UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

THE GEOLOGY OF THE BUSHVELD COMPLEX ON THE SEKHUKHUNE PLATEAU, EASTERN TRANSVAAL

by

ALAN GERALD MARLOW

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

PRETORIA

OCTOBER 1976

ABSTRACT

This study comprises a general geological investigation of the rocks from an area 1 200 square km in size, situated about 50 km north-east of Marble Hall. The area lies upon the Sekhukhune Plateau and is dominated by acid rocks of the Bushveld Complex.

The oldest rocks in the area include hornfels and quartzite of the Pretoria Group which are present in the form of xenoliths in the rocks of the Bushveld Complex, and also as part of the updomed floor of the Complex in the Malope area. The quartzite which occurs in the form of xenoliths has been locally transformed to a pseudogranophyre by a process of feldspathization.

Three suites of Bushveld rocks are present within the area investigated, namely the Rustenburg Layered Suite, the Rashoop Granophyre Suite and the Lebowa Granite Suite. The first out= crop at the base of the Sekhukhune Escarpment which forms the eastern boundary to the area. They have also been discovered on the plateau around Malope to the south-east of the Olifants River, where they appear to overlie the updomed floor of the Bushveld Complex. The rocks of the layered sequence exposed east of the Sekhukhune Escarpment belong to the Upper Zone, whilst the majority of those around Malope are typical of the Critical Zone, although rocks which typify the Upper Zone are also present. The latter seem to transgressively overlie the rocks of the Critical Zone.

The Rashoop Granophyre Suite consists of granophyre and a fine-grained granophyric granite. These rocks are separated from the basic rocks of the layered sequence below by a thin layer of leptite which is considered to be metamorphosed Rooiberg felsite.

The Lebowa Granite Suite consists of an older Nebo Granite and a younger Makhutso Granite. Four facies of the Nebo Granite have been recognized, viz. main, contact, granophyric and aplitic facies, and their textural, mineralogical and chemical differences are discussed. The Makhutso Granite also consists of four facies,

namely the main facies, the contact facies and the aplitic facies, as well as the Koornkopje granite which is considered to be a variety of the Makhutso Granite.

The Makhutso Granite which was previously only known to exist in the Dennilton area, has been found at seventeen separate localities on the Sekhukhune Plateau, and the intrusive relation= ships with the Nebo Granite are described. The Makhutso Granite differs from the Nebo Granite in its higher biotite content and its higher anorthite content of the plagioclase, and also in its trace element composition. It also differs from the main facies of the Nebo Granite in its abundance of zoned plagioclase phenocrysts. The Koornkopje granite differs from the main facies of the Makhutso Granite in its persistent fine-grained nature, and in its lower biotite content and the lower anorthite content of the plagioclase.

SAMEVATTING

Hierdie studie behels 'n algemene geologiese ondersoek van die gesteentes in 'n gebied van 1 200 vierkante km in omvang, geleë ongeveer 50 km noordoos van Marble Hall. Die gebied is op die Sekhukhuneplato geleë en bevat oorheersend suur gesteentes van die Bosveldkompleks.

Die oudste gesteentes in die gebied is horingfels en kwart= siet van die Pretoriagroep, wat teenwoordig is as xenoliete in die gesteentes van die Bosveldkompleks en ook as 'n gedeelte van die opgewelfde vloer van die Kompleks in die Malopegebied. Die kwart= siet wat voorkom in die vorm van xenoliete is lokaal verander na 'n pseudogranofier deur 'n proses van veldspatisasie.

Die gesteentes van die Bosveldkompleks in die ondersoekte gebied behoort tot die Rustenburgse Gelaagde Reeks, die Rashoop-Granofierreeks en die Lebowa-Granietreeks. Die eerste van bogenoemde dagsoom aan die basis van die Sekhukhune-eskarp wat die oostelike grens van die gebied vorm. Hulle is ook op die plato in die omge= wing van Malope suidoos van die Olifantsrivier gevind, waar hulle op die opgewelfde vloer van die Bosveldkompleks lê. Die mafiese gesteentes van die gelaagde opeenvolging oos van die Sekhukhune-eskarp behoort tot die Bosone, terwyl die meeste gesteentes rondom Malope tipies van die Kritieke Sone is, alhoewel magnetietdraende gesteentes van die Bosone ook aanwesig is. Dit wil voorkom asof die gesteentes van die Bosone transgressief bo-oor die gesteentes van die Kritieke Sone lê. Die Rashoop-Granofierreeks bestaan hoofsaaklik uit granofier en 'n fynkorrelrige granofiriese graniet. Hierdie gesteentes word van die mafiese gesteentes van die gelaagde opeenvolging geskei deur 'n dun laag leptiet wat as gemetamorfoseerde Rooibergfelsiet beskou word.

Die Lebowa-Granietreeks bestaan uit die ouer Nebo-Graniet en 'n jonger Makhutso-Graniet. Vier fases van die Nebo-Graniet word herken, nl. die hoof-, kontak-, aplitiese en granofiriese fases, en hul struktuur, mineralogie en chemiese verskille word bespreek. Die Makhutso-Graniet bestaan ook uit vier fases, naamlik die hooffase, die kontakfase en die aplitiese fase asook die sg. Koornkopjegraniet,

'n fynkorrelrige, porfiritiese variëteit van die Makhutso-Graniet.

Sewentien lokaliteite van die Makhutso-Graniet wat voorheen net in die Denniltongebied bekend was, is op die Sekhukhuneplato gevind, en die verhoudings met die Nebo-Graniet word beskryf. Die Makhutso-Graniet word onderskei van die Nebo-Graniet deur sy hoër biotiet-inhoud, sy anortietryker plagioklaas en ook in die same= stelling van die spoorelemente en in die oorvloed van gesoneerde plagioklaaseerstelinge wat dit bevat. Die Koornkopjegraniet verskil van die hooffase van die Makhutso-Graniet in sy deurgaans fyn= korrelrige aard, in sy laer biotiet-inhoud en die laer anortiet-inhoud van die plagioklaas.

C O N T E N T S

LIST OF TABLES

TABLE		PAGE

LIST OF FIGURES

1. INTRODUCTION

The areas studied lie west of the Steelpoort Valley and east of the Olifants River and are situated within the homeland of Lebowa in the Eastern Transvaal. Two rectangular shaped areas have been mapped, namely the Mogaleslokasie area and the Nebo area. The south-eastern corner of the former area joins the north-western corner of the latter. The region is comprised mainly of acid rocks of the Bushveld Complex and meta-sediments belonging to the Pretoria Group of the Transvaal Supergroup, although basic rocks of the Bushveld Complex have been found.

An area of 1 200 square km was mapped using aerial photographs (scale 1:40 000) during June to October of 1974 and May of 1975, as part of a mapping programme for the Geological Survey. The informa= tion was transferred to topographical maps (scale 1:50 000) from which the final geological maps were compiled (Folders I and II).

Previous detailed work in the area is restricted to the rocks adjacent and to the east of the Sekhukhune Escarpment (Lombaard, 1934, p.10; Molyneux, 1974), which forms the eastern boundary to the area. Lenthall (1975) made a reconnaissance geochemical investiga= tion and radiometric survey of the acid rocks of the Sekhukhune Plateau.

No differentiation of rocks of the Spitskop Alkaline Complex was made because a geological map (scale 1:25 000) by Strauss and Truter (1950, Plate XXIII) is in existence. The Spitskop Alkaline Complex was discovered by A.L. Hall in 1910, and subsequently Shand (1921), Strauss and Truter (1950), Verwoerd (1964) and Nel (in preparation) described the rocks of the complex.

2. PHYSIOGRAPHY

2.1 TOPOGRAPHY

The areas studied lie upon the Sekhukhune Plateau, west of the Sekhukhune Escarpment. In the Nebo area the drop in elevation across the escarpment is from 1 460 m to 1 340 m in the north and from 1 520 m to 1 000 m in the south.

The plateau in the Nebo area consists of undulating hills with few outcrops. In the Mogaleslokasie area it consists of rugged hills in the east and flat to gently undulating land in the west. The general level of the plateau in the Nebo aréa does not vary con= siderably, but that in the Mogaleslokasie area dips to the west-north-west.

2.2 DRAINAGE

The Sekhukhune Escarpment acts as a watershed, separating tributaries of the Steelpoort River to the east, from tributaries of the Olifants River to the west. A dendritic type drainage is characteristic of the Sekhukhune Plateau, and most of the rivers follow meandering courses.

The drainage direction in the Nebo area is to the north, with the exception of the area occupied by the Spitskop Alkaline Complex, which is drained to the south. In the Mogaleslokasie area the Olifants River flows towards the north-east, whilst its easterly tributaries which dominate the area, flow towards the north-west.

2.3 VEGETATION

The escarpment is mainly clothed with stunted trees and bush, but where the gradient becomes too high the vegetation is reduced to grass. The plateau in the Nebo area and the lower lying eastern parts of the Mogaleslokasie area are covered by grassland, which may be cultivated in those areas occupied by the Bantu. On the slopes of the steeper hills of the plateau and within the western part of the Mogaleslokasie area, bush is dominant.

3. GEOLOGICAL FORMATIONS

The following rock types and geological formations are present in the area mapped:

RECENT FORMATIONS	Alluvium, sand, soil and talus.
POST BUSHVELD	Dolerite.
SPITSKOP COMPLEX	Alkaline rocks.
BUSHVELD COMPLEX	
LEBOWA GRANITE SUITE	
MAKHUTSO GRANITE	Coarse-grained, porphyritic granite with fine-grained contact facies and fine-grained aplite facies.
NEBO GRANITE	Coarse-grained granite with fine- to medium-grained contact facies, fine-grained aplite facies and granophyric facies.
RASHOOP GRANOPHYRE SUITE	
WATERVAL GRANOPHYRE	Granophyre and fine-grained granophyric granite.
RUSTENBURG LAYERED SUITE	
UPPER ZONE	Ferrodiorite, ferrogabbro and magnetitite.
CRITICAL ZONE	Spotted and mottled anorthosite, norite, pyroxenite and chromitite.
ROOIBERG GROUP	Leptite.
TRANSVAAL SUPERGROUP	
PRETORIA GROUP	Hornfels, quartzite, feldspathic quartzite and pseudogranophyre.

The subdivision of the Bushveld Complex conforms with the most recent suggestions put forward by the Bushveld Working Group of the South African Committee for Stratigraphy (SACS). On the basis of a textural and mineralogical variation further subdivision of the Makhutso Granite, and the insertion of the informal name Koornkopje granite to the subdivision, is suggested.

The informal terms layered sequence and Bushveld granophyre are occasionally used in the following text instead of the formal terms Rustenburg Layered Suite and Rashoop Granophyre Suite respec= tively. The informal term Waterval granophyre (Lenthall, 1973, p. 76) may also be used for the rocks of the Rashoop Granophyre Suite in Sekhukhuneland. The Nebo Granite is the approved name for the granite of the Bushveld Complex which may previously have been referred to as Bushveld Granite, Main Granite or Sekhukhune Granite.

4. TRANSVAAL SUPERGROUP

On the Sekhukhune Plateau the rocks of the Transvaal Super= group belong to the Pretoria Group, and consist of hornfels, quart= zite, feldspathic quartzite and pseudogranophyre. The metamorphic rocks are present in the form of xenoliths within the rocks of the Bushveld Complex, and also as part of what seems to be the updomed floor of the Complex.

In the Sekhukhune Escarpment the rocks exist in the form of xenoliths, sandwiched between the basic rocks of the Bushveld Complex below and the acid rocks above. It is probable that they have been subjected to only one phase of metamorphism, because a layer of leptite screened them from the metamorphic effects of the intrusive acid rocks above. The single phase of metamorphism took place during the intrusion of the layered sequence which lifted the xenoliths from the floor of the Bushveld Complex (Fig. 1A). The acid rocks of the Bushveld Complex were intruded into the Rooiberg felsite, above the xenoliths and were thus not brought into direct contact with them (Fig. 1B).

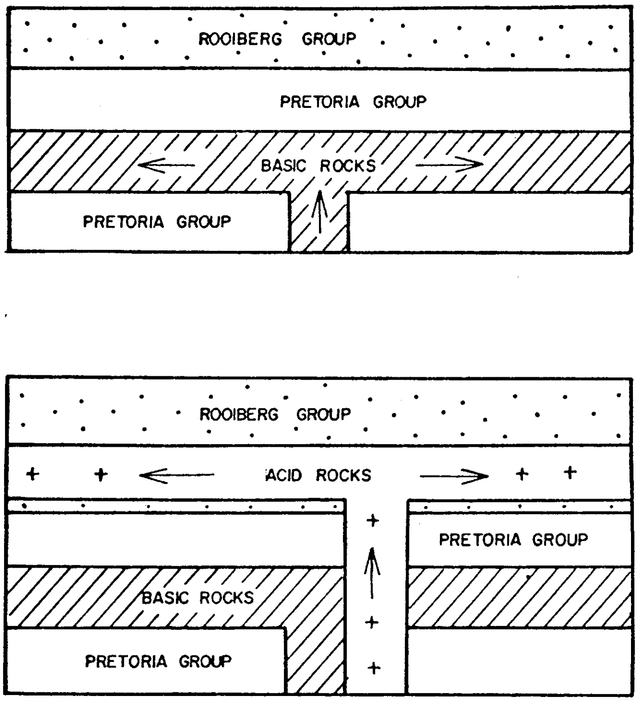
4.1 HORNFELS

The hornfels is present as xenoliths which are situated at the contact between the basic and acid rocks of the Bushveld Complex, as xenoliths within the layered sequence, the Bushveld granophyre, the Nebo Granite and the Makhutso Granite, and also as part of the updomed floor of the Bushveld Complex in the Malope area. The xenoliths with= in the Bushveld granophyre and Nebo Granite are found at or near the Sekhukhune Escarpment, the base of which approximately demarks the base of the acid unit of the complex.

On Vergenoegd 792 KS (Folder IIC2 - henceforth abbreviated IIC2) xenoliths of hornfels up to 5 cm across occur in a dyke of Makhutso Granite. On Duizendannex 816 KS (IF8) hornfels outcrops between leptite below and the fine-grained contact facies of the Nebo Granite above and also between the fine-grained contact facies of the Nebo Granite below and the Bushveld granophyre above. These hornfels bodies contain ptygmatic folds and segregations of quartz and biotite.

(A)

(B)



(A) Intrusion of the basic rocks into the Pretoria Group

(B) Intrusion of the acid rocks into the Rooiberg felsite

Fig. 1 - Schematic representation of the intrusion of the acid and basic rocks of the Bushveld Complex and the incorporation of a xenolith of the Pretoria Group

On Goedverwacht 763 KS (IIA2) the hornfels forms part of the floor of the Bushveld Complex which has seemingly been brought to the surface by anticlinal folding. The hornfels overlies quartzite north of Segwahleng, and a small outcrop was found within quartzite south-east of Segwahleng.

In the Sekhukhune Escarpment on Uitvlugt 887 KS (IJ8), the hornfels is conformable with the layering in the fine-grained granophyric granite which lies above and below it. The fine-grained granophyric granite represents a poorly developed Bushveld granophyre which is located at the base of the acid unit of the Bushveld Complex on Uitvlugt 887 KS. The hornfels displays well-developed layering (Fig. 2), and has been invaded by the fine-grained granophyric granite (Fig. 3).

The hornfels consists of quartz, feldspar, biotite, orthopy= roxene, opaque minerals and cordierite. The quartz may be present as metamorphic aggregates up to one centimetre across. The feldspar is usually sericitized to some degree, and occurs as interstitial grains or as porphyroblasts up to 4 mm in length. The biotite grains may be prismatic or poikiloblastic, the latter reaching 2 mm in length. The cordierite is distinguished by its presence of inclusions, its common twinning and its poorly defined boundaries.

4.2 QUARTZITE

The quartzite is present as xenolithic bodies situated in the layered sequence, at the contact of the latter and the acid rocks of the Bushveld and within the Makhutso Granite. It is also present in the Malope area (IIB2) where it forms part of the floor of the Bushveld Complex.

A large xenolith of quartzite occurs at the contact between the layered sequence and the acid rocks of the Bushveld on and around Boschpoort 843 KS (IG9). Here the quartzite and felspathic quartzite form a wedge-shaped body which lies directly above the layered sequence. The upper contact of the quartzite is mostly overlain by dolerite, but in the south on Tweefontein 848 KS the quartzite is overlain by leptite. The xenolithic body is approximately 550 m thick and appears to consist of an upper, middle and lower quartzite unit, which are separated by two feldspathic quartzite units. These three quartzite beds contain several bands of feldspathic quartzite a few centimetres to a few metres in thickness. Ripple-marks and cross-bedding are also present in the quartzite. A conglomeratic quartzite in this sequence consists of typical coarse-grained quart=

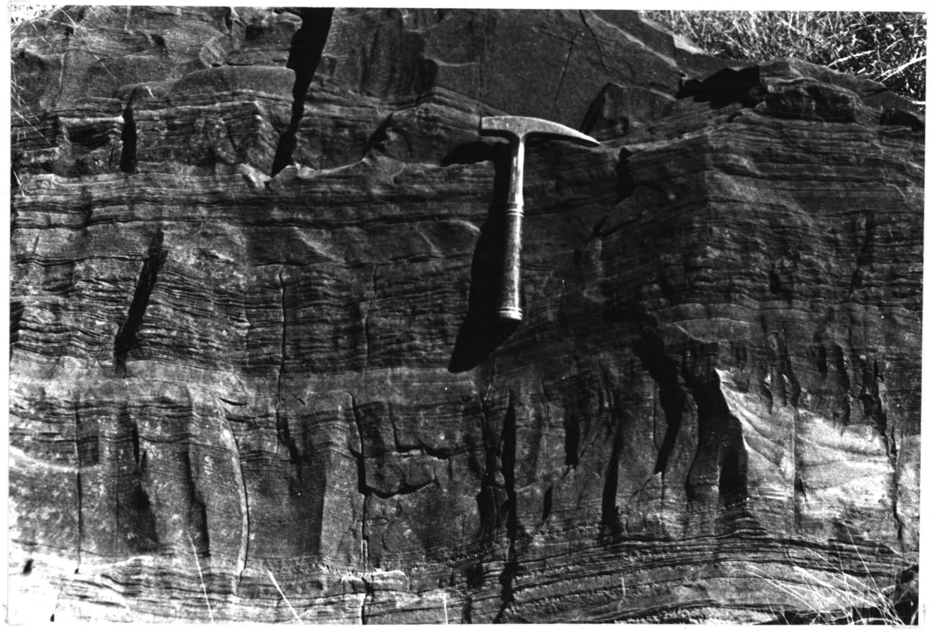


Fig. 2 - Layering in hornfels on Uitvlugt 887 KS (IJ8)

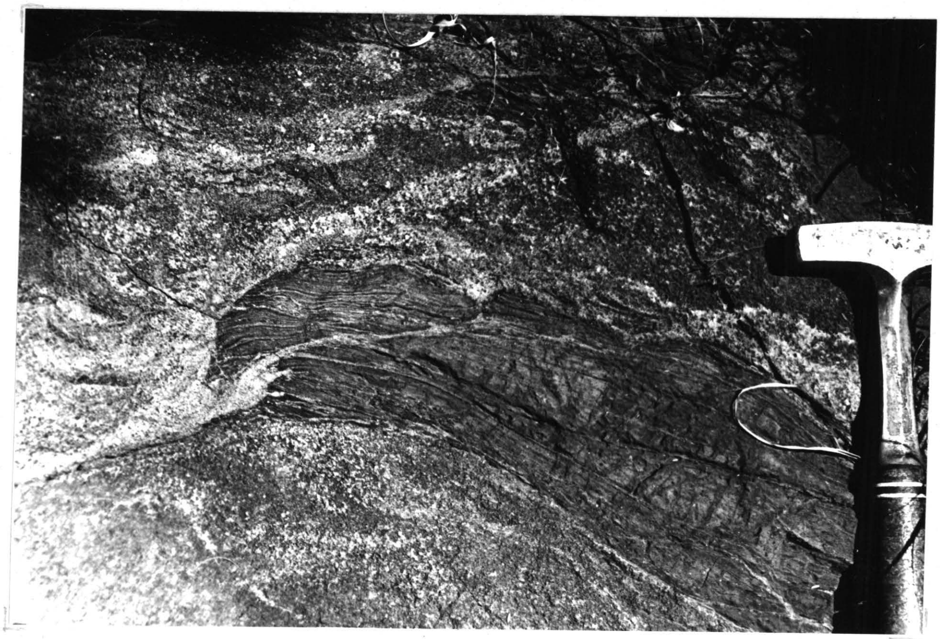


Fig. 3 - Hornfels invaded by fine-grained granophyric granite on Uitvlugt 887 KS

zite enclosing pebbles of feldspathic quartzite. The pebbles are quite scarce, mostly sub-rounded to sub-angular in shape, vary in size from 1 to 5 cm across and lie with their long axes in the plane of bedding of the quartzite.

On Goedverwacht 763 KS (IIB2) three antiforms of quartzite form conspicuous hills which rise above the general level of the Sekhukhune Plateau. The regional dip of the quartzite varies between 14° and 40°. Locally the quartzite has been tightly folded and shear zones with a dominant northerly direction are common. Small xenoliths of quartzite are present in abundance within the layered sequence on Goedverwacht 763 KS and Groblersvrede 844 KS (IF9) and also above the leptite on Duizendannex 816 KS (IF8).

Within the larger body of quartzite on Duizendannex 816 KS mobilization of the quartzite is suggested by the presence of a rheomorphic breccia. The breccia consists of embayed fragments of quartzite which vary in size from a few centrimetres to 20 cm across, sitting in a mobilized quartzite which is in places feldspathized (Fig. 4). Iannello (1970, p. 636) mentions a similar rheomorphic breccia locally developed in the Rooiberg area, which he describes as 'consisting of layers and fragments of undisturbed white quartzite alternating and cemented by dark albitized quartzite'. Rheomorphic breccias are also present on a large scale at the base of the succes= sion of altered sediments lying between the basic rocks and the granite of the Bushveld Complex, north-west and west of Potgietersrus (Strauss, 1947, p. 161).

Several small xenoliths of quartzite a few centimetres across were also found in a dyke of Makhutso Granite on Vergenoegd 792 KS (IIC2).

The quartzite usually consists of quartz with minor amounts of potassium feldspar, biotite, muscovite, hornblende, opaque minerals and sphene. The feldspar when present is usually sericitized, and when mica is present it may either be biotite or muscovite. Rare inclusions of zircon may be present within the quartz grains. Mica is a more abundant constituent of the quartzite on Vergenoegd 792 KS compared with that on Boschpoort 843 KS.

4.3 FELDSPATHIC QUARTZITE

The feldspathic quartzite is present as two units separated by quartzite, within the wedge of meta-sediment on and around Bosch= poort 843 KS (IG9). The surface exposure is poorer than that of the quartzite and the rock forms less pronounced topographic features. It may contain bands of non-feldspathic quartzite, but these are usually only a few centimetres in thickness. Cross-bedding is abundant in places.

The feldspathic quartzite exposed near the escarpment on Twee= fontein 848 KS (IG9), which is underlain by quartzite and overlain by leptite contains veins of fine-grained granite. At the escarpment on Groblersvrede 844 KS (IF9) where the feldspathic quartzite over= lies the layered sequence two south-west trending dykes of ferrogabbro have penetrated the feldspathic quartzite for a few tens of metres.

The amount of feldspar in the feldspathic quartzite has not been determined, but the rock can be distinguished from the quartzite by its pink colour.

4.4 PSEUDOGRANOPHYRE

Feldspathization of quartzite bodies sited at the contact between the basic and acid rocks of the Bushveld Complex has resulted in the development of pseudogranophyre on Duizendannex 816 KS (IF8). The pseudogranophyre has a gradational contact with the quartzite, and it can be correlated with Walraven's (1976) Zwartbank pseudo= granophyre which is developed in the area north of Brits in the western Bushveld.

On Groblersvrede 844 KS (IF9) metamorphism of feldspathic quartzite by an overlying dolerite sill has resulted in the formation of a metamorphic aureole of pseudogranophyre and epidotized quartzite.

The pseudogranophyre is only a few metres wide, but the zone of epidotization extends for approximately 10 m away from the dolerite contact.

The pseudogranophyre consists of individual grains of quartz and feldspar as well as 'micrographic intergrowths' of the two, and minor amounts of hornblende, opaque minerals and sphene. The micrographic intergrowths which are developed by the replacement of quartz by feldspar, do not show a preferred orientation such as the intergrowth rosettes in normal granophyre, and often display a very irregular shape (Fig. 5). The replacement develops in a convergent direction towards the centre of the quartz grain, and the original grains can be detected by observing the optically continuous quartz components of the texture.

Fig. 4 - Rheomorphic breccia in quartzite on Duizendannex 816 KS (IF8)

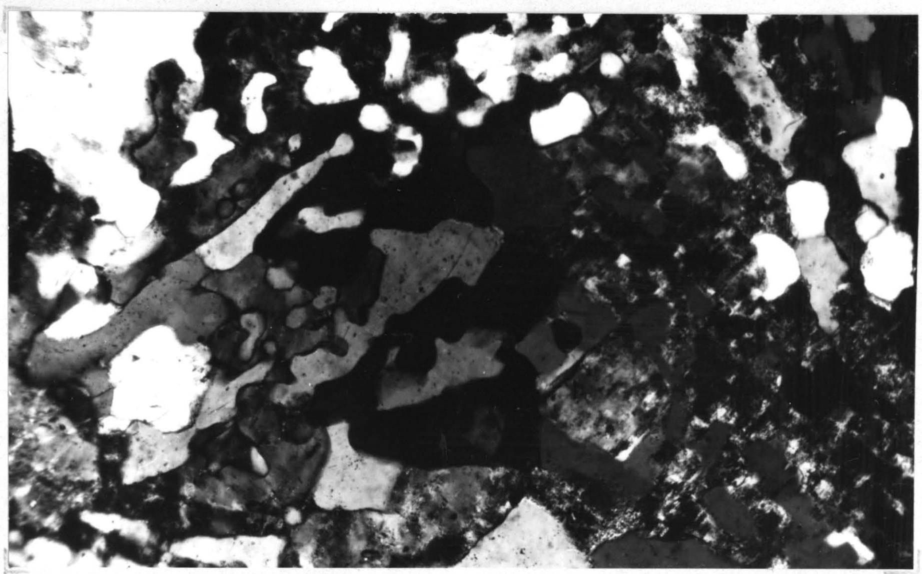


Fig. 5 - Replacement texture in pseudogranophyre. Note the irregular shape of the texture. AGM 100, Duizen=dannex 816 KS (IF8). Crossed nicols, X78

5. ROOIBERG GROUP

5.1 DISTRIBUTION AND FIELD RELATIONSHIPS

Leptite, considered to be metamorphosed Rooiberg felsite lies directly above the basic rocks of the Rustenburg Layered Suite and below the Rashoop Granophyre or the Lebowa Granite. Where meta-sedimentary xenoliths of the Pretoria Group are present at the contact between the acid and basic rocks of the Bushveld Complex, the leptite normally overlies them.

The leptite outcrops along the whole length of the Sekhukhune Escarpment except in the area around Boschpoort 843 KS (IG9), where it has been removed by erosion. West of the escarpment on Tweefontein 848 KS (IG8) two outcrops of leptite were found; the first, just south of Suike, separates quartzite below from Nebo Granite above, and the second, in the Mphofotse River where it is in contact with Nebo Granite and where it has been cut by granite veins in a number of places.

To the west, in the Mogaleslokasie area the leptite is exposed on Goedverwacht 763 KS (IIB2) where it separates basic rocks of the layered sequence below from the contact facies of the Nebo Granite above.

The leptite which is a fine-grained, granular rock has a reddish-brown weathered surface and a dark brown to grey colour when fresh. On Duizendannex 816 KS (IF8) segregations of hornblende are well-displayed in the leptite (Fig. 6). The hornblende seems to have migrated to centres during recrystallization leaving rims free of ferromagnesian minerals. The segregations are easily weathered and impart a characteristic pitted surface to the leptite.

Bedded rocks are well-developed in the leptite on Duizendannex 816 KS (IF8) and Tweefontein 848 KS (IG9). They display thin lamina= tions, cross-bedding and tight to isoclinal minor folds, and represent interlayered sediments within the leptite.

Veins and larger bodies of fine-grained granite are commonly seen within the leptite, throughout the area. These granites appear to be of two types. Firstly those which show gradational contacts with the leptite and which have evidently developed as a result of melting of the leptite (Von Gruenewaldt, 1968, p. 157). They are well-developed on Droogehoek 882 KS and Ironstone 847 KS (IG9). The veins do not favour any particular horizon within the leptite suc= cession and it is probable that the heat required for the melting of the leptite was derived from the intrusion of the basic rocks.

The second type of granite vein seen within the leptite is derived from the Lebowa Granite. It is an intrusive granite which displays sharp contacts with the leptite and includes xenoliths of the latter. The granite veins are well-exposed on Tweefontein 848 KS just south of the source of the Mphofotse River and at the top of the escarpment on Ironstone 847 KS (IG9) (Fig. 7). At the last locality the granite includes xenoliths of hornfels which strongly suggests it was not derived from the leptite. On Goedverwacht 763 KS (IIB2) the leptite is cut by veins of fine-grained granite up to 5 mm across. These veins do not show gradational contacts with the leptite and also appear to be intrusive in nature.

5.2 PETROGRAPHY

The major mineral constituents of the leptite are quartz, plagioclase, orthoclase and opaque minerals whilst the minor consti= tuents may include hornblende, clinopyroxene, biotite and sphene. Interlocking quartz and feldspar grains as well as poikiloblasts of plagioclase and orthoclase which enclose numerous small grains of quartz, indicate that a high degree of recrystallization has taken place. Hornblende may be present as interstitial grains, as poikiloblasts or as segregations. On Duizendannex 816 KS (IF8) the poikiloblasts may be 0,5 cm across, whilst the segregations may be up to 3 cm in diameter. Quartz segregations on Tweefontein 848 KS (IG9) were also observed but were smaller in size than those of the hornblende.

Fig. 6 - Segregations of hornblende in leptite on Duizendannex 816 KS (IF8)

Fig. 7 - Intrusive body of fine-grained granite in leptite on Ironstone 847 KS (IG9). Note the sharp contact and the xenoliths of leptite and hornfels in the granite. (Hammer against granite)

5.3 THE ORIGIN OF THE LEPTITE

The origin of the leptite has been a controversial subject for a considerable period of time. Some authors consider the leptite to represent metamorphosed, recrystallized Rooiberg felsite (Von Gruenewaldt, 1968, p. 156; Molyneux, 1970a, p. 8), whilst others consider it to be metamorphosed and metasomatized Transvaal sediment (Kuschke, 1950, p. 28; Steyn, 1950, p.55; Strauss, 1954, p. 19; Truter, 1955, p. 81; Willemse, 1964, p. 115). Boshoff (1942, p. 50) considers the leptite along with the rocks now grouped with the Rashoop Granophyre Suite to represent the acid differentiate of the basic magma which gave rise to the layered sequence.

The author is of the opinion that the leptite represents a metamorphosed, recrystallized Rooiberg felsite which was brought into its present position during the initial phase of intrusion of the Bushveld Complex (Fig. 1A). The possibility that the leptite represents the acid part of the succession of the Dullstroom Basalt Formation has not been dismissed. Von Gruenewaldt (1966, p. 7) has noted the great resemblance between leptite of xenoliths of Dullstroom Basalt Formation in gabbro of the Main Zone and the leptite of the Rooiberg felsite in the area north of Middelburg. The Dullstroom Basalt Formation lies at the top of the Pretoria Group, above the Houtenbek Shale Formation, in the eastern Transvaal, and contains lenses of leptite, felsite and granophyre (Groeneveld, 1968, p. 16).

6. BUSHVELD COMPLEX

6.1 DETERMINATIVE METHODS

The anorthite content of the plagioclase feldspars from the Bushveld Complex was determined with the aid of the universal stage by means of extinction angles. The extinction angle $[n\alpha']\wedge(010)\perp[100]$ on unzoned albite twins was measured and the An content was obtained from the curve given by Burri, Parker and Wenk (1967, Plate XI).

Zoning in the plagioclase in the granites of the Lebowa Granite Suite was studied with the use of a JEOL JXA-50A electron probe microanalyser. The type of zoning was determined by scanning from the core to the rim of the crystals.

Chemical analysis of the Bushveld granite and magnetitite was carried out by General Superintendence Company (Pty) Ltd. (Table I and Appendixes II and III). Normative composition of new and pub= lished analyses was calculated with the use of an IBM 1130 computer, using the method by Kelsey (1965) (Appendixes II and III).

Modal analysis of the finer grained rock types of the Bushveld granite and granophyre was undertaken by counting between 1200 and 2000 points over an area of 160 to 480 square millimetres per section, with the use of a Swift Automatic Point Counter (Tables II, V, VIII and X and Appendix I). By determining the IC number of each thin section, an analytical error of less than 2,45 per cent was maintained (Chayes, 1956, p.82).

6.2 RUSTENBURG LAYERED SUITE

6.2.1 Distribution and Field Relationships

The basic rocks outcrop along the base of the Sekhukhune Escarpment (Folder I) and occupy the valley floor of the Steelpoort River to the east. Rocks of this suite were also found to be deve= loped on the Sekhukhune Plateau on the farms Goedverwacht 763 KS, Nooitverwacht 791 KS, Vogelenzang 794 KS and Nooitgezien 761 KS (IIB2) where they crop out over a total area of at least two kilometres square.

Basic rocks in the escarpment which belong to the Upper Zone of the layered sequence are poorly exposed, rarely providing un= weathered outcrops, and consist mainly of ferrodiorite. The majority of the basic rocks around Malope are correlated with the Critical Zone although some magnetite-bearing rocks which typify the Upper Zone were also encountered.

Exposures of basic rocks in the Malope area are poor and loose boulders of rocks from the upper part of the Critical Zone, as well as abundant boulders of magnetitite are scattered throughout the area. The irregular outcrops, the sheared and fractured nature of the rocks and the presence of a well-developed shear zone containing massive chromitite south of Segwahleng, indicates that faulting with a dominant northerly direction may have taken place.

Rocks of the Critical Zone in the Malope area appear to overlie the quartzite and hornfels which seemingly represent the updomed floor of the Bushveld Complex. They consist mainly of spotted and mottled anorthosite, norite, pyroxenite and chromitite, although boulders of jade and gossan are present in places. The chromitite occurs in the form of layers which have an approximate northerly strike, and which have a shallow dip to the east.

Rocks typical of the Upper Zone in the Malope area seem to have transgressed the rocks of the Critical Zone on the eastern side of the area between Malope and Segwahleng and consist of ferrogabbro and magnetitite. The latter are present in the form of northerly striking layers in the ferrogabbro. Boulders of ferrogabbro and magnetitite were also encountered east of Malope and north-east of Segwahleng which suggests that the Upper Zone may also be developed in these areas.

6.2.2 Petrography

(a) Critical Zone

The basic rocks of the Critical Zone in the Malope area consist of cumulus plagioclase and orthopyroxene, the former displaying bent and zoned grains, as well as clinopyroxene, biotite and a little quartz. The plagio= clase may be saussuritized whilst the pyroxene may be altered to hornblende or uralite where alteration has been extreme.

Measurement of the anorthite and ferrosilite content of plagioclase and orthopyroxene respectively, in two samples of norite gave results of An_{80}, Fs_{20} and An_{68}, Fs_{32}. This suggests that some of the rocks in the Malope area which have been mapped as Critical Zone may in fact belong to the lower part of the Main Zone.

The chromitite is composed of interlocking grains of chromite with interstitial, saussuritized plagioclase. It has a mottled appearance under the microscope which is caused by the presence of saussuritized plagioclase interstitial to octahedral chromite grains.

(b) Upper Zone

The ferrodiorite which outcrops along the base of the Sekhukhune Escarpment consists of plagioclase (An_{41}), clinopyroxene, hornblende, biotite, magnetite, olivine, apatite and a little quartz.

The ferrogabbro which is typical of the Upper Zone from Malope consists of plagioclase (An_{43}), clinopyroxene, magnetite, hornblende, apatite and minor quartz whilst the magnetitite consists of magnetite with some haematite, ilmenite and a very small amount of altered silicates.

6.2.3 Chemistry of the Magnetite Layers

Chemical analyses of five magnetitite samples from Goedverwacht 762 KS are given in Table I. All five samples were taken from surface exposures between Malope and Segwahleng, within the occurrence of magnetite-bearing rocks typical of the Upper Zone.

TABLE I

CHEMICAL ANALYSES OF FIVE MAGNETITITE SAMPLES FROM GOEDVERWACHT 763 KS

SAMPLE NO	AM 75/6	AM 75/9	AM 75/10	AM 75/11	AM 75/14
SiO_2	3,39	3,09	2,39	1,76	0,63
Al_2O_3	2,62	1,90	2,71	3,14	1,88
Fe_2O_3	43,53	65,80	60,21	44,69	51,02
FeO	27,77	6,91	9,36	30,43	20,49
MgO	1,11	0,70	0,88	1,97	0,47
TiO_2	19,99	19,93	21,47	15,79	23,85
Cr_2O_3 ppm	530	350	360	870	1350
MnO	0,32	0,31	0,27	0,24	0,35
V_2O_5	0,34	0,36	0,32	0,89	0,19
TOTAL	99,12	99,03	97,64	98,99	99,01

Analyst : General Superintendence Company (Pty) Ltd.

The V_2O_5 content of each magnetitite sample has been plotted on a curve (Fig. 8) constructed by Molyneux, in which the elevation of the magnetite layers of the eastern Bushveld above the Main Magnetite Layer has been related to their content of V_2O_5 (Molyneux, 1970b, p. 240). Samples AM 75/6, AM 75/9, AM 75/10 and AM 75/14 plot within Subzone D in the vicinity of layers 17, 18 and 21, whilst sample AM 75/11 plots within Subzone C.

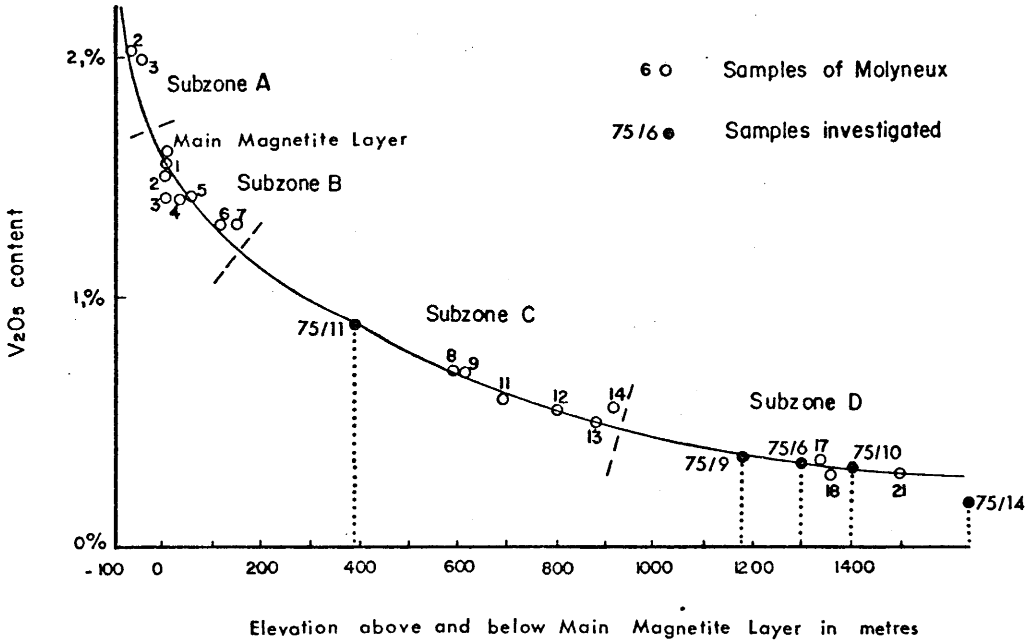


Fig. 8 - Content of V_2O_5 in magnetite layers of the eastern Bushveld related to their elevation above and below the Main Magnetite Layer (after Molyneux, 1970b, p. 240)

Molyneux (1970a, p. 85) has also drawn curves in which the elevation of the magnetite layers above the Main Magnetite Layer has been related to their other major elements. The percentages of TiO_2, Al_2O_3 and MnO of the five analysed magnetitite samples from Goedverwacht 763 KS, when plotted on the above mentioned curves, also indicate that samples AM 75/6, AM 75/9, AM 75/10 and AM 75/14 belong to Subzone D whilst the composition of AM 75/11 indicates that this sample belongs considerably lower in the ferrogabbro.

6.3 RASHOOP GRANOPHYRE SUITE

6.3.1 Distribution and Field Relationships

In the Sekhukhune area the Rashoop Granophyre Suite lies below the granites of the Lebowa Granite Suite and above the basic rocks of the Rustenburg Layered Suite. It is separated from the latter by a thin layer of leptite belonging to the Rooiberg Group. Waterval granophyre is here used in a similar sence as it was originally proposed for by Lenthall (1973, p. 76) i.e. being developed close to the rocks of the layered sequence, often associated with meta= morphosed Rooiberg felsite and stratigraphically below the Nebo Granite.

The Waterval granophyre outcrops on the Sekhukhune Escarpment (Folder I) or within 5 km of it, and its thickness decreases in a northerly direction. It is not developed in the Malope area and probably does not underlie the Nebo Granite throughout the Mogales= lokasie area. Molyneux (1970a, p. 10) considers the thinning of the granophyre in a northerly direction to be possibly due to its assimilation by the granite.

Both granophyre and associated fine-grained, granophyric gra= nite have been mapped as Waterval granophyre. The distinction in the field between the granophyre and the fine-grained granophyric granite is somewhat arbitrary, and is based upon the amount of micrographic intergrowth which is developed within these rocks. If the intergrowth was immediately seen to be abundant the rock was designated a granophyre, whereas if only minor quantities were ob= served through the hand lens after a few moments inspection then the rock was mapped as a fine-grained granophyric granite. The fine-grained granophyric granite continues along the Sekhukhune Escarpment well to the south of the Nebo area where it has been described as a coarse-grained granophyric granite (Von Gruenewaldt, 1972, p. 123).

6.3.2 Petrography

The Waterval granophyre consists of perthite, quartz, plagio= clase (An_{13}), hornblende, biotite, opaque minerals, zircon, sphene and fluorite. The majority of the feldspar and the quartz is micro= graphically intergrown. The modal composition of 10 samples of the granophyre are given in Table II, whilst the average modal compo= sition is given in Table IX (column A) (p.51).

TABLE II

MODAL COMPOSITION OF TEN SAMPLES OF WATERVAL GRANOPHYRE

SAMPLE NO.	AGM 120	AGM 56	AGM 256	AGM 57	AGM 52
K-feldspar	38,8	34,6	39,0	40,8	38,8
Quartz	35,1	35,7	37,8	35,7	36,0
Plagioclase	12,6	19,7	14,2	15,8	15,3
Biotite	3,6	0,9	3,2	1,3	2,8
Hornblende	9,1	8,7	5,1	5,2	5,4
Opaques	0,6	0,1	0,6	1,0	1,4
Zircon	0,1	0,3	0,1	-	0,1
Sphene	0,1	-	-	0,2	0,1
Fluorite	-	-	-	-	0,1
* I.C. No.	110	109	111	132	104

SAMPLE NO.	AGM 117	AGM 49	AGM 20	AGM 21	AGM 8
K-feldspar	40,7	46,6	39,4	46,5	38,3
Quartz	38,8	32,5	37,6	39,1	34,7
Plagioclase	8,4	12,2	20,7	6,1	17,9
Biotite	2,9	2,7	0,3	0,2	0,2
Hornblende	7,7	4,3	1,6	6,4	7,3
Opaques	1,4	1,5	0,3	1,6	0,8
Zircon	0,1	0,1	-	0,1	0,2
Sphene	-	-	-	-	0,6
Fluorite	-	0,1	-	-	-
* I.C. No.	142	73	116	86	77

SAMPLE NO.	FARM	LONGITUDE	LATITUDE
AGM 120	Duizendannex 816 KS	29°53,0'E	24°45,9'S
AGM 56	Hillcrest 881 KS	29°54,0'E	24°57,0'S
AGM 256	Goedgedacht 878 KS	29°52,5'E	24°53,2'S
AGM 57	Hillcrest 881 KS	29°54,0'E	24°57,0'S
AGM 52	De Hoop 886 KS	29°54,5'E	24°55,8'S
AGM 117	Duizendannex 816 KS	29°53,5'E	24°45,7'S
AGM 49	Rietfontein 876 KS	29°47,7'E	24°58,5'S
AGM 20	Tweefontein 846 KS	29°54,5'E	24°50,2'S
AGM 21	Duizendannex 816 KS	29°53,5'E	24°45,3'S
AGM 8	Goedgedacht 878 KS	29°53,9'E	24°51,8'S

* I.C. No. - Number of identity changes on a 40 mm traverse (Chayes, 1956, p. 77)

The micrographically intergrown quartz and feldspar is thought to have developed by the simultaneous growth of these two minerals during crystallization, and no sign of feldspathization was found within the granophyre. Strauss (1954, p. 28) however, believes that although much of it may have formed by this process, a large proportion was formed by the replacement of quartz by feldspar.

The micrographic intergrowths which have developed by the simultaneous crystallization of quartz and feldspar differ from the replacement textures developed in the pseudogranophyre. The former resemble the latter in general appearance but a more careful examina= tion of the two reveals quite striking differences:

(i) The micrographic intergrowths are better developed than the replacement textures and often display a preferred orientation (Fig. 12).

(ii) Micrographic intergrowths may have nuclei of quartz or feldspar (Fig. 9 and Fig. 13) neither of which were observed in replacement textures. The presence of nuclei of these minerals indicates that the micrographic inter= growths resulted from the crystallization of a magma.

(iii) The direction of growth of a micrographic intergrowth and a replacement texture are opposite to one another. The former develops in a radial direction away from its centre, whilst the latter develops in a convergent direction towards its centre.

(iv) Micrographic intergrowths may consist of two optically continuous areas of quartz which are intergrown with one optically continuous area of plagioclase (Fig. 10). This texture was not seen amongst replacement textures.

(v) A micrographic intergrowth often increases in coarseness radially away from its nucleus or centre (Fig. 13), whilst a replacement texture does not. This increase usually results in the loss of order within the intergrowth, the preferred orientation becoming less well-defined.

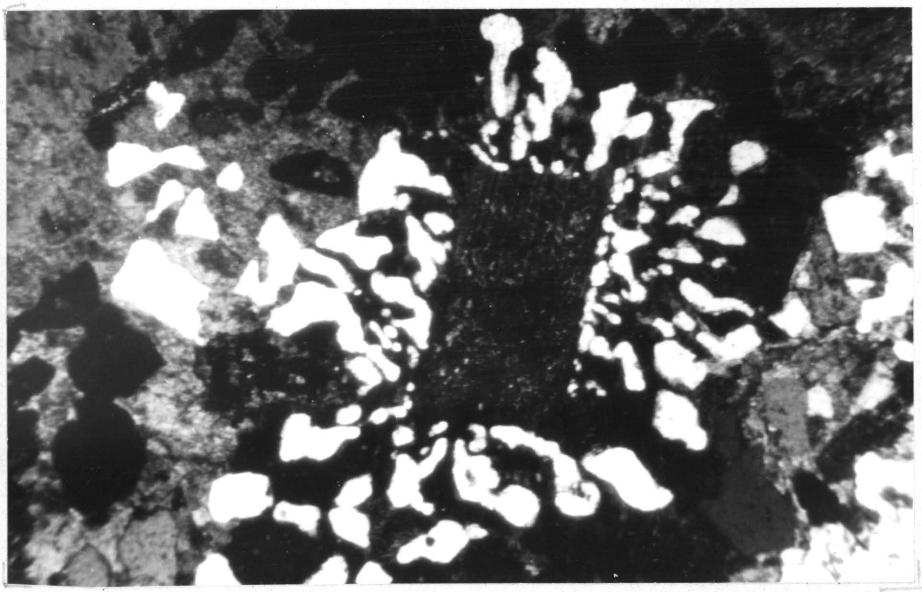


Fig. 9 - Micrographic intergrowth with nucleus of plagioclase in granophyre. AGM 120, Duizendannex 816 KS (IF8). Crossed nicols, x 31

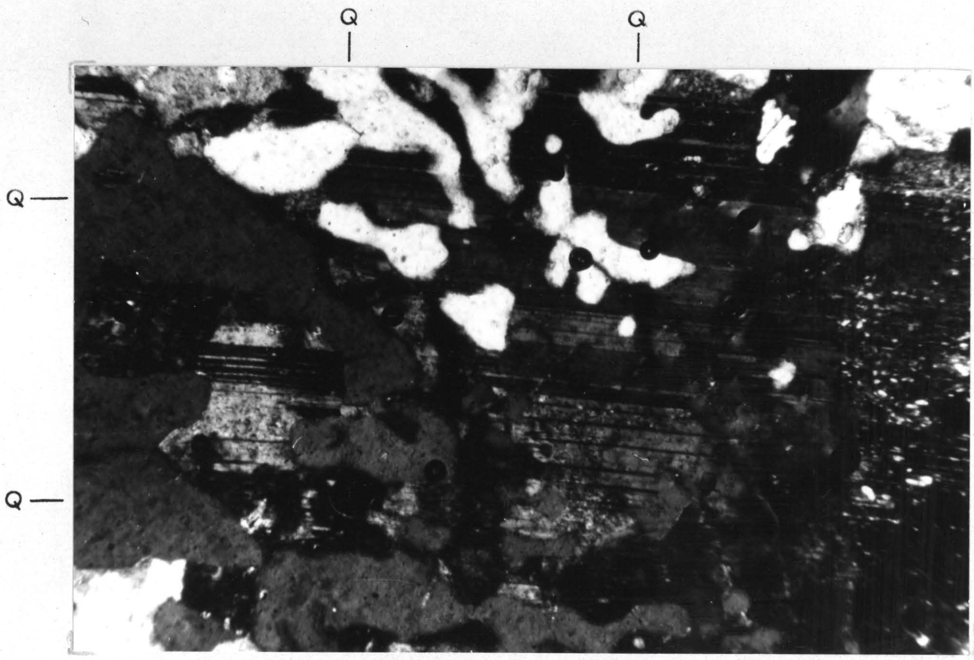


Fig. 10 - Micrographic intergrowth in granophyre consisting of two optically continuous areas of quartz (Q) which are intergrown with one optically continuous area of plagioclase. AGM 57, Hillcrest 881 KS (IJ9). Crossed nicols, x 78

Modal analyses of the micrographic intergrowths in the granophyre have been undertaken in order to determine the ratio of quartz and potassium feldspar within the intergrowths. Von Gruenewaldt (1968, p. 164) carried out the same procedure on a sample of Waterval granophyre from the area west of Bothasberg in the eastern Bushveld. He obtained an average value of 43,7 per cent quartz and 56,3 per cent potassium feldspar and remarked on its close correspondence to the theoretical eutectic ratio 42,2 SiO_2, 57,8 $KALSi_3O_8$ in the binary system silica-leucite.

Eight samples were 'analysed' with the use of a Swift Automatic Point Counter (Appendix I). Point counts were made on between six and ten micrographic units for each sample, and the number of points counted on each unit varied between 110 and 740, averaging 260. The average ratio of quartz to potassium feldspar for each sample is given in Table III. The average value for the eight samples is 39,5 per cent quartz, 60,5 per cent potassium feldspar which also corresponds quite closely to the theoretical eutectic ratio of 42,2 SiO_2, 57,8 $KALSi_3O_8$ and supports the statement by Von Gruenewaldt that the micrographic intergrowths probably resulted from the crystallization of a magma.

TABLE III

AVERAGE RATIOS OF QUARTZ TO POTASSIUM FELDSPAR IN MICROGRAPHIC INTERGROWTHS IN THE WATERVAL GRANOPHYRE

SAMPLE NO.	AVERAGE RATIO OF QUARTZ: K-FELDSPAR	RANGE OF QUARTZ: K-FELDSPAR
AGM 256	39,5 : 60,5	28,9 : 71,1 to 50,0 : 50,0
AGM 56	36,4 : 63,6	32,1 : 67,9 to 46,5 : 53,5
AGM 57	38,7 : 61,3	34,6 : 65,4 to 43,7 : 56,3
AGM 52	37,2 : 62,8	31,5 : 68,5 to 42,9 : 57,1
AGM 10	42,6 : 57,4	32,0 : 68,0 to 48,5 : 51,5
AGM 8	43,2 : 56,8	37,2 : 67,8 to 49,5 : 50,5
AGM 49	40,6 : 59,4	36,0 : 64,0 to 49,0 : 51,0
AGM 117	37,5 : 62,5	29,6 : 70,4 to 44,1 : 55,9

6.3.3 The Origin of the Granophyre

Strauss (1947, p. 161) considers rocks now grouped with the Waterval granophyre north-west and west of Potgietersrus to be highly metamorphosed sediments, and he states that the granophyre situated in the Sekhukhune Escarpment is similar. Boshoff (1942, p. 50) however, has suggested that the granophyre may represent the acid differentiate of the basic magma of the Bushveld.

It is probable that the granophyre originated from the crystallization of a melt which formed by the melting of the Rooi= berg felsite, which represented the roof-rocks of the Bushveld Complex during the intrusion of the layered seqûence. Irvine (1970, p. 1059) has calculated the heat transfer during solidification of layered intrusions, and considers that during the period of accumu= lation of the layered sequence the intrusion could theoretically have melted enough roof-rocks to produce the granophyre. Von Gruenewaldt (1972, p. 126) ascribes the formation of the granophyre to melting of the recrystallized lower parts of the Rooiberg felsite during the intrusion of the layered sequence, and movement of the granophyric liquids to higher levels within the felsite where they spread out, thickened and crystallized as one sheet of granophyre.

6.4 LEBOWA GRANITE SUITE

In the Sekhukhune area the Lebowa Granite Suite consists of two formations; the older Nebo Granite and the younger Makhutso Granite. The Nebo Granite consists of four facies, namely, the main, contact, granophyric and aplitic facies. The Makhutso Granite also consists of four, namely, the main, contact and aplitic facies, as well as the fine-grained, porphyritic Koornkopje granite which is considered to be a variety of the Makhutso Granite (Table IV).

The Nebo Granite is by far the most important of the granites by volume. Of the total surface area occupied by the granites in the area mapped, only 0,2 per cent is taken by the Makhutso Granite

TABLE IV

SUBDIVISION OF THE GRANITES OF THE LEBOWA GRANITE SUITE IN SEKHUKHUNELAND

UNIT	TYPE / VARIETY	CHARACTERISTICS
1. Nebo Granite	1(d) Aplitic facies	(i) Fine-grained and locally porphyritic (ii) Intrusive into 1(b), mainly as sills (iii) More biotite and less hornblende than 1(b) (iv) Lower anorthite content of plagioclase than 1(b) and 1(a)
	1(c) Granophyric facies	(i) Micrographic intergrowth of quartz and feldspar (ii) More resistant to weathering than 1(b) (iii) Remobilized granite (iv) Grades into 1(b)
	1(b) Main facies	(i) Medium to coarse-grained (ii) Red to grey, hornblende biotite granite
	1(a) Contact facies	(i) Fine- to medium-grained (ii) Zoned plagioclase phenocrysts (iii) Higher percentage of ferromagnesian minerals than 1(b) (iv) Higher anorthite content than 1(b) and 1(d) (v) Grades into 1(b)

TABLE IV (continued)

UNIT	TYPE / VARIETY	CHARACTERISTICS
2. Makhutso Granite	2(d) Koornkopje granite	(i) Fine-grained but less porphyritic than 2(a), (b) and (c) (ii) Intrusive into 1(b) as dykes and sills (iii) Less biotite and lower anorthite content of plagioclase than 2(b) (iv) Flow banding at margins only (v) More resistant to weathering than 2(a), (b) and (c)
	2(c) Aplitic facies	(i) Fine-grained, porphyritic (ii) Intrusive into 2(b) as sills. Xenoliths of 2(b). Chilled margin with 2(b) (iii) Petrographically similar to 2(b) (iv) Well-developed flow banding
	2(b) Main facies	(i) Medium- to coarse-grained, porphyritic (ii) More resistant to weathering than 1 (iii) Intrusive into 1(b) and 1(d) as dykes, sills and stocks (iv) White to grey, biotite granite (v) Higher biotite content than 1. Segregations of biotite (vi) Zoned plagioclase phenocrysts and higher anorthite content of plagioclase than 1 (vii) Inclusions of quartzite and hornfels
	2(a) Contact facies	(i) Fine-grained, porphyritic (ii) Petrographically similar to 2(b) (iii) Displays flow banding and mafic mineral concentration at contact with 1 (iv) Grades into 2(b)

and just less than 0,1 per cent by the Koornkopje granite. The aplitic facies of the Nebo Granite occupies just less than one per cent of the area covered by granite.

6.4.1 Nebo Granite

Although the Nebo Granite occurs as four facies, only three of these have been mapped separately. The granophyric facies has been included with the main facies for three reasons. Firstly, because its exposure is too small to show properly on the scale mapped, secondly, because it represents a thermally altered part of the main facies, and thirdly, because it is only present in direct contact with dolerite bodies which have been mapped.

(a) Main facies

The main facies forms the bulk of the rocks intruded as Nebo Granite. It is well-exposed in this area, although it is normally weathered at the surface. It is red to grey in colour, except in the upper part of the Sekhu= khune Escarpment on Goedgedacht 878 KS (IH9) where it is pink, and where, as a result of its higher feldspar and lower mafic mineral content it differs from the normal Nebo Granite. A small, plug-like body of Nebo Granite only a few metres in diameter, occurs north of Suike on Boschpoort 843 KS (IG9).

The granite is coarse-grained and granular on the Sekhukhune Plateau but becomes medium-grained towards its base where it grades into the contact facies. A pseudo-bedding which may represent primary layering in the granite can be observed in places such as in the region of the large dolerite sill in the Mogaleslokasie area (Folder II) and near the escarpment where dips of 10° to 15° towards the west could be measured.

Mineralogically the granite consists of perthite, quartz and plagioclase (An_{11}) as major constituents.

The minor constituents include hornblende, biotite and muscovite whilst the accessories include opaque minerals, zircon, rutile, and fluorite. Myrmekite, not previously described from the Nebo Granite was found in small quantities in many of the thin sections investigated. The feldspar is usually partially sericitized, and horn= blende, the dominant mafic mineral, may show partial alteration to biotite. Apatite and allanite which have been previously recorded in the Nebo Granite from other areas of the Bushveld Complex were not encountered.

Pegmatite is found extensively within the Nebo Granite, throughout the whole of the area. The bodies, however, are usually fairly small. Macroscopically it consists of perthitic feldspar and quartz with major amounts of hornblende and minor amounts of biotite.

A number of authors have stated that the Bushveld granite has been formed at least in part by a process of granitization, assimilation and anatexis (Willemse, 1964, p. 118; Iannello, 1970, p. 649; Molyneux, 1974, p. 331). The author however, considers the Nebo Granite to be almost totally of igneous origin. A certain amount of granitized meta-sediment has been incorporated within the granite as xenoliths, but their size and distribution is so small that they are almost negligible in comparison with the total volume of granite which crystallized from a magma. The origin of the magma is problematical, but it was probably derived from partial melting of a deep-seated gneissic basement (Hunter, 1973, p. 14).

(b) Contact facies

The contact facies constitutes that part of the Nebo Granite which has been chilled against older rocks with which it came into contact during intrusion. It is consequently less differentiated than many of the rocks of the main and aplitic facies. It is well-developed on Driehoek 883 KS (IH9), Tweefontein 848 KS (IG9) and Goedverwacht 763 KS (IIB2), but its width is quite narrow on the last farm.

The facies consists of fine- to medium-grained granite, and its mineralogy is slightly different from that of the main facies in that the quantity of ferro= magnesian minerals is greater and the plagioclase has a higher anorthite content (An_{13}). The phenocrysts of plagioclase are commonly zoned, a feature which was rarely observed in the main facies of the Nebo Granite. The zoning was found to be normal or oscillatory, the sequence of zoning in the latter being normal-reversed-normal. The presence of a fine-grained texture and the zoned plagioclase crystals in the contact facies, sug= gests that the magma cooled more rapidly than that which gave rise to the main facies of the Nebo Granite

(c) Granophyric facies

The granophyric facies constitutes that part of the Nebo Granite which has been effected by metamorphism during the intrusion of basic rocks of post-Bushveld age. It can be correlated with Lenthall's (1973, p. 76) Welge= vonden granophyre of the Zaaiplaats tin-mining area.

The granophyric facies may be a few metres to 50 m in width on either side of a dyke, or above and below a sill. At Tlame on Masleroems Oude Stad 840 KS (IG6) the granophyric zone below the remnants of a dolerite sill is 15 to 20 m thick. This facies is more resistant to weathering than the main facies and sometimes dolerite dykes can be located purely by the presence of two parallel belts of the granophyric granite outcropping in an otherwise exposureless area.

The normal granite in contact with the granophyric facies in places contains veins which have probably developed by the penetration along joints and cracks of hydrothermal solutions associated with the dolerite intrusion. Within some of these veins, crystallization of epidote has taken place.

In the Ngwaritsi River on Probeeren 785 KS (IIC4) a rheomorphic granite dyke cuts the dolerite a few metres from the contact between the dolerite and the granophyric facies of the Nebo Granite (Fig. 11). The dyke is approximately 25 cm thick and has a chilled margin about 0,5 cm wide. In the Ngwaritsi River on Vooruitzicht 787 KS (IIC4) a second rheomorphic granite dyke cuts the dolerite. This dyke is 2 m in thickness and contains tension gashes filled with fine-grained dolerite. The tension gashes reach one metre in length and 10 cm in width, and their presence indicates that the mobiliza= tion of the granite took place before complete solidifi= cation of the dolerite. Within the granophyric phase in contact with a dolerite sill on Vergelegen 819 KS (IF7) rheomorphic granite contains xenoliths of fine-grained dolerite up to 0,5 m across.

Mineralogically the granophyric facies of the Nebo Granite consists of feldspar, quartz and a micrographic intergrowth of the two, minor amounts of hornblende, biotite and opaque minerals. The hornblende may occur as interstitial grains or as prisms rimming the quartz grains. The feldspar is very heavily sericitized.

The presence of a well-developed micrographic texture within the granophyric facies is restricted to the granophyric zone in immediate contact with the dolerite. Away from this contact the micrographic textures become fewer in number, and quickly disappear completely. The intergrowths are thought to be the result of a process of simultaneous crystallization of quartz and feldspar from a cotectic melt formed by partial fusion of the gra= nite. No replacement textures were observed within the rocks of the granophyric facies, and the micrographic intergrowths may display preferred orientations (Fig. 12), feldspar nuclei (Fig. 13) or they may increase in coarseness, radially away from their centres (Fig. 13). Lenthall (1972, p. 29) however, is of the opinion that the micrographic textures in the Weltgevonden granophyre of the Zaaiplaats area resulted from the replacement of quartz by feldspar.

An unusual texture was observed in the feldspar of the granophyric facies in contact with a dolerite dyke on Vlakplaats 802 KS (IIE4). The feldspar has been sericitized and the individual sericite grains are oriented in the form of bow tie structures (Fig. 14). Some small quartz grains and a few hornblende grains which are included in the structure, show a weak con= formability with the sericite grains. The structures abut against quartz grains which were present before their growth, and it appears that they have grown as a result of the metamorphism associated with the dolerite intrusion i.e. at the same time as the development of the micrographic intergrowths.

Bow tie structures and spherulites result from crystal growth governed by poor nucleation, and are most common in media with high viscosity (Spry, 1969, p. 154). The association of bow tie structures and micrographic inter= growths in the granophyric facies leads to the conclusion that the melt from which they developed must have had a high viscosity.

(d) Aplitic facies

The aplitic facies of the Nebo Granite is present through= out the area mapped, but the larger bodies are restricted

Fig. 11 - Remobilized granite dyke in dolerite on Probeeren 785 KS (IIC4)

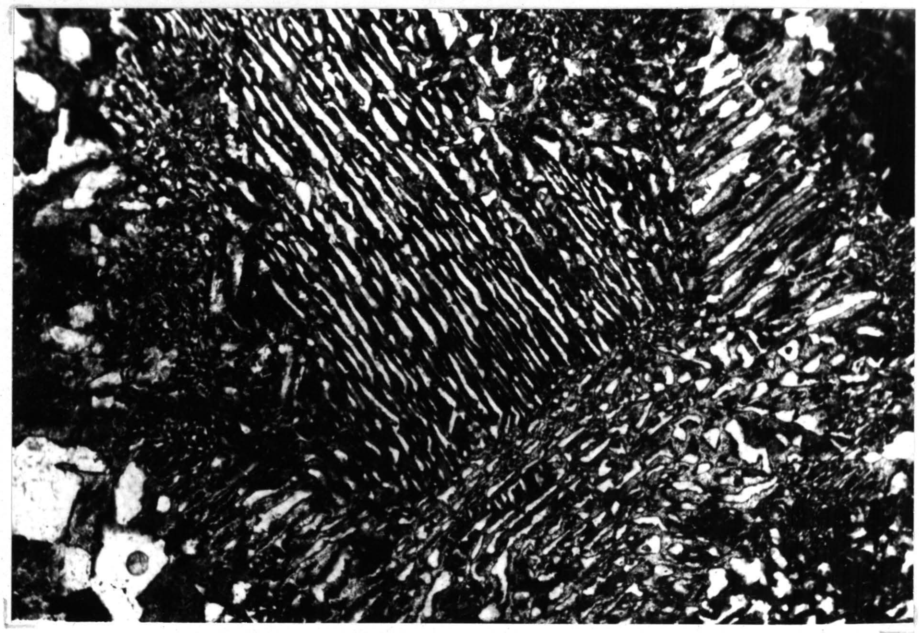


Fig. 12 - Micrographic intergrowth displaying a strongly preferred orientation in the granophyric facies of the Nebo Granite. AGM 148, Vooruitzicht 787 KS (IIC4). Crossed nicols x 78

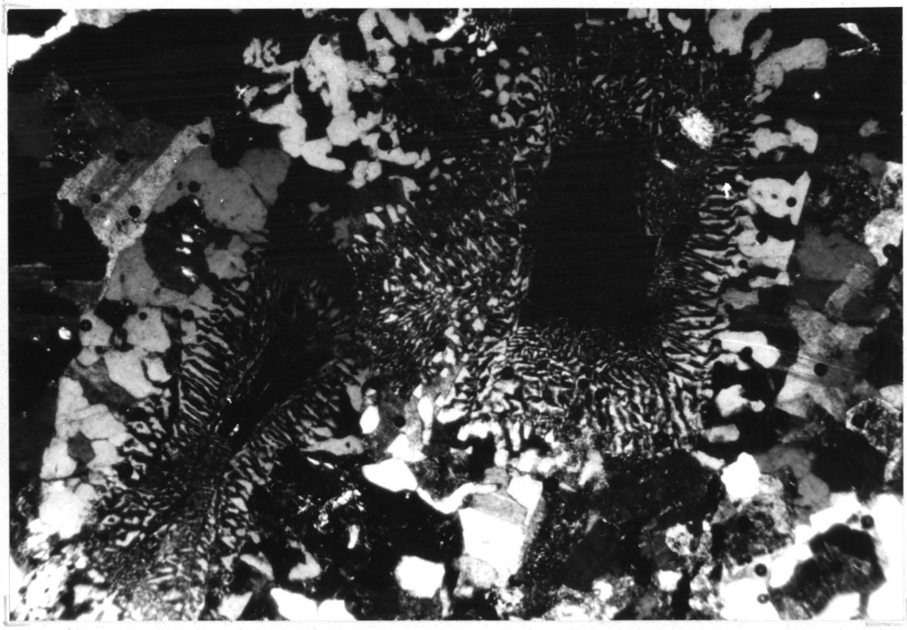


Fig. 13 - Micrographic intergrowths with nuclei of feldspar in the granophyric facies of the Nebo Granite. Note the radial increase in coarseness of the intergrowth. AGM 148, Vooruitzicht 787 KS (IIC4). Crossed nicols. x 31

Fig. 14 - Bow tie structure in sericitized feldspar from the granophyric facies of the Nebo Granite. AGM 134, Vlakplaats 802 KS (IIE4). Crossed nicols. x 31

to the Mogaleslokasie area. These larger bodies exist mainly in the form of westerly dipping sheets, though irregularly shaped bodies are not uncommon. Intrusive into one of these larger sheets on Vergenoegd 792 KS (IIC2) is a dyke of Makhutso Granite (Fig. 20). The bodies are locally porphyritic and may show poorly developed chilled margins against the sharp contacts with the main facies of the Nebo Granite.

The small aplite bodies are usually less than a metre or so across and the jointing within them is better developed than in the surrounding Nebo Granite. At Sehuswane on Koornkopje 801 KS (IIE3) two aplite sills each approximately one metre in thickness dip 45° towards the north-west. On the same farm, between the main road and the body of Makhutso Granite, a third aplite body cuts the Nebo Granite. This aplite is in the form of a dyke which traverses the granite for at least 20 m. The dyke is approximately 15 cm thick and has a dip of 45° to the north.

On Loopspruit 805 KS (IID5) where the secondary road meets the Ngwaritsi River a plug-like body of porphyritic aplite, approximately one metre across cuts the Nebo Granite. The feldspar phenocrysts vary in size from 0,5 to 1 cm in length and display zoning. On Vooruitzicht 787 KS (IIC4) an aplite measuring a few centimetres across, contains segregations of epidote. It is only a few tens of metres from a large dolerite sill, and the epidotization is probably associated with the intrusion of the dolerite.

Mineralogically the aplite consists of quartz, perthite and plagioclase (An_9) as major constituents; biotite and hornblende as minor constituents and opaque minerals, muscovite, sphene, zircon, fluorite and rutile as accessories. Small quantities of myrmekite were also encountered in this rock. The biotite is found both as a primary mineral and a secondary mineral after hornblende.

The modal composition of 10 samples of the aplite are given in Table V, whilst the average modal composi= tion is given in Table IX (column B) (p. 51). Although no modal analysis was made of the main facies of the Nebo Granite, due to its coarse-grained nature, it seems that the aplite contains a larger amount of biotite and a smaller amount of hornblende.

The aplite is always fine-grained which suggests that the main facies of the Nebo Granite had cooled down and crystallized before the injection of the former. Hunter and Lenthall (1973, p. 34) consider the aplites to be part of the residual magma that has been injected into the semi-consolidated Nebo Granite at various stages of the crystallization history of the latter.

(e) Differentiation of the Nebo Granite

The Nebo Granite appears to show a differentiation trend from the contact facies, through the main facies to the aplitic facies. Rhodes (1975, p. 73) states that the aplite to the west of the Mogaleslokasie area probably formed late in the crystallization history of the Nebo Granite, from residual, interstitial magma that was enriched in incompatible elements. He has used the ratio Ba/Rb as a differentiation index, and considers the aplite to have a lower ratio than the main facies of the Nebo Granite.

The average Ba/Rb ratios for the main and aplitic facies of the Nebo Granite have been calculated from new and published analyses (Table VI). The figures in Table VI support the statement by Rhodes that the ap= lite has a lower Ba/Rb ratio than the main facies, which indicates that the former is more differentiated than the latter.

TABLE V

MODAL COMPOSITION OF TEN SAMPLES OF THE APLITIC FACIES OF THE NEBO GRANITE

SAMPLE NO.	AGM 175	AGM 155	AGM 174	AGM 231	AGM 156	AGM 173	AGM 241	AGM 215	AGM 220	AGM 171
K-feldspar	32,2	29,8	31,3	30,3	33,2	33,8	38,2	39,8	39,9	38,6
Quartz	41,6	35,8	42,5	39,8	41,4	41,9	42,2	40,3	39,1	40,0
Plagioclase	22,9	28,6	15,0	25,4	22,2	13,0	15,5	15,2	18,1	14,7
Biotite	2,6	4,7	6,0	1,6	1,3	3,7	1,7	0,6	2,0	5,0
Hornblende	0,4	1,0	5,0	2,5	1,8	7,0	1,8	3,5	0,7	1,4
Opaques	0,2	-	0,2	0,4	0,1	0,4	0,5	0,1	0,1	0,3
Sphene	-	0,1	-	-	-	0,2	-	0,3	-	-
Muscovite	0,1	-	-	-	-	-	0,1	0,2	0,1	-
I.C. No.	> 90	107	90	90	> 90	> 90	> 90	> 90	56	94

SAMPLE NO.	FARM	LONGITUDE	LATITUDE
AGM 175	Loopspruit 805 KS	29°44,2'E	24°41,1'S
AGM 155	Nooitgedacht 789 KS	29°39,6'E	24°38,2'S
AGM 174	Loopspruit 805 KS	29°44,2'E	24°41,3'S
AGM 231	Vergenoegd 792 KS	29°34,5'E	24°39,3'S
AGM 156	Nooitgedacht 789 KS	29°39,6'E	24°38,2'S
AGM 173	Loopspruit 805 KS	29°44,2'E	24°41,3'S
AGM 241	Nooitverwacht 791 KS	29°35,7'E	24°35,9'S
AGM 215	Vergenoegd 792 KS	29°35,1'E	24°38,4'S
AGM 220	Vergenoegd 792 KS	29°35,0'E	24°39,2'S
AGM 171	Mooifontein 806 KS	29°44,5'E	24°42,2'S

TABLE VI

AVERAGE Ba/Rb RATIOS FOR THE MAIN AND APLITIC FACIES OF THE NEBO GRANITE

1		2	
Mean	Standard Deviation	Mean	Standard Deviation
5,61	2,71	0,41	0,18

1. Main facies (average of 5 new analyses /Appendix II/ and 88 published analyses /Lenthall, 1972/)
2. Aplitic facies (average of 4 new analyses /Appendix II/ and 1 published analysis /Rhodes, 1975, p. 73/)

The differentiation index (DI) which is equal to the sum of the normative quartz, orthoclase, albite, nepheline and leucite (Thornton and Tuttle, 1960, p. 670) of available analyses (Appendix II) has been plotted graphically against the weight per cent of the oxides TiO_2, MgO, FeO and CaO for the Nebo Granite and the aplite (Fig. 15). 16 Samples of the main facies have been plotted against 5 samples of the aplitic facies. In as much as the DI gives an indication of the degree of fractionation of a magma (Thornton and Tuttle, 1960, p. 672), it should theoretically be higher for the aplite than the Nebo Granite, which is in fact substantiated by the plots shown in Fig. 15.

The optically determined anorthite content of the plagioclase of the Nebo Granite is given in Table VII, alongside the calculated normative anorthite content. The anorthite content of the plagioclase is highest in the contact facies and lowest in the aplitic facies, and also provides evidence to suggest that the contact, main and aplitic facies of the Nebo Granite were derived from the same magma which differentiated to produce the separate facies.

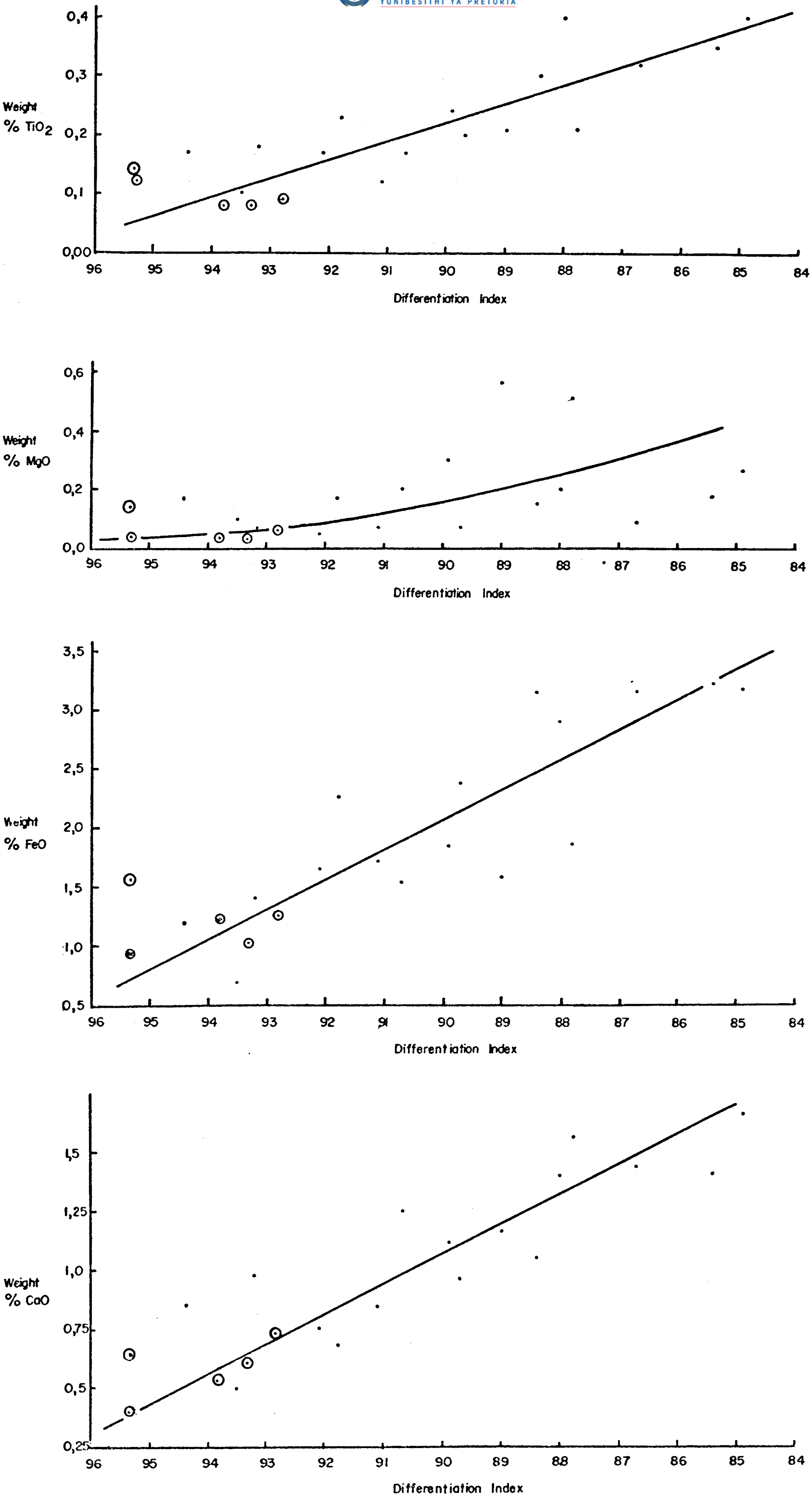


Fig. 15 - Plot of DI versus weight per cent TiO_2, MgO, FeO and CaO for the Nebo Granite (•) and the Nebo Granite aplite (⊙)

TABLE VII

ANORTHITE CONTENT OF PLAGIOCLASE IN THE NEBO GRANITE

FACIES	OPTICALLY DETERMINATION	NORMATIVE CALCULATION*
Aplitic	9	7,4
Main	11	10,9
Contact	13	-

* The normative anorthite content was calculated from the normative compositions given in Appendix II

6.4.2 Makhutso Granite

(a) Distribution and Field Relationships

Seventeen bodies of Makhutso Granite have been found in the Mogaleslokasie area, approximately 25 km west-north-west of Jane Furse Hospital. They are situated along a north-west trending line from Eensgevonden 825 KS through Vlakplaats 802 KS, Koornkopje 801 KS and Derdemaal 797 KS, to Vergenoegd 792 KS (Folder II). The bodies, intrusive into the Nebo Granite, are spread over a total area of about 50 square km, but occupy only about one square kilometre or two per cent of this area.

The name Makhutso Granite was proposed by De Bruiyn and Rhodes (1975, p. 89) for two bodies of biotite-rich granite, one of which is located 30 km north-west of Dennilton close to the Makhutso Trading Store, and the other approximately 30 km south-west of Dennilton. These were the only two bodies of Makhutso Granite known to exist before this study. During 1975 a further number of bodies of Makhutso Granite were located by the author in the Dennilton area (Marlow, 1976).

The Makhutso Granite consists of four facies, namely, the main, contact and aplitic facies, and also a fine-grained, porphyritic variety termed "Koornkopje granite". The contact facies occurs as a marginal granite to the main facies and grades into the latter. Sills of the aplitic facies are present within the main facies (Fig. 19), and xenoliths of the latter may be present in places within the aplite. Locally the aplitic facies also exhibits a chilled margin against the main facies.

The Makhutso Granite has intruded the Nebo Granite in the form of dykes, gently dipping sills and steeply dip= ping stocks. On Vergenoegd 792 KS a steeply dipping, north-north-west trending dyke is intrusive into the main and aplitic facies of the Nebo Granite (Fig. 16 and Fig. 17). It is exposed at four outcrops over 1 km of its length, has a maximum width in the south of 50 m, but thins to 2,5 m in the north where it disappears.

At Hwafeng on Vlakplaats 802 KS a gently dipping sill of Makhutso Granite is intrusive into Nebo Granite. The sill dips to the north-east at approximately 16° and flow banding parallels the contact of the sill and the intruded granite. At Mamorotsi on Eensgevonden 825 KS a second sill of Makhutso Granite in Nebo Granite dips to the north-west at approximately 32°

On Koornkopje 802 KS a steeply dipping stock of Makhutso Granite is intrusive into Nebo Granite. Flow banding within the former indicates that the stock plunges to the north-east by approximately 52°.

The intrusive nature of the Makhutso Granite is indicated by :

(i) xenoliths of Nebo Granite along the contact,

(ii) apophyses of Makhutso Granite in the Nebo Granite,

(iii) a chilled margin,

(iv) dykes (Fig. 16), sills and stocks in the Nebo Granite, and

(v) the sharp contacts between the Makhutso Granite and the Nebo Granite (Fig.17).

An interesting structure was observed at Hwafeng on Vlakplaats 802 KS (Fig. 18). The aplitic facies of the Makhutso Granite has intruded the main facies in a "lit par lit" fashion. Stress in the granites which was probably active during the intrusion of the aplite, resulted in faulting. The faulting brought into juxta= position the two facies of the granite, and contorted the "lit par lit" structure. The presence of the con= torted "lit par lit" structure, besides indicating the direction of movement along the fault, also suggests that the granite was still plastic at the time of faulting.

(b) Characteristics of the Makhutso Granite

The main facies of the Makhutso Granite consists of a medium- to coarse-grained, porphyritic granite which grades into the fine-grained, porphyritic granite of the contact facies. The aplitic facies consists of a fine-grained, porphyritic granite which may display beautifully deve= loped flow banding (Fig. 19).

The granite is more resistant to weathering than the Nebo Granite and usually forms little koppies which stand up above the general level of the Sekhukhune Plateau (Fig. 20). It is a white to grey biotite-rich granite and where exposed is normally fairly fresh.

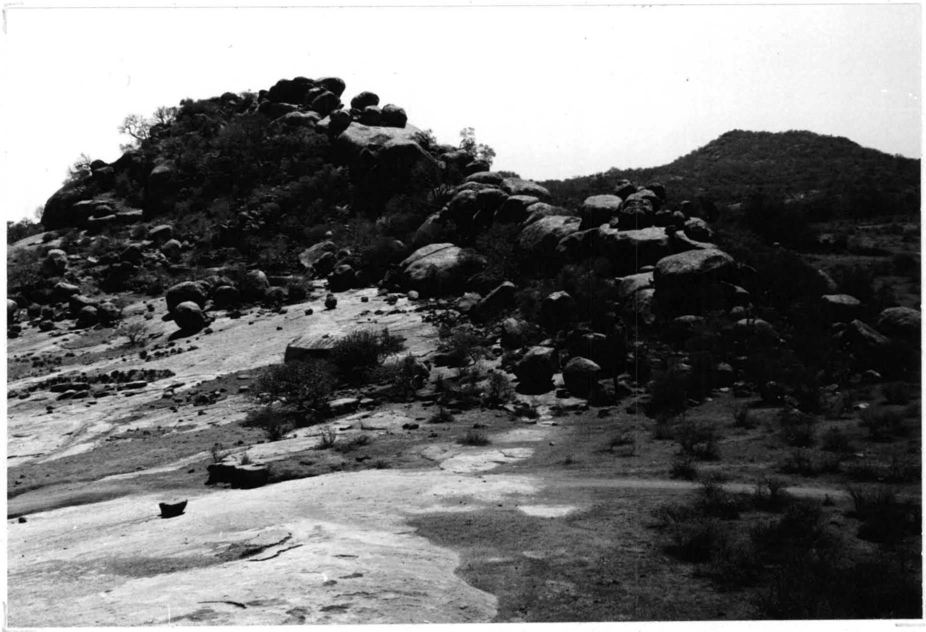


Fig. 16 - Dyke of Makhutso Granite cuts Nebo Granite on Vergenoegd 792 KS (IIC2)

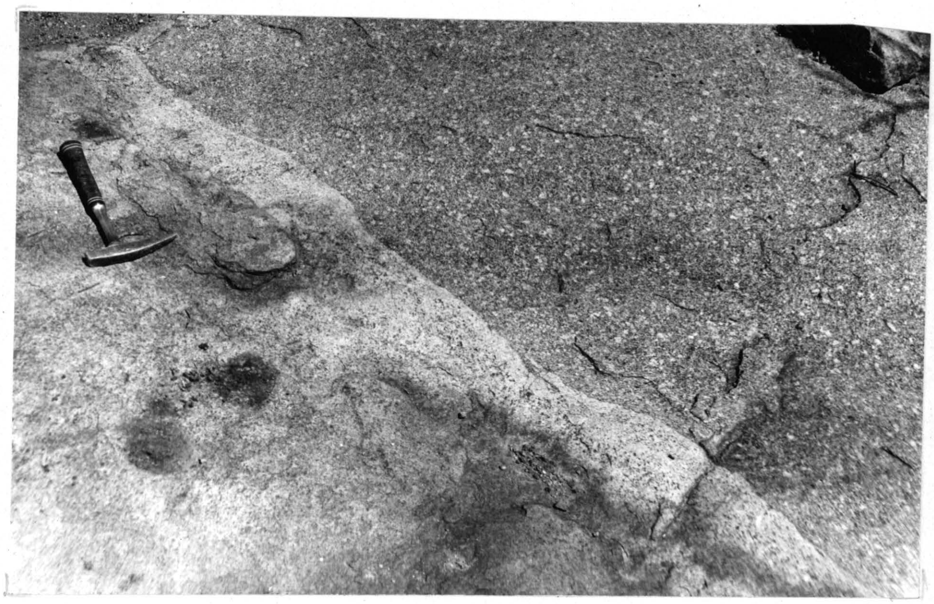


Fig. 17 - Sharp contact between dyke of Makhutso Granite (right) and aplitic facies of Nebo Granite (left) on Vergenoegd 792 KS (IIC2)

Fig. 18 - Contorted "lit par lit" structure between the aplitic and main facies of the Makhutso Granite, on Vlakplaats 802 KS (IIE4). Note the faulted contact between the downthrown aplite (left), and the upthrown, main facies (right)

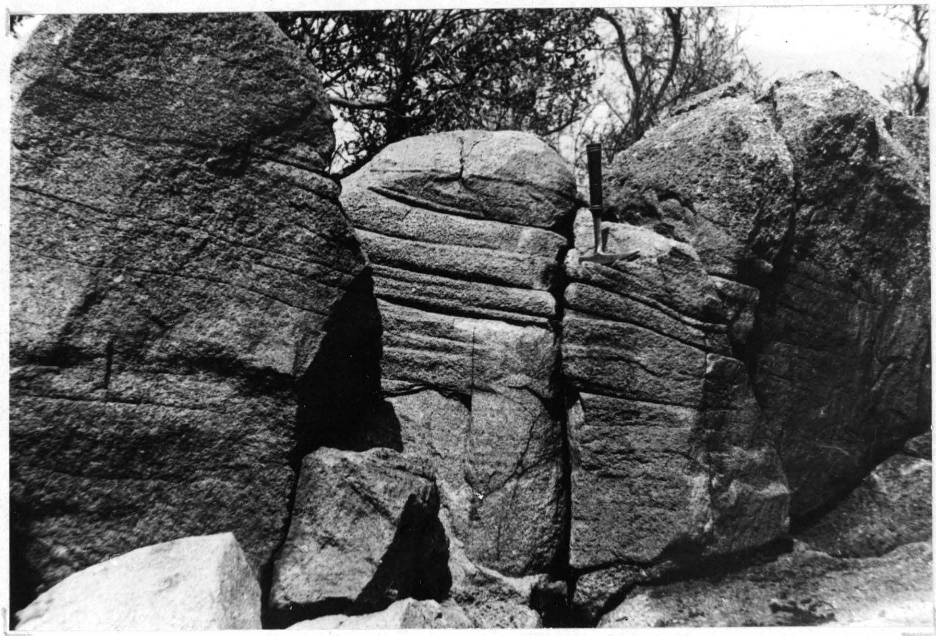


Fig. 19 - Flow banded aplite sill cuts the main facies (top right) of the Makhutso Granite on Eens=gevonden 825 KS (IIE4)

Zoned phenocrysts of plagioclase are characteristic of the Makhutso Granite and can reach 3 cm in length. They may be concentrated in bands which are concordant with the flow banding in the granite. The zoning is normal and oscillatory, the sequence of zoning in the latter being from reversed to normal. The zoning is well-developed throughout the grains, but a narrow sodium-rich rim is usually the most strongly developed feature of the texture.

Randomly scattered segregations of biotite which often display leucocratic haloes are also characteristic of the granite (Fig. 21). They are more or less spheri= cal in shape and usually less than 2 cm in diameter, although some may reach 10 cm across. Small biotite- and hornblende-bearing pegmatites are quite common with= in the Makhutso Granite, whilst pegmatites of graphic granite are present at the contact between the Makhutso Granite and the Nebo Granite. The Makhutso Granite may show a concentration of mafic minerals at this contact (Fig. 24). Small xenoliths of quartzite and hornfels abound within the dyke on Vergenoegd 792 KS, but sur= prisingly are absent in the other bodies of Makhutso Granite. The xenoliths are rounded in shape, and feld= spar phenocrysts in the Makhutso Granite have a tendency to be larger in the rim surrounding the xenoliths.

(c) Petrography

Mineralogically the Makhutso Granite consists of perthite, quartz, plagioclase (An_{12}) and biotite as major consti= tuents. Microcline perthite may also be present as a major constituent. The quartz can reach a grain size of 3 cm but is usually below 1 cm. The plagioclase commonly includes biotite and quartz. The minor constituents comprise hornblende and muscovite, whilst the accessory minerals include opaque minerals, sphene, zircon, fluorite and rutile. The latter mineral was only found within

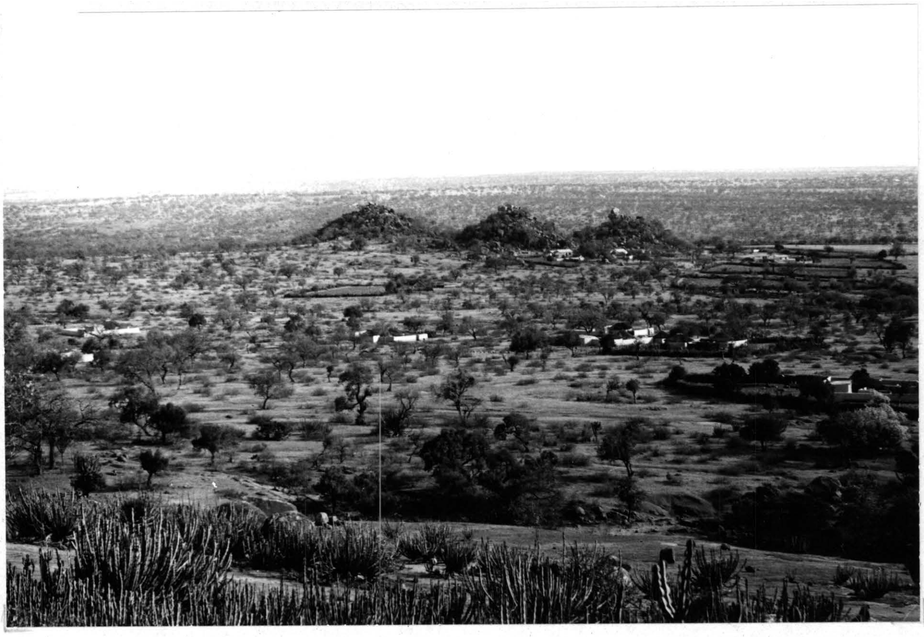


Fig. 20 - The three koppies of Makhutso Granite at Mamorotsi on Eensgevonden 825 KS (IIE4), illustrate the typical way in which this granite is exposed

Fig. 21 - Segregations of biotite in Makhutso Granite on Derdemaal 797 KS (IID2)

the Makhutso Granite on Vlakplaats 802 KS and Eensge= vonden 825 KS (IIE4). Myrmekite was often observed in minor amounts, whilst micrographic intergrowths which are present in places between quartz and potassium feldspar, are both rare and small in size.

The modal composition of 6 samples of the contact facies of the Makhutso Granite are given in Table VIII, whilst the average modal composition is given in Table IX (column C) (p. 51). No modal analysis of the main facies of the Makhutso Granite was carried out because of its coarse-grained nature, but it appears that the two facies do not differ considerably in their mineralogy.

TABLE VIII

MODAL COMPOSITION OF SIX SAMPLES OF THE CONTACT FACIES OF THE MAKHUTSO GRANITE

SAMPLE NO.	AGM 129	AGM 219	AGM 222	AGM 226	AGM 217	AGM 137
K-feldspar	44,9	38,9	41,5	33,3	40,0	31,9
Quartz	34,2	34,3	37,2	32,5	34,9	35,1
Plagioclase	8,0	13,2	10,4	18,1	15,5	20,6
Biotite	8,7	12,9	7,6	15,9	7,5	10,9
Hornblende	4,1	0,5	0,4	-	-	1,2
Opaques	0,1	0,1	0,1	0,1	0,1	0,1
Sphene	-	0,1	-	-	-	0,1
Muscovite	-	-	2,8	0,1	2,0	0,1
I.C. No.	46	58	56	59	70	60

SAMPLE NO.	FARM	LONGITUDE	LATITUDE
AGM 129	Eensgevonden 825 KS	29°40,0'E	24°43,5'S
AGM 219	Vergenoegd 792 KS	29°35,0'E	24°37,9'S
AGM 222	Derdemaal 797 KS	29°33,7'E	24°39,3'S
AGM 226	Vergenoegd 792 KS	29°35,0'E	24°37,8'S
AGM 217	Vergenoegd 792 KS	29°35,0'E	24°38,3'S
AGM 137	Vlakplaats 802 KS	29°37,6'E	24°43,3'S

A comparison between the average modal composition of some of the fine-grained granites of the Lebowa Granite Suite (Table IX), has revealed a difference in both the quartz and biotite content. The modal quartz has been plotted graphically against the modal biotite for each sample analysed , and the contact facies of the Makhutso Granite falls in a field separate from that of the aplitic facies of the Nebo Granite (Fig. 22).

TABLE IX

AVERAGE MODAL COMPOSITION OF WATERVAL GRANOPHYRE, APLITIC FACIES OF NEBO GRANITE, CONTACT FACIES OF MAKHUTSO GRANITE AND KOORNKOPJE GRANITE

	A		B		C		D	
	Mean	S	Mean	S	Mean	S	Mean	S*
K-feldspar	40,4	3,5	34,7	3,8	38,4	4,5	45,1	2,5
Quartz	36,3	1,9	40,5	2,0	36,2	2,0	35,8	3,2
Plagioclase	14,3	4,2	19,1	5,1	14,3	4,3	15,5	2,4
Biotite	1,8	1,3	2,9	1,7	10,1	3,1	3,1	0,8
Hornblende	6,1	2,1	2,5	2,1	1,1	1,4	0,6	0,7
Opaques	0,9	0,5	0,2	0,1	0,1	0,3	-	-
Sphene	-	-	0,1	0,1	-	-	-	-
Muscovite	-	-	0,1	0,1	0,8	1,1	-	-
Zircon	0,1	0,1	-	-	-	-	-	-
Epidote	0,1	0,2	-	-	-	-	-	-

S* - Standard deviation

A - Waterval granophyre (average of 10 modal analyses)

B - Aplitic facies of Nebo Granite (average of 10 modal analyses)

C - Contact facies of Makhutso Granite (average of 6 modal analyses)

D - Koornkopje granite (average of 11 modal analyses)

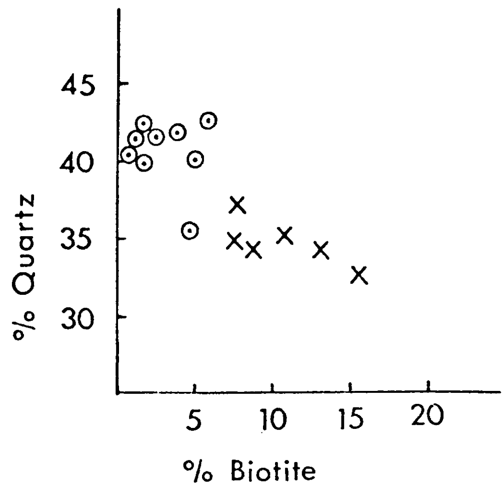


Fig. 22 - Plot of modal quartz against modal biotite for contact facies of Makhutso Granite (x) and aplitic facies of Nebo Granite (⊙)

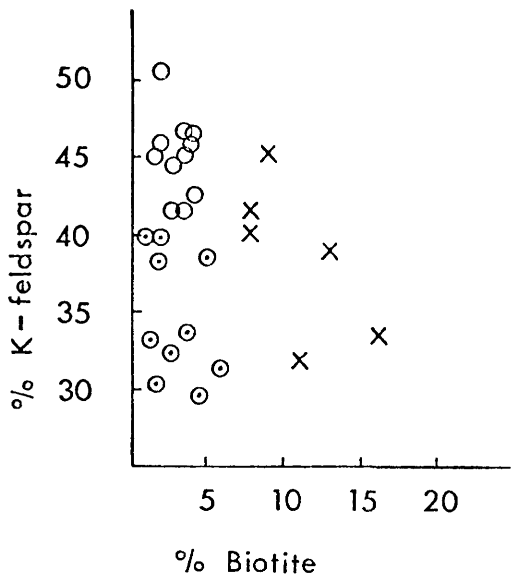


Fig. 23 - Plot of modal biotite against modal potassium feldspar for contact facies of Makhutso Granite (x), aplitic facies of Nebo Granite (⊙) and Koornkopje granite (O)

(d) Koornkopje granite

The Koornkopje granite is present as two sill-like bodies in the Nebo Granite, and outcrops along a north-westerly directed line from Koornkopje 801 KS through Hopefield 800 KS to Derdemaal 797 KS (IID2). The larger body, approximately 1,8 km in length, bifurcates at its north-western end, the two extentions being separated by Nebo Granite. The smaller body measures approximately 0,4 km in length.

Like the Makhutso Granite it is more resistant to weathering than the Nebo Granite and forms more pronounced topographic features. It is a fine-grained, fresh, grey, porphyritic granite and is lighter in colour than the Nebo Granite. However, it is not as fresh or as porphy= ritic as the other facies of the Makhutso Granite. Its fine-grained nature distinguishes it from the Makhutso Granite, which always becomes coarse-grained away from its margins. The contact between the Koornkopje granite and the Nebo Granite is sharp (Fig. 25). Flow banding which is not as well-developed as that in the aplitic facies of the Makhutso Granite, parallels the contact with the Nebo Granite on Koornkopje 801 KS (Fig. 25) and Hopefield 800 KS, but becomes randomly directed on Derdemaal 797 KS.

At the south-western side of the main body on Koorn= kopje 801 KS, a number of sills and dykes can be traced away from the main body for up to 50 m. These bodies, which are usually less than one metre in thickness, are non-porphyritic and finer-grained than the main body and may display well-developed joint sets. The sills and dykes which usually show chilled margins against the Nebo Granite do not follow a preferred direction within the Nebo Granite.

Fig. 24 - Concentration of mafic minerals in Makhutso Granite at its contact with Nebo Granite, on Vlakplaats 802 KS (IIE4). (Hammer against Nebo Granite)

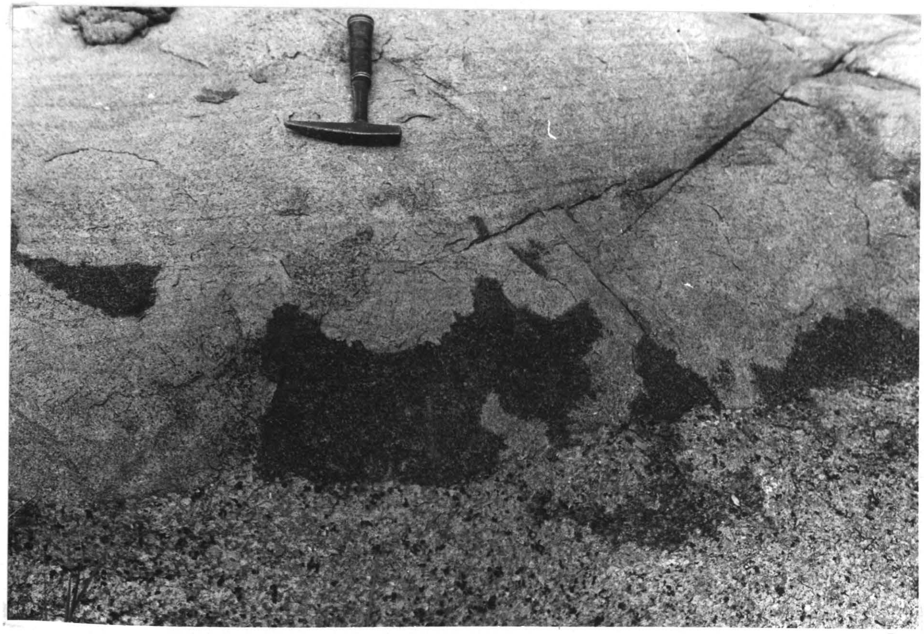


Fig. 25 - Sharp contact between Koornkopje granite and Nebo Granite on Koornkopje 801 KS (IID2). The flow banding in the Koornkopje granite parallels the contact. (Hammer against Koornkopje granite)

Mineralogically the granite consists of perthite, quartz, plagioclase (An_{11}), biotite, hornblende, zircon, fluorite and opaque minerals. Micrographic intergrowths between quartz and feldspar as well as myrmekite are common. Zoning which is to be found in the plagioclase is normal and as in the case of the other facies of the Makhutso Granite the myrmekite is more abundant in the zoned feldspars. Biotite which is always predominant over hornblende occurs as a primary mineral and a secondary mineral after hornblende. The opaque minerals are rare and usually associated with the biotite.

The modal composition of 11 samples of Koornkopje granite are given in Table X, whilst the average modal composition is given in Table IX (column D). The modal biotite has been plotted graphically against the modal potassium feldspar for the Koornkopje granite, the con= tact facies of the Makhutso Granite and the aplitic facies of the Nebo Granite (Fig. 23). The three separate fields on the graph indicates that the Koornkopje granite has a lower biotite content than the contact facies of the Makhutso Granite, and a higher potassium feldspar content than the Nebo Granite aplite. The anorthite content of the plagioclase is also lower in the Koornkopje granite than in the main facies of the Makhutso Granite.

TABLE X

MODAL COMPOSITION OF ELEVEN SAMPLES OF THE KOORNKOPJE GRANITE

SAMPLE NO.	AM 75/27	AM 75/22	AM 75/23	AM 75/20	AM 75/21	AM 75/30	AM 75/31	AM 75/28	AM 75/29	AM 75/24	AM 75/33
K-feldspar	41,5	46,4	44,7	41,6	42,5	50,6	45,1	46,2	45,8	46,5	45,3
Quartz	35,1	30,4	36,6	42,7	38,3	32,6	35,6	33,6	34,9	39,3	34,7
Plagioclase	19,4	16,8	15,4	12,1	14,5	14,9	17,6	15,9	16,9	10,4	16,3
Biotite	3,4	3,9	2,8	2,9	4,1	1,9	1,6	3,8	2,0	3,7	3,6
Hornblende	0,6	2,5	0,5	0,7	0,6	-	0,1	0,5	0,4	0,1	0,1
I.C. No.	78	61	60	67	73	63	74	69	69	68	68

SAMPLE NO.	FARM	LONGITUDE	LATITUDE
AM 75/27	Derdemaal 797 KS	29°34,4'E	24°40,4'S
AM 75/22	Koornkopje 801 KS	29°35,0'E	24°40,8'S
AM 75/23	Koornkopje 801 KS	29°34,7'E	24°40,6'S
AM 75/20	Koornkopje 801 KS	29°35,0'E	24°40,9'S
AM 75/21	Koornkopje 801 KS	29°35,0'E	24°40,8'S
AM 75/30	Derdemaal 797 KS	29°34,6'E	24°40,1'S
AM 75/31	Derdemaal 797 KS	29°34,5'E	24°40,0'S
AM 75/28	Derdemaal 797 KS	29°34,5'E	24°40,4'S
AM 75/29	Derdemaal 797 KS	29°34,6'E	24°40,3'S
AM 75/24	Derdemaal 797 KS	29°34,6'E	24°40,2'S
AM 75/33	Derdemaal 797 KS	29°34,5'E	24°40,2'S

6.4.3 The Petrochemistry of the granites of the Lebowa Granite Suite

Twenty new analyses and thirty-two published analyses of granites from the Lebowa Granite Suite are given in Appendixes II and III. Of the new analyses, five are of the main facies of the Nebo Granite, four of the aplitic facies of the Nebo Granite, six of the Makhutso granite and five of the Koornkopje granite. The published analyses include eleven Nebo Granites selected from various works, one Nebo Granite aplite and twenty Makhutso Granites (Appen= dix IIand III).

A comparison is made between the four types of granite analysed, viz. Nebo Granite, aplitic facies of the Nebo Granite, Makhutso Granite and Koornkopje granite, and the means and standard deviations of the major elements of each group have been calculated (Table XI). One of the analyses of the Makhutso Granite (AM 75/43) has not been included in this comparison, because of its abnormally high SiO_2-content. The sample is a Makhutso Granite aplite, which may have been contaminated by the assimilation of quartzite during its injection.

The major element chemistry of the Makhutso Granite does not appear to differ from that of the Nebo Granite. The SiO_2, Al_2O_3 and MgO content of the two types of granite have been plotted on a triangular variation diagram (Fig. 26). Although there does appear to be a tendency for Makhutso Granite to plot in the direction of the alumina apex it is not possible to distinguish two separate fields. De Bruiyn and Rhodes (1975, p. 90) state that the average composition of the Makhutso Granite in the Dennilton area is very similar to the mean composition of the Nebo Granite.

A students t-test has been applied to the granites in an attempt to determine whether statistically significant differences exist between the major elements of the four types of granite. The degrees of freedom used in the t-test is the total number of analyses in the two groups concerned, minus two (Miller and Kahn, 1967, p. 101). At the 99,5 per cent significance level it was found that none of the four groups differed from one another in any of the oxides. How= ever, at the 99,0 per cent significance level, the Nebo Granite aplite differs from the Nebo Granite in its amount of TiO_2 and CaO. It also differs from the Koornkopje granite in its amount of Al_2O_3.

TABLE XI

MEANS AND STANDARD DEVIATIONS OF THE MAJOR ELEMENTS IN THE NEBO GRANITE, NEBO GRANITE APLITE, MAKHUTSO GRANITE AND KOORNKOPJE GRANITE

	A		B		C		D	
	Mean	S	Mean	S	Mean	S	Mean	S*
SiO_2	74,75	1,89	75,93	0,52	74,15	1,75	75,24	0,87
TiO_2	0,24	0,09	0,10	0,02	0,20	0,07	0,07	0,02
Al_2O_3	11,74	0,93	11,93	0,09	13,15	0,56	12,52	0,40
Fe_2O_3	1,01	0,40	0,80	0,11	0,62	0,19	0,56	0,22
FeO	2,11	0,78	1,19	0,21	1,25	0,76	0,92	0,09
MnO	0,03	0,02	0,03	0,01	0,03	0,01	0,02	0,00
MgO	0,19	0,15	0,05	0,02	0,34	0,33	0,04	0,01
CaO	1,11	0,32	0,59	0,11	0,92	0,40	0,67	0,10
Na_2O	3,23	0,33	3,39	0,13	3,38	0,36	3,30	0,08
K_2O	4,77	0,53	5,08	0,26	4,91	0,51	5,28	0,54
P_2O_5	0,43	0,29	0,60	0,12	0,53	0,21	0,81	0,14

S* - Standard deviation

A - Nebo Granite (average of 16 analyses Appendix II)

B - Nebo Granite aplite (average of 5 analyses Appendix II)

C - Makhutso Granite (average of 25 analyses Appendix III)

D - Koornkopje granite (average of 5 new analyses Appendix III)

The trace element chemistry of the Makhutso Granite does however differ from that of the Nebo Granite. Graphs depicting the trace element composition of the two granites have been constructed.

Sr has been plotted against Rb, Zr, Zn and Ba (Fig. 27, Fig. 28, Fig. 29 and Fig. 30 respectively). Twenty-six analyses of the Makhutso Granite have been plotted as against ninety-seven of the Nebo Granite (9 new analyses and 88 published analyses (Lenthall, 1972)). In each of these graphs two separate fields are present, one being occupied by the Makhutso Granite and the other by the Nebo Granite. Very little overlap exists between the two fields.

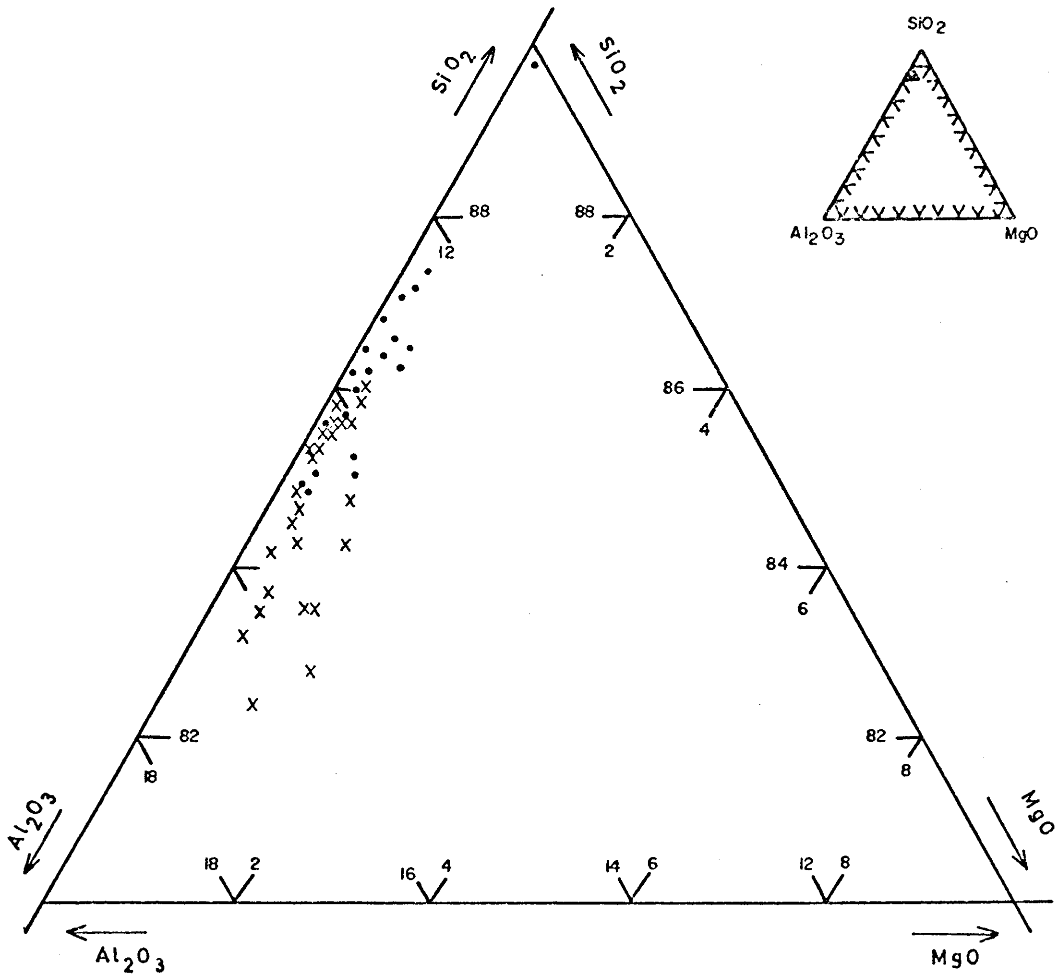


Fig. 26 - Plot of Makhutso Granite (x) and Nebo Granite (•) on a portion of the triangular variation diagram SiO_2 - Al_2O_3 - MgO

De Bruiyn and Rhodes (1975, p. 93) have applied the t-test to the Nebo and Makhutso Granites in an attempt to determine whether statistically significant differences exist in their trace element content. They found that at a 99,5 per cent significance level the Nebo Granite differed from the Makhutso Granite in its amount of Sr, Rb, Zr, Zn and Ba.

As mentioned previously the trace element composition of the Nebo Granite appears to differ from that of the Nebo Granite aplite in its higher Ba/Rb ratio. The means and standard deviations of some trace elements have been calculated for these two granites (Table XII). It seems that Ba is the only trace element investi= gated which appears to show a significant difference between the two granites. The Nebo Granite may contain more Zn than the aplite, but more analyses of the latter are required before this can be sub= stantiated.

TABLE XII

MEANS AND STANDARD DEVIATIONS OF SOME TRACE ELEMENTS IN THE NEBO GRANITE AND NEBO GRANITE APLITE

	A		B	
	Mean	Standard Deviation	Mean	Standard Deviation
Ba	1200	411	121	46
Rb	216	42	305	69
Sr	45	26	17	6
Zr	429	68	327	35
Zn	87	33	46	3

A - Nebo Granite (average of 5 new analyses (Appendix II) and 88 published analyses (Lenthall, 1972))

B Nebo Granite aplite Ba, Rb, and Sr (average of 4 new analyses and one published analyses (Appendix II)) Zr and Zn (average of 4 new analyses (Appendix II))

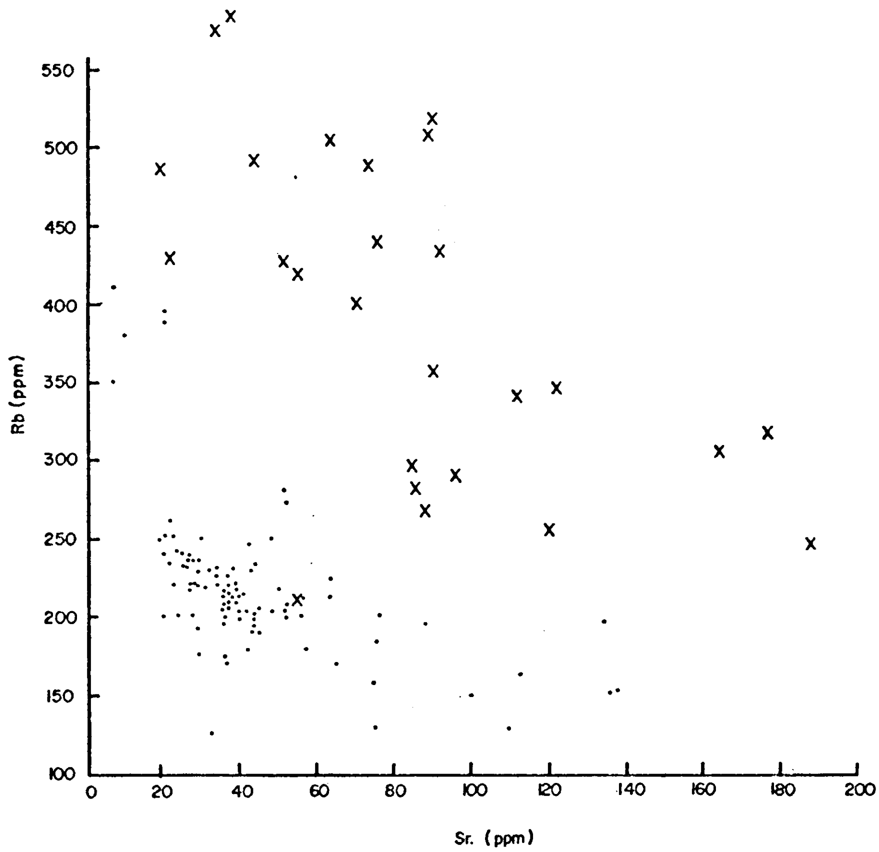


Fig. 27 - Graph of strontium versus rubidium for Makhutso Granite (x) and Nebo Granite (•)

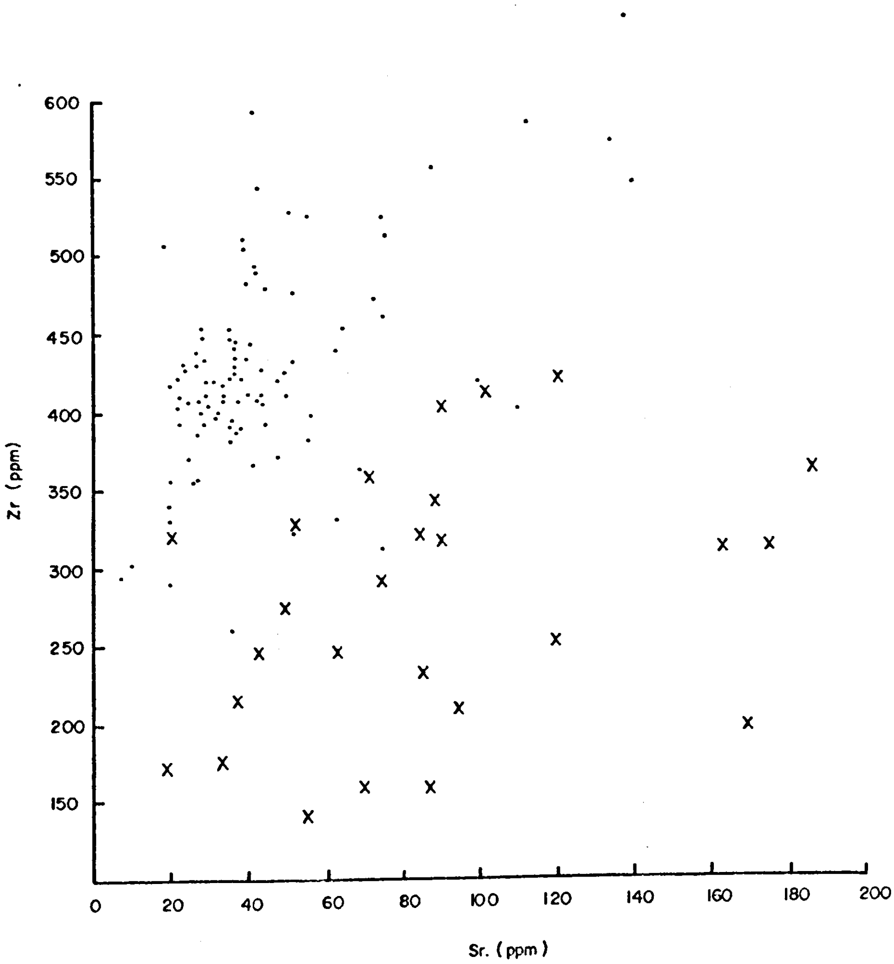


Fig. 28 - Graph of strontium versus zirconium for Makhutso Granite (x) and Nebo Granite (•)

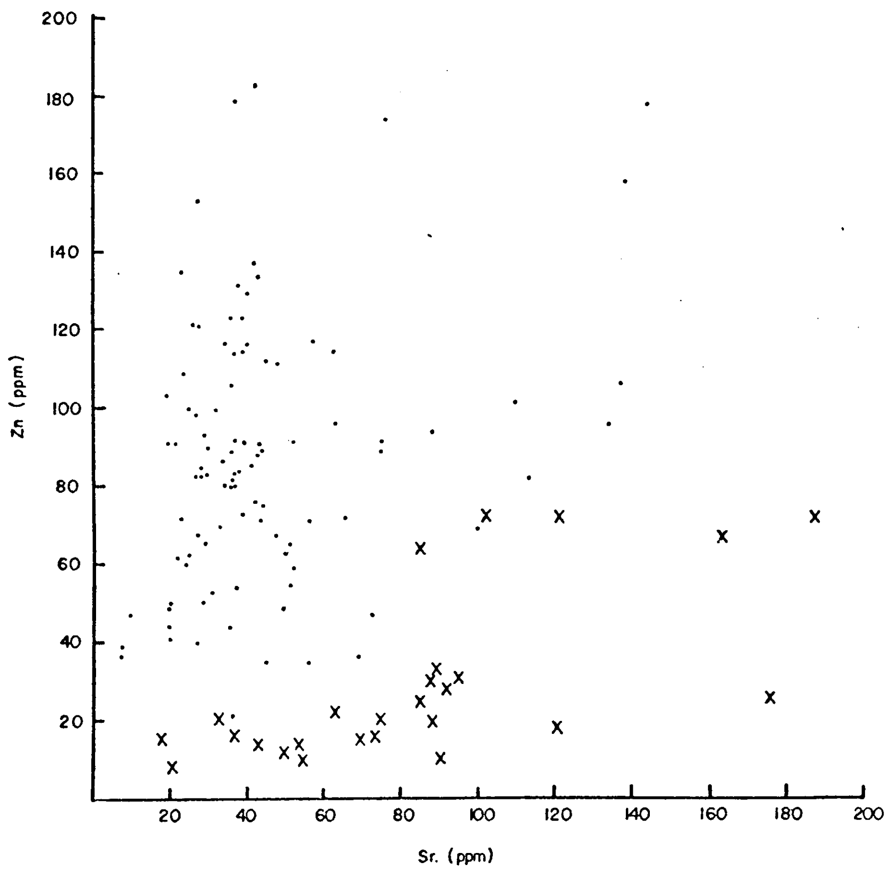


Fig. 29 - Graph of strontium versus zinc for Makhutso Granite (x) and Nebo Granite (•)

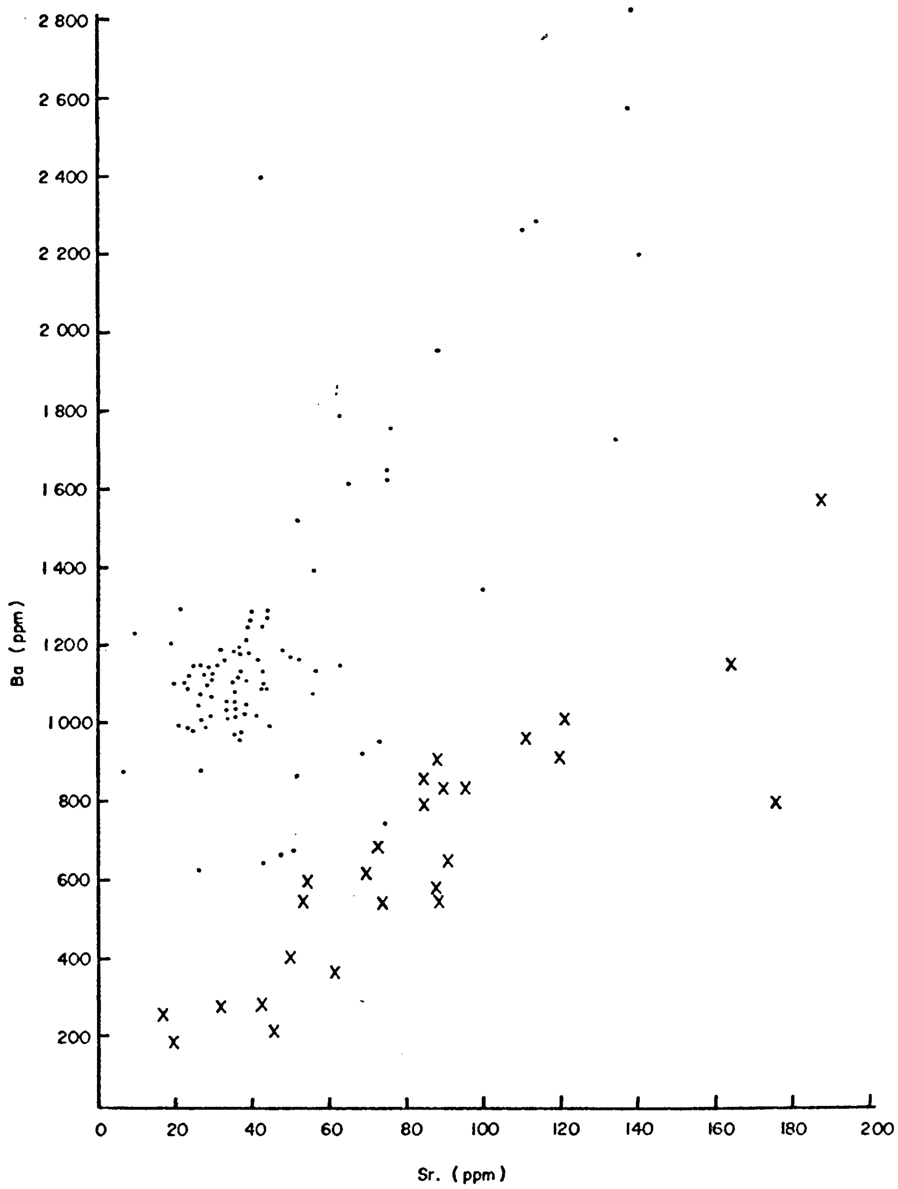


Fig. 30 - Graph of strontium versus barium for Makhutso Granite (x) and Nebo Granite (•)

A comparison has been made between the normative composition of the Nebo and Makhutso Granites. The normative composition of the twenty new and thirty-two published analyses are given in Appendix II and Appendix III, whilst the average normative composition of the four types of granite analysed are given in Table XIII. The Makhutso Granite can be distinguished from the Nebo Granite by the presence of normative corundum and the absence of normative diopside.

TABLE XIII

AVERAGE CIPW NORMS FOR NEBO GRANITE, NEBO GRANITE APLITE, MAKHUTSO GRANITE AND KOORNKOPJE GRANITE

	A		B		C		D	
	Mean	S	Mean	S	Mean	S	Mean	S*
Q	34,25	4,59	34,75	1,07	32,67	2,04	33,91	3,02
c	-	-	-	-	0,73	0,59	0,23	0,18
or	28,26	3,14	30,16	1,78	29,02	2,75	31,19	3,19
ab	27,26	2,71	29,19	0,67	28,59	3,06	27,90	0,66
an	3,42	1,58	2,35	0,53	4,2	1,94	3,13	0,57
di	1,46	1,24	0,33	0,15	-	-	0,02	0,05
hy	2,45	1,43	1,00	0,31	2,34	2,09	1,22	0,29
mt	1,34	0,59	1,23	0,26	0,88	0,26	0,81	0,43
ilm	0,43	0,17	0,18	0,03	0,37	0,15	0,14	0,04
hap	0,08	0,17	0,03	0,01	0,10	0,06	0,05	0,04

S* - Standard deviation

A - Nebo Granite (average of 5 new analyses and 11 published analyses)

B - Nebo Granite aplite (average of 4 new analyses and one published analysis)

C - Makhutso Granite (average of 5 new analyses and 20 published analyses)

D - Koornkopje granite (average of 5 new analyses)

The presence of normative corundum in the Makhutso Granite reflects the high modal biotite content, a mineral not provided for in the calculated C.I.P.W. norm.

6.5 AGE DETERMINATIONS OF THE BUSHVELD ROCKS

A number of age determinations have been made recently on the rocks of the Bushveld Complex. The uranium-lead method was used for the dating of the acid rocks, whilst the potassium-argon method was used for the dating of a ferrogabbro from the Rustenburg Layered Suite. The acid rocks were dated by Dr. A.J. Burger at the National Physical Research Laboratory (NPRL) of the Council for Scientific and Industrial Research, whilst the dating of the ferrogabbro was carried out by F.M. Consultants of Herts, England (Coertze et al., in preparation).

Age determinations were made on seven samples from the area investigated. These included two of the Nebo Granite, two of the Nebo Granite aplite, two of the Makhutso Granite and one of the Makhutso Granite aplite. A sample of the Koornkopje granite was submitted for age dating, but no zircons could be found.

Fairly reliable ages have now been assigned to the following suites of the Bushveld Complex (Coertze et al., in preparation):

Lebowa Granite Suite	(Makhutso Granite	1570 ± 30 m.y.
	(Nebo Granite	1920 ± 40 m.y.
Rashoop Granophyre Suite		2048 ± 40 m.y.
Rustenburg Layered Suite - Upper Zone		2096 ± 12 m.y.

The age of the Nebo Granite aplite is problematical. Some samples of the aplite from the Sekhukhune Plateau which have been submitted for age dating indicate that the rock is younger than the Makhutso Granite, although the high uranium concentration in the zircons casts doubt on the validity of the determined age. Further work is at present being carried out on the age of the aplite by the N.P.R.L.

7. POST BUSHVELD INTRUSIONS

The post-Bushveld intrusions include the Spitskop Alkaline Complex and is associated satellite bodies, and the intrusions of dolerite.

7.1 ALKALINE INTRUSIONS

The Spitskop Alkaline Complex is situated west of the Sekhu=khune Escarpment on Spitskop 874 KS, Eenzaam 875 KS and Rietfontein 876 KS (IJ6) and the alkaline rocks of the complex are intrusive into the Bushveld granophyre and the Nebo Granite. The complex was mapped in detail by Strauss and Truter (1950, Plate XXIII) on a scale of 1:25 000.

A number of small satellite bodies, which occur in the form of vents, sills and dykes surround the complex. Molyneux (1970a, p. 28) mentions the presence of two circular vents and numerous sills, south and east of the complex, respectively. Dykes were found on Spitskop 874 KS (IJ7), Eenzaam 875 KS (IJ8), Uitvlugt 887 KS (IJ8) Rietfontein 876 KS (IJ6), Leeuwkraal 877 KS (IH7) and Goedgedacht 878 KS (IH8).

7.2 BASIC INTRUSIONS

Dolerite intrusions are present throughout the area in the form of dykes and sills. Mineralogically the dolerite consists of plagioclase, clinopyroxene, orthopyroxene, opaque minerals, biotite, hornblende, quartz and an interstitial intergrowth of quartz and potassium feldspar. Zoning which is well-developed in the ortho=pyroxene is also present in both plagioclase and clinopyroxene.

7.2.1 Sills

The largest of the sills is located in the Mogaleslokasie area, covering an area of at least 120 square km. It has the shape of a folded wedge, the northern segment of the wedge dipping to the west, and the southern segment to the north-west. The synclinal fold axis plunges to the west-north-west at about one degree.

Structural contours of the upper and lower surfaces of the sill indicate that each surface probably contains minor anomalies, and that the two surfaces are not likely to be conformable (Folder IV). The isopachs which have been drawn for 0, 30, 60 and 90 m indicate that the sill probably thins from 90 m in the extreme east to nothing on Nooitverwacht 791 KS (IIB3). They also reveal a rapid reduction in sill thickness at Magate on Vooruitzicht 787 K (IIC4) and to a lesser extent on Rustplaats 788 KS (IID4).

The dolerite sheet exposed on Gaataan 796 KS (IIC1) very probably represents a thin westerly extension of the outcropping rim of the large sill. It is unlikely however, that the dolerite sheets exposed on Badfontein 531 KS and Bijldrift 170 KS (IIA1) belong to the same sill.

The largest of the sills in the Nebo area is exposed on and around Groblersvrede 844 KS (IF8) and is probably 90 to 120 m in thickness at its greatest. The sill exposed on Roodepoort 880 KS is a few tens of metres thick along its eastern edge, and displays columnar jointing. Another two sills which are situated at a similar level at the top of the Sekhukhune Escarpment are exposed on Twee= fontein 848 KS (IG9). Molyneux (1970a, p. 27) considers these sills to be probable remnants of an originally continuous sheet.

The outcrops of dolerite exposed at Mamoropye and Tlame on Masleroems Oude Stad 840 KS are all thin, flat-lying sheets. Although a chilled margin is usually present within the dolerite, the grain size inside the sheets varies very little.

Just south of Jane Furse Hospital on Vergelegen 819 KS vertical to steeply dipping veins of epidote traverse the dolerite between 3 and 5 m from its contact with the Nebo Granite. The veins which reach a maximum thickness of 4 cm also contain minor quanti= ties of plagioclase. Composite veins containing an outer wall of epidote and a younger, inner zone of plagioclase are also present.

Epidote veining is also present in the large sill at Magate on Vooruitzicht 787 KS (IIC4) and the dolerite in immediate contact with the veins has been epidotized. In the Ngwaritsi River on Nooitgedacht 789 KS a narrow quartz vein which cuts the dolerite sill carries very minor amounts of galena and pyrite.

Xenoliths in the dolerite are rare, and when present are usually small in dimension. A xenolith of the granophyric facies of the Nebo Granite is located in the large sill on Vooruitzicht 787 KS (IIB4), about 20 m from the top of the sill. It measures only 15 cm at its maximum thickness, but extends for a few metres in width.

Although the age of the dolerite sills is unknown, Strauss (1954, p. 59) considers similar basic intrusions in the granite at Zaaiplaats possibly to be of post-Waterberg age.

7.2.2 Dykes

Dolerite dykes are present throughout the area, and vary in thickness from a few centimetres as in the Ngwaritsi River on Twee= fontein 848 KS (IH8), up to 32 m as at Marwapaka on Drakenstein 784 KS (IIC5).

Jointing in the dykes is a common feature and is usually normal or sub-normal to the walls of the dyke. Mineralization is restric= ted to the presence of minor quantities of pyrite in the dyke south-east of Marwapaka on Drakenstein 784 KS.

7.2.3 Quartz veins

Quartz veins of uncertain age are abundant within the granite in the Motseleope River on Weltevreden 799 KS (IIE1), but only reach one metre in width and a few metres in length. On the adjacent farm Koppiealleen 828 KS a quartz vein a few tens of metres in length contains minor amounts of specular haematite. The veins have an approximate northerly direction which provides evidence to suggest a southerly continuation of the Wonderkop fault.

8. STRUCTURE

8.1 THE MALOPE AREA

In the Malope and Segwahleng areas the floor of the Bushveld Complex which consists of quartzite and hornfels, has seemingly been brought to the surface by anticlinal folding (Folder V). Rocks typical of the Critical Zone of the layered sequence overlie the floor, and in places tongues of basic rocks are seen to penetrate the quartzite. In the eastern part of the area between Malope and Segwahleng rocks typical of the Upper Zone seem to lie transgres= sively over the rocks of the Critical Zone. Although exposures are poor it would seem as though the Nebo Granite east of Malope and north-east of Segwahleng has transgressed all of the layered sequence in this area, to be in direct contact with the quartzite. Trans= gressive relationships between rocks of the layered sequence have been described by Coertze (1970, p. 11) in the western Bushveld, but the relationships described above seem to be different.

The field relationships indicate that although the folding which resulted in the formation of an antiform over Malope may have started well before the intrusion of the layered sequence, it probably continued until after the intrusion of the Nebo Granite. Folding within rocks of the Bushveld Complex has previously been described by Walraven (1974, p. 323) in the area north of Rustenburg and Brits. He considers that tectonism began as early as the start of the intrusion of the layered sequence and continued until after the emplacement of the acid suite.

Hunter (1975, p. 15) considers that features within the Transvaal Basin such as the Crocodile River and Moos River domes reflect the conditions of compressional deformation during the subsidence of the Transvaal sedimentary basin. He is of the opinion that deformation in the area of the domes continued during crystal= lization of the basic magma with the result that conditions for the development of the delicate layering, typical of the gently dipping portions of the Complex, did not pertain, and as an example refers to the absence of layers such as the Merensky Reef in the area south-east of the Dennilton Dome. The absence of the Main Zone and parts of the Upper Zone in the Malope area may also be ascribed to a similar mechanism.

The aeromagnetic map of the Malope area (Aeromagnetic map of the Nylstroom area, 2429DA, 1974) was studied in an attempt to determine how strongly the Upper Zone of the layered sequence is developed in this vicinity. The Upper Zone east of the Sekhukhune Escarpment is typified by an area of relatively high average magnetic intensity, with a fairly dense concentration of magnetic anomalies, whilst the acid suite west of the escarpment, and the basic rocks in the Malope area show a lower average magnetic intensity, with a lack of magnetic anomalies. This suggests the Upper Zone in the immediate vicinity of Malope is of no great thickness.

The discovery of rocks belonging to the Critical Zone of the Bushveld Complex in the Malope area could have far-reaching economic implications in that:

(i) the Bushveld granite seemingly transgresses the rocks of the layered sequence in this area with the result that the lower zones can directly underlie the granite, and

(ii) economically important layers such as the Merensky Reef and the UG2 Chromitite Layer may, if developed here, underlie the Nebo Granite at very shallow depths in the surrounding areas.

8.2 FOLDING

The presence of synclinal folding within the large dolerite sill in the Mogaleslokasie area is not consistent with the inter= pretation of a dome structure over Malope. However, the dolerite body is probably of post-Waterberg age, and may have been intruded in the form of a shallow lopolith. If the dolerite sill was intruded as a flat sheet, then the warping which resulted in its shallow synclinal structure is probably unrelated to the folding which is postulated to have caused the antiform over Malope.

On Drakenstein 784 KS (IIB5) a dolerite dyke exhibits well-developed jointing as a result of an obliquely directed stress relative to the wall of the dyke. The strain in the dyke has been taken up by monoclinal folding on one wall, and minor dislocations, which parallel the jointing on the other. If the shallow synclinal structure of the dolerite sheet in the Mogaleslokasie area is the result of warping, then the inducing stress is probably of the same age as that which caused the observed deformation in the dolerite dyke.

The quartzites on and around Boschpoort 843 KS (IG8) have been folded, and the dip and strike of the bedding planes were measured throughout the area. The poles to the bedding planes were plotted on a Wulff stereographic net and contoured (Fig. 31). Although most of the poles fall on southerly dipping fold limbs the stereogram does indicate a gentle to open type of folding, with an easterly directed fold axis.

8.3 FAULTING

The quartzites on Boschpoort 843 KS have been faulted in the region south and east of Mma-Mosehlanyane (IG8). A major west-south-westerly directed normal fault has downthrown the rocks to the north by 60 to 100 m (Folder III, Section GH). At the eastern end of this fault are three minor north-easterly directed faults, which probably resulted in consequence to the stress occurring after the major faulting.

On Vergenoegd 792 KS (IIC2) the north-north-westerly directed dyke of Makhutso Granite appears to be offset by three north-easterly trending dextral faults.

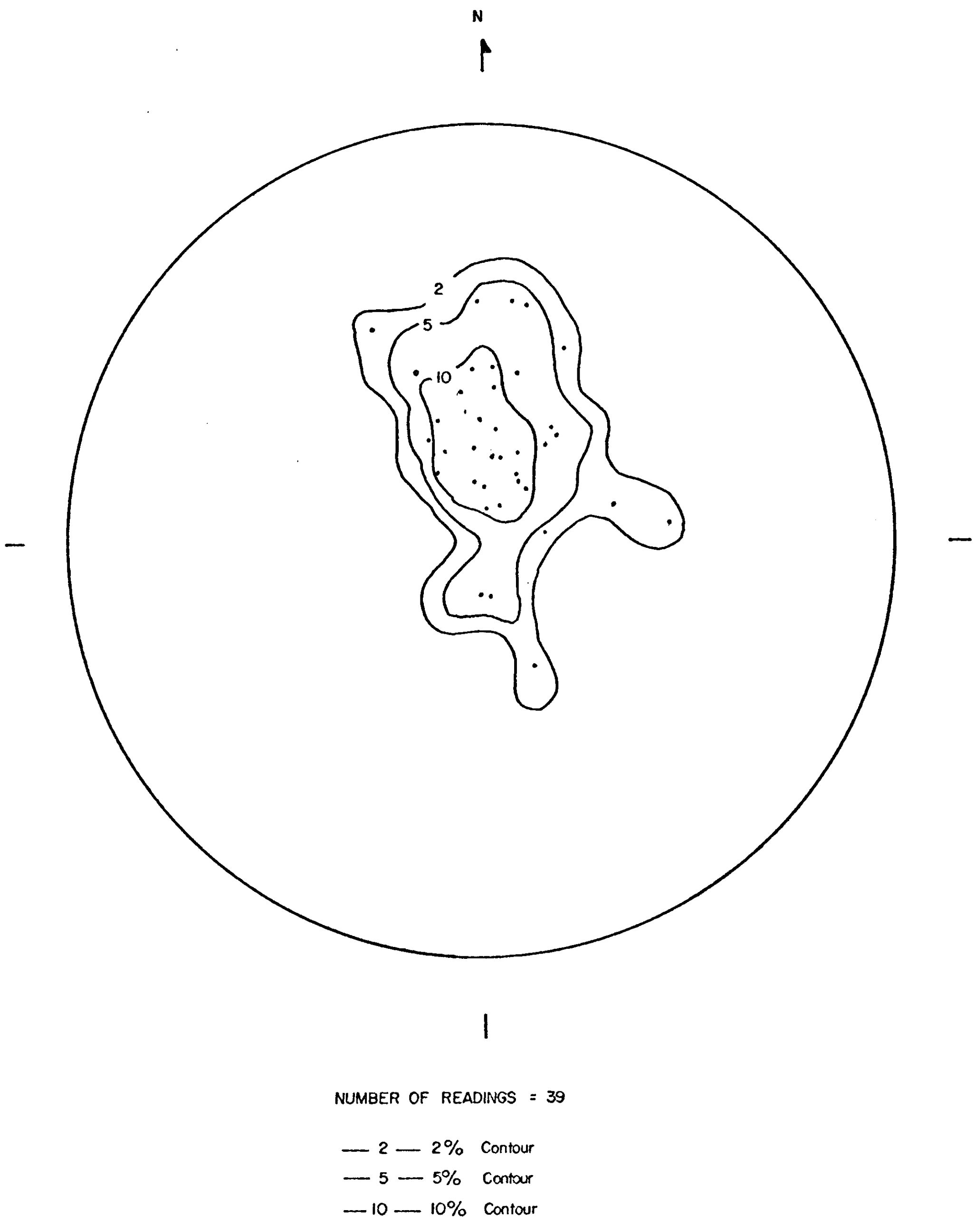


Fig. 31 - Stereogram (Wulff net) of poles of the bedding planes of the folded quartzite on and around Boschpoort 843 KS.

8.4 JOINTING

Strike measurements of the longitudinal and cross joints in the Nebo Granite were measured and plotted on rose diagrams. Three diagrams were drawn, one for the joints in the Mogaleslokasie area, one for those in the Nebo area and a composite diagram for those in both areas (Fig. 32A, C and B respectively). The conclusions derived from the interpretation of the diagrams are summarized below:

(i) The joint system in the Nebo Granite consists of two major sets, one with direction 010°-039° and the other with direction 280°-299°.

(ii) The north-north-easterly directed set is situated between 010°-029° in the Nebo area, whereas in the Mogaleslo= kasie area it is situated between 020°-039°.

(iii) The west-north-west set is the dominant one of the two in the Nebo area whereas in the Mogaleslokasie area it is the north-north-east set.

Strike measurements of the dolerite dykes were also taken and plotted on rose diagrams. Two diagrams were drawn, one for the dykes in the Mogaleslokasie area and one for those in the Nebo area (Fig. 32E and D respectively). The dykes in the first area follow a major direction between 280° and 299°, whilst those in the second follow a major direction between 020° and 049°. Molyneux (1970a, p. 27) recorded a dominant north-north-easterly trend for the dolerite dykes in the basic rocks of Sekhukhuneland. The dykes in each area parallel one of the major joint sets in the Nebo Granite.

Strike measurements of the joints in the dolerite sills were also plotted on a rose diagram (Fig. 32F). The diagram reveals a major joint set with direction 280°-299° and two minor joint sets with directions 320°-329° and 000°-029°. The major joint set and the principal minor joint set in the dolerite parallel the major joint sets in the Nebo Granite.

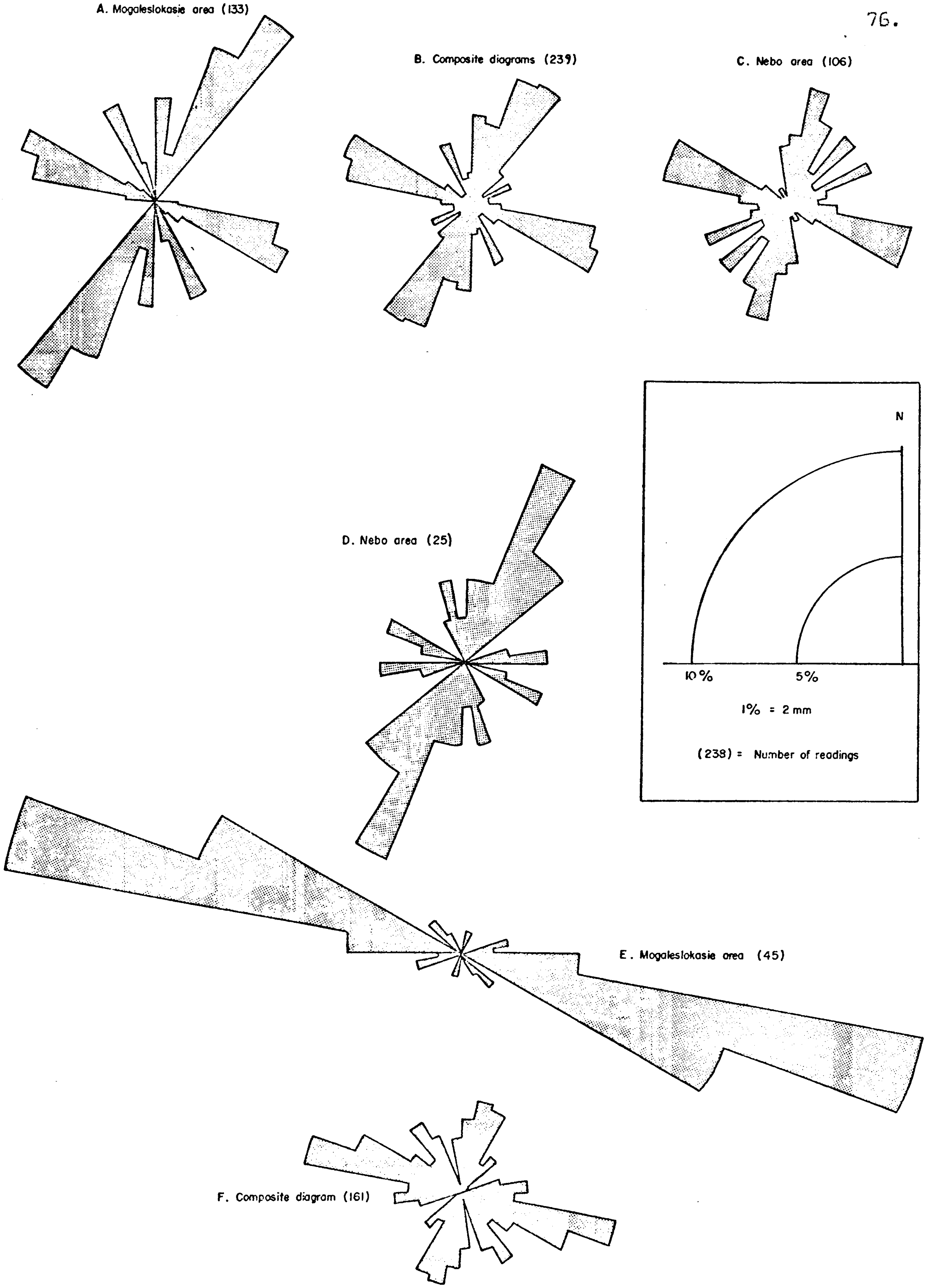


Fig. 32 - Rose diagrams of jointing in the Nebo Granite (A, B and C), strike direction of dolerite dykes (D and E) and jointing in the dolerite sills (F)

9. GEOPHYSICAL OBSERVATIONS

9.1 AEROMAGNETICS

The aeromagnetics of the Mogaleslokasie area (Aeromagnetic map of the Nylstroom area 2429 DA, 1974) have been studied in con= junction with the geological map (Folder II) in an attempt to derive further conclusions concerning the structure of the large dolerite sill in that area. Several important magnetic anomalies are situated over the outcrop of the dolerite sill, and agree well with the mapped contact between the sill and the granite. These anomalies may be caused by one or more of the following possibili= ties:

(i) A non-uniform thickness for the sill. This supports the conclusion made from structural contours of the sill (Folder IV), that the upper and lower surfaces of the sill are not conformable.

(ii) The sill contains areas of differing magnetisation and this could be a reflection of a non-uniform distribu= tion of magnetic minerals.

(iii) The removal by erosion of the upper parts of the out= cropping sill, such as in the deeper valleys.

The area of Nebo Granite which is underlain by the dolerite sill in the vicinity of Nooitgedacht 789 KS (IIC3) is typified by an absence of clear anomalies, although it displays a more irregular magnetic pattern than the areas of Nebo Granite to the south and east of the sill. The absence of strong magnetic anomalies in the vicinity of Nooitgedacht probably indicates that the sill progres= sively reaches a greater depth towards the west. This supports the view that the sill has a shallow synclinal structure which plunges to the west-north-west.

Four total field magnetic anomaly profiles across outcrops of the dolerite sill (Fig. 33) have been constructed from the aeromag= netic map of the Nylstroom area 2429 DA (Fig. 34A, C, E and G). The magnetic strike of the anomalies, which is defined as the strike of the elongation of the anomalies is parallel to the outcrop of the sill, and the profiles have been taken across the outcrop, perpendi= cular to the magnetic strike. Both the amplitude and the form of the anomalies change along different parts of the sill, the change being attributable to the alteration of the strike and dip of the sill.

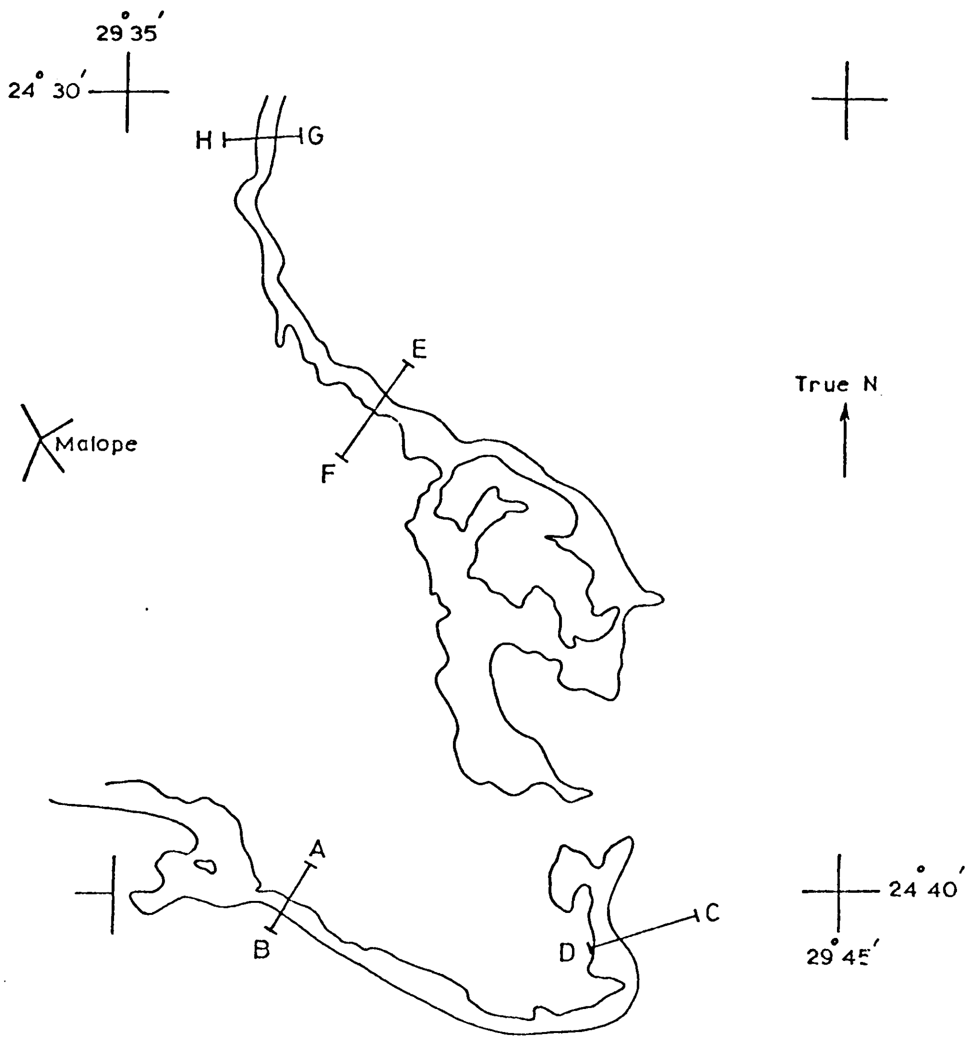


Fig. 33 - Location of the magnetic anomaly profiles (Fig. 34A, C, E and G) drawn across the dolerite sill in the Mogaleslokasie area.

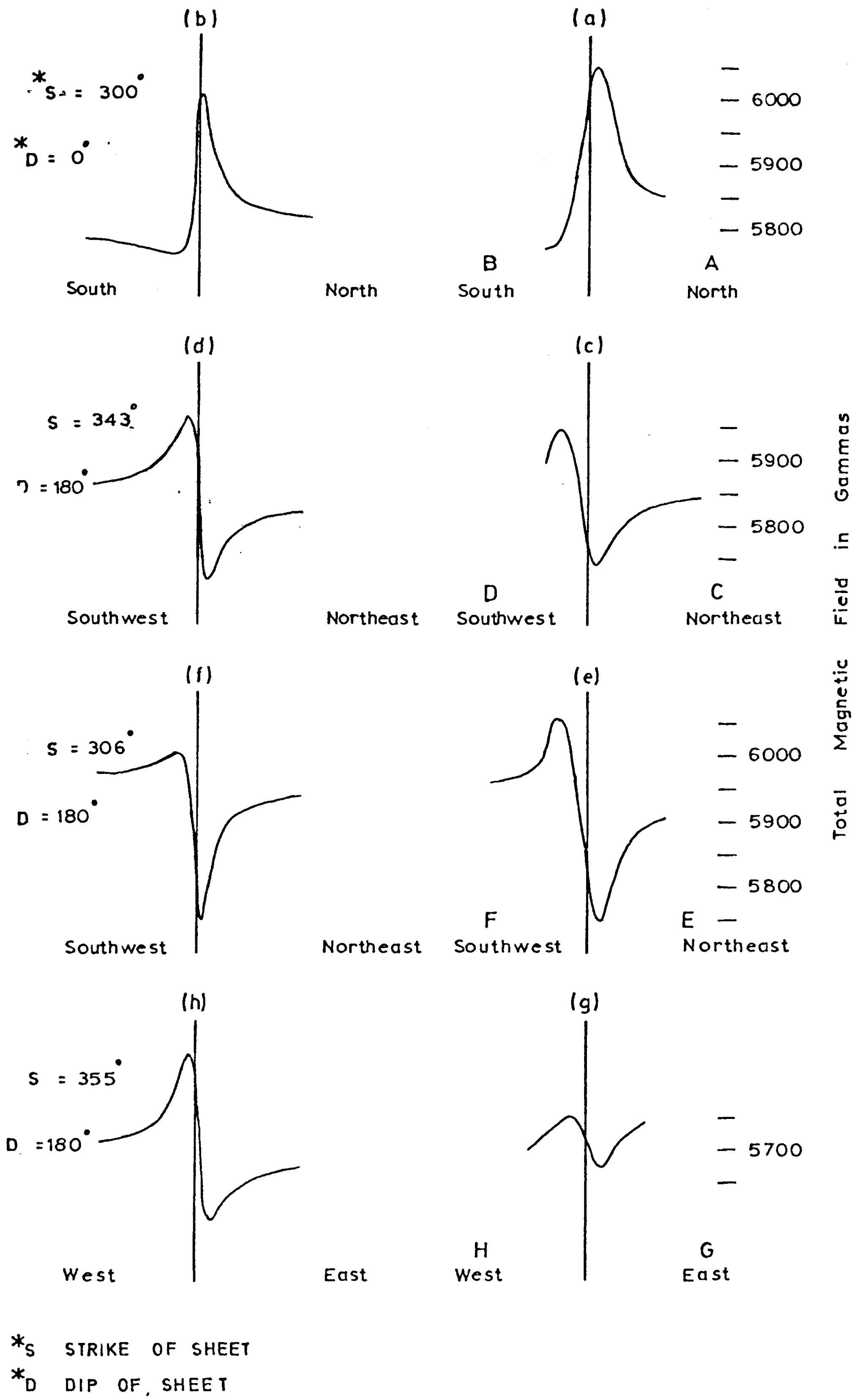


Fig. 34 - Comparison between the total field magnetic anomaly profiles across the dolerite sill in the Mogales= lokasie area (a), (c), (e) and (g); and curves constructed for a thin sheet (Richards, 1976) with similar dip and strike to the comparative profiles (b), (d), (f) and (h).

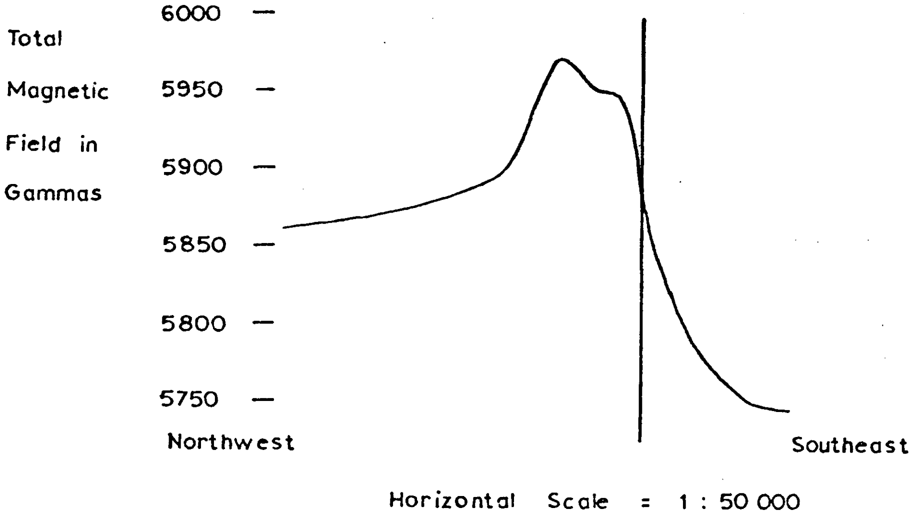
Richards (1976) has constructed curves to show the form and amplitude of magnetic anomalies caused by a thin sheet which would be expected at the various places where the profiles have been drawn (Fig. 34b, d, f and h). The magnetic anomalies have been compared with these curves in an attempt to determine whether the sill contains remanent magnetism. For the purpose of comparing the total field magnetic anomaly profiles with the constructed curves the sill can be assumed to be a flat sheet. The curves fit the observed anomalies fairly accurately, which indicates that the dolerite sill does not contain dominant remanent magnetism.

A number of north-north-east striking linear anomalies are present within the area mapped. One in the Mogáleslokasie area runs from the eastern corner of Lekkerland 767 KS, through Heerlykheid 768 KS to Gelukslokasie, and its profile has been drawn in a direc= tion perpendicular to the magnetic strike on Heerlykheid 768 KS (Fig. 35a).

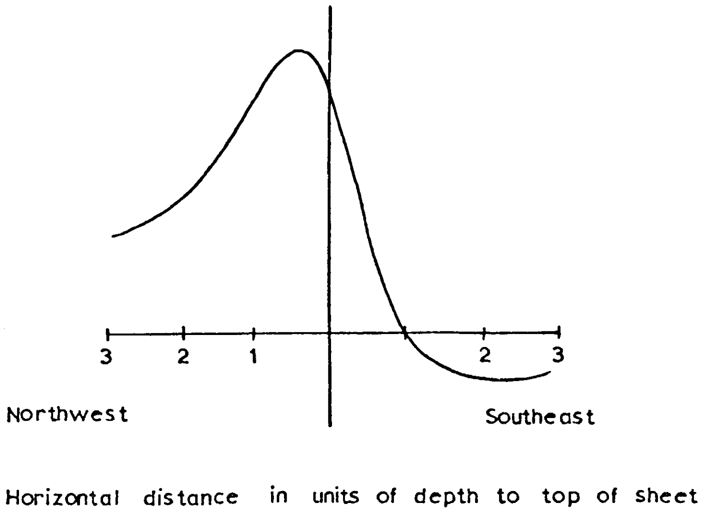
Reford (1964, p. 535) has constructed a group of curves to show the change in form and amplitude of magnetic anomalies caused by a thin sheet, with change in dip and strike at various magnetic latitudes. The anomaly on Heerlykheid 768 KS has been compared with these curves and conforms well with that drawn for a vertically dipping thin sheet with a north-easterly strike (Fig. 35b). It is probable that this anomaly and the others with the same strike are caused by vertically dipping dolerite dykes, which are not exposed at the surface. The strike of the anomalies is parallel to the major dyke direction in the Nebo area.

9.2 AIRBORNE RADIOMETRICS

The airborne radiometrics of the area investigated (Airborne Radiometric maps of the Nylstroom area 2429 DA, DB, DC and DD, 1974) indicate that the basic rocks to the east of the Sekhukhune Escarp= ment are characterized by a uniformly low radioactivity, whilst the granites to the west have a relatively high radioactivity. The high



(a) Total field magnetic anomaly profile on Heerlykheid 768 KS constructed from the Aeromagnetic map of the Nylstroom area 2429 DA



(b) Curve constructed for a vertically dipping thin sheet with north-easterly strike at inclination 60° south (after Reford 1964, p. 535)

Fig. 35 - Comparison between observed anomaly profile (a), and curve constructed for a vertically dipping thin sheet (b)

radioactivity centres correspond to the areas occupied by the aplitic facies of the Nebo Granite in the Mogaleslokasie area. Lenthall (1975, p. 2) also noticed that a slightly higher radioactivity was associated with the presence of aplite in the region west of Nebo.

The granites of the Nebo area are characterized by a fairly low radiometric intensity compared with those from other parts of the Sekhukhune Plateau. In other areas of the Bushveld Complex radio= metric highs generally correspond to the granites which are situated near the roof of the complex, and the low radiometric intensity of the granites in the Nebo area may be due to their low structural level within the acid phase of the complex.

The outcrop of the large dolerite sill in the Mogaleslokasie area coincides with a series of linear radiometric lows.

10. SUMMARY AND CONCLUSIONS

The oldest rocks in the area include hornfels and quartzite of the Pretoria Group which are present:

(i) in the form of xenoliths in the rocks of the Bushveld Complex, and

(ii) as part of the seemingly updomed floor of the Complex.

Locally a pseudogranophyre has developed by the feldspathi= zation of quartzite in contact with:

(i) basic rocks of the layered sequence, and

(ii) dolerite possibly of post-Waterberg age.

Three suites of Bushveld rocks are present within the area investigated, namely the Rustenburg Layered Suite, the Rashoop Granophyre Suite and the Lebowa Granite Suite. Rocks of the first outcrop at the base of the Sekhukhune Escarpment, as well as in the Malope area to the south-east of the Olifants River where they overlie the updomed floor of the Bushveld Complex.

Although field relations at Malope are at present not yet fully understood, the majority of the basic rocks are typical of those encountered in the upper part of the Critical Zone. A small occurrence of rocks typical of the Upper Zone which seem to transgressively overlie the rocks of the Critical Zone is also present within this area. Chemical analyses of samples from magnetitite layers at this occurrence indicate that they belong to Subzone D of the Upper Zone. The presence of the Critical Zone in this area could have far-reaching economic implications in that:

(i) the Bushveld granite transgresses the rocks of the layered sequence in this area with the result that the lower zones can directly underlie the granite, and

(ii) economically important layers such as the Merensky Reef and the UG2 Chromitite Layer may, if developed here, underlie the Nebo Granite at very shallow depths in the surrounding areas.

The Malope area should be studied by means of geophysical techniques to establish the depth of the granite in the vicinity of the basic rocks.

A thin layer of leptite which is considered to be metamorphosed Rooiberg felsite, separates the layered sequence of the Bushveld Complex below from the acid rocks above. The Rashoop Granophyre Suite which consists of granophyre and fine-grained granophyric granite, has probably originated from the crystallization of a melt which formed by the melting of this leptite, which represented the roof-rocks of the Bushveld Complex during the intrusion of the layered sequence. Indication of this melting process is seen in the numerous veins of granitic material which traverse the leptite.

In Sekhukhuneland the Lebowa Granite Suite consists of two units; the older Nebo Granite and the younger Makhutso Granite. Four facies have been recognized within the Nebo Granite, viz. main, contact, granophyric and aplitic. Numerous small sills, dykes and stock-like bodies of Makhutso Granite were emplaced along a north-westerly direction in the Mogaleslokasie area. Four facies have also been recognized within the Makhutso Granite, viz. main, contact and aplitic as well as the Koornkopje granite which is considered to be a fine-grained, porphyritic variety of the Makhutso Granite.

The Makhutso Granite can be distinguished from the main facies of the Nebo Granite by its presence of zoned plagioclase phenocrysts, by its characteristic presence of flow banding, by its higher biotite content, by the lower anorthite content of the plagioclase and also by its trace element chemistry. Apart from these, radiometric dating on several specimens of the Nebo Granite and the Makhutso Granite from this area have shown the Makhutso Granite to be con=siderably younger than the Nebo Granite.

In the Malope area the floor of the Bushveld Complex has seemingly been brought to the surface by anticlinal folding. The folding which may have started well before the intrusion of the layered sequence, probably continued until after the intrusion of the Nebo Granite. The structure provides a further example of folding during the emplacement of rocks of the Bushveld Complex.

A large dolerite sill probably of post-Waterberg age intruded the Nebo Granite in the Mogaleslokasie area, and metamorphism of the granite in contact with the sill resulted in the formation of granophyre typical of the granophyric facies of the Nebo Granite. The sill appears to have a shallow synclinal structure with a fold axis which plunges gently towards the west-north-west.

11. ACKNOWLEDGEMENTS

The author wishes to express his gratitude to the Director of the Geological Survey, Dr. J.F. Enslin, for permission to use information obtained during the coarse of mapping for the Geological Survey in this thesis. He would also like to express his sincere thanks to Dr F.J. Coertze under whose supervision the mapping was carried out, and to Dr C.P. Snyman and Professor G. Von Gruenewaldt under whose guidance this work was done.

REFERENCES

Aeromagnetic map of the Nylstroom area 2429 DA. Scale 1:50 000, 1974. Government Printer, Pretoria.

Airborne radiometric maps of the Nylstroom area 2429 DA, DB, DC and DD. Scale 1:50 000, 1974. Government Printer, Pretoria.

BOSHOFF, J.C., (1942). The Upper Zone of the Bushveld Complex at Tauteshoogte. D.Sc. dissertation (unpublished) University of Pretoria, 79 p.

BRUIYN, H. DE and RHODES, R.C., (1975). A new variety of Bushveld granite in the Dennilton area, Transvaal. Trans. Geol. Soc. S.Afr., 78, 89-95.

BURRI, C., PARKER, R.L. and WENK, E., (1967). Die optische Orientierung der Plagioklase. Birkhäuser Verlag, Basel und Stuttgart, 334 p.

CHAYES, F., (1956). Petrographic Modal Analyses. An elementary statistical appraisal. J. Wiley and Sons, Inc., New York, 113 p.

COERTZE, F.J., (1970). The geology of the western part of the Bushveld Igneous Complex. Geol. Soc. S.Afr., Spec. Publ. 1, p. 5-22

COERTZE, F.J., BURGER, A.J., WALRAVEN, F., MARLOW, A.G., and MACCASKIE, D.R., (In Preparation). Field relations and age determinations in the Bushveld Complex.

FOURIE, P.J., (1969). Die geochemie van granitiese gesteentes van die Bosveldstollingskompleks. D.Sc. Dissertation (unpublished), University of Pretoria, 290 p.

GROUT, F.F., (1935). The compositions of some African granitoid rocks. J. Geol. 43, p. 281-196

GROENEVELD, D., (1968). The Bushveld Igneous Complex in the Stoffberg area, Eastern Transvaal, with special reference to the magnetitite seams. D.Sc. Dissertation (unpublished). University of Pretoria, 172 p.

GRUENEWALD, G. VON (1966). The geology of the Bushveld Igneous Complex east of the Kruis River cobalt occurrence, north of Middelburg, Transvaal. M.Sc. Thesis (unpublished). University of Pretoria, 104 p.

GRUENEWALD, G. VON (1968). The Rooiberg Felsite north of Middelburg and its relation to the layered sequence of the Bushveld Complex. Trans. Geol. Soc. S.Afr., 71, 153-172.

GRUENEWALD, G. VON (1972). The origin of the roof-rocks of the Bushveld Complex between Tauteshoogte and Paardekop in the Eastern Transvaal. Trans. Geol. Soc. S.Afr., 75, 121-134.

HALL, A.L., (1932). The Bushveld Igneous Complex of the Central Transvaal. Geol. Soc. S.Afr., Mem. 28, 560 p.

HUNTER, D.R., (1973). Geochemistry of granitic and associated rocks in the Kaapvaal Craton. Econ. Geol. Res. Unit., University of the Witwatersrand, Inf. Circ., 81, 19 p.

HUNTER, D.R., (1975). The regional geological setting of the Bushveld Complex. Econ. Geol. Res. Unit., University of the Witwatersrand, 18 p.

IANNELLO, P., (1970). The Bushveld Granites around Rooiberg, Transvaal S.Africa. Geol. Rdsch. 60, 630-655.

IRVINE, T.N., (1970). Heat transfer during solidification of layered intrusions. I. Sheets and sills. Can. J. Earth Sci., 7, 1031-1061.

KELSEY, C.H., (1965). Calculation of the C.I.P.W. norm. Miner. Mag., 34, 276-282.

KUSHKE, O.H., (1950). Granitic rocks of the Bushveld, north-west of Brits. M.Sc. thesis (unpublished), University of Pretoria, 45 p.

LENTHALL, D.H., (1972). The application of discriminatory and cluster analysis as an aid to the understanding of the acid phase of the Bushveld Complex. Econ. Geol. Res. Unit., University of the Witwatersrand, Inf. Circ., 72, 33 p.

LENTHALL, D.H., (1973). A proposed nomenclature system for the granophyres associated with the Bushveld Complex. Trans. Geol. Soc. S.Afr., 76, 75-76.

LENTHALL, D.H., (1975). Aspects of the acid phase of the Central and Eastern Bushveld Complex. Econ. Geol. Res. Unit, Univer= sity of the Witwatersrand, Inf. Cir., 99, 20 p.

LIEBENBERG, C.J., (1961). The trace elements of the rocks of the Bushveld Igneous Complex, Part 2. The different rock types. Publ. University of Pretoria, No. 13, 75 p.

LOMBAARD, B.V., (1932). The felsites and their relations in the Bushveld Complex. Trans. Geol. Soc. S.Afr., 35, 125-190.

LOMBAARD, B.V., (1934). On the differentiation and relationships of the rocks of the Bushveld Complex. Trans. geol. Soc. S.Afr., 37, 5-52.

MARLOW, A.G., (1976). Explanatory notes on the Gruisbank Sheet 2529 AA and the Dennilton Sheet 2529 AC. Rep. Geol. Surv. S.Afr., (unpublished).

MILLER, R.L. and KAHN, J.S., (1967). Statistical analysis in the geological Sciences. J. Wiley and Sons, Inc., New York, 483 p.

MOLYNEUX, T.G., (1970a). A geological investigation of the Bushveld Complex in Sekhukhuneland and part of the Steelpoort Valley, Eastern Transvaal, with particular reference to the oxide minerals. D.Sc. Thesis (unpublished), University of Pretoria, 123 p.

MOLYNEUX, T.G., (1970b). The geology of the area in the vicinity of Magnet Heights, Eastern Transvaal, with special reference to the magnetic iron ore. Geol. Soc. S.Afr., Spec. Publ. 1, 228-241.

MOLYNEUX, T.G., (1974). A geological investigation of the Bushveld Complex in Sekhukhuneland and part of the Steelpoort Valley. Trans. geol. Soc. S.Afr., 77, 329-338.

NEL, D.J., (in preparation). A petrochemical investigation of the Spitskop Alkaline Complex, Eastern Transvaal. M.Sc. Thesis (Unpublished), University of Pretoria.

REFORD, M.S., (1964). Magnetic anomalies over thin sheets. Geo=physics 29, 532-536.

RHODES, R.C., (1975). Bushveld granophyre in the Stavoren Tin district, Transvaal. Trans. Geol. Soc. S.Afr., 78, 71-74.

RICHARDS, D.J., (1976). HP 9830A. Programme to calculate magnetic anomalies over thin sheets. Rep. Geol. Surv. S.Afr., (unpublished).

SHAND, S.J., (1921). The nepheline rocks of Sekhukhuneland. Trans. Geol. Soc. S.Afr., V. 24, 111-149.

SPRY, A., (1969). Metamorphic textures. Pergamon Press Ltd., Oxford, 350 p.

STRAUSS, C.A., (1947). Granitization and rheomorphism associated with the Bushveld Igneous Complex, near the eeuwpoort Tin Mine. Trans. Geol. Soc. S.Afr., 50, 161-170.

STRAUSS, C.A., (1954). The geology and mineral deposits of the Potgietersrus tin-fields. Geol. Surv. S.Afr., Mem. 46, 252 p.

STRAUSS, C.A. and TRUTER, F.C., (1950). The Alkali Complex at Spitskop Sekhukhuneland, Eastern Transvaal. Trans. Geol. Soc. S.Afr., 53, 81-130.

THORNTON, C.P. and TUTTLE, D.F., (1960). Chemistry of igneous rocks, I. Differentiation Index. Amer. J. Sci., 258, 664-684.

TRUTER, F.C., (1955). Modern concepts of the Bushveld Igneous Complex. C.C.T.A. South. reg. Com. Geol., First meeting, Salisbury, 77-87.

VERWOERD, W.J., (1964). The significance of granite pegmatites in the Spitskop Complex. Trans. Geol. Soc. S.Afr., 67, 219-226.

WALRAVEN, F., (1974). Tectonism during the emplacement of the Bushveld Complex and the resulting fold structures. Trans. Geol. Soc. S.Afr., 77, 323-328.

WALRAVEN, F., (1976). Notes on the late stage history of the Western Bushveld Complex. Trans. Geol. Soc. S.Afr., 79 (in press).

WILLEMSE, J., (1964). A brief outline of the geology of the Bushveld Igneous Complex, 91-128. In Haughton, S.H., Ed. The geology of some ore deposits of Southern Africa, II, Geol. Soc. S.Afr., Johannesburg, 739 p.

APPENDIX I

MODAL ANALYSIS OF MICROGRAPHIC INTERGROWTHS IN ROCKS OF THE RASHOOP GRANOPHYRE SUITE

SAMPLE NO.	QUARTZ	K-FELDSPAR	POINTS COUNTED
AGM 56 *(36.4:63.6)	35,3	64,7	133
	32,1	67,9	212
	33,2	66,8	208
	32,5	67,5	292
	39,9	60,1	343
	35,5	64,5	231
	46,5	53,5	269
	37,8	62,2	569
	36,0	64,0	111
	35,0	65,0	117
AGM 256	38,9	61,1	573
(39.5:60.5)	36,1	63,9	415
	32,3	67,7	254
	44,7	55,3	264
	50,0	50,0	289
	48,6	51,4	405
	44,2	55,8	208
	28,9	71,1	166
	39,3	60,7	741
	32,4	67,6	343
AGM 57	38,5	61,5	237
(38.7:61.3)	43,7	56,3	198
	39,2	60,8	401
	38,8	61,2	259
	34,6	65,4	175
	42,1	57,9	384
	37,6	62,4	215
	37,4	62,6	263
	38,2	61,8	259
	36,6	63,4	180

* Average ratio of quartz to potassium feldspar in micrographic intergrowths in samples of the Rashoop Granophyre Suite.

APPENDIX I (continued)

SAMPLE NO	QUARTZ	K-FELDSPAR	POINTS COUNTED
AGM 52	38,0	62,0	192
(37.2:62.8)	37,4	62,6	332
	41,2	58,8	238
	31,8	68,2	283
	42,9	57,1	112
	38,5	61,5	208
	34,1	65,9	314
	40,0	60,0	140
	31,5	68,5	143
	36,9	63,1	214
AGM 10	44,1	55,9	161
(42.6:57.4)	32,0	68,0	322
	41,7	58,3	369
	45,9	54,1	316
	37,3	62,7	220
	38,3	61,7	358
	47,6	52,4	696
	48,5	51,5	167
	46,9	53,1	113
	43,9	56,1	319
AGM 8	40,0	60,0	225
(43.2:56.8)	46,2	53,8	130
	37,2	62,8	223
	42,1	57,9	133
	41,6	58,4	250
	49,5	50,5	309
	37,6	62,4	372
	48,6	51,4	222
	42,8	57,2	243
	46,0	54,0	198

APPENDIX I (continued)

SAMPLE NO	QUARTZ	K-FELDSPAR	POINTS COUNTED
AGM 49	49,0	51,0	243
(40.6:59.4)	43,6	56,4	202
	41,9	58,1	241
	37,8	62,2	267
	37,2	62,8	253
	42,6	57,4	291
	40,5	59,5	331
	37,1	62,9	159
	36,0	64,0	258
AGM 117	33,7	66,3	424
(37.5:62.5)	40,2	59,8	199
	29,6	70,4	142
	34,5	65,5	206
	44,1	55,9	236
	42,9	57,1	240

SAMPLE NO	FARM	LONGITUDE	LATITUDE
AGM 10	Roodepoort 880 KS	29°54,2'E	24°55,7'S

For location of other samples see Table II (p.24).

APPENDIX II

TABLES OF CHEMICAL ANALYSES AND C.I.P.W. NORMS OF THE NEBO GRANITE

A NEW ANALYSES

SAMPLE NO.	AM 75/42	AM 75/39	AGM 178	AGM 200	AGM 138
SiO_2	73,33	73,82	71,70	74,49	75,66
TiO_2	0,32	0,20	0,35	0,12	0,17
Al_2O_3	11,75	12,28	12,58	12,45	11,80
Fe_2O_3	0,76	0,53	0,99	0,52	0,74
FeO	3,15	2,39	3,21	1,71	1,66
MnO	0,06	0,05	0,07	0,03	0,04
MgO	0,09	0,07	0,18	0,07	0,05
CaO	1,45	0,97	1,41	0,87	0,76
Na_2O	3,24	3,26	3,30	3,31	3,24
K_2O	4,56	5,21	4,79	5,20	4,99
H_2O+	0,62	0,59	0,63	0,69	0,60
H_2O-	0,05	0,03	0,04	0,06	0,02
CO_2	0,10	0,17	0,18	0,12	$<$ 0,05
P_2O_5	0,02	0,02	0,04	0,02	0,03
Ba ppm	670	944	1720	920	862
Rb ppm	282	283	197	270	274
Sr ppm	51	73	134	69	52
Zr ppm	527	469	570	360	320
Zn ppm	65	47	96	37	55
Total	99,66	99,77	99,74	99,83	99,92
Q	32,33	31,35	29,17	32,34	35,22
or	26,95	30,79	28,31	30,73	29,49
ab	27,41	27,58	27,92	28,00	27,41
an	4,05	3,48	5,36	3,75	2,91
di	2,66	1,05	1,19	0,37	0,57
hy	3,55	3,33	4,44	2,54	2,04
mt	1,10	0,76	1,43	0,75	1,07
ilm	0,60	0,37	0,66	0,22	0,32
hap	0,04	0,04	0,09	0,04	0,07
H_2O+	0,61	0,58	0,62	0,68	0,59
H_2O-	0,05	0,03	0,04	0,04	0,02

Analyst: General Superintendence Company (Pty.) Ltd

APPENDIX II (continued)

B. NEBO GRANITE SELECTED FROM LITERATURE

SAMPLE NO.	No. 1	No. 2	No. 15	No. 6	v	f
SiO_2	73,30	73,48	79,58	75,39	76,00	75,69
TiO_2	0,21	0,21	0,23	0,18	0,30	0,17
Al_2O_3	12,18	12,36	8,91	12,04	11,00	10,75
Fe_2O_3	1,75	1,75	0,52	0,83	0,65	1,31
FeO	1,87	1,58	2,26	1,41	3,15	1,54
MnO	0,06	0,05	0,05	-	0,05	0,02
MgO	0,51	0,56	0,17	0,07	0,15	0,20
CaO	1,57	1,18	0,69	0,98	1,05	1,25
Na_2O	3,14	3,22	2,48	3,57	3,70	3,55
K_2O	5,00	5,09	3,89	5,10	3,30	5,12
H_2O+	0,67	0,50	0,33	0,13	0,70	0,58
H_2O-	0,03	0,10	0,08	0,20	0,15	0,03
CO_2	0,02	0,10	0,04	-	0,15	-
P_2O_5	-	tr	0,29	0,02	0,05	0,12
Total	100,31	100,18	99,52	99,92	100,40	100,33
Q	31,71	31,70	47,76	32,86	37,57	33,66
c	0,00	0,00	0,06	0,00	0,00	0,00
or	29,55	30,08	22,99	30,14	19,50	30,26
ab	26,56	27,24	20,98	30,20	31,30	26,79
an	4,37	4,24	1,52	1,76	3,66	0,00
ac	0,00	0,00	0,00	0,00	0,00	2,85
di	2,85	1,32	0,00	2,60	1,07	4,69
hy	1,59	1,94	3,85	0,41	4,65	0,38
mt	2,53	2,53	0,75	1,20	0,94	0,46
hm	0,00	0,00	0,00	0,00	0,00	0,00
ilm	0,39	0,39	0,43	0,34	0,56	0,32
hap	0,00	0,00	0,68	0,04	0,11	0,28
H_2O+	0,66	0,50	0,31	0,12	0,69	0,57
H_2O-	0,03	0,10	0,08	0,20	0,15	0,03

APPENDIX II (continued)

B. (continued)

SAMPLE NO.	Lieb-24	Lieb-6	Pret 5A	N1	No.3
SiO_2	75,60	72,80	72,7	76,9	75,7
TiO_2	0,24	0,40	0,4	0,1	0,17
Al_2O_3	11,54	12,57	12,8	11,3	11,49
Fe_2O_3	0,85	1,29	1,1	1,5	1,06
FeO	1,85	3,18	2,9	0,7	1,18
MnO	-	-	-	-	0,03
MgO	0,30	0,26	0,2	0,1	0,08
CaO	1,13	1,67	1,4	0,5	0,84
Na_2O	3,20	3,20	3,6	2,5	3,15
K_2O	4,50	4,40	4,9	5,4	4,93
H_2O+	-	-	-	-	0,84
H_2O-	-	-	-	-	0,09
CO_2	-	-	-	-	0,29
P_2O_5	-	-	0,0	0,0	0,03
Total	99,21	99,77	100,0	99,0	99,88
Q	36,22	31,79	28,56	40,46	35,35
c	0,00	0,00	0,00	0,00	0,21
or	26,59	26,00	28,96	31,91	29,95
ab	27,07	27,07	30,45	21,15	29,08
an	3,83	6,94	4,29	2,48	2,20
ac	0,00	0,00	0,00	0,00	0,00
di	1,51	1,17	2,31	0,00	-
hy	2,26	4,15	3,04	0,24	0,88
mt	1,23	1,87	1,59	1,96	1,27
hm	0,00	0,00	0,00	0,14	-
ilm	0,45	0,75	0,75	0,18	0,20
hap	0,00	0,00	0,00	0,00	0,06
H_2O+	0,00	0,00	0,00	0,00	-
H_2O-	0,00	0,00	0,00	0,00	-

APPENDIX II (continued)

C. APLITIC FACIES OF THE NEBO GRANITE

SAMPLE NO.	AM 75/34	AM 75/35	AM 75/38	AGM 231	No. 4
SiO_2	75,84	76,47	75,57	76,55	75,2
TiO_2	0,08	0,08	0,09	0,12	0,14
Al_2O_3	12,00	11,81	12,06	11,95	11,85
Fe_2O_3	0,96	0,73	0,78	0,65	0,90
FeO	1,01	1,22	1,25	0,94	1,54
MnO	0,01	0,04	0,02	0,03	0,03
MgO	0,03	0,03	0,06	0,04	0,07
CaO	0,62	0,55	0,74	0,42	0,64
Na_2O	3,51	3,46	3,30	3,52	3,18
K_2O	4,78	4,83	5,13	5,15	5,49
H_2O+	0,57	0,57	0,55	0,46	0,83
H_2O-	0,03	0,04	0,05	0,02	0,11
CO_2	0,18	< 0,05	0,09	0,05	0,10
P_2O_5	0,01	0,01	0,02	0,01	0,02
Ba ppm	105	80	167	70	185
Rb ppm	242	388	392	250	255
Sr ppm	< 20	< 20	< 20	< 20	5
Zr ppm	388	328	355	289	-
Zn ppm	42	49	49	44	-
Total	99,70	99,92	99,81	99,93	100,10
Q	35,37	35,99	34,54	35,04	32,82
or	28,25	28,54	30,32	30,43	33,25
ab	29,69	29,27	27,92	29,78	29,27
an	2,87	2,43	2,94	1,59	1,90
di	0,12	0,20	0,52	0,36	0,46
hy	0,95	1,54	1,41	0,95	0,15
mt	1,39	1,05	1,13	0,94	1,65
ilm	0,15	0,15	0,17	0,22	0,20
hap	0,02	0,02	0,04	0,02	0,04
H_2O+	0,56	0,56	0,54	0,45	-
H_2O-	0,03	0,04	0,05	0,02	-

APPENDIX II (continued)

D. LOCALITY OF SAMPLES AND REFERENCES

SAMPLE NO.	FARM	LONGITUDE	LATITUDE
AM 75/42	Koornkopje 801 KS	29°35,2'E	24°41,1'S
AM 75/39	Vergenoegd 792 KS	29°34,5'E	24°39,2'S
AGM 178	Loopspruit 805 KS	29°44,5'E	24°41,3'S
AGM 200	Vergenoegd 792 KS	29°34,5'E	24°39,2'S
AGM 138	Koornkopje 801 KS	29°36,9'E	24°41,1'S
AM 75/34	Vergenoegd 792 KS	29°34,8'E	24°37,2'S
AM 75/35	Vergenoegd 792 KS	29°35,4'E	24°37,9'S
AM 75/38	Hopefield 800 KS	29°34,8'E	24°43,5'S
AGM 231	Vergenoegd 792 KS	29°34,5'E	24°39,3'S
No. 1	Groenfontein	Strauss, 1954, p. 56	
No. 2	Appingendam 469	Strauss, 1954, p. 56	
No. 15	Groblersvrede 844 KS	Grout, 1935, p. 291	
No. 6	-	Iannello, 1970, p. 643	
v	Ontevreden 838 KS	Hall, 1932, p. 375	
f	-	Lombaard, 1932, p. 154	
LIEB-24	Vergelegen 819 KS	Liebenberg, 1961, p. 73	
LIEB-6	Welgevonden 567	Liebenberg, 1961, p. 73	
PRET 5A	Veekraal quarry	Fourie, 1969, p. 285	
N1	Visgat 520 KR	Fourie, 1969, p. 285	
No. 3	Van der Merwes Kraal 636 KS	Rhodes, 1975, p. 73	
No. 4	Van der Merwes Kraal 636 KS	Rhodes, 1975, p. 73	

APPENDIX III

TABLES OF CHEMICAL ANALYSES AND C.I.P.W. NORMS OF THE MAKHUTSO GRANITE

A. NEW ANALYSES

SAMPLE NO.	AGM 204	AGM 223	AGM 226	AGM 246	AGM 248	AM 75/43
SiO_2	73,00	71,24	70,68	71,79	71,73	80,71
TiO_2	0,19	0,34	0,35	0,29	0,28	0,08
Al_2O_3	13,44	13,69	14,32	13,66	13,78	9,94
Fe_2O_3	0,33	0,74	0,72	0,79	0,71	0,21
FeO	1,80	2,88	2,66	2,39	2,45	0,86
MnO	0,03	0,04	0,04	0,03	0,03	0,09
MgO	0,24	1,23	0,91	0,39	0,39	0,09
CaO	1,24	1,28	1,58	1,63	1,65	0,73
Na_2O	3,49	2,56	3,02	3,74	3,78	2,38
K_2O	4,77	4,32	4,27	3,96	3,99	4,01
H_2O+	0,75	1,07	0,82	0,68	0,66	0,48
H_2O-	0,05	0,03	0,02	0,06	0,05	0,02
CO_2	$<$ 0,05	0,19	0,18	$<$0,05	$<$0,05	0,28
P_2O_5	0,04	0,06	0,06	0,05	0,05	0,02
Ba ppm	780	1140	1560	950	990	8 87
Rb ppm	297	305	247	341	348	267
Sr ppm	85	164	188	112	121	88
Zr ppm	321	312	362	412	420	157
Zn ppm	64	67	71	73	72	19
Total	99,52	99,87	99,87	99,65	99,75	99,96
Q	30,27	33,49	30,47	29,43	28,89	49,28
c	0,37	2,61	2,00	0,37	0,36	0,40
or	28,19	25,53	25,23	23,40	23,58	23,70
ab	29,52	21,65	25,55	31,64	31,98	20,13
an	5,89	5,95	7,44	7,76	7,85	3,49
hy	3,37	7,25	6,05	4,28	4,47	1,51
mt	0,47	1,07	1,04	1,14	1,02	0,30
ilm	0,36	0,64	0,66	0,55	0,53	0,15
hap	0,09	0,14	0,14	0,11	0,11	0,04
H_2O+	0,74	1,06	0,81	0,67	0,65	0,47
H_2O-	0,05	0,03	0,02	0,06	0,05	0,02

Analyst : General Superintendence Company (Pty.) Ltd

APPENDIX III (continued)

B. ANALYSES FROM DE BRUIYN AND RHODES (1975)

SAMPLE NO.	1	2	3	4	5	6	7
SiO_2	75,73	75,58	73,94	75,16	75,60	75,03	74,11
TiO_2	0,14	0,18	0,21	0,22	0,13	0,20	0,19
Al_2O_3	12,21	12,95	13,24	12,96	12,67	12,85	13,10
Fe_2O_3	0,61	0,62	0,48	0,36	0,80	1,18	0,53
FeO	1,01	0,45	1,01	0,36	0,80	0,63	1,45
MnO	0,03	0,01	0,02	0,03	0,02	0,03	0,03
MgO	0,20	0,63	0,61	0,03	0,03	0,12	0,16
CaO	0,72	0,65	0,96	0,86	0,61	0,54	0,81
Na_2O	3,43	3,10	3,16	3,73	3,86	3,40	3,40
K_2O	4,71	5,26	5,21	5,33	4,73	5,04	5,06
H_2O+	0,57	0,22	0,43	0,29	0,35	0,60	0,58
H_2O-	0,15	0,28	0,16	0,17	0,13	0,14	0,12
CO_2	0,11	0,06	0,08	0,05	0,05	0,05	0,19
P_2O_5	0,03	0,03	0,04	0,04	0,02	0,04	0,04
Ba ppm	297	590	600	823	262	542	573
Rb ppm	421	210	400	353	489	420	510
Sr ppm	51	55	70	90	43	54	88
Zr ppm	273	140	160	316	244	326	316
Zn ppm	12	10	15	10	14	14	30
Total	99,75	100,12	99,67	99,75	99,90	99,99	99,92
Q	35,45	35,15	32,23	31,50	33,45	34,73	32,20
c	0,23	1,04	0,75	-	0,14	0,91	0,65
or	27,83	31,08	30,79	31,50	27,95	29,78	29,90
ab	29,02	26,22	26,73	31,55	32,65	28,76	28,76
an	3,37	3,02	4,50	2,88	2,89	2,41	3,75
di	-	-	-	0,26	-	-	-
wo	-	-	-	0,33	-	-	-
hy	1,67	1,60	2,66	-	0,70	0,29	2,36
mt	0,88	0,89	0,69	0,52	1,15	1,54	0,76
hm	-	-	-	-	-	0,11	-
il	0,26	0,34	0,39	0,41	0,24	0,37	0,36
hap	0,07	0,07	0,09	0,09	0,04	0,09	0,09

APPENDIX III (continued)

B. (continued)

SAMPLE NO.	8	9	10	11	12	13	14
SiO_2	75,76	73,74	75,30	72,43	72,14	72,47	73,58
TiO_2	0,12	0,27	0,17	0,25	0,25	0,21	0,20
Al_2O_3	12,72	13,28	12,65	13,42	13,44	14,30	13,66
Fe_2O_3	0,64	0,72	0,71	0,45	0,56	0,47	0,64
FeO	0,67	1,43	1,01	1,84	1,97	1,70	1,41
MnO	0,02	0,04	0,04	0,02	0,03	0,03	0,03
MgO	0,11	0,29	0,12	0,89	0,85	0,46	0,25
CaO	0,66	1,00	0,80	1,24	1,35	1,38	0,76
Na_2O	3,39	3,28	3,38	2,87	2,88	3,75	3,57
K_2O	4,97	5,06	4,98	4,84	4,95	4,22	5,03
H_2O+	0,33	0,48	0,35	0,70	0,67	0,69	0,59
H_2O-	0,15	0,11	0,08	0,19	0,19	0,09	0,14
CO_2	0,15	0,05	0,11	0,30	0,53	0,11	0,05
P_2O_5	0,03	0,05	0,04	0,07	0,06	0,05	0,04
Ba ppm	199	640	517	820	850	789	548
Rb ppm	584	433	442	290	280	320	521
Sr ppm	37	91	75	95	85	176	89
Zr ppm	212	403	289	210	230	313	343
Zn ppm	16	28	20	30	25	26	32
Total	99,82	99,96	99,87	99,65	100,01	100,09	100,10
Q	35,61	32,10	34,31	32,22	31,17	29,89	30,85
c	0,92	0,70	0,34	1,37	1,03	1,17	1,05
or	29,37	29,90	29,43	28,60	29,25	24,94	29,72
ab	28,68	27,75	28,59	24,28	24,36	31,72	30,20
an	2,29	4,63	3,70	5,69	6,30	6,51	3,50
di	-	-	-	-	-	-	-
wo	-	-	-	-	-	-	-
hy	0,81	2,38	1,36	4,84	4,91	3,58	2,40
mt	0,92	1,04	1,02	0,65	0,81	0,68	0,92
hm	-	-	-	-	-	-	-
ilm	0,22	0,51	0,32	0,47	0,47	0,39	0,37
hap	0,35	0,11	0,09	0,16	0,14	0,11	0,09

APPENDIX III

B. (continued)

SAMPLE NO.	15	16	17	18	19	20
SiO_2	76,34	74,61	75,48	74,78	77,01	76,41
TiO_2	0,08	0,20	0,14	0,20	0,08	0,10
Al_2O_3	12,51	12,88	12,61	13,56	12,33	12,55
Fe_2O_3	0,71	0,90	0,61	0,40	0,29	0,44
FeO	0,56	0,85	0,81	0,72	0,20	0,30
MnO	0,02	0,01	0,03	0,03	0,01	0,01
MgO	0,08	0,05	0,06	0,08	0,05	0,24
CaO	0,44	0,62	0,64	0,95	0,23	0,33
Na_2O	3,76	3,37	3,74	3,85	3,33	2,67
K_2O	4,91	5,41	4,94	4,76	5,75	6,31
H_2O+	0,22	0,58	0,42	0,19	0,46	0,51
H_2O-	0,13	0,09	0,17	0,10	0,12	0,12
CO_2	0,15	0,05	0,11	0,14	0,11	0,05
P_2O_5	0,01	0,03	0,02	0,04	0,06	0,02
Ba ppm	252	687	358	903	181	277
Rb ppm	487	490	507	257	428	575
Sr ppm	19	73	63	120	21	33
Zr ppm	170	359	244	353	323	173
Zn ppm	16	16	22	18	8	20
Total	100,01	99,81	99,90	99,96	100,13	100,17
Q	34,48	32,75	33,04	31,79	35,22	36,08
c	0,23	0,42	0,00	0,44	0,35	0,76
or	29,02	31,97	29,19	28,13	33,98	37,24
ab	31,81	28,51	31,64	32,57	28,17	22,61
an	2,11	2,88	3,03	4,45	0,74	1,56
di	-	-	-	-	-	-
wo	-	-	-	-	-	-
hy	0,54	0,63	0,95	0,91	0,13	0,59
mt	1,02	1,30	0,88	0,57	0,42	0,63
hm	-	-	-	-	-	-
ilm	0,15	0,37	0,26	0,37	0,15	0,18
hap	0,02	0,07	0,04	0,09	0,14	0,05

APPENDIX III (continued)

C. KOORNKOPJE GRANITE (NEW ANALYSES)

SAMPLE NO.	AM 75/20	AM 75/24	AM 75/25	AM 75/27	AM 75/28
SiO_2	76,16	75,84	74,04	75,82	74,36
TiO_2	0,07	0,11	0,04	0,08	0,07
Al_2O_3	12,36	11,96	13,02	12,31	12,94
Fe_2O_3	0,49	0,74	0,17	0,67	0,75
FeO	0,94	1,04	0,92	0,92	0,76
MnO	0,02	0,02	0,01	0,02	0,02
MgO	0,05	0,05	0,05	0,03	0,04
CaO	0,76	0,55	0,60	0,82	0,62
Na_2O	3,25	3,17	3,33	3,35	3,39
K_2O	4,72	5,11	5,99	4,73	5,84
H_2O+	0,62	0,99	0,92	0,68	0,84
H_2O-	0,02	0,05	0,02	0,04	0,03
CO_2	< 0,05	< 0,05	0,19	0,13	< 0,05
P_2O_5	0,01	0,02	0,06	0,02	0,01
Ba ppm	207	649	1030	1120	1650
Rb ppm	321	298	336	308	319
Sr ppm	34	69	79	83	95
Zr ppm	255	223	297	268	221
Zn ppm	32	23	17	31	26
Total	99,55	99,78	99,54	99,80	99,90
Q	36,94	36,11	29,86	36,00	30,64
c	0,54	0,26	0,11	0,23	0,00
or	27,89	30,20	35,40	27,95	34,51
ab	27,49	26,82	28,17	28,34	28,68
an	3,70	2,59	2,58	3,93	2,84
di	0,00	0,00	0,00	0,00	0,14
hy	1,36	1,27	1,62	1,11	0,72
mt	0,71	1,07	0,24	0,97	1,08
ilm	0,13	0,20	0,07	0,15	0,13
hap	0,02	0,04	0,14	0,04	0,02
H_2O+	0,61	0,98	0,91	0,67	0,83
H_2O-	0,02	0,05	0,02	0,04	0,03

APPENDIX III (continued)

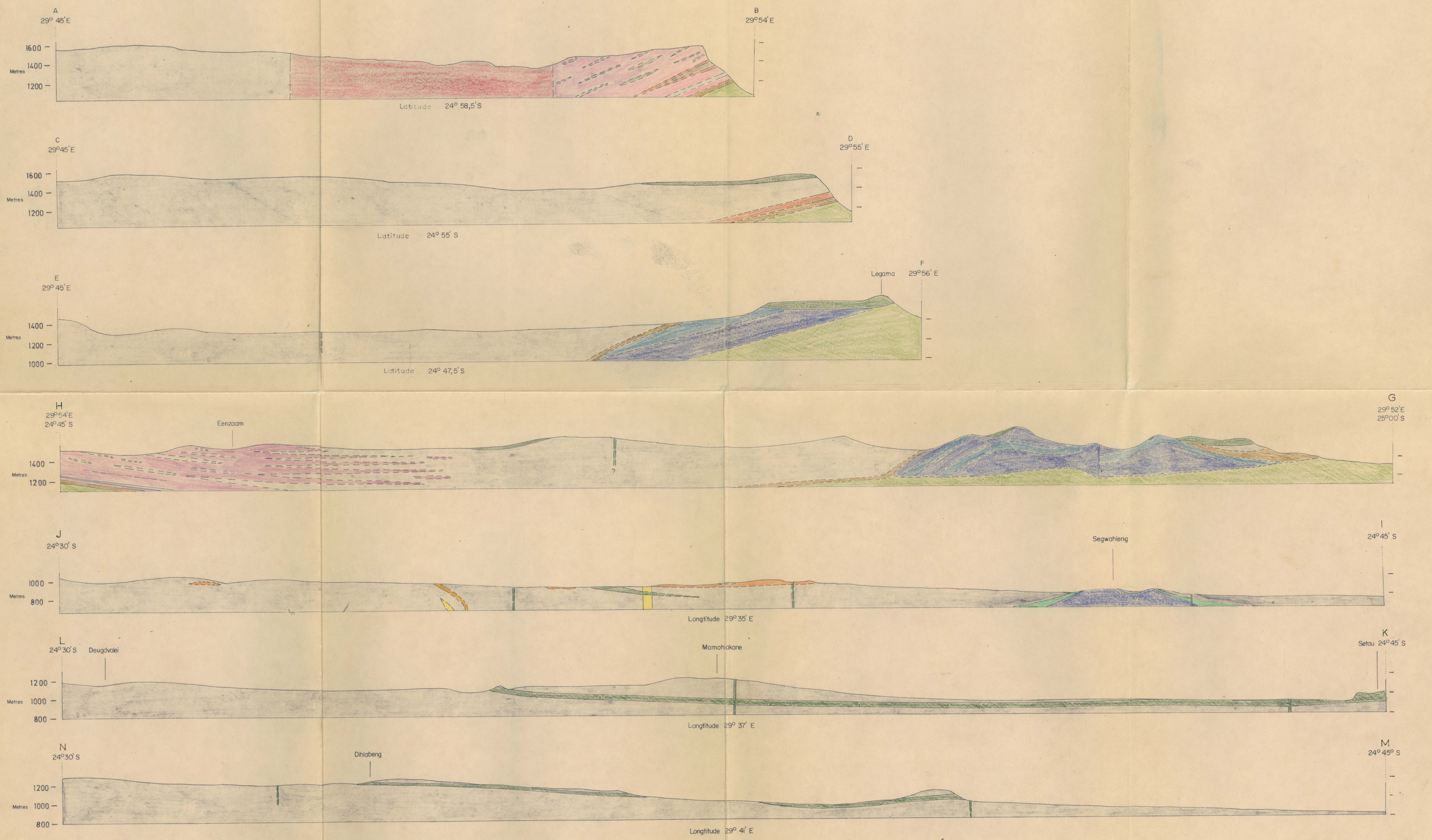
D. LOCALITY OF SAMPLES AND REFERENCES

SAMPLE NO.	FARM	LONGITUDE	LATITUDE
AGM 204	Vlakplaats 802 KS	29°37,7'E	24°42,3'S
AGM 223	Derdemaal 797 KS	29°33,4'E	24°39,2'S
AGM 226	Vergenoegd 792 KS	29°34,9'E	24°37,9'S
AGM 246	Vlakplaats 802 KS	29°39,5'E	24°42,9'S
AGM 248	Vlakplaats 802 KS	29°39,5'E	24°42,9'S
AM 75/43	Eensgevonden 825 KS	29°39,9'E	24°43,6'S
		REFERENCE	
1	Vlaklaagte 221 JR	De Bruiyn and Rhodes, 1975, p. 93	
2	Vlaklaagte 221 JR	De Bruiyn and Rhodes, 1975, p. 93	
3-8	Hartebeestfontein 224 JR	De Bruiyn and Rhodes, 1975, p. 93	
9-10	Gemsbokspruit 229 JR	De Bruiyn and Rhodes, 1975, p. 93	
11-12	Kameelrivier 160 JR	De Bruiyn and Rhodes, 1975, p. 93	
13	Watervlak 34 JS	De Bruiyn and Rhodes, 1975, p. 93	
14	Hartbeestfontein 224 JR	De Bruiyn and Rhodes, 1975, p. 93	
15	Rhenosterfontein 227 JR	De Bruiyn and Rhodes, 1975, p. 93	
16-19	Gemsbokspruit 229 JR	De Bruiyn and Rhodes, 1975, p. 93	
20	Leeuwkop 228 JR	De Bruiyn and Rhodes, 1975, p. 93	
AM 75/20	Koornkopje 801 KS	29°35,0'E	24°40,8'S
AM 75/24	Derdemaal 797 KS	29°34,6'E	24°40,2'S
AM 75/25	Derdemaal 797 KS	29°34,5'E	24°40,2'S
AM 75/27	Derdemaal 797 KS	29°34,4'E	24°40,3'S
AM 75/28	Derdemaal 797 KS	29°34,5'E	24°40,3'S

FOLDER III

GEOLOGICAL CROSS SECTIONS ACROSS THE SEKHUKHUNE PLATEAU

VERTICAL EXAGERATION X 2



ISOPACH MAP OF MOC E DOLERITE SILL

Legend

90 ············ Isopachs. Figures in metres

914 —·—·—·— Structural contour of lower surface of sill. Figures in metres

914 - - - - - - Structural contour of upper surface of sill. Figures in metres

———— Geological boundary of granite and dolerite

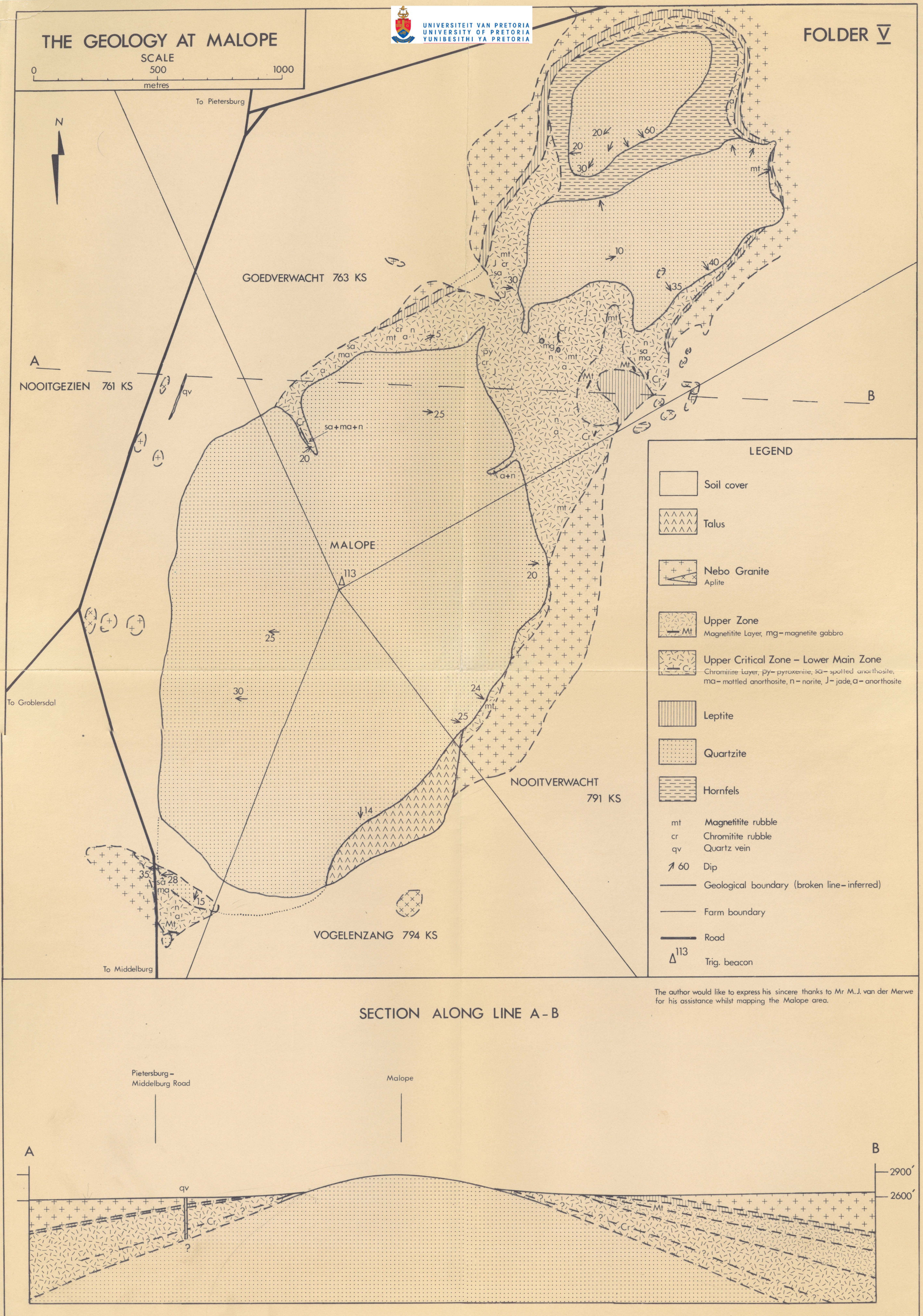
·············· Inferred geological boundary of granite and dolerite

Dolerite

———— Main road

SCALE 1: 50,000

FOLDER IV


THE GEOLOGY AT MALOPE
SCALE
0 500 1000
metres
FOLDER V
UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA
N
To Pietersburg
GOEDVERWACHT 763 KS
NOOITGEZIEN 761 KS
MALOPE
NOOITVERWACHT 791 KS
VOGELENZANG 794 KS
To Groblersdal
To Middelburg
A
B
LEGEND
Soil cover
Talus
Nebo Granite
Aplite
Upper Zone
Magnetitite Layer, mg - magnetite gabbro
Upper Critical Zone - Lower Main Zone
Chromitite Layer, py - pyroxenite, sa - spotted anorthosite, ma - mottled anorthosite, n - norite, J - jade, a - anorthosite
Leptite
Quartzite
Hornfels
mt Magnetitite rubble
cr Chromitite rubble
qv Quartz vein
60 Dip
Geological boundary (broken line - inferred)
Farm boundary
Road
113 Trig. beacon
The author would like to express his sincere thanks to Mr M.J. van der Merwe for his assistance whilst mapping the Malope area.
SECTION ALONG LINE A-B
Pietersburg - Middelburg Road
Malope
2900′
2600′