

TABLE 18

Plagioclase	57.1
Hornblende	41.7
Biotite	1.2
	100.0

The texture is subophitic. The plagioclase has a composition ranging from andesine 48An_{48} to 33An_{33} (on account of positive zoning). It is lath-shaped. The hornblende is hypidiomorphic and bluish green along Z; it has undergone partial replacement by biotite.

(b).- The fine-grained amphibolites and their modifications.

(i).- The fine grained-amphibolites

The principal minerals of this rock are plagioclase and hornblende with subsidiary ore, biotite, chlorite, quartz, sphene and epidote.

A typical modal analysis is given in table 19.

TABLE 19

Plagioclase	38.7
Hornblende	59.7
Ore	1.6
	100.0

The texture is subophitic to granular. The plagioclase occurs in laths 0.2 to 2.0 mm. long and is albite-Carlshad twinned. It shows positive zoning and its composition varies from andesine 40An_{40} to oligoclase 25An_{25} . Reaction (as described below) has occurred ^f_A between the plagioclase laths and the hornblende, and some of the plagioclase crystals have been transformed into finely granular aggregates whose composition varies little from oligoclase 25An_{25} . In one instance observed by the writer, the plagioclase was completely reduced to tiny grains 0.2 to 0.05 mm. in diameter.

The properties of the hornblende are as follows :

2V (-) = 76 to 80°	Z = bluish green
Z/c = 19 to 21°	Y = olive green
	X = light yellow

It occurs in needles or hypidiomorphic plates 1.0 mm. long. The larger crystals are usually poikiloblastic, including numerous grains of quartz or ore. Some of these large hornblende crystals are rimmed with smaller

crystals of hornblende. Several stages of transformation of the hornblende-plagioclase association are usually observable in the same specimen or even in the same thin section. In the first stage, the poikilitic inclusions in hornblende progressively disappear: the core of the hornblende crystals is still crowded with inclusions of ore, but the rim is free of them. The colour of the core is pale green while the rim is bluish green. When the inclusions have completely disappeared, the crystals are bluish green throughout. At the same time, they begin to encroach upon plagioclase, penetrating them and separating laths into grains, which are further corroded until all traces of lath habit have disappeared.

Biotite is present in small quantities replacing hornblende. Grains of ore are rimmed with sphene and are abundant in the groundmass. Quartz and epidote are rare. Some chlorite and prehnite are present in the vicinity of microfractures of the rock.

(ii).- Modifications of the amphibolites.

1.- Light patches

The modal composition of the light patches into which the amphibolites merge progressively along the margin of the northern "granitic" massif is rather variable from sample to sample.

An average of the most common rock type is as follows (table ²⁰ III):

TABLE III²⁰

Plagioclase	48.3
Hornblende	51.0
Biotite	0.7
	100.0

The plagioclase occurs in aggregates of several grains free of amphibole and up to 1 cm. in diameter. It is partly broken down into tiny grains which have recrystallised and are finely imbricated. Its composition varies from oligoclase 28An_{28} to 22An_{22} . The amphibole is hornblende and crystallises in needles or hypidiomorphic plates 0.2 mm. long. These have a bluish green colour along Z and are concentrated in layers or clusters. Biotite (replacing hornblende), sphene and epidote are subsidiary. Ore is very rare. In the vicinity of microfractures, the plagioclase is saussuritised, the biotite chloritised and prehnite occurs.

2.- Brecciated amphibolite

The dark angular (sometimes rounded) fragments of the breccia are of regional fine-grained amphibolite. They show no differences in

constitution or texture from unbrecciated amphibolites. The light material cementing these amphibolites is predominantly feldspathic: amoeboid plagioclase is grouped in aggregates up to 1 cm. in diameter. Its composition varies from andesine 31An_{31} to oligoclase 25An_{25} . It is usually associated with a little interstitial quartz. The aggregates are separated by laminae of large hypidiomorphic (3 to 4 mm.) plates of hornblende; however, some veins may be entirely feldspathic. The gradation along contacts with the amphibolite fragments takes place within less than 1 cm.; from the fragments of amphibolite to the feldspathic veins the plagioclase loses its lath habit and the hornblende progressively diminishes in quantity.

(c).- Dykes cutting the amphibolite.

(i).- Uralite gabbro

The black medium grained rock cutting the amphibolites in dykes was found to be uralite gabbro. Its principal minerals are plagioclase and uralite. Quartz, biotite and sphene are subsidiary.

Modal analyses are as follows (table ²¹IV):

	TABLE IV ²¹	
	I	2
Plagioclase	55.0	39.6
Uralite	44.2	56.1
Quartz	-	2.5
Biotite	0.8	1.8
	100.0	100.0

The texture is ophitic. The plagioclase crystallises in laths 2.0 mm. to 1 cm. long and has normal zoning. Its composition ranges from andesine 45An_{45} to labradorite 60An_{60} . It is albite-Carlsbad twinned and heavily saussuritised (epidote and sericite).

The uralite amphibole occurs in aggregates of long fibrous needles and is pale green to light bluish green. Its fibrous habit renders precise identification very difficult; but, on account of its large optical angle (85° and more), this mineral must be in the actinolite range. This actinolitic character associated with the typical fibrous habit is characteristic of uralite. Quartz is rare and interstitial. Sphene rims grains of ore and epidote and biotite are associated with the amphibole.

(ii).- Granitic dykes

Offshoots from the northern granitic massif are composed of plagioclase, microcline and quartz with some biotite. The grain size is even (5mm.) and the albite-Carlsbad twinned plagioclase has a composition ranging from andesine 32An_{32} to oligoclase 26An_{26} . Microcline is always interstitial and quartz occurs in aggregates. This rock is very similar to the trondhjemite dykes of the northern massif (see chapter IV).

Offshoots from the red granite sheet show no mineralogical differences from the parent rock as described in chapter V.

(iii).- Dykes of dolerite

This rare rock is composed of plagioclase and clinopyroxene up to 5 mm. in grain-size, with subsidiary biotite and ore. It is perhaps similar to post-Karoo dolerites.

IV.- PETROGENETIC CONSIDERATIONS(a).- Facies and origin

The basic assemblage of these rocks is hornblende-plagioclase and they can be assigned to the almandine amphibolite facies; the absence of other characteristic minerals prevents further definition.

The origin of the main fine-grained amphibolites is clear, the subophitic textures pointing out to a magmatic origin. They have resulted from the metamorphism of a large conformable sheet of basic igneous rock. The strong oscillatory normal zoning of the plagioclase is a relic of the magmatic texture of this rock. During metamorphism hornblende is a reactive mineral and the initial subophitic texture undergoes progressive destruction together with redistribution of the minerals.

(b) Transformation of basic rocks into amphibolites

In 1934, WISEMAN recognised three trends in the metamorphism of basic rocks. Suffice it for the purpose of this work to state that the amphibolites of this belt may be assigned to the second series of this author, the abnormal metadiabases, in which hornblende-oligoclase is the assemblage ultimately produced.

SUTTON and WATSON (1951) enlarged WISEMAN's concepts and also distinguished three trends in the metamorphism of dolerites : (i).- Laxfordian metamorphism : hornblende-plagioclase is the final assemblage; (ii).- SW Highlands amphibolites : epidote-chlorite are the first to form and hornblende, which is early-formed, is metastable and readily alters into augite; (iii).- Pyroxene granulites: enstatite-diopside are the stable minerals.

The ortho-amphibolites of the Lilani region bear a strong similarity with those of the Laxfordian metamorphism: hornblende-plagioclase is also here the final assemblage. In the Laxfordian metamorphism, SUTTON and WATSON have studied the effect of metamorphism on dolerites (pyroxene, plagioclase) and observed the following stages of progressive transformations: (i).- Pyroxene rimmed by secondary hornblende; (ii).- Pyroxene completely replaced by poikiloblastic hornblende-quartz aggregates; (iii).- Feldspar laths recrystallizing; (iv).- Quartz-hornblende recrystallizing; (v).- Biotite forming; (vi).- Green augite forming. Unfortunately, a complete series of progressive transformation is not observable in the Lilani region; the initial pyroxene has been completely replaced by hornblende.

It is to be recalled that, in the orthoamphibolite belt hornblende plates are often rimmed with smaller needles or plates of hornblende. Also, poikiloblastic plates of hornblende (inclusions of quartz and ore) show the following evolution: inclusions of quartz disappear, leaving a residual core still retaining inclusions. The core is pale green and the inclusion-free rim of the hornblende is bluish green; the core progressively resorbs the inclusions and the inclusion-free crystals take on a bluish green colour throughout. At the same time hornblende encroaches upon plagioclase laths, separating them into smaller amoeboid grains of oligoclase; some biotite usually forms from hornblende after this stage.

The same trend as in the Laxfordian metamorphism can be recognized here: complete replacement of pyroxene by poikiloblastic hornblende (stage ii); transformation of plagioclase by reaction with hornblende (stage iii) and recrystallization of hornblende (stage iv); formation of some biotite (stage v). As the pyroxene has been completely replaced, stage (i) is no longer observable; apparently the metamorphism was not of the intensity required for augite to form (stage vi). It also seems that in the Lilani region, the recrystallization of hornblende (stage (iv) of SUTTON and WATSON) was a phenomenon synchronous with the recrystallization of plagioclase (stage (iii)). Apart from these features, the similarity of the mineralogical transformations in the orthoamphibolites of the Lilani area with the intermediate stages of the Laxfordian-type metamorphism is unmistakable.

The small inclusions of ore in the hornblende are most probably the residue (magnetite) of the amphibolitisation of pyroxene; at a more advanced stage of metamorphism the residue was completely absorbed by the hornblende and homogenisation of the hornblende with assimilation of the inclusions of ore took place. At the same time, hornblende began to react with plagioclase and to take a bluish green colour throughout. It is of interest to note that SUTTON and WATSON attribute this bluish green colour to incorporation of soda. This tends to show that, as hornblende encroaches upon plagioclase, some soda from the plagioclase has been taken up by the hornblende. However, as the composition of the plagioclase in the process changes, from andesine-oligoclase to oligoclase, the quantity of soda available could not have been very large. On the contrary, lime must have been transferred from the plagioclase into the hornblende in appreciable quantity, in order to ^calcify the plagioclase. This transfer of lime is probably the factor which brought about the homogenisation of hornblende, allowing the core to evolve into normal hornblende. As biotite formed at this stage, it is most likely that this was brought about by the release of potash in solid solution in plagioclase, set free as this mineral reacted with hornblende.

The presence of several reaction stages in these ortho-amphibolites shows that complete equilibrium was not quite reached between the various components of these rocks. Factors responsible for this lack of equilibrium are complex: insufficient metamorphism or duration of metamorphism, distribution of stresses, etc. The writer suspects that the presence of water was of primary importance. Without water, no hydroxyl-bearing mineral such as amphibole could have formed. This presence or absence of water most probably determines whether a dolerite under metamorphism is going to follow the 'wet' Laxfordian trend or the 'dry' pyroxene granulite trend. In this case the writer suggests that the metamorphism of these rocks was stopped at various intermediate stages because water was no more available, or only in insufficient quantities. This supports WILCOX and POLDERVAART (1959)'s statement that water content is more important in the metamorphism of dolerites than the actual temperature reached.

(c).- Evolution of the Ortho-amphibolites

The oldest rock of this belt is the coarse amphibolite occurring in xenoliths in the fine-grained amphibolites. The subophitic texture of this material indicates that it is also of igneous origin. It is unfortunately absolutely impossible to determine its structural shape; this has been disrupted and broken down during the emplacement of the main dolerites (i.e., corresponding to the fine-grained amphibolites before metamorphism), younger in age.

At a later stage of metamorphism, various processes locally modified the aspect and the structure of the amphibolites to ^{form} light patches and breccias in the amphibolite. It is recalled that these breccias are cemented by veins of plagioclase and that the lighter patches are slightly richer in plagioclase than the surrounding fine-grained amphibolites. In the writer's opinion, occurrence of plagioclase in fissures or in patches at the intersection is to be explained by migration of plagioclase from the fine-grained amphibolites into these zones, and not by feldspathization. The writer was struck by the fact that no foreign minerals are to be found in these plagioclase-rich zones: no microcline or biotite indicating infusion of potash or no quartz due to infusion of silica.

On the other hand, YODER and TILLEY (1962) have demonstrated that amphibolites may yield anorthositic phases if the temperature is such that plagioclase begins to melt (this temperature is fairly low) and if a driving force can squeeze the plagioclase out of its mother rock (these writers suggest filter-pressing). Hence, the origin of these concentrations of plagioclase may be traced to the regional amphibolite itself. As for the driving force, RAMBERG (1952) showed that minerals growing in fractured zones have lower free energies than the same minerals in adjacent rocks. Hence, the partial melting of plagioclase and its migration towards low pressure zones (fractures) brought about the concentration of plagioclase in these fissures or fractured zones. This phenomenon operated as well for brecciated zones as for fractures or intersections of fractures, giving rise in the latter case to patches several feet ⁱⁿ diameter.

These fractures and breccias occur mostly in the northern portion of the belt, i.e. in the vicinity of the northern "granitic" massif, and have without doubt been caused by the emplacement of this massif. It may also be suggested that the additional supply of heat from the "granitic" massif brought about the partial melting of plagioclase. On the northern

slopes of the Lilani valley (not studied by the writer), GEVERS (1963) has shown these amphibolites to have been subjected to metasomatism with introduction of soda (plagioclase) and potash (biotite and potash feldspar). The writer will show (chapter IV) that this resulted from the reaction of the northern "granitic" massif on the amphibolites when the acid rock came in close contact with the basic rocks.

An interesting, though somewhat minor, point is the origin of the uralite in the uralite gabbro which is younger than the amphibolites. Uralite is the product of hydration of pyroxene. Was the water necessary for this uralitisation of post-magmatic or metasomatic origin? In other words, has the gabbro been emplaced at a stage of metamorphism for it still to be affected by the latter or after the main period of metamorphism? The writer thinks that this particular rock cannot possibly have undergone regional metamorphism: the plagioclase is relatively fresh, in lath habit, zoned and shows no traces of reaction with amphibole. It is very likely that uralite is the result of autometamorphism by post-magmatic solutions and that the gabbro has been emplaced after the main period of metamorphism.

V.- CONCLUSIONS

The probable succession of events is as follows:-

- (i).- Basic igneous rock in unspecified depth environment.
- (ii).- Emplacement of main body of basic igneous rock from (i).
- (iii).- Burial, tectonism and metamorphism of the complex. Amphibolitisation.
- (iv).- Emplacement of the northern "granitic" massif.
- (v).- Fracturing and partial recrystallisation of the amphibolites at some stage of (iv).
- (vi).- Emplacement at lesser depth levels of red granite sheet to the south with little metamorphic effect on amphibolites.
- (vii).- Emplacement of a few veins of uralite gabbro and dolerites (post-Karoo?).

CHAPTER IV.- THE NORTHERN "GRANITIC" MASSIF

I.- INTRODUCTION

This "granitic" massif is situated some two miles, as the crow flies, to the north of the confluence of the Lilani and Hlimbitwa rivers. It has a trend more or less parallel with the central and metasedimentary belts to the south. Unfortunately, its northern boundary is hidden under the TMS plateau or under the alluvia of the upper course of the Hlimbitwa river, so that hardly more than a mile-from south to north- is open to direct observation. The uppermost headstream of this river is nearly devoid of exposures; but fortunately, in the southern portion of the area, the river turns sharply and flows E-W for a mile or so, entrenching itself deeply in the basement rocks. It is very likely that this abrupt change of course is due to an unexposed E-W fault.

The boundary between the "granitic" massif and the ortho-amphibolitic rocks ~~cropping out~~ ^{cropping out} to the south is far from sharp: transition occurs over about 500 yards. This transition zone is, according to the writer, a reaction or contamination zone between the "granitic" rock and the amphibolitic rock.

With the "granitic" rock are associated basic dykes. These present certain features which will be used according to WEGMANN's methods to determine the geological history of the massif.

II.- THE "GRANITIC" ROCKS

A.- GENERAL FEATURES AND FIELD RELATIONSHIPS

The uncontaminated rock is exposed in the northern portion of the area. It is a medium to coarse-grained rock, having a low colour index and studded with pink spots (feldspar) giving a characteristic pink shade. The rock, however, is far from uniform; very often it is interwoven with a quite different-looking rock which has a grey hue and is fine-grained relatively to the pink granitic rock. In sufficiently large exposures, the grey rock gives the impression of a network transecting the pink rock

and isolating more or less rectangular chunks of the latter, often to form a breccia whose fragments of pink rock are cemented by a matrix of grey rock (Photo 40, Plate XXI). The pink rock seems to be corroded and to occur as relics in the grey rock. The pink rock may also be cut by dyke-like bodies of grey rock (Photo 41, Plate XXI), which can be followed for only 10 yards or so and then vanish or merge into larger patches of grey rock. Xenoliths of pink rock are to be seen in these dyke-like bodies (Photo 60, Plate XXXI).

These observations show that the grey rock is the younger of the two and disrupts the pink rock. SEDERHOLM (1926) has given this type of structure a special name: dictyonitic (net structure). He applied it to the penetration by a network of veins of an older granitic rock which has not been entirely dissolved. Recently (1962), WEGMANN has used this term for a similar type of structure in Norway.

Towards the south of the massif, the colour of the pink rock becomes darker and eventually loses its characteristic tint, taking on a bluish shade due to numerous clots of mafic minerals (hornblende and biotite). In the vicinity of the ortho-amphibolites, dark material usually occurs in the form of long bands, but irregular patches are also formed. The dictyonitic structure is no longer to be seen. There are also a number of amphibolitic relics which have undergone extensive granitization and have no particular orientation (Photo 42 and 43, Plate XXII).

B.- THE NATURE OF THE "GRANITIC" ROCKS

The term "granite" or "granitic rocks", as it is used here, must be understood as a general term designating the complex series of rocks of the northern massif. They actually range in composition from adamellite to quartz-diorite.

This terminology has been used by various writers, such as SEDERHOLM, WEGMANN and, in particular, TURNER and VERHOOGEN (1960, p. 342).

Modal analyses have been carried out.

It can be seen from table ²² that the pink "granitic" rocks have a fairly homogeneous mineralogical composition. All of them are poor in potash feldspar. According to LINDGREN's classification, the term granodiorite is restricted to rocks in which the potash feldspar makes up from 13.3 to 33.3 of the total feldspar.

On this basis none of these rocks can be termed granodiorites (though sample 2 is not far away from the lower limit of this clan). However, French writers (JUNG, 1958 b; H. & G. TERNIER, 1956) consider that all "granitic" rocks with less potash feldspar than plagioclase may be called granodiorites. The American classification appears to be more precise to the writer and these rocks may thus be assigned to the diorite clan and called quartz-diorites to indicate the abundance of quartz. Thus, in the case of the northern "granitic" massif, the term quartz-diorite stands for a rock poor in potash feldspar (less than 1/8 of the total feldspar) and rich in plagioclase and quartz (more than 20% for the latter). Also in the rim of the massif (table ²³ 21), the rock has the composition of a quartz-diorite, though it is here richer in calcic minerals. Samples 1 to 4 have been taken in sequence from the southern rim of the massif towards its interior and exclusively in the rim of bluish rocks (no pink rocks from more central portions are included).

The composition of the grey rock is more variable (table ²⁴ 22). Samples 1, 3 and 6 are too rich in potash feldspar to be quartz-diorites and must hence be called granodiorites. Samples 2, 4 and 5 have a quartz-dioritic composition.

TABLE 22

Pink granitic rocks

	Plag.	Mi.	Ho.	Bi.	Qz.	Epidote	Sphene	Ore
<u>1</u>	54.0	1.3	-	10.8	23.0	9.6	1.3	-/100.0
<u>2</u>	54.6	6.3	-	1.7	36.4	0.3	0.5	0.2/100.0
<u>3</u>	56.6	4.3	-	12.5	25.9	0.2	0.4	0.1/100.0
<u>4</u>	56.0	4.2	-	10.1	26.1	2.3	0.8	0.5/100.0

N.B. sample 1 showed a few traces of contamination by basic material.

TABLE ~~II~~ 23Contaminated pink granitic rocks.

	Plag.	Mi.	Ho.	Bi.	Qz.	Epidote	Sphene	Ore
<u>1</u>	40.6	0.7	4.2	21.9	21.0	11.1	0.3	0.2/100.0
<u>2</u>	47.7	3.9	-	18.2	22.6	6.9	0.3	0.4/100.0
<u>3</u>	47.6	2.1	-	11.1	36.1	2.0	0.7	0.4/100.0
<u>4</u>	48.2	1.8	-	12.4	34.8	1.8	0.4	0.6/100.0

These samples have been taken in sequence from the southern rim of the massif towards its interior.

TABLE ~~III~~ 24Grey granitic rocks

	Plag.	Mi.	Ho.	Bi.	Qz.	Epidote	Sphene	Ore
<u>1</u>	35.7	15.1	-	6.8	39.2	1.2	-	2.0/100.0
<u>2</u>	51.2	0.5	-	25.1	21.9	0.5	0.6	0.2/100.0
<u>3</u>	53.8	10.1	-	9.3	24.3	0.5	1.0	1.0/100.0
<u>4</u>	59.2	7.2	-	3.8	25.2	4.4	0.1	0.1/100.0
<u>5</u>	57.6	3.8	-	15.6	19.9	3.0	0.1	-/100.0
<u>6</u>	58.1	9.6	-	8.2	22.4	1.4	0.3	-/100.0

C.- PETROGRAPHIC DESCRIPTION(a).- The Relics

Inclusions of foreign rock, which are particularly abundant in the rim of the massif, are seen under the microscope to consist of cloudy unidentifiable plagioclase, biotite flakes and some interstitial quartz.

* They undoubtedly represent relics of granitized amphibolite. A few hornblende crystals persist in the groundmass but, towards the rim of the massif...

(b).- The Pink "Granitic" Rocks

These have been shown to be quartz-diorite. Under the microscope, plagioclase occurs in phenocrysts up to 1 cm. in length and in small grains in the groundmass, averaging 0.1 mm. in diameter. The composition of the phenocrysts varies from andesine 33An_{33} to oligoclase 25An_{25} and they are more or less saussuritised (sericite and epidote). Most of the phenocrysts exhibit some normal zoning and are twinned predominantly according to the albite-Carlsbad law. They have wavy extinctions and show some mechanical

twinning⁺ due to incipient cataclasis. They are never perfectly rectangular, their edges are rounded and their outlines are not clear cut. Parts of phenocrysts have been converted into aggregates of small plagioclase grains retaining the same general optical orientation as the large crystals from which they have been derived. Parts of a crystal have been separated by fine groundmass plagioclase resulting from granulation in the interior of such crystals. The groundmass plagioclase has a mean composition of oligoclase 25An_{25} . Detailed examination of the groundmass also reveals that, whilst many plagioclases in it have ragged outlines, some patches consist of neat mosaics of tiny plagioclase polygons tightly packed with delicate imbrication texture.

Potash feldspar is microcline and may occasionally reach 3 mm. in diameter, though it is mostly interstitial. The microcline is seen to corrode the plagioclase and the larger crystals of potash feldspar can dissolve whole patches of the plagioclase groundmass. The larger plagioclase crystals are then usually mantled by the potash feldspar, but are also seen to be corroded by it. Relics of undigested plagioclase are not uncommon in microcline. Usually, in the zone of contact between the two feldspars, the plagioclase is fringed with an albitised rim crowded with droplets or fingers of quartz (myrmekite). Very often, the potash feldspar has partly resorbed ^{the} ~~the~~ myrmekite, but has failed to dissolve its quartz which is isolated in the microcline from the rest of the intergrowth. Also, a few myrmekitic warts growing from the plagioclase into the microcline have been observed. However, these are much less abundant than the first type. Relics of plagioclase within microcline have only fragmentary myrmekitic rims, if any. String perthites are abundant in the microcline, particularly in the vicinity of myrmekite or in granulated and fractured areas of the crystals. Potash feldspar is also present inside some plagioclase, but only in small rectangular patches having the same optical orientation as the crystal host. These patches show no evidence of corrosion and are thus antiperthites, i.e. intergrowths of potash feldspar in a plagioclase lattice resulting from the exsolution of the potash feldspar which had been in limited solid solution in the plagioclase at high temperature.

⁺ Mechanical twinning is a phenomenon well-known to metallurgists: twinning lamellae are bent and end in wedges (MICHOT, 1938).

Flakes of biotite have a maximum length of 1.0 mm. Their pleochroism varies from brown to green. In the contamination zone only, biotite occurs in knots where it replaces hornblende and is associated with hornblende, epidote, sphene and chlorite. It may be altered to a bluish chlorite and to sphene, the latter being the first mineral to appear. A few flakes are embayed by plagioclase crystals and have been partly corroded by it. Ilmenite is left behind as a residue of this corrosion, insoluble in plagioclase.

In the very rim of the contamination zone, hornblende is present (see table II). It always occurs in knots whose outer shells are composed of biotite surrounding cores of hornblende. The biotite has obviously replaced the hornblende; it is also found intergrown with the latter, replacement having been effected from cleavages and cracks. The terminal portions of biotite flakes in direct contact with hornblende are frequently symplectic, i.e. include delicate patterns of tiny drops and canals of quartz. The optical properties of this hornblende are the following :

Z/c	= 20 to 23°	Z = bluish green
2V(-)	= 73 to 77°	Y = olive green
Birefringence	= about 0.023	X = light yellow

Away from the rim of the reaction zone, farther towards its interior, these knots of biotite persist, but the hornblende in the core has been completely replaced. Epidote, sphene, apatite and quartz are associated with these aggregates.

Quartz is common and its individual grains may reach 2 mm. in diameter. It usually occurs in lenticular aggregates, 5 to 6 mm. long. It strongly corrodes the groundmass but only mantles the porphyroblasts. It is also found in rounded inclusions, up to 0.2 or 0.4 mm. in diameter, (without any relationship to myrmekite!) in plagioclase phenocrysts. These appear like relics of former quartz crystals ingested by the plagioclase.

Epidote occurs in small needles in saussurite or in large grains (1.0 mm.) associated with biotite and hornblende.

Sphene is found in the vicinity of biotite-chlorite and hornblende and may also rim the opaque ore, particularly in the hornblende-biotite aggregates of the contamination zone.

Opaque ore is not abundant and is mainly associated with hornblende. An other accessory is apatite which occurs with hornblende and biotite.

(c).- The grey "granitic" rocks

These are finer-grained than the pink quartz-diorite and are more evengrained. The plagioclase may reach 1.5 mm. but on average does not exceed 0.5 to 0.8 mm. Its composition varies from oligoclase-andesine 30An_{30} to oligoclase 15An_{15} . The main composition is about oligoclase 20An_{20} . It has a slight normal zoning and is twinned according to the albite-Carlsbad or albite laws.

The microcline is mostly interstitial, but its scarce porphyroblasts may reach 1.5 mm. in diameter. It slightly corrodes the plagioclase, showing on a smaller scale-the same relationships with it as in the pink "granitic" rocks.

Biotite occurs in schlieren of flakes 0.2 to 0.5 mm. in length.

Quartz grains are 2.0 mm. in diameter and corrode the groundmass.

Epidote, sphene and ore are subsidiary and smaller than 0.1 mm.

D.- CHEMISTRY.

Four specimens in all of pink "granitic" rock have been analysed. Samples 1, 2 and 3 (see table ²⁵ IV) are at various stages of contamination: sample 1 comes from the very edge of the massif, sample 2 is two hundred yards away from this and sample 3 has been taken at about 500 yards from the rim of the massif. Sample 4 is uncontaminated pink "granitic" rock. The analyses are presented in the following form: in the first column are the weight percentages, and in the second the cation percentages. The Niggli values appear in the third column and the norm has been calculated in the fourth column.

Specimen 5 is a sample of grey "granitic" rock.

Cation percentages have been plotted against cation percentage of silicon, i.e. from the heavily contaminated rock of the rim ($n^{\circ}1$) towards the uncontaminated rock ($n^{\circ}4$) (Fig.2). The silicic end-member ($n^{\circ}4$) is seen to be much poorer in magnesium, iron and calcium than the contaminated rocks. Aluminium does not vary significantly, though it increases slightly towards $n^{\circ}4$ specimen. This silicic end-member ($n^{\circ}4$) is richer in sodium but poorer in potassium. The cation percentage of magnesium varies in a spectacular way. From little more than nil in the uncontaminated zone, it reaches 5.3% in the rim of the massif. Ferrous iron and calcium also increase, on the average, in a significant way. Mineralogically, this variation is expressed by the presence of hornblende in sample 1 and by the presence of its replacement products (biotite, epidote) in samples 2 and 3.

TABLE IV 25

CHEMICAL ANALYSES (Analyst : J. LAMBERT)

(i).- Contaminated quartz-diorite from the rim of the massif. Corresponds to sample I in table II.

	Weight	Cation	Niggli Values		Norm
	%	%			
SiO ₂	60.31	56.9	si	196	Ilm = 0.4
Al ₂ O ₃	16.94	18.8	k	0.32	Or = 14.0
Fe ₂ O ₃	2.40	1.6	mg	0.56	Ab = 30.0
FeO	3.02	2.4	-	-	An = 25.0
MgO	3.66	5.3	al	32	Mt = 2.4
CaO	6.01	6.0	fm	32	Wo = 2.0
Na ₂ O	3.29	6.0	c	21	Ens = 10.6
K ₂ O	2.31	2.8	alk	15	Fs = 2.8
TiO ₂	0.25	0.2		100	Qz = 12.8
H ₂ O+	1.08				100.0
H ₂ O-	0.07				
	99.34	100.0			

(ii).- Contaminated quartz-diorite 200 yards away from the rim of the massif. Corresponds to sample 2 in table II.

	Weight	Cation	Niggli Values		Norm
	%	%			
SiO ₂	63.80	60.0	si	23.6	ilm = 0.4
Al ₂ O ₃	16.51	18.3	k	0.28	Or = 15.0
Fe ₂ O ₃	1.10	0.8	mg	0.49	Ab = 36.5
FeO	3.30	2.6	-	-	An = 20.0
MgO	2.31	3.3	al	36	Mt = 1.2
CaO	4.40	4.5	fm	2.6	Wo = 1.0
Na ₂ O	4.04	7.3	c	18	Ens = 6.6
K ₂ O	2.44	3.0	alk	20	Fs = 4.0
TiO ₂	0.26	0.2		100	Qz = 15.3
H ₂ O+	0.83				100.0
H ₂ O-	0.04				
Total	99.03	100.0			

(iii).- Quartz-diorite slightly contaminated. 500 yards from the rim of the massif. Sample I of table I.

	Weight %	Cation %	Niggli Values		Norm
SiO ₂	65.34	61.0	si	253	llm = 0.6
Al ₂ O ₃	17.20	19.0	k	0.13	Or = 6.5
Fe ₂ O ₃	1.32	0.9	mg	0.50	Ab = 44.5
FeO	0.94	0.7	---	---	An = 22.6
MgO	1.19	1.7	al	39	Mt = 1.2
CaO	6.23	6.2			Wo = 3.6
Na ₂ O	4.91	8.9	fm	14	Hem = 0.1
K ₂ O	1.14	1.3	c	26	
TiO ₂	0.39	0.3	alk	21	Ens = 3.4
H ₂ O+	1.02			---	Qz = 18.1
H ₂ O-	0.25			100	---
	99.93	100.0			100.0

(iv).- Uncontaminated quartz-diorite. Upper Hlimbitwa river. Sample 2 of table 1.

	Weight %	Cation %	Niggli Values		Norm
SiO ₂	70.86	66.6	si	361	llm = 0.2
Al ₂ O ₃	17.45	19.4	k	0.13	Or = 7.0
Fe ₂ O ₃	0.40	0.3	mg	0.41	Ab = 43.6
FeO	0.17	0.1	-----		An = 15.6
MgO	0.20	0.3	al	52	Hem = 0.3
CaO	3.08	3.1	fm	4	Cor = 3.1
Na ₂ O	4.80	8.7	c	17	Qz = 30.2
K ₂ O	1.17	1.4	alk	27	---
TiO ₂	0.20	0.1		100	100.0
H ₂ O+	1.08				
H ₂ O-	0.61				
	100.02	100.0			

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