THE GEOLOGY AROUND LEEUWFONTEIN

NORTH-EAST OF PRETORIA

by

P.D. TOENS BSc.

Presented in partial fulfilment of the requirements for the degree of Master of Science, in the Faculty of Science, University of Pretoria.

PRETORIA.

February, 1952.

I N D E X

Page.

Page

----

1. INTRODUCTION

A. Historical.

In 1898 Molengraaf discovered the Leeuwfontein Alkaline Complex and gave a description of a "nepheline-syenite" from the farm Leeuwfontein (320) (2,p.89). In the same year Henderson (1, p.45) gave a description of the soda-syenite under the name of "hatherlite", but in 1904 Molengraaf (3) proposed the name "anorthoclase-amphibole-pyroxene-syenite" for Henderson's hatherlite.

In 1903 Hall (4, p.33) discovered the foyaite plug on Franspoort (426) and in the same year gave a more detailed account of the alkaline rocks from Leeuwfontein. He again discussed the alkaline rocks in 1932 (5).

In 1909 Brouwer (6) gave a very detailed petrographic description of the alkaline rocks of this area. The names he attached to these rocks have been referred to by Shand (8).

However, it was not until 1920 when Professor Shand (8,9) embarked on his self-imposed task of mapping all the larger, and many of the smaller, occurrences of alkaline rocks in South Africa, that the true nature and extent of these outcrops became known.

Van Biljon (10) in a recent paper, has commented on the origin of the syenites and foyaites in the upper part of the Pretoria series.

The diabases, hybrid rocks, hornfelses, and sediments of the area investigated received little more than mention from the various authors who described the alkaline rocks. However, van Biljon in his recent paper describes some of the rocks in this area. Hybrid rocks, similar to some of those found in this area, have been described by Lombaard (15) Daly (17) and

Kynaston (18) in an area near the Premier Mine five miles to the east.

B. Method of mapping.

The area to be described was mapped during the winter months of 1950 on aerial photographs on the scele of 1/20,000.

A printed base map on the scale of 1/25,000 showing the centres of the aerial photographs was enlarged to 1/20,000 with the aid of a pantograph, and the data transferred on to it.

C. General Description of the Area.

The investigated area, which is about 15 miles north-east of Pretoria, measures approximately 5 miles by $2\frac{3}{4}$ miles and is drained by the Leeuwspruit which rises in the south of Franspoort, flows north through the centre of the area and joins the Pienaars River immediately north of the area investigated.

The general strike of the hybrid rocks, "diabases" and sediments is east-west, the dip varies between 18° and 45° north, with an average of about 30°. The alkaline rocks of Leeuwfontein and Franspoort are transgressively intrusive into the country rocks, the alkaline dykes usually run in a north-south direction.

The area may be divided into two fairly distinct regions:

1. The Franspoort Area in the south, and
2. The Leeuwfontein Area in the north.

1. The Franspoort Area.

a) Physiography.

The Franspoort area stretches from south of the Magaliesberg or M_1 quartzites (4714')to the Leeuwfontein or M_3 quartzite horizon (4373'). The area between the ridges is usually between 200 and 500 feet lower.

The Leeuwspruit, which rises in the south of the farm Franspoort passes through the gap in the Magaliesberg quartzites, is joined by the Edendalespruit south of the Baviaanspoort or M_2 quartzite horizon, and then passes through a narrow gap in the Leeuwfontein quartzites south-west of Mr. Braak's house on its way to the north.

On either side of the Leeuwspruit the land rises gently to the east and west. The foyaite dyke in the east of the area forms the watershed between the Pienaars River and the Leeuwspruit. The watershed between the Bynespoort River and the Leeuwpoort-Edendalespruit lies to the west and just outside the area investigated.

The Franspoort area, with the exception of the quartzite ridges and a small area in the north of the farm Franspoort and north-west of Nooitgedacht, is devoid of any bush. The area that is covered with alluvium is suitable for agriculture and grazing.

b) <u>General Geology</u>.

The geological succession going from south to north will be described briefly.

Below the Magaliesberg, or M_1, quartzites there are a few isolated outcrops of typical Pretoria series shales and granophyric norites . A dyke of porphyritic syeno-diorite was found in the Leeuwspruit.

The Magaliesberg quartzites have been recrystallised fairly intensely and in some instances the dip has been almost completely obliterated. Zones of brecciation are common and usually have a north-south or north-east/south-west strike. Mineralisation is evident in a few localities where the re-crystallisation and brecciation have been most intense, a Limonite-like substance (gossan?) is found associated with intense brecciation 500 yards south west of the bridge over the Edendalespruit. Laterite is also very common.

The quartzites show a variation in dip between 35^{O}N and

$20^{O}N$, the average being about $25^{O}N$. The exact thickness is uncertain but it is probably about 1,000 feet. They are overlain by thin bands of shale and quartzite which outcrop only in the east of the area and in the Leeuwspruit. Their dip varies between 45^{O} and 35^{O} N.

The Franspoort foyaite plug lies in an open poort where the strike of the Magaliesberg quartzite hill changes suddenly from east-west to north-west/south-east.

The geological structure of the gap suggests a sagging of the Magaliesberg together with the sediments immediately overlying it. The maximum dislocation appears to be along a zone running north-east/south-west to the west of the foyaite plug, and possibly connected to two major faults shown on the Pretoria sheet to end on the southern part of Vlakfontein (293) after running roughly in a north-east/south-west direction for many miles.

Professor Shand (9, p.82) concludes that "it is probable that the dislocation of the Pretoria beds and the intrusion of the foyaite are probably connected incidents, and that the erosion of the unusually wide and deep poort was favoured by both factors." There must, however, have been a considerable time lapse between the faulting of the Pretoria beds, which are younger than the Bushveld granite but probably pre-Loskop, and the intrusion of the alkaline rocks which are post-Waterberg. The foyaite intrusion in the south of Franspoort (436) is of a transgressive nature and has been described by Shand (9,p.84) "as a large plug or very small stock." It has a rudely elliptical form, with a distinct elongation in a north-east/south-west direction, and measures 3/4 of a mile by 1/3 of a mile.

Above the foyaite plug there is a low rubble-covered ridge consisting of trachy-andesitic rocks that are older than the foyaites. Numerous dykes occur in the trachy-andesites, some of which appear to have acted as feeders to the lavas.

Syeno-dioritic dykes are the most common although a few dykes of monchiquite, and foyaite are also found. Most dykes have a north-south strike and are poorly exposed. In the Leeuwspruit there are numerous dykes and sills of syeno-diorite, as well as an outcrop of very weathered diabase or granophyric quartz-norite associated with quartzites and shales already mentioned.

The trachy-andesitic lavas which stretch for about 600 yards north of the foyaite plug are probably only a thin covering over the quartzites and shales which outcrop in, and to the east of, the Leeuwspruit. In the western section of the area there are no outcrops on this horizon, but as there are numerous sandpits to the west of the Franspoort-Leeuwfontein road, where good quality building sand is obtained, it does not seem likely that alkaline rocks occur near the surface.

North of the trachy-andesite outcrop there is a strip of brack-looking soil which is rich in Na_2CO_3 and NaCl and is probably underlain by an alkaline rock. This strip of soil is bordered by foyaites in the north and east .

The two foyaite outcrops shown on the map in the north of Franspoort (farm) may be connected just beneath the surface. The outcrop in the river appears to be a small oblong plug and is about 75 yards in diameter and is intrusive into quartzites.

The foyaites on the west bank of the Leeuwspruit strike east-west for about 500 yards and are nowhere more than about a 100 yards wide.

The foyaites on the west bank of the Leeuwspruit are intrusive into a lava similar in many respects to that found north of the larger foyaite plug in the south.

North of this small trachyte outcrop there are a few quartzite lenses, and to the north of this there is a large body of granophyric quartz-norite . The granophyric quartz-norite, quartzite, trachy-andesitic lava, and foyaite are cut by numerous dykes of syeno-diorite and foyaite.

The granophyric quartz-norite has an east-west strike and is intrusive into the shales and quartzites immediately below the M_2, or Baviaanspoort, quartzite horizon. At the Edendale Lead Mine it was found to be a transgressive sill (19, p.95).

The M_2 quartzites show considerable variation in dip, 17^{O}N in the west of Nooitgedacht, 74^{O}N, near the confluence of the Edendalespruit and Leeuwspruit and 55^{O}N, in the south of Leeuwfontein. In the north of Franspoort it is only about 30 yards wide and often missing completely due, no doubt, to faulting.

The quartzites are hard and usually light coloured but showing considerable variation in colour in some localities. The M_2 quartzites in the north of Franspoort grade gradually into a finer grained feldspathic quartzites which stretch as far as the M_3 quartzites. On Baviaanspoort, however, a small horizon of altered shale is found overlying the quartzites . A little galena is associated with quartzites and altered shales in the north of Franspoort and in the south of Leeuwfontein.

Intrusive into the fine-grained feldspathic quartzites which overlie the M_2 quartzites there are numerous sill-like intrusions of hybrid rocks which contain xenoliths of quartzite varying in size from less than 1 mm. up to 1½ feet in diameter. These hybrid rocks have been described as felsites by van Biljon, (10 p.48-50) and similar rocks from the Premier Mine have been called "intermediate" rocks or "Premier Mine felsites" by Lombaard (15,p.126).

These hybrid rocks probably owe their origin to the assimilation of quartzite by a gabbroic or dioritic magma connected to the Bushveld gabbros.

Much brecciation has taken place in this area. Most zones of brecciation have a north-east/south-west trend, and some can be followed for almost 200 yards. The brecciation seems to be younger than the emplacement of the hybrid rocks, although not much displacement was noticed.

A few syeno-dioritic dykes are seen to cut the hybrids and fine-grained quartzites in the centre of the area. In the west of the area there is a north-south composite foyaite dyke 2½ miles long, starting immediately west of the Alkaline Complex on Leeuwfontein and cutting the hybrids and sediments both north and south of the M_3 quartzite horizon and finally petering out south of the M_2 quartzites.

Measurements made in the centre of the area show that the fine-grained feldspathic quartzites which overlie the M_2 quartzites have a thickness of about 2,100 feet. The dip, where measurable, is about 30°N.

2. The Leeuwfontein Area.

(a) Physiography. The Leeuwfontein area is bounded in the south by the M_3, or Leeuwfontein, quartzite (4335 feet) which overlies the fine-grained quartzites of the Franspoort area, and has a thickness of about 900 feet and an average dip of about 31°N. Petrographically the quartzite is much the same as the M_1 or M_2 quartzite though not so recrystallised or brecciated.

The Leeuwfontein area is dominated by the Leeuwfontein Alkaline Complex which is eliptical in shape with a north-south elongation. The north-south axis is about 2 1/3 miles long, and the east-west axis about 1¼ miles. It lies in a wide shallow basin drained by the Leeuwspruit (see plate 1). East and west the basin is bounded by the rounded divides

that separate the Leeuwspruit drainage from the Pienaars River drainage (to the west and from the Louwsbakense-loop (to the east). To the north of the Complex the Leeuwspruit passes through a narrow rocky gorge and finally joins the Pienaars River to the north of the area investigated. The area north of the trachy-andesite ridge is well wooded and unsuitable for agriculture. However, the area south of the ridge is almost entirely covered by alluvium and is therefore arable. Some of the commonest varieties of trees occuring in the north of the area were identified through the kindness of Mr. Beekink as Laclea lanceolata or bosquarri, Rhus lancea or kareeboom and Dombeya rotundifolia (E.May) or dikbas.

b. General Geology.

The rim of the basin is formed by numerous bands of quartzite, diabases, hybrid rocks and hornfelses belonging to the upper part of the Pretoria series no shales were found. All these rocks have an east-west strike, and a northerly dip from 35^{0} - 45^{0}N. on the eastern side of the Complex to 30^{0} - 35^{0} N in the western sector. Some of the diabases, however, are transgressive across the strike of the quartzites. The hybrid rocks as well as the hornfelses, and some of the diabases, are considered older than the Complex as they are cut by alkaline rocks and furthermore inclusions of hybrid rocks are found in the syeno-diorites.

The quartzites vary in colour from white to light red, and are fine to coarse in grain. A small pebble conglomerate was found in a prospecting pit west of the trachyte ridge on Leeuwfontein. Ripple marks and cross bedding are common. In the Leeuwspruit north of the Complex the quartzites have been recrystallised, intensely brecciated and metamorphosed. Van Biljon (10, p.8) subdivided the numerous quartzite horizons that overlie the M_3 quartzites, but due to the considerable difference between van Biljon's map and the author's map, and the narrow strip investigated, these different horizons could not be recognised.

The hybrid rocks above the M_3 quartzites differ from those below the M_3 quartzite horizon, in that they are usually diabasic looking and have a grey colour. Those below the M_3 horizon usually have a grey or red colour, a mottled appearance and are fine-grained.

The hornfelses are intensely brecciated and have a light green colour. They occur near the old powder factory east of the Complex.

In the north of the area there are numerous outcrops of amygdaloidal lavas which probably have no genetic relationship to the trachy-andesites of the Leeuwfontein Complex.

One, or possibly two, dolomitic limestone bands run through the north of the area. To the north of the Complex flourite is seen to replace the limestone and quartzite (see plate IX). In the Leeuwspruit the limestone appears to have become plastic and intruded into the brecciated quartzite locally (see plate VII).

A diabasic dyke cuts the Complex and extends for a short way out of it (see map). It may be of Karroo age. In the Leeuwfontein Alkaline Complex the exposures are good on the whole but the wooded slopes on the east side and the cultivated lands in the south and west, conceal the margin of the Complex in these parts. A good contact between the quartzite and soda-syenite is to be seen in the Leeuwspruit.

The history of the Leeuwfontein Complex commenced with the extrusion of trachy-andesitic lavas into which were intruded syeno-diorites, soda-syenites and umptekites. This was followed by the extrusion of a phonolitic lava after which foyaites and urtites were intruded. Late explosive magmatic vapours were responsible for the numerous agglomerate plugs as well as the presence of flourite and possibly carbonatite, north-east of Pretoria.

II. ROCKS OTHER THAN ALKALINE ROCKS OCCURING IN THE FRANSPOORT AREA.

A. General.

A. General.

As has already been mentioned in the introduction a suite of rocks occurs in this area which ranges from a granophyric quartz-norite through a granophyric quartz-diorite and an "intermediate" rock to "felsite". With the possible exception of the granophyric quartz-norite all these rocks mentioned above contain varying amounts of assimilated quartzite. All rocks which contain assimilated quartzite have been mapped as "felsitic and other hybrid rocks". For the general distribution of these rocks see map.

B. The Granophyric Quartz-Norites.

Diabasic-looking rocks, in which brown pyroxene is seen to stand out on the weathered surface, are intrusive into shales and quartzites below the M_2 quartzites and, as has already been noted, these rocks are probably transgressive sills. A few isolated outcrops also occur below the M_1 quartzite horizon.

These rocks contain the following minerals, roughly in order of abundance, altered plagioclase, micropegmatite, altered orthopyroxene and quartz. Accessories are ore in skeletal form, apatite needles and calcite. A little clinopyroxene is found in the specimens collected south of the M_1 quartzites.

These rocks are medium to fine-grained and there is considerable variation in the relative quantities of the various constituents.

The plagioclase is always very altered, and in only one specimen was it possible to determine the composition as ranging from labradorite (An 59) to bytownite (An 75). The average composition is about An 65. Albite twins are the most common, other twins observed were Roc-Tourne and Carlsbad. The feldspar is slightly zonally built and occurs as fairly broad crystals between 0.4 and 0.5 mm. wide.

The feldspar crystals are often surrounded by fairly coarse micropegmatite which may contain, or grade into, homogeneous quartz individuals. In one slide a graphic intergrowth between pyroxene and quartz was noticed.

Quartz occurs interstitially to the other minerals, and often contains small liquid inclusions showing Brownian movement. Some of the micropegmatite may have been formed by the replacement of feldspar by quartz.

Orthopyroxene occurs as large anhedral to subhedral hypersthene crystals. In almost all the specimens, except those taken near the Leeuwspruit, the hypersthene is almost completely altered to fibrous amphibole, chloritic material and biotite (?).

The orthopyroxene is greenish in colour; $2V\alpha = 70° \pm 2°$ and $n\beta = 1.69 \pm$. These properties indicate a composition of $En_{77} . Fs_{23}$ (20, p.406).

In some specimens taken from below the M_1 quartzites a little augite was also seen.

Because of the weathered nature of these rocks a micro-metric analysis proved very unsatisfactory. For the results of the chemical analysis see Table I Column II, Sample T95. According to van Biljon (10,p.35) this rock may be called a granophyric quartz-norite.

A dark fine-grained diabasic rock sometimes occurs near the "felsites" which outcrop just below the M_3 quartzites. It appears to be older than the "felsites" and contains only a little quartz and no micropegmatite. Its chief dark silicate is clinopyroxene which encloses calcic-plagioclase subophitically.

C. Hybrid Rocks.

1. The Granophyric Quartz-Diorites.

In the area overlying the M2 quartzite numerous outcrops of felsitic rocks occur which are often underlain by a contaminated granophyric quartz-diorite which is seen to grade into the "felsite" through an intermediate rock across the strike. These rocks are intrusive into the fine-grained quartzite and hold numerous inclusions of the latter.

Good outcrops of these contaminated granophyric quartz-diorites are to be seen to the east of the foyaite dyke on Leeuwfontein (farm) and also south of the M_3 quartzites on the west bank of the Leeuwspruit on the same farm.

They often hold quartzite inclusions up to two inches in diameter. These rocks usually occur as transgressive sills. One dyke, however, occurs south-south-west of the Baviaanspoort and Leeuwfontein-Franspoort road junction. This dyke is about 125 yards long and about 25 yards wide, it stretches in a north-south direction.

Microscopically the rock is seen to contain weathered feldspar and micropegmatite in roughly equal quantities, pyroxene and its alteration products, quartz and ore. The plagioclase is largely altered to saussurite, and in some cases partially replaced by epidote. Occasional unaltered patches were found to be andesine. The feldspars are usually tabular and have an average length of about 0.5 mm. and are either simply or polysynthetically twinned. Micropegmatite usually encloses a feldspar crystal, but may also occur interstitially to the other minerals.

The size of the components of the coarser micropegmatite units is about 0.012 mm. Towards the outer edge of the units quartz often increases and may grade into a homogeneous quartz individual. Quartz is seen to replace the feldspar in some slides (see plate XVI) and occasional quartz grains are also found in the feldspar.

Quartz occurs interstitially to the other minerals, some of the quartz may be derived from the sediments. The inclusions of quartzite are almost always associated with epidote. Clinopyroxene (salite) is fairly abundant and is the only primary mafic mineral. The crystals are anhedral and up to 0.46 mm. in length. They often enclose plagioclase subophitically. The salite has the following optical properties: $n\beta = 1.69 \pm$, $2V\gamma = 59^{\circ} \pm 2^{\circ}$, $z \wedge c = 45^{\circ} \pm 5^{\circ}$, colourless, not pleochroic. The salite alters to chloritic material, and amphibole, the latter being pleochroic from pale green to light brown and olive-green, and is probably a hornblende.

Accessories are ore in skeletal form or as small subhedral crystals, apatite needles and a little calcite. According to the chemical analysis, the results of which appear on Table I Column III (Sample T.59) this rock may be regarded as a quartz-diorite that has assimilated a certain amount of quartzite. This would account for the fact that the Niggli values only approach, but do not fall within quartz-diorite or normal -diorite (27,p.349).

A micrometric analysis of the granophyric quartz-diorite analysed gave the following results :

Weathered Feldspar.............	35.70.
Micropegmatite.................	35.15.
Melanes........................	21.43.
Quartz.........................	6.72.
Ore, etc.......................	2.00.
	100.00. ?

Along the strike the granophyric quartz-diorite is seen to grade into a fine-grained black rock. Microscopically this black rock is seen to consist largely of extremely fine micropegmatite in which the quartz and feldspar often exhibit parallel orientation, resembling extremely fine polysynthetic twinning in plagioclase. In some specimens the micropegmatite could only be identified by its incomplete extinction and in some cases microchemical tests had to be resorted to. The micropegmatite individuals are usually about 0.1 mm. in diameter. The only other constituents are long slender needles of green chloritic material which are up to 1 mm. in length, have a sub-parallel orientation and are set in the micropegmatite. Small remnants of pyroxene are also seen, as well as a fair amount of carbonate and epidote. Abundant small ore specks are enclosed in the micropegmatite.

2.2. <u>The "Intermediate" Rocks</u> which have already been referred to were found at the base of all "felsite" outcrops that appear east of the Franspoort-Leeuwfontein road. They may also occur as separate intrusions. As one passes from the granophyric quartz-diorite across the strike the rocks are seen to become lighter in colour and finer in grain. Microscopically an increase in the amount of micropegmatite is noticed as well as partial replacement of feldspar by quartz to form quartz "needles". The amount of dark minerals decreases considerably. The feldspar is probably plagioclase, and is always in an advanced stage of alteration and often almost completely replaced by epidote. The feldspars are tabular and have an average length of about 1.5 mm.

A number of quartz "needles" often occur parallel to each other, interstitial to which fine micropegmatite is seen. These groups of "needles" have the same size as the plagioclase laths. Individual "needles" are about 0.02 mm. wide and it would appear that each quartz "needle" represents a lamella of plagioclase. Quartz "needles" are seldom optically continuous and may be composed of anything up to three or four optical units. However, in these groups of parallel "needles" neighbouring units extinguish simultaneously. There are also numerous smaller quartz "needles" seldom optically homogeneous and occuring singly or in groups. A "needle" may traverse two micropegmatite units and be in optical harmony with both, thus forming an integral part of both micropegmatite units. "Needles" interstitial to micropegmatite units are also frequently not optically continuous. Under the binocular microscope it can been seen that the "needles" are not needles at all but very flat tabular quartz bodies. Similar phenomena were observed by B.V.Lombaard (15) in his study of the Premier Mine "felsites" and "intermediate" rocks, the latter closely resembling the rocks under discussion.

The micropegmatite forms the largest single component of the rock, but because of its fine texture it is often difficult to distinguish from the altered feldspar.

In some cases a little chloritic material and ore are the only melanes, in others, however, small clinopyroxene remnants are seen almost completely changed to fibrous amphibole and chloritic material. These remnants may enclose small altered feldspar laths subophitically. A few remnants of orthopyroxene (?) are also seen, but are usually completely altered to chloritic material. Accessories are a little ore occurring in skeletal form or as subhedral crystals. Some specimens contain some carbonate, and most contain apatite in minute quantities.

Some specimens contain small inclusions of quartzite, which is always associated with epidote. In some inclusions epidote and quartz may occur in roughly equal quantities. The quartz of the inclusion does not seem to have undergone much replacement by feldspar. However, a few quartz grains do seem to have been centripetally replaced to form micropegmatite, The degree of replacement is certainly never as great as in the "felsitic" rocks to be described below.

3. <u>The "Felsites".</u>

These "intermediate" rocks described above grade into "felsitic" rocks which are in some cases identical to certain rocks described from near the Premier Mine by Lombaard (15,p.131) and before him by Daly (18,p.757) and Kynaston (17,p.5). Van Biljon (10,p.51) has noted the similarity between the "felsites" of this area and those of Premier Mine. Excellent outcrops of these "felsitic" rocks are found on the west bank of the Leeuwspruit. They appear to be intrusive into the fine-grained quartzites either as sills or transgressive sills. No dykes of these rocks were found although a few small veins of "felsitic" composition cut the "intermediate rocks" described above. The "felsite" bodies dip about 20°N. where measurable, and the quartzites about 35°N.

Four main "felsite" horizons occur between the Leeuwfontein-Franspoort road and the Leeuwspruit (see map). No contacts were found berween "felsite" and quartzite and as the the two rock types weather the same chocolate-brown colour to some depth, much difficulty was experienced in mapping these outcrops. On following the strike it does sometimes appear as if the quartzite grades into the "felsite". However, upon the examination of numerous thin sections and specimens taken along the strike the author was always able to differentiate between "felsite" and quartzite. The similarity between "felsite" and quartzite on the weathered surface is due to the high sericite content of the quartzite which was probably deposited as a feldspathic sand- or siltstone.

Had the feldspathization been caused by the intrusion of "felsite" or by a "transformatory process" which altered the quartzites into "felsite" (see van Biljon 10, p.131) then it would have been expected that quartz grains would have been partially replaced by feldspar to form "pseudo"-micro pegmatite," as is the case of the quartzite inclusions in the felsite, (see plate XIV).

The "felsites" vary in colour from light or dark grey to red or light pink, and most varieties are speckled. All are very fine-grained and contain quartzite xenoliths of varying size which stand out on the weathered surface.

Microscopically the rock consists largely of small colonies of parallel quartz "needles, or single "needles" all set in very fine micropegmatite. Very few, or no, feldspar remnants are seen.

The "felsite" horizon just below the M_3 quartzite horizon and through which the section line passes, (see map) is underlain by a sill of granophyric quartz-diorite which grades into a grey speckled "felsite," through the "intermediate" type already described.

Microscopically, this "felsite" is seen to be made up of quartz "needles" either occuring in parallel, or slightly stellate groups or individually, Individual "needles" are up to 1 mm. long and 0.02 mm. wide. These quartz needles which may be associated with a little saussurite are enclosed by very fine micropegmatite individuals. The micropegmatite is always associated with very finely disseminated chloritic material, the unequal distribution of which causes the mottled appearance. Numerous quartz grains, varying in diameter from 0.2mm. to 5 mm. are seen. These grains appear to have been replaced by feldspar about their periphery to form "pseudo-micropegmatite". The feldspar has since been largely altered to chloritic material and sericite (see plate XIV). Similar phenomena were noted near the Leeuwpoort tin mine by Strauss (21). Accessories are epidote, greenish amphibole (?) and a little ore. A similar "felsite" which outcrops in the Pienaars River near the Baviaanspoort goal, has been described by van Biljon (10, p.53). The result of a chemical analysis of this rock appears in Table II Column III.

A reddish grey variety occurs on the western side of this outcrop. This variety, despite the absence of a mottled appearance, is microscopically very similar to the type described above, except that the quartz "needles" may be partially composed of chloritic material. These "needles" tend to occur singly and not in clusters.

Yet another variety has a brick-red mottled appearance in which quartz and concentrations of chloritic material can be seen in hand specimens. Microscopically the constituents of this type are identical to those described above. No feldspar remnants are seen.

That feldspar of the micropegmatite which has a reddish colour tends to lie in an elliptical or circular pattern giving the rock a peculiar ringed appearance when viewed under low magnification.

These well defined rings which are about 0.2 mm wide enclose areas with diameters of up to 2 mm. The material enclosed consists entirely of very fine micropegmatite and quartz "needles", whereas the enclosing matrix in which the rings are set is very rich in chloritic material and also contains some epidote, amphibole and ore as well as abundant quartz grains.

Two hundred yards south of the outcrop described above there is another low "felsite" ridge which is about midway between the M_2 and M_3 quartzite horizons (see map). Only one type of felsite is found on this outcrop, and is a pink variety not unlike the one described above. On the northern side, or roof, the "felsite" holds many quartzite inclusions that stand out on the weathered surface due to differential weathering. They may vary in size from less than 1 mm. up to 18" in diameter (see plates XI and XII).

The larger inclusions are usually tabular or oval in shape and show great variation in dip. Bedding planes can still be recognised in some of the larger inclusions.

Most inclusions show a lighter reaction border giving the xenoliths a vague outline (see plate XII). Other inclusions have been almost completely digested and may be termed "ghost" xenoliths, others again have no reaction border at all. This varying degree of assimilation may be attributed to the incorporation of quartzite at different depths, Similar inclusions have been noticed at the Premier Mine and Baviaanspoort by Daly, Kynaston, Lombaard and van Biljon.

Microscopically the felsite described above is very much the same as the red variety already described. The quartz "needles" which usually have a parallel orientation and are often strained give the rock a trachytic texture. A few amygdales composed of quartz, exhibiting wavy extinction, are also seen.

Examination of a quartzite inclusion with a reaction border showed the following (see plate XIII):- quartz "needles" with a distinct flow structure about the inclusion. The reaction border has a pink colour due to the enrichment of iron-rich micropegmatite lying between the quartz grains. The quartz grains of the reaction rim, which is quite well defined exhibit an extraordinary replacement or recrystallization in that they have squat laths that jut out from the edges. In some cases the whole quartz grain shows a tendency to be transformed into a mosaic of squat laths or oblong individuals all with the same optical orientation. These laths seldom have straight extinction, a phenomenon that would have been expected had quartz recrystallized. Nevertheless, recrystallization seems to be the only explanation. These laths are usually surrounded by extremely fine "pseudo-micropegmatite." Towards the centre of the inclusion very few such laths are seen. The feldspathic material, however, is seen to replace the quartz grains to form "pseudo-micropegmatite" similar to that shown on plate XIV.

The examination of an inclusion that appeared to be almost completely digested showed the following properties. Near the periphery of the inclusion quartz grains tend to be "fused" to form one unit up to 0.6 mm. in diameter. These units which occasionally form an optical unit always show undulose extinction with the outer edge, and to a lesser extent the whole unit, showing a tendency to transform into short laths or oblong bodies. Some of the quartz may be replaced fo form micropegmatite. Towards the centre of the inclusion the quartz grains(0.1 to 0.2 mm. (diameter) show no tendency to form one unit, but do however, show a tendency to occur in clusters. Only a very few grains show any tendency to form laths. Interstitial to these quartz grains and individuals there are fine pinkish micropegmatite individuals and single quartz "needles" identical to those of the "felsite" proper.

About 200 yards south there is another low ridge consisting of various types of "felsitic" rocks underlain by an intermediate type. The "felsitic" rocks of this horizon consist almost entirely of very fine micropegmatite with single quartz "needles" and grains. The type that forms the roof of the sill consists of slender laths of feldspar up to 4.5. mm. long, the average length is about 1 mm. and the width about 0.16 mm., set in very fine micropegmatite. The feldspar crystals are usually rounded at their extremities and simply twinned, being usually either completely altered or partially replaced by epidote. A few transparent patches were available and it was found that the axial angle varied between $2V\alpha$ 80° to 86° with an average of about 82°, $n\beta = 1.55$. The feldspar is thus andesine. Alkali-feldspar may also be present.

Further south on either side of the Leeuwspruit just north of the junction of the Edendalespruit and Leeuwspruit there are numerous outcrops of "Felsite" and "intermediate" rocks. The area has been brecciated and faulted although the displacement does not appear to have been great. Most of the rocks on the east bank are of the "intermediate" type, those on the west bank are "felsitic" and underlain by an "intermediate" type. The "felsites" are either light grey or brick-red in colour, the latter often containing angular inclusions of quartzite up to 1 inch in diameter. These inclusions exhibit the same characteristics as those already described.

Grey "felsitic" rocks occur south of the Baviaanspoort road near the foyaite dyke on Leeuwfontein (see map). Microscopically they are the same as those described above. However, the outcrops are poor.

C. D. The Sediments.

The fine-grained quartzites are highly feldspathic and were probably deposited as a feldspathic sediment. The quartz grains vary in diameter from 0.1 to 0.35 mm. with an average of about 0.18 which makes these rocks, according to Wentworth's classification (22. p.202), fine to medium-grained quartzites. A few rounded grains of fairly fresh microcline also occur. Interstitial to the grains there is much fine feldspathic material, a little fine quartz and chloritic material is also usually present.

Specimens gathered from near a "felsite" horizon show varying degrees of alteration. The most altered specimens usually have a reddish colour on fresh fracture, and microscopically they are seen to have properties very similar to the centres of the less altered quartzite inclusions in the "felsite" described above.

The writer has nothing to add to Dr. van Biljon's description of the remaining quartzite and shale horizon (10,pp. 9 - 13, 304, 57 - 59).

The Berg-en-Dal limestone horizon was encountered in the east of Franspoort. It is a light green partly silicified limestone and has been described by van Biljon (10, p.40).

III. ROCKS OTHER THAN ALKALINE OCCURING IN THE LEEUWFONTEIN AREA.

A. General.

The relationship between the non-alkaline rocks in this area is much more complex than in the Franspoort area. The matter has been further complicated by the presence of identical diabases of different ages ; the older ones appear to have a genetic relationship with the hybrid rocks. Furthermore, an amygdaloidal lava occurs that is probably not genetically related to the trachy-andesites of the Leeuwfontein Complex.

The general distribution of all rock types in this area has been described in the introduction.

B. The Hybrid Rocks.

The hybrid rocks above the M_3 quartzites differ from those below them in that they are more diabasic looking in hand specimens. Microscopically they are seen to contain more feldspar remnants and have a much higher colour index than those occuring below the M_3 quartzites.

1. Granophyric Quartz Soda-Gabros.

Microscopically these rocks are light grey in colour and medium-grained, often resembling a fine-grained diabase.

Microscopically these rocks are seen to consist largely of micropegmatite, plagioclase (An 40-70) quartz grains, and quartz "needles", pyroxene and amphibole. The feldspar of the micropegmetite is always turbid and altered, the pyroxene and amphibole are largely altered to chloritic material and ore. Accessories are primary ore, calcite, and epidote in some specimens.

A micropegmatite individual often contains a tabular core of plagioclase (see plate XVI). However, in some cases a number of micropegmatite units may enclose a tabular plagioclase crystal.

The plagioclase is usually turbid and in only two slides could the composition of the feldspar be determined. As a rule the plagioclase was found to be simply twinned according to the Carlsbad law. The plagioclase shows normal zoning, in some cases from labradorite (An 60 - 68) and andesine (An 40 - 45). The mantles have a refractive index of $n_\beta = 1.557 \pm 0.002$. The average composition is probably in the region of An 50.

The rock is made up of varying quantities of this type of micropegmatite and a type that does not enclose a tabular plagioclase crystal. Zonal build in the feldspar of the micropegmatite units, especially those with no cores, is often seen. The micropegmatite seems to have been formed by simultaneous crystallization of quartz and feldspar.

Evidence that the plates are pseudomorph after feldspar, was obtained in certain specimens, in that there are tabular (altered) feldspars that resemble the shape of quartz plates, an also the fact that quartz is definitely seen to replace feld - spar in many slides (see plate XV). However, there are broad (altered) tabular feldspars of dimensions not found among the quartz plates. Evidently any replacement of feldspar by quartz was restricted to the slender feldspars.

Amphibole, pyroxene and their alteration products comprise about 35 per cent of these rocks, they occur as fibres or needles, or allotriomorphic crystals with serrated edges interof fine quartz "needles" up to 0.5mm.in length, very fine micro-pegmatite and small quartz grains. In some varieties small turbid feldspars may be seen in a host of micropegmatite. Fine chloritic material, fibrous amphibole, pyroxene (?) and ore are also seen. Melanes make up about 31 per cent of the rock.

The rocks resemble in many ways some of the "felsites" below the M_3 quartzite horizon.

As dark minerals make up at least 31 percent of these "felsites" of the Leeuwfontein area they may be called "mesotype felsites". North of Mr. Day's house a "felsitic " rock over-lies the mesotype "felsite"; it consists largely of quartz grains which appear to have been partically replaced by feldspathic material. Chloritic material and fibrous amphibole are inter-stitial to the quartz grains. Concentrations of hornblende and quartz are seen in hand specimens and measure up to 2 mm. across.

The hornblende was found to have the following properties

$2V\alpha = 66^{0} \pm$ $\quad$ $Z \wedge c = 13^{0} \pm$

Pleochrism : X = pale olive-green, Y = bright green, and
Z = pale green.

This rock is considered to be quartzite which was meta-morphosed by the intrusion of the "mesotype felsites".

C. The Diabases.

The diabases in this area appear to be of two ages, one type is definitely younger than the alkaline rocks and the other apparently older.

On the north-west side of the Complex a diabase outcrop ends abruptly against alluvium, obviously derived from the syeno-diorite and grey soda-syenite as large feldspar crystals are seen in the light grey soil. A few isolated outcrops of grey soda-syenite were also found. Because of this abrupt termin-ation of the diabase it is considered older than the alkaline rocks.

To the north and norty-east of the Complex there are numerous outcrops of diabase of rather doubtful age. Just south of the Kameelfontein road and to the east of the Complex, diabase appears to cut a quartzbearing trachy-andestic rock which grades into an amygdaloidal lava, which, however, is probably genetically related to the Dullstroom volcanics (see Section D).

Immediately north of the eastern trachy-andesitic ridge a narrow diabase dyke can be followed intermittently for about 2,000 yards (see map). Although no contacts are seen and the outcrops are usually very poor the dyke is obviously intrusive into the syeno-diorite of the Leeuwfontein Complex.

Microscopically and macroscopically these two ages of diabase are very similar.

The diabase is fine to medium-grained, the younger types usually are slightly finer in grain. Both types have an ophitic and subophitic texture.

Augite is the predominating dark silicate which is often twinned and with $2V_\gamma = 46^0 \pm 3^0$, $Z \wedge c = 33^0 \pm 3^0$; $n_\beta = 1.68 \pm$.

It is accompanied by fairly fresh zoned labradorite (An 60 - 65), quartz and a little alkali - feldspar which is often intergrown with some quartz to form micropegmatite. Accessories are hypersthene, biotite, chlorite, ore and apatite.

D. The Amygdaloidal Lavas.

Three bands of amygdaloidal trachy-andesitic lavas occur in the Leeuwfontein area (See map).

Macroscopically it is a dense black rock which carries numerous amygdales, never more than a few milimetres in diameter, which stand out on the weathered surface. To the east of the Complex and about 120 yards south of the Kameelfontein road this amygdaloidal lava is seen to grade into an even-grained non-amygdaloidal quartz-bearing trachy-andesite, which, although no contacts are seen, appears to be cut by the syeno-diorites of the Leeuwfontein Complex and a younger (?) diabase (See map).

Microscopically the ground-mass of the lava is seen to consist of small feldspar laths (plagioclase predominating), fibrous hornblende, glass, and quartz. A little pyroxene may also be present. Alteration products like carbonate, chlorite and zeolites are abundant. The amygdales are composed of a mosaic of quartz grains which is often associated with some carbonate.

F.C.Truter (28,p.lxv) is of the opinion that these lava may be correlated with certain andesitic lavas which occur in the Rooiberg and Stavoorn tin mining areas, and which in turn are correlated with the Dullstroom volcanics.

E. The Hornfelses and Altered Quartzites.

Some of the rocks described below as hornfelses should strictly speaking be classed as hybrid rocks. However, the term hornfels, used by van Biljon has been retained as a means of distinguishing between contaminated magmatic rocks (the hybrid rocks) and certain altered quartzites (the hornfelses) which have received additions from the alkaline rocks and pyroxenites in the form of feldspathic material and ferro-magnesian minerals.

To the east of the Complex there is a prominent ridge composed of hornfels (see map). A few smaller outcrops are f found further south. Only one small outcrop was found to the west of the Complex.

The largest outcrop is intimately associated with the amygdaloidal lava described above. To the south of this outcrop the hornfels passes gradually into almost "normal" quartzite through a moderately gneissic quartzite.

The hornfels itself is a brecciated rock having a pale greenish colour on fresh fracture. It has a very rough pitted weathered surface due to differential weathering. The rock appears to be a brecciated quartzite that has received certain additions from the alkaline rocks and pyroxenite of the Complex.

Microscopically the rock is seen to consist of quartz grains varying in diameter from 0.5 mm. to 0.05 mm. These grains are often cracked, contain many liquid inclusions, and have wavy extinction. Interstitial to these quartz grains there is a fair amount of fresh, slightly green pyroxene (diopside Chloritic material, feldspathic material, biotite, calcite and ore are also present in varying quantities. Large concentrations of small circular grains of pyroxene give the rock a mottled appearance. Some specimens have small veins of alkali-feldspar.

Further south, immediately south of Mr. Day's house, there is a fine-grained banded hornfelsic rock which is probably a hornfels in the true sense of the word; it is not brecciated and is composed of small quartz grains intimately associated with biotite, ore and semi-opaque material.

In the Leeuwspruit, near the contact between the soda-syenite and quartzite (see plate viii) to be described later the quartzite is highly altered, and may contain up to about 50 or 60 percent of added material. This rock consists largely of cracked quartz grains, micropegmatite, pale green slightly pleochroic pyroxene, amphibole, biotite, ore and chlorite. Some of the micropegmatite seems to have been formed by the replacement of quartz by feldspar. Other quartz grains have undergone no replacement and are surrounded by small pyroxene individuals. Cracks in the quartz grains are in many cases filled with dark silicates.

Similar altered quartzites are found north of the Complex in the Leeuwspruit. They appear to have become so plastic that they have intruded into the more normal quartzites. To the north and intimately associated with the syenite near the fluorite horizon on Zeekoegat (287), the quartzite is very brecciated and often has a gneissic texture and varies in colour from white to pink. Microscopically the quartzite is seen to contain abundant grains and veins of carbonate. A brownish mineral, probably an alteration product of some dark silicate, which is also seen in the aplite, was found to be present in this altered quartzite. In addition, fluorite is present.

Underlying the limestone, to be described below,,there is a cherty band consisting of bands of black, white or green fine-grained quartzite. Microscopically these rocks are seen to contain a fair amount of small pyroxene "droplets" and are similar to the altered brecciated quartzite described above.

F. Limestone and Fluorite Horizon.

Immediately north of the syenite-aplite to the west of th Leeuwspruit, there is an outcrop of a greyish dolomitic limestone striking east-west and dipping towards the north. Small wavy bands composed of a green substance stand out on the weathered surface (see plate ix). They have the same dip and strike as the limestone.

Microscopically the rock is seen to consist of angular carbonate grains, usually about 0.06 mm. in diameter. The greenish wavy chloritic (?) bands are seen to be riddled with small inclusions.

Purple fluorite is seen to replace the limestone extensively (see plate ix), and to a lesser extent the quartzite. The wavy chloritic (?) stringers seem to resist replacement.

Although the outcrop is fairly extensive, mining operations have long since ceased, due, no doubt, to the impurities obviously present.

Veins of coarse limestone, having idiomorphic crystals of calcite up to 2 cms. long, cut both the limestone and the fluorite. When it cuts the limestone it is often seen to carry some fluorite.

In the Leeuwspruit, and further east, coarse-grained white limestone is seen to outcrop; it is probably an extension c the horizon described above. Plate VII shows how the limestone has become plastic and intruded into the brecciated quartzites and hybrid rocks. The limestone has a pure white colour and is made up of large rounded and interlocking crystals which micro-chemical tests have shown to consist of a mixture of dolomite and calcite, the latter predominating.

The angular inclusions, and the adjoining rocks, consist largely of altered quartzites or quartzitic limestones. A border of impure limestone usually surrounds an inclusion and consists largely of coarser carbonate, a greenish, almost isothropic mineral, possibly chlorite, and a greenish or colourless mineral having yellow or grey interference colours (wollastonite?) and some ore.

To the east of the Leeuwspruit numerous outcrops of a similar limestone occur, and have been quarried at one time or another. Van Biljon (10,, p.86) quotes the results of a chemical analysis of the "limestone taken near the right bank of the Leeuwspruit on Zeekoegat" which contains :

SiO_2	11.35
Al_2O_3	2.74
Fe_2O_3	1.76
FeO	.29
CaO	49.62
MgO	1.49
H_2O (neg.)	.02
H_2O (pos.)	.24
SO_3	.70
TiO_2	trace
P_2O_5	.09
MnO	.15
CO_2	31.67
	100.12

Analyst : C.J.Liebenberg, Chemical Services,
Department of Agriculture, Pretoria.

H. The Quartzites.

As regards the quartzites, the author has nothing to add to what has already been said in the introduction and in van Biljon's recent paper (10,pp.10-11).

IV. GENESIS OF THE HYBRID ROCKS.

The author has come to the conclusion that the "felsite" and to a lesser extent, the granophyric quartz-diorite, consolidated under special and complex conditions that involved both magmatic differentiation and assimilation of quartzites, and possibly some limestone or shale locally.

Bain (23,p.509), in his study of certain hybrid rocks of the Sudbury Complex, concluded that the material assimilated approaches the mass of the original magma itself. Bowen (24,p.827), quite rightly states that "assimilation of such magnitude must assuredly give us pause." The present author will attempt to show that the ratio between diorite and quartzite is in the region of 3.5 : 6.5 (by weight).

Similar abnormal rocks have been described by Daly (25, p.245), from the Moyie sills. He came to the conclusion that assimilation of quartzite accounts for the abnormalities in the sills, and points out "that differentiation may partially mask the direct evidence of assimilation

Hall and du Toit, (26, pp.82-85) came to the conclusion that certain granophyric rocks near the Hartebeestpoort Dam owe their origin to the assimilation of quartzite and shales by gabbro.

It has already been pointed out that no conclusive evidence was found in support of the theory put forward by van Biljon (10,pp.57, 130, etc.,), in his recent paper.

Furthermore, as the granophyric rocks are seen to grade into "felsitic" varieties across the strike, and as the former occasionally occur as dykes, it must be concluded that the "felsites" are also intrusive. In addition it must be borne in mind that when the coarse granophyric quartz-diorite occurs at the base of the sill, it makes up a very small part of the sill, and it therefore appears unlikely that the "felsitic" rocks could have been changed by emanations from the granophyric quartz-diorite.

Lombaard (15,p.140), in discussing the origin of almost identical rocks from the Premier Mine, states "As differentiation in depth proceeded so the generated portions of the parent magma became more acid, but the mixing of the magmas of various stages resulted in hybrid magmas."

The present author believes that the mixing of magmas may have played a minor role, but that the dominating feature was assimilation going hand in hand with differentiation, and thus accounting for the abnormaliies in these hybrid rocks.

The following sequence of events may be postulated :- In a gabbroic magma sill in its journey towards the surface, differentiation and assimilation of quartzites was taking place simultaneously. Due to crystal settling the basal part of the sill would be more melanocratic and would contain little or no dissolved quartzite. This basal part is represented by the granophyric quartz-norite (T.95, Table 1, Column 11).

The middle regions would be more leucocratic and slightly more contaminated by dissolved quartzite. This middle region would be represented by the granophyric quartz-diorite (T.59, Table 1, Column 111), and Lombaard's "intermediate rock" (Table 1, Column IV). The top of the sill would contain a great deal of dissolved quartzite in a dioritic magma. As will be shown the ratio of quartzite to diorite was probably in the region of 4:6 or 3:7 (by weight), and is represented by the "felsites". (Table II.)

Volatile constituents, which may have aided or hastene the dissolving of the quartzites, and most certainly affected the alteration of the minerals in the rock by auto-pneumatolysi would be concentrated in the upper regions of the sill.

The rock types described above may either occur as sills or transgressive sills, either associated with each other as is the case towards Premier Mine, or separately as on Baviaanspoort, Leeuwfontein and Bynespoort. It is, therefore, concluded that they represent successive intrusions hardly separated by a time interval.

Towards the end of the crystallization of this hybrid magma ("felsite"), the feldspars would find themselves out of equilibrium, and be partially or completely replaced by silica, depending on the amount of quartzite assimilated. The norite is thought to have differentiated at least as far as diorite as the plagioclase in the intermediate rocks are andesir

On the advice of Professor Lombaard, the graph (fig. 1) was drawn, using the Niggli values. By comparing this diagram (up to si 500) with the typical differentiation diagrams from th Bushveld, Pidgeon Post, Duluth, the British Tertiary Province, etc. which are all fundamentally the same, very little similarity is noticed, Taking this and the microscopic and field evidence, already discussed, into account we may safely conclude that the "felsites" do not owe their origin to simple or straightforward differentiation, but rather to the assimilation of quartzites. The question now arises as to how much assimilation and how much differentiation actually took place.

From the graph (fig. 1) we may conclude that these "felsites" were not formed by simple assimilation of a quartzite by a noritic magma. If this had been the case then the Niggli values of the "felsite" would have fallen on, or near, the red lines of the graph. Furthermore, as has already been stated, as the plagioclase feldspars of the "intermediate" rocks are often andesine it may be concluded that the magma differentiated at least as far as diorite or possibly even grano-diorite.

It is possible to postulate the composition of the true magmatic portion of the "felsite", as it may be assumed that the Niggli values of the "felsite" have values somewhere between where they would have been had only assimilation taken place, and where they would have been had only differentiation taken place.

It was found that if in the "felsite" the ratio of magma to quartzite was 7 : 3, then the magma would have the following Niggli values :

si	=	328
al	=	28
fm	=	36
c	=	11
alk	=	24

These values fall into melanocratic quartz-diorite and compare very favourably with a type of felsite from the upper zone of the Bushveld Complex which has the following Niggli values :

si	=	316
al	=	28
fm	=	32
c	=	15
alk	=	25

(See Lombaard, 15, pp.155 and 161).

It compares less favourably with a grano-diorite from Ardnumurcman (27, p.430), which has the following values :

si	=	336
al	=	36
fm	=	26
c	=	14
alk	=	24

It is therefore concluded that the "felsites" are composed of about 6 or 7 parts of quartz-diorite and 3 or 4 parts of feldspathic quartzite by weight. It can also be calculated that the postulated magma fraction would have an s.g. of ± 2.677, and that the volumetric ration between magma and quartzite is about 26 : 11.5, or roughly speaking 2:1.

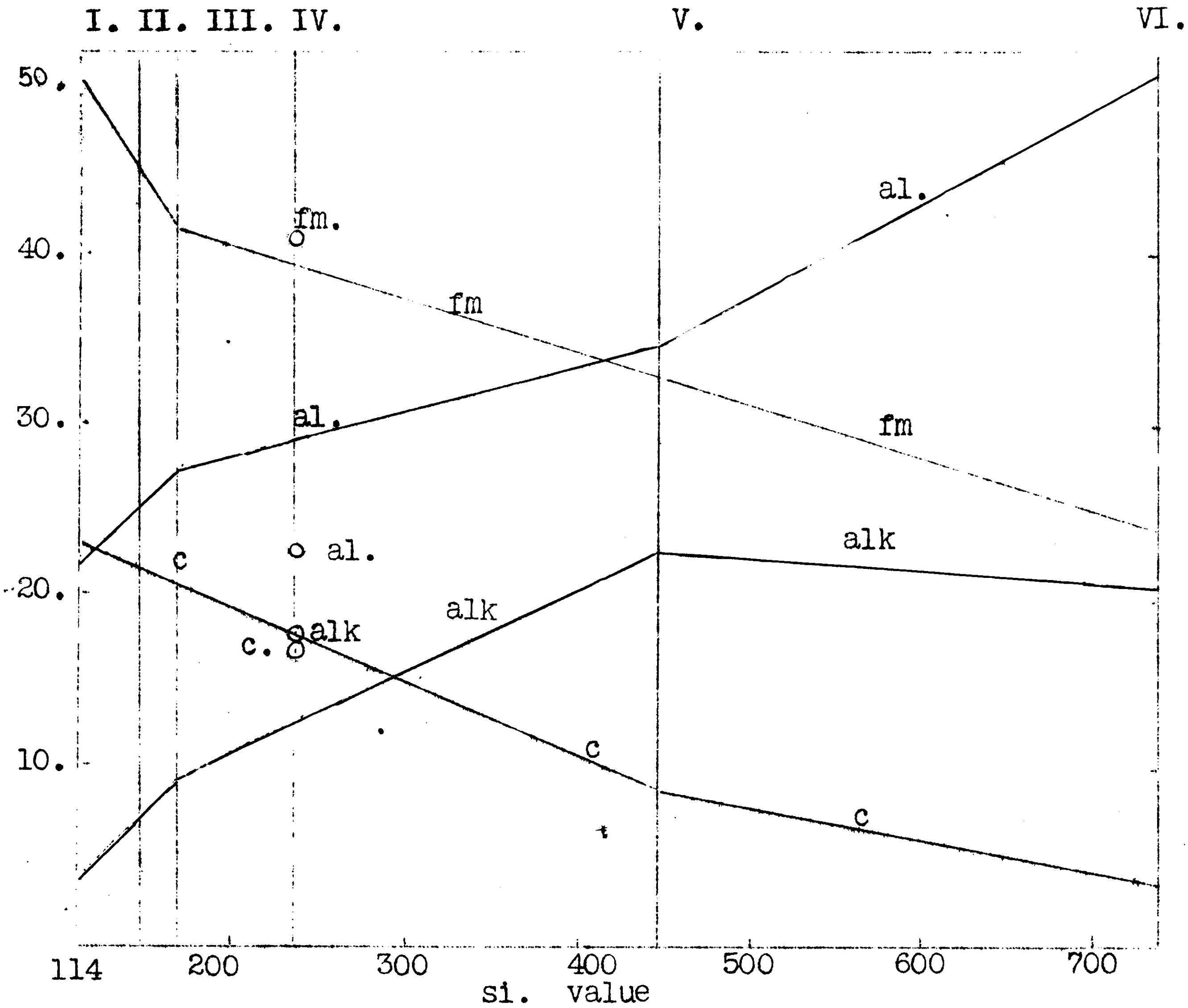


fig. I (for explanation see text),

I. Spotted norite (table I No: 1.)

II. Quartz-bearing granophyric norite (table 1 No: II)

III. Granophyric quartz-diorite (table I, No: III).

IV. "Intermediate" rock from Premier Mine (table I, No: IV).

V. Average of a felsite from Premier Mine and Baviaanspoort (table II, Nos: II and III).

VI. Average of fine grained feldspathic quartzite from Leeuwfontein (table III No: IV.).

V. THE LEEUWFONTEIN ALKALI COMPLEX.

A. General.

The Leeuwfontein Alkali Complex, the physiography of which has already been described in the introduction, covers an area of about 2.9 square miles, the north-south diameter being about two and three-eighth miles, and the east-west diameter about one and a quarter miles.

The rocks appear to have consolidated in the following order :

1. Trachy-andesites and porphyritic dykes of syeno-diorite.
2. Syeno-diorite (white syenite of Shand) and dykes of porphyritic syeno-diorite.
3. Grey soda-syenite (included in Shand's red-syenite), porphyritic syenitic dykes, coarse pegmatite, and aplite.
4. Red soda-syenites, and bostonite dykes.
5. Pyroxenites (and jacupirangites).
6. Phonolites.
7. Foyaites and foyaitic dykes.
8. Urtites and urtitic dykes.
9. Monchiquite dykes.
10. Late magmatic vapours, containing CaF_2 and possibly $CaCO_3$ which caused much brecciation.

B. 1. The Trachy-Andesite Ridges.

Two prominent trachy-andesite outcrops occur in the middle of the Complex, the strike is east-west and the dip, where measurable, varies from 20° to 29° north. These two ridges cover an area of about one square mile, and are completely surrounded and cut by dykes of syeno-diorite (see map).

Two varieties of trachy-andesite are found on the ridges, and there appears to be a slight difference in age between the two. The distinction between these two types is mainly macroscopic. The older and more common variety consists of sub-parallel phenocrysts of white feldspar up to

0.75 cm. long set in a fine-grained brown-grey groundmass in which a few small crystals of dark minerals are seen. The rock weathers to a reddish or light grey colour.

The younger variety is a basaltic-looking rock, weathering black. On fresh fracture the small phenocrysts of grey feldspar, which are up to 0.5 cm. long, can hardly be distinguished from the fine-grained dark grey groundmass.

Microscopically these two varieties differ from each other only in that the older is often very weathered, while the younger is remarkably fresh. The older variety also contains less alkali-feldspar, and the phenocrysts are seen to consist of andesine (An 40 ± 5) usually having a narrow mantle of anorthoclase ($2V\alpha = 66^{0} \pm$). The plagioclase is usually twinned according to the Albite or Carlsbad laws. The following twinning laws were also noted : Albite-Ala, Pericline and Albite-Carlsbad. The plagioclase has mantles of alkali-feldspa which have serrated edges and vary in width between 0.1 and 0.25 mm. They contain many small inclusions of amphibole, ore and biotite, which range in size from 0.0012 mm. or even smaller to about 0.025 mm. A few larger inclusions are also found; the plagioclase contains very few inclusions. A few smaller anhedral phenocrysts of alkali-feldspar riddled with inclusions ar seen in the younger variety. The mantles of alkali-feldspar may often be absent in the older variety.

The groundmass consists of anhedral alkali-feldspars (anorthoclase),with an average diameter of 0.06 mm. andesine may also be present in some cases. In the older variety, an olive-green hornblende (probably barkevikite), biotite and ore are the chief mafic constituents. In the younger variety pale green augite, identical with that of the syeno-diorite is more abundant, and is seen to alter into an olive-green or brown hornblende which is probably barkevikite. Ore which often has a mantle of crystalline sphene, is more plentiful in the younger variety, and usually occurs as inclusions in the amphibole or pyroxene.

Accessories are quartz, apatite and biotite. Calcite, chlorite and zeolites are common alteration products. The texture is trachytic.

The results of an analysis, made by Professor Shand (8, p.237) and shown in Table IV Column 1, appears to be of the younger variety, and falls into normal "larvikitish" which includes the trachy-andesites, according to Niggli's classification (29, p.364).

Shand, (ibid) has called this rock a soda-trachyte (Pretoria type), and then more recently (30, p.397), a trachy-andesite.

It is not possible to calculate the mode because the precise composition of most of the minerals is uncertain. Shand (8, p.238), points out that "alumina probably enters into all six of the principal minerals; and soda, potash, lime, magnesia and iron appear in three or four minerals each". The norm shows olivine but this mineral is not present in the rock; it is probably represented by biotite. The following proportions were ascertained by Shand (ibid):-

Anorthoclase	65 - 70 per cent by volume.
Plagioclase................	12 - 15 " " " "
Melanes	20 " " " "

(of which hornblende; say 12 per cent; augite $2\frac{1}{2}$ per cent; biotite 2 per cent; titeno-magnetite $2\frac{1}{2}$ per cent; apatite 1 per cent). The anorthoclase contains about 60 per cent of the albite molecule.

2. Inclusions in Syeno-Diorite.

Numerous inclusions of trachy-andesite are found in the syeno-diorite (see map), thus proving conclusively that the trachy-andesites are older than the syeno-diorite, although chemically they are more closely related to the grey soda-syenites (see graph, figure 2).

3. Brecciated Variety.

To the west of the trachy-andesite ridge there are numerous outcrops, often having a brecciated appearance, and weathering to a brick-red or grey colour. These rocks closely resemble certain trachytic rocks north of the foyaite plug on the farm Franspoort.

Microscopically these rocks are seen to consist of small feldspar laths up to 0.4 mm. long, but usually about half that size, and showing a distinct flow structure. These laths are associated with a fair amount of chloritic and carbonatitic material, the latter being more abundant in the more intensely brecciated varieties. Some contain fair amounts of brownish amphibole. Ore is abundant and generally occurs as minute individuals, although a few larger individuals are found occasionally. The feldspar laths consist of twinned plagioclase and untwinned alkali-feldspar, the latter often having a reddish colour due to haematite dust. These rocks which ar probably the same age as the trachy-andesite described above, are cut by a composite foyaite dyke (see map).

4. Chill-Phase of Syeno-Diorite.

Light grey trachytic-looking rocks occur as stringers in the quartzites at the contact between quartzite and syenite in the north and north-east, and also in the extreme south of the Complex. Although these rocks have a faint trachytic texture, they are obviously a chill-phase of the syeno-diorites or grey soda-syenite. They are intruded by dykes and stringers of umptekite in the southernmost occurrence.

Pink medium-grained rocks intermediate between trachy-andesite and syeno-diorite are found immediately south of the western trachy-andesite ridge. They closely resemble some of the numerous syenitic dykes found in the area, and probably represent a chill-phase of the syeno-diorite against the trachy-andesite.

Amygdaloidal andesitic or trachy-andesitic lavas, which are not genetically related to the alkali rocks of the Complex, have already been described in a previous chapter.

C. <u>The Syeno-Diorite or the White Syenite (Aker type of Shand)</u> (8, p. 238).

After the trachy-andesite lava flows had solidified, the syeno-diorite magma welled up towards the surface, and the trachyte ridge is probably nothing more than a large inclusion in the syeno-diorites, as shown in the vertical section of the map (see back).

The syeno-diorites are composed of large tabular soda-plagioclase crystals, surrounded by a mantle of anorthoclase, which often has a pink colour. These rocks seldom contain more than 15% of dark minerals, the most important of which are augite hornblende, soda-amphibole and biotite.

There are three main varieties, all very similar, and the distinction is once again chiefly a macroscopic one.

<u>1. The Pink Variety</u> is the most common (sample T204, Table IV) and covers by far the largest area marked as syeno-diorite on the map. The rock is composed of plagioclase crystals up to 1 cm. long and between 1 and 3 mm. wide. They are usually white, but may have a very pale pink or greenish-grey tint in some localities. These light coloured plagioclase crystals are surrounded by a mantle of pink anorthoclase usually about 1 mm. wide. Dark minerals occur interstitially to the feldspars.

The plagioclase is andesine (An 35) and the most common twinning laws are Albite and Carlsbad. The feldspar of the mantles is a microperthitic alkali-feldspar with properties similar to the anorthoclase of the grey-syenite (see Section D).

The dark minerals are, in order of abundance, a hornblende (probably barkevikite), ferroaugite, and a blue soda-amphibole. Accessories are biotite, quartz, apatite, ore, sphene and a little zircon. Although the plagioclase is usually decomposed the rock is fairly fresh on the whole. The most important alteration products are : chloritic material carbonate sericite, saussurite and epidote.

The pyroxene is ferroaugite, it is usually colourless but may have a pale green or pink tint indicating the presence of a little acmite or titanium respectively. The ferroaugite has the following optical properties:-

$2V\gamma = 50^{0} - 53^{0}$; $Z \wedge c = 38^{0} - 44^{0}$; $n\beta = 1.712 \pm 0.005$.

The ferroaugite changes into a hornblende (probably barkevikite) to a greater or lesser degree which has the following optical properties :

$2V\alpha = 72^{0} \pm 2^{0}$, $Z \wedge c = 12^{0} - 18^{0}$, $n\beta = 1.690 \pm 0.005$.

Pleochroism; light brown to olive-green.

A lavender-blue fibrous amphibole is also present. It shows almost straight extinction and is pleochroic from bright green to light olive-brown. It is usually associated with epidote.

2. <u>The Grey Variety</u> occurs on the east bank of the Leeuwspruit 200 yards south of the bridge over the spruit. A few isolated outcrops also occur about 400 yards north of the middle of the eastern trachyte ridge, no contacts are seen between this and the other varieties of alkali-rocks.

Macroscopically this rock differs from the first variety in that most of the feldspar has a steel-grey colour. Pink feldspar is less plentiful and it does not always form a mantle about the plagioclase. Microscopically, however, the total amount of alkali-feldspar appears to be about the same as that of the first variety, that is, equal to or slightly les than the plagioclase.

The plagioclase is again andesine. It is usually very fresh and the anorthite content varies between 35 and 40, making it slightly more calcic than the pink variety. The most common twins are again Albite and Carlsbad.

The alkali-feldspar enclosing the plagioclase crystals often shows patchy extinction, due no doubt to incomplete exsolution. Accurate measurements are, therefore, not easily made.

The alkali-feldspar has the following optical properties :

$2V\alpha = 70^{\circ} \pm 2^{\circ}$, $n\beta = 1.536 \pm 0.003$

γ and pole of (010) are between 4° and 12° apart.

β and pole of (001) are usually about 10° apart.

The properties are similar to that of the perthite of the grey soda-syenite which was shown by chemical analysis to be an anorthoclase holding about 60% of the albite molecule. The soda-syenites are discussed in the next section.

Quartz is usually fairly abundant and individuals are up to 1.5 mm. in diameter. The quartz is clear and contains many minute inclusions. The contact between quartz and feldspar is usually sharp. However, occasional intergrowths between both types of feldspar and quartz were noticed.

In samples taken from near the Kameelfontein road the mafic constituents are the same as the first variety except that blue soda-amphibole is seldom present. However, in samples taken from the area north of the trachy-andesite ridge reddish-brown biotite is the predominating, and often the only, dark mineral. It appears to be an alteration product of the bakevikite.

It is probable that this quartz-bearing, slightly more calcic variety represents an earlier phase of the syeno-diorites.

3. The Melanocratic Variety is found in the Leeuwspruit at the Southern extremity of the Complex. This type differs from the varieties described above in that it may contain up to 30% or more of dark minerals. Both types of feldspar are usually white, the plagioclase is oligoclase (An 35).

The chief mafic constituent is again a pale green, faintly pleochroic ferroaugite with a slight pink tint ($2V\gamma = 56^{o}$, $Z \wedge c = 38^{o} - 44^{o}$) which changes into barkevikite and ore. The barkevikite has the following optical properties:

$2V\alpha = 74^{o} - 80^{o}$, $Z \wedge c = 12^{o} \pm$ Pleochroism:

X = yellow, Y = dark brown, Z = chocolate brown.

Dark brown biotite is also present. A noteworthy characteristic of this variety is the abundance of slightly purple idiomorphic sphene crystals which often contain small inclusions of apatite crystals.

As in the other varieties the melanes occur interstitially to the feldspars, small inclusions of the dark minerals may be present in the feldspar especially in the anorthoclase mantle.

From the results of a chemical analysis of the syeno-diorite (Table IV Sample T204) and from the calculation of the norm which has a normative ratio of Or : Ab : An. of 15.36 : 45.61 : 15.16. it is obvious that these rocks have a composition between that of a syenite and diorite. According to the Niggli Classification (29, p.364) these rocks fall into "maenaitisch" which is a soda-syenite and includes some of the akerites, or "kassaitisch" (an essexite-diorite). Shand, influenced by Brogger's work in Sweden, has preferred to call these rocks akerites, the present author, however, prefers the more self-explanatory name of syeno-diorite (see Hatch and Wells '31, p.173 etc.).

4. Inclusions.

Many inclusions of trachy-andesite are found in the syeno-diorite and three small inclusions of hybrid rocks like those described in Chapter III.

Inclusions vary in size from less than 1" to 30 yards or more in diameter. As can be seen from the map these inclusion decrease in size and number as one goes north from the trachy-andesite ridge. Unfortunately the area south of the ridge is covered by alluvium. The inclusions are essentially the same as the trachy-andesites of the ridge and, as a rule, are very fresh. In certain light coloured varieties near the old dynamite factory to the east of the Complex sulphide ores can be seen in hand specimens.

D. The Soda-Syenites and Umptekites.

The intrusion of the syeno-diorites were followed by the emplacement of a grey soda-syenite with which is associated an aplite and an umptekite pegmatite.

A later, brick-red, extremely altered soda-syenite or umptekite marks the end of the syenitic phase and the start of a foyaitic one. For the distribution of these above mentioned varieties see map.

Outcrops fail in a tantalising way near the contact between syeno-diorite and grey soda-syenite but the author is of th opinion that the one grades into the other within a narrow transition zone of a few yards. The contact between the umptekite pegmatite and grey soda-syenite is also gradual. This is seen to great advantage in the bed of the Leeuwspruit north of the Kameelfontein road. No contacts were observed between the brick-red soda-syenite or umptekite and the grey soda-syenite but as the two types occur within feet of each other there is no doubt in the author's mind that they represent two separate intrusions. The brick-red variety appears to be intrusive int the pegmatite.

A good contact between quartzite and grey soda-syenite is to be seen in the Leeuwspruit north of the Kameelfontein road. A poorer contact was observed in the bed of a small spruit 650 yards to the west (See Section F).

1. <u>The Grey Soda-Syenite</u> weathers very much like granite and is an ideal ornamental building stone. Good specimens are obtainable from a quarry situated at a large tor about 250 yards south of the Kameelfontein road.

On the weathered surface this rock has a light grey or light-red colour, but on fresh fracture the feldspar, which is the main constituent, has a very light grey or buff colour. The rock is leucocratic and consists largely of perthitic anorthoclase individuals up to 1.5 cm long. A narrow ill-defined mantle of pink feldspar surrounds the lighter cores. Microscopically the only difference between the mantle and the core is that the pink mantle is more coarsely perthitic and contains a little haematite dust.

The dark minerals are essentially the same as those of the syeno-diorite, in that the most abundant mafic constituent is a hornblende (probably barkevikite) occuring as large subhedral crystals holding numerous inclusions of apatite and ore. Ore is often seen to unmix along the cleavage planes.

The optical properties are as follows :-

$2V\alpha = 80^{\circ} \pm$; $Z \wedge c = 16^{\circ} \pm$; $n\beta = 1.675 \pm$.

Pleochroism is from olive-brown to dark chocolate brown. Accessories are brown biotite, a little very altered greenish pyroxene, some blue soda-amphibole, ore (titanomagnetite) apatite, sphene, sulphide ore (pyrite (?)) a little quartz and some purple fluorite. The chief alteration products of the amphibole are green epidote, calcite, iron oxide and chlorite. The feldspar is usually fairly fresh but may be partially altered to the normal alteration products of feldspar, including carbonates.

The results of a chemical analysis appears in Table IV Column III (T.239). According to the Niggli classification (29,p.264) the magma type is "Kassaitisch" (an essexitediorite which includes Brouwer's Leeuwfonteinite), and had it an fm. value of 25 instead of 24.25 it would have been "maenaitisch". As the rock contains anorthoclase and no plagioclase, as is the case in the syeno-diorites, it is proposed to call this rock a soda-syenite so as to differentiate between it and the syeno-diorite.

2. The Pegmatitic Phase.

The soda-syenite develops a pegmatitic phase in the eastern part of the Complex which can be followed for about 1000 yards (See map). Its relationship to the syeno-diorites is uncertain, but it is seen to grade into the grey soda-syenite in the bed of the Leeuwspruit to the north of the Kameel-fontein road. The red soda-syenite appears to be intrusive into the pegmatite.

The pegmatite is composed largely of anorthoclase crystals which have a distinct sub-parallel orientation with the (010) faces lying in a vertical plane. Dark minerals which are very scarce occur either interstitially to the feldspars or as minute inclusions therein.

There are actually two types of pegmatites, viz:

a) The Pink Variety is composed of pink anorthoclase crystals up to 6" long (See plate VI). The dark minerals are highly altered and consist largely of biotite, epidote and chloritic material and carbonates with a little amphibole and pyroxene visible in some slides. Other accessories are apatite, ore fluorite, quartz and sphene. The quartz may be secondary.

Professor Shand (8, p.241) was able to obtain fresh material by blasting; the results of his analysis appear in Table IV, Column IV.

(b) The Light Grey Variety which outcrops in the Leeuwspruit south of the bridge has light grey anorthoclase crystals, and, in contrast to the pink variety the dark minerals are beautifully fresh. On the left bank of the spruit the dark constituents are concentrated in stringers, which suggest that differential movement took place in the plastic mass during freezing. (8,p.235) (See plate V). In these concentrations the dark minerals are usually set in very fresh anorthoclase, the former making up about 50% or more of the rock.

Pyroxene which is the most abundant dark mineral, usually has a parallel orientation and is optically similar to those found in the foyaites. It is a faintly pleochroic pale-green aegirine-augite, slightly zonally built, with a dark green border. It has the following optical properties :

$2V_{\gamma} = 80^{\circ} \pm 2^{\circ}$; $Z \wedge c = 58^{\circ} \pm$, $n_{\beta} = 1.72 \pm$.,

which according to Winchell (20, p.415) would give this pyroxene a composition of about 63% diopside and 37% acmite.

The pyroxene changes into a hornblende, probably barkevikite, with the following properties :

$2V_{\alpha} = 80^{\circ} \pm 2^{\circ}$., $Z \wedge c = 20^{\circ} \pm$, $n_{\beta} = 1.67 \pm$.,

Pleochroism is from light reddish-brown to dark-brown often having a border of a green amphibole which is pleochroic from green to brown.

Next in abundance is brown biotite, Iron ore occurs as inclusions in the amphibole and pyroxene and is probably an alteration product of the latter. Apatite and sphene are the most important accessories.

In hand specimens a pink mineral can very often be seen occuring interstitially to the feldspars. In thin section it is seen to consist of fibrous zeolites similar to those of the foyaites. The red colour may be due to contamination by iron oxide from the mafic constituents, inclusions of which, as well as ore and apatite, are found in the zeolites. These clusters of zeolites which may be up to 3 mm. in diameter probably compose less than one percent of the rock. It is likely that these zeolites are alteration products of nepheline, and the pegmatite may therefore be referred to as an umptekite, as is borne out by the analysis of the pink variety which incidentally contains no zeolites but some quartz, which, however, may be secondary.

3. The Aplite.

In the north-west of the Complex there is a light red, fine to medium-grained, soda-syenite aplite (see map). It is intimately associated with quartzites and quartz breccias and itself is brecciated in parts. From field evidence it appears to be a sill or dyke that has been injected into the quartzites prior to the emplacement of the brick-red variety described in the next section.

The rock is equigranular and consists largely of anorthoclase and subordinate andesine laths (An 35) up to 1 mm. long. As the feldspars are usually stained with hematite dust it is often difficult to distinguish the plagioclase from the anorthoclase.

Although the rock must be described as leucrocratic, dark minerals are fairly abundant and consist largely of fine chloritic material, epidote, and a yellowish-red alteration product, which may be derived from barkevikite which is plentiful and is often associated with the chlorite and epidote. Accessories are quartz and apatite.

A few of what appear to be small amygdales, but may be inclusions of quartzite, are seen and consist largely of quartz individuals shewing undulose extinction, and are usually associated with carbonate.

This rock shows a cousinly relationship towards both the syeno-diorite and the normal grey soda-syenite, and may be called a soda-syenite aplite to distinguish it from dykes of darker fine-grained bostonites and porphyritic soda-syenites, both of which, unlike the aplite, have a marked trachytic texture

4. The Brick-Red Variety is composed largely of brick-red perthitic anorthoclase crystals up to 2.5. cm. long, showing a distinct parallel orientation with the (010) faces vertical. Carlsbad twinning can often be recognised in hand specimens. Joint planes are often filled with purple fluorite. Good specimens are to be obtained from a quarry just south of the bridge over the spruit. The rock is a good ornamental building stone.

North of the foyaite body (see map) it is intensely brecciated and the brecciation appears to have been of an explosive nature. The rather angular fragments of syenite are cemented together with carbonatitic material.

In thin section the red colour is not as homogeneous as it appears to be in hand specimens and is probably caused by the breaking up of the unstable ferri-orthoclase molecule. Stringers of haematite impregnated anorthoclase are usually parallel to the (010) face.

In this variety the dark minerals are completely altered to green epidote, chloritic material, carbonate, soda-amphibole and ore. Zeolite clusters are always present and may occur either interstitially to the feldspars or as inclusions therein. Nepheline was not identified for certain but it is quite possible that it may be represented by the zeolites.

Unfortunately, no alalysis has been made of this rock, but it may, however, be called a soda-syenite, or an umptekite, depending on its exact chemical composition.

Between the brick-red variety and the pegmatites there is a finer-grained red Umptekite or soda-syenite which appears to be a finer phase of the brick-red variety. South of the Kameelfontein road in a small waterhole near the quarry this finer variety is seen in contact with, and probably intrusive into, the pink pegmatite. North of the road, however, it appears to be intrusive into the normal brick-red variety.

This finer variety is also fairly leucocratic. There is no parallel orientation of the feldspars which vary in size from very small to anything up to 3 cm. in length. The feldspars are very much like those of the brick-red umptekite already described, however, exsolution seems to have been more complete and this may account for the more normal optical properties, viz:

$2V\alpha = 54^{\circ} \pm$, $n\beta = 1.530 \pm 0.005$.

The dark minerals are fairly fresh and similar to those of the grey pegmatite. The pyroxene is slightly greener and probably contains a little more of the acmite molecule.

Interstitial to the feldspars there are many zeolites probably pseudomorph after nepheline, like those of the grey pegmatites they have a reddish tint, and are often associated with carbonate.

E. A Detailed Discussion of the Anorthoclase.

The feldspar is either a crypto or patchy perthite, the in textbooks. Furthermore upon consulting Alling's tables (32, p.65) it is seen that an anorthoclase having about 50 - 60 percent of the albite molecule would have $2V\alpha = 74^{\circ} - 80^{\circ}$.

The seemingly abnormally high refractive index is more difficult to explain, but is probably due to the high albite content and the presence of some anorthite in the molecule.

According to Alling (32,p.66) this mineral should be called a hyperperthite as this is the term he suggested for soda-rich anorthoclase. The author, however, proposes to follow Bellankin (quoted by Alling 32,p.66) by simply calling this mineral perthitic soda-anorthoclase.

Mr. Game (personal communication) of the British Museum, has recently investigated an anorthoclase from Central Nigeria which is very similar to the anorthoclase described above. It has the following properties : $2V\alpha = 52{\cdot}5^{\circ}$, $n\beta = 1.5349$. The angle between pole of (100) and $\alpha = 8^{\circ}$; and that between pole of (010) and $\gamma = 5^{\circ}$. On cleavage fragments the extinction of (001) on (010) = 5.9°, and of (010) on (001) = 0.8°. A part of Mr. Game's analysis is subjoined;

K_2O	3.88
Na_2O	8.17
CaO	1.50
	13.55

This feldspar from Nigeria differs from that of Leeuwfontein in that it is not perthitic and is polysynthetically twinned. It is very fresh .

F. The Contact between Quartzite and Soda-Syenite.

The only good contact is in the Leeuwspruit north of the Kameelfontein road (see map) where a very good contact is seen between a pinkish phase of the grey soda-syenite and quartzite (see Plate VIII).

The syenite forms a narrow dark grey chill zone which consists of small fresh perthitic feldspars usually about 1 mm. in diameter interstitial to which there is a little pyroxene, biotite, amphibole, ore and quartz.

The contact between this chill zone and the syenite is rather abrupt, little stringers of coarser grey soda-syenite cut this chill zone.

The contact between the chill zone and quartzite is not easilly pinpointed and seems to be rather vague.

The quartzite immediately next to, and up to 25 yards away from the contact is highly altered and in some cases may contain more than 50% of added material in the form of feldspar, micropegmatite, pyroxene, amphibole and ore. Similar altered quartzites are found a little further north in the Leeuwspruit and have already been described.

G G. Foyaites, Urtites and Related Rocks.

1. General: The main foyaite-urtite body (see map) lies above the Kameelfontein road and is elonagted in a north-south direction. It measures about 1000 yards by 300 yards. The urtites outcrop in the northern half of the body, which is bordered on the south, east and north by red soda-syenite whereas on the west it is bordered by the grey soda-syenite. Only one poor contact was found in the north-east of the body, for the rest the actual junction is obscured by overburden.

The foyaites and urtites hold numerous inclusions of jacupirangite (pienaarite) and phonolite as well as being cut by numerous foyaitic and urtitic dykes.

Brouwer (6, p.37 - 76) in his study of South African alkaline rocks devotes no less than 39 pages to the foyaites of Leeuwfontein and describes them under the following headings :- aegirine-foyaite, aegirine-amphibole foyaite, pienaarite (jacupirangite) and tawite (sodalite rock).

Shand (8, p.242) states that "The distinction of aegirine-foyaite from aegirine-amphibole foyaite is rather a distinction of handspecimens than one of rock facies." Furthermore he maintains that the body consists of a "single outcrop of aegirine-foyaite in which sodalite and blue soda-amphibole are variable constituents."

Shand (ibid) also states that feldspathoids do predominate in some varieties, it is these varieties that the author proposes calling urtites, and it would include Brouwer's sodalite-rich aegirine-foyaite (see Column VI, Table V).

The name pienaarite for certain pyroxene rich inclusions has been considered uncalled for by Shand (8, p.244) and he proposes the term jacupirangite for these rocks.

2. The Foyaites occur in the southern and northern portion of the area marked foyaites and urtites on the map. A small outcrop, a few paces in diameter, is found in the red syenite on the west bank of the Leeuwspruit just north of the bridge. The main constituent is tabular crystals of perthitic anorthoclase varying in length from a few mm. to about 5 cm. with an average of about 2.5 cm. The feldspars usually have a parallel orientation with the (010) faces vertical. Subordinate minerals are nepheline, sodalite, pyroxene, amphibole, sphene and ore all of which occur in varying amounts.

Most varieties are more or less equigranular some, however, are slightly porphyritic having phenocrysts of anorthoclase and nepheline set in a fine-grained groundmass of small laths of anorthoclase and albite along with sodalite sphene and the usual accessories.

The anorthoclase is very similar to that of the light grey umptekite pegmatite. The crystals are twinned according to the Carlsbad law, the composition plane is usually irregular. The perthite is both patchy and crypto and the optical properties are as follows :

$2V\alpha = 76^{\circ} \pm 2^{\circ}$

Angle between (001) and $\beta = 9^{\circ} - 12^{\circ}$

Angle between (010) and $\gamma = 0^{\circ} - 2^{\circ}$.

$n\beta = 1.528 \pm 0.002$. Extinction on cleavage fragments are the same as those of the pegmatite.

Thus the anorthoclase probably has about the same composition as that of the syenites. The refractive index is more normal; this may be due to a smaller percentage of anorthite or albite molecules.

The nepheline, which is often zonally built, may have a reddish stain and occurs interstitially, and more rarely as inclusions, in the feldspar. The crystals are usually idiomorphic and vary in diameter from less than 0.5 mm. to about 1.5 cm. The nepheline may alter to fibrous zeolites along cracks and cleavages, in some specimens the nepheline has been completely altered to zeolites which are often associated with a little carbonate.

The zeolites are either light grey or colourless and have yellow, blue or red interference colours. They may be either length fast or length slow. They have a small $2V\gamma$ and probably belong to the natrolite group of zeolites.

Another alteration product is colourless in ordinary light and has a pale yellow interference colour. It is uniaxial positive and not fiberous. This is probably what Brouwer (6, p.61) calls hydronephelite. Dana (34, p.657), however, states that hydronephelite is a mixture of natrolite, hydrargillite and diaspore. Hydronephelite is not mentioned in Winchell's Elements of Optical Mineralogy (1950). Rogers and Kerr (35, p.254), however, state that it is an alteration product of nepheline, but apart from saying that it is closely related to cancranite, they give no description of it. Winchell (20, p.354) states that cancranite may be positive or negative (Roger and Kerr give it only as positive) and it therefore seems possible that hydronephelite is now considered as a variety of cancranite.

The sodalite crystals are seldom as large as those of nepheline and are almost always idiomorphic. They occur either as inclusions, or interstitially to the feldspars and nepheline. The sodalite is often very fresh and seems less susceptible to alteration than the nepheline. In other varieties again it is almost completely altered to zeolites.

In handspecimens the sodalite has a grey colour with a vitreous lustre. Under the microscope the fresh sodalite is seen to hold many minute inclusions giving the sodalite a greenish tint under low magnification.

The inclusions are often arranged in zones parallel to the crystal sides. In some cases, however, the inclusions form a maze usually confined to the centre of the individual. The aegirineaugite crystals are often zonally built, and the outer zones hold many small inclusions of nepheline, feldspar and sodalite. Because of dispersion of the optic axis in white light the following properties were ascertained in sodium light.

$2V\chi = 80^{\circ} \pm$, $Z \wedge c = 80^{\circ} \pm$, $n\beta \geq 1.76$

Pleochrism: X emerald. **Y** olive-green., **Z** olive-brown

These properties indicate an aegirine-augite holding 70 or 82 percent of the acmite molecule (20, p. 414).

The amphibole seems to have been formed entirely by transformation of aegirine-augite. The soda-amphibole has the following properties (determined in yellow light because of dispersion) $2V\alpha = 54^\circ \pm$; $Z \wedge c \doteq 40^\circ$; $n\alpha = 1.665 \pm 0.004$ Pleochroism: X = brown-green; Y = blue-green; Z = green-brown. Brouwer (6, p.61) calls this arfvedsonite but it is probably kataphorite which, however, lies in the arfvedsonite series (20, p. 440).

Accessories are sphene (often idiomorphic) apatite, biotite, titanomagnetite, and purple fluorite.

The only available analysis is obviously faulty (Table 4, Column 5).

Shand (8, p.243) made the following measurements on the weathered surface of one of the "course-grained, sodalite-rich foyaites":-

Nepheline (and sodalite)	45	volumes	percent.
Feldspar	46	"	"
Aegirine (and soda-amphibole)	9	"	"

According to measurements made by the present author feldspathoids usually made up between 30 and 40 percent and in some cases as low as 10 percent by volume of the rock.

3. The Urtites.

The urtites occur in the central portion of the outcrop of alkaline rocks. There are many local variations, and contacts between urtite and foyaite may be either sharp or gradual.

The urtites are very coarse-grained rocks; the chief constituent being large idiomorphic nepheline crystals up to 1 cm. in diameter with subordinate anorthoclase, sodalite and pyroxene. Accessories are sphene and fluorite.

The feldspar is interstitial to the nepheline and contains many sodalite inclusions as well as a few of nepheline. The pyroxene is interstitial to all other constituents as a rule, but smaller crystals occasionally may be found as inclusions in the anorthoclase.

The order of crystallization was as follows : sodalite, nepheline, feldspar, pyroxene.

The nepheline crystals that are still fairly fresh have a grey colour with a vitreous lustre on fresh fracture. Those that have been largely altered to zeolites have a dull red colour. The zeolites have the same properties as those described under the foyaites, they are often associated with a little carbonate.

The pyroxene and accessories are remarkably fresh as a rule. They are the same as those of the foyaites.

Brouwer's sodalite-rich aegirine-foyaite (see Table IV Column VI) is a typical urtite. The following results were obtained on a Shand integrating stage (measurements on a finer-grained facies).

	Sample No: 1.			Sample No: 2.		
Nepheline	53	volumes	percent	30	volumes	percent.
Sodalite	13	"	"	38	"	"
Total feldspathoids	66	"	"	68	"	"
Feldspar	30	"	"	25	"	"
Dark minerals	4	"	"	7	"	"

4. Structures Due to Differential Movement in the Plastic Mass.

In the south of the foyaite outcrop there is a marked banding in the foyaites very similar to those found in the grey soda-syenite pegmatite. This banding is in a north-south direction and all minerals have a very marked parallel orientation. This concentration of melanes gives the more melanocratic zones a composition similar to that of the jacupirangite inclusions described below.

5. Inclusions.

Inclusions of jacupirangite and phonolite are rather common in the foyaites and may be angular or rounded blocks of varying sizes, which have often been partially digested by the foyaitic magma.

(i) Phonolite inclusions are fairly common and two of the larger ones, measuring about 25 yards in diameter, are shown on the map. These inclusions are almost identical to a phonolite from Leeuwkraal 21 miles to the north (see smaller map) and described by Shand (9, p.91).

These inclusions must represent a lava flow which took place after the syenites were emplaced, but before the foyaites erupted. They therefore would have a composition intermediate to the syenites and foyaites. This is borne out by the chemical analysis of the phonolite from Leeuwkraal done by Professor Shand

The phonolite from Leeuwfontein is a dark grey rock with numerous phenocrysts of perthitic anorthoclase, up to 2 or more cm. long and usually twinned according to the Carlsbad law. The anorthoclase crystals have serrated edges and contain many small inclusions of liquid or glass, sodalite, pyroxene, amphibole and, ore associated with sphene. These inclusions are more abundant towards the outer rim.

The groundmass consists mainly of smaller perthitic anorthoclase individuals varying between 1 and 0.2 mm. in diameter. Sodalite, aegirine-augite, soda-amphibole, ore and sphene are also found in the groundmass. Nepheline was not identified for certain. Shand (8,p.244) did a quantitative test for chlorine and found it to be 0.36 percent, corresponding to 5 percent of sodalite in the rock.

According to Shand (ibid) this rock is so decidedly under-saturated that it must be called a sodalite-phonolite.

(b) Jacupirangite.

A few small ill-defined inclusions, seldom more than a foot in diameter are found in the southern part of the foyaite body. These inclusions probably represent an alkilised phase of the pyroxenite which outcrops on the east side of the Complex and is described in the next section.

The jacupirangite is a heavy black rock holding about 75 percent of melanes often having a parallel orientation. The main constituent is beautifully fresh pale green pyroxene, followed by ilmenite and idiomorphic sphene crystals, each of which exceeds ten per cent. Apatite and magnetic iron ore are also conspicious.

The melanes are set in a groundmass of fairly fresh nepheline and anorthoclase. A little sodalite and purple fluorite may also be present.

The pyroxene is zonally built, with the cores having a light green colour and the borders a grass-green colour. It is only slightly pleochroic. The cores have the following properties :-

$2V\gamma = 60^\circ - 64^\circ$; $Z \wedge c = 46^\circ - 50^\circ$; $n\beta = 1.72\pm$.

The borders have the following properties:-

$2V\gamma = 94^\circ\pm$; $Z \wedge c = 75^\circ \pm$; $n\beta = > 1.725$.

Some green borders, however, are very narrow and differ only slightly from the core.

These properties indicate the following composition (20, p.415):

Cores.		Border.
Hedenbergite (CaFe)	50 percent	----
Diopside (CaMgFe)	40 "	40 percent
Acmite (NaFe)	10 "	60 percent

Brouwer (6,p.45) has called this rock a pienaarite, the results of an analysis appear in Table IV, Column VII.

Shand (8,p.244) considered the name pienaarite uncalled for and proposed the term sodalite-bearing jacupirangite.

H. The Pyroxenite Body.

A pyroxenite body on the east side of the Complex (see map) is rather ill-defined and outcrops are poor. It is a heavy black banded rock and consists almost entirely of pyroxene and its alteration products.

The broader bands consist almost entirely of fresh, anhedral, slightly zonally built light green pyroxene crystals.

The narrower bands consist of finer pyroxene that has been almost completely altered to amphibole, ore and other alteration products. A little apatite, ore and sphene are also present. Feldspathoids and feldspar were not identified for certain.

The pyroxene is very similar to that of the jacupirangite the slightly greener boarders, however, differ only very slightly from the cores.

The pyroxene has the following properties:

$2V\gamma = 62^{\circ}\pm$; $Z \wedge c = 52 \pm$; $n\beta = 1.725 \pm 0.005$.

The chemical composition would therefore be the same as the lighter coloured cores of the jacupirangite.

The origin of the pyroxinite and jacupirangite is discussed in Chapter VII Section A.

I. The Last Phase of the Eruption.

Microscopically this rock resembles the trachy-andesite but it is impossible to say whether it is related to the trachy-andesite or the syeno-diorite as it is never seen to cut either of the two.

The plagioclase is andesine (An 35 - 42) and in most specimens is almost completely altered to the usual alteration products. The plagioclase crystals are often rounded at the extremities and the edges are usually serrated. Occasionally a very narrow band of alkali-feldspar may surround the plagioclase phenocrysts.

The groundmass consists of small laths of twinned or untwinned anorthoclase. Plagioclase occurs in subordinate amounts A little ferro-augite, which may in some cases be almost completely altered to amphibole or chlorite and other alteration products, is also present. Accessories are apatite and some primary ore.

These rocks may be called syeno-diorite porphyries and are genetically related to either the syeno-diorites or trachy-andesites (8,p.245).

(b) The Soda-Syenite types are the most common in the Complex itself. The best outcrops are found in the Leeuwspruit and to the north of the eastern trachyte ridge where one could be followed for almost 200 yards (see map).

These rocks are the freshest of all the dyke rocks and consist of phenocrysts of pale grey feldspar 1 or 2 cm. long and set in a bright red, fine-grained base.

The phenocrysts consist of anorthoclase which has serrated edges and holds many small inclusions of dark minerals. These large anorthoclase crystals often have small cores of plagioclase.

The groundmass consists largely of coarsely perthitic anorthoclase containing much haematite dust and having an average diameter of about 0.1 or 0.2 mm.

The dark minerals are the same as in the more common type of syeno-diorite, that is, slightly green ferro-augite ($2V_\gamma = 54^\circ \pm$ $Z \wedge c = 48^\circ \pm$) largely altered to a greenish amphibole, possibly barkivikite, as well as biotite and ore. Accessories are apatite and sphene.

Shand (8, p.245) has noted the similarity between certain Pilansberg dykes from Bank and those described above.

Shand (ibid) calls these rocks akerite-porphyries but as they contain so little plagioclase it would appear more correct to call them soda-syenite porphyries. As these dykes are only seen to cut the syeno-diorite and trachy-andesite and not the soda-syenites it may be concluded that they are later than the syeno-diorites, but earlier than the soda-syenites.

The ratio of phenocrysts to groundmass varies considerably. In some cases the phenocrysts may be packed so close together that the rock resembles the syeno-diorite or soda syenite; in others again the phenocrysts may be sparsely scattered throughout the groundmass. In some localities small stringers composed entirely of material like that of the groundmass are seen to cut the dykes described above.

(2) <u>Bostonites</u>.

Dirty brick-red, fine-grained, soda-syenitic dykes are abundant throughout the Complex (for their distribution see map). Outcrops are good but mostly unfresh and the width is seldom more than a few feet. Good contacts are not uncommon.

The bostonites cut all rock types except the foyaites and are genetically related to the red soda syenite.

Microscopically the rock is seen to consist of small anorthoclase laths from 0.4 to 1.4 mm. by about 0.1 mm. set in a groundmass composed of smaller laths. The feldspar has a red tint due to haematite dust.

The rock contains much finely disseminated ore, a reddish or yellowish-brown alteration product possibly of a pyroxene or amphibole, as well as chloritic material, epidote and much carbonate. The texture is trachytic.

Some of these rocks, however, are not typical bostonites as they contain a fair amount of dark minerals, whereas the typical bostonite from Boston, U.S.A., contains only 5.9 percent total iron and magnesia. These rocks, however, are still leucocratic and the name bostonite (proposed by Shand 8, p.245), therefore, seems the most suitable, especially as it helps to distinguish them from the coarser grained porphyritic varieties on one hand, and the aplite on the other hand.

A variety just west of the western trachy-andesite ridge contains a fair amount of quartz and can be called a quartz-bostonite.

3. Foyaites.

There are three main foyaite dykes in the area:-

(a) A composite dyke 2¼ miles long.

(b) A 350 yard dyke of tinguaite.

(c) A small dyke in the south of the foyaite body.

(a) A Composite Foyaite Dyke runs from the western side of the Leeuwfontein Complex to south of the M_2 quartzites, a distance of about 2¼ miles (see map).

Parts of this dyke were mapped by Shand (8, p.245) who also gave a short description of it. Hall (4, p.83) has also remarked on its unusual appearance. Van Biljon's (10) mapping of it is incorrect.

This dyke consists of two phases; an earlier and coarser foyaite into which was intruded a later and finer-grained variety.

This intrusive nature is not always evident and sometimes only the one or the other variety is seen in outcrops.

The coarser variety is much more abundant and is rather variable in appearance. It is composed of stellate groups of tabular feldspars up to 1 cm. in length and having either a red o white colour. These stellate feldspar groups are set in a fine-grai grained chocolate coloured base in which small pseudomorphs after nepheline can be seen.

The finer grained variety has a brownish-red colour, and is essentially the same as the coarser type; the feldspars are between 1 and 2 mm. in length.

The feldspar is anhedral perthitic anorthoclase, often simply twinned and containing small inclusions of dark minerals, mostly aegirine-augite.

The chocolate coloured base is composed of smaller anortho clase individuals, alteration products of nepheline, small idiomorphic aegirine-augite crystals and a remarkable quantity of little wedges of sphene.

The nepheline has been completely altered to colourless zeolites possibly of the natrolite group, ($2V_{\gamma} = 59^{\circ} \pm$; $n\beta = 1.490 \pm 0.005$) interference colours are white or pale yellow). Som sections have an opaque or semi-opaque alteration product of nepheline.

The aegirine-augite occurs as idiomorphic crystals as a rule, but sometimes may be arranged in stellate fibres. Its optic properties are identical to those of the foyaites of the Complex. The pyroxene may change into a little blue soda-amphibole and ore.

(b) A Tinguaite Dyke was found in the north of the foyaite body. Shand (8, plate XIII) has mapped it as bostonite but he does describe a tinguaite (8, p. 246) from the north of the body which appears to be the same rock.

This dyke is about 350 yards long and only a few feet wide. It has a red or greenish colour, with a few grey phenocrysts of grey feldspar and many little spots of reddened nepheline. The dykes are fairly fresh in places and consist of feldspar laths between 0.03 and 3 mm. in length and aegirine-augite needles up to about 0.4 mm. long and micaceous nepheline pseudomorphs. The feldspar and the pyroxene have a rudely parallel orientation and a faint flow structure, hence the name tinguaite. Accessories are a little secondary blue soda-amphibole, ore and purple fluorite.

(c) A Fine-Grained Foyaite dyke is found in the south of the foyaite body and except for the fact that it is finer grained it is identical to the foyaites which it cuts.

4. Monchiquites (?).

Numerous small dykes, of what may be called monchiquites are found in the Leeuwspruit just north of the Leeuwfontein Complex (see map). They are intrusive into the quartzites and appear to have intruded after the quartzites were brecciated

These rocks consist of a few ill-defined phenocrysts of: (a) nepheline pseudomorphs composed of zeolites, carbonate, chlorite and other alteration products, and (b) fairly fresh aegirine-augite. These phenocrysts are set in an almost black groundmass which is composed of highly altered aegirine-augite and feldspar. Zeolites are also present and may be an alteration product of nepheline.

Other highly altered melanocratic dyke rocks occur near the fluorite horizon, but as the rocks are so highly altered their original composition is rather uncertain. They are coarse-grained rocks and consist of large dark phenocrysts which may be pseudomorphs after aegirine-augite and are composed of chloritic material, carbonate and soda-amphibole. These phenocrysts are set in a reddish fine-grained groundmass consisting of the usual alteration products of feldspar and feldspathoids.

(5) Ijolites.

(a) A Jacupirangite dyke only a few feet long occurs on Zeekoegat in the urtites of the Complex. It is almost completely obscured by long grass and thorn trees. Macroscipally it does not resemble the jacupirangite inclusions. It is a fine-grained greenish-black rock with numerous phenocrysts of fairly fresh light red nepheline crystals, as well as a few clusters of white anorthoclase and dark green aegirine-augite crystals set in a greenish-black groundmass composed of small zonally built allotriomorphic aegirine-augite crystals, blue soda-amphibole (an alteration product of aegirine-augite) nepheline, sodalite fluorite and calcite. There is a possibility that this outcrop may be an inclusion and not a dyke.

(b) An Urtite dyke, which except for its finer grain, is exactly the same as the urtite which it cuts. It is largely composed of nepheline pseudomorphs with subordinate amounts of perthitic anorthoclase and needles of aegirine-augite.

(6) Carbonatites.

It has already been stated that the intrusive limestone shown in Plate VII is probably a mobilised sedimentary limestone. However, just north of the area investigated there Dr. Truter has found a small carbonatite dyke which may be related to the alkaline rocks.

VI. ALKALI ROCKS OF THE FRANSPOORT AREA.

For a general description of the area see the Introduction

A. The Franspoort Foyaite Plug.

1. Foyaite. The foyaite plug is intrusive into

the Magaliesberg quartzites and shales. The actual outcrop measures about three-quarters of a mile by one-third of a mile with a distinct north-east/ south-west elongation.

As the southern part of the plug is covered by alluvium the southern boundary is rather uncertain. However, owing to the presence of a few ill-defined outcrops of quartzite just north of the Cullinan road (see map) there is some doubt as to whether the foyaite actually extends as far as the road as was claimed by Shand (9, p.83).

On the northern side of the plug the contact between lavas and foyaitescan be drawn in with a fair amount of accuracy as they often outcrop within a few feet of each other No contacts were seen but it is fairly certain that the foyaite are younger than the lavas.

There is very little to add to Shand's description of the foyaites (9, pp.84 - 86) which he describes as "a light grey rock of medium-grain composed of white feldspar laths averaging 5 mm. in length with grey nepheline crystals (1 to 3 mm.), small black aegirine prisms, and occasional grains of purple fluorite."

Shand (ibid) calls the feldspar microperthite but according to its optical properties it holds almost equal quantities of orthoclase and albite, it therefore seems more correct to use the term perthitic anorthoclase. The feldspar is similar to that found in rocks from Leeuwfontein and it is almost always twinned according to the Carlsbad law and has the following optical properties:

$2V\alpha = 72^\circ \pm$

The angle between pole of (001) and β = $12^\circ - 14^\circ$

" " " " " (100) " α = $14^\circ - 20^\circ$

" " " " " (010) " γ = $0^\circ - 4^\circ$

For further details as regards the petrology of the foyaite see Shand (9, p.84). The results of Shand's analysis appear in Table V Column I.

A melanocratic phase of the foyaite, not noticed by Shand, occurs to the west of the Franspoort-Leeuwfontein road. It contains a large amount of greenish-brown hornblende (barkevikite), and large idiomorphic sphene crystals. Feldspathoids are less abundant than in the more common variety of foyaite. No pyroxene was observed.

2. Inclusions.

There are numerous dark inclusions in the foyaite. They are usually an inch or less in diameter and are more abundant on the northern side of the plug where a few larger ones up to almost a foot in diameter were found.

(i) The smaller inclusions are made up as follows .
An outer rim composed of small biotite flakes and a little augite, which surrounds a larger core composed of chlorite, serpentine and other alteration products. Usually a little fluorite is also present. The core of these inclusions is similar to the groundmass of the Monchiquite dykes described in the next section.

(ii) The larger inclusions of ijolite are composed of roughly equal quantities of light coloured silicates (feldspar and feldspathoids) and dark minerals (barkevikite, aegirine-augite, biotite and sphene). In some cases barkevikite, which is an alteration product of aegerine-augite, is the most abundant mafic constituent. In others, which are usually more leucocratic, zonally built aegirine-augite is the predominant dark mineral. The aegirine-augite and barkevikite are subhedral and have an average diameter of about 0.18 mm

These inclusions probably originated in a similar way to the jacupirangites of Leeuwfontein.

3. Dyke Rocks.

A reddish foyaite dyke is intrusive into the margin of t] foyaite near the west bank of the Leeuwspruit. For a detail(description of this dyke see (9,p.86).

A smaller dyke (about 20 yards in length and only about one foot wide) was found on the northern side of the plug. It is a fine-grained leucocratic foyaite and petrographically it is identical to the foyaite which it cuts.

A poor outcrop of a syenitic dyke is found on the west bank of the Leeuwspruit at the northern extremity of the foyaite plug (see map). It is a grey medium-grained rock consisting of a mosaic of alkali-feldspar crystals with plagic clase cores. Set in this groundmass are abundant slightly pink idiomorphic ferrosalite or ferroaugite crystals which have an average diameter of about 0.5 mm., and which are seen to alter to amphibole and chlorite. Accessories are apatite, which occurs as inclusions in the pyroxene, and ore which often has mantles of crystaline sphene. Interstitial zeolite are abundant and they may be pseudomorphs after nepheline although feldspathoids were not identified. This rock is ver much the same as certain dyke rocks further north that cut the northern foyaite occurrence.

B. Lavas North of the Foyaite Plug.

Before describing the foyaites further north it is proposed to examine the lavas and dykes immediately north of t foyaite plug described above, so that this area can be dealt with as an entity. Lavas which outcrop just north of the foyaite plug were noticed by Shand (9, p. 87) who described them as "soda-trachytes and phonolites closely related to the soda-trachyte of Leeuwfontein." Van Biljon (10, p.34) regards them as altered shales.

There are two distinct types of lava in this area. The earlier(?) phase, which is by far the most abundant, is fed by dykes of syeno-diorite while a second, and later, phase seems to be fed by monchiquite dykes.

Most of the lavas have a brecciated appearance, probably due to the lava being rather viscous or ropey. Near an old kraal 400 yards north of the foyaite plug the lava holds inclusions of quartzite. Near this kraal Shand(9, p.84) found a prospecting pit which showed quartzite again. The fact that quartzites are found in the prospecting pit, and in the bed of the Leeuwspruit, indicates that lavas form only a very thin crust above the quartzites and shales today.

These lavas are all obviously older than the foyaites and are probably genetically related to the trachy-andesites from Leeuwfontein (9,p.87).

(1.) <u>The Darker Variety</u>.

Small intermittent outcrops of a black lava occur (i) to the east of the Franspoort-Leeuwfontein road, and (ii) on the west bank of the Leeuwspruit in the south-east corner of th main lava outcrop which occurs immediately north of the foyaite plug (see map).

(i) Those occuring in the area to the east of the Franspoort-Leeuwfontein road have a flinty appearance, are extremely fine-grained and are composed of biotite or hornblende and some feldspar laths set in a fine-grained partly isotropic groundmass. The rock has a distinct trachy-.tic texture, it also holds numerous small amygdales of carbona and chloride.

(ii) Further to the east on the west bank of the Leeuwspruit a similar lava is seen to hold a few prenocrysts of pyroxene pseudomorphs, as well as a few amygdales composed of quartz, carbonate, chlorite and serpentine (?). The groundmass consists of small feldspar laths up to 0.2 mm x 0.02 mm. Interstitial to the feldspar laths and making up about one-third of the groundmass there is much ore (iron oxide) as well as some chloritic material. A few larger grains of a sulphide ore can be recognised in hand specimens.

These lavas, especially those near the spruit, are cut by monchiquite dykes which appear to have acted as feeders to the lava.

(2). The Lighter Variety constitutes almost the whole of the area marked trachy-andesite immediately north of the foyaite plug. It is intimately associated with type (1) in the south of the area. Macroscopically it is rather variable, it may have either a reddish colour (usually the case in the brecciated varieties) or it may be grey. The rock has a pitted surface due to differential weathering.

Microscopically this variety is seen to consist of abundant polysynthetically twinned plagioclase (oligoclase to andesine) laths about 2 mm. in length, and subordinate anorthoclase. Interstitial to the feldspars, which are often very altered, there are numerous small crystals of amphibole (barkevikite(?)) together with some rounded grains of green pyroxene. Ore is abundant with sphene and apatite present in small amounts. Some varieties are slightly porphyritic and have small plagioclase phenocrysts. Carbonate is abundant, especially in the brecciated varieties. The dark minerals often show a tendency to occur in clusters. As neither feldspathoids nor quartz were identified the rock may be called a trachy-andesite.

These lavas are cut by numerous dykes of syeno-diorite which acted as feeders to the lava (see map).

(3) Dyke Rocks.

As has already been mentioned, numerous dykes are seen to cut the lavas.

(a) Monchiquite Dykes. Certain dykes termed monchiquites by Shand (9, p.86) are found on the west bank of the Leeuwspruit north of the foyaite plug. It is a dense black rock with ferroaugite phenocrysts up to 1 cm. in diameter. It weathers to a reddish-brown colour and little grains of magnetite are seen to stand out on the weathered surface. Apart from the augite the only other primary constituent present in any quantity is magnetite; it forms irregularly shaped grains up to 1 mm. in diameter, which are often enclosed in the ferroaugite. The groundmass of the rock is full of magnetite dust, serpentine, chlorite and other decomposition products, so that its original nature is not easily determinable, in parts a little feldspar is present. The ferroaugite which may alter along cracks to chloritic material with the exsolution of a little ore is almost colourless and not pleochroic, it may sometimes have a faint pink colour. It has the following optical properties:

$$2V\gamma = 48^{\circ} \pm 2^{\circ}$$
$$Z \wedge c = 45^{\circ} \pm ; \quad n\beta = 1.705 \pm 0.003.$$

These properties indicate a composition of hedenbergite$_{22}$, diopside $_{18}$, clinoenstatite $_{28}$ and clinoferrosilite$_{32}$ (20, p. 408).

(b) Syeno-Diorite Dykes are by far the most common dyke rocks and they closely resemble the syeno-diorite dykes from Leeuwfontein. Scores of these dykes were found in the lavas immediately north of the Franspoort foyaite plug (see map). They vary in length from a mere outcrop of a yard or less to about 200 yards in length and are seldom wider than a yard or two. They are seen to grade into the darker finer grained trachy-andesites and no doubt acted as feeders to the lavas.

Two sills were also found outside the area marked as trachy-andesite on the map, they are situated in the Leeuwsprui one north and one south of the foyaite plug (see map).

Microscopically these rocks are seen to consist of grey or pinkish tabular phenocrysts of plagioclase up to about 1 cm. in length set in a light red or grey groundmass.

The plagioclase is polysynthetically twinned andesine (An 42 - 47) and usually twinned according to the Albite and Carlsbad laws, it is often almost completely altered to the usual alteration products. In some slides the andesine has a very narrow mantle of alkali-feldspar. In the two sills mentioned above a few phenocrysts of altered anorthoclase were found.

The groundmass consists of small laths of reddish feld-spar (probably an alkali-feldspar) seldom more than 0.4 mm. long and 0.003 mm. wide and a fair amount of finely disseminated carbonate, chlorite, ore, as well as some brown amphibole and greenish pyroxene. Some of the larger ore crystals have mantles of crystalline sphene.

Clusters of zeolites were seen in some slides and it is possible that they may be derived from nepheline. Sphene and apatite are accessories. Quartz and feldspathoids were not identified.

C. The Area North of the Main Lava Occurrence.

1. Brack Soil.

North of the outcrop of trachy-andesitic lavas there is a stretch of brackish soil about 200 yards wide, with an approximate east-west trend. It is heavily charged with salt and is almost devoid of any vegetation. An analysis of a sample scraped together on the surface by van Biljon (10, p.35) gave the following results :

Na_2Co_3	:	10.60
Na cl	:	0.118
Sulphate	:	t r
H_2O at 100^oC	:	7.53
Insoluble matter	:	82.16.
		100.408

Analyst : S.Sunkel, Chemical Services, Department of Agriculture, Pretoria.

This strip of brack soil is probably underlain by foyaite which is seen to outcrop to the north and east.

In the Leeuwspruit to the east of the brack soil and about 500 yards north of the main foyaite occurence there is a small oblong foyaite plug which is about 75 yards in diameter. This outcrop is probably connected to the foyaites that outcrop a few yards to the west and extend for almost 600 yards in an east-west direction (see map). This dyke-like occurence of foyaite is bordered by the brack soil in the south and by trachy-andesitic rocks, in/to which it is intrusive, to the north. The possibility that these foyaites may be connected to the larger outcrop further south is discussed in the next Chapter.

2. The Foyaites (9, p.83. and 10, p.35).

(a) Leeuwspruit. The foyaite in the Leeuwspruit is intrusive into quartzites. Unfortunately no contacts are to be seen and fresh specimens are difficult to obtain .
The foyaite may either have a dirty red or light grey colour

depending on the colour of the feldspar which is the predominating constituent. As a rule, the red variety is slightly coarser than the light coloured type in which red pseudomorphs after nepheline can be seen in hand specimens.

Microscopically the foyaite is seen to consist of tabular anorthoclase crystals up to 5 mm. long, interstitial to which the nepheline pseudomorphs occur. The reddish stain of the feldspar and nepheline pseudomorphs (zeolites) appears to be due to haematite dust. The chief dark mineral is ferrosalite which occurs as euhedral or subhedral crystals up to 1.8 mm. in diameter, and either interstitially to, or as inclusions in, the feldspar. The ferrosalite may be partly altered to barkevikite (?) which in turn changes into chloritic material and ore. Accessories are apatite (which occurs as inclusions in ferrosalite), ore, sphene and a little secondary carbonate.

The feldspar is a slightly perthitic anorthoclase which often has a small core of andesine (An 30 - 35). The anorthoclase has the following properties : $2V\alpha = 77^{o} \pm 3^{o}$, angle between pole of (001) and $\beta = 15^{o} - 16^{o}$. These properties indicate a composition similar to the anorthoclase of Leeuwfontein.

The ferrosalite is slightly zonally built, has a faint pink colour, and is very slightly pleochroic. (The pink tint indicates the presence of titanium). It has the following optical properties : $2V\gamma = 60^{o} - 62^{o}$, $Z \wedge c = 44^{o} - 46^{o}$, $n\beta = 1.715 \pm 0.005$. These properties indicate a composition equal to that of ferrosalite, with about 5% of either the acmite or jadeite molecule present (20,p.410).

The ferrosalite changes into an amphibole which has such intense pleochroism that the universal stage could not be utilised. The following properties were however determined : pleochrism : X greenish-brown, Y and Z dark brown to very dark brown; $n\beta$ = 1.69±. The extinction angle is about 20°.

These properties indicate that the amphibole is a hornblende and probably barkevikite (20, p.442).

(b) West bank of Leeuwspruit. Here the foyaite that forms the dyke-like occurrence is more leucocratic than the type that occurs in the spruit. Here, a coarse grained, brick-red or light grey foyaite is seen to occur as well as a light grey extremely leucocratic aplite. Long stringers of aplite are seen to cut the lavas.

Microscopically the coarser variety on the west bank of the spruit differs from that which occurs in the spruit in that : (i) the chief dark mineral is not ferrosalite but zonally built aegirine-augite which usually occurs as small anhedral crystals seldom more than 0.5 mm. in diameter.

(ii) The nepheline is seldom completely altered to zeolites and other alteration products.

(iii) The feldspar is more coarsely perthitic and has no core of plagioclase.

The pyroxene alters into soda-amphibole and ore. Accessories are small euhedral sphene crystals, fluorite (with which is often associated a brownish alteration product) and apatite.

The foyaite aplite (the results of an analysis appear on Table V Column II) consists of small coarsely perthitic anorthoslcase laths up to about 1 mm. long. They are simply twinned as a rule and exhibit a distinct parallel orientation. Interstitial to the feldspars, small, more or less euhedral nepheline, and sodalite crystals occur with a maximum diameter of about 0.3 mm. The sodalite contains many minute inclusions which are not arranged in zones, as is often the case in the Leeuwfontein foyaites. A few small crystals of fresh aegirine-augite occur which in some cases may be partially altered to blue-green soda-amphibole and ore. Accessories are apatite (which occurs as inclusions in the pyroxene) and sphene. The aplite is remarkably fresh for a rock of this nature, the feldspars and feldspathoids being only slightly altered to the normal alteration products.

3. The Lavas.

An ill-defined outcrop of lavas with an east-west elongation and measuring about 500 yards by 100 - 150 yards, occurs just north of the foyaite aplite, stringers of which cut the lavas.

The lavas in the south of this outcrop are represented by a black flinty variety which, going towards the north, grades into a reddish brecciated type which is very similar to those lavas which outcrop north of the main foyaite body further to the south. According to the Niggli classification these rocks are normal theralites (see Table V Column IV) but they may be grouped with the trachy-andesites.

Microscopically this black flinty variety is seen to have a trachytic texture. It is composed of small, simply twinned feldspar laths with which is associated many rounded crystals of a greenish soda-amphibole (?) which are pleochroic from dark olive-green to greenish-brown. Accessories are sphene and ore as well as a little secondary chlorite and carbonate.

The reddish brecciated variety is composed of a few small phenocrysts of very altered plagioclase (andesine) set in a groundmass of small feldspar laths. Interstitial to the feldspar laths there is much chloritic material, ore, and also some isotropic material. There are also large and small patches of secondary carbonate which are usually associated with chlorite, ore and apatite.

The results of a chemical analysis of this rock appears in Table V, Column IV, and according to the Niggli classification (19, p.365) it is a normal theralite. Van Biljon (10, p.36) maintains it is a "highly altered calcareous shale" and not a lava.

Van Biljon (10, p.37) mentions that a "chocolate coloured type of 'intermediate' rock suggests a passage between shale and foyaite." But near the spot where foyaite stringers are seen to cut the lava small dykes of this 'intermediate' rock are also seen to cut the lavas and will therefore be discussed under dyke rocks. Chemically, however, this rock is intermediate between the foyaites and lavas. The results of the chemical analysis appears in Table V, Column III. According to the Niggli classification this rock, like the Leeuwfontein trachy-andesites is an essexite-diorite (29, p.364).

4. <u>The Dyke Rocks</u>.

There are numerous dyke rocks in this area and they can be divided into two main groups namely syeno-dioritic and foyaitic dykes.

To the east of the lava outcrop an interesting composite dyke occurs (see map), which can be followed for about a 135 yards and is about 30 yards wide. The southern extremity is associated with quartz brecciation. The first phase of this dyke has a syeno-dioritic composition and consists of light coloured, highly altered, tabular plagioclase (andesine) crystals up to 2 cm. in length and set in a fine-grained dirty red groundmass which is composed of reddish feldspar laths arranged in a stellate fashion. A few large anorthoclase individuals may also be present. The dark minerals have been completely altered to chlorite, carbonate, epidote and other alteration products. Accessories are sphene, apatite and ore. This variety contains numerous inclusions of quartzite and carbonate up to 1 inch in diameter. Identical dykes with an east-west strike occur 100 and 150 yards to the north-east. Shand (9, p.87) called this rock a camptonite but as it contains alkali-feldspar and no labradorite it may tentatively be called a syeno-diorite.

A smilar looking, but foyaitic rock, with a finer grain and a light red groundmass is intrusive into the rock described above. This rock is composed of weathered plagioclase (andesine) laths, often with small mantles of anorthoclase, set in a groundmass composed of small feldspar laths and abundant pseudomorphs after nepheline. The dark minerals are almost completely altered to chloritic material, epidote, ore and carbonate. Accessories are sphene and apatite. Tentatively this rock may be called a nepheline syeno-diorite.

This composite dyke is cut diagonally by a narrow very fine-grained, highly altered brownish-red foyaitic(?) dyke. This dyke is composed of small altered feldspar laths of about 0.1 mm. in length and set in a highly altered and partly isotropic groundmass in which small concentrations of zeolites (pseudomorphs after nepheline(?)) and abundant carbonate can be seen. Occasional pseudomorphs after amphibole (?) as well as a reddish alteration product also occur.

The foyaite outcrop in the spruit is cut by a similar dyke to the one described above. It is composed of small phenocrysts of almost completely altered plagioclase with small mantles of anorthoclase. These phenocrysts which are up to 2 mm. in length are set in a fine-grained groundmass consisting of small feldspar laths with which is associated much chloritic material, carbonate, zeolites and other alteration products.

The most common dyke rock in this area is a fine-grained grey to brownish-grey rock in which rounded carbonate individuals up to 3 mm. in diameter are seen in some specimens. Thes dykes strike north-south as well as east-west and cut the lavas quartz-norites and possibly also the foyaites(see map). Rocks of a similar nature, but not holding any rounded calcite individuals are considered by van Biljon (10, p.37) to be "intermediate" between the trachytes and foyaites and that ther is "a serial colour change....from the shale to, and into, the alkaline rocks across the strike", but as has already been noted, this "intermediate" rock was found to be intrusive into the lavas and possibly also the foyaites.

Microscopically these dyke rocks are seen to be composed of a few phenocrysts of andesine, but the greater part of the rock consists of small ill-defined crystals of plagioclase and anorthoclase ($2V\alpha = 74^{\circ} \pm$). The feldspar which is usually quite fresh may be slightly altered to carbonate and other alteration products in some cases. The dark minerals, which make up about twenty percent of the rock, are ferroaugite and brown hornblende, probably barkevikite, which is an alteration product of the ferroaugite. The melanes occur as beautiful idiomorphic crystals measuring 0.5 by 0.02 mm. Barkevikite is usually more abundant than augite which forms larger crystals s some of which appear as phenocrysts.

Calcite is extremely abundant and some of the larger patches are associated with chlorite, ore, apatite and fresh barkevikite needles.

Shand called these rocks camptonites (9, p.87) but for the same reasons stated previously, and in the light of the results of a chemical analysis of van Biljon's 'intermediate' rock (Table V Column III) these rocks may be called syeno-diorites. Apart from the numerous stringers of foyaite aplite that cut the lavas there are a few fine-grained foyaite dykes, very similar, but darker than, the aplite, situated in about the middle of the lava occurrence.

A small foyaite dyke similar to the aplite was also found in the Leeuwspruit south of the small plug in the spruit

VII. DISCUSSION ON OBSERVATIONS.

A. The Alkali Rocks of the Leeuwfontein Area.

There is very little to add to Professor Shand's remarks (8, p.246) and what follows must be regarded only as an addition to his observations. The origin of the alkaline rocks is discussed under a separate heading.

From the variation diagram (fig.2) it is obvious that we have to do here with a continuous differentiation series.

Contrary to all expectations it was found that the trachy-andesite is chemically more closely related to the soda-syenite than to the syeno-diorite (see fig.2). If it were not for the convincing evidence that the trachy-andesites are definitely older than the syeno-diorites there would have been some justification in assuming that they were younger than the syeno-diorites and about the same age as the grey soda-syenites.

The difference between the trachy-andesite, syeno-diorite and grey soda-syenite is, however, so small that there does not seem to be any ground for suspecting any serious abnormality in the trend of the differentiation.

It is therefore suggested that the trachy-andesites, syeno-diorites and grey soda-syenites represent different phases of the same magma in which the rate of cooling, rather than the differentiation, played the major role. Very little importance is therefore attached to the fact that the trachy-andesites are strictly speaking chemically more closely relate to the soda-syenites than to the syeno-diorites.

Furthermore the si value shows a great variation, it increases from 192.4 in the syeno-diorite, to 225 in the umptekite after which it drops suddenly to 133.2 in the urtite On the contrary the SiO_2 value is fairly constant and lies between 48.36 percent and 60.24 percent.

The pyroxenite probably owes its origin to the crystal settling under gravitational forces of the pyroxene, sphene and ore of the soda-syenite . Then with the emplacement of the foyaite the pyroxenite was broken up and probably alkilize giving rise to the peculiar inclusions in the foyaite which Brouwer called pienaarite and Shand jacupirangite.

Figure 3 attempts to show that when the differentiation reaches soda-syenite the precipitation of diopside (increase o c and fm) and sphene (increase of ti) takes place while the residue undergoes differentiation to form the umptekites, foyaites and urtites.

This process is very similar to that which led to the formation of the pyroxenite bands in the Bushveld gabbros whic have been described by Lombaard (16, p.35).

According to Shand's definition (9a, p.XIX) the urtites, foyaites and umptekites are alkaline rocks but not the grey soda-syenites, syeno-diorites and trachy-andesites which are meta-aluminous rocks.

B. The Alkali Rocks of the Franspoort Area.

As at Leeuwfontein we here have to do with a volcanic vent and the sequence of events seem to have been as follows :

Firstly, there was an extrusion of at least two varieties of rather viscous lava which was fed by dykes.

After the consolidation of the lavas, foyaites which are genetically related to the lavas, were injected into the lavas and underlying sediments. It is unlikely that any of the foyaites penetrated as far as the surface and subsequent erosion has exposed the foyaites and sediments that underlie the lavas,

On the map two foyaite occurences are shown as two separate outcrops. This conclusion is based on the fact that Shand found quartzite below the lavas in a deep prospecting pit, which is now covered in, and also that quartzites outcrop in the Leeuwspruit between the two foyaite occurences. However, it is quite likely that these two foyaite occurences are actually connected not far below the surface as postulated in figure 5.

Figure 4 shows the trend of differentiation in the Franspoort area from theralite through essexite-diorite (trachy ahdesite) to foyaite.

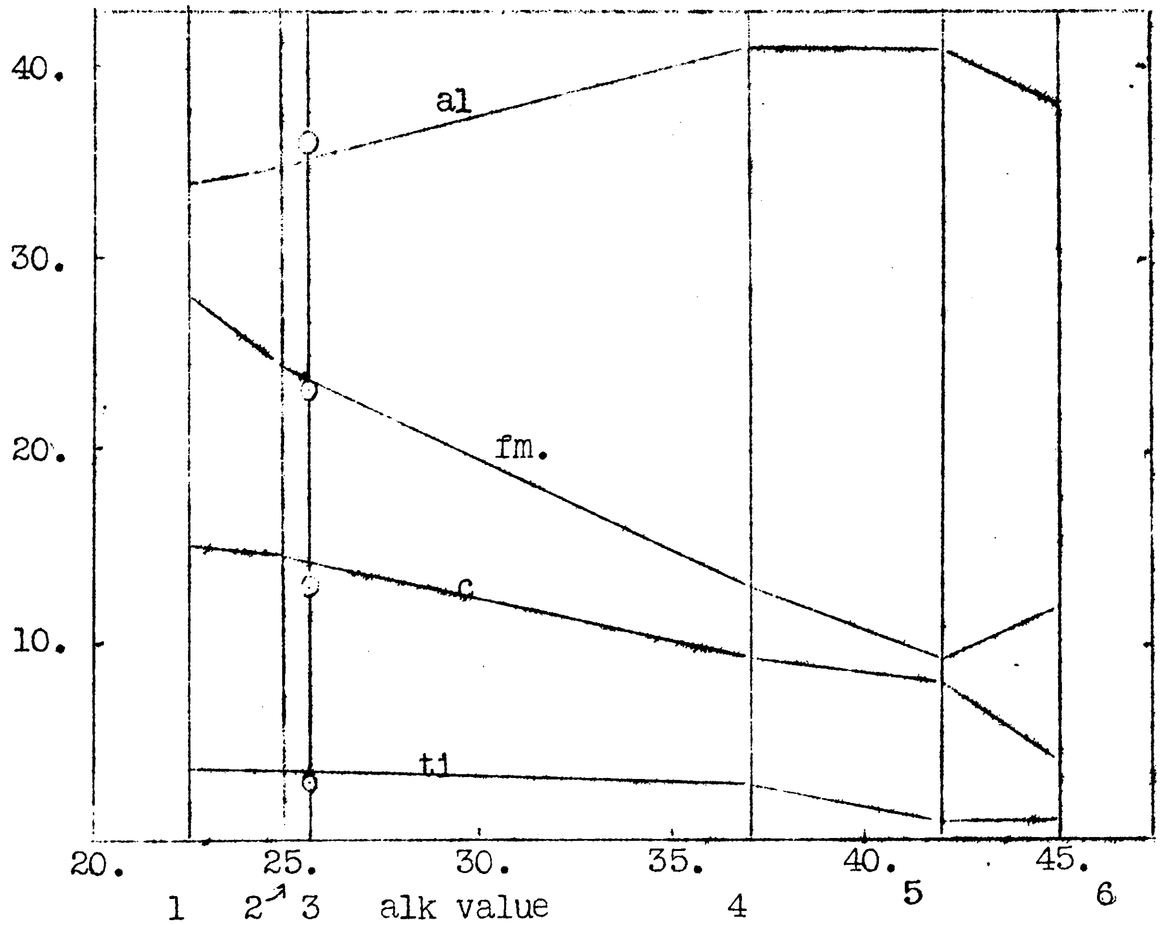
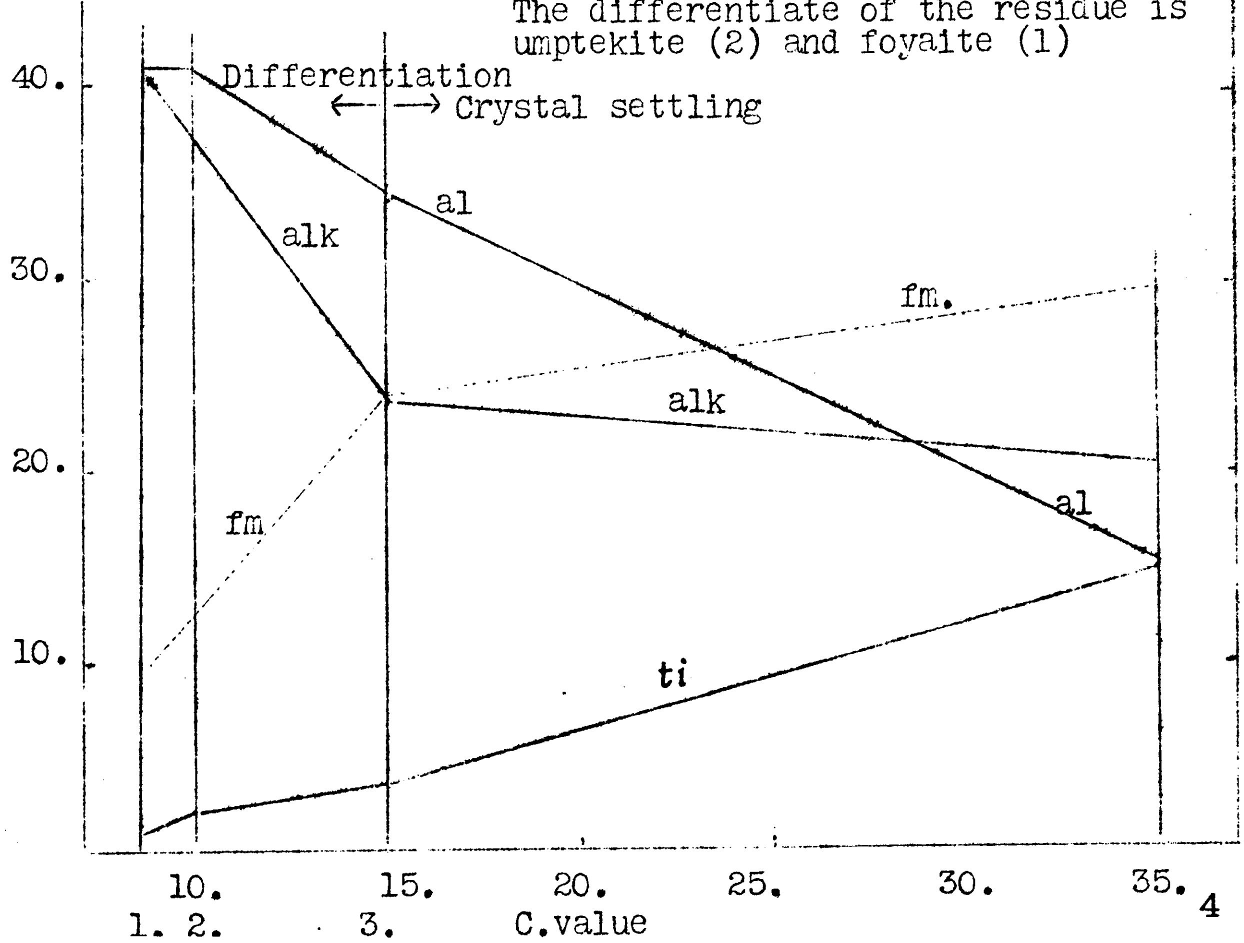


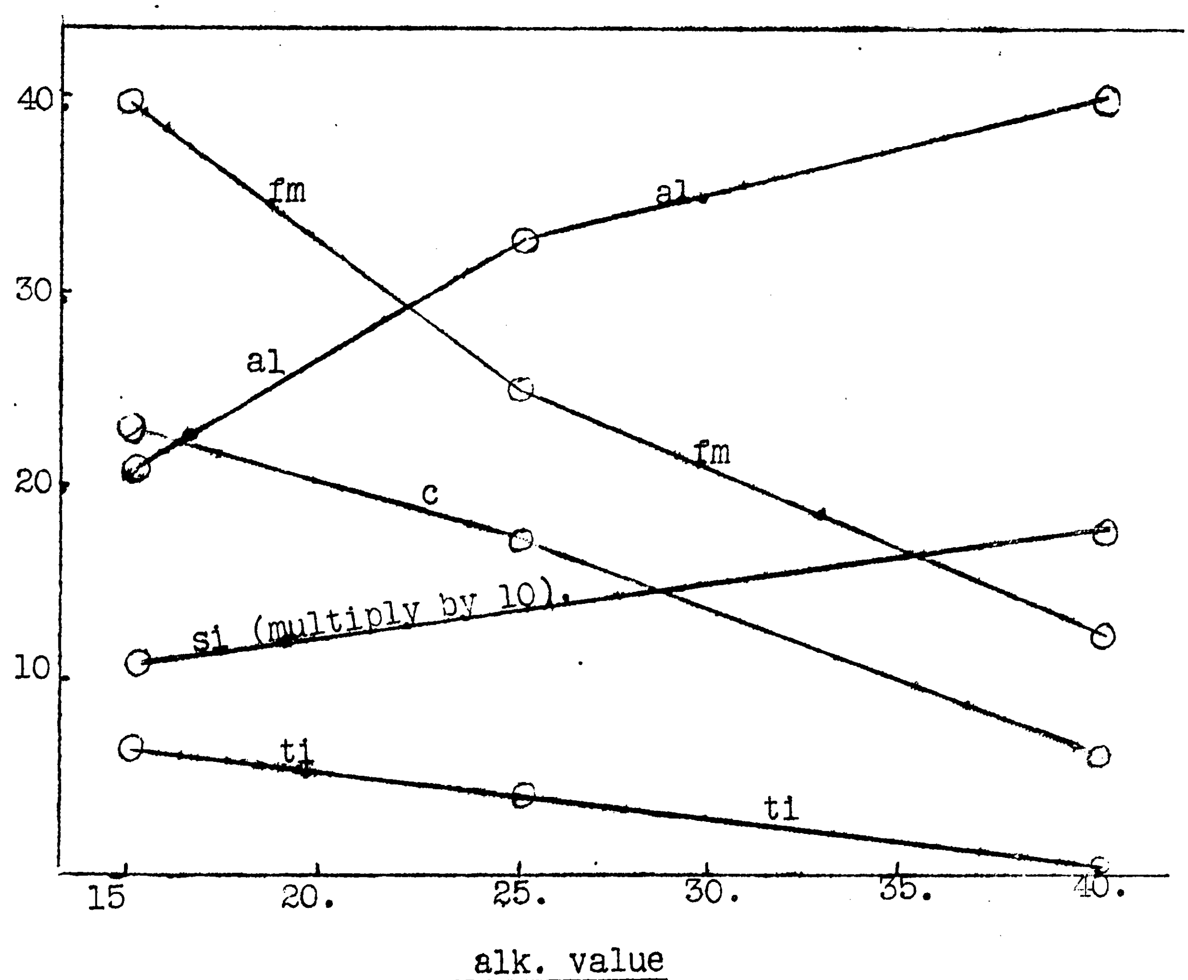
fig. 2. Leeuwfontein Area :
Variation-diagram to show the variation from syeno-diorite (1), through Soda-syenite (2) (and trachy-andesite (3) and umptekite 4 to foyaite (5) of Leeuwfontein and of Franspoort (6).

fig. 3.

Formation of Pyroxenite.

When the differentiation reaches soda-syenite (3) the precipitation of diopside (increase of fm) and sphene (increase of ti.) takes place to form Pyroxenite (4)
The differentiate of the residue is umptekite (2) and foyaite (1)

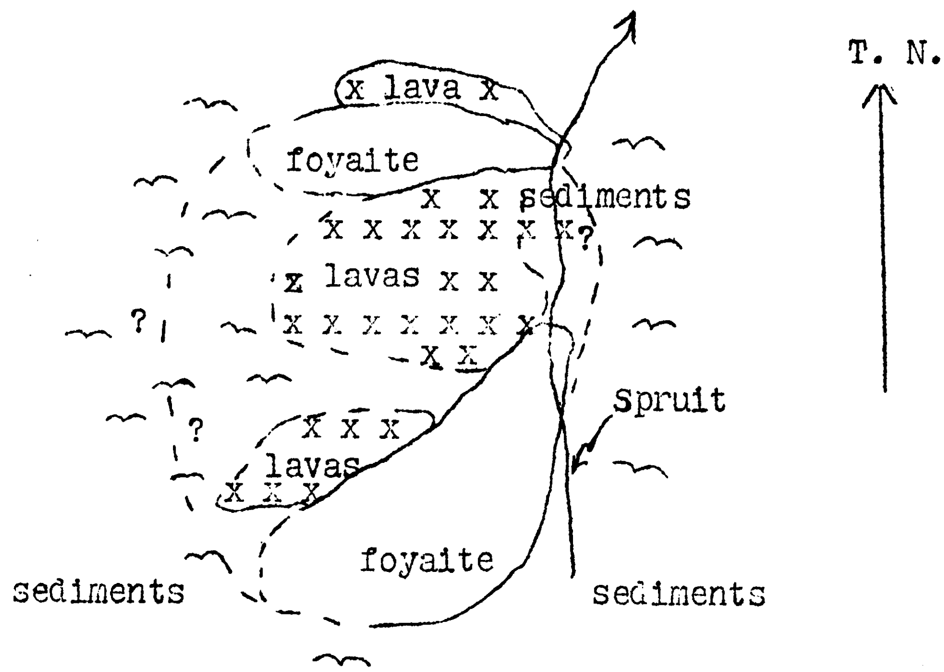


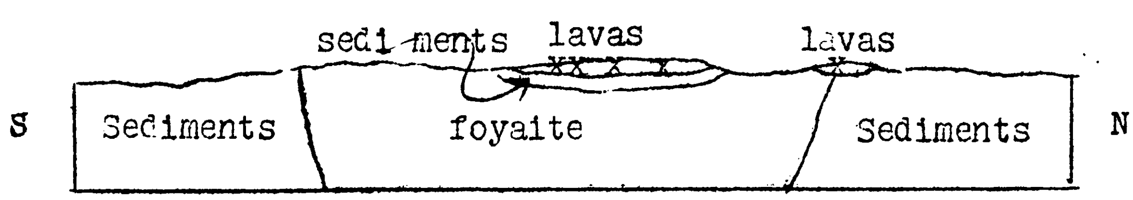


Theralite Trachy-andesite Foyaite Aplite.

fig. 4. Franspoort Area.

Variation Diagram to show variation from a tonalitic lava through trachy-andesite to foyaite aplite.





Vertical section.

Same scale as map.

1,500 yards

fig. 5 Showing the possible extent of the foyaite occurrences on Franspoort.

VIII. ORIGIN OF THE ALKALI ROCKS.

A. Metasomitic Origin.

In The Southern Part of the Franspoort Area.

The foyaites appear to be transgressively intrusive into the Magaliesberg quartzites. Van Biljon (10, p.34) claims that these foyaites take "up a stratigraphical position comparable to the Visserhoek limestone horizon," but even if this were so one may well ask if this would necessitate the foyaite being derived from the limestone? Furthermore. the Visserhoek limestone has a width of about 25 yards and the foyaites a width of at least 500 yards. The author therefore feels that the theory that the foyaites were derived from the Visserhoek limestone horizon may be dismissed without further comment.

The lavas above the foyaites are typical extrusive lavas; this is confirmed by the fact that they are fed by numerous dykes of a syeno-dioritic composition. The author therefore considers it unlikely that they are altered shales as claimed by van Biljon (10, p.34).

(2) In the Northern Part of the Franspoort Area.

Van Biljon (10, p.36) maintains that as regards the lavas "Field relations make it almost certain that the dark compact rock . . . . is a highly altered mobilised calcareous shale in which metasomatism played no mean part."

Furthermore, he maintains (page 37) that because the foyaite outcrop is parallel with and confined to the shale horizon, and because "a serial colour change seems to exist from the shale to and into the alkaline rocks across the strike" through an "intermediate" rock, the lavas and foyaites are altered shales. If, what has already been said about this "intermediate" rock in Chapter VI, Sections 3 and 4, and the fact that numerous stringers and small dykes of foyaite cut the lavas is taken into consideration, Dr. van Biljon's conclusions seem a little hasty.

Furthermore the foyaite aplite and the foyaite from the plug further south are chemically almost identical, suggesting that they were not formed by the metasomatism of such widely different rocks as shale and limestone. It may also be argued that van Biljon's diagram (10, p.39) proves magmatic differentiation.

(3) In the Leeuwfontein Area.

Van Biljon (10, p.72) maintains that the trachy-andesite ridge lies on the extrapolation of the Gifkop quartzites which lie above the M_3 quartzites. As the trachy-andesite ridge lies to the north of the Gifkop quartzites, van Biljon seems to imply that they owe their relative position to faulting (see van Biljon's map).

It may well be asked why only the part that was faulted away should have changed into trachy-andesite, while the Gifkop quartzites, which outcrop just north of Mr. Braak's house, are of a normal slightly feldspathic type.

Furthermore, van Biljon (10, map) has drawn in faults on either side of the trachyte ridge, presumably with the intention of implying that that particular part of the quartzite which has been altered to trachy-andesite has been removed to the north. The author, however, was not able to find any evidence of faulting that could have caused a displacement of at least a thousand yards. To the west of the trachy-andesite ridge detailed mapping failed to show any sign of a major fault. On the east the whole area is covered by alluvium, thus making the drawing of any fault here purely hypothetical

Furthermore, the M_3 quartzites show no sign of faulting in the area south of the Complex. Consequently it seems unlikely that the trachy-andesites originated in the manner as postulated by van Biljon.

As regards the syenites, van Biljon (10, p.142) states: "The majority of the outcrops show a tendency to parallel the regional strike of the sediments". Of the foyaites, he maintains that the larger occurrences seem to be confined to the limestone horizons. A glance at the map, however, will show that the syenites and foyaites cut across quartzites, shales, hybrid rocks, hornfelses, pyroxenites and diabases. The author therefore dismisses van Biljon's postulations as incorrect.

Moreover, had the Leeuwfontein foyaite been formed from a shale or limestone it would require a band at least 500 feet thick. Such a band is nowhere to be found, and in any case, the foyaite occurs south of the limestone horizon in the north of the area.

Of the amygdaloidal trachy-andesitic rocks described in Chapter III, Section D, van Biljon (10, p.157) writes: "From their persistent occurrence on limestone horizons or their close association with metasomatically altered limestone remnants above M_4 it is concluded that the alteration or disappearance of the limestone and the appearance of the amygdaloidal rock-types seem to be connected incidents, in short, the rock strongly suggests a metamorphic (or metasomatic) origin."

Although it is admitted that the amygdaloidal lava does occur near a limestone horizon in the north of the area, in no other locality is it found near such an horizon or even a possible limestone horizon.

Furthermore, it is difficult to imagine an amygdaloidal andesite or trachy-andesite being derived from a limestone, and at the same time the trachy-andesite of the Leeuwfontein Complex being derived from a quartzite.

Van Biljon maintains (10, p.109) that all the dyke rocks occur on, or adjacent to, limestone horizons or suspected limestone horizons. The author finds this view completely untenable for the following reasons :-

1) Dyke rocks strike north-south, whereas the limestone horizons have an east-west strike,
2) A north-south foyaite dyke, almost 2½ miles in length, cuts shales, quartzites, "felsites", hybrid rocks, trachy-andesites and diabase, all of which have an east-west strike,
3) Dyke rocks are more or less evenly distributed throughout the area.

Concerning the origin of the alkaline rocks van Biljon (10, p.143) states : "From field relationship, distribution, size of individual outcrops and frequency of occurrences, it is difficult to postulate a magma in depth from which all the syenite could be derived". But it may be argued that a process by which syenites, foyaites and related lavas may be derived from the alteration of sediments is much more unlikely, especially as similar rocks are supposed to form from such widely different sediments as quartzites, shales and limestones.

The author therefore concludes that the alkaline rocks are not metasomatic or metamorphic rocks, but are in fact uncontaminated differentiation products of a basaltic magma as described in the next Section.

B. MAGMATIC ORIGIN.

Before discussing the genesis of the alkaline rocks it is necessary to inquire into their age.

The alkaline rocks of the "Franspoort Zone", Pilansberg and Spitskop have been interpreted as a late phase of the Bushveld petrogenetic cycle by Brouwer (6, p.31) and Shand (8 and 9).

As most of the alkaline occurrences in the Transvaal are found either in, or very near, the Bushveld Complex, this was for some time the most logical explanation of the origin of the alkaline rocks. Hall (4, p.83) however, pointed out that this view was not justified because of the considerable lapse of time between rhe intrusion of the Bushveld Complex and that of the alkaline rocks.

Strauss and Truter (11, p.118) in discussing this long interval state that "after the emplacement of the Bushveld Complex there was a period of erosion prior to the deposition of the sediments of the Loskop System which contains pebbles of Bushveld rocks. The Loskop system is separated from the overlying Waterberg system by a strong angular unconformity . The alkali rocks in the Pilansberg and in the 'Franspoort Line' are known to be post Waterberg, as inclusions of Waterberg rocks are found in the Pilansberg eruptives, and dykes of bostonite and tinguaite associated with the 'Franspoort Line' cut across Waterberg sediments north-east of Pretoria. Boulders of Pilansberg rocks occur in the Dwyka tillite, and Karroo sediments cover the alkali rocks of the 'Franspoort Line' unconformably near Hammanskraal. The alkali rocks of Pilansberg and the 'Franspoort Line' are therefore post-Waterberg and pre-Karroo". Furthermore, they point out that at Spitskop there is no means of dating the Complex "beyond the fact that it definitely post dates, and clearly has no genetic connection with the Bushveld Complex".

Daly, (36, p.477) has suggested that this group of rocks has arisen primarily through the "desilication" of magmas of normal composition by contact with carbonate rocks.

Shand, (37, p.140) a great supporter of Daly's "desilication" theory, suggests that the mass of limestone forming a core about half a square mile in area at Spitzkop, was carried up by the granitic magma of the Bushveld Complex from the underlying Transvaal Dolomite.

Strauss and Truter (II, p.115), however, have found that the limestone is devoid of any sedimentary characteristics and also that it contains xenoliths of alkaline rocks. Furthermore, they state on page 121 that "It seems improbable that small alkali complexes should always succeed so eminently in mobilising sedimentary limestone, and that considerably larger complexes of non-alkaline composition should equally invariably fail to do so. It seems much more likely that the limestone associated with alkali rocks resulted from, rather than caused the generation of an alkali magma."

Professor Shand's objection (38, p.497) to a carbonatite magma was that it would be a "highly explosive liquid". This statement, however, can be looked upon as proving the existence of a carbonatite magma as carbonatites are invariably associated with extreme brecciation, thus proving its explosive nature (11, p.121).

Thus, in the light of the discoveries of Strauss and Truter (11, pp 114 - 116) as well as work done by von Eckerman at Alno, Davies (39) in Uganda, Mennell (40) in Rhodesia and many others, we are forced to look upon the origin of the alkali rocks in a totally different light.

Now that the Daly-Shand hypothesis has been more or less discarded, we have two ways in which an Alkali Complex may be formed, neither of them contradictory to each other, viz:

(1) In certain Complexes, such as at Spitzkop (II, p.122) where the parental magma, which gave rise to the Complex was of a peridotitic composition and where the carbonatites were developed by differentiation along certain definite lines. At Spitzkop, the first rocks that were injected were theralites and biotite pyroxenites. These were followed by an injection of ijolite, emanations from which fenitised the granites and the previously injected pyroxenites into various alkali rocks by the removal of silica and addition of Na, Ca, Al and Fe. Due to the intense metasomatism concentric sheet structures were developed into which were injected foyaites, syenites and finally carbonatites.

(2) In the alkali rocks of other areas it is however necessary to visualise a different type of process, one that does not involve fenitisation or desilication, but straightforward magmatic differentiation from a basaltic or peridotitic magma. This appears to be the case at Leeuwfontein, where rocks are seen to range from trachy-andesite and syeno-diorite through soda-syenite, umptekite and foyaite to urtite. The final phase is represented by the phosphorus-bearing fluorite, carbonatite and much brecciation.

That a trachytic rock may be derived from a basaltic magma has been shown in many instances; for example, in a sill in the Grand Canyon in Arizona a sheet of 200 - 300 metres thick is composed of olivine diabase which grades into a hornblende syenite (36, p.467). Furthermore, in the Lebombo Mountains nepheline-basalts are intimately associated with the basalts (12, p.284).

According to Bowen (41, pp.238 - 9), trachytic magma may be produced by the pure crystal fraction of basaltic liquid. From the analogies of artificial "dry" melts he notes two possibilities:-

(1) Sufficiently slow cooling of a basaltic magma may "permit the complete resolution of olivine (or excess of olivine) and thus determine a trachytic differentiate."

(2)"In the typical basalt-trachyte association the differentiation may proceed still further in the alkaline direction, and give phonolitic trachyte with a deficiency of SiO_2 below that necessary to convert all the alkalis and alumina into feldspars."

For the formation of phonolites from a basaltic magma, Shand (30, p.334) has suggested that the following may hold good : "plagioclase + olivine = nepheline + pyroxene." This could also explain the origin of urtites, jacupirangites, foyaites and other alkaline rocks.

For a carbonatite to be a differentiation product of an igneous magma does not seem impossible when the true facts are examined. Tomkieff, according to Shand (30, p.325) contends that the greater part of the CO_2 normally present in an eruptive magma escapes during the consolidation, but under suitable conditions it may be so concentrated during the last magmatic stages that "not only did the carbonates crystallize out, but they formed an independent carbonatite magma-fraction". He suggests that the upper zone in the pipe that supplied the Fen rocks was originally composed of an alkali-pyroxenite magma rich in CO_2, and that from it there arose by "crystallization-differentiation combined with diffusion of alkalis and volatiles" three main rock series, namely, a series of silicate rocks from urtite to jacupirangite, a series of iron ore rocks, and a carbonatite series.

Grout (42, p.82) states :"Carbonic acid is known to be present in many magmas, and if it is held under pressure while the magma crystallizes, some of it may not unreasonably be expected to combine with the metals as carbonates as the rock cools."

As there is definite proof that fluorite is present as a late magmatic product of alkali intrusions, as at Pilansberg and Leeuwfontein, it seems quite logical that $CaCO_3$ could al be present.

In the Franspoort Zone of eruptions there was an explosive release of pressure towards the end of the cycle of in trusions, and numerous agglomerate plugs, some containing red Bushveld granite inclusions, are found in this area. At Derd poort a breccia piercing the Magaliesberg quartzites contains much crystalline limestone. Venter (11, p.82) considered it t be derived from the Transvaal Dolomite formation, while van Biljon (10, p.42) held it to be from the Visserhoek limestone horizon. In the light of new evidence, however, this plug ma be looked upon as a carbonatite plug, genetically related to th Franspoort Zone of intrusions (see also 12, p.198).

The question arises as to what cycle of igneous eruption the basaltic magma that gave rise to the alkaline rocks is connected. There are two possibilities.

1) The alkali rocks are connected to the Waterberg series of intrusions, which includes diabases, quartz-diorites and diorites. This, however, is not accepted on the ground that Waterberg volcanics occur only in the Northern Transvaal and not in the area north-east of Pretoria. It would therefore seem unlikely that Waterberg volcanics would occur only outside, and

never in, the Waterberg series in the area about Pretoria. Hall (4), however, regarded the trachy-andesites from Leeuwfontein as a typical Waterberg lava.

2) A more likely connection can be postulated with the alkali granites of the Parys-Vredefort area. Here there are numerous outcrops of younger alkaline granites that are intrusiv into the older gneisses, the Witwatersrand and Transvaal systems Associated with this younger granite are numerous alkali dykes which may be connected to the Pilansberg Complex. It appears therefore quite likely that these alkali granites of the Parys-Vredefort area may be genetically related to the rocks of the Pilansberg.

Thus it is suggested that most, if not all, of the alkali rocks are not genetically related to the Bushveld Complex, but rather to a later post-Waterberg phase of eruption which may also have given rise to the alkali granites of the Parys-Vredefort area. The presence of the alkali rocks in, or near, the Bushveld Complex can then be explained only as mere coincidence, and the numerous outcrops of alkali rocks in the Pretoria area (see small map) represent chimneys or vents which are connected to a large body below the surface which measures at least 30 x 40 miles. Apart from the 23 known outcrops (excluding dykes) which occur to the north and east of Pretoria inclusions of foyaite have been found in the Premier Mine (8, p.99) and in the Pretoria Salt Pan (44). It would, therefore, seem more correct to speak of the "Franspoort Zone", rather than the "Franspoort Line".

Lombaard (15, p 127 and 134) has described a small occurrence of albite-syenite from near the Premier Mine which, he suggests, may be related to the norites of the Bushveld, since it is seen to grade into the felsites which in turn, grade into norites. Similar relationships appear to be evident from syenite and foyaite occurrences near Rayton and Bronkhorstspruit shown on the small map. Mapping by the Geological Survey is still in progress here, and more details will soon be available. It is suggested that these syenites and foyaites may in reality be related to the fayalite-diorites of the upper zone of the norites that have assimilated dolomite or magnesia-bearing shales. The fayalite would then be converted to pyroxene, which may cause some of the feldspar to be represented by feldspathoids if the total silica content is low enough.

The postulation that the albite-syenites may be related to the fayalite-diorites may be strengthened by the fact that Professor Lombaard has recently discovered the Upper Zone to the west of the Pretoria Centrocline.

IX. ECONOMIC ASPECTS.

1. Ornamental building stones are periodically quarried in the grey soda-syenite and brick-red soda-syenite on Leeuwfontein, and from the foyaite koppie on Franspoort.

2. Impure fluorite which occurs to the north of the Leeuwfontein Complex was at one time mined but operations have long since ceased.

3. Limestone was also previously quarried to the north of the Leeuwfontein Complex on the farm Zeekoegat.

4. The feldspar of the leucocratic phase of the grey pegmatite may be of economic value.

5. Isolated outcrops of galena are found in old prospecting pits on, or near, the M_2 quartzite horizon on the farms Franspoort and Leeuwfontein.

6. Good quality building sand is found on Franspoort between the M_1 and M_2 quartzite horizons.

7. van Biljon (10, p.171) found traces of gold on the hornfels ridge to the west of the Leeuwfontein Complex.

Table I.

NORITIC, DIORITIC, AND INTERMEDIATE ROCKS.

	I	II	III	IV
SiO_2	51.52	54.10.	56.85	65.43
Al_2O_3	17.10	16.00	15.61	10.62
Fe_2O_3	.46	1.88	2.95	1.14
FeO	5.74	6.28	5.46	4.75
MnO	0.02	0.13	0.14	0.14
MgO	10.72	6.52	4.49	4.11
CaO	10.00	7.44	6.50	4.42
Na_2O	1.70	1.48	2.10	3.46
K_2O	0.20	1.70	2.08	2.44
P_2O_5	0.02	0.09	0.13	0.42
H_2O +	0.13	1.90	1.86	2.19
H_2O -	0.01	0.16	0.18	0.11
TiO_2	0.44	0.56	0.76	1.11
CO_2	n.d	0.90	0.62	nil
BaO	n.d.	0.53	0.68	nd
	100.06	99.67	100 .41	100.34
S.G.	2.98	2. 88	2.88	2.73

Niggli Values.

	I	II	III	IV
si	114.00	147.80	171.70	242.00
al	22.00	25.75	27.76	23.00
fm	50.50	45.04	41.06	41.00
c	23.50	22.31	21.01	17.50
alk	4.00	6.89	10.16	18.50
k	0.08	0.43	0.39	0.32
mg	0.71	0.59	0.49	0.56

The magma-type of I is normal-gabbroid, II is si-gabbrodioritic. III is not well represented but approaches "perléeitisch" which falls within quartz-diorite, IV is not well represented but approaches normal quartz-diorite (29, p.359).

N O R M S.

		I.		II.		III		IV.	
	Q	2.40		9.96		14.11		21.36	
	or	1.11		10.07		1.28		14.46	
	ab	14.15		12.53		17.72		29.34	
	an	38.64		31.99		26.98		6.12	
di	wo	4.64		2.21		2.32		5.57	
	en	3.30	8.86	0.96	4.43	1.41	4.52	3.30	10.85
	fs	0.92		1.26		0.79		1.98	
hy	en	23.50	30.36	15.44	23.43	9.44	15.08	7.00	11.22
	fs	6.86		7.99		5.64		4.22	
	mt	3.71		2.72		4.17		1.62	
	il	0.76		1.06		2.10		2.13	
	ap	0.00		1.80		0.34		1.01	
	H_2O etc	0.18		2.64		2.66		2.30	
		100.17		100.63		99.96		100.41	

I. Spotted norite, Schaapkraal (442) Lydenburg District. Trans.geol.Soc. S.Afr. Vol. 37, p.17. Analyst : B.V.Lombaard.

II. Granophyric-quartz-norite, (T95) Franspoort (426) Analyst : A.Kruger, Chemical Services, Pretoria.

III. Granophyric quartz-diorite (T.59) Leeuwfontein (320) Analyst A.Kruger, Chemical Services, Pretoria.

IV. "Intermediate rock" Carlsruhe (17) Pretoria District Trans. geol. Soc. S.Afr. Vol 35, p.132. Analyst B.V.Lombaard.

TABLE II

FELSITIC ROCKS.

	I	II	III	IV
SiO_2	77.78	75.13	77.05	72.66
TiO_2	0.52	0.20	0.55	0.45
Al_2O_3	8.81	9.96	10.12	10.20.
Fe_2O_3	1.12.	1.14	0.64	0.80
FeO	1.26	1.72	1.44	2.73
MnO	0.06	0.08	0.07	0.07
MgO	2.78	2.20	2.17	2.53
CaO	0.37	1.08	1.74	3.03
Na_2O	2.57	1.89	1.12	1.76
K_2O	3.48	3.57	3.97	3.45
H_2O +	1.10	1.96	1.03	1.23
H_2O -	0.09	0.07	0.04.	0.05
P_2O_5	0.29	0.12	nil	0.12
CO_2	--	1.22	0.29	0.54
Cr_2O_3	--	--	tr	tr
SO_3	--	--	--	0.72
	100.23	100.34	100.23	100.34

Niggli Values

	I	II	III	IV
si	472.00	446.00	454.40	380.50.
al	31.00	35.00	35.16	36.03
fm	37.00	33.50	32.52	20.90
c	3.00	7.00	10.98	19.49
alk	29.00	24.50	21.32	23.46
k	0.47	0.55	0.69	0.56
mg	0.68	0.59	0.59	1.08

These felsitic rocks do not even approach any magma type.

N O R M S

	I	II	III	IV
Q	44.64	45.72	48.60	40.05
or	20.57	21.13	23.91	20.57
ab	22.01	16.77	9.43	15.20
an	0.28	----	6.39	9.45
c	0.61	2.86	1.53	---
di	---	---	---	1.40
hy	7.79	6.48	6.46	8.77
mt	1.62	1.62	0.93	1.16
il	0.91	0.46	1.22	0.91
ap	0.67	0.34	---	0.34
C	---	1.67	0.70	1.10
H_2O	1.19	2.03	1.07	1.28
	100.29	99.08	100.24	100.23.

I. "Felsite", Dornkloof (431), Pretoria District, Trans.ge Soc.S.Afr. Vol 35, p.142.
Analyst : B.V.Lombaard.

II. "Felsite" 125 metre depth Premier Mine, Trans.geol.Soc S.Afr. Vol. 35, p.142. Analyst B.V.Lombaard.

III. Spotted "felsite" Baviaanspoort, Trans.geol.Soc. S.Afr. Vol. 52, p.126. Analyst: C.J.Liebenberg.

IV. Grey "Felsite" near right bank of Hartebeest-spruit in south of Kameelfontein, Trans.geol.Soc. S.Afr. Vol. 52, p.126.
Analyst : C.J. van der Walt.

TABLE III.

FELDSPATHIC QUARTZITES FROM LEEUWFONTEIN (320).

	I	II	III	IV
SiO_2	78.84	84.47	78.23	80.51
Al_2O_3	10.83	7.39	10.27	9.49
Fe_2O_3	2.56	2.24	1.12	1.97
FeO	--	--	0.57	0.19
CaO	0.28	0.25	0.50	0.34
MgO	0.75	0.31	0.96	0.67
K_2O	3.71	2.39	3.71	3.27
Na_2O	0.10	0.14	0.46	0.23
H_2O +	2.46	2.23	2.50	2.40
H_2O -	0.16	0.06	0.26	0.16
SO_3	0.38	0.51	0.41	--
TiO_2	0.16	0.28	0.16	0.20
P_2O_5	0.03	0.05	0.05	--
MnO	0.04	0.03	0.06	0.05
Cr_2O_3	nil	nil	nil	nil
CO_2	nil	nil	nil	nil
	100.30	100.35	99.26	99.48
S.G.				2.62.

Niggli Values		
	si	735.5.
	al	51.1
	fm	24.5
	c	3.3.
	alk	20.6
	k	0.9
	mg	0.37
	c/fm	0.14
	ti	1.37

I, II, and III: Results of analyses of feldspathic quartzites ove a thickness of 210 feet in the south of Leeuwfontein (320-); IV i an average of I, II and III, Trans.geol.Soc. S.Afr.Vol.52, p.126

Analyst : C.J.van der Walt, Chemical Services, Pretoria.

TABLE IV.

ALKALI ROCKS FROM LEEUWFONTEIN (320·)

	I	II	III	IV	V.	VI	VII
SiO_2	58.72	57.51	58.38	60.24	56.12	.35	49.20
TiO_2	1.11	1.36	1.24	0.94	0.46	0.45	7.13
Al_2O_3	18.49	17.22	17.68	18.54	19.62	23.10.	9.23
Fe_2O_3	0.49	2.72	2.48	0.54	2.32	2.48	7.73
FeO	5.14	4.02	3.23	2.36	0.90	1.89	3.24
MnO	0.02	0.21	0.17	0.01	--	--	--
CaO	3.98	4.08	3.72	2.29	2.07	2.51	11.55
MgO	1.48	1.88	1.53	0.76	0.13	0.89	1.35
Na_2O	6.10	5.38	5.55	6.59	9.50	13.20	6.20
K_2O	3.37	2.60	3.16	5.44	4.17	5.58	1.96
H_2O +	0.23	0.92	0.69	0.50	3.50	2.91	2.20
H_2O -	0.30	0.12	0.12	0.72			
P_2O_5	0.48	0.44	0.36	0.27	nd	nd	0.06
F	0.04	nd	nd	0.02	nd	nd	nd
cl	nd	nd	nd	0.00	0.80	1.49	nd
SO_3	nd	nd	nd	0.04	nd	nd	nd
S	nd	nd	nd	0.07	nd	nd	nd
CO_2	nd	0.90	0.95	0.43	nd	nd	nd
BaO	nd	0.12	0.46	nd	nd	nd	hd
ZrO_2	nd	nd	nd	nd	nil	nil	nil
	99.95	99.48	99.72	99.76	99.59	100.85	99.85
SG	2.744	--	---	2.638	--	---	---

Niggli Values.

	I	II	III	IV	V	VI	VII
si	195.5	192.4	201.30	225.1	198.20.	133.8	163.70
al	36.28	33.96	35.91	40.83	40.83	37.66	15.27
fm	23.10	28.22	24.25	13.16	9.48	13.19	28.91
c	13.89	14.86	14.35	9.16	7.83	7.45	34.76
alk	26.85	23.66	25.49	37.13	41.89	41.69	20.25
k	0.27	0.24	0.27	,0.35	0.22	0.15	0.17
mg	0.32	0.33	0.33	0.32	0.07	0.28	0.19
C/fm	0.60	0.52	0.57	0.70	0.83	0.56	1.20
ti	2.72	3.42	3.21	2.65	1.23	0.49	15.05.

The magma-type of 1 is "Larvikitisch" (an essexite-diorite which includes the trachy-andesites). The magma type of II and III is either "maenaitisch" (a soda-syenite) or "kassaitisch" (an essexite-diorite). The magma type of IV is umptekite, V is normal foyaite, VI is urtite, and VII is pienaarite. (See 29, pp. 364, 263, 356).

N O R M S

		I	II	III.	IV	V	VI	VII
Q		--	4.80	402	--	-	--	--
or		17.03	15.36	18.70	32.17	24.60	21.50	11.69
ab		50.59	45.61	46.90	47.56	44.36	14.60	27.26
ne		--	--	--	4.20	18.25	45.65	.3.69
an		13.10	15.16	14.00	4.90	--	--	--
Na_2SO_4		--	--	--	0.03	--	--	--
Na_2cl_2		--	--	--	--	1.30	2.46	--
CaF_2		--	--	--	0.02	--	--	--
di	wo	1.50	1.16	1.28	1.90	0.36	3.60	3.90
	en	0.45	0.60	0.75	0.86	0.30	2.11	3.36
	fs	1.00	0.45	0.45	1.06	--	1.12	--
ol	fa	6.32	--	--	2.24	--	--	--
	fo	2.96	--	--	1.41	--	--	--
hy	en	1.10	4.02	3.21	--	--	--	--
	fs	2.11	2.90	1.85	--	--	--	--
ac		--	--	--	--	--	1.50	13.90
il		2.12	2.58	2.35	1.60	0.90	0.88	6.83
mt		0.70	3.94	3.60	0.76	1.55	2.78	--
hm		--	--	--	--	1.25	--	2.87
		1.15	1.01	1.00	0.34	--	--	1.35
ti		--	--	--	--	--	--	8.63
wo		--	--	--	--	.14	1.63	13.30
Pr		--	--	--	1.20	--	--	--
H_2O etc.		0.53	1.94	1.76	1.63	3.50	2.91	2.20
		100.66	99.53	99.87	100.80	99.61	100.74	98.98

I. Trachy-andesite Trans.geol.Soc.S.Afr. Vol. 24 p.237
Analyst : S.J.Shand

II. Syeno-diorite (T.204)
Analyst: A.Kruger, Chemical Services, Pretoria.

III. Grey soda-syenite (T.239) . Analyst: A.Kruger, Chemical Services, Pretoria.

IV. Umptekite pegmatite. Trans.geol. Soc.S.Afr. Vol. 24, p.241. Analyst S.J.Shand

V. Foyaite. Trans.geol.Soc.S.Afr. Vol. 24, p.243. Analyst: F.Pisani (the figure for Al_2O_3 is almost certainly too high, for it makes the molecular proportion of alumina exceed that of soda, in spite of the presence of aegirinaugite and sodalite in the rock).

VI. Urtite (Brouwer's sodalite-rich aegirine-foyaite) Trans. geol. Soc. S.Afr. Vol. 24, p.243.
Analyst : F.Pisani.

VII. Jacupirangite (Brouwer's Pienaarite) Oorsprong en samestelling der Transvaalsche Nepheline-syeniten (1910) p.50.
Analyst: F.Pisani.

Table V.

ALKALI ROCKS FROM FRANSPOORT (426-).

	I	II	III	IV
SiO_2	53.94	56.10.	53.00	43.40
Al_2O_3	20.70	21.00	18.90.	13.63.
Fe_2O_3	2.04	2.60	2.50	4.32
FeO	1.92	1.40	4.30	7.04
Cr_2O_3	--	--	--	nil
MnO	0.04	0.12	0.28	0.25
CaO	1.18	1.70	5.50	8.41
MgO	0.36	0.60	1.80	3.95
K_2O	5.24	5.50	3.60	2.90
Na_2O	9.76	8.90	6.30	4.03
P_2O_5	0.01	0.02	0.25	0.54
SO_4	--	--	--	0.17
H_2O +	3.30	1.30	1.30	2.07
H_2O -	0.29	nil	nil	0.13
TiO_2	0.35	0.40	1.90	3.30
CO_2	--	--	--	5.64
CaF_2	0.55	--	--	--
cl	0.17	--	--	--
	99.85			
less O = cl	......0.04	99.64	99.63	99.78
	99.81			

NIGGLI VALUES.

	I	II	III	IV
si	166.3	184.1	156.4	114.0
al	38.48	40.60	32.86	21.08
fm	11.73	13.63	24.99	40.07
c	3.88	5.97	17.39	23.64
alk	43.82	39.81	24.78	15.10.
k	0.35	0.28	0.27	0.32
mg	0.144	0.22	0.32	0.39
ti	0.834	1.24	4.22	6.50.
c/fm	0.34	0.44	0.70	0.59

The magma type of I and II is normal foyaite. III is "Kassait-isch", an essexite-diorite and may be called a trachy-andesite, IV is a normal theralite. (29, p.363 - 365)

NORMS.

	I	II		III		IV	
or	30.58	32.50		21.15		17.14.	
ab	26.78	32.82		31.46		15.20	
ne	27.55	23.01		11.93		10.23	
an	---	1.11		12.66		10.55	
Na_2Cl_2	0.35	--		--		--	
wo	---	1.05		--		--	
di wo		1.74		6.50		11.61	
di en	4.61	1.51	3.25	3.51	12.78	7.53	22.44
di fs		---		2.77		3.30	
ol fo	0.55	---		1.27	2.29	3.10	4.73
ol fa		---		1.02		1.63	
ac	2.77	---		---		--	
mt	1.62	3.47		3.50		6.25	
il	0.61	0.91		3.60		6.07	
hm	---	0.15		---		---	
ap	---	---		0.65		1.35	
CaF_2	0.55	---		---		---	
H_2O etc.	6.00	1.30		1.30		7.84	
	101.91	99.87		101.32		101.80	

I. Foyaite from main body Franspoort (426). Trans.geol.Soc. S.Afr. Vol 25, p. 85. Analyst: S.J.Shand

II. Foyaite aplite in north of Franspoort (426). Trans.geol.Soc. S.Afr. Vol 52, p.37. Analyst C.J.F. van der Walt, Chemical Services, Pretoria.

III. Syeno-diorite dyke (or lava) van Biljon's "Intermediate" rock adjacent to aplite. Trans.geol.Soc.S.Afr. Vol.52, p.37. Analyst C.J.F. van der Walt, Chemical Services, Pretoria.

IV. Lava adjacent to III . (Van Biljon's altered calcareous shale). Trans.geol. Soc.S.Afr. Vol. 52, p.37.. Analyst: C.J.Liebenberg. Chemical Services, Pretoria.

ACKNOWLEDGMENTS.

For financial assistance the author is indebted to the Council for Scientific and Industrial Research which granted him a bursary, and also to his parents, without whose financial and moral support this thesis would never have been written.

The writer also wishes to express his thanks to Professor B.V.Lombaard, under whose guidance the laboratory investigations were carried out; to Dr. H.J. Nel, Messrs. G.Koen and S.Zagt of the Geological Department, Pretoria University, who were always willing to give assistance; to Dr. F.C.Truter for his help and for putting certain unpublished maps of the Geological Survey at the author's disposal; to Professor W.Q. Kennedy and Mr. O. von Knorring for the x-ray photographs and analysis of the feldspar; to the Braak and van Esch families for hospitality received while in the field, and to his numerous other friends who assisted in preparing the photographs and maps.

REFERENCES.

1. Henderson, J.A. — Transvaal Norites, Gabbros & Pyroxenites and other South African Rocks. (1898) P.45.

2. Molengraaf, G.A.F. — Note on Present Knowledge of the Occurrence of Nepheline Syenite in the Transvaal. Trans.geol.Soc. S.Afr 1903, 89 - 90.

3. Molengraaf, G.A.F. — Geology of the Transvaal, 1904, (P. 45 - 46).

4. Hall, A.L. — The Area to the North of the Magaliesberg Range. Ann. Rep. Geol.Sur.Transvaal for 1903 (page 33).

5. Hall, A.L. — The Bushveld Igneous Complex of the Central Transvaal Geol. Sur. S.Afr. Mem., 28, 1932.

6. Brouwer, H.A. — Oorsprong en Samestelling der Transvaalshen Nephelene-Syenieten (1910).

7. Brouwer, H.A. — Geology of the Alkali Rocks in the Transvaal. Jour. of Geol. 1917.

8. Shand, S.J. — The Igneous Complex of Leeuwfontein Trans. geol.Soc. S.Afr. Vol. XXIV.

9. Shand, S.J. — The Alkaline Rocks of the Franspoort Line. Trans. geol. Soc.S.Afr. Vol XX

9a. Shand, S.J. — The Problem of the Alkaline Rocks Presidential Address 1922. Trans.geo Soc. S.Afr. Vol. XXV, p. xix.

10. van Biljon, S. — The Transformation of the Upper Part of the Pretoria Series. Trans. geol. Soc. S.Afr. Vol. LII.

11. Strauss & Truter. — The Alkali Complex at Spitzkop, Sekukuniland, Eastern Transvaal, Trans geol. Soc. S.Afr. Vol. LIII.

12. du Toit, A.L. — Geology of South Africa (Oliver and Boyd).

13. Wager, P.A. — A remarkable Rock from the Pretoria Saltpan, Trans.geol.Soc.S.Afr.Vol.XXV

14. Venter, F.A. — Breccias & Associated Rocks Occuring North East of Pretoria. Trans.geol. Soc. S.Afr. Vol. XXXVI p.41.

15. Lombaard, B.V. — The Felsites and Their Relations in the Bushveld Complex, Trans.geol.Soc. S.Afr. Vol. XXXV.

16. Lombaard, B.V. — On the Differentiation and Relationships of the Rocks in the Bushveld Igneous Complex. Trans.geol. Soc. S.Afr. Vol. XXXVII.

17. Kynaston. — Report on the Area lying to the N.E.

of Hatherly etc. Ann. Rep. Geol. Sur. Tvl. for 1903, pp. 3 - 6.

18. Daly, R.A. — Bushveld Igneous Complex of the Transvaal. Bull.geol.Soc. Amer. Vol. XXXIX.

19. Lead Deposits in the U. of S.A. and S.W.A. Geol. Sur. S.Afr Mem. No: 39.

20. Winchell, A.N. and H. — Elements of Optical Mineralogy. Part II, Fourth Edition (Wiley).

21. Strauss, C.A. — Granitisation & Rheomorphism Associated with the Bushveld Granite near the Leeuwpoort Tin Mine. Rep. Trans. geol. Soc. S.Afr. Vol. L.

22. Twenhofel, C.K. and collaborators. — Treatise on Sedimentation. Second Edition (McGraw Hill).

23. Bain, G.W. — The Amount of Assimilation by the Sudbury Norite Sheet. Jour. of Geol. Vol. XXXIII.

24. Bowen, N.L. — The Amount of Assimilation by the Sudbury Norite Sheet. Jour. of Geol. Vol. XXXIII.

25. Daly, R.A. — Geology of the North American Cordillera at the Forty Ninth Parallel.

26. Hall & du Toit. — On a Section Across the Floor of the Bushveld Complex at the Hartebeestpoort Dam; West of Pretoria. Trans. geol. Soc. of S. Afr. Vol. XXVI.

27. Burris, and Niggli, P. — Die Jungen Eruptivgesteine De Miditerranen Orogens.

28. Truter, F.C. — A Review of Vulcanism in the Geological History of South Africa, Trans. geol. Soc. S.Afr. Presidential Address Vol. LII.

29. Niggli, P. — Uber Molekularnorme zu Gesteinsberechnung. Schw.Min. Und. Pet. Mitt. 1936

30. Shand, S.J. — Eruptive Rocks (Murby).

31. Hatch and Wells. — The Petrology of the Igneous Rocks. (Geo. Allen & Urwin Ltd.) 1937.

32. Alling, L.A. — Interpretative Petrology (1937).

33. Ho, T.L. — Mineralogical Abstracts, V.439 (1934)

34. Dana, E.S. — A Textbook of Mineralogy (Wiley) (1945).

35. Rogers & Kerr. — Optical Mineralogy (McGraw Hill)(1942

36. Daly, R.A. — Igneous Rocks and the Depths of the Earth (McGraw Hill) 1933.

37. Shand, S.J. The Nepheline Rocks of Sekukuniland. Trans. geol.Soc. S.Afr.Vol. XXIV.

38. Shand, S.J. The Present Status of Daly's Hypothesis of the Alkaline Rocks. Amer.Jour. of Sci. 243A (Daly Volume) 1945 pp. 495 - 507.

39. Davies, K.A. The Phosphate Deposits of Eastern Province Uganda. Econ.Geol. XLII 2, 1947, pp. 137 - 146.

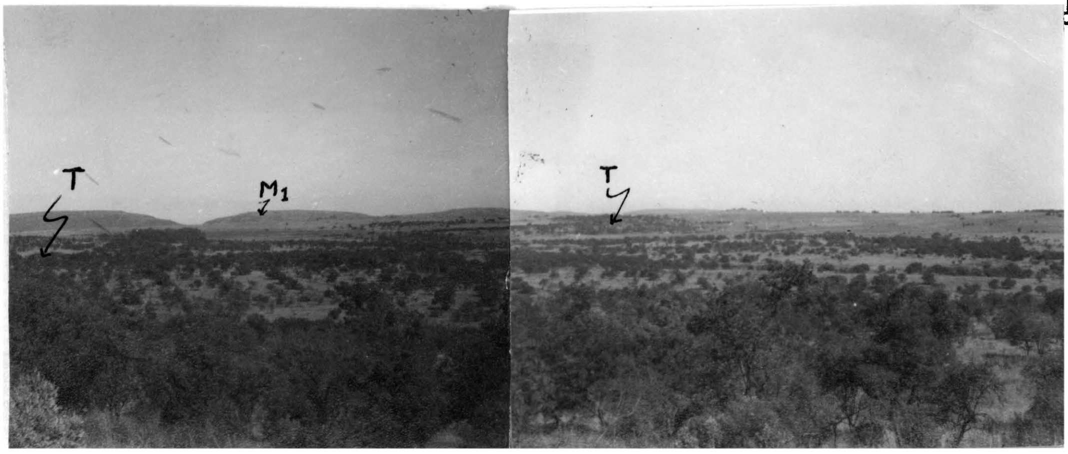
40. Mennell, F.P. Ring Structures with Carbonate Cores in Southern Rhodesia. Geol. Mag. LXXXIII, 3, 1946. pp. 137 - 140.

41. Bowen, N.L. The Evolution of the Igneous Rocks (Princetown) 1928.

42. Grout. Petrology and Petrography (McGraw Hill) 1932.

XIII PLATES.

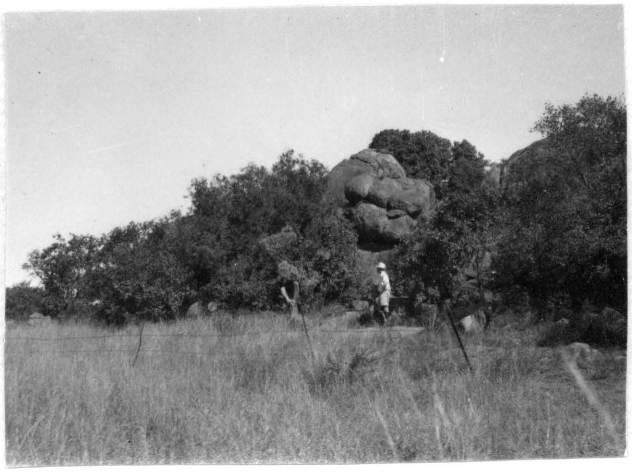
PLATE I.



Panoramic view of the Leeuwfontein Complex looking south-west and west from a quartzite ridge east of the Kameel-fontein road.

T = Trachyte Ridges. M_1 = M_1 quartzites.

PLATE II.



A tor of grey soda-syenite, Leeuwfontein.

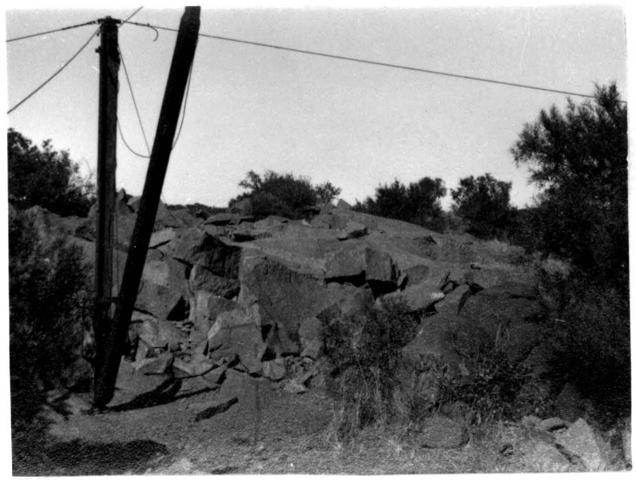


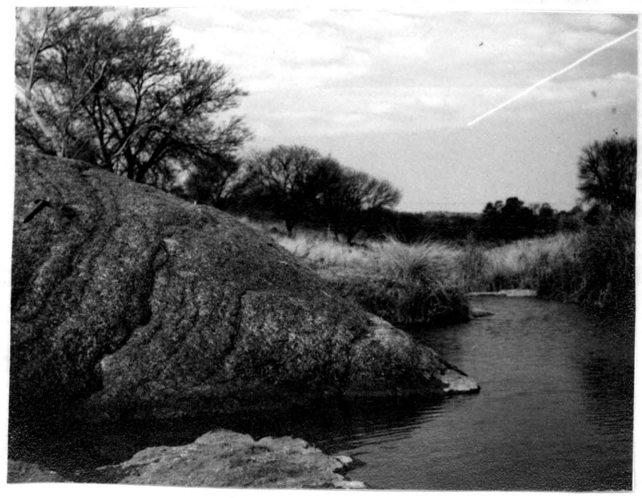
PLATE III.

The quarry in the red soda-syenite, Leeuwfontein.

PLATE IV.

Trachy-andesite ridge, Leeuwfontein.

PLATE V.



Melanocratic bands in soda-syenite pegmatite, Leeuwfontein.

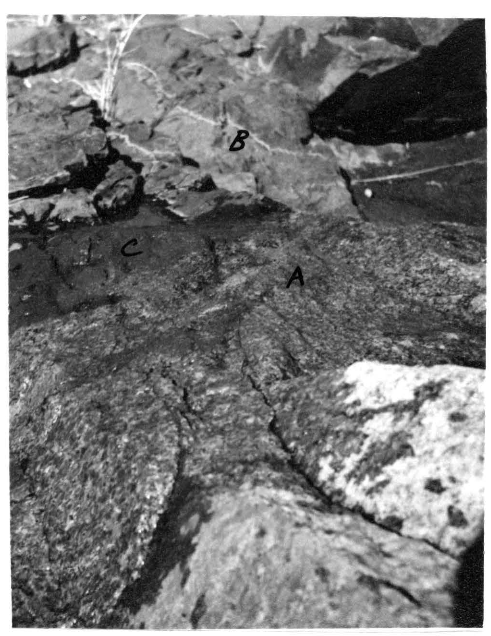
PLATE VI.

The soda-syenite pegmatite, Leeuwfontein.

PLATE·VII.

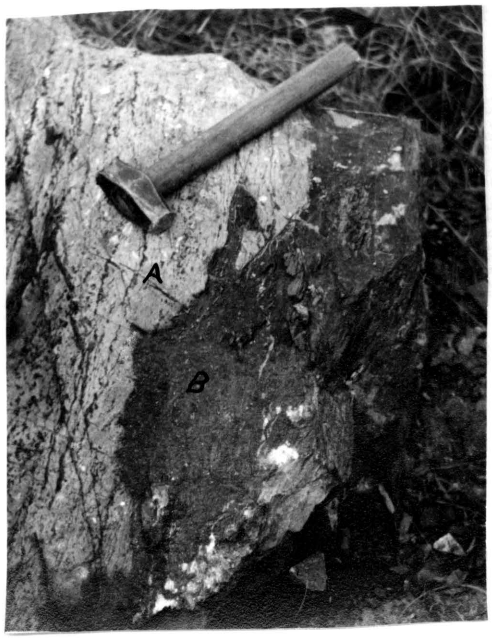
Intrusive limestone in the Leeuwspruit north of Leeuwfontein Complex.

PLATE VIII.



Contact between soda-syenite (A), and quartzite (B), Chill zone of syenite (C).

PLATE IX.



Replacement of Dolomite (A) by Fluorite (B), Leeuwfontein.

Plate X

The foyaite koppie on Franspoort, with the Magaliesberg running towards the south-east in the background.

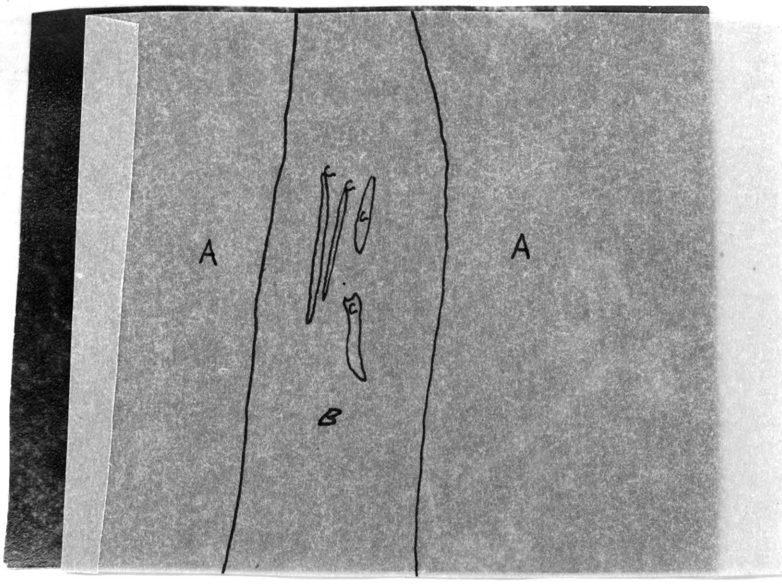
PLATE XI.

Quartzite inclusion in "felsite" on Franspoort showing rather a vague outline in the upper part of the inclusion. The darker grains in the inclusion are concentrations of pink micropegmatite.

PLATE XII.

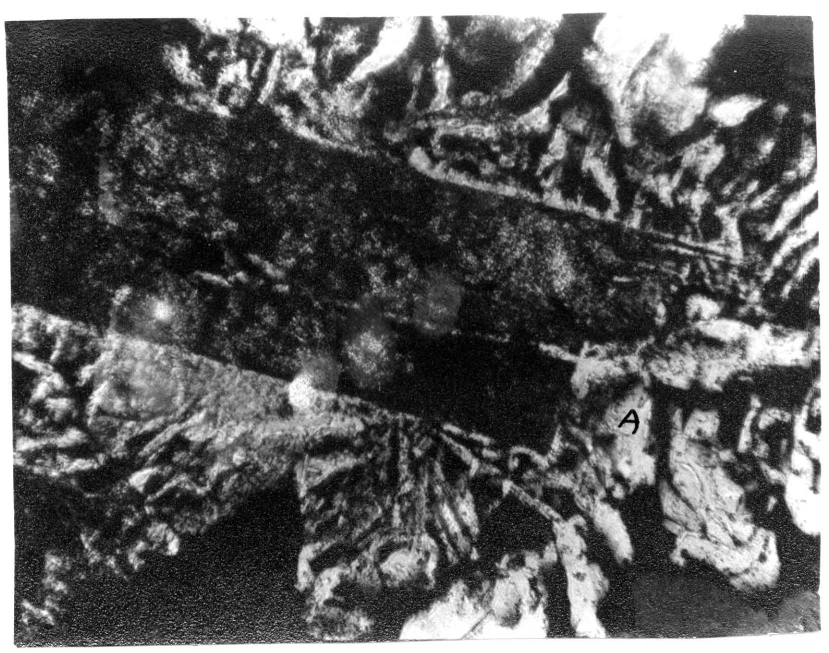
Quartzite xenoliths in "felsite", Franspoort. The large inclusion which is about 8 inches long has been partially digested on either side whereas the contact is fairly sharp at the extremities. The bedding plane is along the length of the inclusion.

PLATE XV.



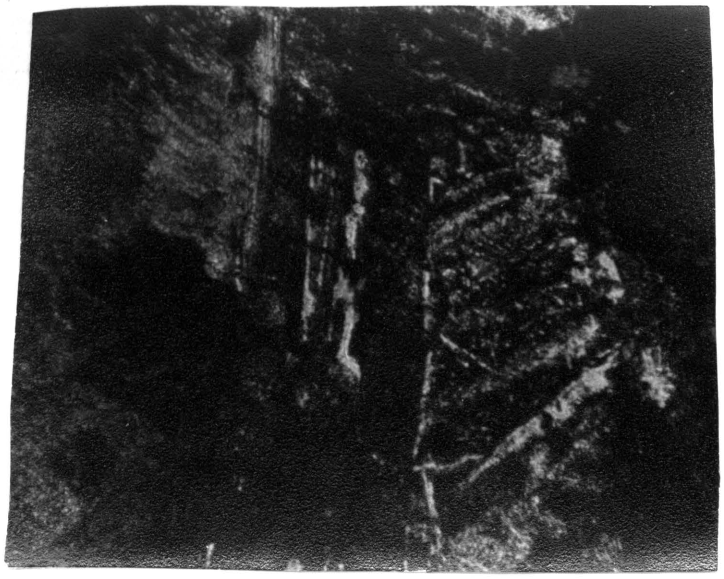
Quartz (white) (C) replacing turbid feldspar (dark)(B). A. is micropegmatite or myrmekite. X 130.

PLATE XVI.



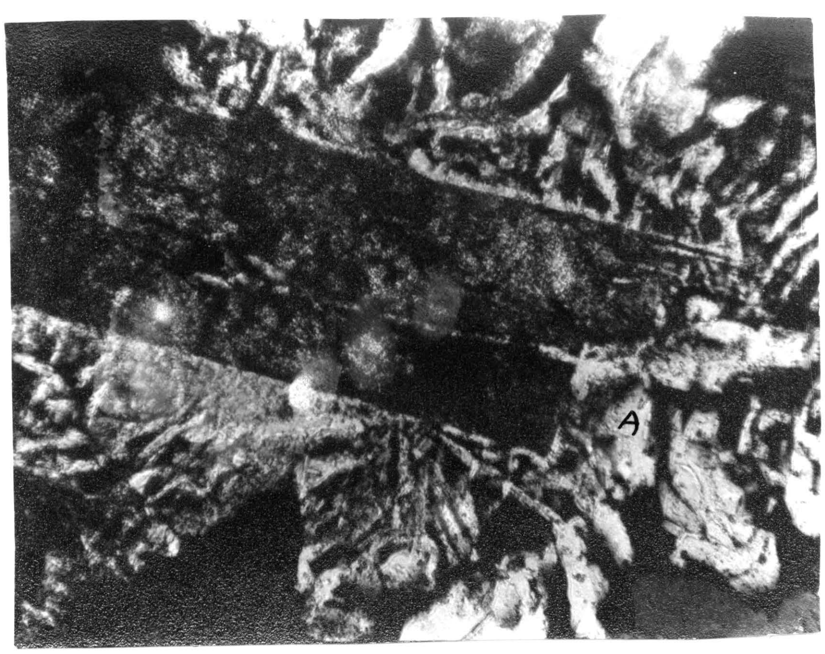
Micropegmatite enclosing a tabular feldspar crystal (dark). Quartz has replaced feldspar to form myrmekite at A.
X 130.

PLATE XV.



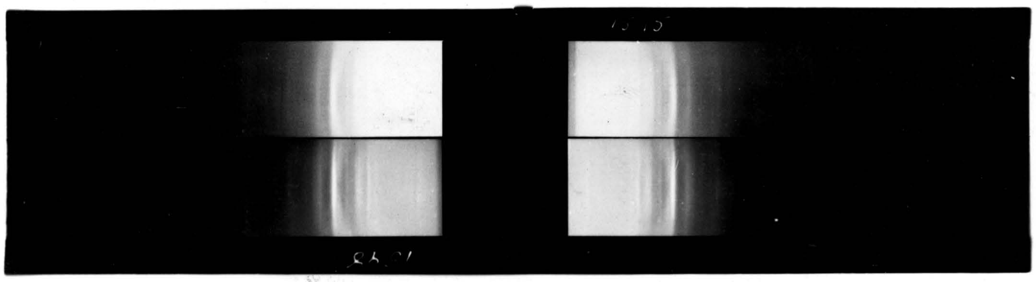
Quartz (white) (C) replacing turbid feldspar (dark)(B).
A. is micropegmatite or myrmekite. X 130.

PLATE XVI.



Micropegmatite enclosing a tabular feldspar crystal (dark).
Quartz has replaced feldspar to form myrmekite at A.
X 130.

PLATE XVII.



X-ray powder photographs of the anorthoclase of the pink umptekite pegmatite (upper photo) and that of the brick-red soda-syenite (lower photo).

O.von Knorring.

ALKALINE ROCKS IN THE PRETORIA VICINITY.