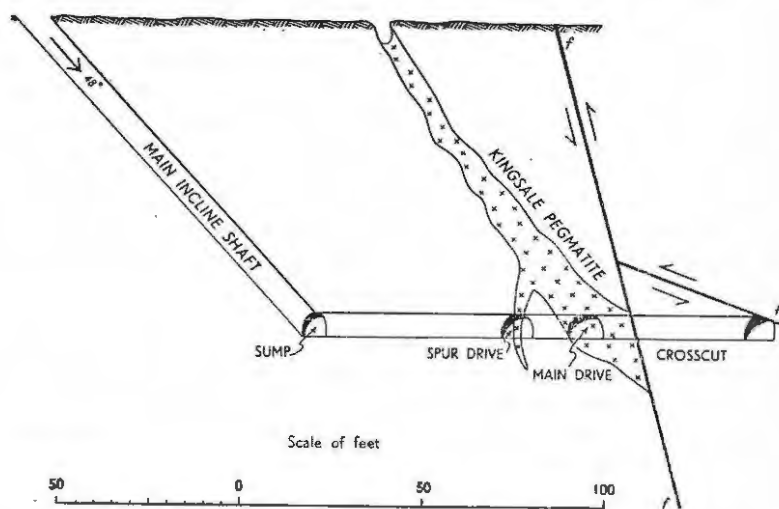


Fig.16 Faulting of the Kingsale Pegmatite

Strong drag-folding in the mica-schist on the fault plane as well as faulting of the second order encountered at the end of the cross-cut show that the movement has been of a reverse nature and of sufficient magnitude to carry the other faulted contact of the Kingsale pegmatite up beyond the present land surface. It seems probable, too, that its original extension in depth was not great and that the remnant has been completely removed by erosion.

The South Reef pegmatite was a wide body at surface but mica was very sparse. At 50 ft. down it narrowed very considerably and the dip flattened. This narrow pegmatite carried payable mica throughout to a depth of 120 ft., where it became uneconomic. It was worked from 1944 to 1947 and produced less than 40 per cent. of the total mica from the

Kingsale Claims, but it constituted more than 60 per cent. of the total value. This is because the main production from the North Reef was at an earlier date when prices were presumably lower.

The Kingsale production, which ceased in 1954, totalled 62 tons 1,211 lb. valued at £24,741.

The *Kirrie I Mine* is  $5\frac{1}{2}$  miles north-east of Miami Village.

Here there are two strong, parallel pegmatites about 150 ft. apart and striking a little west of north (magnetic). In addition, there are several smaller pegmatites to the south, which have been worked or prospected in a small way. Of the main parallel pegmatites, the one on the west has the only workings of any consequence. It has a surface strike of 600 ft. with the main opencast workings near the southern end. It is clear from the waste that this section of the pegmatite was rich in spotted quality mica. Large sizes, frequently including Nos. 1 and 2, have reputedly been cut. Some of it was of inferior red spotted quality, however.

In May, 1954, the deepest part of the open working was cleared with the intention of finding a suitable site for shaft sinking. The result was disappointing and no work in depth was undertaken. The mica books were of small average size and often broken, striated and interleaved. The pegmatite carries very little microcline and the damage to the mica would appear to have been caused largely by post-pegmatite movements. It can be assumed that the pegmatite was not unlike that of the Beckett Mine. That is, plagioclase-rich with disseminated mica, tending towards a hanging-wall concentration in places. Here there is a belt of highly micaceous schist four miles long which includes the rich Zonkosi and Beckett mines. All are concordant.

At a greater depth the pegmatite may well be less disturbed with a possibility of much valuable mica. A pegmatite having this strike length is likely to extend to appreciable depth and to exhibit pinch and swell characteristics as well as rolling. These features should not constitute a deterrent to further exploration.

In the southern face of the open-cut the pegmatite is 6 ft. wide. About 30 ft. north of this point it appears to have a cross-section resembling Fig. 7 and to become as much as 45 ft. wide in a horizontal spread of the pegmatite. Below, it suddenly narrows, dipping first east and then steeply west. The deepest point in the open working was 30 ft. At the northern end of the open cut the depth attained is 18 ft. and here the pegmatite is 12 ft. wide. There is a tramming way to the east out of the open cut and in it a pegmatite, 15 ft. wide, was encountered. It dips east and carries small mica and is probably a spur.

There is another open cut north of the main working where the pegmatite was very decomposed and the mica rather soft red and striated. It contains filling which is rich in mica. North from here the pegmatite narrows somewhat and is rich in rather small-sized broken mica which has a tendency to be buckled. The pegmatite carries more quartz than felspar. A number of small marginal pits farther north suggest small parallel pegmatites or spurs. Towards the northern end



are books of mica measuring as much as 12 in. across, but these were too broken to be of value. Some beryl has been taken from this northern end.

The pegmatite which parallels the main pegmatite on the east has a strike of 450 ft. It would appear to be of little interest and the workings are all rather shallow prospect trenches. It is zoned in part but its extremities are quartz-rich and the mica lying around on the surface is broken and buckled, but some small sizes have been cut.

About 250 ft. east of the southern end of the main open-cast working is another pegmatite which has been worked open-cast over a short strike. This pegmatite is also rich in quartz with very little microcline. Much of the mica was broken, buckled and striated. Several other quartz-rich pegmatites have been prospected south of the main working and several hundred yards south-west of the Kirrie I is a deep open-cast working with a short strike.

The *Kirrie II Mine* is about 800 yds. east of north of the Kirrie I Mine. The workings are also on a concordant pegmatite striking north and dipping west. It has been worked opencast into the hill side from a point near the south bank of the Nyaocha River along about 130 ft. of strike and to a maximum depth of about 35 feet. Some fairly large sizes of good quality, spotted mica were mined. The pegmatite was unzoned and without defined walls. It was in effect a mass of intercalated pegmatite and schist forming soft ground.

Fifteen annual declarations of cut mica from all the Kirrie claims, starting in 1924 and ending in 1954, total 49 tons 1,447 lb. valued at £8,339.

The *Konde Mine* is reported to be  $3\frac{1}{2}$  miles north-west of the Grand Parade Mine. In this area some half-dozen unnamed pegmatite workings are indicated on the map. In 1954, 1 ton 97 lb. of cut mica was sold for £484.

The *Kwagga Mine* is 26 miles north-west of Karoi Township and three quarters of a mile south of the Rkwesa Mine, in the Urungwe East Group of mica mines.

There are two pegmatites close together giving rise to small kopjes. Only the north-eastern one has been worked for mica. It is a lenticular body bearing a discordant relationship to the gneiss. At one end it strikes north-north-west and at the other south-east. The dip is at a steep angle to the north-east and the overall surface strike is about 300 ft. It is very wide about mid-strike, but the workings do not reveal a cross-section of it. There has been an appreciable amount of prospecting and shallow shaft sinking, but there has been no attempt at systematic mining.

The pegmatite is zoned, but no mica concentration has been revealed. The main mass of the pegmatite is of quartz and microcline, with discontinuous quartz lenses forming a core in places. There has been some quarrying on the hanging-wall side of the pegmatite and there are several shallow shafts from which there has been no development. The quarrying has revealed an intermediate or core margin zone rich in wedge-

shaped, herring-bone muscovite that often forms radiating masses in which one book may cut across another. Individual books or wedges attain a length of 5 ft. but it is all valueless for sheet mica.

In the area of the shafts there is a plagioclase-rich zone having flat, disseminated books of spotted quality mica from which sheet mica has been cut. This pegmatite has an ideal topographical setting for large-scale open-cast development, but more work is necessary to establish that the result would be profitable.

In 1959, a shaft was sunk near the south-east end of this pegmatite and it located a small plagioclase-rich spur or extension of the main pegmatite. It contained some good, hard, flat mica, but the pegmatite had no extent.

The second pegmatite is a wide, lenticular, zoned body with a strong quartz core. It has a north-east strike of about 150 ft. and there is a short westerly-striking spur. A number of shallow prospect pits have not revealed anything of economic value.

The mine produced during the years 1948-9, 1953 and 1958-9. The total for the first four years amounted to 4 tons 1,385 lb. valued at £1,990. The output for 1959 has been declared with those of the Locust and Julia mines.

The *Lamlash Mine* is reported to be eight miles north of Miami Village. In 1927 it produced 1,456 lb. of cut mica valued at £35.

The *Lancastrian Mine* is on Crown land a mile west of Miami Village.

Several small pegmatites have been prospected and waste mica cuttings reveal that ruby mica has been produced. There is a shallow inclined shaft on a small pegmatite which strikes north-west and dips south-west. There is in addition a timbered vertical shaft which was full of water when inspected.

In 1945 the mine declared 871 lb. of cut mica valued at £119.

The *Last Chance Mine* is reportedly  $1\frac{1}{2}$  miles north-east of the Rae Mine, which is five miles west-north-west of Miami Village. The mine is certainly on Hillandale Farm but it may be one of two unnamed workings which are shown on the map in this vicinity.

A pegmatite  $1\frac{1}{4}$  miles north-east of the Rae Mine strikes 160 degrees (magnetic) and dips east-north-east. Costeans extend along 270 ft. of strike and there is a shallow shaft. The pegmatite contains a fair abundance of microcline and is unzoned. The mica is of ruby quality, but the books are very broken. Some are flat and small sizes could be cut, but some are buckled.

About 700 yds. south-east of these workings is a north-striking pegmatite on which an appreciable amount of development has been done, but little or nothing can be seen of the pegmatite.

In 1945 the mine yielded 184 lb. of mica valued at £61.

The *Last Hope Mine* is on Haslemere Farm, 4.8 miles south-west of Miami Village.

History and development: The claims do not appear on the list of mining claims registered before July, 1920, but it was presumably pegged shortly after this date. It was first registered by the Barratt Brothers and was reported on by C. A. B. Colville, Inspector of Mines, in August,



1921. Then it had been opened up along 300 ft. of strike to a depth of 10 ft. The claims were later transferred to Barratts Mica Co. and were operated almost continually until 1930, when the mine was closed down as a result of the slump. In 1935, 300 lb. of mica were sold for £5 and this came, presumably, from the waste dump. The claims were abandoned and were reregistered in September, 1942, by Mrs. I. W. Southey. They were transferred to H. C. Tremlett at the end of 1945. In 1952 they were purchased by the Rhodesia Mica Mining Co. Ltd., for a large sum which was in excess of their true value. The Company operated the mine until 1956 and abandoned the claims in May, 1959.

The mine attained a vertical depth at the bottom of No. 1 inclined shaft, of about 280 ft. At this depth there is a short 5th level but the mica had become too sparse and small to be payable. Also the mine was badly in need of complete reorganization. The 3rd level was driven a total distance of 1,140 ft. but only 600 ft. was in the payable shoot.

Pegmatite: The surface plan of the mine is given in Fig. 17.

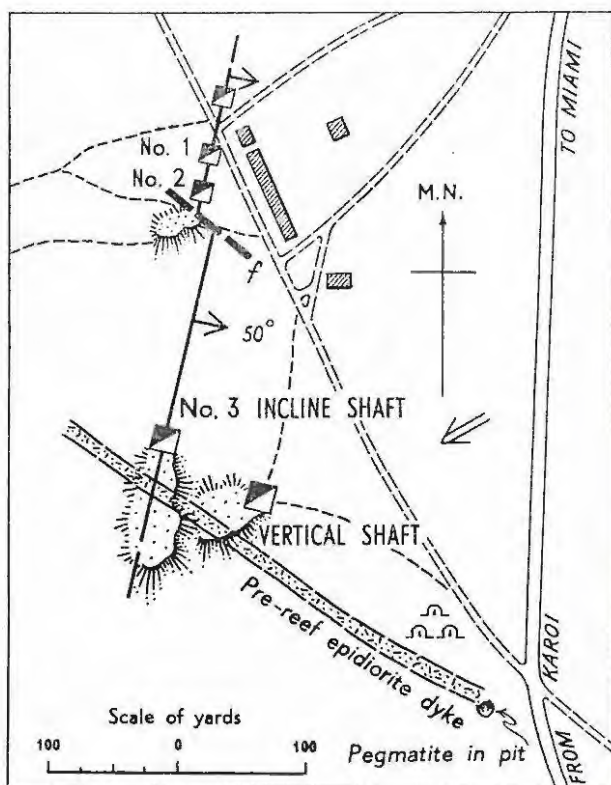


Fig.17. Surface plan of the Last Hope Mine

The pegmatite bears a discordant relationship to the gneiss and, in character with this type of structure filling, it has a long strike and regular width over the payable area. The pattern of the mica shoot is



shown on Plate X. The average width of the pegmatite is 5 ft. and the average dip is 50 degrees to the east. The workable mica is concentrated on the hanging-wall of the pegmatite and, as is typical of mica books which have formed on the walls, they have a tendency to be orientated with their cleavage planes at right angles to the walls. Apart from the mica shoot and narrow border zones, which carry most of the tourmaline, the main body of the pegmatite is not zoned. In other words, there are no intermediate zones and there is no core zone. This type of structure may be referred to as a simple zoned pegmatite (see p. 84). The main mass of the pegmatite comprises an anhedral intergrowth of quartz, plagioclase feldspar and small muscovite with the quartz often apparently in the highest proportion.

The concentration of the mica and size of the books was not impressive by some standards, such as the Hendren and Beckett mines, but this was, in a measure, compensated for by the high quality of the green-brown mica. In the area of the main shoot the pegmatite carried no economic mica on the foot-wall but at one point a few small books were seen. However, in the short No. 5 level drive south, a cross-cut revealed that the pegmatite has widened to 12 ft. and that larger, though sparse, books have developed on the foot-wall. The hanging-wall is weak here, but it does seem reasonable to anticipate another shoot in depth if the pegmatite retains its composition and characteristics. So many mines have been abandoned at relatively shallow depths after the shoot, on which the mine was developed, had expired even though the pegmatite continued strongly or even stronger in some instances. When the actual end of the pegmatite is in sight there are often clear advanced indications of it. On the 4th level about 120 ft. north of No. 3 inclined shaft the character of the pegmatite changes. It has become richer in small disseminated mica, often referred to as "mussel" mica and the hanging-wall mica shoot has diminished in size and gradually disappeared. At 190 feet. north of this shaft the pegmatite turns north-west in the direction of the foliation of the gneiss and ends.

**Faulting:** A great deal of the workings in the upper levels was inaccessible at the time the mine was investigated. The fault shown south of No. 2 inclined shaft in Fig. 17 has displaced the pegmatite at the surface but the fault dies out below No. 2 level. Two other small faults are indicated on the mine plan below this fault. The one shown on No. 4 level is merely a foliation plane and it is probable that the one shown between No. 2 and 3 levels also may not be a fault. A fault is also indicated south of No. 3 inclined shaft but it is a pre-pegmatite epidiorite dyke which has caused a tightening of the structure and a slight local change of strike. Movement along the dyke margins, though small, has resulted in bad ground due to circulating water. This dyke occurs very near the southern end of the mica-shoot.

There is evidence that the fissure along which the Last Hope pegmatite was emplaced was a normal fault. Barren, tourmaline-rich pegmatite have been cut by the mica pegmatite and apparently displaced. These barren pegmatites are concordant bodies. On No. 4 level near the northern end of the drive some post-reef movement in the pegmatite walls can be observed, but in some other parts of the mine there has been no marginal movement.

General: The mica shoot can be regarded as worked out above the 5th level. Even if any mica remains in pillars or unstoped ground in the upper levels of the mine, bad ground and abundance of water would render reopening of the mine unprofitable. Any future the mine may have will be in depth, and this is an uncertain proposition.

Output: A total of 22 declared annual outputs, starting in 1922 and ending in 1956, amounted to 221 tons 1,317 lb. of cut mica valued at £137,104. With this return is some mica from both the Ruby Valley and Easter Gift mines. (See also under beryl.)

The *Laurel Mine* is reported to be eight miles north of Miami Village. It produced in 1925 and 1928 when 2 tons 735 lb. of cut mica were sold for £161.

The *Lazi Mine* is shown on the map, 11 miles north-north-west of Miami Village. This is half a mile west of the Karoe River and 1½ miles from the northern edge of the map. The pegmatite, which has a strong quartz core, gives rise to a small kopje. The strike is 218 degrees and the dip north-westerly. The hanging-wall of the pegmatite has been open-cast over a distance of 70 ft. and to a depth of 12 ft. Rock waste concealed the wall zone, if one exists, but it appears that much of the mica extracted came from the core margin. In 1947-8, 2 tons 621 lb. of cut ruby mica was sold for £1,287.

The *Lea Mine* is reported to be five miles north-west of Miami Village. It could be one of half a dozen or more unnamed pegmatite workings in the vicinity of the Ndola, Piper and Tito mines. In 1928 it declared 506 lb. of presumably spotted mica, valued at £27.

The *Linden Mine* is eight miles north-north-east of Miami Village and half a mile north of the Red Star Mine. Surface workings indicate a concordant pegmatite striking a little west of north and having a westerly dip. There was little to be seen in the abandoned workings at the time of the visit. In 1930-1, and 1952 a total of 4 tons 1,153 lb. of cut ruby mica was sold for £516 which would indicate small sizes or inferior quality mica.

The *Lion Hill Mine* is on Crown land, eight miles north-north-west of Miami Village. In this vicinity the main pegmatite is a beryl-bearing one but parallel to it and 100 yds. or more south of it is a pegmatite with a small open-cast mica working. But it is not known whether the declared mica production came from here. However, 600 to 700 yds. north of the beryl mine is another parallel pegmatite which has been extensively mined for mica but declarations may have been made under some other name. In 1921 the Lion Hill declared 1 ton of mica valued at £250. (See also under beryl.)

The *Little Lynx Mine* is on Crown land, 3½ miles north of the Catkin Mine and 1,000 yards north-west of the Lynx Mine.

The pegmatite can be traced for 400 ft. on a north-east strike. It dips at 50 degrees to the south-east at surface but flattens to 25 degrees at the bottom of a 32 ft. inclined shaft. From the bottom of this shaft there is a very short drive to the north-east. On the surface there has been a little shallow prospecting.



In the area of the shaft there is a quartz core with marginal microcline. Wedge-shaped, herring-bone mica forms a rich intermediate zone concentration between the microcline and the plagioclase-rich wall zone. No wall-zone mica has developed. As is usual with such mica concentrations it is practically useless for sheet mica. However, on the side of the zone adjacent to the plagioclase there are some books which are not striated throughout and from these some sheet mica was cut. The mica is ruby coloured at surface but becomes somewhat brownish at the bottom of the shaft. The percentage cuttability of this mica is so low that it certainly could not be profitably mined.

The small amount of mica cut from here has not been declared under this name nor has the working been registered.

The *Locust Mine* is on Crown land in the Urungwe East Group, 27½ miles north-west of Karoi Township.

The mine was developed to a vertical depth of about 220 ft. over an average strike of about 160 ft. The seven levels which had been driven averaged some 25 ft. apart. On the bottom level the pegmatite is very wide and of good appearance with the northern face in a distance of 140 ft. from the sub-inclined shaft. At this northern end the pegmatite ends suddenly with a two-prong termination, decreasing from a width of 8 ft. to nothing. Mica books in this bottom level had good crystal form with cross sections of about a square foot. Before the pegmatite was fully developed in depth the mine changed hands. In 1959 it was completely stoped to surface. The waste was not removed and much mica remained underground with it owing to poor sorting after blasts. The mine is now flooded.

**Pegmatite:** At surface the pegmatite strikes almost true north and dips east at 40 degrees. Underground there are many local variations in dip and strike caused by rolling of the pegmatite where it has been influenced by the folding of the gneiss. The pegmatite and gneiss bear both discordant and concordant relationships to one another. In the upper levels the association is generally concordant but in depth it is more commonly discordant. On surface there is an exposed strike of about 300 ft. but underground the longest drive is 210 ft. with pegmatite still in both faces.

The quartz core and intermediate zones are discontinuous. Where the quartz core is strongly developed, as at the northern end of the pegmatite on the surface, and on the 6th level, there is a typical sequence of zones as given in the Hendren V description. However, the Hendren core is far more continuous, the Locust core being pod-like. It is 9 ft. wide above the level of the floor but disappears at floor level. Nor is it seen in the small stope just above the 6th level. On the 6th level the pegmatite is 30 ft. wide. Microcline occurs as idiomorphic crystals in the quartz and there is also some tourmaline, blue beryl and mica. Some of this mica occurs as quite large, irregular and broken books which are partly clear and ruby in colour. Some apatite occurs in the plagioclase-bearing intermediate zone near the quartz. At one point there is an assemblage of minerals composed of mica, tourmaline, apatite and cleavelandite which appear to constitute a fracture filling.



In the upper levels of the mine the economic mica, which is of an inferior spotted quality, is practically confined to the hanging-wall. Where the foot-wall has been exposed, mica is present, but rarely do the books attain economic proportions. On the 6th level, however, a very definite and payable foot-wall shoot makes its appearance.

The mica books have, for the most part, the characteristic orientation, with their cleavage planes tending to be normal to the walls. But there is also the occasional appearance of the thick book or "C" type of mica (see p. 87). Occasionally there has been a development of completely disconnected mica shoots.

The inclusion of "horses" of gneiss in the intermediate zone on the 2nd and 7th levels (No. 6 A) has resulted in local, rich concentrations of mica on the hanging-wall. Thus, in addition to the normal shoot, large mica books have formed around the inclusions.

In the absence of quartz, microcline alone forms the core zone. The southern ends of all the drives reveal a predominance of microcline in the pegmatite and the other zones have become quite insignificant. Here the mica has become too small to be payable. In places, too, the pegmatite has completely changed its character and all semblance of zoning has disappeared. Then the mica is present as abundant, small, disseminated books which are referred to as "mussel" mica. The whole texture is finer grained and equigranular and is an indication of the end of the pegmatite.

Driving north, on the other hand, quite a different picture is presented. Above the 5th level there is often no core zone and the pegmatite is composed predominantly of plagioclase with only here and there a little centrally disposed microcline. At the northern ends of the drives the mica becomes small and mostly unpayable. But the pegmatite is often still wide and of good appearance. Continued driving might reveal further payable mica.

Mining was easy, as the mine was relatively dry and with few exceptions the ground was good. No faults were located.

Output: The mine produced almost continuously from 1946 to 1959, missing only one year in 1947. Production figures include some mica from the Rkwesa, Julia and Kwagga mines. In all, 98 tons 1,776 lb. of cut mica were sold for £32,859.

The *Lynx Mine* is three miles north of the Catkin Mine and  $9\frac{1}{2}$  miles by road to the main Karoi to Chirundu road.

This mine first produced in 1927 and was worked intermittently until 1936. According to records it lay dormant until it was reopened about the middle of 1959. A report on the mine was apparently written by E. A. B. Prior in July, 1937, but only the compass survey plan, which was prepared to accompany the report, is to hand. This shows a large open-cast working 150 ft. long and over 60 ft. wide. Two vertical shafts, 45 ft. apart, have been sunk to 80 ft. Both have apparently cut the pegmatite and two short drives had not been connected. An inclined shaft has been sunk at the southern end of the open working and is shown as having reached 54 ft. in depth. There is a 15 ft. drive to the north off this shaft at the 38-ft. level.

When mining recommenced in 1959, it was found that considerably more work had been done than is indicated on this plan. Later, in 1960, when the mine changed hands, an attempt was made to get below the old workings. The vertical shaft was sunk to 90 feet where further old workings were encountered and a winze or inclined shaft was seen to extend well below this level.

It appears that the mine was developed and stoped without the claims having been registered and the mica produced must have been declared from some other mine. However, the mica was very wastefully mined, for an appreciable quantity was obtained by both later operators. They produced ruby mica of extremely high quality. There may well be a large body of mineable pegmatite in depth.

**Pegmatite:** A full section of the pegmatite had not been exposed when the mine was visited in July and October, 1959. However, the pegmatite had been sufficiently opened up to indicate that, for development purposes, it should be regarded as a homogeneous pegmatite with disseminated mica. The average direction of strike is about 15 degrees (magnetic) and the dip easterly. A hanging-wall contact revealed a dip of 65 degrees, but the old plan shows a dip of 50 degrees. Being a markedly lenticular body, the dip and strike will be variable. The pegmatite could be traced on surface for 180 ft. and has an apparent width of 40 to 50 ft. At the southern end the body clearly pinches out, but at the northern end it seems to end very abruptly as if faulted, though, on account of waste, no actual contacts could be seen.

The pegmatite is relatively rich in both muscovite and biotite and the two minerals are often interleaved. Broad laths of biotite on occasion exceed five feet in length. There are indications that there was an incipient tendency towards zonal development in the pegmatite but that it was apparently upset by multiple injection. Small barren masses of both perthite and quartz occur. In one mass of perthite there is a concentration of small mica and some apatite such as is commonly found on the core margin of pegmatites.

The large muscovite books occur in an aggregate of quartz and plagioclase which is an assemblage normally associated with the wall zones of zoned pegmatites. No indication could be found that the mica was confined to any particular part or section of the pegmatite. Some sort of zoning may, however, occur in depth where the pegmatite is narrower. It is clear that in the upper levels the whole mass of pegmatite should have been stoped out and development planned accordingly.

In addition to the main pegmatite there is a narrow zoned pegmatite, 3 ft. wide at surface, on the foot-wall side of the main body and striking at right angles to it. It dips north at 40 degrees and may well be a spur. It has been followed down by means of an inclined shaft which has collapsed. In this small pegmatite, mica books occur on both walls.

**Output:** It is very probable that the declared outputs are very much less than they should be since it seems almost certain that some of the mica has been declared under some other name. Between 1927 and 1936 a total of 13 tons 718 lb. of mica were sold for £3,111, whereas the 1959 production of 2 tons 55 lb. fetched £3,430.

The *Madondo Mine*, which is recorded merely as Urungwe East Group, declared 272 lb. of mica in 1944 valued at £69.

The *Majestic Mine* is 10½ miles from Miami Village on a bearing of 6 degrees east of north.

A plan of the workings, dated 1952, indicates that the mine has been operated in two sections, and it appears very much as if these are on two pegmatites which are close together and very nearly on the same line of strike.

The main workings are to the north-west. This pegmatite, which has a rather curved strike of approximately north-west, has been worked open-cast for about 160 ft. There were two inclined shafts with the main shaft attaining a depth of about 90 ft. The lowest level is the 52 ft. level which has been driven 120 ft. and below it there has been a little under-hand stoping along a 50-ft. section south-east of the shaft. Above this level the pegmatite has been symmetrically stoped about the Main Incline shaft for a little over 100 ft. of strike and to a depth of 30 ft. There has also been a very small amount of stoping between the 30-ft. and 52-ft. levels, on both sides of the shaft.

The mine was reopened in 1955 in conjunction with the Zamona (Egg) Mine but no development was undertaken.

The pegmatite in the workings bears a discordant relationship to the gneiss. They both have the same direction of strike but the pegmatite dips at about 40 degrees to the south-west across the foliation. The mica shoot in the main pegmatite is unusual in that it forms only a foot-wall concentration. The books are badly buckled and broken, and ribband structures are strongly developed. Some of the books have marked marginal granulation. The pegmatite as a whole has a granulitic structure. It is suggested that intrusion took place before the close of the orogenic cycle and that a normal hanging-wall mica shoot developed, but that later movements overturned the dyke so that the hanging-wall became the foot-wall.

The other pegmatite workings mentioned have the same direction of dip and strike but this pegmatite has quite a different structure from the first. It has been open-cast on both hanging- and foot-walls over a total strike of 120 ft. An inclined shaft has provided ventilation for an adit level which attains a maximum depth of nearly 40 ft. A very small area has been stoped on both sides of the incline above the adit level. This work suggests that there is a wide-zoned pegmatite which was not payable in depth.

The small amount of unbuckled mica which could be cut from this pegmatite was apparently first quality spotted. In 1952 the mine declared 5 tons 1,057 lb. of cut mica valued at £2,449.

The *Major Mine* is on Crown land, six miles north-west of Miami Village and a mile east of the Berea Mine.

Two pegmatites have been mined on these claims. They are about 400 yds. apart on opposite sides of a stream. The pegmatite on the west strikes 70 degrees (magnetic) and dips steeply to the north-north-west. It is typically zoned, with hanging- and foot-wall mica shoots that



appear to have been stoped to their economic limits. The foot-wall shoot has not been stoped right to the surface and some large books of ruby mica were seen still in place. The pegmatite appears to bear a concordant relationship to the sillimanite-rich gneiss. Adjacent to the pegmatite the sillimanite has been converted to coarse mica aggregates.

This working was reported on by Prescott Upton, a mining engineer, in February, 1928. The pegmatite had been exposed in trenches and shallow workings for some 840 ft. There were three shafts with the deepest attaining a depth of 75 ft. with a short drive in each direction. Probably there was a relatively small rich shoot.

About 300 ft. to the south of this pegmatite is another which is somewhat *en echelon* to the east. It has a strong quartz core, but only a short strike. It was unsuccessfully prospected for mica.

The other main pegmatite, which is 400 yds. east of that first described, has a surface strike exceeding 1,150 ft. It trends 23 degrees (magnetic) and has an easterly dip of about 55 degrees at a point 640 ft. from its northern end. At the northern end of the strike the pegmatite has a quartz core. There is some trenching and an inclined shaft on the hanging-wall side of the core, where, at surface, the muscovite is rather small and dissminated but the biotite is quite large. About 200 ft. south of this shaft a cross-trench reveals that the pegmatite is 50 ft. wide and composed predominantly of microcline with irregular quartz blobs. South from here the pegmatite becomes less and less attractive from a mica point of view and it attains a width of about 200 ft.

Quite a reasonable quantity of mica was extracted from this pegmatite and some of it was reportedly of fair size and excellent ruby quality.

Two other pegmatites of little apparent value occur to the south of this pegmatite.

The claims were worked sporadically from 1924 to 1952 with a long break from 1926 to 1943. In all, 3 tons 211 lb. of cut ruby mica were sold for £1,244.

The *Makomba Mine* is six miles north-north-west of Miami Village. There are a number of pegmatites here but only two, which are about 900 yds. apart, were of any consequence.

The more easterly of the two has a large white quartz core which gives rise to a small hill. It has a short north to south (magnetic) strike and an easterly dip. Shafts were sunk on both the foot- and hanging-walls, but only a little work was done.

The other pegmatite also strikes north and south across a small stream and has been worked on both banks. Two vertical shafts occur on the northern side of the stream and there is some open work on the south side of it. This was clearly the main producer. The mica was apparently of small average size, but of a high quality and was disseminated throughout the pegmatite.

The mine produced from 1926-30, and in 1936-7, yielding a total of 14 tons 1,280 lb. of cut mica valued at £1,768.

The *Manza Mine* is on Crown land,  $8\frac{1}{2}$  miles a little north of east of Miami Village.

This mica-producing pegmatite occurs in a lower metamorphic zone than the great majority of mica producers. It is a concordant pegmatite striking north and dipping fairly steeply to the east. At the southern end of an opencast working there has been some driving off a shallow shaft. This section appears to have yielded a large amount of striated mica of rather low cuttability.

A pegmatite rich in tourmaline has been prospected for beryl at a point 150 yds. north-east of the mica producer.

Another pegmatite, parallel to the first, occurs 500 yds. north-east of it. It appears to have been first worked for mica over a short strike and to a shallow depth, but later, trenching was extended north in search of beryl. In all, about 410 ft. of strike was prospected to a depth of about 5 ft. The mica seen on the dump was of a good size, but a trifle buckled.

The mine declared mica outputs in 1924, 1943-4 and 1951-2. In all, 5 tons 506 lb. of mica fetched £2,307. (See also under beryl.)

The *Makukutsi Mine* is a little over three miles south-west of Miami Village. There were originally 14 blocks of claims covering a large number of small, poor, pegmatites.

A pegmatite striking east and dipping south was worked open-cast to a shallow depth over 250 ft. of strike. It continues in both directions beyond the working and has a wide mid-portion which was not fully exposed. The mica appears to have been somewhat disseminated with something of a foot-wall concentration. Many of the books were ruined by abundant inclusions of quartz and tourmaline. The pegmatite itself is very rich in quartz.

About 300 yds. to the north-east is another pegmatite which carries much small mica throughout a wide body. This pegmatite is also rich in quartz, but mica possibly forms the main single constituent. In both these pegmatites, feldspar was not seen in the outcrop but occurs in small amount on the waste dumps.

These pegmatites yielded green mica with a percentage of spotted quality. Some was rather striated. There is still much mica here but, because of the small average cuttable sizes, mining became uneconomic.

The mine produced in 1920-1 and again in 1937. In all, 13 tons 1,250 lb. of cut mica were sold for £3,362.

The *Mapoffa Mine* is  $5\frac{1}{4}$  miles north-east of Miami Village. Several pegmatites have been prospected in this area but only one has produced mica. There is an open working, 175 ft. long, on a wide-zoned pegmatite which appears to have been mined to a depth of about 20 ft. The bottom of the working was full of water so that any winzing would not have been detected. The mica, which is densely spotted, appears to have come from the foot-wall of the pegmatite which bears 140 degrees (magnetic) and has a rather flat dip to the south-west. A quartz core can be traced on surface for 150 ft. south-west of the open working.

There is a parallel pegmatite 54 ft. west which has been prospected for beryl and another beryl working occurs 400 yd. west.

In 1943, 200 lb. of mica were produced, valued at £75. (See also under beryl.)



The *Marco Mine* is reported to be four miles south of the Lynx Mine and 700 yd. south of the Naodsa River. In 1952 it produced 814 lb. of mica valued at £72.

The *Mary's Luck Mine* is  $5\frac{1}{2}$  miles north-east of the Catkin Mine and  $1\frac{1}{2}$  miles south of the Catkin Fly-chamber.

This is a concordant pegmatite striking north-north-east with an easterly dip. It is zoned with a quartz core exposed on surface. The northern end was worked open-cast in a small way and then an inclined shaft was put down immediately north of it on the foot-wall of a hanging-wall spur which branches northwards from the main body. This incline was sunk some 30 ft. and a very small amount of driving was done on a weak foot-wall shoot. The hanging-wall of the spur had not been exposed in the underground working, but on surface there is a little open-cast on what appears to be the hanging-wall of the spur. Later a shallow prospect shaft was sunk a little to the south on the main pegmatite, but this work exposed neither walls. This pegmatite clearly warrants further prospecting.

In 1956 it produced 202 lb. of cut ruby mica valued at £130.

The *Masakira Mine* is reported to be on Crown land, seven miles south-east of the Julia Mine. The Julia Mine is about a mile from the western edge of the map and about five miles south-west of the Locust Mine. The Masakira produced for two months in 1954, when 72 lb. of cut mica were sold for £26. (See also under beryl.)

The *Mascot Mine* is reported to be six miles north of Miami Village. There are a number of unnamed pegmatite workings shown on the map in this general vicinity. The mine produced from 1922 to 1929, with the exception of 1923 and 1928, and in 1945. It yielded 5 tons 112 lb. of cut mica valued at £640.

The *Masterpiece Mine* is reported to be three miles south of Miami Village. In 1926 it produced 40 lb. of mica valued at £2.

The *Matambudziko Mine* is on Crown land in the Urungwe East Group on the north bank of the Naodsa River, two miles south-west of the Catkin Mine. A small west-striking pegmatite which dips steeply south has been trenched for mica on the margins of the core. There has been a small production of mica which has not been declared under this name.

The *Matches Mine* is  $1\frac{1}{2}$  miles south-west of Miami Village. In 1954, 117 lb. of mica valued at £13 was extracted from a small approximately south-striking pegmatite which was trenched to a shallow depth along the strike. (See also under beryl.)

The *Mavis Mine* is reported to be  $4\frac{1}{2}$  miles north-west of Miami Village. In 1944 it produced 110 lb. of mica valued at £31.

The *Maxin Mine* is some four miles east-north-east of Miami Village and a little east of the Eland's Luck Mine. There are several pegmatites on these claims and the Maxin III is a repegging of an old mica working on a zoned pegmatite. Beryl was taken from the area of the quartz core and gleaned from the old waste dump.



Quartz veins on the Maxin II claims carried wolframite and a small production came from the rubble shed from them.

In 1953-54 the claims declared 44 lb. of mica valued at £13. (See also under tungsten and beryl.)

*Mazurka Mine* (see *Grand Slam Mine*).

The *M'Boko Mine* was reputedly north of Miami Village on the north bank of the Mpopu River. It was presumably later included in one of the Grand Parade blocks. In 1920 it produced 1,343 lb. of mica valued at £168.

The *Merry Dream Mine* is on Ruwanzi Ranch a little over eight miles south-east of Miami. A north-striking pegmatite, which gives rise to a small kopje, has been mined opencast and by means of adits to a shallow depth. It produced from 1945-48 when 2 tons 141 lb. of mica were sold for £748. (See also under beryl.)

The *Meyer Mine* is reportedly four miles north of Miami Village. In 1927 it produced 1,825 lb. of mica valued at £79.

The *Mhindupindu Mine* is on Crown land in the Urungwe East Group, 1,100 yards east-north-east of the Lynx Mine.

The pegmatite is in many respects similar to that on the Lynx Mine and has ruby mica, of somewhat smaller size and in less quantity. There is a long surface strike trending north-east and the dip is south-east. Some work has been done off an inclined shaft near the north-east end of the strike, but this was inaccessible. There is also a wide shaft down to 20 ft. on the foot-wall of the pegmatite. Another *en echelon* pegmatite occurs on the foot-wall side to the north-east.

In 1955 it declared 196 lb. of mica valued at £36.

The *Miami Claims* occupied an area situated a little over two miles south-south-west of Miami Village and between the Turning Point and Phoenix 314 Claims. The Miami (426) block of claims was repegged as the Walhalla and the Miami I (427) was repegged as the Althea. The name Miami is the only one shown on the map partly because of the problem of space and partly because by far the largest production was declared under this name.

When the Miami Claims were reported on by C. A. B. Colville, Inspector of Mines, in August, 1921, they were the property of the Anglo American Rhodesian Exploration Co. Several pegmatites were being worked open-cast to a depth of about 30 ft. Shafts were sunk to cut the pegmatites below the surface workings and it is reported that the quality of the mica improved at a depth of 40 to 50 ft. Clear ruby, slightly stained, and green cloudy mica are said to have been cut.

When this present survey was made there was little to be seen on the claims.

As the Miami, the claims produced sporadically from 1919 to 1929 when 54 tons 1,196 lb. of mica were sold for £11,968. The Althea declared 1,543 lb. of mica valued at £30 in 1930, and the Walhalla, 1,185 lb. of mica valued at £37 in 1935. The total of these outputs amounts to 55 tons 1,924 lb. valued at £12,035. (See also *Tolstoi Mine*.)

The *Mica King Mine* claims are  $1\frac{1}{2}$  miles north, and west of north of Miami Village. They were an early pegging on the Field and consisted originally of four blocks straddling the Mpofu River west of the numerous Grande Parade claims.

The Mica King I workings are on the granite-gneiss contact a quarter of a mile south-west of the Grand Parade Mine on the edge of a vlei which drains into the Mpofu River. The pegmatite follows a schist-filled fissure in the granite striking 348 degrees (magnetic) and having an easterly dip. It has been trenced along 240 ft. of strike right to the edge of the vlei which may be occupying a line of faulting. It is narrow at the northern end of the workings and wide at the southern end.

The pegmatite is reported to have been extremely rich in large ruby mica books which have a green stain. Mica occurred as shoots on both the hanging- and foot-wall. After lying dormant for 20 years the mine was reopened in order to extract a remnant of the foot-wall shoot. In so doing a payable spur was found at the northern end of the strike.

The Mica King II workings are about 500 yd. south of the Grand Parade Mine and are a repegging of the Carmine Mine. There are two closely situated pegmatites having an *en echelon* arrangement. They strike north and dip east at 60 degrees. At surface they have a discordant relationship to the gneiss, but in depth some degree of concordance developed due to folding of the gneiss. The southern pegmatite has a strike of 400 ft. The northern one is somewhat shorter.

Both pegmatites carry rather small, sparsely disseminated ruby mica books in a homogeneous albite-rich matrix. Biotite occurs throughout and is often intergrown with the muscovite. The Sunspot and Grand Parade South Prospect mines had similar characteristics at the surface and became highly payable in depth. Unfortunately the Mica King pegmatites weakened rapidly and were not worth pursuing below about 40 ft.

The Mica King I produced from 1922-5 and in 1945-6, yielding a total of 22 tons 1,257 lb. of cut ruby mica valued at £12,232.

The Mica King II, which was reopened in 1956, has no declared output under this name, but as the Carmine Mine it produced 369 lb. of ruby mica in 1920 valued at £13.

These properties must not be confused with the Mica King in the Urungwe East Group which produced in 1959 and is a repegging of the D.L. mine.

The *Mica View Mine* is on Crown land in the Urungwe East Group,  $5\frac{1}{2}$  miles north-west of the Catkin Mine and  $1\frac{1}{4}$  miles a little west of south of the Rkwesa Mine.

The pegmatite which strikes true north and dips east at from 75 to 80 degrees gives rise to a ridge along which the body can be traced for about 750 ft. It bears a discordant relationship to the gneiss. At its widest point it is about 20 ft. It has a strong spur which branches off into the hanging-wall about midway along the strike. On the foot-wall of the main body there is a parallel pegmatite of no consequence.



The main pegmatite is somewhat assymmetrically zoned and there is a quartz core in the northern half of its strike. Ruby mica books occur sparsely along the hanging-wall where they are orientated, as usual, at right angles to the wall. The border zone forms a very sharp contact with the gneiss. Where the quartz core disappears, a microcline-quartz assemblage forms the core and is rich in wedge-shaped, herring-bone muscovite with a little biotite.

The spur, which strikes 253 degrees (magnetic) and has a southerly dip of 80 degrees, bears a concordant relationship to the gneiss. It has a quartz-microcline core and an overall length of 180 ft. At its extremity it is 30 ft. wide and appears to have been faulted. Both sides of the body have been trenched for mica and the core has been mined for beryl. Wedge-shaped mica forms a core margin concentration as in the main pegmatite, and in places biotite, tourmaline and haematite are present.

The workings on the main pegmatite are in the northern half of the strike and, apart from a little prospecting of the foot-wall, are confined to the hanging-wall. There is some shallow trenching and a little driving not many feet below it. A vertical shaft has been sunk on the hanging-wall side of the core at a point 180 ft. from the northern end of the strike, where the spur joins the main body. The shaft was inaccessible at the time the mine was visited. A plan, probably not up to date, shows a 50-ft. level drive, some 90 ft. long, extending both north and south of the shaft. The spur pegmatite has been followed into the main body by means of an adit. There appears to have been a little stoping on the spur but the workings were inaccessible.

Between 1944, when the first production was declared, and 1958, 13 tons 966 lb. of ruby mica was sold for £12,238. A little mica from the Julia Mine is included in this figure. (See also under beryl.)

The *Micron Mastadon Mine* is on Crown land just south of the Masterpiece Farm road and  $1\frac{3}{4}$  miles south-east of Miami Village.

There is some shallow open-cast work on a discordant, zoned pegmatite with a short north-west strike and an apparently vertical dip. It carries very sparse, broken books of high-quality ruby mica along the south-west wall and green beryl in the quartz core. There is much tourmaline, and some iron-rich garnets occur in the intermediate zone.

In 1954-5 the mine yielded 596 lb. of cut mica valued at a little under £222. (See also under beryl.)

The *Missouri Claims* are on Kachichi Farm almost on its western boundary with Haslemere Farm. They are four miles south-west of Miami Village and three-quarters of a mile a little south of east of the Last Hope Mine.

Nothing is to be seen of the pegmatite on the surface, and the underground workings are inaccessible. From the shallow open-cast workings it is apparent that the strike is approximately north-east with a south-east dip. It has been trenched for 165 ft. and an inclined shaft at the north-east end was filled with water. There are also two vertical shafts. Much small, clear, brown mica was seen about the workings.



The claims were held during the years 1947-9, but there is no record of production under the name of Missouri.

The *Mixer Mine* is recorded as being 15 miles north-west of Miami Village. Depending on the accuracy of this bearing, the mine will be just in or just outside of the area mapped. In 1948 it declared 893 lb. of cut mica valued at £188.

The *Mobo Mine* is reported merely as being in the Urungwe Mica Field, East Group. In 1944 it declared 1,371 lb. of cut mica valued at £238.

The *Moonraker Mine* is a mile south-south-west of Miami Village. Two uninteresting, parallel pegmatites have been mined to a shallow depth to produce 158 lb. of mica in 1945 valued at £21.

The *Mormond Hill Mine* is on Ruwanzi Ranch, eight miles south-east of Miami.

There are shallow open-cast workings over 330 ft. of rather curved strike which has an average north to south trend and an easterly dip of 70 degrees. From a plan it appears that two shafts were sunk to a depth of 60 ft. in the northern sector. They went out of mica and it would seem that the pegmatite has pinched. There has been a little development and stoping down to a depth of about 45 ft. from both shafts, but the workings are not interconnected and there is a small dip fault between them.

The mine produced intermittently for eight years between 1925 and 1948, to yield 7 tons 173 lb. of mica valued at £2,377. Some mica from the Poll Mine is included in this total.

The *Mount Royal Mine* is on Ruwanzi Ranch, two miles south-south-east of the Mormond Hill Mine and  $1\frac{3}{4}$  miles north-west of the Aneta trigonometrical beacon.

The pegmatite is a concordant body trending north-west to south-east on a steep valley slope. It was mined open-cast to a depth of about 20 ft. and an adit was driven below this. The pegmatite is ideally situated for adit mining and the fact that more work was not undertaken suggests that the pegmatite became unpayable below the open-cast working. The mica was apparently white and of a good quality.

The mine produced in 1921-2, and 1927 when 9 tons of mica were sold for £2,204.

The *Mupo Claims* are on Crown land a little over two miles east of north of the Rkwesa Mine. A shaft was sunk to 20 ft. on a quartz-mica pegmatite rich in small "mussel" mica, in the hope that the sizes would improve. There are other pegmatites of a similar character in the vicinity and they give the impression that the mica grew *in situ* from the country rock as the result of the mineralizing action of a locally derived or hydrothermal quartz injection. There has apparently been no production.

The *Mutt Mine* is reported to be  $1\frac{1}{2}$  miles west of the Zonkosi (497). In 1937 it produced 165 lb. of mica valued at £12.

The *M.R.S. Mine* is on Crown land, a mile south east of the Rkwesa Mine and 25 miles north-west of Karoi Township.

A pegmatite having an east-north-east trend and a flattish dip to the north-north-west has some shallow workings extending over 330 ft. of strike. There is a discontinuous quartz core and, in its absence, microcline constitutes the core. At one point there is much wedge-shaped, herring-bone mica on the quartz core margin with some books attaining 2 ft. in length. Some flat, hanging-wall mica occurs in a favourable quartz-plagioclase base, but it is very broken and only small sizes can be cut. From the nature of the workings it would appear that some beryl has been mined though none has been declared.

In 1952-3, 580 lb. of mica were produced, valued at £328.

The *Ndare Mine* is reportedly five miles south-west of Miami Village and it may well have been repegged as the Tom Tom or some other mine shown on the map in this vicinity. In 1947 it produced 1 ton 605 lb. of mica valued at £160.

*Near Go Mine* (see *Ova Mine*).

The *New Prospect Mine* is reportedly a quarter of a mile west of the Outpost Mine, which places it on Crown land,  $11\frac{1}{2}$  miles north-west of Miami Village. Its production was declared with the Hendren Mine in 1950-1.

The *Northern Star Mine* locality is given as 1.1 miles north-west of the Red Star homestead. This is in an area which was later well prospected for beryl, so that the Inky Beryl Mine or the Khan Mine may well be a repegging of this mine. In 1944-5 it declared 5 tons 520 lb. of mica valued at £1,048.

The *Nuneaton Mine* is eight miles north-north-west of Miami Village.

The pegmatite, which bears a discordant relationship to the gneiss, strikes north and dips east at 50 degrees. It has been trenched continuously along 210 ft. of strike. It continues south beyond the open work but is out of mica after a microcline core appears. The trench contained some filling but from what could be seen there must have been a hanging-wall shoot.

The small books of mica seen were flat and had good crystal form, but the larger books were a little buckled. It may be a pegmatite worth re-investigating.

It was worked from 1926-8, and yielded 8 tons 742 lb. of brown-green spotted mica valued at £838.

The *O.K.O. Mine* is on Crown land in the Urungwe East Group,  $1\frac{1}{2}$  miles a little south of west of the Locust Mine and  $8\frac{1}{2}$  miles north-west of the Catkin Mine.

Between the O.K.O. pegmatites and the Locust Mine there are a number of pegmatites which have been prospected. The main O.K.O. workings are at the western end of a long ridge and on the eastern side of a prominent small kopje. The pegmatite, which bears a discordant relationship to the gneiss, has a marked curvature with an east-south-east strike at one end, and a south-western strike at the other end. The main effort has been made on the south-west end where the dip is at 45 degrees to the north-west. The pegmatite has been trenched, chiefly on the hanging-wall side of a continuous quartz core, for a distance of

165 ft. and to a depth of between 10 and 12 ft. The pegmatite seems to have suffered some crushing, and buckled mica can be seen on the mica-waste dump. Wedge-shaped, herring-bone mica is abundant on the foot-wall of the core and this may account for the small amount of foot-wall trenching and the single shallow inclined shaft here.

Another pegmatite with similar structure occurs to the west-south-west and appears to have yielded a little mica. It strikes north-north-east and dips to the west-north-west. It also has undergone some crushing. The mica on the waste dump is wedge-shaped core margin mica. In addition to a little openwork, an adit was started but did not reach the pegmatite.

There is a third pegmatite in the vicinity and it has been worked for beryl.

Th Claims produced in 1947-48, and in 1954, yielding a total of 1 ton 774 lb. of cut mica valued at £440. (See also under beryl.)

The *Optimist Mine* is reported to be six miles north-west of Miami Village. Its output includes mica from the Panorama Mine. These mines were operated in 1943-44, when 972 lb. of cut mica was sold for £192.

The *Othello Mine* is on Crown land, 9¼ miles east-north-east of Miami Village and 1¼ miles east of Masterpiece Farm.

A narrow, north-striking pegmatite, dipping east at 75 degrees, has been trenched for some 240 ft. to a very shallow depth except at one point where a depth of 18 ft. was attained. There is a very narrow quartz core in places and some schist inclusions were noted. The working was primarily for beryl and it contained a negligible amount of mica. Some triplite occurs with the beryl.

In 1954, 3 lb. of mica were sold for 8s. 7d. (See under beryl.)

The *Outpost Mine* is on Crown land, 11¼ miles north-west of Miami Village and 1,200 yards east-north-east of the Outpost trigonometrical beacon.

The mine is situated on the western slope of a very steep valley, and the pegmatite strikes downhill on a bearing of 50 degrees, with a north-westerly dip. It is a discordant body with a strong quartz-microcline core which carries much core margin mica at the top of the slope. There is also some biotite and tourmaline. At the bottom of the slope the pegmatite is 20 ft. wide and here the core has a width of 15 ft. but as one proceeds up the slope pegmatite increases to an apparent width of 100 ft.

There has been some hanging- and foot-wall trenching at the bottom of the hill, but no wall zone mica has developed. The mica cut from here was in small sizes from striated, disseminated mica books in the intermediate zones which contain a mixture of plagioclase and microcline feldspars.

From 1925-27 the mine produced 1 ton 191 lb. of cut ruby mica valued at £210.

The *Ova Mine*, a repegging of the Near Go Mine, is 3¼ miles north-east of Miami Village.



From verbal reports this mine is one which should be worth re-opening. It is at present flooded but there are three vertical shafts open to surface, with no signs of collapsing. An unsuccessful attempt was made to de-water the mine in the middle of 1959. The failure was occasioned by poor management and lack of capital.

Little can be seen of the pegmatite on the surface, but the close spacing of the shafts and the abundance of mica waste on the dump suggest a short, rich shoot which may not have been bottomed. The mica is of spotted quality.

Nearby, on the opposite side of a watercourse, some open-cast work has been done on a pegmatite with a strong quartz core. This work has been undertaken for beryl, but whatever was won was not declared under the name of this property.

The mine produced as the Ova from 1943-47, when 26 tons 1,690 lb. of mica were sold for £6,434. As the Near Go it declared 8 tons 7,731 lb. of mica in 1925 valued at £1,319.

The *Owl Mine* Claims are nine miles north-west of Miami Village.

Two main pegmatites have been worked. The No. 1 Mine, which was the main mica producer, is 300 yd. west of the No. 2 Mine, which was a beryl producer.

The No. 1 Mine is on the north-west slope of a spur or ridge. The pegmatite is a discordant body striking north-south and dipping east (magnetic). This trend is parallel to the foliation of the gneiss but the dip is across it. Not much could be seen of this pegmatite as the underground workings were inaccessible, and the 270 ft. long open-cast working was partly filled. However a picture of the structure has been built up from a plan of the workings and information supplied by Mr. N. A. Tatham who managed the mine.

The pegmatite is a zoned body with the main production coming from the hanging-wall shoot. On the foot-wall there was rather a small shoot of a somewhat discontinuous nature. A pattern of the shoot appears on Plate X. The hanging-wall shoot, for the length of strike, produced an exceptionally large tonnage of mica. It is reported that, at one stage in its development, 30,000 lb. of boxed mica was won during the period of a month. The mica-shoot was mined down to a depth of 278 ft. over an average strike of about 200 ft.

Like so many mines, the pegmatite continues strongly south of the workings. Just south of the open cut it is 20 ft. wide and has a wide microcline-rich core. Biotite and tourmaline appear on the waste dump.

The Owl II Mine was an old mica prospect. The pegmatite, which has a strong quartz core, occupies a discordant structure striking 55 degrees (magnetic) and dipping north-west. It has a 500 ft. long out-crop which is disposed equally on either side of a watercourse and, before it was blasted through, the pegmatite made a solid rock bar across it. In this watercourse, there is a good cross-section of the pegmatite. The core here is 25 ft. wide and the pegmatite has been trenched for mica along 120 ft. of strike to a depth of about 10 ft. on the hanging-wall side. On the south-west side of the watercourse the core is of pure

quartz, but on the opposite side large crystals of microcline that are idiomorphic towards the quartz occur in the quartz and on its margin. Large wedge-shaped, herring-bone muscovite crystals occur with all orientations, in the microcline. In any one microcline crystal, however, the mica wedges radiate from a common nucleus with the thin ends of the wedge pointing to the common point. Some tourmaline crystals, apatite and some beryl occur with this assemblage.

The main section worked for beryl is south-west of the watercourse, on the foot-wall side of the core, where there is a large body of microcline. Large beryl crystals have been taken from the felspar and occasionally have extended a little way into the quartz of the core. Some of the smaller beryl crystals are yellow and occur with interstitial muscovite as radiating to sub-parallel, pencil-like crystals in the microcline. This beryl has the same specific gravity as quartz which is lower than that of the average green beryl of the district. Some cerrusite has been found with the beryl.

Small fracture fillings occur in this pegmatite and were noted, on occasion, to extend from the microcline into the quartz of the core. The composition of these fillings is plagioclase, muscovite, quartz and tourmaline.

The mine declared its first mica production in 1924 and its last in 1950, but it lay dormant for 15 years between 1928 and 1943. By far the greater production came after the reopening. In all, 131 tons 1,793 lb. of spotted quality mica was sold for £41,878. (See also under beryl.)

The *Panorama Mine* is reported to be 600 yd. north-west of the Optimist Mine and its production has been declared with that of the Optimist.

The *Papyrus Mine* locality is given as seven miles south of Miami Village. This area has been repegged and worked over for beryl. This may well be the unnamed old mica working near the middle of Rockwood Farm. In 1925, 371 lb. of mica were sold for £20.

The *Parrott Mine* is on Crown land in the Urungwe East Group, four miles west of the Catkin Mine and about 500 yds. south-west of the Poll Mine.

Here a wide, simple or homogeneous, microcline-rich pegmatite has been mined open-cast for 150 ft. on the hanging-wall side of a north striking pegmatite which has an easterly dip of 60 degrees. It bears a discordant relationship to the gneiss. At the southern end, beyond the open working, is a shallow inclined shaft, while to the north a vertical shaft has been sunk on a narrow, barren-looking, concordant pegmatite.

A little to the west there has been some prospecting of a narrow, poor-looking pegmatite.

The mica is broken, of small size and rather striated. Some garnets and a little tourmaline are also present in the pegmatite.

In 1930 the mine declared 1 ton 557 lb. of ruby mica valued at £131.



The *Peaceful Valley Mine* is reported to be eight miles north of Miami Village. In 1944 it declared 1,954 lb. of spotted quality mica valued at £224.

The *Peak Mine* is on Crown land,  $12\frac{3}{4}$  miles north-west of Miami Village and about 400 yds. north of the Chikunda Mine.

The quartz of the core zone of this pegmatite forms a conspicuous white outcrop on a ridge. It strikes on 300 degrees and dips to the south-west. About 100 ft. of surface strike has been prospected by shallow disconnected pits and short trenches, and a very shallow adit level has been driven for 25 ft. along the foot-wall of the core. There is a zone of mica and tourmaline in a base of plagioclase on the core margin. The mica, though split into ribbands, is flat and small sizes of ruby quality can be cut. There is a wide intermediate zone of plagioclase, and microcline is absent. However, on surface some typical wedge-shaped, core margin mica was seen. There has been no declaration under the name of Peak and any mica produced from here was presumably declared with the Chikunda Mine, which was operated at the same time by the same owner.

The *Pearl Mine* is six miles north-north-west of Miami Village on the north-west slope of a prominent hill from which one can see some of the Hendren Mine workings.

This pegmatite was primarily a beryl producer, but as it also yielded some mica it is described in this section. It is considerably larger than the average run of beryl pegmatites and is undoubtedly one which would yield more beryl if the price were to be increased to a figure which would warrant hard-rock mining.

It has a somewhat variable strike of between east and north-east with a westerly dip of 40 degrees. It occupies a concordant structure, can be traced on the surface for over 1,000 ft. and attains a width of 25 ft. A normal sequence of zones is displayed. The quartz core is a conspicuous feature and beryl has been mined both from the core and its margins. There is a core margin concentration of large wedge-shaped, herring-bone mica, a middle intermediate zone composed predominantly of microcline or perthite, a narrow outer intermediate zone of plagioclase and quartz with small mica, and a weak hanging-wall zone of rather small ruby mica books from which some economic mica has been obtained. Finally, there are the usual border zones.

The main working consists of 315 ft. of open trenching along the middle of the pegmatite to a maximum depth of 30 ft. Two shallow hanging-wall shafts have been sunk to prospect the mica which was evidently too small and sparse to pursue in depth. Shallow trenches and pits occur at intervals along the strike.

Tourmaline occurs along the wall zones. Much apatite was seen on the waste dump together with triplite and secondary strengite. Some pyrrhotite also occurs with the triplite.

During the period 1952-3 the mine produced 1,476 lb. of ruby mica valued at £516. (See also under beryl.)



The *Pene Mine* is reportedly on Crown land in the Urungwe East Group of mines, 100 yds. west of the A.N.D. Mine. In 1953 it declared 32 lb. of mica valued at £3.

The *Pet Mine* is  $8\frac{1}{2}$  miles north-north-west of Miami on the cliff-like northern bank of the Karoe River.

The pegmatite is emplaced along a concordant structure striking 85 degrees (magnetic) and dipping north at 85 degrees at its western end and vertically at the eastern end. Its western end outcrops down the cliff and thus it is ideally suited to development by adit driving. The pegmatite has about 700 ft. of strike, but only the western sector proved payable along about 150 ft. of strike and to a rather shallow depth. It has been stoped to surface. There are two adit levels some 35 to 40 ft. apart. In the upper adit the pegmatite pinches out about 30 ft. from the cliff. The lower adit starts as a cross-cut and then turns along the strike.

East of these workings the pegmatite is about 18 ft. wide. It has a quartz core, and microcline-rich core margin zones over most of its length. There is also the usual wedge-shaped muscovite forming intermediate zones, but the books are small. A foot-wall mica shoot was mined but, where the pegmatite was narrow near the western end, the whole body was mined.

On the opposite side of the valley, near the confluence of the Karoe and one of its tributaries, an east-striking and south-dipping quartz-rich pegmatite has been mined. It had a short, rich, hanging-wall shoot of spotted quality but somewhat buckled mica. Nearby there is a small pegmatite which has yielded some beryl and is probably the Daz Mine.

Spotted mica was produced in 1945 and 1949, when a total of 2 tons 187 lb. was sold for £1,091. (See also under beryl and *Hendren V Mine*.)

The *Phoenix Mine* claims were situated between two and three miles south of Miami Village down the line of the old Miami to Sinoia road. These were amongst the earliest claims operated on the Field.

A number of pegmatites have been prospected on these claims but many only to a shallow depth.

The Phoenix (314) is a shallow open-cast working,  $2\frac{1}{4}$  miles south-south-west of Miami Village. A wide body of pegmatite with a very short strike carries sparsely disseminated mica.

The main Phoenix workings are  $3\frac{1}{4}$  miles south of Miami and three-quarters of a mile east of the Simba Mine, right on the edge of a vlei, and all the workings were full of water. The pegmatite strikes north and south and has been worked open-cast between a shaft and the vlei. South of the shaft a quartz core outcrops and there are several prospect trenches north and south of it. The overall surface strike of the pegmatite is 336 ft. Much of the mica mined appears to have been striated.

The claims produced from 1919 to 1921 when 7 tons 937 lb. of spotted mica were sold for £2,988. (See also under beryl.)

The *Pilot Mine* locality is given merely as Urungwe Mica Fields, East Group. In 1922 it produced 1,800 lb. of mica valued at £225.

The *Piper Mine*, a repegging of the Adder Mine, is  $5\frac{1}{2}$  miles north-west of Miami Village on Cheti Farm.

This pegmatite is, if anything, an even more ideally zoned one than the Hendren V which is described in detail, so that less detail will be given of the composition of the various zones here which are more or less the same.

The pegmatite bears a concordant relationship to the sillimanite-gneiss, which strikes east-north-east and dips to the north-north-west at 55 degrees. As a result of the resistant nature of the quartz core, erosion has produced a ridge-like feature on which the quartz forms quite a conspicuous spine.

Both hanging- and a foot-wall mica shoots have been developed. The former is as usual the stronger and more persistent, though the foot-wall mica is well developed at the surface in the neighbourhood of the inclined shaft. The pattern of the hanging-wall mica shoot and the presumed limits of the pegmatite, together with the main development, are given in Fig. 18.

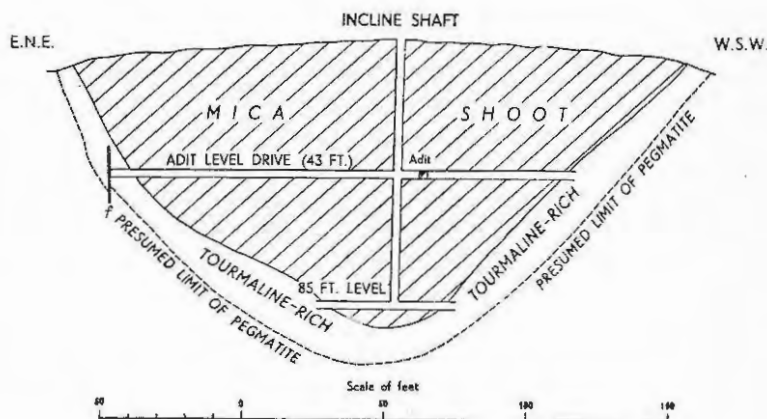


Fig. 18. Longitudinal projection of the Piper Pegmatite

The two mica shoots do not form a continuous envelope enclosing the inner zones but thin out before the extremities of the pegmatite and give way to tourmaline with some small mica. This zone of tourmaline in prolongation with the mica shoot was seen in all the development faces on the hanging-wall except one. This exception is the east face on the adit level (43 ft. level) where development has stopped on a small fault. Payable mica had, however, ceased to exist in the mica shoot before this point was reached, and it is certain that tourmaline would appear at no distance beyond the fault. Development of the foot-wall shoot had not reached the extremities of the mica shoot when the mine was last visited, but a similar pattern to that of the hanging-wall is likely. The width of the wall zones is determined by the size of the individual mica books which lie one deep with their cleavage planes orientated roughly normal to the walls.

The mica, which is of a spotted quality, like that of the Hendren V Mine, has, for the most part, good crystal forms. Its habit is variable even in adjacent crystals, so that a pseudo-hexagonal crystal may be

found next to one having good rhombic form. The rhombic form is due to the absence, or weak development, of the clinopinacoidal faces.

The largest books seen *in situ* measured 16 by 18 in. in the cleavage plane. Where there is a local diminution in mica concentration, plagioclase, which occurs interstitially to the mica and is the predominant mineral in the outer intermediate zone, forms the wall-zone along with quartz and small disseminated mica.

Muscovite of the usual valueless type makes its appearance again on the core margin where it forms a discontinuous zone varying in width from an inch or two to about 12 in. Where it is disrupted, offshoots of this mica zone form vein-like concentrations of small mica deep in the core-zone or right through it and then local concentrations of microcline, with quartz, form the core. This occurs in the cross-cut on the adit level just east of the inclined shaft where the quartz of the core tapers out and microcline occupies the central position in the pegmatite. Some manganese was found along the approximate plane of contact between this mica zone and the outer intermediate zone.

The lenticular quartz bodies are symmetrically disposed in relationship to the pegmatite as a whole. Microcline feldspar occurs in subordinate amount in the quartz but occasionally it forms quite large masses. It also occurs marginally to the quartz as a core margin zone. But, for simplicity, it is here regarded as part of the core because of the discontinuous nature of the quartz. The pegmatite has a maximum width on the adit level of about 15 ft. and the core is about 8 ft. wide.

Some beryl has been mined from the core-zone in the surface workings.

The nature of some of the development can be seen in Fig. 18. However, as the Adder Mine, part of the hanging-wall mica shoot was mined open-cast to adit level in the area of the inclined shaft before later underground development, as the Piper Mine, was undertaken. All payable mica in both shoots has been stopped. With increased mica prices and demands for smaller sizes some more mica may yet be profitably extracted from this pegmatite.

As the Adder, the mine produced 1 ton 890 lb. of spotted quality mica valued at £341 in 1921. As the Piper, the mine produced 8 tons 1,839 lb. of spotted quality mica during 1955-56 valued at £4,923. (See also under beryl.)

The *Pippin Mine* is reported to be 600 yd. north-east of the Catkin Mine. In 1953 it declared 143 lb. of mica valued at £44. (See also under beryl.)

The *Poll Mine* is 500 yd. north-east of the Parrott Mine and four miles west of the Catkin Mine.

The pegmatite occupies a discordant fracture striking north and dipping east at 70 degrees at the collar of an inclined shaft which has been put down on the hanging-wall side of a quartz core. There is evidence of a very weak hanging-wall mica shoot which presumably improved in depth. Much striated and interleaved mica on the waste dump may have come from the core margin in depth. There is nothing



of the pegmatite to be seen on the surface other than at the inclined shaft. It is inferred that it is a zoned pegmatite which has a short strike. There are two vertical shafts still open at the surface.

There is a parallel pegmatite, 140 yd. east of the main one. It is cut by a meta-dolerite dyke which may also cut the main pegmatite. This second pegmatite has a shallow prospect trench on it which has revealed nothing of value.

There have been six annual declarations of production between 1930 and 1946, amounting to 5 tons 1,225 lb. of cut ruby mica valued at £2,769. Some mica may have been declared with that of the Mormond Hill Mine.

The *Princess Claims* are on Cheti Farm, four miles north-west of Miami Village. A pegmatite striking north-east and dipping north-west at 40 degrees has been prospected by means of an inclined shaft on the hanging-wall where a few small books of ruby mica can be seen. On the waste dump are quartz, microcline and some wedge-shaped core mica. There is no record of any production.

The *Prospect Mine* is on Hillandale Farm, four miles north-west of Miami Village and 1,200 yd. south-west of the Princess Mine.

From the nature of the workings of the pegmatite, which could not be seen *in situ*, strikes 350 degrees (magnetic) and has a steep easterly dip. There is some driving in both directions off a shaft at about 14 ft. from surface and below this there was water in the shaft. Plagioclase, with small mica and tourmaline, can be seen on the dump, but microcline is the most abundant mineral. Waste mica nearby reveals that some ruby mica has been cut. Much of the mica mined was very striated.

It is not known whether there was more than one Prospect Mine, for in the schedule of productions there is one output for 1944, amounting to 471 lb. valued at £189, but the locality is vaguely given as Urungwe Mica Fields, East Group. (See also under *Hendren V Mine*.)

The *Radio Mine* is on Crown land about two miles a little south of east of Miami Village and 500 yd. north of the Kingsale Mine. There are some shallow open-cast workings on a pegmatite that appears to be of little further interest. In 1944-45 it produced 1,145 lb. of mica valued at £337.

*Radnor Mine* (see *Grand Slam Mine*).

The *Rae Mine* is on the north-west boundary line of Pitlochry Farm, 400 yd. south-east of its northermost beacon and five miles west-north-west of Miami Village.

A pegmatite, which has been prospected on surface over 400 ft. of strike, strikes north-east and dips to the north-west. There appears to have been a vertical shaft and several inclined shafts which have all caved and contain water to near the surface. From the distribution of these shafts and the surface workings it appears that both hanging- and foot-wall shoots have been worked and that the pegmatite was a typically zoned one.

N. A. Tatham, who once managed the mine, has stated that the pegmatite narrowed in depth and that the two wall-zones came close together after the disappearance of the core. The whole pegmatite could be mined except at the south-west end where it was wider and mica of any consequence was on the hanging-wall only.

At a depth of between 120 and 150 ft. both the mica shoots and the pegmatite give way to a concentration of almost pure tourmaline three feet wide, so that the body had the appearance of a steeply dipping coal seam.

The mica, which was of a high-quality ruby, is reported to have had the highest dielectric strength of any from the Field, withstanding up to 120,000 volts per millimetre.

The mine produced from 1924-7 and then lay dormant for 16 years. It was then worked from 1944-6 and in 1951-2. During these years it yielded a total of 33 tons 406 lb. of ruby mica valued at £16,879. In addition, 100 tons of waste was sold for £175 in 1952.

The *Red Star Mine* is seven miles north-north-east of Miami Village.

The main workings are on a pegmatite in low ground on the west bank of the Mohoa River, where five shafts had either collapsed or were full of water. Their line of strike is north-north-west and there was a westerly dip. Nothing can be seen of the pegmatite *in situ*.

In an unpublished report on the Mica Fields in 1943, R. Tyndale-Biscoe has briefly described the Red Star as follows: "The pegmatite dips west at 75 degrees and has been opened up on a strike of 300 ft. The dyke is quite regular in the northern part of its strike, where the mica shoot is about 200 ft. long. At the south end it becomes irregular and develops into a big blow sending out offshoots. The dyke is 6 to 8 ft. wide where at present under development. The books occur on foot- and hanging-wall sections, and the mica is a good hard ruby".

About 300 yards south-south-west of this working is a large pegmatite striking on 160 degrees. It apparently carried discontinuous values. A long cross-trench has been put through the body which is 75 ft. wide at this point. The pegmatite can be traced for 600 ft. south of here and it gives rise to a long, low, ridge-like feature along which there has been shallow prospecting at a number of points. An open-cast working 90 ft. long, on this pegmatite starts 60 ft. north of the cross-trench. A north-east spur has also been embraced in this working which has produced quite a large quantity of striated mica of low cuttability. Discontinuous shallow trenching continues north of this open cut.

Several pegmatites have been prospected south of this large pegmatite. The southernmost of these strikes at 348 degrees and has an easterly dip. Some discontinuous, shallow surface workings have revealed some small, striated, densely stained, mica books. Just north of this is another similarly situated pegmatite which has been open-cast to a shallow depth along 150 ft. of strike. This work has revealed larger books of mica of a better quality. Both these pegmatites bear a concordant relationship to the gneiss.

North-east of this last-mentioned pegmatite is one which has been mined to a shallow depth for beryl.

These workings have been operated discontinuously between 1926 and 1953 and include some mica from the Starlet and Linden mines. In all, 21 tons 1,850 lb. of mica have been sold for £9,117. (See also under beryl.)

The *Redwing Mine* is reported to be six miles north of Miami Village. Its outputs have been declared with those of the Easter Parade. (See also the *Rixon 2 Mine*.)

The *Retlaw Mine* is reported as being seven miles north of Miami Village. In 1947 it declared 882 lb. of mica valued at £116.

The *Retriever Mine* is three miles south-west of Miami Village on high ground which owes its prominence to the number of pegmatites in this area.

The highest point is occupied by an outcrop of quartz. West of this is an open-cast working which cuts right through the hill on a pegmatite with an easterly dip. The hanging-wall of the pegmatite carries spotted mica and a shallow Australian winze in the bottom of the open working has reached a depth of 40 ft. from surface. This pegmatite is believed to be one which will still yield payable mica.

Shallow workings on other pegmatites in the vicinity have revealed nothing of value.

In 1927-8 the mine yielded a total of 5 tons 1,055 lb. of spotted quality mica valued at £393.

The *Rex Mine* is reportedly five miles north of Miami. In 1920-1 it declared a total of 1 ton 1,063 lb. of mica valued at £183.

The *Ridge Mine* is 12½ miles north-west of Miami Village. The mine is a quarry-like working on the western slope of a ridge. Here, there is a concordant, wide, lenticular pegmatite striking north and south. There is a quartz-microcline core, 60 ft. wide, which has been blasted for beryl at a later date than the mica working. Only small disseminated books of mica, interleaved with biotite on occasion, could be seen. In 1943 the mine declared 1,524 lb. of mica valued at £572.

The *Rita Mine* is on Crown land, 8½ miles north-east of Miami Village.

This pegmatite was earlier prospected for mica without success, and only became registered as the Rita when it was later mined for beryl. The mica produced at this time was incidental and of little value.

There are three parallel, north-striking pegmatites which dip west. The main working is on the eastern pegmatite which has a quartz core 10 ft. wide and has a surface strike of about 800 ft. Beryl was found in the surface rubble along the whole length of strike, but when the mine was visited there was only 135 ft. of trenching along the core to a depth of 8 ft. This quartz core contains occasional large crystals of microcline as well as beryl. The felspar in the working adjacent to the core was too decomposed for megascopic identification but is presumably microcline.

Radioactive tantalum-columbite has been mined from the rubble adjacent to large quartz boulders from the core. Some of this mineral was used for an age determination of the pegmatite (see p. 82).



The central pegmatite is 60 ft. to the west of that just described. Trenching, and shallow beryl-workings on high ground have revealed a 3-foot quartz core. The rubble between these two pegmatites has also yielded some beryl.

The western pegmatite is 285 ft. from, and *en echelon* to the south-west of the centre pegmatite. There are some shallow workings at the north end of the strike. However, it continues south into the Yvette Claims where it has been mined for beryl at two points.

In 1954 the Rita Claims declared 86 lb. of mica valued at a little over £10. (See also under beryl and tantalum-columbite.)

The *Riverbend Mine* locality is vaguely given as Urungwe Mica Fields, East Group. In 1944 it declared 1,931 lb. of mica valued at £239.

The *Rixon 2 Mine* is reportedly six miles north of Miami, which is the same locality as has been given for the Redwing Mine. In 1921 it declared 3 tons of mica valued at £750.

The *Rkwesa Mine* is on Crown land in the Urungwe East Group, 6½ miles north-west of the Catkin Mine.

The pegmatite, which occupies a discordant structure, strikes at 214 degrees (magnetic) and has a south-easterly dip of 60 degrees. It has been trenched for 600 ft. A collapsed inclined shaft and a vertical shaft, 105 ft. on the hanging-wall side, have not made contact with the pegmatite. They merely served as a good local water supply. There has been no cross-trenching from which one can obtain the thickness of the pegmatite and there is very little to be seen *in situ*. From waste rock the pegmatite would appear to be a quartz-plagioclase-rich body which contains much small mica along the border zones. No microcline was seen so it is presumably a simple pegmatite with disseminated mica rather like the Beckett Mine pegmatite. This may be a pegmatite worth further investigation.

About 180 ft. away to the west there is what appears to be a barren pegmatite, while south-west and north-west of it are pegmatites which have been prospected but have disclosed little of value.

The mine was operated from 1944-8, 1953-4 and 1956-7 during which periods it yielded 12 tons 239 lb. of spotted quality mica valued at £3,403. (See also under beryl.)

The *Ruby "B" Mine* is on Crown land 6½ miles north-west of Miami Village and three-quarters of a mile north of the Major Mine.

The pegmatite, which occupies a discordant structure, has a surface strike of about 700 ft. on a bearing of 20 degrees (magnetic) and an easterly dip of between 45 and 50 degrees. It has been worked open-cast over much of the surface strike where it attained a maximum width of 12 ft. Structurally, it appears to be the kind which has been referred to in this bulletin as the simple-zoned type; that is, it is zoned only in so far as there was the development of a hanging-wall mica shoot. However, although payable mica was confined to the hanging-wall, in places a concentration of small books with good crystal outlines appeared on the foot-wall. The mica shoot on the hanging-wall carried quite a remarkable concentration of mica.

The old mine was completely stoped. This revealed a shoot which was 555 ft. long and 115 ft. deep with a semi-circular outline.

The mine was reopened in 1947 by means of an inclined shaft to 135 ft. below the old stope. Driving revealed some fair mica but work was discontinued as being uneconomic at the time.

A pegmatite has been mined 150 yd. away to the east and is presumably Ruby "C" Mine. The strike is 55 degrees (magnetic) and the dip 54 degrees to the south-east. The structure, like the Ruby "B" pegmatite, is discordant. It would appear that there was a weak hanging-wall mica shoot and that the pegmatite was of a rather simple type.

There is a shallow open-cast working along 60 ft. of strike and in the middle of this working is an inclined shaft. An adit has been put in at a shallow level from the hanging-wall side where the ground falls away sharply.

There is another pegmatite *en echelon* to the Ruby "C" 450 ft. away to the south-east. It forms the top of a hill but it does not appear to carry payable mica.

The Ruby "C" mine only produced in 1927 when 390 lb. of cut mica of spotted quality was sold for £33. The Ruby "B" first produced in 1920 and then again in 1924-28 and in 1947-48. Together with the small Ruby "C" output the total amounts to 25 tons 700 lb. valued at £3,685.

The *Ruby Kop Mine*, which was apparently later repegged as the All Rich Mine, has been given the former name on the map. It is  $8\frac{1}{2}$  miles north-by-east of Miami Village.

The workings were reported on by C. A. B. Colville, Inspector of Mines, in 1921. This report seems to indicate that a fairly rich mica shoot existed. He reported, however, that there was an enormous amount of waste mica owing to tourmaline and quartz inclusions.

As it can be seen today, the work done consists of a long open cut up the slope of a ridge-like feature. The strike is east-north-east and the dip to the south-south-east. The mica shoot appears to have been at the west-south-west end of the strike in the vlei at the bottom of the hill. Here there is evidence of an old collapsed shaft.

As the Ruby Kop, the mine produced 2 tons 1,689 lb. of mica in 1920 valued at £532 and as the All Rich, it produced in 1921 and 1937, yielding 2 tons 301 lb. valued at £530.

The *Rugby Mine* is reportedly six miles north-east of the Catkin Mine. In 1952 it declared 67 lb. of mica valued at £18. (See also under beryl.)

The *Sabie Mine* is reportedly on Crown land,  $3\frac{1}{2}$  miles north-east of the Red Star Mine. In 1952 it declared 1 ton 1,280 lb. of cut mica valued at £168.

The *Sable Mine* is on Crown land,  $6\frac{3}{4}$  miles north-by-east of Miami Village. It is situated in granite country which is full of gneiss inclusions. A pegmatite with a curved strike and southerly dip has been worked open-cast to a shallow depth. Little was to be seen of the pegmatite because of water. The mine produced 805 lb. of mica in 1920 valued at £69.



The *Salitros Mine* is on Crown land, seven miles north-by-east of Miami Village. Little can be judged of the pegmatites from the present state of the old workings. In 1921, C. A. B. Colville, Inspector of Mines, reported that good clear mica was being mined open-cast on the Salitros and Spahrep blocks. The mine was operated in 1920-21 and, in a small way in 1925. The total of 4 tons 104 lb. of mica extracted and cut was valued at £951.

The *Screw Mine* is on Crown land, 700 yd. south-east of the Beckett Mine. The pegmatite, which is one of the Beckett-Kirrie-Zonkosi group has been mined open-cast to a shallow depth. Outputs have been declared with the Zonkosi Mine.

The *Simba Mine* is on Eureka Farm, 3½ miles south-south-west of Miami Village. It may be a repegging of the Doreen Mine.

The pegmatite is a concordant, markedly lenticular, body. It is more than 60 ft. wide in the open-cast working which is about 70 ft. in length. It has an average strike of north-west and it dips south-west.

There was some fallen ground in the bottom of the open working. From what is revealed of the pegmatite it does not seem to be worth further investigation. Probably the mica was disseminated and rather broken. There is no clear evidence of zoning but the pegmatite is not strictly homogenous. It would appear that some incipient zonal development was upset by movement and multiple injection of material which resulted in a telescoping or jumbling up of the already crystallized material.

A drive 20 ft. in length has been put in to the north-west from the floor of the open working. In it is a concentration of worthless, spotted, wedge-shaped, herring-bone mica and nearby is a little tourmaline and weathered iron-rich garnet.

Beryl, together with a little triplite, has been extracted from the vicinity of irregular quartz masses. Beryl has also come from a very closely situated west-striking pegmatite which has a large quartz core. It outcrops 50 yd. south of the vertical shaft on the main pegmatite. This shaft has been sunk below the depth of the open working, but little development work has been done from it.

There are pegmatite workings 700 yd. north-east of the big open-cast working described above and they may be the Simba 2 Mine. Here two discordant, parallel pegmatites occur 12 yd. apart and both have been trenched along the foot-wall sides of their quartz cores. The pegmatite on the south-west has two shallow shafts 20 ft. deep, one near each end of the open working. Neither pegmatite looks very promising for mica.

Outputs which have been declared from 1952 to 1954 include mica from the Simba, Simba 2, Top Hat and Tom Tom mines. In all, 5 tons 761 lb. of mica were sold for £3,490. (See also under beryl.)

The *Skylark Mine* is reportedly eight miles north-west of Miami Village. In this locality there are a number of unnamed pegmatite workings on the map. In 1931 the mine declared 1 ton 719 lb. of mica valued at £109.



The *Slumber Mine* is reported to be six miles north of Miami Village. However, according to the information given on an old claims plan it may well be the mine shown on the map as Tito, a little under  $5\frac{1}{2}$  miles north-north-west of Miami. The Slumber produced in 1926 and 1930, declaring a total output of 302 lb. of mica valued at £31.

The *Small Slam Mine* is on Crown land,  $2\frac{3}{4}$  miles east of Miami Village.

The pegmatite is emplaced along a discordant fracture striking on a bearing of 54 degrees (magnetic) with the foliation of the schist, but dipping to the north-west across it. Open workings on the strike of the body commence in a vlei and continue up a ridge and over the other side in a north-east direction. This pegmatite was opened up as a mica prospect, but was mined for beryl at a later date. There is also a large open-cast working on a parallel pegmatite on the north-west side of the ridge. These pegmatites are rich in tourmaline.

A plan of the Small Slam Mine shows two vertical shafts 200 ft. apart. The northern shaft was down to 75 ft. with driving at this level extending for 135 ft. in a southerly direction. The southerly shaft is down the hill and was only 15 ft. deep. It would appear that both the hanging- and foot-wall were prospected and that the pegmatite is over 60-ft. wide.

The mine produced from 1936-38 and in 1945. In all, it declared 5 tons 1,037 lb. of mica valued at £1,353.

The *Sorotie Mine* is  $3\frac{1}{2}$  miles south-west of Miami Village on Kachichi Farm.

Four or more pegmatites have been prospected on these claims, but the mine is on a pegmatite on the south-west side of a watercourse. Nothing could be seen of the pegmatite *in situ* at the time of the visit, but the workings indicate a strike trending north-north-west and a dip of 57 degrees to the east-north-east.

It has been mined opencast over only a short distance, but the total strike is in excess of 300 ft. Underground development was from a vertical and an inclined shaft. A 49-ft. level was driven equally in both directions for a total distance of 160 ft.

Rather striated, spotted mica occurs on the waste dump and it contains many inclusions of quartz and tourmaline. Much green apatite can be seen on the waste dumps which have been combed for beryl. The waste rock indicates that the contact schist is rich in tourmaline. The pegmatite is a plagioclase-rich one that had a high concentration of mica in the section worked. It is not known whether the shoot has been bottomed.

A nearby pegmatite, which has a quartz core, has been worked for beryl. On the opposite side of the watercourse is a pegmatite which strikes almost at right angles to the main pegmatite and it has been prospected discontinuously over a short distance.

The mine produced from 1944-8 and declared a total of 24 tons 1,979 lb. of spotted mica valued at £6,783. (See also under beryl.)

The *Southern Cross Mine* is reportedly six miles north of Miami Village. Both the Rixon 2 and Redwing mines are recorded as having the same locality, so that the Southern Cross may be a repegging of one of these. It was worked in 1926-7 and declared a total of 2 tons 1,613 lb. valued at £289.

The *Spahrep Mine* is on Crown land, seven miles a little east of north of Miami. It adjoins the Salitros claims on the west. In 1921, C. A. B. Colville, Inspector of Mines, reported that good clear mica was being mined open-cast on both the Spahrep and Salitros blocks. In 1921 it declared 2 tons 966 lb. of mica valued at £621.

The *Spider Mine* is on Crown land,  $7\frac{1}{2}$  miles north-west of Miami Village and half a mile west of the Karnie Mine.

Here a zoned pegmatite, which occupies a discordant structure, striking on a bearing of 210 degrees and dipping to the south-east, has been mined open-cast along 300 ft. of strike. It reportedly carried hanging- and foot-wall mica shoots and these were stoped down to 56 ft. at the deepest point, which was about mid-strike. It is believed that the mica in these shoots has not been exhausted.

Development was by means of two inclined shafts. A vertical shaft situated 120 ft. south of the Main Incline attained a depth of 95 ft., but did not, apparently, cut the pegmatite; nor was it connected to the main development in any way.

C. A. B. Colville reported on the mine in 1921. Large mica books were in abundance, but were stained and did not "cut very well".

The mine produced in 1920 and again from 1925-7. A total of 5 tons 1,348 lb. of spotted mica was sold for £853.

The *Stalingrad Mine* is reportedly eight miles north-west of Miami Village. It may well be one of the many unnamed pegmatite workings south-west of the Hendren Mine. In 1945 it declared 1 ton 835 lb. of mica valued at £753.

The *Starlet Mine* is on Crown land, eight miles north-north-east of Miami Village. It consists of a shallow open-cast working on an uninteresting looking pegmatite striking north-west and dipping south-west at 85 degrees. In 1945 it declared 1,830 lb. of ruby mica valued at £855. (See also under *Red Star Mine*.)

The *Sunspot Mine* is on Hillandale Farm,  $3\frac{1}{2}$  miles west-north-west of Miami Village.

The form of the mica shoot is shown in Plate X. Much of the underground information was obtained from N. A. Tatham, who managed the mine. The pegmatite could not be studied *in situ*.

The pegmatite, which bears a discordant relationship to the gneiss, strikes north and dips east at 55 degrees. Surface workings and prospect pits indicate a surface strike of 450 ft., but the payable length of the shoot averaged about 180 ft. and attained a depth of 220 ft.

An interesting feature of the mine is that the mica shoot was, in effect, a sub-outcropping one. There was little or no mica at surface and at 45 ft. down it was still badly fractured with a low cuttability in a pegmatite only 3 ft. wide. At 60 ft. the mica improved in every way.

It was, for the most part, disseminated throughout the pegmatite, but tended to form on the hanging-wall, where the body attained the width of 6 ft. or more. The mica, which is of ruby quality, was in good sizes, hard and flat. A feature of this mica shoot, as was found on the Piper, Hendren V, Rae and Catkin mines, was that at the bottom of the shoot the place of mica was taken by tourmaline.

The mine produced in 1925, 1928, 1943 and 1949-53. In all, it declared 55 tons 1,189 lb. of cut ruby mica valued at £48,985.

The *Swallow Mine* is five miles north-east of Miami Village. Workings are on a concordant pegmatite on low ground where there is very little to be seen of the pegmatite. It has a long north-west strike and a south-westerly dip. In 1945 it declared an output of 1 ton 619 lb. valued at £270.

The *Sweep Mine* is reportedly five miles north-east of Miami Village and may adjoin the Swallow Mine. In 1944 it declared an output of 1,490 lb. of mica valued at £121.

The *Taguta Nhamo Mine* is on Crown land in the Urungwe East Group, 6½ miles a little east of north of the Catkin Mine.

The only surface indications of the pegmatite are a few large white quartz outcrops which suggest a very short, zoned body. There is a shallow shaft which had water at a depth of 15 ft. In the shaft the pegmatite can be seen striking on a bearing 20 degrees and having an easterly dip of 75 degrees. There is a quartz-microcline core with occasional quartz masses. The intermediate zone is predominantly of plagioclase with graphic quartz. Mica thins on the waste mica dump reveal that some good ruby mica was cut into sizes which contained a proportion of No. 3 and 4. There is also much fish-tail mica which must have been taken from the core zone.

The mine produced from 1954-6 and in 1958. In all, 182 lb. of mica was declared and sold for a little less than £96.

The *Tak Mine* is on Crown land, nine miles north-east of Miami Village.

The mine was opened up mainly as a beryl rubble working. A crystal of beryl weighing half a ton was reputedly found in the rubble just below the surface.

The pegmatite has a large quartz core which forms the highest point on a hill. Some mica occurs in decomposed felspar on the margin of the core. The pegmatite also carries tourmaline and the schist exposed along the ridge contains a fine concentration of the mineral.

In 1954 the mine declared an output of 29 lb. of mica valued at a little under £20. (See also under beryl.)

The *Teaser Mine* is reportedly 3½ miles north of Miami Village and presumably was one of the pegmatites worked in the Trezona Mine area. In 1929 it declared 301 lb. of mica valued at £36.

The *Teddy Claims* are on Haslemere Farm a mile south-east of the Last Hope Mine. There is no open working, but a line of three shallow shafts indicates a north-south strike of more than 180 ft. and a possible



westerly dip. Judging from the waste dump the pegmatite is quartz-rich with tourmaline and small mica. The mica seen was stained, spotted and somewhat buckled. There was no production.

The *Terwin Mine* is on Crown land, six miles north-west of Miami Village.

There are two markedly lenticular pegmatites some 210 ft. apart with an old mine track between them. The pegmatite to the north of this track forms a small hillock and has an irregular quartz core which attains a width of 3 ft. Perthite is predominant in the core margin zone. The pegmatite has been mined along its centre over a distance of 85 ft. to a maximum depth of 15 ft., leaving the margins intact. This suggests that it was prospected primarily for beryl and that what mica was produced came from an intermediate zone. There were a few cuttable books of spotted mica to be seen. This pegmatite strikes on a bearing of 25 degrees.

The pegmatite on the south side of the track also forms a small hillock. The strike of this body is on a bearing of 65 degrees and it has been worked primarily for beryl. There is a wide quartz core with decomposed marginal feldspar which is presumably microcline. A little small, striated, mica can be seen. Both pegmatites carry a little tourmaline.

In 1954 the mine declared 1,692 lb. of mica valued at £250. (See also under beryl.)

The *Tsetse Mine* is reportedly 2,000 yards south-east of Chitenje hill and it may well have been repegged as the Danny Boy Beryl Mine which is  $4\frac{1}{2}$  miles north-east of Miami Village. In 1934 the Tsetse Mine declared 912 lb. of mica valued at £109.

The *Tito Mine* is on Crown land,  $5\frac{1}{2}$  miles north-west of Miami Village.

The pegmatite occupies a discordant structure striking north with the foliation of the gneiss, but dipping steeply across it to the east at 50 degrees. It has been prospected along 250 ft. of surface strike and the position of the underground development indicates that a hanging-wall mica shoot has been mined by means of three rather shallow shafts. The pegmatite appears to be rich in microcline and this may account for the rather broken and striated appearance of much of the mica seen.

In 1945-6 the mine declared 3 tons 1,972 lb. of ruby mica valued at £1,587. (See also the *Slumber Mine*.)

The *Tolstoi Mine* is reportedly on claims which were a part repegging of the Walhalla Claims which in turn were a repegging of the Miami (426) Claims. It was mined in 1936-7 and declared 2 tons 64 lb. of mica valued at £410.

The *Tom Tit Mine* is on Crown land,  $4\frac{1}{2}$  miles north-east of Miami Village. Some shallow trenching on several small pegmatites was undertaken for beryl. In 1954 it declared 11 lb. of mica valued at 10s. 10d. (See also under beryl.)

The *Tom Tom Mine* is on Maunga Farm,  $5\frac{3}{4}$  miles south-south-west of Miami Village.

Two small workings, 400 ft. apart, on the edge of a vlei, were full of water when the site was visited. A mine plan shows that the northern workings were stoped out along a strike of 60 ft. to a depth of 57 ft. To the south the pegmatite was worked open-cast along a short strike and a drive 60 ft. long, was put in at the 25-ft. level.

The mine was operated from 1950 to 1952 when 13 tons 119 lb. of cut mica was sold for £5,944. In addition 159 tons of crude mica was also sold in 1952 for £2,620. (See also under beryl and the *Ndare* and *Simba* mines.)

The *Top Hat Mine* is on Eureka Farm,  $3\frac{3}{4}$  miles south-by-west of Miami Village.

Two pegmatites about 200 ft. apart have been mined, the one for beryl and the other for mica. The main work is on a short south-striking pegmatite. There is a foot-wall inclined shaft and a vertical shaft 40 ft. deep. The hanging-wall of the body has been stoped almost to surface. This is the mica working.

The other pegmatite, which was the beryl producer, is a concordant body with a quartz core. It has been mined by means of a wide open working to a depth of about 12 ft.

In 1952 it declared 2 tons 426 lb. of mica valued at £1,344. (See also under beryl and the *J.J.* and *Simba* mines.)

The *Townley Mine* is reportedly four miles east of Miami Village. In 1930 it declared 1,965 lb. of mica valued at £148.

The *Trezona Mine*, originally comprised some four blocks, on Crown land,  $3\frac{1}{2}$  miles north of Miami Village.

There are a number of pegmatites which have been prospected on these claims. The main workings are on a pegmatite about 650 yds. from the mine house. The open-cast working here reveals nothing of interest. The underground development was apparently stoped down to a depth of 100 ft. Later a vertical shaft was sunk to a depth of 150 ft. and 75 ft. of driving undertaken. This work did not disclose anything of value. Large books of somewhat buckled, ruby mica are believed to have been extracted from this pegmatite.

Three other pegmatites have been prospected to the north-east of the house. The one nearest the house appears to have yielded a fair quantity of ruby mica, judging from the nearby waste dump, but nothing can be seen of the pegmatite *in situ*. Some six or seven pegmatites have been prospected within the environs of the house and some have yielded beryl.

The mine produced continuously from 1923 to 1935 and from 1943 to 1945 to yield 108 tons 1,144 lb. of ruby mica valued at £21,184. (See also under beryl.)

The *Try Again Mine* is on Haslemere Farm a mile south of the Last Hope Mine. Little information can be gained from the small old workings. It produced in 1944-5 and in 1947 and had a total output of 1 ton 1,144 lb. valued at £221.



The *Turning Point Mine* is on Kachichi Farm two miles south-west of Miami Village where a large number of pegmatites are concentrated in a relatively small area.

The later half of the war years, and the few years following, saw the major production from the Turning Point Claims. Emphasis was on speedy production and not on the future of the mines. No detailed reports were made. Only the No. 3 Mine (T.P. 3) has a more or less up-to-date plan. It is certain that at the time of writing the claims are by no means worked out, but much difficulty may be experienced in reopening some of the workings because of bad ground and much water.

The T.P. 1 workings are 250 yds. north-west of the mine house, which is on the highest point of the low hill north of the road. The pegmatite is a concordant one striking east and dipping at 40 degrees to the south. In the inclined shaft which is 40 ft. deep, the pegmatite is 6 ft. wide and zoned with rather sparse mica on both walls. From the books, spotted mica is well as some clear, brown-green mica can be cut. At the time of working it was evidently a sub-economic pegmatite.

A second pegmatite striking north and dipping east has been mined opencast along 420 ft. of strike with the deepest point at the northern end of the working. This pegmatite evidently occurs on both the T.P. II and T.P. III blocks of claims. A plan of this mine, which is believed not to be up-to-date, shows a shaft down to 70 ft. near the northern end of the large open cut. No underground development is indicated. However, it is believed that the pegmatite was actually mined down on the incline to a depth of about 120 ft. It has also been stated that when work ceased there were large books of mica to be seen in the pegmatite. The large size of the open cut appears to have been due to the presence of numerous concordant spurs branching upwards from the main pegmatite.

There is some opencast working and evidence of old collapsed shafts in the vlei to the north of the large open cut. This area is very wet and the ground bad and it is believed that some African miners who were buried by a fall of ground were never unearthed. This pegmatite may be a continuation of the main pegmatite farther south.

South of the deepest point in the main open-cast working on the second pegmatite, and near the middle of it, where the trenching was 20 ft. deep, an inclined shaft was sunk a further 40 ft. Two more shafts, about 60 ft. apart were sunk near the southern end of the open cut. They were down 45 ft. and connected by a drive. This short section appears to have been stoped to surface.

Two other pegmatites, both parallel to the second pegmatite, have been mined to the east of the main opencast working. The most easterly of these is the T.P. 3. The centre pegmatite has been mined open-cast, and a shaft sunk in 1959 revealed that it has been faulted off at about 20 ft. from surface.

The T.P. 3 pegmatite still carries a good concentration of economic mica at the bottom of the old workings and the mine is at present being reopened. The mica is spotted but of a better quality than the



densely spotted, rather soft mica from the large open-cast work of the second pegmatite to the west of it. Some clear brown-green quality can also be cut. The T.P. 3 pegmatite is of good appearance and is composed predominantly of plagioclase with subordinate quartz and only a little microcline. It has exhibited something of a pinch and swell structure. Where normal widths occur a hanging-wall mica shoot has developed, but judging from the widths of some of the old stopes, rich disseminated mica occurred in the "blows" in the pegmatite. The development and stoping so far undertaken indicate that the mica shoot is likely to have an outline not unlike that of the Last Hope Mine (See Plate X) which gives one some idea of how much mica remains in the present shoot below the deepest working.

This pegmatite dips east at 50 degrees and occupies a discordant structure. For the most part the foot-wall was not seen so that the average width is not known. Pegmatite rich in mica, could be seen in two short drives north off the inclined shaft and in a very dangerous, newly reopened, old vertical shaft 120 ft. north of the inclined shaft. At all three places the pegmatite is very rich in mica books of large size and good quality.

North of the inclined shaft the mica shoot has been stoped out above the first level right to the surface along a strike of 133 ft. with the depth of the working decreasing northwards. North of this there is, on surface, a 20 ft. section of ground intact, followed by another open-cast working 155 ft. long which is also deepest at its southern end. It is not certain whether there are two pegmatites in line or one pegmatite with two disconnected mica shoots. The latest work on this pegmatite was confined to the southern end, where a depth of about 80 ft. has been reached. The drive 30 ft. long to the north which was mentioned above is at a depth of 80 ft. and the other is 10 ft. above it. The inclined and vertical shafts have attained the same depth and are interconnected very nearly opposite one another.

About 500 yd. south-east of the T.P. 3 Mine, and also possibly on the same block of claims, is a north-west-striking pegmatite which dips south-west at about 50 degrees. There is a long, shallow, and fairly wide open-cast working on this body. At the south-east end of the working there is evidence of an old collapsed inclined shaft. The waste dump indicates that fairly large sizes of densely spotted mica have been mined, though, from what can be seen of the pegmatite, very little mica is in evidence. Another pegmatite with a sparse, disseminated mica has been mined open-cast at a point 300 yd. north-east of the last-mentioned working.

The T.P. V pegmatite is about 400 yd. east-south-east of the mine house. The pegmatite reveals at the present level of the open working, a high concentration of broken, buckled and interleaved green mica which is quite useless, for sheet mica. However, green mica apparently gives the best colour when powdered so that it may yet be exploited.

Production was declared from these claims from 1935-37, from 1943 to 1954 and in 1956 and 1959. A total of 156 tons 1,461 lb. of cut or

block mica was produced and sold for £56,973. In addition, from 1950 to 1953, 535 tons of waste mica was sold for £1,250. (See also under beryl.)

The *United Ireland Mine* locality is vaguely given as the Urungwe Mica Fields, East Group. It produced in 1923-24 and declared a total of 1 ton 1,561 lb. valued at £445.

The *Unknown Mine* is reportedly about 150 yd. south of the Aqua Mine. Its outputs were declared with those of the Burnley Mine. (See Aqua Mine.)

The *Utah Mine* is reportedly eight miles south-east of Miami Village and is possibly one of the many old workings on Ruwanzi Ranch. In 1948 it declared 17 lb. of mica valued at £3.

The *V.8 Mine* is on Crown land in the Urungwe East Group, seven miles north-west of the Catkin Mine and  $1\frac{1}{4}$  miles west-south-west of the Rkwesa Mine.

Three pegmatites have been prospected but the main working is on an almost pipe-like pegmatite on which there is an oval-shaped open-cast working 20 ft. deep and 20 ft. long. In the middle of the working, quartz with large masses of microcline is exposed. This is surrounded by a zone composed of plagioclase, quartz and microcline. Here there are laths of biotite and very broken muscovite. Some of the muscovite has crystal forms, but it is very buckled. The feldspars, too, appear to have suffered granulation. The margins of the pegmatite were not exposed.

The north-striking pegmatite which dips east occurs 150 yd. away to the south-south-west. It is 6 ft. wide and of a simple character. It has been trenched along 35 ft. of strike to a depth of 5 ft. A small pit in a nearby parallel pegmatite has revealed a concentration of biotite.

These pegmatites were mined primarily for beryl, but in 1953 the mine declared 27 lb. of mica valued at £6. (See also under beryl.)

The *Van's Luck Mine* is reportedly  $1\frac{1}{2}$  miles east of Miami Village. In 1944 it declared 449 lb. of mica valued at £124.

The *Vectis Mine* is said to be six miles north-east of Miami Village. It produced in 1926 and 1945, declaring a total of 1,644 lb. of mica valued at £97.

The *Verna Mine* is  $2\frac{1}{4}$  miles south-east of Miami Village.

Several pegmatites have been prospected in this area. The main working is on a body striking at 293 degrees (magnetic) and having a southerly dip. There are 150 ft. of shallow open-cast work and several shafts, but apparently there has been little underground development. The pegmatite is zoned and the mica appears to have been taken from the hanging-wall. The books are likely to have been rather striated and the cuttable sizes small.

In 1943 it declared 510 lb. of ruby mica valued at £191.

The *Vernal Mine* is reportedly two miles east of the Kingsale Mine. In 1952 it declared 16 lb. of mica valued at £6. (See also under beryl.)

The *Victoria Mine* is said to be three miles south of Miami Village. This may be one of several old pegmatite workings between the Phoenix and Phoenix 314 mines. In 1944 it declared 1 ton 111 lb. of mica valued at £256.

The *Victorious Mine* is reportedly five miles north-east of Miami Village. In this locality there are two unnamed pegmatite workings shown on the map. In 1945 it declared 1 ton 979 lb. of mica valued at £468.

The *Vivi Mine* is five miles north-north-east of Miami Village. The underground workings are inaccessible and there is little to be seen of the pegmatite on surface. In 1919 it declared 500 lb. of mica valued at £63.

The *Wagga Mine* is reportedly nine miles north-west of Miami Village. In 1931 the mine declared 1,073 lb. of mica valued at £77.

The *Walhalla Mine* (see *Miami Mine*).

The *Washer Mine* is reportedly seven miles north-east of the Poll Mine. Its early outputs have been declared with those of the Parrott Mine but it declared a separate output of 415 lb. of mica in 1959 valued at £181.

The *Waterfall Mine* is said to be seven miles north-west of Miami Village. In 1925 it declared 108 lb. of mica valued at £8.

The *W.B. Mine* is reportedly 4½ miles south-west of Miami Village. Its main production was in 1944 with a small output in 1945. In all, 1 ton 510 lb. of mica was sold for £242.

The *Wee Wallie Mine* locality is vaguely given as Urungwe Mica Fields, East Group. In 1954 it declared 562 lb. of mica valued at £209.

The *White Rose Mine* is recorded as 12 miles north of Miami Village. The distances given for many mine localities by miners and prospectors were not map distances so that the mine may or may not be within the limits of the map. In 1944 it declared 231 lb. of mica valued at £29.

The *Wild Pig Mine* is on Eureka Farm, 4½ miles south of Miami Village.

The pegmatite has an irregular strike averaging about 3 degrees (magnetic) and a steep westerly dip. There is an open-cast working 330 ft. long on the hanging-wall side of a quartz core. Striated mica can be seen on the waste dump.

A parallel pegmatite with a strong quartz core occurs 80 yd. to the west. This has been worked for beryl which has been rooted out from among the boulders of quartz. Discontinuous shallow open workings extend over 700 ft. of strike. The beryl has come mainly from the quartz core and rubble.

In 1952 the mine declared 26 lb. of mica valued at £4. (See also under beryl.)

The *Winter's Whopper Mine* is on Crown land, 7½ miles north-west of Miami Village.



This is on a wide, zoned pegmatite which gives rise to a small hillock. It has such a short strike that the body is almost pipe-like. There is about 90 ft. of surface strike on a bearing of 75 degrees (magnetic) and a northerly dip. The width is about 50 ft.

There is a quartz core which is enveloped in coarse microcline. However, in places there are concentrations of wedge-shaped, herring-bone muscovite books up to 18 in. long, arranged in divergent and radiating clusters, between the quartz and the potash felspar. Where the books of mica occur partly in felspar and partly in the quartz of the core, they very clearly commenced crystallization in the felspar. Tourmaline is also present in the core margin zone.

Plagioclase, often with graphic quartz intergrowths, occurs as an intermediate zone outside the microcline. Some books of spotted, striated mica can be seen on the hanging-wall where it is exposed. Concentrations of small mica with plagioclase and quartz were observed in two places where they were unrelated to the zoning. They would appear to have formed as fracture fillings.

The pegmatite was opened up for beryl, which has been taken from the core margin on the hanging-wall side as well as from the core. Some large crystals transgress the contact between the core and the core margin.

The mining has been done open-cast to no great depth and the foot-wall is still intact except for trenches which have cross-cut the core at both ends.

In 1952 the mine declared 577 lb. of spotted mica valued at £137. (See also under beryl.)

The *Wisden Mine* is reportedly three miles north-west of Miami Village. In 1936 it declared 1,418 lb. of mica valued at £106.

The *Yen's Luck Mine* is recorded as on Crown land, about one mile south-east of the Zamona Mine. In 1952 it declared 17 lb. of mica valued at £2. (See also under beryl.)

The *Yorkshire Mine* is reportedly nine miles south-east of Miami Village. In 1926 it declared 275 lb. of mica valued at £22.

The *Zamona Mine* is on Crown land, a little under 10 miles due north of Miami Village. The mine was repegged as The Egg in 1955 but the first name has been retained on the map because it is thus locally known.

Because of its well-developed quartz core the pegmatite forms a kopje which is the highest and most conspicuous point in the area. It is typically zoned with mica books on both walls and on the core margins. But the latter are, as usual, valueless. The hanging-wall mica shoot is the stronger and the books exceed three feet in cross section, but they are rather buckled and broken. However, flat mica can be cut and is a first-quality spotted. The pegmatite is a concordant one and typically lenticular. It has a short strike trending north-north-west and it dips to the west-south-west.

It has been worked open-cast on the hanging-wall side and there has been a little shallow prospecting at surface on the foot-wall side of the core. At the northern end a trench has been dug across the core and

from this trench there is a shallow shaft off which there is a foot-wall drive. From the southern end an adit has been put in for 90 ft., all in gneiss under the pegmatite. At the end of the adit a shaft has been sunk to 20 ft. and more abortive driving undertaken in search of the pegmatite. The pegmatite was finally found in a cross-cut from the adit. The presence of fill indicates that some stoping was undertaken above the adit level.

The Zamona declared outputs in 1920 and 1924 when 1 ton 970 lb. of mica was sold for £332. As The Egg, the mine produced in 1955-6, declaring a total of 7 tons 1,627 lb. valued at £3,192.

The *Zig Zag Mine* is reportedly on Haslemere Farm, the homestead on which is five miles south-west of Miami Village. In 1952, 1 ton of crude mica was sold for £20.

The *Zonkosi Claims* at one time comprised eleven blocks situated between five and six miles north-east of Miami Village. These covered a number of pegmatites in a highly micaceous north- and south-striking belt of schist.

At a point  $5\frac{1}{4}$  miles north-east of Miami and about 450 yds. south of the Kirrie I Mine there is a large open-cast working on a concordant pegmatite striking on 325 degrees and having a westerly dip. Another pegmatite *en echelon* to the south-west appears to have carried very little mica. About 300 yds. north-west is another concordant pegmatite which also has a westerly dip. It, too, has been mined open-cast. There are other pegmatites which have been prospected in the vicinity and all seem to have the same characteristics as the Kirrie I and other pegmatites in this belt, that is, simple in character with disseminated mica in varying concentrations.

The Zonkosi 5 block includes part of the south-eastern extension of the Beckett pegmatite and the pegmatite *en echelon* to the south-east, 90 ft. on the foot-wall side of the Beckett. This last body has been mined open-cast along 500 ft. of strike and underground to a depth of 120 ft. where the pegmatite has pinched to a narrow width. In the north-western end the pegmatite pinched out, but in the opposite face the pegmatite is very wide indeed. Structurally and in the quality of the mica this pegmatite is similar to the Beckett pegmatite.

The claims produced sporadically between 1920 and 1935, from 1944-8 and from 1953-6. The greatest single production was in 1944 when over 70 tons of cut and boxed mica were declared. With the Zonkosi mica is some from the Beckett, Bee, Cork and Screw mines. The total production is 179 tons 977 lb. valued at £42,852.

### BERYL MINING

The mineral beryl is the only important ore of the metal beryllium. However, other beryllium minerals, with a higher percentage of beryllium than beryl, have been identified from the Miami area. These are phenacite, hurlbutite, chrysoberyl, euclase and herderite in order of decreasing beryllium content. The phenacite was identified by the late Dr. K. P. Chikara and come from an old, unnamed mica working shown on the map  $8\frac{3}{4}$  miles north-east of Miami and 700 yds. south-by-

west of the Hank's Hope Beryl Mine. This pegmatite also yielded yellow beryl. The other beryllium minerals will be mentioned under the name of the mine where they were found, in the description of individual properties.

There have been no very large beryl producers in the District so that no statistical summary is warranted. From the start of beryl mining in 1950 until the end of 1959 there were, within the area mapped, a total of 178 mines which produced between them a total of 1,186.83 tons of beryl valued at £141,896 16s. 3d. One-fifth of this amount has come from 27 miles on Ruwanzi Ranch.

The Southern Rhodesia Geological Survey has produced a Mineral Resources Series in which No. 6 is on Beryl and has recently been revised.

At the time of writing, the United Kingdom Atomic Energy Authority is engaged in an investigation of beryl-bearing pegmatites in the Urungwe District and elsewhere in the Colony, with the intention of assessing the beryl potential of the country. Should the price of beryl be increased, as is anticipated, there will be a minor "rush" back to the Fields and the work of the Authority, if published, will be in great demand.

Because it was not possible to supervise the mining of beryl in many of the remote and inaccessible parts of the area a very loose mining practice soon developed. Since many of the pegmatites are small and because very little beryl was taken from them, quite a number were not registered. Beryl which was gleaned from such pegmatites, or in rare cases stolen, has been declared from other registered claims. For this reason some of the declared beryl outputs have to be treated with reserve.

There are very many beryl workings on the map without names and the reason for this is that, if the registered owners troubled to erect claim beacons, they seldom, if ever, went to the trouble of erecting plates with the name and number of the claims. Africans who were found working unsupervised properties could seldom give the owner's name, much less the name of the mine.

The beryl outputs have been obtained by hand picking of crystals and larger fragments so that appreciable quantities have been lost, either due to fragmentation or the small sizes of crystals. Laboratory scale flotation methods of recovery have been developed but if such a process proves economic for low-grade deposits it is doubtful whether it could ever be applied in an area like Miami where the pegmatites are small and widely distributed.

A field guide to assist in the identification of beryl, using bromoform and benzene, is given by N. E. Barlow (32).

#### THE BERYL MINES

The *Adelphi Mine* is on Eureka Farm, 4½ miles south of Miami Village. Beryl has been won from shallow open-cast workings on a microcline-rich pegmatite striking north-west. In 1954 it declared 0.63 tons of beryl valued at £77 7s.



The *African Beryl Mine* is reportedly in the Urungwe Reserve about eight miles south-west of the Catkin Mine and two miles south of the Naodsa River. In 1954 it declared 0.8 tons of beryl valued at £90 12s. 3d.

The *Aird Mine* is reportedly on Moniak Farm with its D. claim beacon about 1,700 yds. east of the Magugisi trigonometrical beacon. Outputs of beryl declared in 1958-9 amounted to 4.75 tons valued at £469 17s. 10d.

The *Akata Mine* is on Strathyre Farm, 2½ miles west-south-west of Miami Village. In 1954 it declared 0.4 tons of beryl valued at £328. (See also under mica.)

The *Amby Mine* is on Rockwood Farm, 7¾ miles south-by-east of Miami. This pegmatite working has apparently not been registered and the name has been given by the writer so as to be able to identify it. It has produced white beryl and about 1 ton of amblygonite. The latter was transported to Salisbury but not sold. The beryl has been sold under some other name.

The *Anniversary Mine* is on Crown land, 1,500 yds. east-by-north of the Grand Parade Mine. Beryl has been won from shallow open-cast workings on a pegmatite with a quartz core. In 1953 it declared 2.64 tons valued at £385 6s. 10d.

The *April Fool Mine* is reportedly on Crown land, three miles east of the Rkwesa Mine. This places it in the vicinity of the D.L. Mine which is described in the mica section. In 1952 it declared 0.15 tons of beryl valued at £16 5s. 9d.

The *Bad Luck Mine* is reportedly on Crown land, 1½ miles west of the KM Mine which is 4½ miles south-east of Miami Village. In 1953 it declared 1.41 tons of beryl valued at £208 2s. 10d.

The *Bakwa Holdings Mine* is reportedly on Crown land, 100 yds. east of The Mount Mine which is 7½ miles south-east of Miami Village. The mine produced in 1955-9, declaring a total of 30.77 tons of beryl valued at £3,298 9s. 11d.

The *Beesack Mine* is reportedly 1½ miles south of the Danny Boy which places it about three miles north-east of Miami Village. This description also places it in the vicinity of the Pumpkin Mine and it may well be a repegging of this property. In 1956 it declared 8.75 tons of beryl valued at £994 1s. 2d.

The *Beryl Mine* is on Crown land, 5¾ miles north-by-east of Miami Village. It produced in 1952-3 declaring 3.8 tons of beryl valued at £532.

The *Beryl Hill Mine* is reportedly on Crown land, 1½ miles north-west of the Mormond Hill Mine, which is 8¾ miles south-east of Miami Village. In 1952 it declared 2.74 tons of beryl valued at £265 5s.

The *Betty Ver Mine* is reportedly on Crown land in the Urungwe East Group, about five miles north-east of the Julia Mine, which would place it a little over a mile north-east of the Locust Mine. In 1955 it declared 0.21 tons of beryl valued at £23 18s. 4d. (See also under mica.)

The *B.F. Mine* is on Crown land,  $4\frac{1}{2}$  miles east-north-east of Miami Village. The pegmatite, which has a coarsely granulated quartz core, gives rise to a small hillock. The body strikes east and dips south. It has been worked opencast on both sides of the hillock. An adit put in on the south side did not reach the pegmatite. The mine was operated from 1953-4 and produced a total of 8.7 tons of beryl valued at £1,112 11s. 1d.

The *B.H. Mine* is reportedly 200 yds. east of the Mapoffa Mine which is  $5\frac{1}{4}$  miles north-east of Miami Village. It was operated from 1952-4 producing 3.94 tons of beryl valued at £521 10s. 4d.

The *Bicycle Mine* is on Crown land, eight miles east-by-north of Miami Village. Shallow open-cast workings occur along a south-striking pegmatite. Later some secondary uranium mineral was discovered on the waste dump and the pegmatite was repegged. This mineral formed a yellow coating on the triplite which often occurs with the beryl. In 1953 the mine declared 1.18 tons of beryl valued at £158 7s. 6d.

The *Birthday Gift Mine* is on Kachichi Farm,  $1\frac{1}{4}$  miles south-west of Miami Village. There are two pegmatites here about 150 to 200 yds. apart. The northern one which strikes north-west is an old mica working and the other has been scratched to a depth of a few feet for beryl. In 1953 it declared 1.56 tons of beryl valued at £243 13s. 3d. (See also under mica.)

The *Blue Nuns Mine* is reportedly on Chelvern Estate,  $1\frac{1}{4}$  miles north-north-east of the homestead. It produced in 1957-8 declaring 6.15 tons of beryl valued at £651 18s. 1d.

The *Blue Sky Mine* is reportedly in the Urungwe Native Reserve, three-quarters of a mile south-west of the confluence of the Mrerechi (Mlelechi) and Kalelegi (Karerechi) rivers. It is, therefore, presumably on the western edge of the map. In 1954 it declared 0.18 tons of beryl valued at £22 7s. 2d.

The *Bluff Mine* is on Crown land,  $7\frac{3}{4}$  miles north-west of Miami Village. In 1952 it declared 1.02 tons of beryl valued at £106 14s. 4d. (See also under mica.)

The *Blyvooruitsig Mine* is  $4\frac{1}{4}$  miles north-north-west of the Catkin Mine. It produced in 1953-54, declaring 6.23 tons of beryl valued at £853 5s. 4d. (See also under mica.)

The *Bold Mine* is six miles north-west of Miami Village.

This pegmatite has been worked or prospected for mica in the past, but it has been reworked for beryl in recent years. It is a large body striking at 28 degrees (magnetic) that has been worked open-cast along 75 ft. of strike to a depth of 12 ft. This mining has been done on the western slope of a ridge and is insignificant in comparison with the size of the pegmatite in which discontinuous quartz lenses in microcline constitute the core zone. On the margins of this core are narrow wall zones of plagioclase, microcline and quartz.

In 1953 the mine declared 8.32 tons of beryl valued at £1,196 18s..

The *Boodle Mine* is reportedly on Crown land, five miles east of Kapiri Hill which feature is  $5\frac{1}{4}$  miles east-by-north of Miami Village. It declared outputs in 1951-52 amounting to 2.73 tons fetching £780.

The *Boundary Mine* claims are on Garahanga Farm 1,100 yd. south-west of the eastern farm beacon. In 1957, 1.16 tons of beryl valued at £127 17s. 10d. was declared from the claims.

The *Buffalo Mine* is on Buffalo Downs Farm near the northernmost corner beacon. Production has been declared from three blocks of claims known as the Buffalo Nos 1, 2 and 3. The Buffalo 1 Mine is  $6\frac{1}{2}$  miles south-east of Karoi Township. This pegmatite strikes north-north-west and has been mined open-cast along the margins of the quartz core. Beryl has also been won from the rubble shed from the pegmatite. Outputs have been declared for 1956-57 amounting to 6.14 tons valued at £693 19s. 3d.

The *Buffoline Mine* is reportedly on Springbok Height's Farm, 1,700 yd. north-east of its north-west corner beacon. The farm borders the main north road eight miles south-east of Karoi. In 1957, 1.33 tons of beryl were sold for £153 10s. 8d.

The *Bufroi Mine* is on Buffalo Downs Farm, 400 yd. north-west of the homestead and seven miles south-east of Karoi Township.

There are three or more closely situated pegmatites here. A pegmatite in the African compound striking north-east and dipping south-east has been prospected on both sides of the quartz core over 300 ft. of strike. Large books of valueless muscovite occur on the core margins.

There is another pegmatite on the same strike as the first, with the same direction of dip, and 100 yd. south-west of it. It carries large books of soft, yellow mica, but none has been prepared for sale. The beryl extracted from this pegmatite occurred in many colours which included white, green, red, yellow, brown and blackish. The white beryl was much intergrown with quartz. In addition a crystal of tantalocolumbite weighing 130 lb. was also extracted. It assayed 5 per cent. of tin. Unfortunately the open workings were shallow and the ground too decomposed to ascertain the structure of the pegmatite when the property was visited.

Between the two pegmatites mentioned above is another, striking at 80 degrees (magnetic) and having a southerly dip. From it beryl and a little tantalocolumbite was extracted. Other beryl-bearing pegmatites, which had not been mined at the time of the visit, occur in the vicinity of the homestead.

In the period from 1954-58, 40.52 tons of beryl, valued at £4,672 13s. 1d. were extracted. (See also under tantalocolumbite.)

The *Bunion Mine* is reportedly in the vicinity of Chitani trigonometrical beacon on Grippos Farm. This beacon is about  $3\frac{1}{2}$  miles south-east of Karoi Township. In 1953 the mine declared 0.43 tons of beryl valued at £128 1s. 6d.

The *Butterfly Mine* is reportedly on Ruwanzí Ranch, half a mile south-west of the First Leg Mine which also does not appear on the map. It is presumably about 12 miles south-east of Miami Village. In 1954 it declared 1.18 tons of beryl valued at £128 1s. 6d.

The *Candy Mine* is in the Urungwe Reserve near the western edge of the south-western sector of the map and is  $5\frac{1}{4}$  miles a little south of west of Magunge.



The pegmatite can be traced for more than 300 ft. on a north-north-east strike and it attains a width of 50 ft. It is composed of coarse microcline with lenses and irregular masses of quartz. Concentrations of wedge-shaped, herring-bone muscovite occur in the felspar. The workings consist of a small amount of shallow trenching at the northern end.

In 1956 the mine declared 0.04 tons of beryl for which no value is given.

The *Capricorn Mine* is reportedly on Ruwanzi Ranch,  $1\frac{1}{2}$  miles south of the Nyahumwa Mine which is eight miles south-east of Miami Village. Outputs were declared in 1954-55 amounting to 22.1 tons of beryl valued at £2,618 17s. 4d.

The *Centenary Mine* locality is given as the Urungwe Reserve about  $5\frac{1}{2}$  miles north-east of Sengwe Hill. The locality of the hill, which has a local native name, is not known and the mine may consequently not be within the area of the map. It produced in 1954-58 declaring 9 tons of beryl valued at £1,370 9s. 11d.

The *Chamanza Mine* is reportedly four miles north of The Mount Mine which is  $7\frac{1}{2}$  miles east-south-east of Miami Village. In 1956 it declared 0.41 tons of beryl valued at £46 7s. 6d.

The *Changa Mine* is reportedly in the Urungwe East Group,  $2\frac{1}{2}$  miles north-north-west of the Locust Mine. In 1955 it declared 0.31 tons of beryl valued at £28 5s. 10d.

The *Chelvern Mine* is reportedly on Chelvern Estate,  $1\frac{1}{2}$  miles east of the homestead. In 1957 it declared 0.2 tons of beryl valued at £16 17s. 3d.

The *Chengetai Mine* is reportedly on Crown land in the Urungwe East Group, two miles north of the Rkwesa Mine which places it in the vicinity of the Mupo Mine shown on the map. In 1953 it declared 0.03 tons of beryl valued at £4 19s. 2d. (See also under mica.)

The *Chola Mine* is reportedly in the Urungwe Reserve, two miles south of the Karereshi Dip. The river of this name runs approximately parallel to and close to the western margin of the map in the south-west. However, the locality of the dip is not known as the reserve was a prohibited area for cattle at the time of this survey. The mine produced in 1957-59 declaring 5.17 tons of beryl valued at £551 2s. 4d.

The *Clan Mine* is on Ruwanzi Ranch,  $7\frac{1}{2}$  miles south-east of Miami Village. There are some shallow open-cast workings on a concordant pegmatite striking north-east. In 1953 it declared 2.83 tons valued at £406 16s. 3d.

The *Clancy Mine* is a little over half a mile north-west of the Clan Mine on the opposite (west) side of the Miami River. There is some shallow trenching on a pegmatite with the same trend as the Clan Mine.

The *Consul Mine* is reportedly on Ruwanzi Ranch, about 300 yd. east of the Mormond Hill Mine which is  $8\frac{1}{4}$  miles south-east of Miami Village. In 1954 it declared 0.18 tons of beryl valued at £23 18s. 6d.

The *Coronation Glen Mine* is reportedly about five miles north-east of the Julia Mine which would place it somewhere east of Chitvutsigo Hill and a mile or so in a northerly direction from the Rkwesa Mine. There is an old pegmatite working in this vicinity. In 1953 it declared 0.27 tons of beryl valued at £41 12s. 10d.

The *Count Mine* is possibly on Ruwanzi Ranch as its reported locality is two miles north-west of the homestead on Collingwood Farm. It should, therefore, be about 12½ miles south-west of Miami Village. In 1953 it declared 0.28 tons of beryl valued at £38 7s. 3d.

The *Cub Mine* is on Moyale Farm, three-quarters of a mile south of the northern corner beacon and 13 miles south-east of Miami Village. The writer discovered the beryl here in a virgin pegmatite and the later workings were not visited. It declared outputs in 1954-55 totalling 6.29 tons valued at £792 1s. 9d.

The *Danny Boy Mine* is on Crown land, 4½ miles north-east of Miami Village.

When visited, the mine consisted of a very shallow open-cast and some rubble workings. It would appear reasonably certain that the tonnage of beryl declared did not all come from the working shown on the map as the Danny Boy. Some of it has probably come from one or more of the small beryl workings between a mile and half a mile south of it.

Declared outputs in 1952-5 amounted to 12.34 tons valued at £1,694 19s. 2d.

The *Dan-y-Graig Mine* is reportedly six miles east of Kapfundi Hill, which places it about 5½ miles south-south-west of the Catkin Mine. In 1953 it declared 0.41 tons of beryl valued at £57 15s. 10d. (See also under mica.)

The *Daz Mine* is reportedly on Crown land, about eight miles north-west of Miami Village. It has a common claim beacon with that of one of the Pet Mine claims. The mine has produced in 1960-1, which is after the 1959 closing date of outputs for this bulletin so that its production figure is not given.

The *Denise Mine* is reportedly on Crown land, 2½ miles north-west of the Beckett Mine and may well be a repegging of the old Spahrep or Salitros mica mine claims. In 1953 it declared 0.33 tons of beryl valued at £50 0s. 3d.

The *Discovery Mine* is reportedly in the Urungwe Reserve north of the Candy Mine and 300 yds. south of the road to the Gil Gil and Nzoie mines. It produced in 1956-9, declaring 10.21 tons of beryl valued at £1,071 1s. 9d.

The *Double Top Mine* is reportedly on Crown land, a mile north of the Naodsa River and 1½ miles north-west of the Naodsa-Katsiga river confluence. The Katsiga tributary is not known and may not be within the area of the map. In 1957 it declared 1.7 tons of beryl valued at £180 12s. 0d.

The *Dungusha Mine* is four miles north-east of Miami Village. There is a shallow open-cast working along the quartz core of an east-striking pegmatite. Production in 1952-3 was declared at 16.32 tons valued at £1,964 8s. 1d. (See also under mica.)

The *Easter Gift Mine* is on Haslemere Farm, half a mile south-west of the Last Hope Mine. It produced beryl in 1953 and 1956, totalling 4.46 tons valued at £690 6s. 5d. (See also under mica.)

The *Elise Mine* is  $4\frac{1}{2}$  miles west-by-north of Miami Village on the north-eastern boundary of Pitlochry Farm. It produced beryl in 1951 and 1953, totalling 2.79 tons valued at £199 5s. 4d. (See also under mica.)

The *Fall Claims* are reportedly on Crown land, about  $2\frac{3}{4}$  miles south of the Kingsale Mine. There is no record of production.

*Falls Mine* (see *The Falls Mine*).

The *First Chance Mine* is reportedly on Ruwanzi Ranch, three miles south-west of the Shamwarrie Mine, which is  $7\frac{1}{4}$  miles south-east of Miami Village. In 1954 it declared 1.64 tons of beryl valued at £222 0s. 5d.

The *First Dig Mine* is reportedly  $1\frac{1}{2}$  miles north of The Mount Mine, which is  $7\frac{1}{2}$  miles east-south-east of Miami Village. It declared productions in 1953-4 amounting to 1.47 tons of beryl valued at £221 16s. 3d.

The *First Fortune Mine* is reportedly on Crown land in the Urungwe East Group, about six miles west of the Catkin Mine. It declared productions in 1953-4 totalling 1.87 tons of beryl valued at £214 6s.

The *First Leg Mine* is reportedly on Ruwanzi Ranch about half a mile north of the Grace's Luck Mine which also is not shown on the map. It is presumably about 12 miles south-east of Miami Village near the common beacon of the four farms Ruwanzi, Garahanga, Moyale and Collingwood. Many of the pegmatites in this vicinity are small and the declared output may well have come from a number of them. It declared outputs from 1954-8 amounting to 34.24 tons valued at £3,920 3s. 11d.

The *Floris Luck Mine* is on Ruwanzi Ranch, nine miles south-east of Miami Village (see Plate XVII). The pegmatite has been mined open-cast to a fair depth over a very short strike. The presence of water and waste completely obscured the pegmatite when the site was visited. It declared outputs from 1952-5 amounting to 21.17 tons valued at £2,627 0s. 9d.

The *Freddie's Mine* is on Ruwanzi Ranch,  $7\frac{1}{4}$  miles south-east of Miami Village. Here a small pegmatite striking north and dipping east has been mined open-cast to a shallow depth for a short distance. In 1954 it declared 2.05 tons valued at £246 17s.

The *G.G. Mine* is reportedly about three miles south-west of the Merry Dream Mine, which is on Ruwanzi Ranch, eight miles south-east of Miami Village. In 1953 it declared 0.25 tons of beryl valued at £31 18s. 1d.

The *Grace's Luck Mine* is reportedly on Ruwanzi Ranch, about  $1\frac{1}{2}$  miles south-east of the First Chance Mine. It would seem more likely to be on Moyale or Garahanga Farm. In 1954 it declared 7.99 tons of beryl valued at £1,000 12s. 6d.

The *Grand Parade Mine*, which is two miles north of Miami Village, is fully described in the mica section. The beryl declared came presumably from the Beryl Reef which is on the east side of the main working at the southern end (see Plate XVI). In 1954 it declared 0.68 tons of beryl valued at £81 14s. (See under mica.)



The *Grand Slam Beryl Mine* is near the south-east corner of Collingwood Farm, 15 miles south-east of Miami Village. This must not be confused with the Grand Slam Mica Mine, which is 10½ miles north-west of Miami.

Three concordant pegmatites have been mined open-cast to shallow depths. Two of these are about 100 yds. apart and some 700 yds. east of the homestead. The third is about 500 yds. south of the others and 1,000 yds. south-east of the homestead.

Two of these are the "normal" type of beryl-bearing pegmatites with strong quartz cores and wide microcline-rich core margin zones. The northernmost pegmatite differs from the others in both structure and composition. Scientific interest in the pegmatite was aroused following the discovery and identification of about 2½ lb. of the beryllium phosphate hurlbutite. Later, a little herderite was also identified. The pegmatite strikes north-west and south-east with, in the open working, the north-east contact almost vertical and the opposite wall dipping north-east at 71 degrees. At the north-west end of the pegmatite there is about 60 ft. of open-cast work. Where benched at the south-east face, a good cross-section of the pegmatite is exposed and this is reproduced somewhat diagrammatically in Fig. 19.

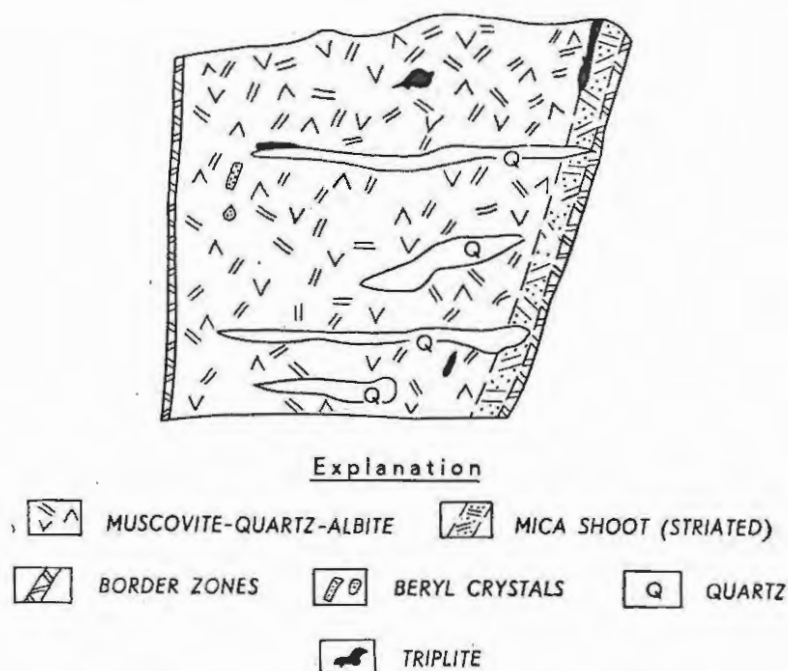


Fig.19 Diagrammatic cross-section of the Grand Slam pegmatite, looking south-east

The body is about 15 ft. wide at the surface. The muscovite in the mica shoot is highly striated and the zone is about 14 in. wide. The main mass of the pegmatite is composed predominantly of albite feldspar, near oligoclase in composition. Quartz and small muscovite are present and, but for the mica shoot zone, the pegmatite structure is of the simple type. The beryl occurs in this matrix. Irregular masses of triplite are present as apparent replacements of the feldspar. Horizontal and somewhat parallel quartz lenses occur as shown in the figure. Tourmaline is present in the wall rock on the margins of the pegmatite. Unfortunately, no hurlbutite was identified *in situ*.

In many respects this pegmatite is anomalous and appears to be an exception to the rules established elsewhere on the Field.

Beryl was declared from these claims from 1951-5 and totalled 29.82 tons valued at £3,547 12s. 7d.

The *Gumbura Mine* is reportedly in the Urungwe Reserve, four miles south-east of the confluence of the Mlelechi (Mrerechi) and Maombe rivers which would place it a mile or so west of Magunge. In 1954 it declared 0.08 tons of beryl valued at £10 1s. 4d.

The *H.B. Mine* is on Crown land, five miles north-east of Miami Village. There are shallow open-cast workings on a north-west-striking pegmatite. It produced in 1952-53, declaring 7.22 tons of beryl valued at £1,026 10s. 9d. (See also under mica.)

The *Half Way Mine* is apparently one of a group of unnamed pegmatite workings shown on the map,  $2\frac{1}{2}$  miles south-west of Miami Village. It produced in 1952-53, declaring 7.32 tons of beryl valued at £821 0s. 7d.

The *Haka Mine* is reportedly on Collingwood Farm, about a mile west of the Grand Slam Mine. It produced in 1954-56, declaring a total of 7.81 tons of beryl valued at £908 13s. 11d.

The *Hank's Hope Mine* is shown on the map as on Crown land,  $9\frac{1}{4}$  miles north-east of Miami Village. This pegmatite has been worked open-cast for beryl, but there is no record of a mine registered under this name.

The *Happy Valley Mine* is six miles north by east of Miami Village. In 1956 it declared 1.41 tons of beryl valued at £166 18s. 7d.

The *Hash Knife Mine* is on San Michele Farm on the south bank of the Miami River,  $7\frac{3}{4}$  miles south of Miami Village. Here there are shallow workings in rubble shed from a very small pegmatite occurring between outcrops of gneiss. In 1953 it declared 1.47 tons of beryl valued at £204 17s.

The *Hendren Mine* claims occupy a large area situated some eight miles north-west of Miami Village. The numerous pegmatites which have been mined on these claims have been fairly fully described in the mica section. In 1953-54, outputs of beryl amounted to 9.53 tons valued at £990 10s. 8d. (See also under mica.)

The *Honey Beryl Claims* are on Garahanga Farm east of the Honey wolfram Claims and 1.4 miles west-by-south of the eastern farm boundary (see Plate XVII). In 1953-54, 3.28 tons of beryl was sold for £433 10s. 10d.

The *Hope Kachiya Mine* is reportedly on Crown land, about  $1\frac{1}{2}$  miles east-north-east of the Kachiya Mine which is on Crown land,  $6\frac{1}{4}$  miles south-east of Miami Village. It declared outputs from 1955-57 amounting to 6.32 tons of beryl valued at £699 18s. 5d.

The *Idle Joe Mine* is on Zebra Downs Farm,  $13\frac{1}{2}$  miles south-south-east of Miami Village (see Plate XVII). Here a small pegmatite with a quartz core outcrops in a vlei where it has been mined open-cast to a shallow depth. In 1953 it declared 0.91 tons of beryl valued at £98 10s. 4d.

The *Inver Mine* is on Moniack Farm, nine miles south-by-east of Miami Village. A concordant north-striking pegmatite which dips east at 50 degrees is traceable for more than 300 ft. and is about 8 ft. wide. It has been trenched into rising ground at the northern end of the strike. Here it appears that it was intended to drive an adit which was prohibited by dangerous ground. The pegmatite face was obscured by rock-fall. In 1954 it declared 2.4 tons of beryl valued at £300 3s. 10d.

The *Isabel Mine* is  $11\frac{1}{2}$  miles a little east of north of Miami Village. It declared outputs in 1953-54 totalling 0.42 tons of beryl valued at £36 19s. 5d. (See also under mica.)

The *Jan Mine* is  $6\frac{1}{2}$  miles north-west of Miami Village. It declared outputs of beryl from 1953-56 totalling 5.67 tons valued at £814 0s. 10d. (See also under mica.)

The *Jill Mine* is reportedly on Crown land adjacent to the Dan-Y-Graig Mine on the west. It declared outputs in 1953-54 amounting to 5.05 tons of beryl valued at £743 12s. 2d. (See also under mica.)

The *Jinga Mine* is reportedly two miles west of the Centenary Mine and it is not certain whether it is in the map area. In 1954 it declared 0.21 tons of beryl valued at £21 18s. 9d.

The *Jo Mine* is on Crown land, four miles east of Miami Village. The pegmatite which strikes north-east and dips north-west has been mined open-cast to a shallow depth. In 1953 it declared 4.49 tons of beryl valued at £685 10s. 9d. (See also under mica.)

The *Kachiya Mine* is on Crown land,  $6\frac{1}{4}$  miles south-east of Miami Village. It declared outputs of beryl in 1954-55 amounting to 4.49 tons valued at £329 10s. 3d.

The *Kamonde Mine* is in the Urungwe Reserve, a little over five miles north-west of Magunge and  $2\frac{1}{4}$  miles from the western edge of the map in the south-western sector. In 1956 it declared 0.38 tons of beryl valued at £38 6s.

The *Karere Mine* is reportedly seven miles south-east of Manyangau Kopje. The probable locality is more fully given in the mica section. In 1953 it declared 3.13 tons of beryl valued at £477 15s. 2d. (See also under mica.)

The *Khan Mine* is shown on the map as  $7\frac{1}{2}$  miles east-north-east of Miami Village. A west-striking pegmatite with a quartz core has been mined open-cast for a short distance and to a shallow depth. It declared outputs in 1952-53 amounting to 12.06 tons and valued at £1,856 8s. 4d.



The *K.M. Mine* is on Crown land,  $4\frac{1}{2}$  miles south-east of Miami Village. A small concordant pegmatite striking east-north-east occurs on the north side of a vlei. Beryl has been won from rubble shed from the pegmatite, and from a very shallow depth along the surface of the pegmatite. In 1954 it declared 1.43 tons of beryl valued at £244 16s. 10d.

The *Korner Mine* is reportedly on Ruwanzi Ranch,  $1\frac{1}{2}$  miles south of the northernmost beacon and half a mile east of the Miami River. In 1954 it declared 1.27 tons of beryl valued at £157 5s. 8d.

The *Kramac Mine* is reportedly six miles south-east of Miami Village. In 1953 it declared 4.54 tons of beryl valued at £803 3s.

The *Last Hope Mine* is on Haslemere Farm, 4.8 miles south-west of Miami Village. It is not known whether the small amount of beryl declared came from the main mica-bearing pegmatite or from some other pegmatite on the claims. In 1953 it declared 0.44 tons of beryl valued at £69 8s. 1d. (See also under mica.)

The *Leaf Mine* is on Crown land,  $6\frac{1}{2}$  miles north-north-east of Miami Village. In 1952 it declared 2 tons of beryl valued at £280.

The *Len's Luck Mine* is presumably in the Urungwe Reserve near the Guinea Fowl Mine, which is a little over a mile from the western edge of the map and  $4\frac{3}{4}$  miles west-north-west of Magunge. It declared outputs of beryl in 1953-54 totalling 1.82 tons valued at £243 19s.

The *Lillington Mine* is on Mafalo Farm,  $15\frac{3}{4}$  miles south-east of Miami Village. The pegmatite is a discordant body striking at 342 degrees (magnetic) with the foliation of the schist but dipping across it in an easterly direction at an angle of 65 degrees. The pegmatite has a simple structure and is composed of albite, near oligoclase in composition, with some quartz and small mica. It has been mined open-cast for 123 ft. to a depth of 18 ft. Here the body is 12 ft. wide and persists in both faces. A fair amount of triplite has been extracted, but no tourmaline.

The mine's declared outputs of beryl in 1953-54 amounting to 5.82 tons valued at £795 12s. 3d. (See also under tantalum-colmbite.)

The *Lion Hill Beryl Mine* is on Crown land, eight miles north-north-west of Miami Village.

Beryl was known to exist on these claims as far back as 1930 before the mineral was sought after as an ore of beryllium.

The prime beryl producer here is a large pegmatite, striking approximately east and west and dipping steeply to the north. It is zoned, with a strong quartz core, an inner intermediate zone of perthite in which are large wedge-shaped, herring-bone muscovite crystals towards the core margin. The wall zones are of albite and quartz. Beryl occurs in the perthite and quartz of the core.

The hanging-wall of the pegmatite has been stripped along 160 ft. of strike and 60 ft. of core have been removed from the western end of the open working. A short adit has been driven along the foot-wall of the core where there are several large beryl crystals to be seen *in situ* as well as the partial casts of those that have been removed. Some of

these attained 4 ft. in length and 8 in. in diameter. There is clearly much beryl still to be had here, but the present price of beryl does not permit hard rock mining.

In 1954 the mine declared 5.5 tons of beryl valued at £602 10s. (See also under mica.)

The *Loloma Mine* is reportedly in the Urungwe Reserve, about three-quarters of mile north of the junction of the Maombe and Mlelechi (Mrerechi) rivers, which places it about six miles north-west of Magunge. It declared productions of beryl in 1954-5 amounting to 6.89 tons valued at £933 6s.

The *Lucky Gift Mine* is reportedly on Crown land in the Urungwe East Group, five miles north-east of the Julia Mine, which is a mile outside the western margin of the map and about five miles south-west of the Rkwesa Mine. This should place the mine a mile or so north of the Rkwesa Mine. It declared outputs of beryl in 1952-3 amounting to 7.32 tons valued at £971 9s. 3d.

The *Lyre Prospect* is on Crown land, 5½ miles north-west of Miami Village. Two pegmatites about 200 yds. apart have been prospected for beryl. If any of the mineral has been found it has been declared under some other name.

The *Mafalo Mine* is on Mafalo Farm, a mile south of the Grand Slam Mine and 15 miles south-east of Miami Village. Here there are some shallow open-cast workings on a north-west-striking pegmatite. It declared beryl outputs from 1953-5 amounting to 2.47 tons valued at £369 5s. 6d.

The *Mahoa or Mahowa Mine* is reportedly on Crown land, three-quarters of a mile south-east of Kirrie 4350 B.M. Claims and declared outputs of beryl from 1953-5 amounting to 18.19 tons valued at £2,339 11s. 7d.

The *Manza Mine* is on Crown land, 8½ miles a little north of east of Miami Village. Productions for the years 1953, 1955 and 1956 have come from more than one pegmatite. These total 4.37 tons valued at £555 9s. 4d. (See also under mica.)

The *Mapoffa Mine* is on Crown land, 5¼ miles north-east of Miami Village. In 1957 it declared 0.06 tons of beryl valued at £5 13s. (See also under mica.)

The *Masakira Mine* is reportedly on Crown land, seven miles south-east of the Julia Mine, and is therefore presumably south of the Poll and Parrott mines. In 1954 it declared 0.05 tons of beryl valued at £5 7s. 4d. (See also under mica.)

The *Matches Mine* is 1½ miles south-west of Miami Village. A shallow open-cast working on a narrow pegmatite striking north-by-west yielded 0.59 tons of beryl in 1954 valued at £83 9s. 2d.

The *Maxin (6693 B.M.) Mine* is on Crown land, four miles east-north-east of Miami Village. It declared outputs of beryl in 1953-4 amounting to 6.9 tons valued at £996 14s. 7d. (See also under mica and tungsten.)

The *May Flower Mine* is reportedly on Ruwanzi Ranch, a mile south-south-west of the First Leg Mine and half a mile north of the Butterfly Mine, neither of which appear on the map. It declared outputs of beryl from 1955-7 amounting to 32.36 tons valued at £3,637 13s. 3d.

The *Medicine Hat Mine* is reportedly on Ruwanzi Ranch, a mile north-east of the Capricorn Mine. This places it about nine miles south-east of Miami Village. In 1955 it declared 0.43 tons of beryl valued at £52 14s. 8d.

The *Merry Dream Mine* is on Ruwanzi Ranch, eight miles south-east of Miami Village. In 1954 it declared 2.11 tons of beryl valued at £277 13s. 7d.

The *Mica View Mine* is on Crown land in the Urungwe East Group, 5½ miles north-west of the Catkin Mine. It produced beryl from 1952-4 and in 1958 amounting to 68.58 tons valued at £9,627 3s. 3d. (See also under mica.)

The *Micron Mastadon Mine* is on Crown land, 1½ miles south-east of Miami Village. Its beryl output during the period 1954-6 amounted to 0.24 tons valued at £26 0s. 7d. (See also under mica.)

The *Midge Mine* is reportedly on Ruwanzi Ranch, half a mile north-east of the First Leg Mine. In 1956 it declared 0.85 tons of beryl valued at £93 3s. 3d.

The *Mount Pleasant Mine* is on Crown land, seven miles east-south-east of Miami Village. In 1953 it declared eight tons of beryl valued at £1,080.

*Mount Mine* (see *The Mount Mine*.)

The *Muami Mine* is reportedly about a mile east of The Mount Mine and quarter of a mile north of the Miami River. In 1956 it declared 1.37 tons of beryl valued at £159 2s. 8d.

The *Ndola Mine* is on Cheti Farm, a little over four miles north-west of Miami Village. A microcline-rich pegmatite with a quartz core strikes at 80 degrees (magnetic). It has been mined open-cast over 30 ft. of strike and partly refilled. Large herring-bone, wedge-shaped muscovite, tourmaline and triplite occur in the pegmatite. In 1953 it declared 1.2 tons of beryl valued at £199 13s. 4d.

The *Ness Mine* is on Moniac Farm, 10 miles south-south-east of Miami Village (see Plate XVII). A comparatively small pegmatite has been mined over a short strike to a depth of a little over 40 ft. The quartz core which outcrops at the surface disappears at the bottom of the working. The total outputs for 1953-4 amount to 18.57 tons of beryl valued at £2,467 18s. 7d.

The *Nightmare Mine* is reportedly on Ruwanzi Ranch, two miles north-east of the First Leg Mine. In 1958 it declared 1.32 tons of beryl valued at £126 9s.

The *Nishat Mine* is on Cheti Farm, half a mile north-north-west of the Ndola Mine and 4½ miles north-west of Miami Village.

A discordant pegmatite with an approximate east to west strike of over 300 ft. and a northerly dip, has been mined open-cast over 50 ft. of strike at the western end. The pegmatite is composed predominantly



of microcline with irregular quartz masses. Near the eastern end of the open working is a core zone with pod-like concentration of muscovite 10 ft. long. Plagioclase forms an intermediate zone on the exposed hanging-wall side of the body and there is a weak hanging-wall mica zone. Zoning of the pegmatite, as a whole, is ill-defined and discontinuous. The pegmatite has also been prospected about 100 ft. east of the main open working.

The mine produced beryl in 1954, and 1958-9, totalling 12.1 tons valued at £1,622 5s. 5d.

The *Nyahumwa Mine* is on Ruwanzi Ranch, eight miles south-east of Miami Village. Two pegmatites, 200 yds. apart, have been mined open-cast to a shallow depth. It declared beryl outputs in 1953-4 amounting to 9.61 tons valued at £1,430 4s. 9d.

The *Nyangoma Mine* is on Nyangoma Farm, about 600 yds. north-west of the homestead and 16 miles south-east of Miami Village. In 1953 it declared 0.52 tons of beryl valued at £65 5s.

The *Nyelele Mine* is reportedly on Ruwanzi Ranch, about half a mile south-east of the Last Chance Mine. In 1954 it declared 0.62 tons of beryl valued at £83 15s. 4d.

The *O.K.O. Mine* is on Crown land in the Urungwe East Group, 1½ miles west-by-south of the Locust Mine. It declared outputs of beryl in 1952-3 amounting to 6.5 tons valued at £810 19s. 1d. (See also under mica.)

The *Old Mine* is on Crown land, 11½ miles north-north-west of Miami Village, and is situated in a steep-sided, deep gully overlooking the Mkwicbe Gorge. Here a south-striking, microcline-rich pegmatite, over 50 ft. wide, has been mined open-cast to a shallow depth. Irregular masses of quartz occur in the felspar and there is some herring-bone mica and tourmaline. It declared outputs of beryl in 1953-4 totalling 10.37 tons valued at £1,621 16s. 5d.

The *Othello Mine* is on Crown land, 9¼ miles east-north-east of Miami Village. In 1954 it declared 6.62 tons of beryl valued at £900 14s. 11d. (See also under mica.)

The *Owl Mine* is nine miles north-west of Miami Village on Crown land. Beryl outputs were declared in 1952-53 totalling 29.05 tons valued at £2,800 6s. 7d. (See also under mica.)

The *Palladium Mine* is reportedly adjacent to the Half Way Mine, 2¾ miles south-west of Miami Village. A number of shallow pegmatite workings are shown on the map in this locality. In 1953 it declared 1.45 tons of beryl valued at £224 0s. 4d.

The *Pearl Mine* is on Crown land, six miles north-north-west of Miami Village. It produced beryl from 1951-53 totalling 43.63 tons valued at £4,987 10s. (See also under mica.)

The *Pet Mine* is 8½ miles north-north-west of Miami Village. In 1952 it declared 0.46 tons of beryl valued at £49 16s. 8d. (See also under mica.)

The *Phoenix Mine* is situated at between two and three miles south of Miami Village. In 1959, 0.07 tons of beryl was sold for £6 13s. 7d. (See under mica.)

The *Pick Mine* is reportedly on Crown land five miles north-east of the Beckett Mine. In 1954 it declared 0.15 tons of beryl valued at £17 13s. 4d.

The *Piper Mine* is on Cheti Farm, 5½ miles north-west of Miami Village. Beryl outputs from 1953-55 amount to 2.12 tons valued at £288 0s. 5d. (See under mica.)

The *Pippin Mine* is reportedly on Crown land in the Urungwe East Group, about 600 yd. north-east of the Catkin Mine. In 1953 it declared 0.13 tons of beryl valued at £19 14s. 2d. (See also under mica.)

The *Pumpkin Mine* is on Crown land, 3½ miles east-north-east of Miami Village. There are relatively small open-cast workings on two closely spaced pegmatites. Beryl outputs have been declared for 1950-51 and 1953, totalling 64.34 tons valued at £4,261 6s. (See *Beesuck Beryl Mine*.)

The *Queen Anne Mine* is on Buffroi Farm, 8½ miles south-east of Karoi Township.

The main beryl-bearing pegmatite is a concordant, zoned body with a proved strike of more than 350 ft. trending north-east and dipping steeply to the south-west. Its full width was not exposed but appears to be of the order of 20 ft. It has a strongly developed quartz core and pockets of beryl were mined open-cast, mainly from along its margins. The pegmatite is very coarse and large crystals of felspars, beryl, tourmaline and mica were extracted. The mica is green and very striated. The beryl crystals varied considerably in size, the largest single crystal weighing 807 lb.

A discordant pegmatite outcrops 50 yd. west of the workings and is traceable for a considerable distance. Some beryl has reportedly been found in rubble shed from this dyke. Another pegmatite strikes across the line of the workings some 75 yd. to the north.

The mine produced beryl from 1953-55 amounting to 21.71 tons valued at £2,781 5s. 4d.

The *Raindrop Mine* is reportedly on Ruwanzi Ranch, a quarter of a mile east of the Grace's Luck Mine. It declared outputs of beryl from 1955-58 amounting to 30.79 tons valued at £3,393 19s. 7d.

The *Ramsgate Mine* is reportedly three-quarters of a mile north of the Denise Mine which is described as 2½ miles north-west of the Beckett Mine. In 1954 it declared 0.33 tons of beryl valued at £43 19s. 5d.

The *Red Star Mine* is on Crown land, seven miles north-north-east of Miami Village. The many pegmatites here are described in the mica section. Outputs of beryl for 1952-53 amount to 0.59 tons valued at £72 9s. 2d. (See also under mica.)

The *Renda Mine* is on Crown land, 11 miles north-by-west of Miami Village. The main pegmatite, which strikes north-west, gives rise to a prominent ridge overlooking a steep valley. There is a series of shallow pits along the strike of the body but much of the beryl has come, reportedly, from rubble shed from the pegmatite. Chrysoberyl occurs in small veins along the margins of the quartz core. Another pegmatite, parallel to the first, has a large quartz core and gives rise to a prominent small kopje about 100 yd. to the north. A little beryl has come from the north side of the core. The small amount of work done here from 1952-54 has produced 14.83 tons of beryl valued at £1,917 8s. 10d.

The *Rita Mine* is on Crown land, 8½ miles north-east of Miami Village. It produced beryl from 1953-55 totalling 11.38 tons valued at £1,568 4s. (See also under mica and tantalocolumbite.)

The *Rkwesa Mine* is on Crown land in the Urungwe East Group, 6½ miles north-west of the Catkin Mine. It declared beryl outputs during the years 1953-54 and 1957 totalling 2.14 tons valued at £289 2s. 7d. (See also under mica.)

The *Roko Mine* is reportedly on Demavend Farm, about 100 yd. south of the Tricolour 2 Mine. In 1954 it declared 1.15 tons of beryl valued at £156 6s. 9d.

The *Rubislaw Mine* is reportedly on Zebra Downs Farm, 1,200 yd. south-east of the homestead and must, therefore, be very near the Idle Joe Mine. In 1954 it declared 0.24 tons of beryl valued at £27 18s. 10d.

The *Rugby Mine* is reportedly on Crown land in the Urungwe East Group, six miles north-east of the Catkin Mine. In 1953 it declared 0.35 tons of beryl valued at £43 11s. 9d. (See under mica.)

The *Ruwanzi Mine* is reportedly on Ruwanzi Ranch, about two miles south of The Mount Mine and 150 yd. east of the old telephone road. In 1958 it declared 0.4 tons of beryl valued at £37 17s.

The *Sable Ridge Mine* is reportedly on Sable Ridge Farm with its C claim beacon 1,500 ft. east of the north-west farm beacon. In 1957 it declared 0.57 tons of beryl valued at £59 3s. 3d.

The *Samson Mine* is on Demavend Farm, 6¾ miles south-south-west of Miami Village. A zoned pegmatite with a 3 ft. wide quartz core, at surface, can be traced 460 ft. on an east to west strike. It dips north at 70 degrees. At a depth of 8 ft. the core has narrowed to 12 in. Coarse microcline occurs marginally and carries, in places, abundant herring-bone mica. There is an outer intermediate plagioclase-rich zone and on the hanging-wall are some fairly large books of very broken muscovite. Beryl, which came from a very small pocket at the eastern end of the strike in 1955, amounted to 0.81 tons valued at £94 17s.

The *Scorpio Mine* is on Ruwanzi Ranch, 8¾ miles south-east of Miami Village. Here, there is some shallow trenching on a concordant pegmatite striking north-north-west. It declared beryl outputs in 1952-53 amounting to 9.03 tons valued at £1,146 0s. 4d.

The *Serfes Mine* is reportedly 500 yd. north-west of the Freddie's Mine which latter is on Ruwanzi Ranch on the south bank of the Miami River, 7¼ miles south-east of Miami Village. In 1954 it declared 0.18 tons of beryl valued at £19 11s. 1d.



The *Shamwarrie Mine* is on Ruwanzi Ranch,  $7\frac{1}{2}$  miles south-east of Miami Village. Here, a decomposed pegmatite striking at 41 degrees and dipping south-east has been trenched for 135 ft. to a depth of about 10 ft. Much striated mica appears on the waste dump. It produced beryl from 1952-54, declaring a total of 8 tons valued at £1,082 13s. 11d.

The *Shato Mine* is reportedly on Crown land, eight miles north-west of the Lizzie Mine, which is stated to be on Sipofeneni Farm, two miles north-west of the Grand Slam Mine on Collingwood Farm. It produced beryl from 1953-55 amounting to 11.21 tons valued at £1,600 1s. 10d.

The *Simba Mine* is on Eureka Farm  $3\frac{1}{2}$  miles south-south-west of Miami Village. Beryl outputs declared in 1952 and 1954 amount to 0.84 tons valued at £105 13s. 4d. (See also under mica.)

The *Sorotie Mine* is on Kachichi Farm,  $3\frac{1}{2}$  miles south-west of Miami Village. In 1953 it declared 0.8 tons of beryl valued at £124 2s. 1d. (See also under mica.)

The *Southern Fancy Mine* is reportedly on Nyaramanda Farm with the D claim beacon 400 yd. north-east of the south-west farm beacon. In 1956 it declared 7.57 tons of beryl valued at £851 10s. 3d.

The *Southern Star Mine* is reportedly on Crown land, about four miles north of Kapiri Hill and a mile west of the Mpofu River. It is possibly one of the workings shown on the map under a mile south of the Yvette Mine, which is  $8\frac{1}{2}$  miles north-east of Miami Village. In 1956 it declared 3.31 tons of beryl valued at £373 1s. 10d.

The *Spencer Mine* is reportedly on Ruwanzi Ranch, about three-quarters of a mile north of Honey 6125 B.M. Claims on Garahanga Farm. In 1954 it declared 2.25 tons of beryl valued at £313.

The *Star Turn Mine* is in the Urungwe Reserve,  $3\frac{1}{4}$  miles west of the Clinic near Magunge.

The workings are mainly in rubble derived from two *en echelon* pegmatites striking north-east. The smaller of the two has been prospected for 200 ft. along the margins of a strong quartz core where there is much microcline and herring-bone mica.

The other pegmatite is structurally similar to the first and has been mined along 270 ft. of strike. The rubble has not been cleared from the outcrop and appears to have been shifted back and forth in search of loose beryl crystals. For this reason work came to a standstill before the real pegmatite was encountered.

Beryl outputs for 1956-7 total 5.23 tons valued at £591 17s. 2d. (See also under tantalum-columbite.)

The *Sunday Mine* is reportedly on Ruwanzi Ranch, a quarter of a mile north of the Floris Luck Mine. From 1955-7 it declared 4.46 tons of beryl valued at £429 4s. 9d.

The *Supplement Mine* is reportedly on Mwala Farm, 1,500 yds. south-east of the homestead and south of the road from Karoi to Doma. It declared outputs in 1952-3 amounting to 0.52 tons valued at £69 19s. 3d.

The *Sylvia Claims* are on Eureka Farm,  $4\frac{1}{2}$  miles south of Miami Village. They were a repegging, for beryl, of old mica workings east of

the Wild Pig Mica Mine. One of the pegmatites here carries a little amblygonite. No production of beryl has been declared under this name.

The *Tak Mine* is on Crown land, nine miles north-east of Miami Village. It declared outputs of beryl in 1954-5 amounting to 4.57 tons valued at £474 17s. 4d. (See under mica.)

The *Terwin Mine* is on Crown land, six miles north-west of Miami Village. In 1954 it declared 1 ton of beryl valued at £115. (See also under mica.)

The *Thames Valley Mine* is on Kiplingcotes Farm, 11 miles south-south-east of Miami Village (see Plate XVII). A narrow pegmatite striking north-west has been trenched for a short distance to a shallow depth. It declared outputs of beryl in 1953-4 amounting to 3.39 tons valued at £487 3s. 11d.

The *The Falls Mine* is on Crown land, 3½ miles south-east of Miami Village. Two parallel pegmatites and a third *en echelon* to the north-east have been mined for beryl, but the production up to and including 1959 has not been declared under this name. It has been repegged and there are later productions for 1960 and 1961.

The *The Mount Mine* is on Crown land, 7½ miles south-east of Miami Village. The pegmatite gives rise to a small hill where quite extensive open-cast work has been undertaken. The rubble, too, has been well worked. Outputs of beryl from 1955-9 amount to 25.85 tons valued at £2,678 7s. 5d.

The *Three Castles Mine* is reportedly three miles south-east of the Tricolour Mine, which should place it on San Michele Farm near the Hash Knife Beryl Mine. In 1953 it declared 0.86 tons of beryl valued at £139 6s. 10d.

The *Tom Tit Mine* is on Crown land, 4½ miles north-east of Miami Village. It declared outputs of beryl in 1954-5 amounting to 3.7 tons valued at £447 9s. 3d. (See also under mica.)

The *Tom Tom Mine* is on Maunga Farm, 5¼ miles south-by-west of Miami Village. Beryl was produced in 1950-2 totalling 2.29 tons valued at £211 8s. 5d. (See also under mica.)

The *Top Hat Mine* is on Eureka Farm, 3¼ miles south-by-west of Miami Village. Beryl was produced in 1952-3 totalling 5.72 tons valued at £851 18s. 2d. (See also under mica.)

The *Trezona Mine* is 3½ miles north of Miami Village. In 1950 it declared 1.25 tons of beryl valued at £84. (See also under mica.)

The *Tricolour Mine* claims are partly on Rockwood and partly on Demavend farms, about six miles south-by-west of Miami Village.

The Tricolour I workings are on Rockwood Farm where, in a small area, at least five pegmatites have been worked or prospected. Some of the pegmatites were clearly old mica workings of unknown name. Many of these pegmatites are zoned, with quartz cores and microcline-rich margins, and it is these which have yielded beryl from the cores. The margins of some of these pegmatites were not exposed and the mica seen was of the usual striated and interleaved type.

The Tricolour II Claims are on Demavend Farm. The main working is on a wide pegmatite striking north-west and dipping south-west. It can be traced on the surface for over 700 ft., but the disconnected open workings only extend over 300 ft. of strike. The pegmatite is zoned and only the core area and near margins have been mined, to a maximum depth of 14 ft. at one point. There are a few other zoned, beryl-bearing pegmatites in close vicinity. These were also at one time prospected for mica but the mica is very broken and striated.

In 1952-3 the claims yielded 12.11 tons of beryl valued at £1,632.

The *True Blue Mine* is reportedly on Ruwanzi Ranch bordering the Grace's Luck Claims on the west. In 1955 it declared 3.31 tons of beryl valued at £372 5s. 3d.

The *Trying Mine* is reportedly on Rockwood Farm, the homestead on which is  $5\frac{1}{2}$  miles a little west of south of Miami Village. From 1953-9 declared outputs of beryl totalled 11.74 tons valued at £1,344 17s. 7d.

The *Turning Point Mine* claims are on Kachichi Farm, two miles south-west of Miami Village. In 1953, 0.47 tons of beryl was declared from block 4607 B.M. This was valued at £67 14s. 9d. (See also under mica.)

The *Unique Mine* is reportedly three miles north of Magugisi Hill and the trigonometrical beacon, which is eight miles south-by-east of Miami Village. In 1952 it declared 0.19 tons of beryl valued at £21 0s. 4d.

The *Uphill Mine* is reportedly on Crown land, two miles north-north-west of the Zamona (The Egg) Mica Mine. In 1958 it declared 2.02 tons of beryl valued at £261 4s. 9d.

The *V. 8 Mine* is on Crown land in the Urungwe East Group, seven miles north-west of the Catkin Mine. The 1952-3 productions of beryl total 6.23 tons valued at £744 2s. 3d. (See also under mica.)

The *V.G. Mine* is reportedly in the Urungwe Reserve, about 1,000 yds. north of the confluence of the Mrerechi (Mlelechi) and Maombe rivers. In 1959, 1.06 tons of beryl was sold for £97 0s. 4d.

The *Vernal Mine* is reportedly two miles east of the Kingsale Mine. In 1953 it declared 0.19 tons of beryl valued at £20 13s. 10d.

The *Widow's Cruise Mine* is reportedly 120 yds. west of the Tom Tom Mine, which is on Maunga Farm,  $5\frac{1}{4}$  miles south-south-west of Miami Village. In 1956 it declared 0.96 tons of beryl valued at £101 12s. 10d.

The *Wild Cat Mine* is on Rockwood Farm, seven miles south of Miami Village. Two narrow *en echelon* pegmatites striking north-west have been trenched discontinuously to a shallow depth. One of these revealed a fair quantity of striated mica. Beryl produced in 1953-4 and 1956 totalled 5.65 tons valued at £757 11s. 11d.

The *Wild Oats Mine* is on San Michele Farm,  $8\frac{1}{4}$  miles south of Miami Village. A pegmatite with a quartz core and striking at 340 degrees (magnetic) has been mined opencast for 45 ft. along the strike and refilled. It has declared productions of beryl from 1953-6, totalling 24.17 tons valued at £1,732 18s. 2d.



The *Wild Pig Mine* is on Eureka Farm,  $4\frac{1}{2}$  miles south of Miami Village. Its production of beryl from 1952-4 totals 3.65 tons valued at £491 17s. 8d. (See also under mica.)

The *Winter's Whopper Mine* is on Crown land,  $7\frac{1}{2}$  miles north-west of Miami Village. Beryl was produced from 1951-4 and 1957-8 totalling 61.45 tons valued at £6,446 1s. 11d. (See also under mica.)

The *Xmas Gift Mine* is reportedly on Crown land, about six miles north-east of the Majestic Mine. It produced beryl in 1957-8 totalling 36.97 tons valued at £4,554 10s. 7d.

The *Yen's Luck Mine* is reportedly on Crown land, about one mile south-east of the Zamona Mine. In 1952 it declared 5.43 tons of beryl valued at £645 11s. 5d. (See also under mica.)

The *Yvette Mine* is on Crown land,  $8\frac{1}{2}$  miles north-east of Miami Village. The pegmatite, which has been scratched in a small way for beryl, is a continuation of one of the Rita pegmatites. No production is given under this name.

The *Zaranyika Mine* is reportedly on Crown land, one mile south-east of the Major Mine which is  $6\frac{1}{4}$  miles north-west of Miami Village. Beryl was produced in 1954-5 totalling 1.71 tons valued at £188 16s. 1d.

## WOLFRAM MINING

The main production of wolfram from the Urungwe district has come from an arcuate belt of country about nine miles long with its middle part pegged as the Honey Claims on Garahanga Farm about  $11\frac{1}{2}$  miles south-east of Miami Village (Plate XVII). In addition, some wolfram has been declared from the Maxin II claims, four miles east-north-east of Miami and some eleven miles north-by-west of the Honey Claims and from the Bangalang Claims near the homestead on Mafalo Farm, eight miles east-south-east of the Honey Claims. During the excavation of the foundations for the tobacco barns on Toro Farm just west of Miami a lump of wolfram which had come from a quartz vein was found.

Unpublished reports have been made on the wolfram occurrence by K. P. Chikara, R. Tyndale-Biscoe, F. W. Prokop and the writer. The belt was designated as the Honey Wolfram Belt by Prokop who made a very thorough and detailed investigation of the deposit. Prokop and two other members of the Honey Syndicate worked the eluvial deposit on quite a large scale. The main effort was made on the Honey Claims. The carefully delineated, economic, eluvial concentrations were stripped using a Caterpillar 955 traxcavator and the ore concentrated by means of a double 8 ft. diamond concentration pan and a hand-operated jig. Prior to this major effort at working the claims, they were operated by the individual farmers on their own farms. The general method employed was to pay Africans for the ore produced, but this led to a most haphazard rooting around. Wolfram was

obtained from both primary and secondary sources but once the easily won primary ore was removed, it became clear, from its sporadic distribution that deeper mining would be uneconomic.

#### *The Primary Ore Deposits*

The ore is contained in high temperature, hydrothermal quartz veins and there is evidence that pneumatolysis has also played a part. The reefs follow the foliation strike of the mica-schists but occasionally dip at steeper or flatter angles across it. An exception to this trend was seen on the Honey Claims where a narrow reef rich in wolframite, and thought to be possibly a spur off a larger body, strikes almost at right angles across the foliation. The ore-bodies are quartz veins with a lenticular habit and rather short strike. They carry, for the most part, conspicuous tourmaline which in the Honey Claims is more abundant in the northern blocks than in the southern. However, even where tourmaline is not much in evidence in the quartz, it is abundant in the schist on their margins. In addition the reef and schist carry bands of the mineral but in the latter it is more usually present in fairly large granular concentrations and divergent and radiating needles. Individually the tiny granules exhibit perfect idiomorphism under the microscope.

The quartz has, with few exceptions, a sugary texture but where it is glassy it has been partly sheared and mylonitized. It is noticeable that the wolfram usually occurs in the quartz apart from the tourmaline. In addition to the tourmaline and wolfram the quartz carries haematite (locally altered to limonite), some muscovite, amorphous manganese oxide, traces of ilmenite and copper staining. Rhombohedral solution cavities suggest that a carbonate has been present, probably as spathic iron. Fractures in the quartz near wolframite crystals are often a yellow, iodine-like colour suggestive of tungstic ochre. The haematite is possibly an alteration product of pyrites. A borehole put down a little west of the barns on Garahanga Farm struck a 12 in. wide quartz reef which carried pyrites at a depth of 180 ft. Prokop has reported that scheelite and gold (up to 1 dwt.) occasionally occur near the walls of an ore shoot. The following table of analyses of Honey wolfram concentrates is given in his report:

|                 |                | <i>Per cent.</i> |                |
|-----------------|----------------|------------------|----------------|
|                 | <i>Average</i> | <i>Minimum</i>   | <i>Maximum</i> |
| WO <sub>3</sub> | 67.64          | 65.00            | 72.00          |
| Sn              | 0.10           | Trace            | 0.48           |
| As              | 0.03           | Trace            | 0.15           |
| Mo              | Trace          | Trace            | 0.16           |
| Cu              | Nil            | Nil              | Trace          |
| Bi              | 0.08           | Trace            | 0.17           |

The high specific gravity and very perfect cleavage of the wolfram make it easily distinguishable from the haematite, tourmaline and other associated minerals. It occurs both as small disseminated specks and in crystals of up to several inches in length, occurring singly or in clusters.

PLATE XVIII



Wolframite pseudomorph after scheelite from Maxin II Claims, Urungwe District (actual size).

Photo: H.J.C.



Occasionally it occurs in lenticular seams as much as 8 in. wide. One narrow quartz reef yielded about half a ton of hand-cobbed wolfram from quite a small pit. This reef was exceptional, for the majority carry sporadic crystals of varying size. These, in most instances, are hypidiomorphic with a tabular habit. As a result of shearing and crushing of the reefs they are often cracked or have undulose cleavage surfaces. Twinning can sometimes be observed.

A crystal of wolfram from the rubble from a quartz reef on the Maxin II Claims, four miles east-north-east of Miami Village provided an interesting exceptional form. This is a penetration-twin consisting of two tetragonal by-pyramids (Plate XVIII) which is the form scheelite could be expected to take, and is thought to be a pseudomorph. The mineral is black with a sub-metallic lustre and there is no evidence of the cleavage which is so perfectly developed in wolfram. The crystal weighs 73 grams and an analysis by J. P. Allchin revealed 59.79 per cent. of tungsten. One of the pyramid faces is incomplete as it has been moulded on quartz and here a little scheelite was found at the contact of the quartz and the wolfram.

### Structure

The schists curve round a granite plug or cupola which occurs to the west of the wolfram belt and is shown on Plate XVII. Probably the granite contact, the schist and the wolfram belt are concentric and a thermal control is likely to have operated. Tourmaline-bearing quartz veins without wolfram flank this main belt and they in turn are flanked by beryl-bearing pegmatites.

A schedule of production from the Honey Wolfram Belt is given below.

| <i>Name of Claims</i> | <i>Years</i> | <i>Tonnage</i> | <i>Value £</i> |
|-----------------------|--------------|----------------|----------------|
| Borgy . . . .         | 1956         | 0.57           | 340            |
| Ellerslie . . . .     | 1952-1954    | 0.81           | 799            |
| Honey . . . .         | 1952-1957    | 40.02          | 27,183         |
| Magugisi . . . .      | 1955         | 0.14           | 70             |
| Makashi . . . .       | 1956         | 0.04           | 25             |
| Stanco . . . .        | 1952-1953    | 2.00           | 1,697          |
| Tawona . . . .        | 1953         | 0.85           | 651            |
| Vixen . . . .         | 1952-1954    | 3.42           | 2,296          |
|                       | 1956         |                |                |
| TOTAL . . . .         | 1952-1957    | <u>47.85</u>   | <u>33,061</u>  |

The *Bangalang Mine* which is on Mafalo Farm, 18½ miles south-east of Miami Village produced 0.18 tons of wolfram in 1953-4 valued at £90. This came mainly from the rubble of a quartz vein.

The *Maxin II Mine* which is four miles east-north-east of Miami Village declared 0.22 tons of wolfram in 1954 valued at £60. Associated with a quartz reef in this vicinity was a reef of almost pure garnet. A single crystal of wolfram reportedly came from a small pegmatite on the Tom Tit Claims a mile north of the Maxin II. (See also under mica and beryl.)

## TANTALO - COLUMBITE

Tantalo-columbite has been found only in small amount as a by-product of beryl mining. Analyses are not available of the percentages of the end members, tantalum and niobium, in this isomorphous series but some of the specific gravities which were determined ranged from 5.3 - 5.8 and indicate a much higher niobium than tantalum content. Specific gravity determinations alone are likely to be very misleading, however, especially if titanium is present. A specimen of the mineral which had a specific gravity of 6.5 and could normally be expected to assay 46 per cent. tantalum was found by J. P. Allchin to contain 15 per cent. niobium, 1.2 per cent. tantalum and 40.3 per cent. titanium.

The mines listed in the schedule of production given below, will be found in the beryl section where their localities are given.

| <i>Name</i>          | <i>Year</i>      | <i>Tons</i>        | <i>Value £</i>      |
|----------------------|------------------|--------------------|---------------------|
| Bufroi . . . .       | 1954-1955        | 0.11               | 105                 |
| Kramac . . . .       | 1955             | 0.20               | 179                 |
| Lillington . . . .   | 1954             | 0.01               | 5                   |
| Rita . . . . .       | 1954             | 0.24               | 261                 |
| Star Turn . . . .    | 1957-1959        | 0.49               | 561                 |
| <b>TOTAL . . . .</b> | <b>1954-1959</b> | <u><u>1.05</u></u> | <u><u>1,111</u></u> |

## GOLD

Only two gold mines occur within the area of this bulletin map. The chief interest in these mines is that they reveal a Piriwiri System gold mineralization which is younger than the Basement Complex gold mineralization.

The *Kent Mine* is on Crown land in the Lomagundi district, 1½ miles east of the Angwa River in the extreme south-east corner of the map.

An unpublished report was made on the mine in October, 1936, by J. C. Ferguson, of the Southern Rhodesia Geological Survey, and is the only information available.

Reefs of bluish quartz having a north-east strike are evidently quite common on the claims but are probably irregular and discontinuous. The main workings are on a reef of very variable width but which averages about 20 in. A vertical shaft was down 80 feet with cross-cuts at 34, 50 and 80 ft. Short drives were put in each way on the two upper levels. The values were apparently low. A grab sample taken from the dump of reef from the 50-ft. level assayed 3 dwt. of gold per ton. Some shallow work which may not be on the same reef has been done north-east of the shaft.

The mine declared outputs in 1940, 1946 and 1947. A little under 100 oz. gold and 14 oz. silver was extracted from 1,322 tons milled and was valued at £794. This gives an average recovery of 1½ dwt. per ton and a fineness of 877 parts per thousand.

The *Winchester Mine* is on Crown land, two miles from the eastern edge of the map and 14 miles south-south-east of Miami Village.

As Government Mining Engineer, W. Ralston visited the mine in July, 1940, and wrote a short note. The reef was not seen, but was described by the owner as a red siliceous schist striking at 310 degrees (magnetic) and dipping west at 85 degrees. There was a line of old workings below which the ground was said to have been stoped to a depth of 50 ft. A shaft 20 ft. to the west was down to a depth of 100 ft. and a cross-cut had not yet intersected the reef which was, elsewhere, reportedly 3 ft. wide and assaying 4 dwt. gold per ton.

When visited in 1953 an adit had been driven in a northerly direction from the steep southern slope of the ridge and was connected to the surface by shafts. However, it was not certain from the accessible workings just what was regarded as ore.

There is no record of production.

### GRAPHITE

Slaty graphitic rocks form an upper group in the Piriwiri System and are well displayed in north-eastern sector of the map. In addition, narrow graphitic beds occur in the lower Phyllite Group and are present in all the metamorphic grades of this group but are very sparse. The graphite in these beds is clearly of metamorphic origin and is derived from indigenous carbonaceous material. The quality of the graphite improves with increasing metamorphic grade, altering from dull, compact, earthy material to a steel-grey colour with a metallic lustre. This transformation is from what is known as "amorphous" graphite to "flake" graphite though both forms are, in fact, in the crystalline state. In the phyllites the graphite is all "amorphous", in the sillimanite-gneisses it contains a small percentage of "flake" whereas in the coarse granite-gneiss "flake" graphite predominates.

In 1959 the Anglovaal Rhodesian Exploration Co. (Pvt.) Ltd., registered 11 graphite claims in the Urungwe District in the name of Stembok Mining Co. (Pvt.) Ltd. The writer is indebted to the Anglovaal Company for making all their information on these deposits available to him. This included a report by one of their geologists, M. v. D. Steyn, and the results of beneficiation tests on a bulk sample of ore from the "Graphite King" deposit.

These registered claims are divided into three groups which are known as the Graphite King group, the Manyangau group and the Miami group (Plate XIX). The nearest of the five registered claims in the Manyangau group is two miles north of the edge of the bulletin map and 15 miles north-east of Miami Village. The Miami group is on Crown land and disposed as follows: the Chiten Claims are  $4\frac{1}{4}$  miles north-east of Miami; the Griffen Claims about four miles east-north-east of Miami; the Katchia Claims are  $6\frac{1}{2}$  miles south-east of Miami; and the Akoynak Claims form a parallel belt a mile east of the Katchia. These graphite bands can be traced south on to Kankombe and Nyamipipi farms. Of the three groups only the Manyangau group can produce "flake" graphite.

The *Graphite King Mine* is on Crown land,  $2\frac{1}{2}$  miles south-west of the Rkwesa Mine and  $26\frac{1}{2}$  miles north-west of Karoi.



Here there is an open-cast working about 90 ft. long and 20 ft. deep on a nearly vertically dipping graphitic body striking east and west. The western end has been tunnelled in, a short distance. In the face there are some veins of haematite and limonite and granitic lenses. Curved foliation planes in the graphite-rich bands have produced lenticular structures. The material at the bottom of the open working is still soft enough to be worked with a pick. No assessment has been made of the tonnage of readily available graphite here but it is reasonably large.

Graphite, gneiss and pegmatite rubble occur on the small nearby kopje to the south-west of the open working and graphitic material can be traced discontinuously for about three-quarters of a mile to the east. A small percentage of "flake" graphite is present in this deposit.

A bulk sample of graphite-bearing ore from the Graphite King deposit was sent to the metallurgical laboratory of the Anglo-Transvaal Consolidated Investment Co. Ltd., in Johannesburg for treatment. The whole sample was crushed and subjected to floatation tests. The concentrate was then sent to the Anglo American Corporation to carry out upgrading tests. The results of these tests were summarized as follows: "Very little improvement in grade of graphite can be achieved by electrostatic separation of fractions of the range  $-49 + 200$  mesh. The  $-200$  mesh fraction does not appear to be amenable to this type of separation, but a liquid-liquid separation yields a grade of over 74 per cent. graphite. The graphite appears to be intimately associated with mica, and extremely fine milling appears to be necessary to liberate the graphite mineral, as indicated by the  $-325$  fraction, which has a grade of 69 per cent. graphite.

The Graphite King Mine produced in 1944 and 1945 when 13 tons of washed graphite was sold for £406.

#### KYANITE

There is a narrow belt of country in the north-eastern sector of the map which contains a considerable tonnage of kyanite. If suitable markets can be found this mineral is certain to prove an economic proposition. The belt is over 11 miles long and starts just south of the Mpofu River,  $1\frac{1}{2}$  miles east of the Judy Beryl Mine, strikes south through the eastern sector of Masterpiece Farm, crosses the Angwa River just north of its confluence with the Miami River and leaves the eastern margin of the map a mile north of where the Angwa River itself does.

The kyanite is of petrographic interest in that it forms perfect pseudomorphs after chiastolite. A photograph of one of these crystals appears on Plate III and photomicrographs appear on Plate V. A petrographic description is given on pages 28-32.

The economic source of this mineral is in the rubble and possibly in the decomposed rock. The fresh rock which is very hard, is not likely to be an economic source of the mineral. The rubble not only provides easily won ore but weathering has also assisted in its purification by weathering out much of the included biotite and graphite that form the chief impurities at the extremity of the axes of the black cross.

The most accessible and richest sector of this kyanite belt is on Masterpiece Farm where numerous blocks of claims have been registered as the Chipungwe by Keir and Cawder (Rhod.) Ltd. Bulk samples of the ore have been sent to the United Kingdom for beneficiation and calcining tests as well as to the Government Metallurgical Laboratory in Salisbury. The writer is indebted to Keir and Cawder Ltd., for permission to publish the findings of the Metallurgical Laboratory as well as the following three analyses of the kyanite from the rubble:

TABLE OF ANALYSES

| Sample No.                          | (Per cent.) |       |        |
|-------------------------------------|-------------|-------|--------|
|                                     | I           | A/43  | A/56   |
| Si O <sub>2</sub>                   | 41.27       | 44.3  | 46.43  |
| Al <sub>2</sub> O <sub>3</sub>      | 57.20       | 52.2  | 51.95  |
| Fe <sub>2</sub> O <sub>3</sub>      | 0.37        | 1.2   | 0.35   |
| Ti O <sub>2</sub>                   | 0.49        | 0.09  | 0.25   |
| Cr <sub>2</sub> O <sub>3</sub>      | 0.03        | 0.03  | Nil    |
| Mn <sub>2</sub> O <sub>4</sub>      | 0.04        | 0.01  | Tr.    |
| Ca O                                | 0.19        | 0.30  | 0.06   |
| Mg O                                | 0.11        | Tr.   | 0.04   |
| Alk. metals<br>as Na <sub>2</sub> O | 0.05        | 0.35  | 0.06   |
| Ig. loss.                           | 0.52        | 1.25  | 1.02   |
| Totals                              | 100.27      | 99.80 | 100.16 |

Unfortunately the names of the analysts is not known. No. 1 was analysed by a Salisbury consultant and the other two were done overseas, presumably by Leeds University.

Mr. I. A. Cowperthwaite, geologist to Keir and Cawder Ltd., submitted a bulk sample of kyanite from the Chipungwe Claims to the Government Metallurgical Laboratory on the 2nd October, 1959. This assayed as follows:

Alumina (Al<sub>2</sub>O<sub>3</sub>) = 54.39 per cent., silica (SiO<sub>2</sub>) = 43.16 per cent. and iron oxide (Fe<sub>2</sub>O<sub>3</sub>) = 2.0 per cent.

A number of flotation tests were undertaken in a 500 gram Laboratory Cell with satisfactory results. An acid circuit was used with Reagent 824 and Frother 63 and in one test a product was obtained which assayed as follows: Al<sub>2</sub>O<sub>3</sub> = 61.00 per cent., Si O<sub>2</sub> = 37.00 per cent. and Fe<sub>2</sub>O<sub>3</sub> = 1.15 per cent.

Tests, using batches of 10 lb., were then undertaken in a commercial half-size flotation cell with disappointing results. However, further tests were undertaken in April, 1961, using a new reagent and a product was obtained which assayed as follows: Al<sub>2</sub>O<sub>3</sub> = 59.9 per cent. Si O<sub>2</sub> = 31.7 per cent., Fe<sub>2</sub>O<sub>3</sub> = 1.6 per cent., ignition loss = 1.1 per cent. This product would probably be acceptable to the trade.

## RUTILE

Rutile, which is a titanium dioxide ( $\text{TiO}_2$ ) is the prime ore of the metal titanium. It occurs in what appears to be a very unusual form on the "I Wonder" claims which are situated on Crown land,  $9\frac{1}{4}$  miles east-by-south of Miami Village. The host rock of the rutile and its probable mode of origin are briefly described on page 21 and a photograph of a specimen of the ore appears on Plate IV. Exposures of the rutile host rock in the Miami River were covered with a white efflorescence. Scrapings were collected for analysis by J. P. Allchin, chemist to the Southern Rhodesia Geological Survey, who reported as follows:

|                                                          | <i>Weight<br/>per cent.</i> |
|----------------------------------------------------------|-----------------------------|
| (i) Approximate composition:                             |                             |
| Soluble fraction after drying at $110^\circ\text{C}$ .   | 43                          |
| Insoluble fraction after drying at $110^\circ\text{C}$ . | 32                          |
| Water removable at $110^\circ\text{C}$ .                 | 25                          |

The pH of distilled water containing 10 per cent. of the powder sample as received was 3.5.

(ii) Chemical composition of Soluble Fraction:

Mainly ferrous and ferric sulphates (the former approximately 20 per cent. by weight reckoned as  $\text{Fe SO}_4$  against the sample as received — determined by simple volumetric titration). Nitrate, titanium, phosphate, sodium and potassium were recognized as minor constituents.

A sample of the rutile received at the Geological Survey Office on the 25th August, 1944, gave the following results on analysis:

|                         | <i>Per cent.</i> |
|-------------------------|------------------|
| Ti $\text{O}_2$         | 84.70            |
| Si $\text{O}_2$         | 5.44             |
| $\text{Al}_2\text{O}_3$ | 4.05             |
| $\text{Fe}_2\text{O}_3$ | 4.89             |
| FeO                     | 0.32             |
| Mg O                    | Tr.              |
| Ca O                    | Tr.              |
| $\text{P}_2\text{O}_5$  | 0.10             |
| Mn O                    | Nil              |
| F                       | Tr.              |
| $\text{H}_2\text{O}$    | 0.96             |
| <i>Total</i>            | 100.46           |

*Analyst: E. Golding*

A sample of hand-cobbed rutile was sent by the owner of the claims to South Africa for milling and concentration and the following information was received:

The ore was stamp-milled through a 100 battery screen and classified. The sands were then concentrated over a James sand table taking a top cut to include the fine material as No. 1 concentrate, and a cut lower down the table as No. 2 concentrate. The sand was then reconcentrated



over the table, but separation of the rutile from the gangue was very difficult, the concentrate obtainable, however, was retained as No. 3 concentrate.

| <i>Product</i>              | <i>Per cent.<br/>Weight</i> | <i>Per cent.<br/>TiO<sub>2</sub></i> | <i>Head value<br/>a/c for</i> | <i>Per cent.<br/>Value</i> |
|-----------------------------|-----------------------------|--------------------------------------|-------------------------------|----------------------------|
| <i>Heads</i>                |                             | 92.4                                 |                               |                            |
| No. 1 Table concentrate . . | 44.9                        | 97.33                                | 43.70                         | 48.4                       |
| No. 2 Table concentrate . . | 19.5                        | 96.85                                | 18.89                         | 20.9                       |
| No. 3 Table concentrate . . | 5.9                         | 93.12                                | 5.49                          | 6.0                        |
| Sand . . . . .              | 19.5                        | 80.40                                | 15.68                         | 17.4                       |
| Slime . . . . .             | 10.2                        | 64.24                                | 6.55                          | 7.3                        |
| Calculated head . . . . .   | <u>100.0</u>                |                                      | <u>90.31</u>                  | <u>100.0</u>               |

Nos. 1 and 2 concentrations taken together average 97.09 per cent. TiO<sub>2</sub>.

It would appear that if hand-cobbed ore were treated by a simple washing process a high-grade product could be obtained.

#### *Structure*

A compass survey of the deposit was made but the plotted data were lacking in essential detail for an unequivocal assessment of the structure to be made. This was due to paucity of outcrop and an insufficiency of prospecting trenches and pits. Exposures can be observed over a strike of some 1,800 ft. from north to south and having a maximum lateral distribution, midway along the strike, of 300 ft. The picture suggested is of a lenticular body of coarse tremolite-rock having these dimensions. An oblique fault appears to cut across the body near the northern end and an epidiorite dyke is intrusive into the eastern mid-portion almost immediately south-west of the main prospect pit. The dips of the adjoining schists are of the order of 60 degrees to the east. Of course, it may be that, instead of a single wide lens, there are two or more *en echelon* bands or the repetition of a single band due to folding or faulting.

#### *Mineralization*

The rutile crystals and clusters are of sporadic occurrence, though in some exposures there appears to be a fair concentration. Some of the prospect pits reveal much sugary quartz replacing the tremolite-rock and in others there is more secondary haematite than rutile, which would make concentration of the ore difficult. There seems to be little possibility of much eluvial rutile being found.

There appears to be too small a tonnage of ore to make it an economic proposition for a company scale of operation. A small dump of rutile was seen near the main pit which is in very decomposed rock. There is, however, no record of any sale of ore.

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