THE GEOLOGY OF AN AREA NEAR SHABANI, RHODESIA, WITH SPECIAL EMPHASIS ON AN OCCURRENCE OF YOUNGER GRANITE.

by

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(1964)

Plate 1.

ABSTRACT

The following account is a description of Archaen rocks found near Shabani, Southern Rhodesia, with special emphasis on the occurrence of a recently located younger granite. It is proposed that hydrothermal solutions, enriched in carbonate and silica, escaped from the granite and reacted with the serpentinised dunite in the Shabani Ultrabasic Complex to form chrysotile asbestos.

A petrological examination and structural analysis has been completed on the basement gneiss, the local Bulawayan rocks including the Shabani Ultrabasic body, and the younger granite.

Slight deformation of the gneiss by the Shabani Ultrabasic and granite establishes the gneiss as being the oldest formation, although irregular amphibolite bodies discovered in the gneiss are thought to represent an altered older rock, possibly of Sebakwian age.

In the Bulawayan greenstones, some of the basic lavas are spilites and not andesites as previously thought. A remarkable 'resistor' of banded ironstone has been found in the younger granite. This outcrop can be traced along strike to unaltered banded ironstones in the Bulawayan sediments.

Layering of olivine crystals in the dunite near the Honeybird Mine, verifies that crystal settling has occurred

in the Shabani Ultrabasic, a process previously advanced to explain the various dunite, peridotite, pyroxenite and gabbro layers. This layering probably determined the attitude of the original fractures, in which chrysotile was later deposited.

Emplacement of the younger granite appears to have been along a major crustal tension fracture, or low pressure area, created in late Bulawayan times. The absence of large scale deformation structures in the surrounding rocks, is indicative of an infiltration process rather than one of injection.

The granite is a distinctive, pink, leucocratic rock, having a medium-grained, hypidiomorphic granular texture, and composed essentially of quartz, microcline-microperthite and oligoclase. Three chemical analyses of the granite illustrate its uniform aplitic composition. However, volume analyses, calculated on twelve granite specimens, show a distinct variation in the mineral assemblages, with a marked increase in free silica towards the centre of the granite from 34-54%, and a comparable decrease in the plagioclase anorthite content. These trends are interpreted as further evidence for a magmatic emplacement.

Lamprophyric dykes, pegmatites, aplites and quartz veins associated with the granite are described. A correlation between these quartz veins and the talc zones found in the Shabani Ultrabasic is thought to exist, for both represent siliceous hydrothermal channelways.

Gold mineralisation, which is widespread throughout the area, is thought to have occurred in late Shamvian times, and is not associated with the younger granite intrusion.

Finally, a probe into recent views held on the granite problem is presented. This research shows that a potash rich granite can be emplaced as a low temperature fluid having a high water content, and is therefore an ideal source for the chrysotile asbestos-forming hydrothermal solutions.

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INTRODUCTION

General Statement.

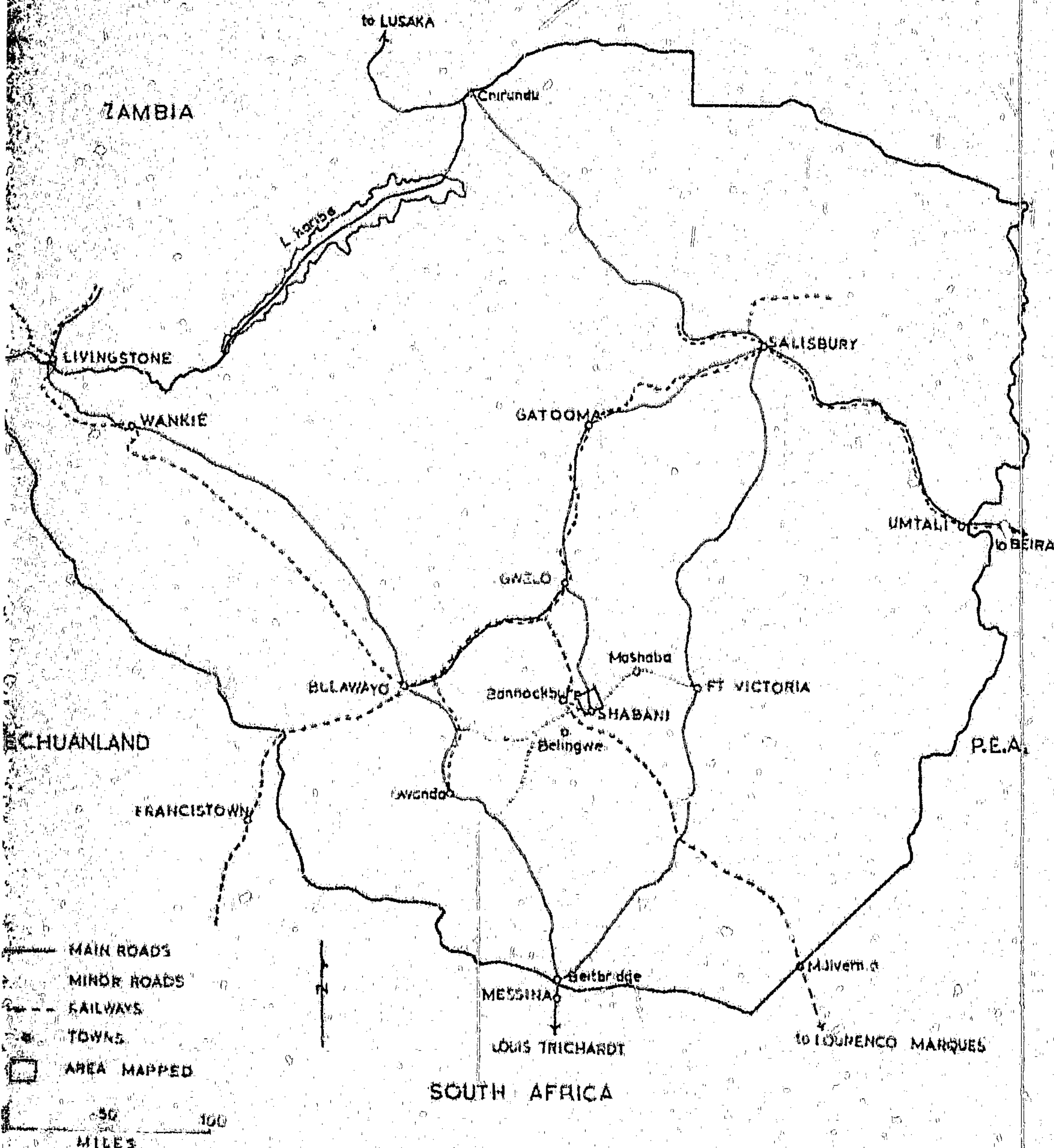
During the early geological reconnaisance by Laubscher (1963), a range of granite hills was located north-west of the Shabani Ultrabasic Intrusion. These granite kopjes became extremely important, when they were found to post-date the Bulawayan Sedimentary Series, and could therefore have been emplaced contemporaneously with the formation of chrysotile asbestos at Shabani. Although the hypothesis of a cooling granite providing the hydrothermal solutions for fibre formation at Shabani was first postulated by Keep (1929), this has since been disputed by Laubscher (1963), who derives his solutions from connate water expelled during the downfolding of the Bulawayan Sediments. This view is not held by the writer, who has mapped the area in detail during a part-time investigation, from January 1962 to August 1964. This examination, which commenced with the mapping of a granite stock north-west of the Honeybird Mine, has now been expanded to include the western end of the Shabani Ultrabasic, the surrounding granite-gneiss basement, and the Bulawayan Sediments.

Reconnaissance mapping has shown the granite to extend in a north-easterly direction as far as the Lundi River, 12 miles away. Similar granites have been examined in the Mashaba and Belingwe districts, and also younger granites

Fig. 3.

FIG. 3.

MAP OF RHODESIA SHOWING LOCATION OF SHABANI.



intruded into the Bulawayan System farther afield, e.g. the Nalatale granite at Fort Rixon. The influence of the granite on the mineralisation of the district, principally gold and chrysotile asbestos, was also studied.

Asbestos mining and associated products are discussed, together with other local economic materials, principally gold. Two small gold workings are described, with a brief survey of several other local properties.

Location of Area.

Shabani Town, described by Keep as Shabani North, is situated 130 miles due north of Beitbridge, and 90 miles east of Bulawayo. By road these distances are approximately 180 and 120 miles respectively.

The area investigated is roughly 2 miles N.W. of Shabani Town. The co-ordinates of the area mapped are approximately $29^{\circ}56'$ - $30^{\circ}2'$ East, and $20^{\circ}20'$ - $20^{\circ}25'$ South. The detailed regional mapping covered an estimated area of 15 square miles. The confining boundaries are the Bulawayan Series to the south, west and north, with the main Shabani-Gwelo road forming the eastern boundary (Map, Fig.2).

Shabanie Mine, which has recently been described in detail by Laubscher (op.cit.) is the largest chrysotile asbestos producer in Africa. It consists of a number of separate ore bodies, all of which are within a two mile radius of Shabani Town, the municipal centre.

Communications.

Shabani is connected by a wide tar road with Selukwe in the north, and by tar strip roads west to Bulawayo and east to Mashaba and Fort Victoria. A dirt road links Shabani with Belingwe and West Nicholson to the south, where it joins the Bulawayo-Beitbridge National road (Fig.3).

Shabani is linked to the main Lourenco Marques railway line by a 14 mile branch line from Bannockburn.

The town boasts a small airfield, which is in use all the year round by light aeroplanes.

Shabani History.

There is very little information written on the early settlement of the Shabani district. Ancients are known to have worked several of the small gold mines and claims in the area, i.e. the Sabi, Sabi Vlei, Old Cross and New Cross Claims, Nixs Claims and F.B. Claims. Several older Shabani residents, who were originally small workers, state that all the local gold mines showed signs of ancient development, a fact that has already been commented on by Mehliss and Goldberg (1961). The oldest mine in the district is the Sabi, which was originally pegged in 1894. This is approximately 8 miles S.E. of Shabani and is unique in the area, for it has been mined intermittantly up to the present day. Other early registered gold mines are the Gatling Hill Mine (1899) and the Humorist (1900), both of which have closed down.

Although the presence of chrysotile asbestos was evidently known earlier by the local prospectors, the first official record was a sample of chrysotile asbestos exhibited in the Bulawayo Museum from the Belingwe District in 1906. The Belingwe District in those days included Shabani; but apparently this specimen was of poor quality, and Keep (1929) doubted that the asbestos came from Shabanie Mine. Poor quality fibre does exist at Shabani, e.g. the Sheffield Claims, where harsh fibre occurs in serpentinites intruded into the Bulawayan Sediments. Harsh fibre also outcrops at surface, especially on low lying ground where humic acids have altered the silky chrysotile fibre.

Renewed interest was shown in the years from 1915-1917, when the present day deposits were pegged by Mr. M. Kerr for the Rhodesian and General Asbestos Corporation Limited. In 1919 one of the mines on the eastern limit of the main fibre bearing bodies (Nil Desperandum), was taken over by the African Asbestos Mining Company Limited, a subsidary of Turner Bros. Asbestos Limited, England. Today this company controls all the central portion of the Shabani Ultrabasic, i.e. the main economic chrysotile area, with the separate mines and claims being amalgamated into Shabanie Mine.

Farming in the district is difficult due to a generally low annual rainfall, and extremely high temperatures in the summer. Many of the farms were lands originally granted to the pioneers and early settlers, and as stated by Keep (op.cit.), if it were not for the mines, several of the smaller farms would not have survived.

The large local native population is mainly comprised of the Makaranga tribe. This tribe was easily subjugated by the invading Matabele in the middle of the 19th Century and it is said, offered less resistance than any other tribe.

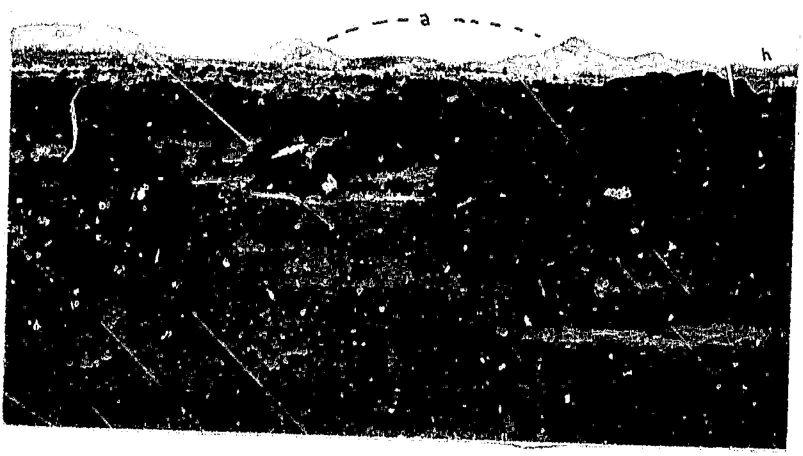
<u>Geography.</u>

<u>Climate.</u>

As a result of the low altitude (Shabani Town is 3100 ft. above sea level) and the encircling hills, the district records some of the highest temperatures in Southern Rhodesia in summer. Frequently these exceed 100°F, and are often coupled with a high humidity immediately before, and during, the rainy season. October is often known as 'suicide' month in Southern Rhodesia, and this colourful colloquial phrase is an apt description of Shabani on a hot sultry October day.

Rainfall is extremely variable, but the yearly average of 22", is normally lower than for most parts of the country.

Plate 2.



Looking SE towards Shabani.
Foreground - younger granite.
Centre - the gneiss plain.
Background - Shabani Ultrabasic hills.
(a) - anticlinal structure.
(h) - Honeybird Mine.

The rains fall between October and February, with scattered showers and thunderstorms in March and April. The remainder of the year is dry, with warm days and cool nights. Occasionally an overcast day with a light drizzle (locally termed 'guti') may arise, although this is exceptional. Frost does not normally occur, but during the winter temperatures may occasionally fall below 40°F, and frost can then develop on high ground.

Relief.

The average height of the district above sea-level is 3,100-3,200 feet. The landscape features are related to the differential rates of weathering of the underlying rocks. The main physical features are summarised briefly below.

The Bulawayan geosynclinal deposits, which strike in a N.W. direction and dip steeply to the S.W., form a series of hills and valleys parallel to the main strike. Banded ironstones, deposited at the base of the Bulawayan Series, form a prominent knife-edged escarpment rising to 500-600 feet above the general ground level. Ultrabasic and basic rocks, collectively called greenstones, are intruded parallel to the sediments, and generally give rise to lower and more rounded hills; an exception is in the extreme N.W., where at Dadaya Kop 4137' they form the highest peak in the district. The Shabani Ultrabasic sill is identified by steep rolling hills rising to 3690 feet, deeply dissected by cross-cutting valleys. The dunite, which normally weathers rapidly, develops a resistant silicified capping on high ground; this tends to protect it from further erosion, and leads eventually to the formation of a steep-sided pinnacle (Plate 2). Carbonated-talc zones and diabase dykes in the dunite develop narrow flanking depressions along the sides of hills, and are easily discernable from slope profiles.

The older gneiss, peneplained already in pre-Bulawayan times, forms the bulk of the low lying ground today. When freshly exposed, the gneiss is extremely hard and competent, especially unweathered specimens collected from underground on Shabanie Mine. Under the present climatic conditions the gneiss decomposes rapidly, mainly by kaolinisation of the felspars. The gneiss-ultrabasic contact frequently occurs on high ground. This phenomenon is the logical result of differential weathering, for the ultrabasic is more resistant to erosion than the gneiss, as can be observed everywhere in the district. Worst (1956), explaining similar contacts in the Belingwe district, believes that the ultrabasic was intruded into an established gneiss landscape.

The intrusive younger granite forms a narrow range of whale-backed exfoliated hills, striking in a N.E. direction. Occasionally steep sided 'castle' kopjes may be developed, but these are the exception rather than the rule. The main hills rarely rise to more than 200-300 feet above the surrounding terrain; there is a distinct gradual increase in elevation when traversing from the gneiss on to the granite.

Quartz veins and aplites form narrow ridges which are distinctive in the field and on aerial photographs. Some of these ridges may develop into major physical features rising to 200 feet above normal ground level.

Drainage.

The Shabi River and its tributaries form the main drainage system of the area mapped. This river, flows from North to South until it encounters the Bulawayan hills where it swings to the South-East, is a tributary of the regional Lundi-Sabi river network. Locally the Shabi river system is controlled by faulting, shear-zones, dykes and the gneiss foliation.

The Shabi ceases to flow from May/June to October/November, when it becomes a succession of small pools, whilst the minor tributaries only flow intermittently following heavy rains. Due to the spasmodic but violent flooding, the tributaries frequently change course, leaving temporary oxbow channels in the abandoned river bed. The gradient of the Shabi river is 1:350, measured over 8 miles from the Ngome bridge to the Bulawayo road bridge (Fig. 1), but locally varies considerably. In places it has excavated a bed up to 15 feet deep, partly by pothole action; often the true depth is concealed by sand deposits. These are excavated by local building contractors, who annually rotate their working sites, the deposits being renewed during the rainy season when the rivers are in flood. Because of the faster rate of deepening of the main channels, the shallower tributaries form narrow steep-sided gullies or dongas where they enter the main stream; due to rapid downcutting of their beds in order to attain the grade of the Shabi river.

Owing to the unrealiable seasonal rainfall, numerous small dams have been constructed on the gneiss, which although foliated, is poorly jointed and therefore provides a reasonably impermeable floor. Additional water is provided by pits in the river bed and boreholes drilled on prominent structural features, e.g. shear zones.

On the land bordering the younger granite a radial drainage pattern has been developed through springs originating at the granite-gneiss contact. Even during the wet season the granite itself appears arid, for the surface waters are rapidly taken underground by a well formed joint system. Some of the springs are perennial, although they may disappear again within a few feet of their outlet during the dry season. They form useful markers for mapping the contact where it is concealed. Similarly, major joints and shear fractures can often be interpolated from the linear distribution of trees and shrubs.

As a result of the intermittent flow of the river system, stagnant water is commonplace and forms ideal conditions for the propagation of bilharzia and breeding grounds for the malarial mosquito. Fortunately the latter has almost been eradicated; but the scourge of bilharzia is rife, particularly amongst the native population.

Vegetation and Soils.

A distinct suite of trees and shrubs is associated with each of the major rock formations. Frequently the vegetal demarcation near the geological contacts is sufficiently sharp to be used as a guide for mapping. This is especially true for the granite-gneiss contact, which in places is concealed beneath a deep soil cover.

The serpentine rocks are more resistant to erosion than the dunite; but both decompose to a rich dark brown soil which supports a thick bush growth. Thorn bushes are the most prolific variety, especially the hooked rambling thorn (Usinga Acacia Verek), and the knobbly thorn (Acacia Nigrescens). A distinctive marker bush, Euclea Eylesii, known locally as the "chinda" (asbestos) bush, is associated with the talc footwall and the talc

Plate 3.

Younger granite/gneiss contact on the Shabi river.

Foreground - gneiss.
Centre - Shabi river.
Background - Younger granite.

zones and dykes cutting the Ultrabasic intrusive. Similar bushes are associated with the basic soils derived from amphibolite remnants in the gneiss.

The gneiss supports a thinner and more open vegetation, consisting of thorn bushes separated by sparsely covered coarse grass clearings. The soil varies from light to dark grey in colour, depending on the percentage of mafic minerals present. Mopani, wild fig and euphorbia trees are occasionally found.

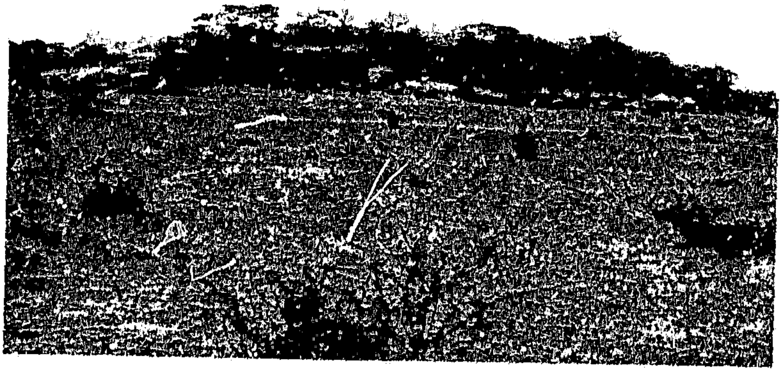
The granite soil consists of coarse grains of quartz and kaolinised felspars; its colour, coarseness and angular nature are distinctive. The soil is nearly an exact replica of the solid granite, for there has been very little mixing with foreign soils, due to the poor surface drainage. Thorn bushes are almost completely absent, the principal cover being coarse grass. Widely scattered mopani and wild fig trees are common on this rolling grassland. Euphorbia, baobabs and aloes occur on the granite hills themselves together with a wide variety of shrubs and creepers.

Human Settlements.

The local tribes prefer to live on the granite for a number of reasons:-

1. A constant supply of water, reasonably free of bilharzia, can be obtained from the springs flowing from the granite.

Plate 4.



Makaranga village in typical granite setting.

Plate 5.

'Semi-desert' landscape resulting from overgrazing by native cattle.

2. Shelter from the elements is provided by siting the village in the lee of granite kopjes (Plate 4).
3. Due to the lack of undergrowth, any threat from hostile tribes or wild animals can easily be detected.
4. The open grassland offers reasonable pasture for cattle and goats.
5. Superstition has implanted in the native's mind the notion that the granite is a "good luck" area.

Unfortunately, because of this preference for granite localities and the naturally poor soil, the grasslands are easily overgrazed, which leads to the formation of "semi-desert" conditions (Plate 5).

Outside the tribal lands, whose population in 1964 was estimated at 100,000 natives, the largest settlement is Shabani with a European population of approximately 1800. The latter is directly or indirectly associated with the mining of chrysotile asbestos. Drinking water is a scarce commodity, but is obtained for the town from a seven miles long pipeline from dams on the Lundi river, whilst untreated water is pumped from the mine. Belingwe (population 350) is the only other neighbouring settlement; this is mainly a farming community, though small asbestos and gold mines occur scattered throughout the district.

Fig. 4.

GEOLOGICAL FORMATIONS

Gold Mineralisation.		SHAMVIAN?
Quartz Veins.	Hydrothermal Activity.	
Talc Zones.		
Aplites & Pegmatites.	Acid Igneous Activity.	UPPER BULAWAYAN
Lamprophyres.		
Granite.		
Diabase Dykes.		
Actinolite-felspar Rock.	Shabani Ultrabasic Intrusion.	LOWER BULAWAYAN
Actinolite Rock.		
Pyroxenite.		
Peridotite & Harzburgite.		
Dunite.		
Talc Carbonate Rocks.		
Greenstones.	Geosynclinal Rocks.	
Sediments.		
unconformity.		
Gneiss	Basement.	SEBAKWIAN?
Amphibolite		

General Geology of the Shabani-Belingwe District.

The rocks exposed in the Shabani-Belingwe District are Precambrian, with the exception of recent deposits of soil, river gravel, surface limestone and alluvium (Fig. 4).

The earliest Archaen rocks identified are the amphibolite zones in the gneiss. These irregular and highly altered bodies are thought to represent ancient basic intrusions into granite or sediments, for they are definitely a pre-gneiss formation. With the development of a gneissic structure, these basic zones grade imperceptably into a dioritic ortho-gneiss at the contact. Similar altered basic rocks have been observed in the Mashaba area (Wilson personal communication).

The gneiss basement, which forms extensive low-lying plains, covers the greater part of the area investigated. The gneiss underlies the Bulawayan schist belt to the west and south, and continues north and east without interruption into the Mashaba District.

Although poorly exposed, sufficient outcrops are available to show that the direction of foliation varies considerably locally, but has an overall N.N.W. trend. The gneiss is predominently a medium-grained, grey, leucocratic rock, with a well foliated porphyroblastic texture. Fine and coarse-grained varieties with poorly developed foliation are also found. The composition is mainly granitic, but does grade locally into a dioritic gneiss. This latter rock is normally associated with the amphibolite/gneiss contact rocks.

The results of radio-isotope age determination on specimens collected from the gneiss are not yet available; but the rock definitely predates the Bulawayan Series. Macgregor (1951) has defined this gneiss as pre-Bulawayan, but probably post-Sebakwian, and is therefore the earliest of the Rhodesian Archaen granites, with the amphibolite rocks possibly being of Sebakwian age.

Peneplanation of the gneiss was followed by deposition of the Bulawayan sediments, consisting of an alternating series of conglomerates, banded ironstones, quartzites and phyllites. Shallow water conditions must have existed at the time, for the conglomerates are intraformational and contain banded ironstone and gneiss pebbles.

With the development of the Bulawayan geosyncline, large submarine outpourings of basaltic and andesitic lavas occurred, together with the intrusion of basic and ultra-basic dykes and sills. Due to their metamorphic alteration, these rocks have been grouped together as the Greenstone Series. Near Shabani these sediments and greenstones form a high range of hills striking NW, the dip being to the SW. This range is part of a wide syncline that plunges in a southeasterly direction. According to Worst (1956), the same Bulawayan formation south of Belingwe, some 22 miles south of Shabani, forms a syncline plunging NE. It would therefore appear that the rocks of the Bulawayan System form an "S"-shaped basin whose centre, and widest development, is approximately 6 miles east of Belingwe. This irregularly shaped synclinal feature has been commented on by Macgregor (1951), who envisaged a simple sinking of the crust in the geosynclinal basin, with elevation of the gneiss foreland by isostatic readjustment.

The Shabani Ultrabasic body was intruded as a sill into the gneiss, during the early stages of development of the eugeosyncline. The Ultrabasic has a strike length of 9 miles in a NW direction, i.e. parallel to the strike of the Bulawayan rocks, and dips in a general southwesterly direction at $30^{\circ} - 60^{\circ}$. The sill has an estimated thickness of 5000 feet and has segregated from the base upwards into dunite, peridotite, pyroxenite and gabbro fractions. Scattered serpentine masses, intruded between the Bulawayan sediments and greenstones, had previously been considered to be sills (Keep 1929 and Worst 1956); but recently Laubscher (op.cit.) has suggested the possibility of their being ultramafic lavas, poured out subaqueously on Bulawayan sediments prior to the eruption of basic lavas.

Following on the consolidation of the Shabani Ultrabasic and the final development of the Bulawayan eugeosyncline, together with the associated compensating isostatic movements, a diabase dyke swarm trending ENE was intruded. These dykes, which invade all earlier formations in the area, have proved to be a valuable time indicator.

Finally, NW of Shabani, a pink unfoliated leucocratic granite, rich in potassium, was intruded. The granite has a discontinuous strike length of 12 miles in a NE direction; its elongation therefore is approximately at right angles to the trend of the Bulawayan eugeosyncline. This granite, whose outcrop width ranges from ½ to 4 miles, is intrusive into the Bulawayan rocks; it is similar to granitic bodies recently mapped in the Mashaba District (Wilson personal communication), whose strike of elongation is also comparable. Associated with these granites is a series of aplites, pegmatites, and quartz veins, whose strike is generally N to NNW, in the latter case following the gneiss foliation.

Gold-bearing quartz veins were then emplaced on a wide scale, trending in every direction; on the original map of Keep (1929), however, preferred trends E and NE can be discerned. The majority of the small workings on these veins are now flooded or have caved in, making further investigation impossible. Only two mines are being worked at the present day, neither, however, being large producers.

The formation of the large chrysotile asbestos orebodies at Shabani clearly took place after the intrusion of the ENE diabase dyke swarm; it is the writer's contention that these important economic deposits are related to the emplacement of the intrusive younger granite.

Previous Work.

Apart from early mining reports of limited scope, the only regional geological work in this area is that carried out by Keep (op.cit.). For the Shabani District, this is still the standard published work of reference. A more recent publication by Worst (1956), describing the geology of a neighbouring area, has helped, however, to clarify certain local geological features. The latest investigation is the very detailed account by Laubscher (op.cit.), on the mode of occurrence and genesis of the chrysotile deposits within the Shabani Ultrabasic. In this thesis he presented the following summary of Keep's views.

1. Deposition of Bulawayan sediments and greenstones on pre-existing basement.

2. Intrusion of ultrabasic rocks, including the Shabani Ultrabasic body, into Bulawayan rocks.
3. Intrusion of "granite-gneiss" by magmatic stoping, and tilting of the older formations, with subsequent compression of these rocks.
4. Compression jointing developed in the Shabani Ultrabasic.
5. Magmatic gases and vapours, emitted from the cooling granite-gneiss, entered joint planes in the Ultrabasic causing serpentinisation.
6. Emplacement of serpentinous solutions in cooling fractures in the Ultrabasic, with the crystallisation of chrysotile asbestos.

During stages (5) and (6), shearing and the formation of talcose and actinolite rocks occurred, as well as the development of brittle fibre from serpentine and chrysotile fibre around the edges of the serpentine rock mass.

The main differences between Keep's and Laubscher's views are as follows:-

1. Deposition of Bulawayan sediments and greenstones on a peneplaned surface of gneiss (Keep's "granite gneiss").
2. Intrusion, with subsequent segregation, of the Shabani Ultrabasic <u>into</u> the "granite-gneiss", now shown to be <u>older</u> than the Shabani Ultrabasic and <u>not</u> intrusive into the latter.

3. Intrusion of a diabase dyke swarm.
4. Development of shear zones in the gneiss and Ultrabasic.
5. Intrusion of a younger unfoliated granite with associated aplites, pegmatites and quartz veins.
6. Serpentinisation of the Ultrabasic by "hydrothermal" solutions largely derived from connate water, forced out of the eugeosynclinal Bulawayan sediments and lavas by orogenic compression.
7. Formation by these solutions of chrysotile asbestos in structurally suitable areas of the dunitic portion of the Ultrabasic.
8. Increasing carbon dioxide content of these solutions converted silky chrysotile fibre into brittle fibre, and eventually into talc pseudomorphs.

Two of the most essential differences between Keep's work and Laubscher's present findings are the relationship of the "granite-gneiss" to the Shabani Ultrabasic, and the derivation of the chrysotile-producing hydrothermal waters.

Since the publication of Keep's Bulletin in 1929, Shabanie Mine has developed into the largest chrysotile mine in Africa and one of the premier asbestos producers in the world. In the course of this expansion, a vast amount of new geological information has come to light, from underground development, surface mapping and bore-holes.

The following points, serve to clear up the relationship between the gneiss and the Shabani Ultrabasic.

1. Intrusion of diabase dykes into the gneiss and ultrabasic, occurred prior to the serpentinisation and steatization processes, which Keep related to the "granite-gneiss".
2. Ultrabasic rocks in contact with the gneiss are not foliated. The only foliation or shearing developed is in areas of hydrothermal activity.
3. Xenoliths of basic rocks observed in the gneiss have been altered to amphibolites and amphibole-felspar rocks, with a strong gneissic foliation developed near their contacts.
4. Better artificial exposure and detailed mapping of the contact zone has clearly established the intrusive nature of the latter; among other relevant features, the gneissic foliation in the western area has quite obviously been disturbed by the Ultrabasic.
5. The Bulawayan rocks have been tilted through nearly 90°. If the Shabani Ultrabasic were pre-gneiss in age, it would originally, at the time of intrusion and differentiation, have had a dip of 30° to the north. This would bring the well segregated dunite layer out on top and place the narrow poorly segregated pyroxenite and actinolite-felspar rocks at the base. (See Geol. Map

Figure 1). This would be radically in contradiction with known differentiation trends and therefore extremely improbable.

6. In the Mashaba area, which has a geological setting similar to that of Shabani, the chrysotile-bearing ultrabasic rocks are quite clearly intrusive into the gneiss.

Laubscher, along with other workers, e.g. Mehliss (1953) and Morgan (1956), has questioned the existance of a Pre-Bulawayan System, i.e. the Sebakwian. Previously it had been assumed that the Shabani Ultrabasic had been intruded into Sebakwian sediments, which were later "granitised" to form the gneiss. The present investigation, too, has yielded no definite evidence of any residual sedimentary features in the gneiss. This, however, may in part be due to the generally poor exposure of the gneiss. Xenoliths of basic rocks (amphibolites) have been found in the gneiss, closely comparable with similar bodies in the Mashaba District. Therefore, although the Shabani Ultrabasic is definitely of Bulawayan age, it is considered premature to discount the existance of the Sebakwian System in this area. In the neighbouring Mashaba and Fort Victoria regions Wilson (personal communication) has mapped large numbers of smallish xenolithic serpentinite bodies within the gneiss.

A major discrepancy between previous work and the present investigation relates to the influence, or otherwise, of the younger granite on the formation of chrysotile asbestos and the mineralisation of the District generally, e.g. gold. Keep (op.cit.) mentioned the existence of an unfoliated pink granite in the Wedza peak area, but considered this to be a local variation of the grey "granite-gneiss", and not a separate later intrusion. In the course of a visit to this area, however, the writer found it to be closely comparable to the Shabani younger granite occurrences. Similar granites have also been described by Worst (op.cit.) in the Southern Belingwe District. He considered them to be late phases of the main gneiss. Several of these granites, were visited to establish whether they are merely phases of the same main granitic cycle or later intrusions. The writer believes the latter to be the case, and that they are not directly associated with the main gneiss.

As a result of detailed mapping at Shabani, the writer has proved the existence of a very much later period of granitic intrusive activity. Due to its allegedly dry nature, the influence of this granite on the formation of chrysotile fibre has been entirely discounted by Laubscher (op.cit.), who also doubts the effect of numerous quartz, aplite and aplite-pegmatite veins that have emanated from it. Considering the similar age relationship of the younger granite and the formation of chrysotile asbestos, it is the writer's opinion that Keep's view as to the source of the hydrothermal solutions is now justified. All that requires alteration is to substitute the recently discovered younger granite as the source of the solutions instead of Keep's "granite-gneiss".

<u>Work Accomplished.</u>

1) A map (Fig. 2) of the most signigicant area was constructed on "permatrace", by compiling a mosaic of aerial photographs on a scale of 1:6400. By means of a pantograph, this map was later enlarged to a scale of 1:5000. In order to obtain a broader geological background, a larger area was mapped (Fig. 1) on a scale 1:20000, using Government aerial photographs of the same scale.

2) The main detailed mapping was plotted in the field directly on tracing paper overlays, strike and dip readings being taken by a Bruntön compass compensated to read True North. The maximum error is believed to be $\pm 1^{\circ}$ in bearing and 30 minutes in inclination.

Location of position in the field was easily obtained on the granite and in most areas of the gneiss, due to the open nature of the veld. Some difficulty was experienced on the Bulawayan sediments, the amphibolite bands in the gneiss, and the ultrabasic outcrops, which weather to a rich soil and support a very heavy bush growth. The error in location is probably of the order of 10-20 feet, increasing to 40 feet in dense bush regions.

3) Due to the depth of weathering, outcrops other than on the younger granite were normally rather rare. Therefore every stream, gully and donga needed to be traversed, and changes in soil and vegetation recorded. Six hundred and thirty hand specimens were collected. These do not include samples of sand and mineralised quartz vein material, collected for heavy mineral content analysis.

4) Volume analyses were carried out, principally on thin sections of granite, using a Swift automatic counter; the error established on two specimens from sections cut along three axes was of the order of $\pm$ 3% for the chief minerals.

5) Plagioclase compositions were derived from optical determinations using a Fedorov Universal Stage. A number of composition curves were used to determine the anorthite contents, e.g.

(a) Nikotin Twin axes curve.

(b) Smith and Van der Kaaden Curves for the optic axial angles.

(c) Slemmons $X \wedge TA$ and $Y \wedge TA$ Curves (Albite-Ala B Twin Law).

(d) Slemmons $Z \wedge CP$ Curves.

(e) Naidu maximum extinction angle method.

Fig. 5.

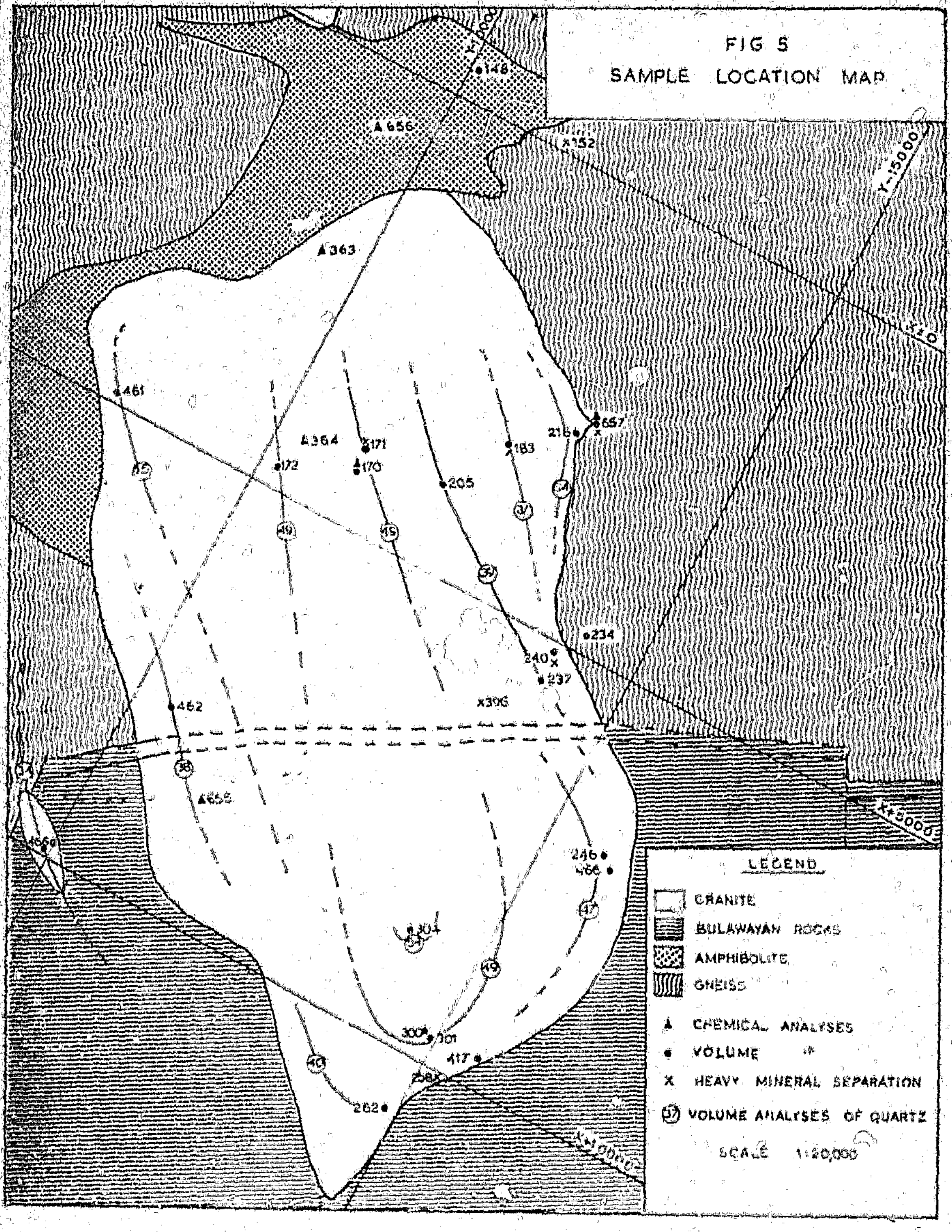


FIG 5
SAMPLE LOCATION MAP

These values were checked by refractive index measurement of cleavage fragments parallel to the (001) plane. The refractive index liquid was mixed on the slide, and the resulting refractive index value read from a Berek refractometer.

6) Three chemical analyses of younger granite were carried out, two by Turner and Newell and one by the Southern Rhodesian Government Laboratory; Analyses of aplite, gneiss and amphibolite were also undertaken by the latter. Niggli values and norms have been calculated for these rocks, together with three Mashaba analyses, and the granite-gneiss of Keep.

7) Heavy mineral separation was done by first crushing to -100 to +200 mesh and then treating 10 gram samples with bromoform. The three concentrates - heavy magnetic, heavy non-magnetic, and light minerals, were then weighed carefully to obtain relative ratio percentages.

8) A brief investigation was undertaken of several small gold workings and prospects in the District. Panned samples from a number of gold prospects were also examined.

9) Polished sections were made of ore samples from the Dove Claims, Warrick gold Claims, and Gatling Hill Claims; further polished sections were made of banded ironstone and a gold-magnesite occurrence on Shabanie Mine.

10) Photomicrographs were taken of relevant features found in thin and polished sections.

11) All field observation data were structurally plotted on a Wolfe equal angle and Schmidt equal area stereographic net, and contoured.

PETROLOGY

Petrographic Description of the Gneiss Basement

Normal Grey Gneiss.

In hand specimen the gneiss appears largely as a medium-grained, banded, light-grey rock; extremely competent, but tending to fracture along its foliation. The degree of foliation alters considerably, but in nearly all localities a slight foliation is developed. Although variations in composition do occur, the gneiss is principally granitic, altering to a dioritic gneiss adjacent to xenolithic bands of altered basic rock.

Quartz and felspar are the main mineral constituents, with varying amounts of ferromagnesian minerals (amphibole and biotite). Magnetite, ilmenite and secondary limonite, as well as sulphides, mostly pyrite, occur as accessories.

The parallel alignment of ferromagnesian minerals, frequently segregated into narrow bands, is responsible for the well marked foliation. In the more leucocratic varieties, the orientation of quartz and felspar crystals provides a rough, ill-defined foliation. The quartz is occasionally present as 'pod'-shaped masses elongated in the direction of foliation, forming augen gneisses where the felspar is similarly deformed.

Microscopic examination shows the gneiss to have a foliated porphyroblastic fabric, with only rare development of granoblastic fabric.

Quartz is anhedral to subhedral, fractured and displaying intense strain extinction.

The felspars were invariably altered, while sericite and clay minerals replace euhedral orthoclase; the plagioclase is partly or completely sausauritised.

The amphibole is either euhedral or subhedral, and is normally hornblende or actinolite altering to chlorite.

Biotite, together with the rarer muscovite, occurs as ragged anhedral plates, frequently bent and fractured.

Epidote, sphene, magnetite and ilmenite and various sulphides are found as accessories.

Microcline-microperthite, albite, apatite and tourmaline have also been identified in thin section, but these minerals were mainly found in specimens taken either near the granite contact or close to aplite-pegmatite veins in the gneiss. They show a lesser degree of alteration and deformation than the minerals in the main mass of gneiss, and are thought to have been introduced into the latter from the younger granite.

Banded Pink Gneiss.

Local variations in colour depend on the proportions of the various minerals present. A distinctive banded pink gneiss is found near the Bulawayan sediments and ½ mile west of the Shabani Ultrabasic. The colour is due to an abnormally high percentage of microcline-microperthite associated with quartz, which appear to have been intruded lit-par-lit fashion along the foliation planes of the gneiss. Evidence for this supposition is as follows:-

1) In all thin sections examined, the original orthoclase and plagioclase crystals in the gneiss are highly fractured, and in most cases completely altered to sericite and paragonite. As a result, the identification of the plagioclase felspars is extremely difficult. Because of its rare occurrence, determinations based on lamellar twinning cannot be taken as representative.

2) The original quartz grains in the gneiss are invariably fractured, display strong strain extinction, and except in the augen gneisses, are rarely more than 5mm in diameter. The grains are subhedral to anhedral, forming an ill-defined banded mosaic under crossed nicols. Due to mylonitisation they may display a crushed zone along their borders.

3) In the separate lit-par-lit veins of banded pink gneiss under discussion, larger unfractured quartz crystals, showing only slight strain extinction, are associated with fresh microcline-microperthite crystals, the distinctive pink tint of the latter giving rise to

the overall colour of the rock. These minerals invade fractures in the sericitised plagioclase, a feature which, together with their much lower degree of cataclastic deformation suggests either selective remelting of the grey gneiss or later injection, possibly associated with the intrusion of the younger granite. The fact that this pink gneiss is found near the contact of the normal grey gneiss with the Bulawayan sediments, viz in a locality ideally suited as a channelway for subsequent intrusion is an additional point in favour of this hypothesis.

The latter deduction is also supported by observations at the younger granite/gneiss contact on the Shabi river (Fig. 2). Here the gneiss is of the normal grey variety, but near the contact is seamed with veins and stringers of the younger pink granite (Fig. 18). In most outcrops examined these granitic veins run parallel to the gneissic foliation. It therefore appears reasonable to assume that the pink lit-par-lit banded gneiss under discussion, situated only a mile south of the outcropping younger granite, could have been derived from the injection of quartzo-felspathic material either from this granite, or a similar body at depth. If the latter is the case, then such a concealed granite would occur considerably closer to the western end of the Shabani Ultrabasic. This point is of significance regarding the source of the hydrothermal waters responsible for the formation of chrysotile asbestos.

Talc-garnet Bands.

The occurrence of narrow talc-garnet zones in the gneiss, are taken as a probable indication of the existence of a pre-gneiss formation Three narrow garnetiferous talc schist bands were mapped in river cuttings, and due to their low resistance to erosion, many more are undoubtably concealed. The garnet is a deep red variety, in the almandine range, with crystals normally 2-3mm in diameter. The average width of these zones was from 5-8 feet, with a near vertical dip, and striking due north parallel to the gneissic direction. They could therefore represent incompetent layers in the pre-gneiss rocks, or ancient dykes that have yielded under stress.

Shabanie Mine Gneiss.

Fresh exposure of gneiss have been opened up by underground development at Shabanie Mine on 3, 5, 7 and 9 levels, Birthday Section. These have been fully described by Laubscher (op.cit.). Of special interest is the occurrence of numerous aplites, pegmatites, quartz veins and shear zones not only in the gneiss footwall, but also within the Ultrabasic body. They also cut and displace members of the diabase dyke swarm.

The evidence strongly indicates that these acid dykes and veins are connected with the period of intrusion of the younger granite. The nearest surface outcrop of the latter is seven miles away at this point. There is no inherent reason why residual melts highly charged with volatiles should not penetrate to considerable distances away from their parent magma. Nevertheless a concealed granite at depth, could shorten this distance considerably, and it has already been mentioned in connection with the banded pink gneiss that there is some evidence for the presence of a concealed body of younger granite, viz. only half a mile to the west of the Shabani Ultrabasic.

Furthermore, close examination of the gneiss underground on the Birthday Section, shows it to be similar to that outcropping on surface close to the younger granite, except for the presence of carbonate. Underground, near the gneiss/Ultrabasic contact, some specimens contained up to 10% carbonate, but on surface this mineral was not identified in the gneiss.

The formation of large quartz lenses in the gneiss between the Birthday and Nil Desperandum Sections, have been previously explained as having formed through the release of silica during the process of serpentinisation of large portions of the Ultrabasic. This notion is disputed by the writer as the introduction of carbonated waters into the dunite, with removal of magnesium and silica, would involve a large change in volume, which, however has not been observed in underground mapping. Furthermore, in the western portion of the Ultrabasic no quartz lenses at all have been mapped, although the dunite there has also been completely serpentinised. It is therefore suggested that the siliceous solutions responsible for the prominent wide quartz veins, which follow the gneiss foliation for several miles, were impeded by the massive Shabani Ultrabasic body. They then spread along its foot-wall contact, to form lenses of quartz in suitable structural areas. This would best explain the phenomenon of the prominent quartz veins "dying out" at the Ultrabasic contact.

Apart from the shear zones already mentioned, gneiss specimens collected near the Bulawayan sediments and adjacent to the Shabani Ultrabasic, in thin section show a much greater degree of cataclastic deformation than the gneiss near the younger granite. Megascopically they appear to be similar, but mylonitisation of felspar and quartz, as well as pronounced strain extinction of the latter, contrast with a much lower degree of fracturing in the gneiss near the granite.

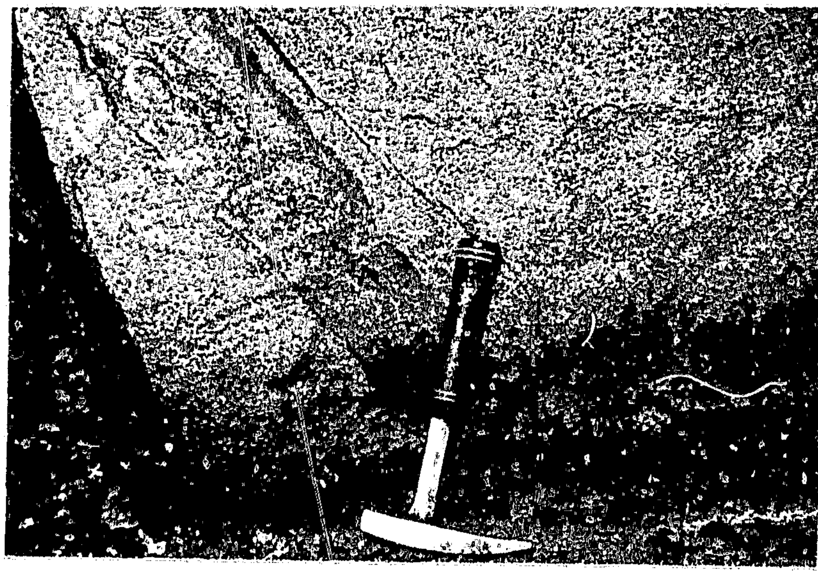
These features are probably connected with stronger differential movements during tectonic deformation in zones of inhomogeneity. The more intensive shearing and fracturing of the latter, would provide a greater degree of permeability, and an easy path for the late magmatic differentiates and hydrothermal solutions emanating from late or post tectonic intrusives, such as the younger granite.

Amphibolite.

During the preliminary mapping, the body of amphibolite shown on maps (Figs. 1 & 2) was taken to be a large altered and recrystallised basic dyke, separating the southern stock of younger granite from the larger body to the north. Detailed mapping disclosed a very irregular outline, whose borders grade imperceptably into an amphibole felspar gneiss. The amphibolite is therefore now considered to be a xenolithic body within the gneiss, probably to be correlated with the Sebakwian basic and ultrabasic rocks of the North Midlands.

Not only the passage of the amphibolite into hornblende gneiss, with gradual decreasing hornblende content is proof, but the presence within the body of a banded amphibolite conforming to the foliation of the enveloping gneiss is also significant.

Plate 6.



Recrystallisation of amphibolite along a fracture, with a distinct increase in grain size towards the centre of the fracture.

Plate 7.

A micrograph of amphibolite being replaced by quartz and felspar near the gneiss contact. Polarised light. X 28. Slide X 4662.
a = amphibole. q = quartz.

Much of the amphibolite has a coarse porphyroblastic texture. The grain size, however, ranges from 1mm to 2 cm. Alternating variation in grain size and felspar content gives rise to a distinct banding in many of these rocks, which is parallel to the gneiss foliation. The coarse and fine bands may have a width of only a few feet, or show a gradual change over 50-100 feet. Remobilisation along fractures parallel to this banding frequently occur (Plate 6). The felspar-amphibole ratio within the banded and more massive rock varies considerably. The amphibole content, principally hornblende, ranges from 10-90%; the rock thus passing from a true amphibolite, through a felspathic amphibolite into a hornblende gneiss.

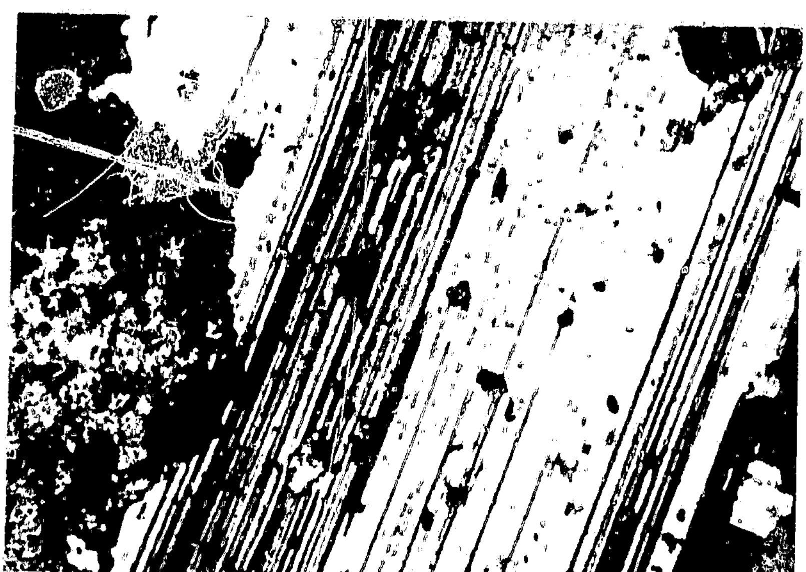
The amphibole crystals are euhedral to subhedral, fractured and having a poorly developed cleavage. Two ages of crystal growth are evident with the later and generally larger crystals of hornblende displaying a poiceloblastic texture, having enveloped smaller anhedral amphibole crystals (Plate 7). Remnant plagioclase and quartz crystals were never observed within the amphibole porphyroblasts, whilst plagioclase crystals frequently contained hornblende residuals.

Where possible the plagioclase felspar was determined, and found to be distinctly more calcic, (20-35%An i.e. oligoclase - andesine), than that of the younger granite,

Plate 8.

A micrograph of amphibole-felspar gneiss, having a linear fabric, with the felspar (oligoclase-andesine) replacing hornblende. X 30. Crossed nicols. Slide X 4674.

Plate 9.



Micrograph showing poikiloblastic texture in plagioclase, enclosing amphibole and epidote residuals. X 60. Crossed nicols. Slide X 4661.

the contact relationships with which will be described later.

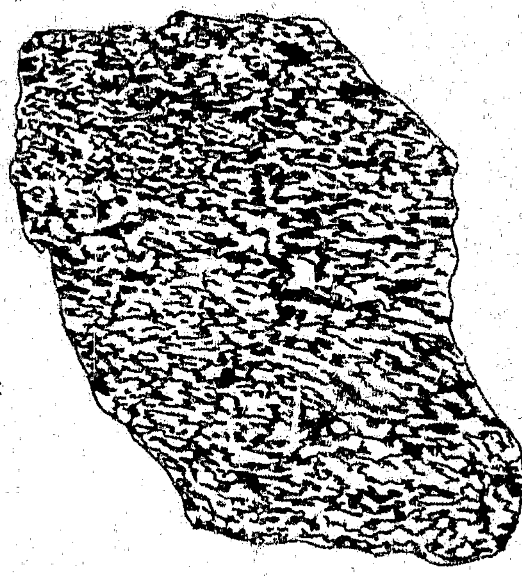
Unfortunately the majority of the felspars, as in the gneiss generally, are sericitised, which has obliterated all optical features that could be used for assessing An. content. Where the felspar has been determined i.e. (An 20-35%), it is probable that this plagioclase has developed from solutions emanating from the younger granite, and replacing original sericitised material. Zoned plagioclase crystals, particularly when they have a sericitised core, are taken as clear evidence for replacement.

In the central portion of the amphibolite body, a distinct banding occurs parallel to the gneiss foliation. This banding ranges from a perfect lineation of felspar and amphibole crystals (Plate 8), to a rather vague preferred orientation, with the shorter prismatic plagioclase crystals forming clots or irregular clusters. Around these clusters amphibole needles, principally actinolite, have flowed as if the former had acted as an obstruction (Fig. 6). These distinctive actinolite-gneiss zones in the centre of the body, are taken to represent ancient shear zones, perhaps incompetent bands in the original basic rocks, which during the formation of the enveloping gneiss, failed under the dynamic stresses.

Figs. 6 & 7.

FIG 6

REMOBILISATION OF AMPHIBOLE-FELSPAR ROCK, HAVING A PREFERRED ORIENTATION PARALLEL TO THE GNEISS FOLIATION.



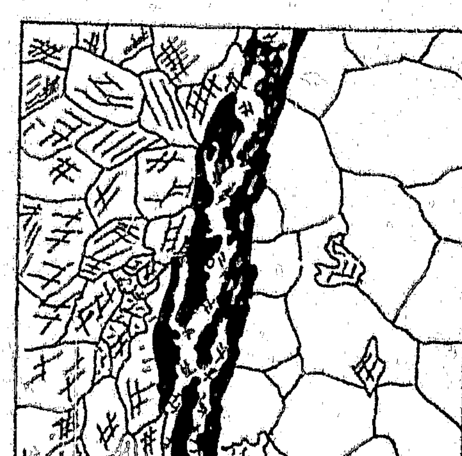
MAINLY FELSPAR

MAINLY AMPHIBOLE

SCALE=NATURAL SIZE

FIG 7

THIN SECTION OF THE AMPHIBOLITE GRANITE CONTACT, WITH A NARROW REACTION FRONT



HORNBLENDE

YOUNGER GRANITE MINERALS

OPAQUE MINERALS (IRON ORE)

SCALE

5 mm

Microcline-microperthite - Hornblende Contact Rock.

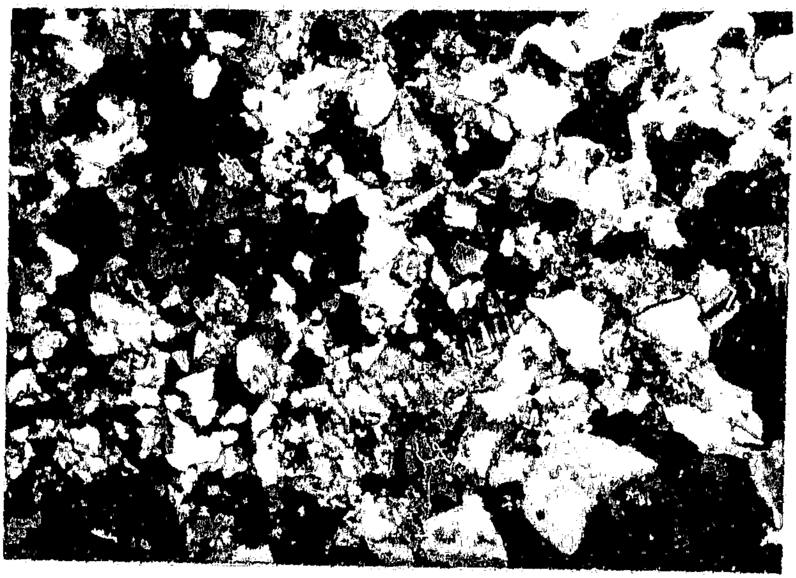
Near the amphibolite/younger granite contact, a hybrid pink microcline-microperthite - hornblende rock occurs, cut by numerous epidote stringers. The outcrop of this rock is approximately 10 feet wide, grading rapidly into an amphibole-felspar rock in which zoned and partially replaced plagioclase crystals occur, and finally into a true amphibolite. Plagioclase may develop a poiceloblastic texture containing amphibole remnants (Plate 9). The zoned plagioclase crystals range outwards from An_{30} to An_{10}. Microcline-microperthite replaces hornblende and plagioclase to an increasing degree as the younger granite contact is approached.

Granite veins containing tourmaline cut across the amphibolite, and a thin section across one of these veins (Fig. 7) shows the development of a reaction zone (basic front?) along the contact.

In several localities, the passage from true pink granite to massive amphibolite takes place over a distance of only twenty feet, proving that the emplacement of the younger granite was definitely resisted by the amphibolite barrier between the two granite bodies (Fig. 2).

Near the contact the younger granite attains a deeper pink colouration. Whether this is due to an increase in iron, assimilated from the amphibolite, is uncertain;

Plate 10.



Micrograph of chilled margin of the younger granite at the gneiss contact. Decrease in grain size from right - left. X 22. Crossed nicols. Slide X 4671.

Plate 11.

A micrograph of younger granite, showing replacement of early sericitised plagioclase by microcline-microperthite. X 22. Crossed nicols. Slide X 4815.
mm = microcline-microperthite. pl = plagioclase.

chemical analysis does not confirm an iron increase.

The amphibolite-granite contact frequently shows a surface concentration of quartz rubble. In the microcline-microperthite contact rock already described, quartz is entirely absent, although it is certain that the microcline-microperthite and some of the plagioclase have been introduced from the granite. If the solutions emanating from the granite were preferentially deprived of their felspathic content, this would result in a relative increase in silica near the younger granite contact.

Gneiss-Younger Granite Contact.

Due to the influence of fluids from the granite, the marginal gneiss may have a migmatic appearance, with striking injection gneisses developed in places. Veins of quartzo-felspathic material and pure quartz may cut across the gneiss foliation, or be injected parallel to it. These increase in volume as the granite contact is approached. Even where numerous granitic veins occur in gneiss, they have not disturbed the gneissic foliation to any extent, indicating a quiet emplacement of granitic material by permeation and replacement.

No evidence of ordinary thermal metamorphism occurs at any of the contacts observed between the granite and the gneiss, other than a narrow chilled margin (Plate 10).

Fig. 8.

Chemical Analyses of the gneiss

Sample No.	657	656	Mashaba-Ft. Victoria.	Keep's granite-gneiss.
Laboratory No.	64/225	64/228	62/69	-
%				
SiO_2	71.52	49.34	69.88	70.84
Al_2O_3	14.30	14.57	17.23	14.25
Fe_2O_3	0.41	3.56	0.50	0.74
FeO	2.23	7.26	2.56	4.08
MgO	0.97	7.81	0.33	1.11
CaO	2.06	9.65	3.21	2.72
Na_2O	2.73	2.36	4.73	3.60
K_2O	4.37	0.88	1.00	1.32
H_2O^+	0.79	2.30	0.41	
H_2O^-	0.07	0.20	0.03	0.75
CO_2	0.10	trace	nil	0.25
TiO_2	0.30	1.44	0.15	0.38
P_2O_5	0.09	0.24	0.09	nil
MnO	0.05	0.12	0.02	0.05
S	nil	nil	nil	0.08
	99.99	99.73	100.14	100.17

Niggli's Norm Estimation

	657	656	Mashaba-Ft. Victoria	Keep's granite-gneiss
Q	30.6	0.9	28.1	33.6
Ab	25.0	22.0	42.5	33.0
Or	26.5	5.5	6.0	8.0
An	8.5	27.5	15.0	12.0
En	2.8	22.4	0.8	3.2
Fs	3.0	7.2	3.4	5.2
C	2.2	-	3.2	2.8
Il	0.4	2.0	0.2	0.6
Mt	0.5	3.8	0.5	0.8
Ap	0.3	0.5	0.3	-
Cc	0.2	-	-	0.6
Wo	-	8.2	-	-
Pr	-	-	-	0.2
	100.0	100.0	100.0	100.0

Similarly the occasional gneiss xenoliths in the marginal portion of the granite are also unaltered, except for a narrow mixed zone 2-15mm. wide; thin sections across the latter show some introduction of material from the granite (Plate 11). Fractures within these xenoliths may contain stringers of granitic material, clearly indicating the relative age relationship. The reaction zone along aplite and pegmatite dykes is generally considerably wider, due to their higher volatile content.

Volume And Chemical Analyses.

A specimen of poorly foliated gneiss collected from near the granite contact gave the following volume analysis:- quartz 23%, microcline-microperthite 8%, biotite and muscovite 2%, hornblende 2%, plagioclase 1%, pyrite, magnetite and ilmenite 1%, fine-grained groundmass of quartz, chlorite, sericite and various clay minerals 63%. Two specimens of gneiss from (a) near the Bulawayan sediments (banded pink gneiss), and (b) near the Ultrabasic footwall at the Honeybird Mine, gave higher quartz readings of 30-35%, with a lower percentage of finer-grained groundmass and alteration minerals 55-58%

Chemical analyses were undertaken by the Southern Rhodesian Geological Survey, of a specimen of amphibolite (No.656), and of the gneiss (No 657) near the younger granite contact. The results tabulated opposite in Fig. 8, include the granite-gneiss of Keep (1929) and an analysis of gneiss from the Mashaba-Fort Victoria district (Wilson pers. comm.). Both the Shabani gneiss analyses have a high magnesia content, due probably to the assimilation of amphibolite, compared with the Mashaba-Fort Victoria gneiss. There is a large difference in the percentage of potash between the recent gneiss analysis No.657 and Keep's analysis. Because of the proximity of specimen No.657 to the younger granite, the high potash value is no doubt due to infiltration of potash rich solutions from the younger granite, a feature already observed at the younger granite/ amphibolite contact.

Niggli norms of the gneiss analyses are plotted together with those of the younger granite in Figs. 10 and 11.

Description of the Bulawayan Rocks.

Introduction.

Near Shabani, rocks of this system, comprising altered sediments and greenstones, form the northern part of the Manjeri Range. They have been mapped from the railway cutting north of the Bulawayo road, to approximately a mile beyond their contact with the main body of younger granite, in the north, a distance of 7½ miles along strike (see map Fig. 1).

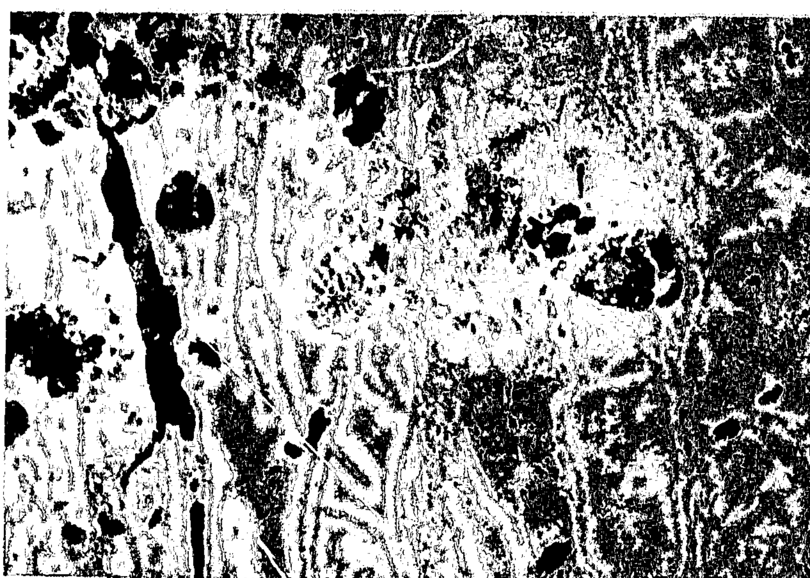
The sedimentary rocks consist of an upper group of conglomerates, grits and quartzites underlain by banded ironstones. These are succeeded by greenstones, consisting of highly altered basic lavas, dolerites and serpentinised ultrabasic rocks. The latter are found between the lavas and underlying sediments. On the large map (Fig. 2), due to poor exposures, the contact between the serpentinised ultrabasic rocks and the altered basic lavas is not shown. The small map (Fig. 1) shows a tentative division between these two rock types.

Only the main features of these rocks will be briefly discussed. Emphasis is placed on points referring to problems of wider implication.

Plate 12.

Banded ironstone micrograph showing the colloform texture of haematite (dark grey). Limonite = light grey. Polished section X 70.

Plate 13.



Micrograph of banded ironstone remnant in the younger granite. Contorted colloform bands of limonite (white) replacing haematite (grey). Polished section X 60.

Sedimentary Series.

Banded Ironstone.

The weather-resisting banded ironstones form the crest of the main range of hills. They are of the usual type, consisting of iron-poor quartz bands alternating with high-grade magnetite and haematite layers. Local variations in the total iron content are clearly visible macroscopically along strike, and with decreasing iron the rock passes into a ferruginous quartzite.

The contact between the banded ironstone and the gneiss is usually covered by scree and alluvium. To the south-east of the area mapped, two exposures of this important contact were located. These two exposures are 5½ miles apart along strike, but exhibit similar features. The contact is marked by a narrow grit zone. According to Laubscher (op.cit.), the gradational passage from gneiss to arkosic grit is due to the latter representing detritus accumulated by weathering on the floor of the gneiss.

Intense folding of parts of the banded ironstone is a common feature. It is due to deformation of an incompetent layer between more competent bands. This type of folding has been termed intraformational corrugation, resulting from differential movement between two layers. The folding may be due to yielding under the weight of overlying rocks, or it may reflect the regional stresses that cause the tilting of the Bulawayan rocks.

The fold axes displayed in the contorted bands plunge steeply west at approximately ± 80°, and strike parallel to the general dip of the sediments; they therefore cannot represent depositional gliding features.

As a result of the resistant nature and near vertical inclination of the banded ironstone, fault displacements are clearly visible in the field and on aerial photographs. The majority are sinistral strike slip faults, with the exception of a pivotal fault located near the northern limit of outcrop. On the north side of this fault the banded ironstone is concealed, but the igneous members dip steeply east (Fig. 2).

In this region a wide iron-rich quartz vein cuts right across the stock of younger granite. It is marked on surface by a distinctive iron-rich gossan. The strike of this vein is parallel with that of the banded ironstones; furthermore, it is also comparable in width. There are no other quartz veins locally with a similar high iron content. Micrographs of two polished sections of this rock are shown opposite (Plates 12 & 13). At first it was difficult to envisage that the vein could represent a structural "resistor" of banded ironstone within the granite. It was therefore considered to have resulted from the infilling of an extensive fracture caused by the transmission of late regional stress forces along the Bulawayan contact and across the granite. This fracture could have been assisted by the tension joints in the granite, approximately parallel to the Bulawayan strike. Hydrothermal solutions following this fracture could have become enriched in iron from the neighbouring banded ironstone. However, since these early views were formulated, a small banded ironstone outcrop has been located just north of the younger granite, in direct continuation of the iron-rich quartz vein. The significance of this feature is discussed in detail under 'Mode of emplacement of the younger granite'.

Conglomerates, Grits and Quartzites.

An excellent exposure of these lower Bulawayan sediments occurs in the railway cutting through the Shabi hill, SSW of Shabani. Pebbles identified in the conglomerates are of quartz, gneiss and banded ironstone. All the gneiss pebbles exhibit a distinct lineation, clearly visible megascopically, due to the preferred orientation of hornblende and biotite. Together with the pebbles of quartz, they no doubt originated from the underlying peneplaned floor of the pre-Bulawayan gneiss.

The pebbles of banded ironstone in conglomerate bands, provide evidence of oscillations in the ancient shoreline of the Bulawayan geosyncline.

Although only three good exposures were found, it is significant that no pebbles of serpentine or pink granite were noted.

No trace of current bedding was observed in the grits or quartzites. The finer grained quartzites have developed a slaty cleavage.

The following points illustrate the sedimentary nature of the Bulawayan contact with the gneiss:-

(a) Foliated gneiss pebbles found in the conglomerate bands.

(b) Linear shoreline conditions occurring over 10 miles of strike, with a shallowing in a NW direction.

(c) No evidence of intrusive tongues and apophyses extending from the gneiss into the sediments.

(d) No trace of thermal metamorphism found in the sediments.

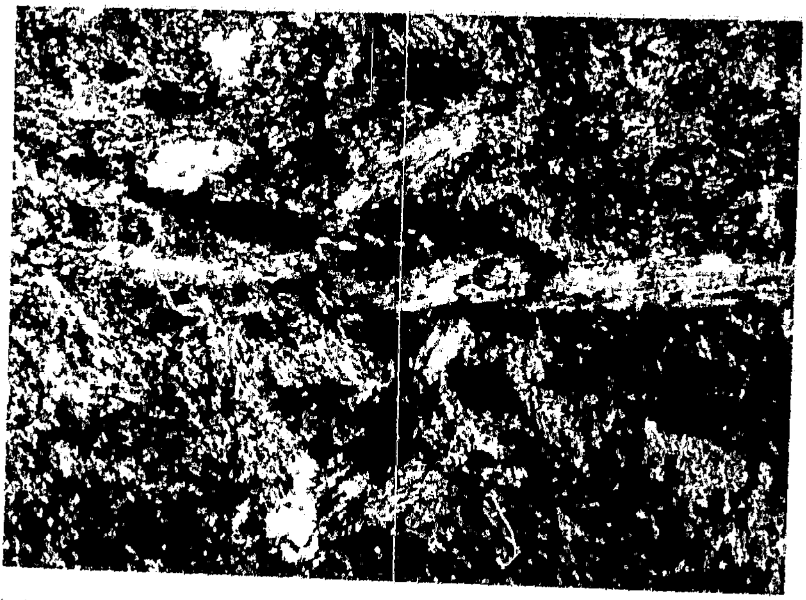
Greenstone Series.

These have been subdivided in the text into serpentinites and spilitic lavas. On the large map (Fig. 2), the area covered by these rocks has been called serpentinised ultrabasic and basic rocks. On the 1:20,000 scale map (Fig. 1) the division used by Laubscher (op.cit.) has been adopted, and the contact between the serpentinites (serpentinised ultrabasic rocks) and the greenstones (serpentinised basic lavas) indicated. The reason why

Plate 14.

Weathering of vertical dipping Bulawayan serpentinized ultrabasic rock. Compression direction parallel to the hammer-head.

Plate 15.



Micrograph of Bulawayan serpentinized ultrabasic rock showing elongation of amphibole crystals by cleavage planes. [illegible]. Crossed nicols. Slide A 4-[illegible].

this contact is not shown on Fig. 2, is due to their poor exposure near the younger granite and their similarity in hand specimens and thin sections, especially the latter near the younger granite where they are completely serpentinised. Furthermore, as described below, there is some doubt as to their mode of emplacement; and if they are extrusive their contact could well be gradational.

Serpentinites.

These occur as an almost continuous belt between Bulawayan basic lavas and sediments to the W and SW of the Shabani Ultrabasic, with which they were previously thought to be associated, in the form of one or more steeply dipping sills (Plate 14). More recently, however, Laubscher (op.cit.) considers that these rocks are not intrusive sills but extrusive ultramafic lavas.

The rocks are nearly completely serpentinised and may contain cross and slip-fibre chrysotile asbestos. The fibre, however, is normally of the harsh variety and has therefore little economic value.

South of the stock of intrusive younger granite, these ultrabasic rocks build two gently rounded hills. The rock here is blue-black in colour and consists of feathery antigorite with tremolite/actinolite needles. Accessory minerals include magnetite and ilmenite altering to leucoxene. The tremolite crystals frequently exhibit narrow twin lamellae, representing gliding planes along which the crystal has been elongated (Plate 15).

Outcrops along the granite contact show the serpentinite has been subjected to severe dynamic metamorphism, but no thermal effects from the granite are noticeable. This rock, also blue-black in colour, is completely serpentinised and contains narrow seams of chrysotile asbestos, rarely exceeding 5mm in width. The fibres are mostly crenulated.

Narrow talc and talc-chlorite schist bands occur within the serpentinite, exposed in a stream bed south of the granite contact. These bands are up to six feet wide, and maintain the normal northwest strike of the Bulawayan sediments. They are therefore thought to represent zones of shearing caused by differential strike movements.

North of the younger granite intrusive, the Bulawayan rocks are represented by serpentinites, and form the highest peak in the area (Dadaya Kop 4137 ft.). Except for this hill, the surrounding land in the northern area is completely flat and without outcrops. The Bulawayan/gneiss contact has therefore been largely mapped by differences in soil and vegetation.

Serpentinised ultrabasic rocks were described by Keep (1929) from the western boundary of the Bulawayan rocks. Although these rocks outcrop 8-10 miles southwest of the

Plate 1[illegible].

[illegible] spilitic [illegible] Nicols.

mapped area, they were investigated and found to be in every respect identical with the rocks along the eastern margin i.e. near Shabani. They could therefore represent the same horizon and being conformable with the Bulawayan sediments and basic lavas, they are probably extrusive ultramafic lavas. Furthermore, their outcrops conform with the major synclinal structure of the Bulawayan System in the Shabani-Belingwe region.

Spilites.

The general nature of the Bulawayan lavas is well known. Only certain special features will be mentioned here. Specimens of a fine-grained, black, amygdaloidal lava, from outcrops to the west of the area mapped, in thin section showed the vesicles to contain epidote, chlorite, calcite and euhedral plagioclase. The composition of the latter was determined by refractive index, optic axial angle measurements, and checked by lamellar extinction and twin axes parameters. All these methods gave an anorthite content of 5-8%. The plagioclase is therefore albite, and since this discovery, several other occurrences of basic pillow lavas were examined. In each case thin sections showed the plagioclase felspar to range from albite to oligoclase (Plate 16).

These rocks therefore have all the characteristics of a spilite, inclusive of a submarine geosynclinal environment.

Furthermore, their association with ultrabasic rocks is also fulfilled. Unfortunately, the main lava occurrence is poorly exposed, being concealed beneath a thick cover of vlei soil. It is only in the extreme northwest that reasonable exposures occur; but these are outside the area covered by the large scale aerial photographs. Therefore, the identification of spilitic lavas is confined for the present to the area west of the younger granite intrusion.

Shabani Ultrabasic : Western Area.

This suite of basic and ultrabasic rocks has recently been described in detail by Laubscher (op.cit.), who considers them to be associated with the early stages of formation of the Bulawayan eugeosynclinc. The Ultrabasic is thought to have been intruded into the gneiss as a sill, which on cooling segregated from the base upwards into dunite, peridotite, pyroxenite and gabbro. This sill has an estimated thickness of plus 5000 feet in the central area; but in the western portion it is considerably less. The Rhodesian and General Asbestos Co. Ltd. have mining rights extending into this western area, called the Nulli Secundus claims; but the far western limit of the Ultrabasic is held by the Honeybird Mine, which recently closed down in 1962.

Although only about one third of the Shabani Ultrabasic falls within the limits of Map (Fig. 2), all the major rock types are represented. A description of this portion of the Ultrabasic intrusion, which dips 30-50^{o} south, is outlined briefly below, from the footwall upwards.

Talc and Talc-magnesite Zone.

Along the contact between the Ultrabasic and the gneiss there is always a narrow zone of talc and talc-magnesite rock. In the area mapped this zone has an estimated true thickness, based on surface exposures, of 120 feet and is considerably thinner than on the Birthday Section in the central area, where a thickness of 500 feet is exposed underground.

Shearing parallel to the strike and dip of the Ultrabasic is common, forming talc schists separated by more competent bands of talc-magnesite rock. Talc pseudomorphs after chrysotile asbestos were found on the Honeybird Mine property. This footwall talc zone no doubt is due to the action of CO_2-rich hydrothermal solutions on dunite and peridotite. The solutions must have flowed along the sheared footwall contact of the gneiss and Ultrabasic, concentrating in the central area where an anticlinal flexure occurs. Wherever the Ultrabasic was suitably fractured, these solutions permeated along shear planes to form the characteristic talc zones, which in turn, have determined the positioning of the chrysotile orebodies.

As a result of this footwall talcification, the gneiss is nowhere in contact with unaltered Ultrabasic; the absence of thermal metamorphism at the gneiss contact is therefore only inferred. This apparent lack of reaction between the Ultrabasic and the gneiss, coupled with the almost undisturbed nature of the gneissic foliation observed at the talc-gneiss contact, led earlier workers to assume that the "granitisation" process was post-Ultrabasic.

Laubscher (op. cit.) explains the lack of thermal metamorphism in the intruded rocks by the emplacement of the Ultrabasic as a low temperature crystal mush.

In the opinion of the writer, the undisturbed gneissic foliation in the footwall gives additional weight to the supposition that the Ultrabasic was intruded as a horizontal sheet, subsequently tilted to the south during the Bulawayan orogeny. If this is correct, then the gneissic footwall need not be disturbed, but the hanging-wall gneiss should show the effect of updoming. From the map (Fig. 2), it can be seen that the western hangingwall gneiss foliations have reflected these movements.

Carbonated Serpentine Zone.

The transition from talc to serpentinised dunite is usually marked by a carbonated serpentine zone consisting of magnesite, talc and serpentine. This rock is extremely competent. In the area of the Honeybird Mine it is poorly developed, and only a narrow band 10-12 ft. wide could be found in the old adit. There were a few traces of brittle chrysotile fibre near the new quarry. On Shabanie Mine, brittle fibre is commonly found associated with the carbonated serpentine zone, where it is thought to be the result of prolonged activity of CO_2-rich hydrothermal solutions, the latter eventually rendering earlier formed chrysotile fibres brittle.

A complete gradation occurs between true silky chrysotile and talc, depending on the degree of replacement of the fibre by talc and magnesite. The effect of this chemical change is to lower the tensile strength of the fibre. Because of the narrow footwall talc and carbonated serpentine zones in the western section, and the poor development of the brittle fibre, it is evident that the hydrothermal solutions in this area were low in carbon-dioxide.

Footwall Serpentine.

Although this serpentine is a yellow-green and rather soft rock, it is nevertheless very resistant to weathering and makes an attractive building stone.

The host rock for the formally mined fibre orebodies at the Honeybird Mine consists of a completely serpentinised dunite. The formation of this serpentine has been influenced by the presence of a sub-parallel diabase dyke in its hangingwall.

Fibre seams in the green serpentine are mostly short, up to ¼" in width, though wider seams, up to ¾", have been recorded. They occur as cross fibre seams in parallel fractures, dipping from 40-50° south. Probably due to the incompetent nature of the serpentine, the chrysotile fibres are usually bent and crenulated to a far higher degree than seams found in partially serpentinised dunite.

The chrysotile fibre in the wider seams was usually fractured and therefore did not materially affect mill production, which yielded only short fibre grades.

Magnetite, magnesite and picrolite are associated with the fibre seams, which are cut by steeply dipping slips and fractures. The latter contain similar gangue minerals, and may parallel the rare steep dipping fibre seams, which conform to the gneiss foliation.

An interesting feature of the old Honeybird Quarry is the influence of slip planes and talc zones on the mining operation. On blasting the rock broke cleanly along these planes of weakness, leaving the quarry with vertical sides which have stood for many years without caving.

Serpentinised Dunite.

The diabase dyke forming the hangingwall of the old quarry enters the talc footwall further to the west (see map Fig. 2). Near this point another quarry was developed and an inclined shaft put down to approximately 500 feet below surface. This quarry, and most of the underground workings, were abandoned when a landslide of waste rock and mill fines flowed into the quarry and threatened the incline. Unlike Shabanie Mine, there has been little or

Plate 17.

Micrograph of black dunite from the Shabani Ultrabasic intrusive, showing a distinct layering of olivine crystals. Location - Honeybird Mine. X 50. Crossed nicols. Slide X 6435.

no geological mapping of the quarry and underground development, both of which are now largely inaccessible.

The chrysotile host rock is similar to that found on Shabanie Mine, consisting predominently of black dunite, with south-dipping fibre seams in serpentinised fractures. The fibres are not crenulated as in the completely serpentinised rock.

The dunite does not appear to weather as rapidly as that at Shabanie; fresh specimens were available on the waste rock pile. Two specimens, examined under the binocular microscope, showed the olivines to occur in distinct layers (Plate 17), a feature not previously observed on Shabanie Mine. This adds weight to the hypothesis that the various layers of the Ultrabasic body are largely due to differentiation by crystal settling.

<u>Comparison of the Honeybird Mine with Shabanie Mine.</u>

Most of the information on the Western Area, other than that derived from general surface mapping, has been obtained from the examination of adits and the old quarry at the Honeybird Mine. As mentioned earlier, the new quarry and workings are no longer accessible. Further information was obtained from personal communication with previous employees of the Mine. Although the information available is therefore not as detailed as that on Shabanie

Mine, nevertheless a close similarity in geological features can be discerned, indicating a comparable genesis of the orebodies. These features are outlined below:-

1) The majority of fibre seams strike and dip parallel to the Ultrabasic footwall. The writer believes that this fact may lend further weight to the hypothesis of crystal settling. Tectonic stresses on whose directional effects the contact itself would exert an influence, could select the initial layering of the olivine crystals as planes of release.
2) A corresponding age relationship has been established between the formation of diabase dykes and talc zones, and the metasomatic processes of steatisation and serpentinisation.
3) Gangue mineral assemblages are identical.
4) Structural influence of the talc zones and dykes in controlling the location of the orebodies is marked in both cases.

Genesis of the Chrysotile Asbestos Deposits.

According to Laubscher's and the writer's own observations, the formation of chrysotile asbestos deposits is thought to have taken place as follows:-

1) Fracturing of the Ultrabasic parallel to the footwall contact, due to different degrees of competence of the

Ultrabasic rocks and the gneiss.

2) Intrusion of the NE trending diabase dyke swarm.
3) Development of wrench and thrust faults, by regional compression in a sub-horizontal plane, along a N24° to 30°E direction.
4) Introduction of hydrothermal solutions along the Ultrabasic footwall, along the major wrench and thrust faults and other zones of shearing and fracturing.
5) Formation of serpentine, part of which was deposited in the parallel fractures, where under suitable stress conditions chrysotile commenced to grow.
6) Economic fibre seams developed in areas where there was a regular supply of serpentinous solutions, and where the force of crystallisation was coupled with a decreasing load on the seam walls.
7) Increasing carbon-dioxide content in the hydrothermal solutions, or prolonged flow of the latter, caused steatisation of the serpentinised footwall and by replacement led to the formation of chrysotile asbestos pseudomorphs.

Black Dunite.

This rock forms the major part of the Ultrabasic. It has an estimated thickness, from borehole information, of a minimum of 2,500 feet in the central part, but is considerably thinner in the western section. Although fresh specimens were unobtainable from surface and few boreholes have been drilled in this area it nevertheless appears from observations in the quarry, that the dunite is more resistant to weathering than the Shabanie Mine equivalent. The olivine crystals are normally euhedral, with serpentine developing along fractures.

Segregated Hangingwall Rocks.

In ascending order from the black dunite, these rocks have been identified as peridotites with 5-20% pyroxene grading upwards into harzburgites and pyroxenites. The latter have largely been uralitised into actinolite rock as a result of concentration of magmatic water in the upper portion of the Ultrabasic. The final differentiate is thought to have been gabbro altered by magmatic water to an actinolite-felspar rock. These four major hangingwall zones are well developed in the western area, and are briefly described below:-

Peridotite and Pyroxenite.

As a result of crystal settling, the dunite grades upwards into a peridotite rock. Since this gradation is quite diffuse, a dividing line is difficult to establish by surface mapping. It is only in boreholes drilled in the far eastern area, that it has been possible to define a clearer boundary. The peridotite is dark-grey, medium-grained and resistant to weathering.

The pyroxenes are predominently euhedral to subhedral orthopyroxenes, that have partially altered to actinolite along fractures and crystal boundaries. With an increasing amount of pyroxene (+20%), the peridotite grades into harzburgite and finally into pyroxenite. In the western portion of the Ultrabasic the harzburgite differentiate has not been plotted on the maps (Figs. 1 & 2), due to insufficient information. In this area pyroxenite is poorly represented, the bulk having been altered to actinolite rock; a narrow lenticular remnant of this rock occurs south of the Honeybird Mine, where it forms a distinct densely wooded ridge.

Actinolite and Actinolite-felspar Rock.

Uralitisation of the pyroxenes first gives rise to a mixed actinolite-pyroxene rock, with cores of residual pyroxene in actinolite, and eventually forms a pure actinolite rock. This rock is dark-green and has a medium-grained hypidiomorphic texture. Calcic plagioclase, altering to zoisite, is at first only present as an accessory, but progressively increases towards the hangingwall gneiss contact. Near this contact specimens collected were found to contain more plagioclase than actinolite, and to include small amounts of quartz.

This actinolite-felspar rock has been described by Laubscher (op.cit.) as an altered gabbro. Had contamination with the gneiss occurred, these marginal rocks would contain more potash in the felspars, as well as more quartz.

Diabase Dykes.

General Description.

The diabase dykes shown on the geological maps are members of a swarm that characterise the region. They trend N70°-90°E in the gneiss, and N30°-70°E in the Shabani Ultrabasic, with an overall dip ranging from vertical to 70°SE. Small wrench faults displace the dykes northwards, creating a false northerly composite strike. The dykes have proved to be extremely useful as a chronological guide, particularly with regard to the delimitation of chrysotile fibre formation. The change of strike in the Ultrabasic is a reflection of the different competence and fracture pattern of this body compared with the gneiss.

Due to differential weathering, the dykes frequently form prominent features. On the ground they can often be traced along strike for several miles, and usually stand out well on aerial photographs.

Weathering along cooling joints leads to the formation of the characteristic rounded boulders, having an oxidised coating that appears to resist further decomposition.

Because their direction is nearly parallel to that of shear planes along which mineralised quartz veins have been emplaced, every linear feature on aerial photographs needs to be investigated in the field. Owing to their similarity in strike the dykes have not proved to be of much use in the determinations of relative age for most of the NE striking gold bearing quartz veins. However, an exception is found on the Red Knight Mine, 1 mile east of Shabani, where a narrow offshoot from the gold vein displaces a diabase dyke. This contrasts with the structural relationship of the Hazard Mine reef, 8 miles SE of Shabani, which is cut off by a similar dyke. Therefore it appears that either the period of ore mineralisation extended over a long time, or else there are two distinct ages.

In the Shabani Ultrabasic, the dykes are faulted by the talc shear zones; in the footwall region the dykes themselves have been completely steatised to form a blocky talc-carbonate rock.

Specimens have been collected from both surface and underground exposures (Shabanie Mine). The colour of these rocks varies from dark green to black, and ranges from medium to fine grained, depending on their width, which may be up to 30 feet. Chilled margins are evident particularly in the wider dykes.

In thin section the rock is seen to consist of labradorite-andesine felspar and augite in various stages of alteration. The alteration products include secondary actinolite, epidote, chlorite, zoisite and sericite. Several slides show only a grey mass of chlorite, zoisite and cloudy felspar.

There does not appear to be any decrease in alteration away from the younger granite; in fact one of the least altered specimens came from the actual contact. Granite/dyke contacts appear to be extremely sharp in the field, and thin sections confirm this observation. It has been argued that this lack of reaction indicates a "dry" condition of the younger granite (Laubscher, 1963). Where a narrow aplite vein was seen to cut the same dyke, only 20 feet away, it has considerably altered this dyke. Therefore, by the same argument, the aplite must be considered as being "wet".

On Shabanie Mine the dykes, which pre-date the formation of chrysotile, have frequently formed structurally favourable areas for fibre growth.

In the writer's opinion, one of the main links between the period of emplacement of the younger granite and the formation of chrysotile asbestos, is the age relationship between the diabase dykes and talc zones (hydrothermal channelways) in the Ultrabasic, and between the diabase dykes and veins of aplite, pegmatite and quartz within the gneiss. This is further discussed under "Conclusions".

Petrographic Description of the Younger Granite.

General Description.

This granite is predominently pink to red in colour, but may locally be greyish-white. It is a medium-grained rock, composed essentially of quartz and felspar. Biotite is normally only present in subordinate amounts. Accessory minerals identified include muscovite, tourmaline, epidote, apatite, zircon, ilmenite and pyrite.

The rock generally has a hypidiomorphic, equigranular texture. There is little variation in grain size within the main granitic area mapped. A slight increase in grain size, away from the contact with the Bulawayan rocks is, however, discernable at the extreme south-western tip (Fig.2). A more marked increase in grain size was observed on a large exfoliated kopje (Majowe Hill) in the north-east area (Fig.1). Here the granite changes from medium-grained at the base of the hill to a coarser grained rock on the top. It has to be stressed, however, that these features are exceptional, and random granite samples will invariably be medium grained.

An average mineral assemblage, based on volume analyses, is as follows:- quartz 41%, microcline-microperthite 42%, plagioclase 16%, biotite 0.5%, accessories 0.5%.

In hand specimen quartz is evident as normal grey to colourless vitreous grains. It is usually anhedral; euhedral crystals are occasionally developed, appear to be a later formation and are noticeably larger. Possibly

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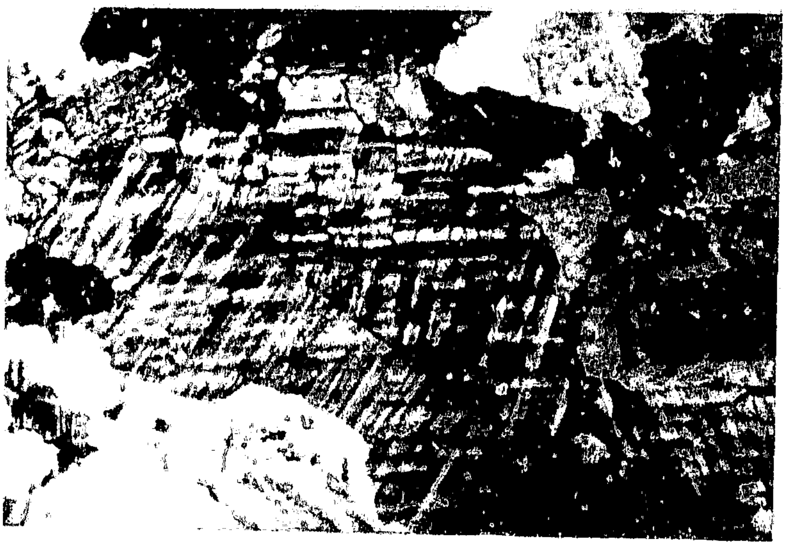
Plate 18.

Micrograph of younger granite showing zoning in microcline-microperthite phenocryst.
X 32. Crossed nicols. Slide X 4642.

Plate 19.



Younger granite micrograph showing simple twinning in microcline-microperthite crystal.
X 28. Crossed nicols. Slide X 4687.

they grew in residual pockets of magma, enriched in volatiles trapped in an almost consolidated crystal mush. In one slide (X4928) such euhedral crystals had apparently grown in a miarolitic cavity.

In thin section only some of the anhedral quartz veins show fracturing and strain extinction. These are comparable in appearance to the quartz grains found in the gneiss. Perhaps these represent residuals from the palingenetic or anatectic fusion of the gneiss. Most quartz grains, however, appear to have crystallised out simultaneously with felspar (micrographic texture), or slightly later.

Three felspar minerals were identified, namely microcline, plagioclase and microcline-microperthite. Orthoclase was not observed in any of the granite thin sections. The felspars are mostly subhedral to euhedral, with plagioclase white and microcline and microcline-microperthite pink in colour. Plagioclase can occasionally be identified macroscopically by lamellar twinning, and the rarer microcline-perthite by its cross-hatched twinning. Although microcline has been identified in thin section, and from volume analyses constitutes 10% of the rock, it is thought by the writer that this mineral is probably a finely twinned microcline-microperthite. It has therefore been included in the microcline-microperthite total of 42%. Twinned and zoned microperthite have been identified

Plate 20.

Micrograph of altered pegmatite vein near the granite/amphibolite contact, showing euhedral apatite crystals. X 40. Crossed nicols. Slide X 4676.

(Plates 18 & 19), but these are relatively rare. The plagioclase was found to be oligoclase by a number of methods which are compared and described later.

Biotite and muscovite are normally only sparingly present. Concentrations of muscovite do however occur along fractures. The biotite is reddish-brown and occurs as ragged anhedral plates. Pleochroic haloes around zircons were not noted.

Euhedral crystals of apatite and tourmaline are usually extremely rare, but local concentrations were found, especially near the amphibolite/granite contact (Plate 20).

Epidote is usually found as small, brownish-green, subhedral to euhedral crystals occurring in narrow stringers, and occasionally in isolated pockets. Its greatest development was in the zone of contact with the Bulawayan greenstones.

Ilmenite, in small amounts, was found to be present in every slide examined, normally considerably altered to leucoxene.

Pyrite is extremely abundant locally in the Bulawayan/granite contact zone. In a localised area in the south-west extremity of the granite (Fig. 2), pyrite makes up 5-10% of the rock. As a result of weathering of the pyrite, the rock has been rendered coarse and pitted. Large vughs are found coated with sulphur derived from the reduction of the pyrite.

Fig. 9.

Chemical Analyses of the Younger Granite.

Sample No.	655	S363	S364	170(aplite)	Chinoia Younger granite.
Laboratory No.	64/226	"	"	64/227	63/394
%					
SiO_2	75.05	76.40	77.00	76.46	73.39
Al_2O_3	13.68	13.34	13.56	12.95	14.06
Fe_2O_3	0.40	0.40	0.30	0.09	1.02
FeO	0.75	0.27	0.27	0.68	0.73
MgO	0.20	0.57	0.51	0.21	0.33
CaO	1.00	0.31	0.30	1.03	1.40
Na_2O	3.79	4.23	4.20	3.48	3.82
K_2O	4.30	4.40	3.80	3.90	4.30
H_2O	0.51	-	-	0.62	0.60
CO_2	0.05	-	-	0.02	0.14
TiO_2	0.11	-	-	0.10	0.01
P_2O_5	0.03	-	-	0.04	0.07
MnO	0.03	-	-	0.04	0.04
	99.99	99.93	99.96	99.62	99.91

Niggli's Norm Estimation

Q	31.9	31.1	34.3	37.0	30.2
Or	26.0	26.0	22.5	23.5	25.5
Ab	34.5	38.0	37.5	32.0	34.5
An	4.5	1.5	1.5	4.0	5.0
C	1.2	1.2	2.3	1.7	1.6
Mt	0.5	0.4	0.3	0.3	1.1
Il	0.2	-	-	0.2	-
Cc	0.2	-	-	-	0.4
Ap	-	-	-	0.3	0.3
En	0.4	1.6	1.4	0.6	1.0
Fs	0.6	0.2	0.2	0.4	0.4
	100.0	100.0	100.0	100.0	100.0

Chemical Composition of the Younger Granite.

Two chemical analyses of the granite were carried out by Turner and Newell Laboratories, Manchester, on samples taken from the central and eastern margin of the main granite mass. A third sample of granite from an exposure in the NW area was analysed by the Southern Rhodesian Geological Survey. No analyses of this granite had been carried out previously (Fig. 9).

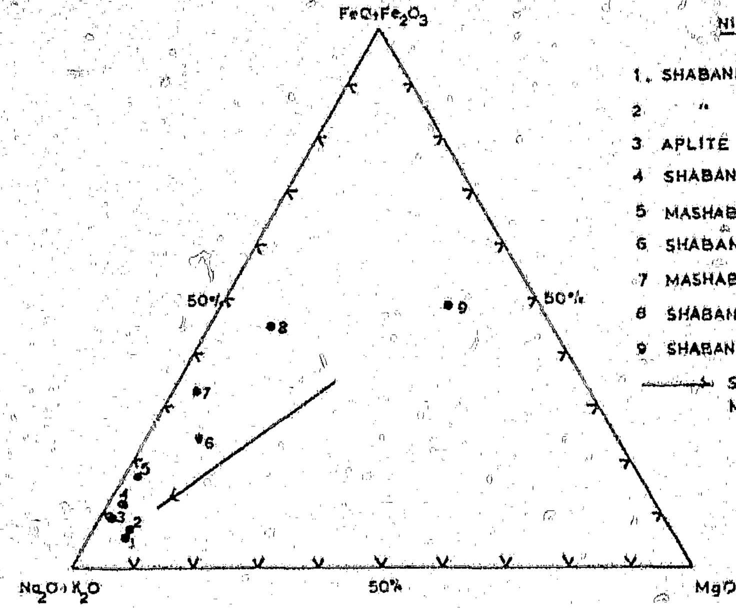
For purposes of comparison analyses of similar intrusive granites from the Mashaba - Fort Victoria District, recently completed by the S.R.G.S. on samples collected by J. Wilson, have also been listed.

Niggli values and norms have been calculated for each of these analyses. The analyses show the younger granite to be potash-rich, high in Na_2O, but low in CaO. The iron and magnesium content is extremely low. Silica and alumina together make up nearly 90% of the rock; the latter is hence very leucocratic and rather aplitic in composition.

The analyses of these younger granites are very similar to those of potash-granite and aplite as given by Soper (1963). Their composition corresponds closely with the end member of Whitfield's (1959) and Soper's series, consisting of equal amounts of quartz and potash felspar and plagioclase combined, with biotite as a minor constituent.

Figs. 10 & 11.

FIG 10

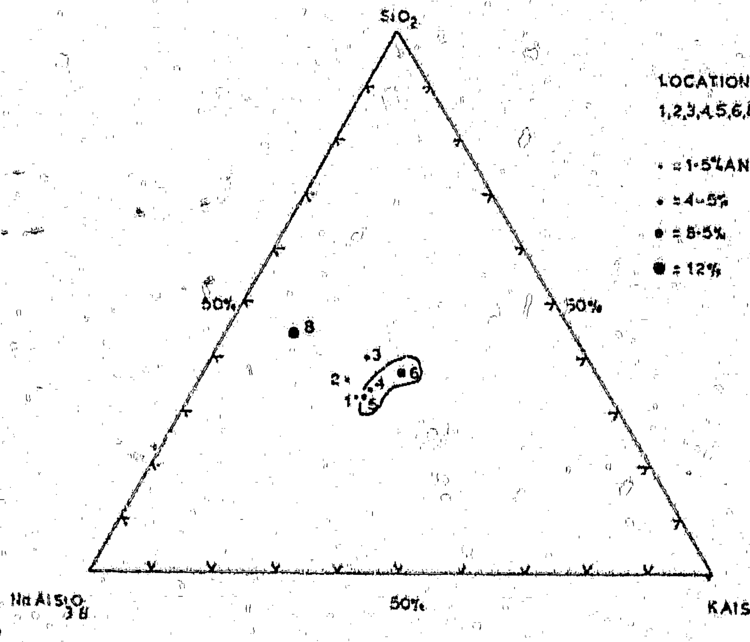


NIGGLI NORMS

1. SHABANI YOUNGER GRANITE S364.
2. " " " S363.
3. APLITE S120.
4. SHABANI YOUNGER GRANITE S655.
5. MASHABA " "
6. SHABANI GNEISS S657
7. MASHABA "
8. SHABANI GNEISS (after KEEP 1929)
9. SHABANI AMPHIBOLITE S656

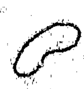
→ SOPER'S 1963 CALC-ALKALINE MAGMATIC DESCENT

FIG 11



LOCATION OF SAMPLE NUMBERS 1,2,3,4,5,6,&8 AS ABOVE.

• = 1·5% ANORTHITE		Nos 1 & 2.
• = 4–5%	"	Nos 3, 4 & 5.
● = 8·5%	"	No 6.
● = 12%	"	No 8.



REPRESENTS NORMATIVE ALBITE ORTHOCLASE & QUARTZ FROM 571 ANALYSED PLUTONIC ROCKS WITH OVER 80% Q, Ab & Or (WASHINGTON'S TABLES – BOWEN & TUTTLE 1958)

These series, which lead to a potash-rich granite, can arise by magmatic differentiation. Whitfield (1959) believes that it would have been extremely fortuitous for the series to have evolved by metasomatic processes. This, however, is the magmatists approach, and does not take into consideration differential mobilisation (Backlund 1946), or granitisation of potash-rich sediments.

Simonen (1948) has demonstrated a general increase in potash content from syn-kinematic to late-kinematic granites in Finland. This has been shown to be a very widely spread feature. The setting of the younger granites in the Shabani-Mashaba region indicates that they are very late- or post-tectonic, with reference to the Bulawayan orogeny. It is possible that they post-date the succeeding Shamvaian tectonism, but unfortunately there have been no age determinations undertaken.

The tabulated analyses of the three Shabani younger granite specimens (Fig. 9), have been plotted on a triangular variation diagram (Fig. 10). They are compared with an aplite analysis of a vein in the gneiss near the granite contact. Further comparison is made with analyses of specimens collected by J. Wilson from two younger granite localities in the Mashaba and Fort Victoria areas.

In order to demonstrate the distinct contrast between the gneiss and younger granite, three analyses of the

Shabani gneiss have been plotted, together with a gneiss analysis from the Mashaba-Fort Victoria area (Fig. 8)

The location of specimens from Shabani on which chemical analyses have been completed are shown on Fig. 5, together with positions of specimens used in the volume analyses.

The younger granite analyses are also compared on a variation diagram (Fig. 11) with the plots of 571 granite pluton analyses listed in Washington's Tables, that contain over 80% quartz, plagioclase and potash felspar (Bowen 1958).

Probably the most important feature arising from the analyses of these Rhodesian younger granites is their remarkable constant chemical composition. The analyses of the Rafingora granite (post-Lomagundi) described by Stagman (1961), and those of Hunter (1956) from the Mbabane and Hlatikula granites (Swaziland G4 subgroup), are mentioned as they are identical in composition to the Shabani younger granites, and furthermore are considered to be late magmatic differentiates.

Volume Analyses.

Method and degree of accuracy.

16 thin sections were cut from 12 specimens of younger granite and detailed volume analyses carried out on them, using a Swift electronic point counter.

Slide variation.

In order to obtain reliable results, two counts per slide of +1000 point determinations were taken along N-S and E-W traverses. The maximum error per slide arising between these two counts, for the mineral quartz is 5.2%. The variation between N-S and E-W traverses for the three principal minerals, i.e. quartz, microcline-microperthite and oligoclase are plotted in Fig.12. Where the variation exceeded 5.5%, a third reading was taken.

Sample variation.

To establish the volume variation per sample, two specimens - Nos. 183 and 462 - were selected, and three slides cut from each parallel to the principal axes of the samples. The maximum variation for quartz found in specimen 183 was 3.7%, whilst for 462 it amounted to 8.4%. The large variation in 462 is due to one low reading of 33.1%. By taking the mean value of two readings per slide, the maximum variation in quartz per specimen is reduced accordingly to 1.4% for slide 183, and 4.1% for slide 462. If the low reading of 33.1% quartz in 462 is omitted, the sample variation is depressed to 1.8%. The % value for the twelve readings for specimens 183 and 462 are given in Fig. 13. By taking the mean value of each pair of readings, the sample variation for a medium grained equigranular granite, which has no preferred mineral

Figs. 12, 13 & 14.

FIG 12

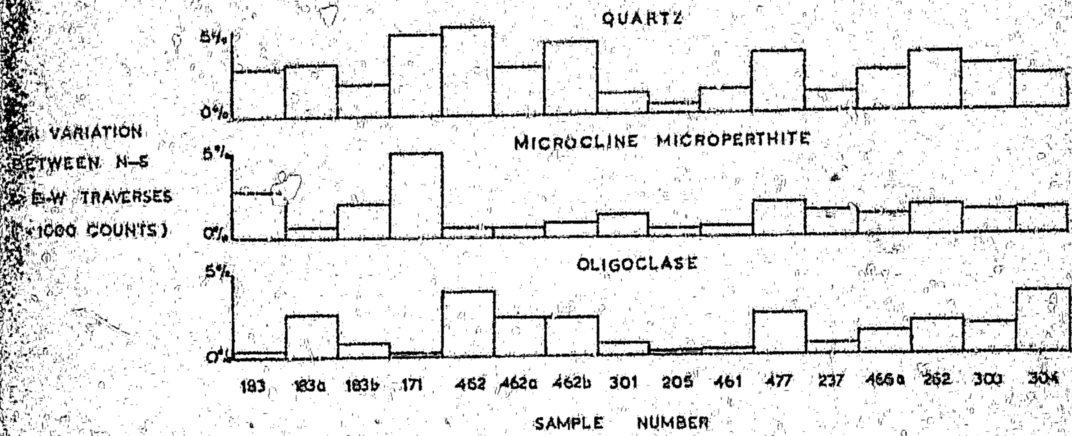


FIG 13

		QUARTZ	MICROCLINE MICROPERTHITE	PLAGIOCLASE	BIOTITE	EPIDOTE	OPAQUE MINERALS
183	E–W	37·4	48·6	12·0	1·1	TR	0·9
	N–S	34·6	51·4	12·2	1·0	"	0·8
183a	E–W	38·2	48·7	10·3	1·7	"	1·1
	N–S	35·2	49·3	12·9	1·6	"	1·0
183b	E–W	38·3	47·2	13·1	0·9	"	0·5
	N–S	36·5	49·2	12·2	1·2	"	0·9
462	E–W	38·3	45·2	14·9	0·3	1·3	TR
	N–S	33·1	45·7	18·7	0·2	2·3	"
462a	E–W	38·6	42·8	18·0	0·2	1·0	"
	N–S	41·5	41·8	14·9	0·2	1·6	"
462b	E–W	37·1	42·5	18·3	0·5	1·8	"
	N–S	39·8	42·0	16·1	0·5	1·6	"

FIG 14

	% VOLUME AVERAGE FROM 12 ANALYSES	MEAN VARIABLE BETWEEN E-W & N-S TRAVERSES
QUARTZ	41	2·7
MICROCLINE MICROPERTHITE	42	1·4
OLIGOCLASE	16	1·6

orientation is as follows:- quartz 1.4 - 1.8%, microcline-microperthite 1.8 - 3.2%, plagioclase 0.8 - 1.0%. These are comparable with the slide variation (Fig. 12), and will approximate to the mean variable for each mineral (Fig. 14).

Variations in locality.

An attempt was made to determine the variation between granite specimens taken from the same locality. Specimens 300 and 301 were selected from granite outcrops approximately 180 feet apart in the western granite area. Their mean mineral composition is shown below:-

Specimen No.	Quartz.	Microcline Microperthite.	Plagioclase.
300	48.9	34.7	16.4
301	51.8	32.3	17.9

A small variation occurs between the two principal constituents: quartz and microcline-microperthite, whilst plagioclase remains more or less constant. Due to this slight variation between quartz and microcline-microperthite, their use as possible indicators for variations in the composition of the granite pluton was investigated. The mean volume analyses of these two minerals were plotted at each sample locality. From this it is immediately apparent that there is an increase in quartz values towards the centre and an increase in microcline-microperthite towards

Figs. 15A & B.

FIG 15a

YOUNGER GRANITE TRAVERSES

Scale 1:20000 see FIG 5.

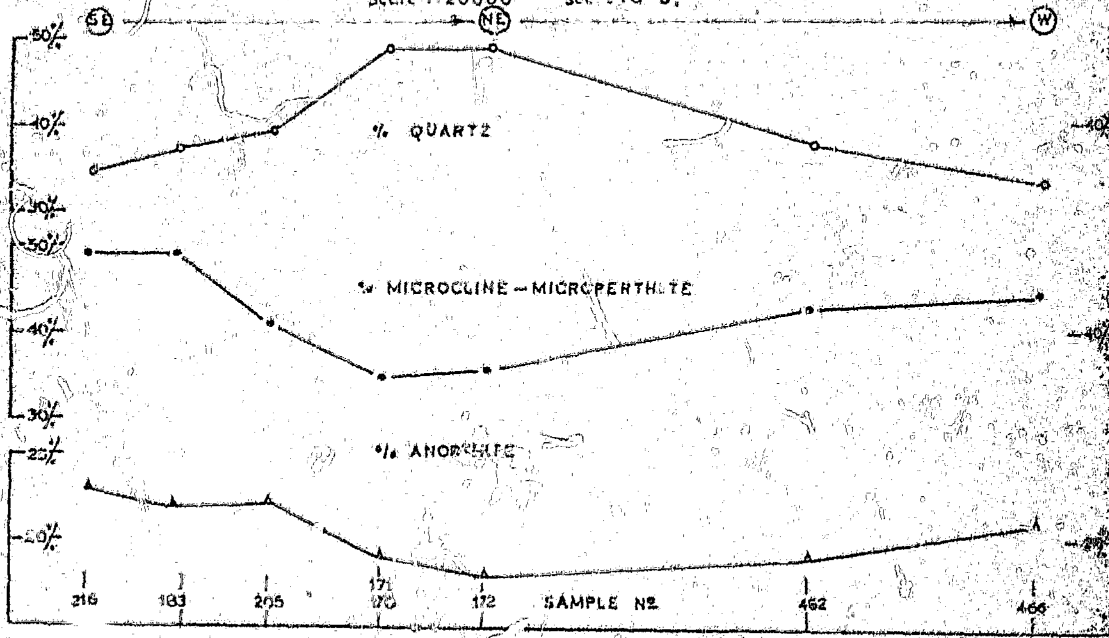
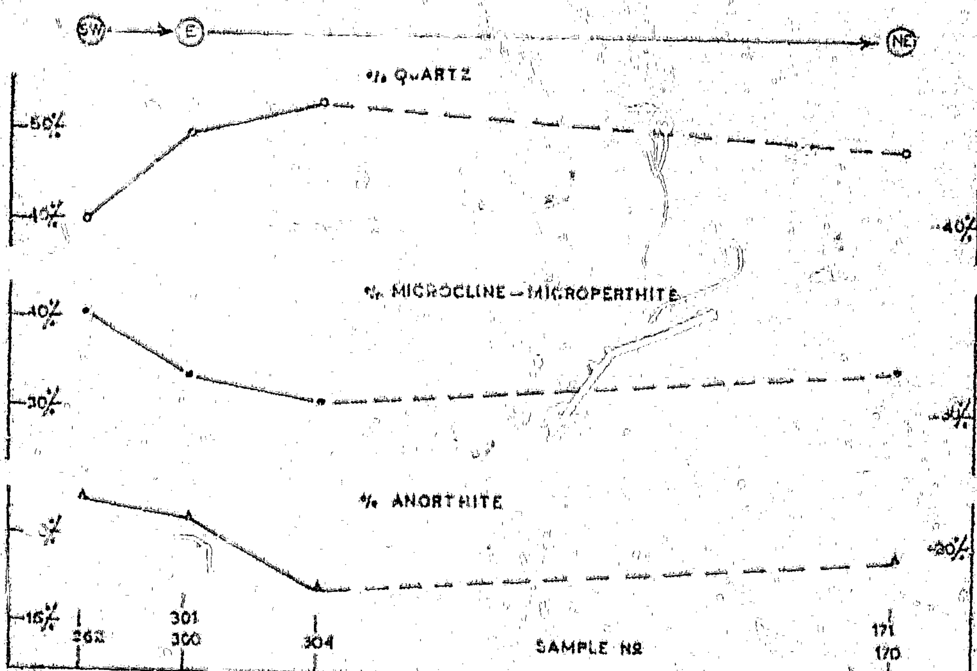


FIG 15b



the margins (Figs. 5 & 15). In the directions indicated, quartz increases from 34% to 54% and microcline-microperthite from 32% to 51%.

These large variations cannot be explained by sample or slide anomalies. Similarly, they are not due to bias by the author, for the following reasons:- (a) The specimens were collected at random during the field mapping of the granite. (b) The trend was observed only when all the volume analyses had been completed and their positions plotted. Traverses N.W. and S.E. across the granite are shown in Fig. 15.

The importance of these trends are stressed, as they indicate emplacement of the elongated body of granite from a central tension fracture or low pressure area, in the gneiss. The latter has a free silica count of only ± 23%, which is considerably lower than the free silica minima of 34% in the granite.

The mineral variation ascertained can be explained in various ways. The well known Soret effect has often been invoked to explain such features. The "transformationists" would propose that after emplacement of the granite from a central fracture, and while still in a sufficient degree of permeability, further solutions emanating from the same fracture, may have entered the mass in two phases:-
(a) an early felspathisation phase, followed by (b) a later silicification phase.

Plagioclase Determinations.

Introduction.

As a result of the variations in relative mineral assemblages within the granite ascertained by the volume analyses, it was hoped that by carrying out a comprehensive examination of the plagioclase, variations in its composition might also be noticeable. This proved to be the case, for anorthite content varied from 10-19% in the central body, to 16-23% at the margin (Fig. 15). Furthermore, the lower sodic value does not appear to alter around the granite periphery; it is therefore concluded that the gradational variation is due to the relatively faster ionic migration of calcium compared to sodium, and not assimilation of country rock. If the latter were the case, then the western portion of the granite, where it is in contact with serpentinised ultrabasic and basic rocks, should have a higher calcium content than the granite at the contact with gneiss.

Measurements of 2V.

The anorthite content for different values of 2VZ were read off from Smith and Van der Kaaden graphs for plutonic plagioclase, reproduced in Slemmon's paper (1962).

Due to the large axial angle, which varies from 89-104^{o} for the Z optical direction, with the main range being from 91-96^{o}, it was only rarely possible to measure both optic axes. By doubling the angle, 2VZ was obtained, but this method also doubled the observational error. Corrections for differing indices of refraction for plagioclase and glass were made using the Federow graph. These corrections depressed the observed 2VZ angle by 1-2 degrees. Inaccuracies in measurement and plotting are believed to be of the order of $\pm$ 2% An, for the mean value derived from repeated readings.

The plagioclase range for the main granite, using the corrected 2VZ measurement, according to Smith's (1958) graph is 15-23% An., and from Van der Kaaden's (1951) graph, 14-21% An. The author considers the latter result to be nearer to the true value. The mineral can therefore be defined as oligoclase (Fig. 16).

Parameters of twinning axes for complex albite-ala B twins.

Parameters of the twin axes were plotted and compared with the relative positions of X Y Z. Using the stereographic construction, positions of X and Z optical direction poles and the twin axis were then compared with Nikitin's values for complex twins. The identification of the twin law was achieved by (a) comparing the position of the twin axis with the composition plane, and (b) calculation of the approximate anorthite content, by comparing the Z optical direction of each subindividual and the normal, to the composition plane (Z/\CP).

It was found that the majority of the plagioclase felspars examined are complex twins of the albite-ala B law, and occasionally of the albite-carlsbad law.

Anorthite values obtained from Nikitin's curves are tabulated in Fig. 16. They are compared with the results obtained from Slemmon's graph, derived from the angles measured between the X and Y optical directions and the twinning axis. The anorthite content of plagioclase in the granite ranges from 11-22% according to Slemmon's graphs, and from 10-23% according to Nikitin. Although the range variation appears similar, there is a noticeable decrease in the lower limit of anorthite content derived from Slemmon's figures, compared with values obtained by the other methods. An average value arrived at from twelve thin sections of granite, gave the following results:-

2V (Smith, op.cit.).	= 20%
2V (Van der Kaaden, op.cit.).	= 18.5%
Twinning Axis (Slemmon's, op.cit.).	= 21%
Twinning Axis (Nikitin, op.cit.).	= 19%
Refractive Index (9 thin sections).	= 18%

It is the opinion of the writer that results arrived at by using twin axis determinations can be misleading, unless a large number of readings are taken and the results compared with another method. Even with extreme care, errors can occur in (a) observational determination of the X, Y and Z optical directions; (b) stereographic plotting of these directions; (c) observation and plotting of the composition plane; location of the twin axis. The latter case proved to be the principal source of error, due to the close stereographical plotting of the Z optical directions on the lower hemisphere. This resulted in a large triangle of error between Z, Z_1, Y, Y_1 and X, X_1, and therefore a relatively inaccurate twin axis plot.

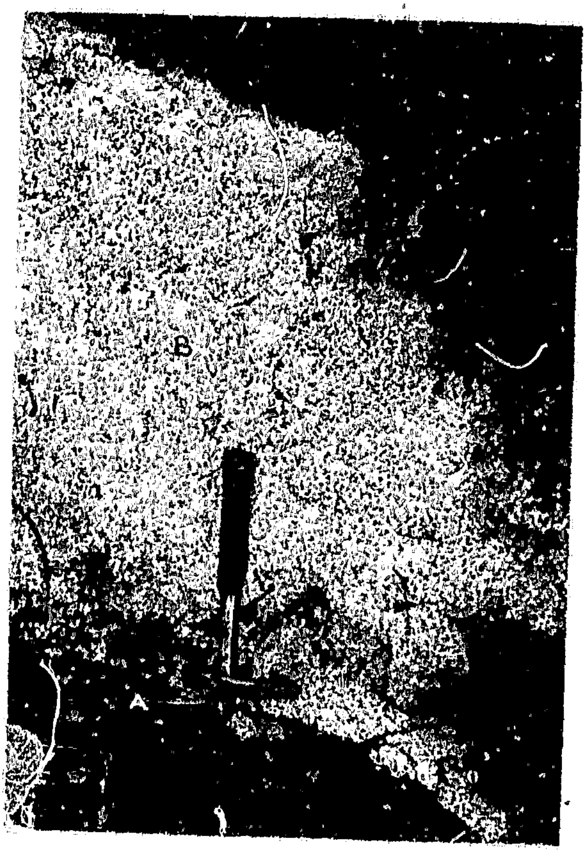
Refractive index determinations of (001) cleavage flakes.

Plagioclase identifications were carried out on nine hand specimens, by crushing felspar fragments, recognising (001) cleavage flakes and determining their refractive indices. Using normal immersion liquids, the third decimal place of the refractive index was obtained by mixing the liquids directly on the glass slide, and measuring the index immediately with a Berek Refractometer. A range in anorthite content of 13-21% was established, which compares favourably with the previously noted results obtained from 2V and twin axis measurements.

Maximum extinction angle.

Plagioclase crystals in two thin sections were determined, using the method described by Naidu (1958). Although the results were comparable to those obtained by other methods, there was no improvement in accuracy or speed; this method was therefore discarded.

Plate 21.



A. Melanocratic lamprophyre dyke with small xenolith of younger granite.

B. Younger granite.

C. Leucocratic lamprophyre dyke.

Both dykes are finer grained than the granite.