THE GEOLOGY OF THE COUNTRY.

SURROUNDING LOSKOP DAM, TRANSVAAL.

by

L. E. WOLHUTER.

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I - ABSTRACT.

The Loskop System in its type locality has been investigated. It consists predominantly of arenaceous sediments and minor shales, siltstones and conglomerates. Lithologically the components of this system are remarkably similar to those of the overlying Waterberg System. Heavy mineral concentrates from rocks of both systems were investigated to determine whether there were sufficient points of difference to demarcate the Loskop System from the Waterberg System on petrographical data. The similarity of these heavy mineral suites agrees with the close correspondence in nature of the sediments in which the minerals occur and is not corroborative of the grouping of the rocks of the Loskop System into a separate stratigraphical entity.

Evidence of volcanicity contemporaneous with the deposition of a portion of the Waterberg System is present in the area mapped in the form of pyroclastic material intimately associated with intensely folded Waterberg beds. The latter are overlain by practically undisturbed strata of the same system. The intraformational and local folding in the Waterberg beds is thought to be due to subaqueous slumping at the time of eruption of the pyroclastic material.

A description is given of the Rooiberg Felsite; in particular its chemical composition is compared with that of Karroo Rhyolite and with felsite of the "Premier Mine Type". The latter type is distinctive in several respects but especially in its high mg content.

When plotted on Smithson diagrams, the length; breadth ratios of zircons obtained from the felsitic lava of the Bushveld Complex are found to be very much the same as those obtained for sediments of the Loskop System.

Two new chemical analyses are reported.

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II - INTRODUCTION.

An area approximately 120 square miles in extent surrounding Loskop Dam, the latter half - way between Middelburg and Groblersdal, was geologically surveyed during 1952. It is roughly bounded by the co-ordinates 25° 24' and 25° 30' South Latitude and 29° 14' and 29° 30' East Longitude (See plate 1).

Previous work in this area was carried out by Mellor (1906) and Lombaard (1931). Mellor mapped the Rooiberg felsite as the Volcanic Series of the Lower Division of the Waterberg System. Rocks of the Loskop System were assigned to the Shale and Sandstone Series of this Division whilst the Waterberg System proper was mapped as an Upper Division, the so-called Sandstone and Quartzite Series. Work by Hall and members of the Shaler Memorial Expedition in 1922 resulted in the separation of the Lower and Upper Divisions of the Waterberg System despite the fact that at the time no angular unconformity had been detected between the two formations (du Toit, 1954, p.209). The felsite and sediments of the Lower Division of the Waterberg System were then classified as the Rooiberg Series of the Transvaal System and mapped as such by Lombaard (1931).

In his presidential address to the Geological Society of South Africa in 1949, F.C. Truter (pp.lxvi - lxviii) pointed out the unconformable relationship existing between certain rocks of the Rooiberg Series, which be then called the Loskop System, and the formations over - and underlying them in a locality south - west of Loskop Dam. Here on a portion of the farm Hondekraal 114, beyond the limits of the area at present under consideration, flat- dipping sediments of the Waterberg System cover a truncated anticline of the Loskop System and consequently the latter was regarded as forming a separate system. Although resting on Rooiberg Felsite in the Loskop Dam area with no apparent unconformity, between Witbank and Balmoral the Loskop System transgresses on to sediments of the Pretoria Series.

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The object of the present investigation was in the first instance to aquire information about the Loskop System, its composition, structure and relationships in the area from where it has been named - the vicinity of Loskop Dam.

The classification of clastic sediments suggested by Twenhofel has been followed in the present treatise. The scheme of classification is shown in table 1.

TABLE 1.

GRADE SIZE OF THE CLASTIC SEDIMENTS.

Type.	Limiting dimensions (mm.)	Lithified Product
Coarse-grained clastics (Rudaceous Deposits).	Larger than 2mm.	Conglomerates, Breccias, Grits.
Medium-grained clastics (Arenaceous Deposits)	0.06 - 2mm.	Sandstones, Quartzitic sandstones, quartzites.
Fine-grained clastics		
a. Silt Deposits	0.004-0.06 mm.	Siltstones
b. Argillaceous Deposits.	smaller than 0.004 mm.	Shales.

III - PHYSICAL FEATURES.

A. Surface Relief

The country is one of high relief and the physiography is dependant on definite geological formations. Along the northern and western extremities of the area the hard, resistant felsite builds ridges having an average height of more than 4,000 feet above sea-level. Towards the south, southerly dipping rocks of the Waterberg System form a series of parallel escarpments and attain a maximum elevation of sbout 5,000 feet in the plateau region on Driefontein 339. Intervening

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between these two formations, the softer sandstone of the Loskop System forms a broad valley.

The elevation of Loskop Dam where it overflows is 3270 feet above sea- level.

B. Drainage.

The entire area is drained by the Olifants River and its tributaries. Much of the low-lying ground on the farms Vergelegen 93, Tweefontein 197, Weltevreden 103 and Fontein Zonder End 538 is flooded by the waters of the Loskop Dam, but, according to older maps (see Geological sheet 18 Moos River), the Olifants River originally meandered in a north- easterly to easterly direction across the valley and cut through the felsite ridges at the present site of the dam-wall. The Krantz Spruit flows northwards through the Waterberg and Loskop systems in the south-eastern portion of the area but swings abruptly west when it meets the barrier of felsite ridges.

The Olifants River is joined by many small streams originating as springs in the Waterberg System. In their descent to the valley they have cut deep and narrow gorges in the rocks of this system. Due to the reduced gradient at its point of departure from the area of high relief, the Krantz Spruit has deposited a large amount of flood debris at the foot of the mountains on Zeekoegat 89.

The drainage courses from the felsite ridges consist mostly of kloofs and gullies that carry water only for short periods during and after rains.

IV - GEOLOGICAL FORMATIONS.

The following geological formations are present in the area:

Tertiary and Recent deposits	Surface drift, soil and alluvium.
Waterberg System	Sandstone, quartzitic sandstone, quartzite, grit, sedimentary breccia, conglomerate, pyroclastic rocks and shale.
Rooiberg Felsite	Felsitic Lava, pyroclastic rocks, contemporaneous sediments.

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Intrusive Rocks

Pre-Loskop :	Granophyric Granite- porphyry
Post-Loskop:	Dolerite

V. - THE ROOIBERG FELSITE AND ASSOCIATED ROCKS.

A. DISTRIBUTION.

The Rooiberg felsites occupy the northern and western portions of the area under discussion. The succession consists of felsitic lava and interbedded pyroclastic rocks and sediments.

B. DESCRIPTION OF ROCK TYPES.

1. The Felsitic Lava:

The prevailing type of felsite is a hard dense, brick-red rock with splintery fracture but black and grey varieties are by no means uncommon.

In his treatise on the felsites and their relations in the Bushveld Igneous Complex, Lombaard (1932,pp. 157-159)distinguished four classes of felsite according to their structural and textural characteristics. The classification is summarised in table 2.

TABLE 2.

CLASSIFICATION OF BUSHVELD FELSITES.

Varieties	Non-porphyritic Felsite.	Porphyritic Felsite	Felsite with directed texture	Pyroclastic Felsite.
Phenocrysts	None	a. Albite b. Oligoclase		None
Types	a. Pseudospherulitic types b. Granophyric types c. Uniformly finegrained (glassy or felsitic) types		Trachytic, Flow-banded & Amygdaloidal varieties.	Volcanic breccia, Tuff.

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Except for trachytic and porphyritic varieties carrying phenocrysts of microperthite, examples of all the remaining felsites are found in the area under discussion. Lombaard's group of "pyroclastic felsites" are more aptly renamed "felsitic pyroclastic rocks" and are discussed under a separate heading.

Feldspar phenocrysts in porphyritic felsite are restricted to the range $Ab_{92}An_8$-$Ab_{84}An_{16}$ Twinning is common, mostly according to the albite law, less often the ala law.

a. Pseudospherulitic and pseudospherulitic granophyric felsite.

True spherulites are described by Rosenbush (1923, pp. 79-80) as consisting of radially arranged individuals of a particular mineral species. He separated from these his so-called "pseudosphärolithe" (pseudospherulites) which are radial aggregates of more than one mineral species e.g. quartz and feldspar. Lombaard (1932, p.157) noticed that the pseudospherulites in some felsites were often "imperfectly spherical and sometimes with a core of more granular quartz and feldspar" and when in addition whey were embedded in a granophyric instead of a felsitic base, the rock was termed a "speudospherulitic granophyric felsite"

A slightly porphyritic, brick-red variety of felsite from Zaagkuil 108 (Wo 25)* exhibits this texture very clearly (Plate 4A). The groundmass is a micrographic intergrowth of quartz and feldspar and contains many diversely orientated acicular microlites of quartz. Green chloritic material occurs as cores of the imperfectly developed pseudospherulites, as macroscopically visible phenocrysts and as shreds intimately mixed with the matrix.

A dark-grey amygdaloidal variety(Wo24) from Zeekoegat 89 shows a peculiar sponge- like network under the microscope (Plate 4B). The rudely spherical interspaces are translucent in ordinary light, and microcrystalline under crossed nicols. Under high magnification and convergent polarized light a few of these "spheres" exhibit feeble black crosses and in one specific case a truly pseudospherulitic texture. These spherical bodies are therefore all considered to be pseudospherulites.

* The numbers in brackets refer to samples collected by the author and now in possession of the Department of Geology, Pretoria University.

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The material forming the network and surrounding the pseudospherulites is brown, slightly granular and intimately mixed with green chloritic material. Untwinned plagioclase phenocrysts (average size 0.9X 0.35 mm.), quartz amygdules and large quantities of dark crystallites are also present. The feldspars have a compositon $Ab_{89}An_{11}$ and all are twinned according to the albite law. The crystallites swirl around the phenocrysts and amygdules but pass through the pseudospherulites in undisturbed flow-lines (Plate 4B).

Colony and Howard (1934,p.517) noticed that spherulites growing in menthol exert no push on obstacles in their path. So long as the menthol remains altogether liquid, microlites move toward the growing spherulite to be incorporated in it in haphazard arrangement. When the liquid becomes highly viscous, however, free movement of the microlites is prohibited and they are incorporated in the spherulite in the arrangement they possess when viscosity overtakes them.

In the case of the felsite just described, the spherulites can therefore be considered as having formed at a time when the lava was highly viscous; the crystallites were engulfed by the growing spherulite and exhibit a parallelism in their orientation in conformity with the flow.

Spherulites forming in an acid lava will in the nature of the case usually consist of quartz and feldspar in radial intergrowth. The remaining liquid surrounding the spherulites would therefore have become enriched in ferromagnesian components and being the last portion of the lava to solidify would probably have a slightly granular texture. Subsequent devitrification and chemical alteration partly destroyed the original truly spherulitic texture and resulted in the conversion of ferromagnesian minerals to chlorite.

The amygdules consist of recrystallized chalcedony still showing the original colloform structure and are surrounded by coronas of radially arranged quartz and feldspar intergrowths. The rock was probably subjected to metamorphic effects which caused the recrystallization of the colloidal silica filling the vesicles and also the devitrification of the rock itself. The amygdules then served as nuclei for the growth of a second generation of spherulites.

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A few grains, presumably olivine, were also encountered in this specimen. The small size of the grains did not permit the accurate determination of their optical properties and composition.

b. Granophyric Felsite.

Only two specimens of typical granophyric felsite were recognized under the microscope. Both are of a brick-red colour and contain phenocrysts of feldspar in a groundmass of quartz and feldspar micrographically intergrown (Plate 5A).

In the one sample (Wo22) collected from Zeekoegat 89, the feldspar phenocrysts are completely altered to sericitic material and the composition of the original mineral is only inferred from its crystal shape. In the other sample (Wo27) from Weltevreden 103 the feldspar is fairly fresh and often twinned.

Small phenocrysts of rhombic pyroxene are sometimes associated with the feldspar.

c. Uniformly fine-grained (glassy) felsites. (Plate 5B).

Owing to the extremely dense character of felsite in hand-specimen, it is impossible to state the relative abundance of the various types in the field but judging by the frequency with which the fine-grained types are encountered under the microscope, they seem to be the most widely distributed.

They are characterised by a "uniform felsitic or glassy texture, the absence of pseudospherulites and the only subordinate content in micropegmatite. As the micropegmatite increases, they go over into granophyric felsite. This type also includes the cases where the minerals are uniformly granular of fibrous without any orientation, so long as they are very fine in grain" (Lombaard, 1932,p.157).

The microcrystalline texture may be:

(i) Original, due to the rapid cooling of the lava, or

(ii) Secondary, due to the devitrification of a natural glass.

They often contain large numbers of incipient crystals and, like the two types of felsite already described, may be either porphyritic or non-porphyritic.

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d. Felsite with directed texture.

(i) Amygdaloidal varieties : They seem to prevail in the lower portions of the Rooiberg Felsite.

The amygdules occur in a groundmass that may exhibit any of the textures previously described.

Spherical amygdules vary in size from microscopic particles to individuals of 10 mm. diameter whereas pipe amygdules may be anything up to 20 mm. in length

The amygdules are mostly composed of quartz and ocasionally calcite or of both calcite and quartz in the same amygdule (Plate 6A).

(ii) Flow-banded varieties: They are present only in the upper portions of the felsitic lava at present exposed for example on Zeekoegat 89 and consist of alternating bands of microcrystalline and coarser-grained material that may exhibit a granophyric or spherulitic texture.

2. The Felsitic Pyroclastic Rocks:

Several discontinuous bands of pyroclastic rocks are present in the felsites east of the Loskop Dam-wall.

They occur either singly or associated with bands of quartzite.

A greyish-brown specimen (Wo 44) from Rietvallei 92 consists of angular felsite fragments of variable shape and size ($\pm \frac{1}{2}$ mm. to 5 mm.) in a greenish-grey, finegrained matrix. Microscopically, the rock contains in addition to the felsitic fragments, abundant sub-angular quartz grains (avge. diameter 0.25 mm.) and a subordinate amount of clastic feldspar (avge size: 0.25 mm in diameter)

The matrix reveals none of the cusp and lune textures commonly associated with volcanic dust, but it compares favourably with certain altered tuffs described by Pirsson (1915, p.207) in so far that between crossed nicols the matrix is composed of "a mosaic of feebly, polarizing particles producing a so-called 'pepper and salt' appearance". Furthermore, chemical alteration has given rise to "shreds of sericite, patches of carbonates and limonitic material"

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Two other samples (Wo 45/6) both greyish-green in colour and collected just south of the common boundary of Rietvallei 92 and Laagers-drift 82 were also examined. The angular shards are very well defined in polished sections but difficult to distinguish from the matrix under the microscope, both specimens being considerably altered. The shards are completely devitrified and contain quite considerable amounts of secondary epidote and green chloritic material. The brown, finely- comminuted matrix carries alteration products such as sericite, carbonate and chlorite and is heavily charged with magnetite dust. Other clastic material in evidence is subangular to angular quartz, quartzite and feldspar.

Vesicular glass shards are present in a dark, slate-grey tuff (Wo 67) from Zeekoegat 89. Although the vesicles are not consistent in shape, they neverthaless tend to be elongated, indicating a drawing out of the still plastic lava fragments that were blown into the air during the eruption.

T A B L E 3.

GRADE SIZE OF PYROCLASTIC ROCKS.

(Part of Twenhofel's (1939,p.291) modified version of the Wentworth and Williams classification of pyroclastics).

Dimensions, mm.	Fragments.	Lithified Products.
4 to 32	Small to medium lapilli	Fine- grained volcanic breccia
$\frac{1}{4}$ to 4	Coarse "ash"	Coarse-grained tuff
$\frac{1}{4}$ or less	Fine "ash"and dust	Fine-grained tuff

Each grade is composed of 50 percent or more of the dimensions indicated.

Although some of the shards are more than 20 mm. in diameter, the average size of the majority of fragments in the four specimens de-

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scribed above is between 2 and 4 mm. This places them in the class of course-grained tuffs (See table 3). Lithologically the three Rietvallei samples are "crystal-lithic tuffs", being a mixture of felsite, quartz and feldspar fragments whilst the Zeekoegat sample is a relatively pure "lithic tuff" consisting almost exclusively of lava fragments (Pirsson, 1915, p.193).

3. Contemporaneous sediments in the Rooiberg Felsite:

Interstratified bands of sediments, striking roughly east-west and dipping steeply to the south (Plate 6B) are present in the felsites along the northern boundary of the area. They are mostly reddish-brown, white, grey and dark-brown quartzite, sandstone and shale.

Detrital quartz is the predominant constituent, the remainder of the clastic material being chiefly composed of felsitic and feldspar fragments. Feldspar may occasionally be present to such an extent as to necessitate the classification of the rock as an arkose.

VI - CHEMICAL COMPOSITION OF FELSITE.

In view of the fact that felsites are extremely fine-grained rocks, it is not readily possible to record distinguishing mineralogical differences between them. For this reason chemical analyses are of special importance. In the circumstances all available chemical analyses of South African felsites are compared with those of a number of rhyolites of the Karroo System.

The analyses of three felsites, considered by Hall (1938,p.22) to be "less common Bushveld types" are shown in table 6. Actually specimen I from the Moos River valley, is now considered to be of pre-Witwatersrand age (Truter, 1949, p.liv), whereas Lombaard (1932,p.142) considers the other two from the Olifants River Tinfields, to be of the "Premier Mine Type": the rocks from both localities being "alike in texture, structure and mineral composition, as well as the quartz-pseudomorphs they possess". Their chemical similarity and position on the k-mg diagram (fig.4) seem to confirm this belief.

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TABLE 4.

CHEMICAL ANAYSES OF "PREMIER MINE TYPE" FELSITE.

	I	II	III	IV
SiO_2	77.78	75.13	77.05	72.66
Al_2O_3	8.81	9.96	10.12	10.20
Fe_2O_3	1.12	1.14	0.64	0.80
FeO	1.26	1.72	1.44	2.73
MgO	2.78	2.20	2.17	2.53
MnO	0.06	0.08	0.07	0.07
CaO	0.37	1.08	1.74	3.03
Na_2O	2.57	1.89	1.12	1.76
K_2O	3.48	3.57	3.97	3.45
H_2O+	1.10	1.96	1.03	1.23
H_2O-	0.09	0.07	0.04	0.05
TiO_2	0.52	0.20	0.55	0.45
P_2O_5	0.29	0.12	Nil	0.12
CO_2	-	1.22	0.29	0.54
	100.23	100.34	100.23	99.62

NIGGLI - VALUES

	I	II	III	IV
si	460	447	470.5	366
al	31	35	36.5	30
fm	37	33.5	30.5	34
c	3	7	11.5	16.5
alk	29	24.5	22	19.5
k	0.47	0.55	0.70	0.57
mg	0.68	0.59	0.65	0.66
al-alk	2	10.5	14.5	10.5

I Felsite, Doornkloof 431, Pretoria District (Lombaard 1932,p.142), Analyst: B. Lombaard.

II Felsite from the wall of Premier Mine (Lombaard, 1932,p.142). Analyst: B. Lombaard.

III Spotted felsite, Baviaanspoort 470 (van Biljon, 1949,p.126) Analyst: C.J. Liebenberg.

IV Grey felsite near right bank of the Hartebeest Spruit in the South of Kameeldrift 521 (van Biljon, 1949,p.126.)Analyst:C.J. Liebenberg.

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TABLE 5

CHEMICAL ANALYSES OF BUSHVELD FELSITES

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
SiO_2	73.84	72.6	72.81	74.58	67.77	70.19	72.03	72.50	68.25	71.35	71.33	74.00
Al_2O_3	9.56	11.9	11.97	11.11	12.60	12.05	11.30	12.40	11.15	10.15	13.26	12.45
Fe_2O_3	2.06	3.05	2.79	2.55	4.44	3.65	1.37	3.35	1.95	3.10	0.24	0.47
FeO	2.87	2.3	2.63	1.69	3.00	3.20	3.78	2.15	6.50	4.70	4.62	1.83
MgO	0.47	0.4	0.00	0.00	0.12	0.12	0.05	0.25	0.50	0.30	0.05	0.37
MnO	0.23	-	0.17	0.10	0.14	0.13	0.09	-	-	-	0.19	0.17
CaO	2.02	1.6	0.06	0.06	1.72	0.12	0.81	0.50	3.40	2.90	1.45	0.99
Na_2O	2.03	3.05	3.34	4.46	5.16	4.07	5.09	2.80	3.00	3.20	3.26	3.09
K_2O	4.70	3.65	5.31	4.76	3.82	5.02	4.50	4.70	4.05	3.60	3.88	4.93
H_2O +	1.03	0.7	0.64	0.53	0.39	0.31	0.66	0.75	0.05	0.30	0.89	0.39
H_2O -	0.15	0.1	0.09	0.08	0.05	0.05	0.08	0.2	0.05	0.30	0.43	0.13
TiO_2	0.35	0.3	0.68	0.50	1.15	0.70	0.63	0.20	0.50	0.30	0.39	0.48
P_2O_5	0.25	0.1	0.15	tr	0.12	0.13	0.08	0.10	0.35	0.00	0.13	0.09
CO_2	0.01	-	-	-	-	-	-	-	tr	tr	-	-
	99.57	99.75	100.64	100.42	100.48	99.74	100.47	99.90	99.75	100.20	100.12	99.44

Niggli-Values

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
si	418	385.5	401	429	297	350	367	399	294	339	372	433
al	32	37.5	39	37.5	32.5	35	34	40	28	28	40.5	42.5
fm	27.5	25.5	24	20	27	28	22	25.5	32.5	31.5	22	15
c	12.5	9.0	1	0.5	8	0.5	4	3	16	15	8	6.5
alk	28	28.0	36	42	32.5	35.5	40	31.5	23.5	25.5	29.5	36
k	0.60	0.44	0.51	0.42	0.32	0.45	0.37	0.52	0.47	0.42	0.44	0.51
mg	0.15	0.13	0.00	0.00	0.03	0.03	0.01	0.08	0.09	0.06	0.11	0.21
al-alk	4	9.5	3	-4.5	0	-0.5	-6	8.5	4.5	2.5	11.	6.5

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scribed above is between 2 and 4 mm. This places them in the class of course-grained tuffs (See table 3). Lithologically the three Rietvallei samples are "crystal-lithic tuffs", being a mixture of felsite, quartz and feldspar fragments whilst the Zeekoegat sample is a relatively pure "lithic tuff" consisting almost exclusively of lava fragments (Pirsson, 1915, p.193).

3. Contemporaneous sediments in the Rooiberg Felsite:

Interstratified bands of sediments, striking roughly east-west and dipping steeply to the south (Plate 6B) are present in the felsites along the northern boundary of the area. They are mostly reddish-brown, white, grey and dark-brown quartzite, sandstone and shale.

Detrital quartz is the predominant constituent, the remainder of the clastic material being chiefly composed of felsitic and feldspar fragments. Feldspar may occasionally be present to such an extent as to necessitate the classification of the rock as an arkose.

VI - CHEMICAL COMPOSITION OF FELSITE.

In view of the fact that felsites are extremely fine-grained rocks, it is not readily possible to record distinguishing mineralogical differences between them. For this reason chemical analyses are of special importance. In the circumstances all available chemical analyses of South African felsites are compared with those of a number of rhyolites of the Karroo System.

The analyses of three felsites, considered by Hall (1938,p.22) to be "less common Bushveld types" are shown in table 6. Actually specimen I from the Moos River valley, is now considered to be of pre-Witwatersrand age (Truter, 1949, p.liv), whereas Lombaard (1932,p.142) considers the other two from the Olifants River Tinfields, to be of the "Premier Mine Type": the rocks from both localities being "alike in texture, structure and mineral composition, as well as the quartz-pseudomorphs they possess". Their chemical similarity and position on the k-mg diagram (fig.4) seem to confirm this belief.

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TABLE 6.

CHEMICAL ANALYSES OF LESS COMMON BUSHVELD FELSITE

	I	II	III
SiO_2	72.75	73.85	74.05
Al_2O_3	11.45	11.85	11.70
Fe_2O_3	0.80	1.20	0.80
FeO	3.60	2.60	2.70
MgO	0.40	2.35	1.95
MnO	0.05	---	---
CaO	0.70	1.00	1.05
Na_2O	1.50	2.80	2.45
K_2O	6.90	2.10	2.55
H_2O +	1.50	1.30	1.35
H_2O -	0.15	0.25	0.15
TiO_2	0.35	0.25	0.25
P_2O_5	0.10	0.10	0.10
CO_2	0.30	0.05	0.60
	100.55	99.70	99.70

NIGGLI - VALUES

	I	II	III
si	413	394	417
al	38.5	37.5	39
fm	24	35.5	32.5
c	4.5	5.5	6
alk	33	21.5	22
k	0.75	0.33	0.41
mg	0.14	0.53	0.50
al-alk	5.5	16	17

I Black, slightly porphyritic felsite, Bloempoort 562, Pretoria District (Lombaard, 1931, p. 25). Analyst: H.G. Weall.

II Spherulitic silicified felsite, Kwaggafontein 531, Potgietersrust District. (Wagner, 1927, p.54). Analyst: H.G. Weall.

III Nodular silicified felsite, Salie Sloot 396, Potgietersrust District (Wagner, 1927, p. 54). Analyst: H.G. Weall.

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T A B L E 7

CHEMICAL ANALYSES OF ACID LAVAS FROM THE KARROO SYSTEM.

	I	II	III	IV	V	VI
SiO_2	68.93	72.83	72.05	68.94	71.41	66.40
Al_2O_3	12.56	11.60	12.79	11.60	13.94	12.91
Fe_2O_3	4.76	3.01	3.57	2.01	0.63	3.87
FeO	1.51	0.71	0.83	2.67	0.78	2.56
MnO	0.05	0.03	---	---	0.09	0.09
NgO	0.22	0.80	0.47	0.59	0.09	0.53
CaO	1.70	0.52	1.98	2.40	0.62	2.32
Na_2O	3.39	2.19	2.60	2.41	3.75	3.30
K_2O	4.52	6.00	4.46	4.31	4.74	3.09
H_2O +	0.98	1.29	} 0.95	} 4.95	4.09	3.16
H_2O -	0.05	0.43	}	}	0.34	1.09
TiO_2	0.42	0.29	---	---	0.01	0.54
P_2O_5	tr	0.05	---	---	tr	0.16
CO_2	0.84	0.00	---	---	---	---
Ce earths	---	---	---	---	tr	---
	99.93	99.65	99.70	99.88	100.49	100.02

NIGGLI - VALUES

	I	II	III	IV	V	VI
si	334.7	450.4	376.5	359	425	315.5
al	35.9	41.9	39	35.5	48.5	36
fm	25.3	17.9	21.5	24.5	8	28
c	8.8	3.5	11	13.5	4	11.5
alk	29.9	36.7	28	26.5	39.5	24.5
k	0.47	0.65	0.53	0.54	0.45	0.38
mg	0.06	0.29	0.17	0.19	0.09	0.13
al-alk	6.0	5.2	11	9	9	11.5

I Rhyolite, red porphyritic, near railway milestone 55¾, Komatipoort.(Lombaard. 1952,p.195). Analyst: W.H. Herdsman.

II Rhyolite, Nuanetsi River, Southern Rhodesia (Lightfoot, 1938,p.195). Analyst: E. Golding.

III Rhyolite (Quartz-Porphyry), Lebombo (Hall, 1938,p.23). Analyst: ?

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IV Pitchstone, Lebombo. (Hall, I938, p.23). Analyst: ?

V Rhyolite, Manuan Creek, Lebombo. (Hall, I938, p.26). Analyst: G.T.Prior.

VI Glassy rhyolite, Indulawane Mill, Lebombo (Hall, I938, p.26). Analyst: G.T.Prior.

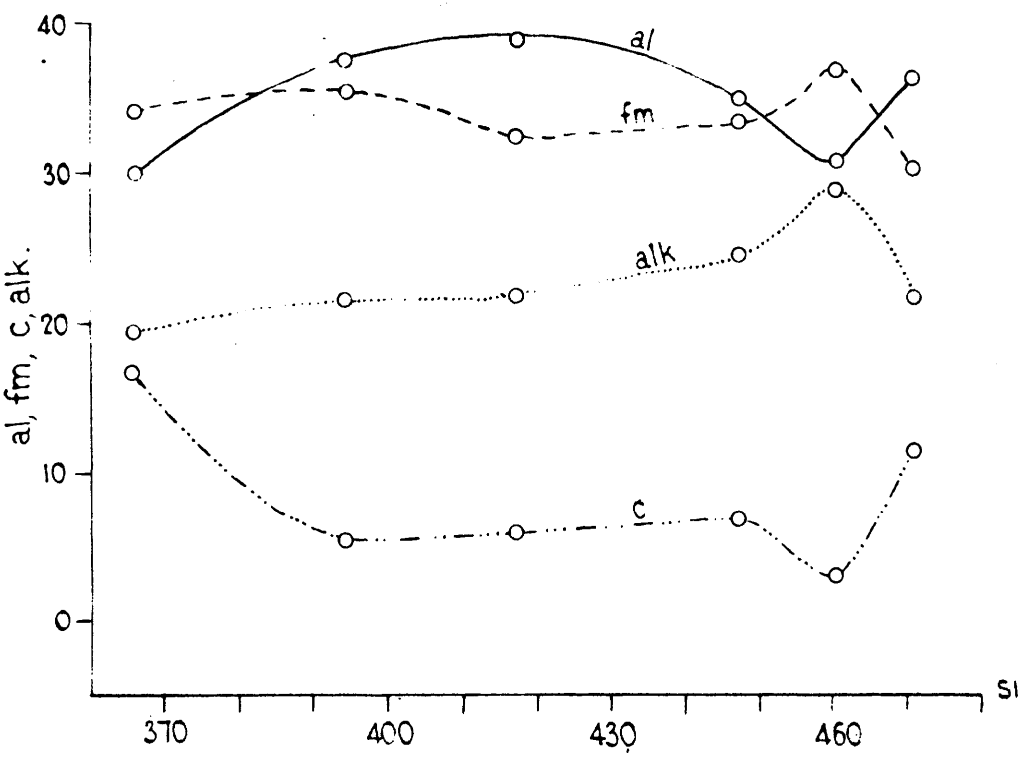

Fig. 1 :- Variation in Niggli - values of "Premier Mine Type" Felsite

In order to obtain an overall picture of the chemical analyses, diagrams have been constructed after the methods of Niggli. (See figures 1-4).

The following conclusions can be drawn from the chemical composition of the rocks given in tables 4 to 7.

I. Chemically the typical Bushveld Felsite closely resembles the Karroo Rhyolite but differs noticeably in its mg-value from the "Premier Mine Type" (P.M.T.) Felsite (See fig. 4).

2. In the case of the Karroo Rhyolite al and alk vary more or less sympathetically and tend to increase with increase of si. In contrast fm and c decrease with increase of si and are in antipathetic relationship to al and alk. These are normal

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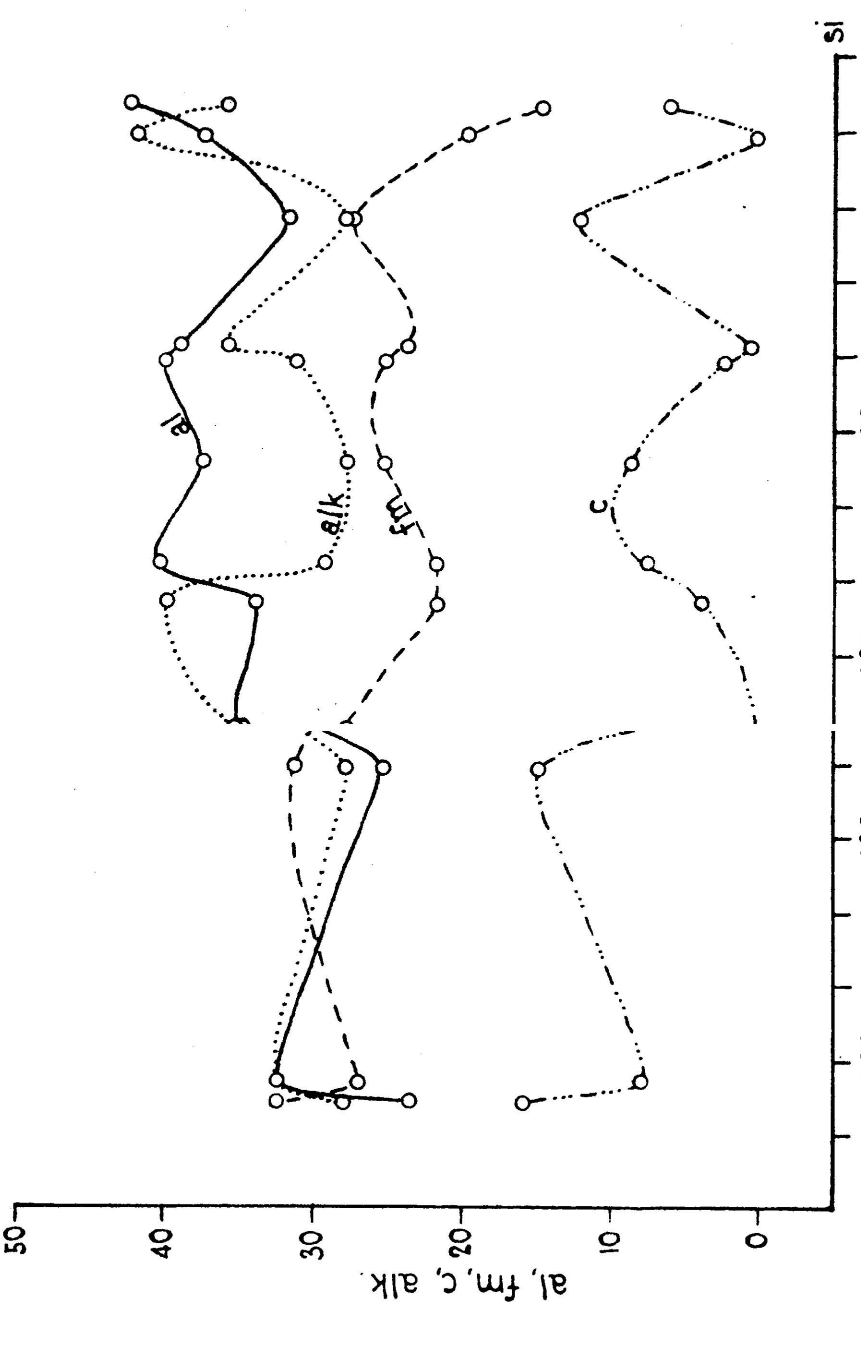

Fig. 2 :- Variation in Niggli -lues of Bushveld Felsite

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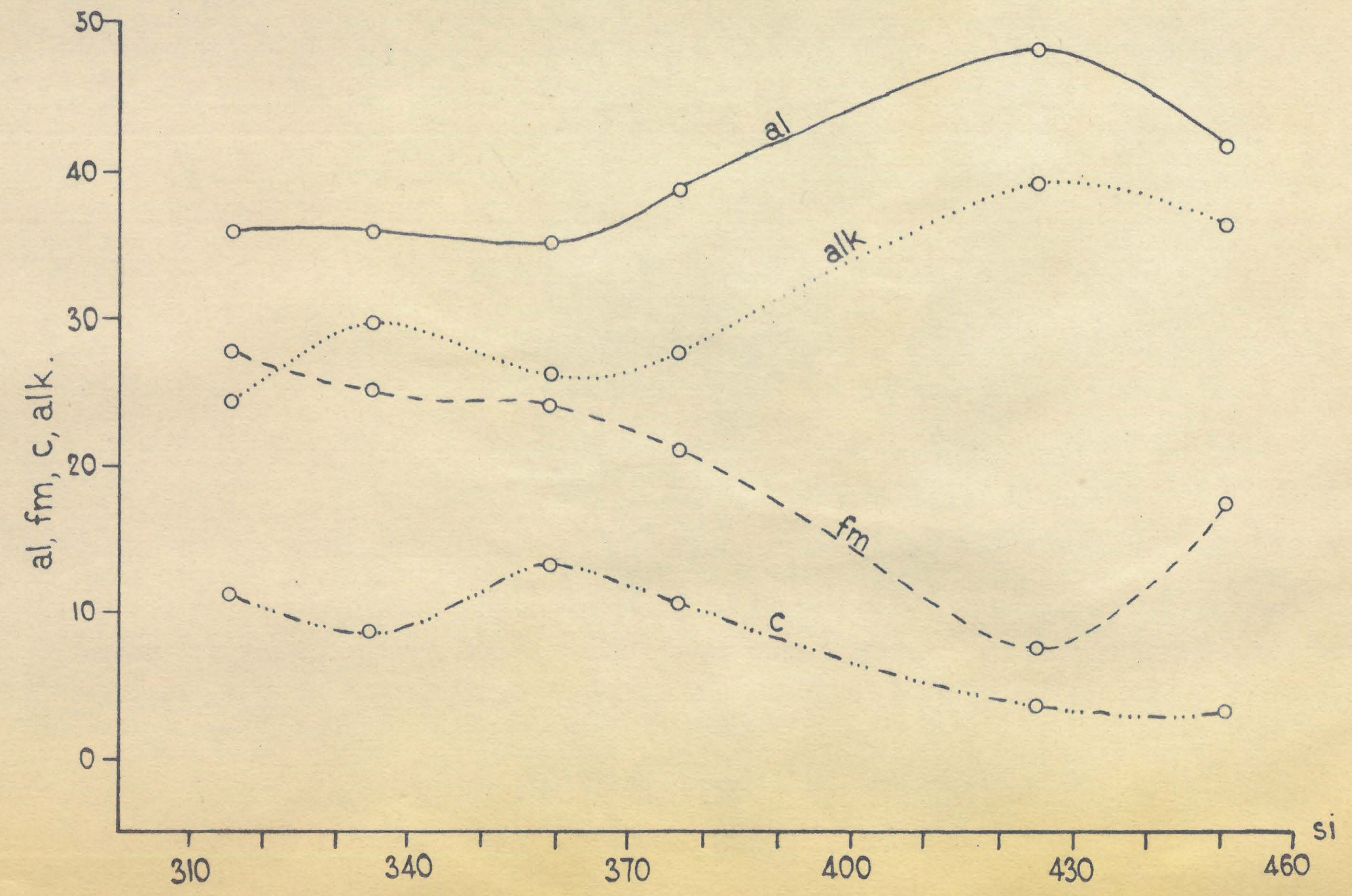

Fig. 3:- Variation in Niggli - values of Karroo Rhyolite.

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differentiation trends indicating a decrease in femic and calcic constituents with increase in silica.

3. Although the al, alk, c and fm curves of the typical Bushveld Felsite are complicated by fluctuations, their general trend is similar to those of the Karroo Rhyolite The latter differs from the Bushveld Felsite mainly in having higher al and lower fm- values. On the other hand alk and c appear to be of much the same order in both rhyolite and felsite.

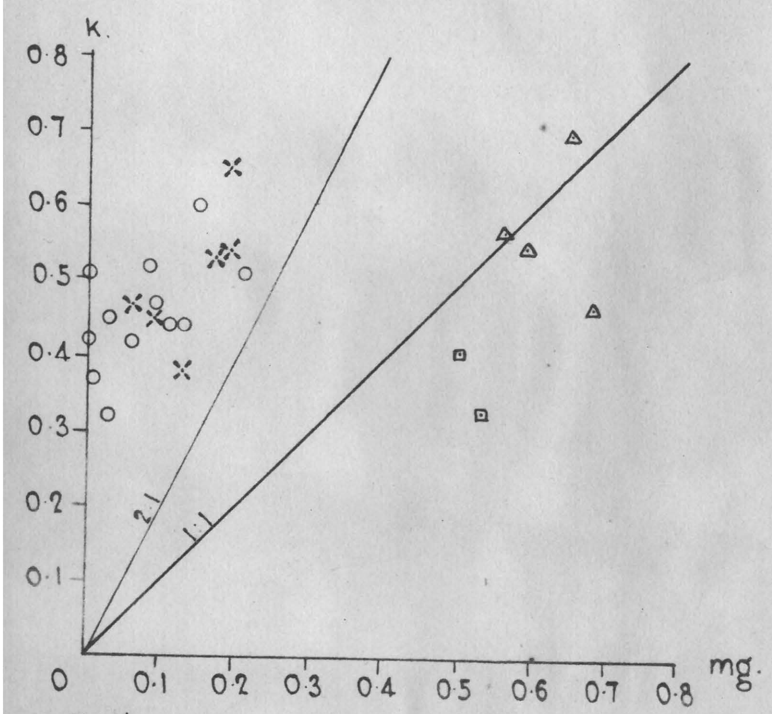

Fig. 4 :- k-mg Diagram for various felsites and Karroo Rhyolites. (O=Bushveld Felsite, Δ=PMT Felsite; X=Karroo Rhyolite; □=Felsite from Olifants River Tinfields)

4. The P.M.T Felsite has even higher fm values than the Bushveld Felsite but the alk values are much lower. The c-values appear to be slightly higher in the case of the P.M.T. Felsite while the al values in both cases are more or less the same.

5. Chemically the P.M.T. Felsite can best be distinguished from the Bushveld Felsite and Karroo Rhyolite by means of the k-mg diagram (fig. 4). The ratio k to mg is always more than 2 to 1 for Bushveld Felsite and Karroo Rhyolite and approximately equal to or less than 1 to 1 for the P.M.T. Felsite.

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The latter also generally seems to have an al-alk value in excess of 10 whereas the corresponding value for the Bushveld Felsite is usually lower than 10. The Karroo Rhyolite is not restricted to these limits and may have an al-alk value either higher or lower than 10.

6. Microscopically the P.M.T. Felsite differs mainly from the Bushveld Felsite in that it contains the peculiar pseudomorphous quartz plates described by Lombaard (1932 pp. 131 and 135). The presence of a pebble of such a pseudomorphous quartz plate bearing felsite in a grit of the Waterberg System (see page 27) definitely proves the Pre-Waterberg age of this rock-type and therefore presumably too the P.M.T. Felsite.

7. The k-value of the felsite from Zaagkuil 108 (1,table 5) is the highest obtained so far for any normal Bushveld Felsite. The norm of this rock is as follows:

quartz		39.22
orthoclase		27.80
albite		17.29
anorthite		3.06
	($CaSiO_3$	2.09
diopside	($MgSiO_3$	0.60
	($FeSiO_3$	1.58
hypersthene	($MgSiO_3$	0.60
	($FeSiO_3$	1.85
magnetite		3.02
ilmenite		0.61
Apatite		0.67
calcite		tr
water		1.18
		99.57

C.I.P.W. Symbol; I (II).3.1 (2).(2)3

Niggli values of this rock are shown in table 4. The magma-type (Niggli, 1936,pp.342) is si-syenitegranitic

VII - THE LOSKOP SYSTEM.

The Loskop System occurs as a belt of sediments, approximately 3,500 feet thick, stretching from Hondekraal 114 in the south- west to Zeekoegat 89 in the east, as indicated on the occompanying geological map (Plate1)#. The change in strike from east-west to north-east-south-west is

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accompanied by a considerable decrease in dip and a concomitant increase in surface width.

Owing to the homogeneity and apparently identical dip and strike of the Loskop and Waterberg strata in the area under discussion, there was no direct means of determining the contact between the two systems.

On a portion of the farm Hondekraal 114, beyond the south-western boundary of the geological map, the eastern flank of a truncated anticline, comprising the uppermost beds of the Loskop System (see Truter 1949,p.lxvii) runs obliquely across a prominent scarp of the Waterberg System. The anticline levels out in an easterly direction at the base of the mountain where the Loskop beds become normal and undisturbed. At this point the unconformable relationship between the Waterberg and Loskop systems disappears and the contact between the two systems is continued toward the east, into the area under review, as a conformable one. The boundary between the Loskop and Waterberg systems has therefore been extrapolated from the area of the unconformity on Hondekraal 114. It runs near the base of the scarp of the Waterberg System which flanks the prominent valley of the Olifants River and Krantz Spruit. This valley has originated by the weathering of the rocks of the Loskop System which is mostly soft, often feldspathic sandstone. An impersistent conglomeratic zone, forming the base of the Waterberg System, also assists in locating this inferred physiographical as well as geological boundary.

The area occupied by rocks of the Loskop System may be divided into an eastern sector and a western sector. The system commonly commences with an intermittent band of conglomerate developed mainly on the farms Groenvallei 113 and Rhenosterhoek 106 west of Loskop Dam and on Zeekoegat 89 at the eastern boundary of the area. Occasionally a thin band of shale is present just below the conglomerate. The shale may also occur singly at the base of the System if the conglomerate band is absent. The outcrop of conglomerate on Zaagkuil 108 ends abruptly against felsite owing to a dip fault. The pebbles everage 3 or 4 inches in diameter but spherical and ellipsoidal boulders up to 8 inches in diameter are common.

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A. THE EASTERN SECTOR.

It includes all rocks of the Loskop System east of the dam. They are intensely cross-bedded, dip southwards at high angles (Plate 7A) and for the most part form a narrow flat valley.

At the base of the felsite ridges and following on them in a southernly direction a reddish-brown conglomerate (Plate 7B) composed solely of felsite pebbles set in a sparse, fine-grained matrix, represents the basal zone of the Loskop System. A band of reddish-brown shale overlain by conglomerate, crops out in a small kloof just north of the point where the Krantz Spruit swings directly west.

The valley floor of the Krantz Spruit is covered with a deep sandy soil and outcrops are virtually restricted to the bed of the Spruit. They consist almost exclusively of an intensely cross- bedded purplish-brown uniformly graded sandstone, the average diameter of the grains being 0.33 mm. The predominant allogenic constituents are quartz and felsite while plagioclase and potash feldspar grains occur in subordinate quantity. The cement is sericitic and contains flakes of secondary muscovite and ragged grains of opaque ore.

B. THE WESTERN SECTOR.

The strata in this sector have a moderate dip, exhibit practically no cross-bedding and occupy a broad valley studded with numerous koppies.

1. Rudaceous deposits.

A dark-brown, sandy matrix and the presence of white quartzite pebbles in addition to those of felsitic origin characterise this conglomerate in contrast to that of the eastern sector which is almost free of groundmass and contains only felsite pebbles. The quartzite pebbles are composed of material similar in appearance to the quartzite of the Magaliesberg Stage of the Pretoria Series (See Truter, 1949, p. lxvi).

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The only other rock-type representative of course-grained clastics is an isolated patch of purplish grit near the common boundary of Groenvallei 113 and Hondekraal 114.

2. Arenaceous deposits.

They form the bulk of the rocks of the Loskop System, the general type being a medium-grained sandstone (Plate 8A). Colours vary from white to grey and from purple to reddish-brown.

The allogenic constituents are predominantly quartz and lesser quantities of felsitic lava, chert and felspar. Marked strain shadows are common to the quartz grains. Grading in most cases is fairly uniform, the average grain size being between 0.3 and 0.4 mm. in diameter. The majority of grains are angular to subangular. Well-rounded grains are rather exceptional. The cementing medium consists of sericitic or argillaceous material which may surround individual grains either completely, or partly when the latter occur in clusters. The sandstone is termed quartzitic when the majority of grains become mutually interferent with one another thus forming the characteristic mosaic pattern. The authigenic constituents are chloritic material, opaque ore, calcite and epidote.

3. Fine-grained deposits (shale and siltstone).

They are sparingly present in the Loskop System and occur most frequently at or near its base.

The shale consists of sericitic and other argillaceous material containing numerous scattered quartz grains.

The siltstone has well-developed bedding planes and is composed of approximately equal quantities of clastic grains and cement. Owing to its fine-grained character, the matrix is difficult to identify. The detrital material is largely sub-angular quartz grains

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of which the individuals are completely surrounded by the cementing medium. Grading is uniform and the average grain size is 0.005 mm. in diameter.

VIII - THE WATERBERG SYSTEM

Composed of a great thickness (approximately 6,500 feet) of well-bedded quartzose rocks, the Waterberg System as shown on the accompanying map (Plate 1), is the northern extension of the synclinal basin of Waterberg beds which cover a large area on the adjoining Middelburg sheet.

In the south the beds are almost horizontal but the dip increases rapidly towards the north.

Lithologically the Waterberg System comprises sandstone, grit, quartzitic sandstone, quartzite and to a lesser degree conglomerate, sedimentary breccia pyroclastic material and shale. The prevailing colours are purplish and reddish-brown and less commonly white, grey, yellowish and orange.

1. Rudaceous Deposits.

An impersistent conglomerate band frequently indicates the base of the Waterberg System (Plate 8 B). The pebbles, composed of white and grey quartzite and reddish-brown felsitic lava are closely packed together and very little of the matrix is in evidence. The latter is a dark, ferruginous, sandy material that weathers out readily.

Two additional conglomeratic zones are found higher up in the succession. They do not have a particularly widespread distribution but rather appear to be a series of lenticular washes.

The one zone is situated well below a prominent diabase sill. Outcrops are chiefly located near the Hartebeestplaats 85 Trigonometrical Beacon (Ha-at 85) and south of the common boundary of Welgevonden 114 and Voetpadskloof 187. A hard, reddish-brown sedimentary breccia is associated with the latter occurrence. It consists almost entirely of angular fragmental material but eventually passes laterally into a small pebble conglomerate.

The other conglomerate zone is above the diabase and is confined

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to the scarp and plateau regions east, north and north-west of the Voetpad N. Trigonometrical Beacon (Vo-ad N.331). The pebbles consist of quartzite, felsite and chert and may either be well rounded or may show only a slight degree of attrition. The matrix is more often sandy than gritty or quartzitic. Differential weathering of this sandy matrix and local accumulation of the pebbles result in numerous patches of loosely strewn pebbles and boulders along the scarp.

Grits are widely distributed throughout the Waterberg System. Mixed grading is evident in all specimens and particles vary from approximately 0.002 mm. to about 5 mm. in diameter; the majority of grains being between 2 and 3 mm. The bulk constituent is quartz, rounded to sub-angular in shape. Inclusions, undulose extinction and secondary outgrowths are frequently characteristic of the quartz grains. The remainder of the detrital material consists of quartzite, chert, felsite, muscovite or may be of unusual composition such as graphic granite, quartz schist and recrystallized chalcedony. Of particular interest is a pebble of the "Premier Mine Type" Felsite in a sample collected in Kliprivier 88. The identification is based on the presence of peculiar pseudomorphous quartz plates (Plate 9 A). Daly (1928, p.757) called these quartz plates "clear cut pseudomorphs after feldspar" and Wagner (1927, pp.52 and 54) suggested a similar origin for them in felsite from the Stavoren Tin Mining area. Lombard (1932, p.141) considered them to be pseudomorphous after some mineral which was "markedly out of equilibrium with conditions which prevailed later" (i.e. conditions which prevailed during hybridisation of the magma) and mentions biotite or partially grown feldspar as minerals that could possibly have been replaced by quartz.

In a recent publication, Wager, Weedon and Vincent (1953) describe a granophyre from Coire Uaigneich, Isle of Skye, containing phenocrysts which were found to be quartz paramorphs after tridymite (p.267). These former tridymite phenocrysts are remarably similar to the quartz plates of the "Premier Mine Type" felsite. In both cases, the phenocrysts have a plate-like form and are composed of many individual

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quartz grains. The phenocrysts of the Skye granophyre however, average 0.5 mm. in length and are generally smaller than those of the felsite which vary in size in different specimens. Some of the quartz plates described by Lombaard (1932, p.131) range in length up to 8 mm. whereas others never exceed 1.5 mm. in length.

Other rudaceous deposits evident in the Waterberg System are thin pebble washes parallel to the bedding planes of the sandstone in the southern plateau region. The sub-angular to rounded pebbles are of felsite, quartzite, vein quartz and various kinds of chert and jasper.

2. Arenaceous deposits.

The sandstone of the Waterberg System differs very little from that of the Loskop system. In view of the general petrographic description that has already been given of the latter, it will suffice to add that the grading of detrital material in the Waterberg Sandstone is not as uniform as in that of the Loskop System. Moreover, although sericitic material is still the prevailing cementing medium, limonitic and especially siliceous varieties are much more in evidence in the sandstone of the Waterberg System.

The quartzitic sandstone, towards the southern boundary of the area, is frequently studded with isolated pebbles of the same composition as those of the pebble washes. Quartzite is chiefly restricted to the lower portions of the Waterberg System. Their absence from the upper strata seems to indicate that load metamorphism could have been largely responsible for the conversion of sandstone to quartzite. Two kinds, namely metamorphic and sedimentary quartzite are distinguishable under the microscope. In the metamorphic quartzite a complete recrystallization of the quartz grains has taken place, resulting in "a homogeneous, quartzose rock of mutually interferent quartz pellicles" (Milner, 1952, p.370). In the sedimentary quartzite the individual grains are firmly cemented by secondary silica which is often in optical continuity with the enclosed grain. (Plate 10 A).

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3. Argillaceous Deposits.

Purplish and grey shale occurs as thin impersistent bands intercalated with the coarser-grained sediments. The most prominent outcrops are on Zeekoegat 89 and Kluitjiesfontein 369. They occupy a valley-like depression between ridges of sandstone. The shale outcrops over the rest of this depression are either covered by soil and talus or else the shale has transgressed laterally into a soft, friable, reddish-brown sandstone which occurs frequently towards the west.

Thin bands of shale, usually not exceeding 2 inches in thickness, are found higher up in the succession and ocassionally grade downwards through sandstone into grit.

4. Pyroclastic Rocks.

On Polfontein 272 a zone of intensely folded Waterberg sediments associated with volcanic breccia, is sandwiched in between undisturbed, gently-dipping beds of sandstone and grit. The locality is readily identified from the main road between Middelburg and Groblersdal by a conspicuous hillock east of milestone 23. (Plate 10 B). The small area over which the disturbed strata and pyroclastic rocks are distributed, was mapped on a 1:2000 scale (see plate 2). The elevation of the lowest point on the map was arbitrarily taken as zero and contour-lines mapped in at 10 ft. intervals. The disturbed rock is a reddish-brown, blotchy sandstone composed of subangular quartz grains and minute fragments of devitrified volcanic glass. The rock is coarse-grained and poorly graded (diameter of grains varies between 0.06 mm. and 1 mm.) There is sometimes a complete absence of bedding planes, especially in the rocks composing the hillock and in such cases bedding orientation could not be determined. Cream coloured patches or blotches in the sandstone denote areas where leaching of the reddish-brown, ferruginous cement has taken place.

Owing to the general disturbed character of the surrounding rocks, the relationship of the pyroclastic material in the field is not always clear. Some occurrences are presumably interbedded with the aqueous

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sediments. The one occurrence through which the profile passes, is roughly elliptical in outline and is clearly transgressive to the bedding of the surrounding sandstone. It probably represents a centre of eruption.

The pyroclastic rocks are chiefly made up of angular fragments of bluish grey glass set in a hard purplish matrix also exhibiting irregular, leached reddish and yellowish patches. The size of the fragments varies considerably and although some are more than 40 mm. in length, the majority seems to fall between the limits of 1 and 4 mm. Following Twenhofel (1939, p.291) the rock is designated a coarse-grained tuff.

Under the microscope the fragments appear as angular glass shards (Plate 11 A), the majority of which hardly show any reaction towards polarized light. Devitrification has in some cases produced a microcrystalline granular or spherulitic texture. Slightly elongated vesicles in some of the shards (Plate 11 B) prove almost beyond doubt their volcanic origin.

Subangular quartz, varying between 0.05 mm. and 2 mm. in diameter and sometimes poikilitically enclosing biotite, is the other major clastic constituent. The matrix is optically inert and appears to be ultra-fine volcanic dust. It is usually partly replaced by limonite. The shards contain many quartz inclusions that have an average diameter of approximately 0.04 mm. The origin of these inclusions may be two-fold:

a. Phenocrysts of quartz formed during an early stage of consolidation of the magma may have provided the material. During the explosion of the volcano they might have been comminuted and ejected to the surface, being ultimately enclosed in fragments of lava.

b. They may represent remnants of the country rock through which the vent has been drilled.

To conform to the requirements of the first possibility, even an acid magma would have to be exceptionally rich in silica if quartz was

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to crystallize in such large quantities at such an early stage of consolidation. Moreover, in view of the complete absence of crystal form amongst the quartz inclusions and also in view of the highly quartzose nature of the surrounding rocks, it seems more reasonable to assume that the inclusions were derived from the country rock.

A dyke, approximately 18 inches in width and consisting of numerous colourless microlites in a matrix of dark, opaque ore, cuts through both the folded and the undisturbed strata.

That volcanic activity was contemporaneous with the deposition of the sediments is proved by the mixing of pyroclastic and sedimentary material and the subsequent unconformable covering of the folded strata by normal, gently-dipping beds. (See profile, Plate 2).

The axial planes of the folds have a general north-easterly strike. One would rather expect a more haphazard or perhaps even a concentric arrangement if the folding was accomplished solely by the explosive force of a volcano. It is possible that at the onset of volcanicity, tectonic disturbances might locally have tilted the strata. Reposing on this sloping floor, unconsolidated sediments were in process of deposition. Near their angle of rest, these sediments would be liable to become unstable and resort to subaqueous slumping. The direct result of this would be "complex deformation of the slumped mass, unconsolidated water-saturated beds and consolidated material yielding in different ways. The unconsolidated superficial sediments are highly plastic and are thrown into involved fold structures, while the underlying beds which have been partially consolidated show less complex folding, minor thrusting and in some cases brecciation." (Hills, 1940, p.15). It can be visualized that such a mass of unconsolidated sedimentary material moving downwards on a sloping surface, will tend to have parallel fold axes. The ejection of pyroclastic material took place at the time of slumping. During this brief period of volcanicity deposition of the sediments proceeded without interruption. Sand mingled with the products of explosion and could even have come to fill up the open vent or conduit. With the

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cessation of volcanic activity and slumping the disturbed area was unconformably covered by normal sedimentary strata. The main centre of eruption need not have been in the area investigated or could have been covered up by later Waterberg beds. Evidence of volcanic activity of Waterberg age is also known from Doornkop 506 along the Little Olifants River (Truter 1949, p.lxix).

IX - HEAVY MINERAL ANALYSES

A. LOSKOP AND WATERBERG SYSTEMS

The Waterberg System reposes unconformably upon the Loskop System. As mentioned previously, the nature of the contact is disconformable on the farm Hondekraal 114, south-west of Loskop Dam, whereas in the area under discussion, it is nonconformable. Boswell (1916, p.164) states that "unconformities are usually emphasized by the changes in mineral composition and these support palaeontological and field evidence." With this in mind, heavy mineral concentrates from sandstone of the Loskop and Waterberg systems were investigated in order to determine whether there were sufficient differences to demarcate the Loskop System from the Waterberg System on petrographical data.

The differentiation or correlation of strata by means of their heavy minerals is based on the degree of similarity between the heavy mineral suites - "great similarity leading to the inference that the same cause has been at work in the two or more samples and dissimilarity implying independent (and thereby, in a single basin of deposition, non-synchronous) origin" (Dryden, 1935, p.396).

Samples could not be collected in a traverse straight across the Loskop System from top to bottom, owing to lack of continuous outcrops, but by lateral off-sets a complete traverse was possible.

All samples were restricted to the arenaceous sediments which are the most suitable rocks for heavy mineral investigation. Samples from the Loskop System are numbered L.1 to L.8 and those from the Waterberg System W.1 to W.8 in ascending order.

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T A B L E 8

CHARACTERISTICS OF HEAVY MINERALS FROM THE LOSKOP AND WATERBERG SYSTEMS

		SAMPLE NO.	L.1	L.2	L.3	L.4	L.5	L.6	L.7	L.8	W.1	W.2	W.3	W.4	W.5	W.6	W.7	W.8
ZIRCON	Colour	Colourless	973	921	972	944	950	933	983	964	904	870	928	959	875	725	779	955
		Brown, Yellow	18	79	8	48	50	56	14	36	84	70	52	41	75	125	191	0
		Opaque	9	0	20	8	0	11	3	0	112	60	20	0	50	150	30	45
	Shape	Rounded	625	954	980	972	982	967	984	968	988	1000	984	987	1000	975	926	993
		Angular	45	46	20	28	18	11	8	28	12	0	4	0	0	8	74	7
		Idiomorphic	330	0	0	0	0	22	8	4	0	0	12	13	0	17	0	0
	Zoning	Zoned	801	675	699	670	612	674	625	426	432	551	560	397	310	312	394	303
		Non-Zoned	199	325	301	330	388	326	375	574	568	449	440	603	690	688	606	697
OTHER MINERALS		Rutile per 1000 Zircons	21	28	40	28	62	11	14	18	52	0	20	67	50	8	103	7
		Titanite per 1000 zircons	9	0	616	404	397	0	0	0	0	0	0	0	0	0	0	0
		Tourmaline per 1000 zircons	0	0	5	4	0	0	0	4	0	0	0	0	0	0	15	0
		Apatite per 1000 zircons	0	0	0	36	0	0	0	0	0	0	0	14	0	17	15	25
			LOSKOP SYSTEM								WATERBERG SYSTEM							

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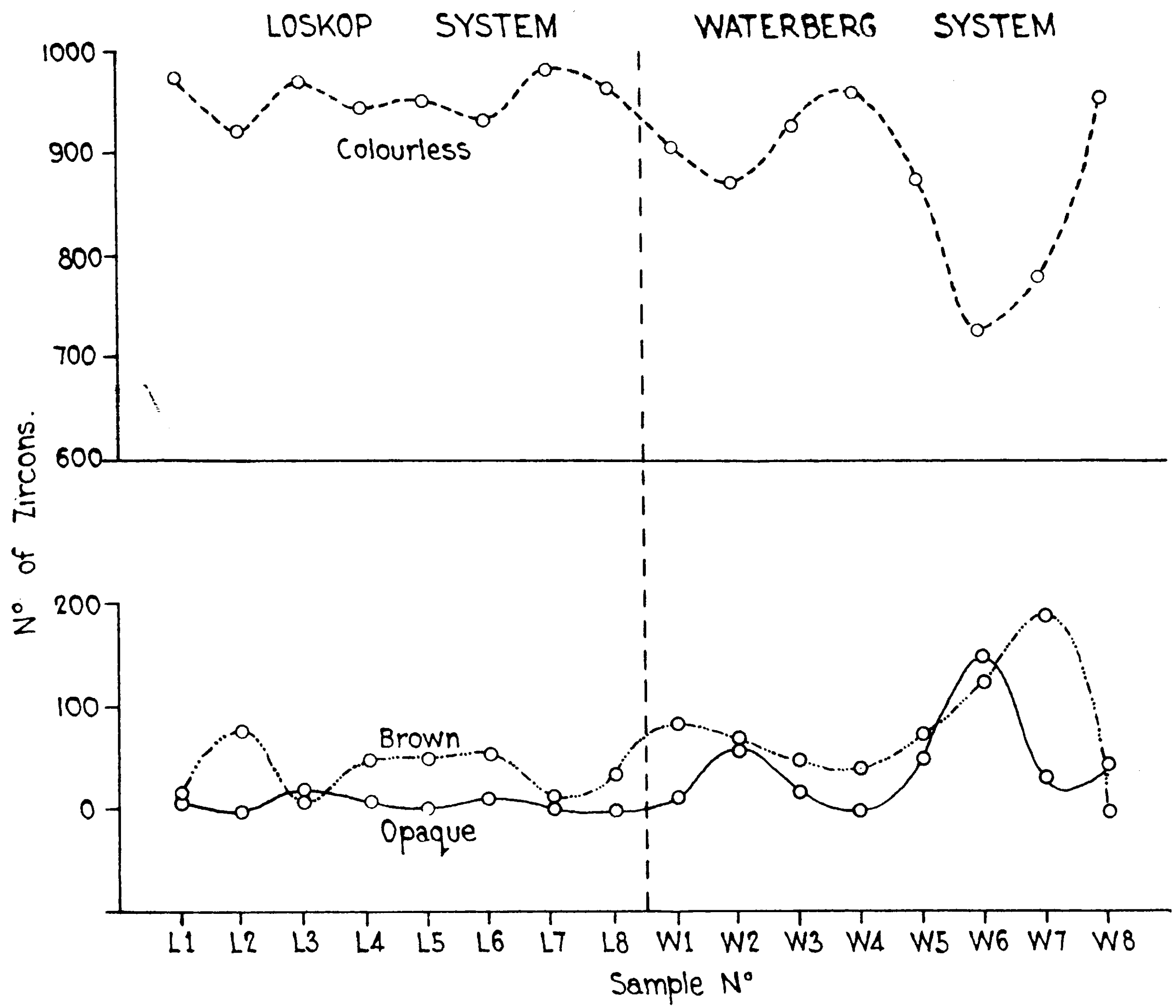

Fig. 5 :- Variation in number of colourless, brown & opaque Zircons per 1000 grains.

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Rocks from which heavy minerals were to be separated were crushed to pass through a 200 mesh Tyler sieve and the dust then removed by washing and decanting. The residue was boiled for approximately 20 minutes in 1:1 dilute hydrochloric acid in order to remove limonite stains on mineral grains, excess ferruginous material and iron particles derived from the mortar. The drastic acid treatment was resorted to after a brief preliminary survey of the heavy minerals present revealed the absence of species likely to be affected by the acid. Heavy minerals were separated from the crushed rock with bromoform, washed with alcohol and dried. The concentrate was then split into a magnetic and a non-magnetic fraction by means of an electromagnet in order to remove as much as possible of any ore still present at this stage. The non-magnetic fractions were mounted in canada balsam for microscopic examination.

The non-magnetic heavy mineral concentrates are chiefly composed of zircon, rutile and titanite grains, of which zircon forms the bulk constituent. The different heavy mineral species will be desribed separately.

1. Zircon

The classification of the zircons is based on variations in colour, shape and zoning of the grains. The total number of zircon grains counted per sample, usually between two and three hundred, has in each case been recalculated to a total of one thousand.
The results obtained are shown in Table 8.

Figure 5 shows the variation in the number of colourless, brown and opaque zircons per thousand zircon grains in the different samples.

The number of colourless grains in samples of the Loskop System fluctuates around the 950 mark, decreases to 904 in the first sample of the Waterberg System, to 870 in the second and thereafter increases to 959 in sample W.4. There is a considerable decrease of colourless zircons in the next two samples (W.5 and W.6) and at the same time a corresponding increase in the number of brown and opaque varieties. This is followed once more by an increase of the colourless grains and a total of 955 is reached in sample W.8.

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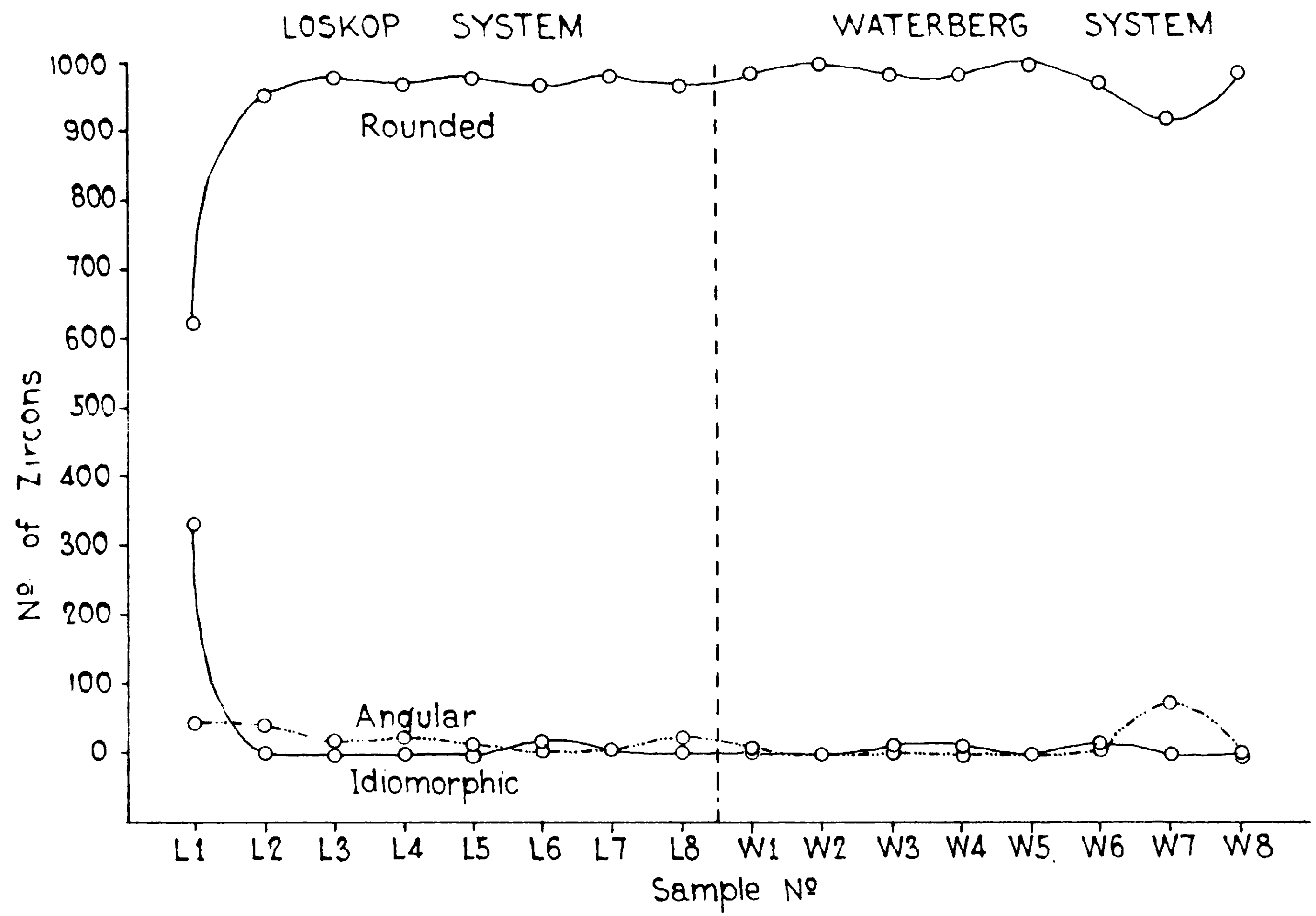

Fig.6:- Variation in number of rounded, angular and idiomorphic Zircons per 1000 grains.

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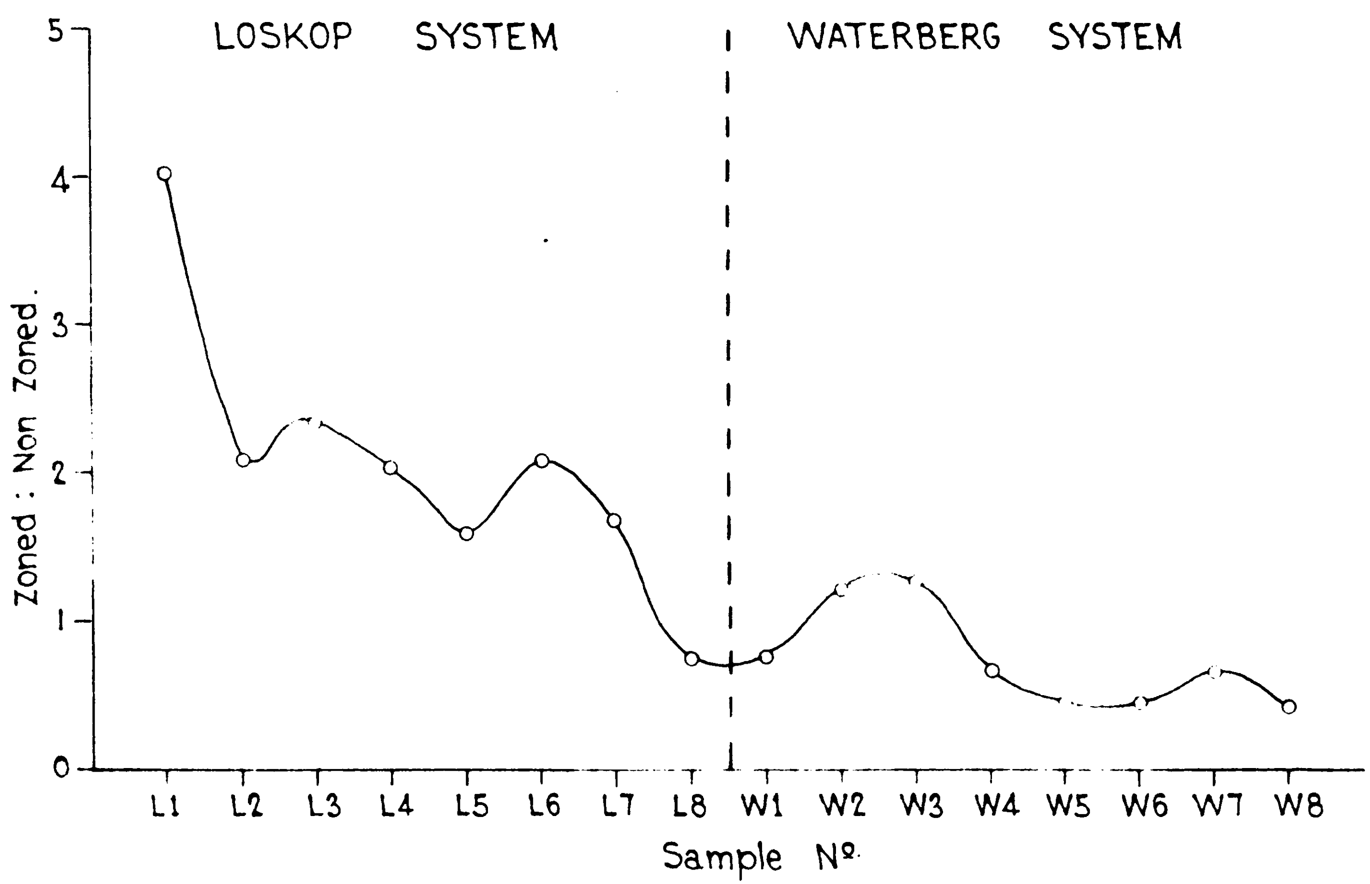

Fig. 7:- Ratio of Zoned to Non-Zoned Zircons

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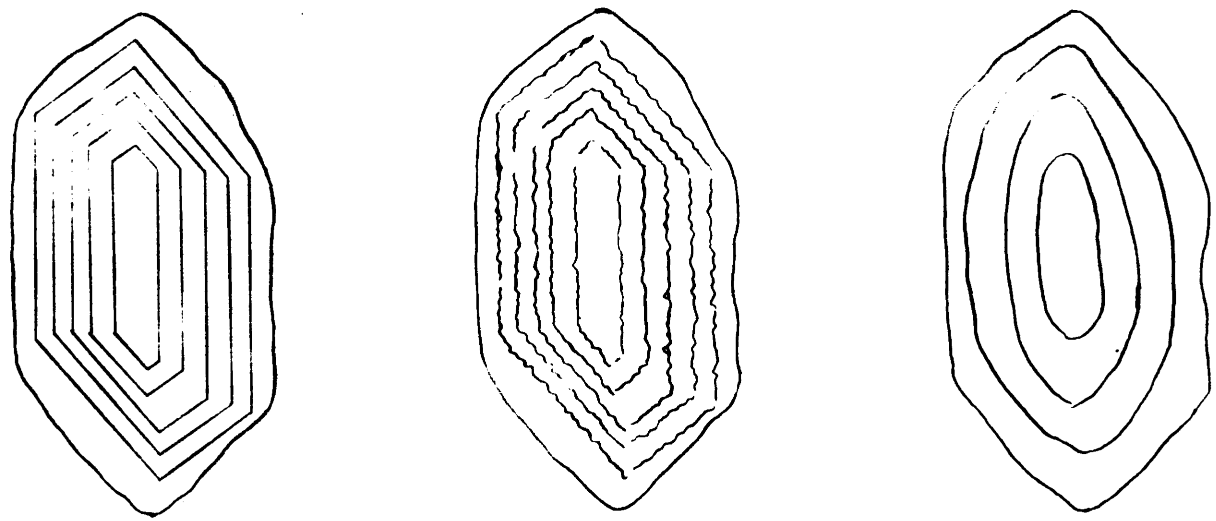

Fig. 8.

a. Geometrically perfect zoning in zircon grain.
b Rudely parallel (irregular) zoning in zircon grain.
c. Ellipsoidal zoning in zircon grain.

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Figure 6 shows the variation in the number of rounded, angular and idiomorphic zircons for every thousand zircon grains per sample. With the exception of sample L.1, the number of rounded zircon grains in all samples exceeds 920. Sample L.1, was collected just above the contact between the Rooiberg Felsite and the Loskop System and contains an unusually large number of idiomorphic zircon grains.

Figure 7 shows the variation in the ratio of zoned to non-zoned zircons in the different samples. Although the tendency of the graph is complicated by minor fluctuations, there seems to be a general decrease in the proportion of zoned grains relative to the non-zoned grains from the base of the Loskop System to the top of the Waterberg System. No sudden change in general direction can be observed when the curve is followed across the contact between the Loskop and Waterberg Systems. In the case of the Loskop System, the lowest value obtained for the ratio zoned to non-zoned zircons is 0.74 and the highest 4.02. The highest and lowest values for samples of the Waterberg System are 1.27 and 0.43.

Three distinct types of zoning are distinguishable in zircon grains:

a. Geometrically perfect type (Figure 8 A).
   The zones are delineated by clearly defined straight lines arranged parallel to original crystal faces.

b. Rudely parallel (irregular) type (Figure 8 B).
   As the name implies the zone boundaries are irregular but still rudely parallel to original crystal faces.

c. Ellipsoidal Type (Figure 8 C)
   The zone boundaries are ellipsoidal in outline. Combinations of any two of the three types of zoning mentioned above may be present.

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The following types of zircon were distinguishable in the heavy mineral suites of the Loskop and Waterberg Systems:

a. Zoned Zircons.

(i) Idiomorphic zircon grains showing no sign of attrition and occurring in the sandstone at the base of the Loskop System. They are colourless, squat prismatic crystals combining the prism (110) and bipyramids (III) and probably (311).

Occasionally the bipyramid (311) is very prominently developed and gives rise to a wedge-shaped crystal. All the idiomorphic grains are zoned.

The zoning is of the geometrically perfect type and in the majority of cases distributed evenly throughout the crystal. Inclusions, if present, are small rod-like, round or irregularly shaped bodies and are distributed haphazardly through the crystal. Only in exceedingly rare cases do the rod-like inclusions appear to be orientated parallel to crystal faces. The inclusions are generally colourless and have a very low binefringence. The refractive index is lower than that of the enclosing zircon. The zircon grains sometimes have slightly pitted surfaces.

(ii) Grains identical in respect of colour, zoning and inclusions to the idiomorphic zircons described above but exhibiting varying degrees of attrition and fracturing. They represent the rounded counterparts of the idiomorphic crystals.

To facilitate subsequent descriptions they are termed the Z.1 type.

(iii) Rounded prismatic and anhedral zircon grains commonly characterised by irregular zoning and less often by ellipsoidal zoning. Pitting and especially fractures are almost always present, often to such an extent as to partially mask the zoning tendency of the grains. The prismatic grains are mostly stumpy, but slender, acicular varieties are fairly common. Inclusions are similar to those found in the

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idiomorphic zircons. Although prevailingly colourless, the brownish varieties are confined to this group which is termed the Z.2 type.

b. Non zoned Zircons.

(i) Colourless ellipsoidal or spherical grains seldom containing inclusions. The degree of fracture in these grains varies from one sample to the other. Their surfaces are generally smooth. They are hereafter referred to as the Z.3 type.

(ii) Grains of a very faint pinkish tinge but regarded as colourless in the general classification (Table 8) constitute the final group of zircons present in samples of the Loskop and Waterberg systems. Pitting, fracturing and inclusions are common features. The grains are mostly prismatic or spherical and occasionally angular. The inclusions are similar to those found in the zoned grains. Zircons in this group are named the Z.4 type.

In specimen L.1 collected very near the base of the Loskop System, zoned grains constitute approximately 80% of all zircons. The majority of these are idiomorphic grains and grains of the Z.1 type. Idiomorphic zircons are absent from all but six of the remaining samples and in these they occur only in very small quantities. The Z.1 type decreases rapidly upwards through the Loskop System and in sample L.6 there are hardly any left. Hereafter they show a gradual increase through the lower portions of the Waterberg System and eventually the number of Z.1 type zircons reaches a peak in sample W.3 In this specific sample the Z.1 type zircons are once more in excess of the Z.2 type. As the top of the Waterberg System is approached, they once again decrease and are completely absent in sample W.8.

Of the non zoned zircons the Z.4 type is always in excess of the Z.3 type. The latter forms approximately thirty to forty per cent of all non zoned zircons in the Loskop System

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but upwards through the Waterberg System they become progressively scarcer.

From the base of the Loskop System upwards and throughout the Waterberg System the degree of rounding and fracturing of the zircon grains increases. Fracturing not only hampers the identification of the type of zoning but also makes the differentiation of Z.3 and Z.4 types difficult.

2. Rutile.

Present in all but one (W.2) of the heavy mineral concentrates of the Loskop and Waterberg Systems. The rutile grains of both systems are identical in appearance. They commonly show an anhedral form but prismatic grains are frequently encountered and may have striae parallel to the c-axis or transverse lamellae due to polysynthetic twinning. All rutile grains are distinctly pleochroic in shades of reddish brown and yellowish brown.

3. Titanite.

This mineral is restricted to the concentrates of the Loskop System, especially samples L.3, L.4 and L.5. It occurs as anhedral grains as well as wedge-shaped idiomorphic crystals. The shape of the titanite suggests an authigenic origin and the mineral is therefore of little diagnostic value.

4. Tourmaline and Apatite.

Green pleochroic tourmaline and colourless apatite are both sparingly present in the rocks of the Loskop and Waterberg systems. It is possible that apatite, which was not recognized in the preliminary survey was partly destroyed during the acid treatment. There is again no noticeable difference between the tourmalines and apatites in the concentrates representative of the two systems.

It follows from the foregoing pages that the two sets of concentrates representing sandstone of the Loskop and Waterberg Systems respectively,

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correspond very closely as regards both qualitative and quantitative considerations. This is a surprising result since it not only implies that the sediments of both formations were derived from the same distributive province, but also that the relative areas presented to the forces of denudation by the different rock types in the distributive province remained essentially unchanged in the period intervening between the deposition of the two systems.

It is also somewhat unlikely that the Waterberg System was essentially formed of degradation products of the Loskop System because in that case the curve indicating the ratios of zoned to non-zoned zircons of the Waterberg System should have shown an opposite trend to that of the Loskop System - the upper portions of the Loskop System would have yielded the lower portions of the Waterberg System and the lower portions of the Loskop System would have contributed to the upper portions of the Waterberg System. Any indication of such a mirror image relationship of the curve indicating the ratios zoned to non-zoned zircons of the Waterberg System to that of the Loskop System is entirely lacking (see Figure 7.)

The similarity between the heavy concentrates from the Loskop and Waterberg systems is paralleled by the close correspondence in nature and appearance of the sediments of the two formations. The deposition of the Loskop and Waterberg systems under similar environmental conditions is thus clearly suggested. The net outcome of the present investigation, although admittedly limited in scope, is therefore not corroborative of the grouping of the rocks of the Loskop System into a separate stratigraphical system.

B. THE ROOIBERG FELSITE

The breadth and length of seventy zircon grains obtained from the felsitic lava were measured and plotted on the diagrams designed by Smithson (1939, pp.351-353). Because zircons are sparingly present in the felsite the grains from four different concentrates had to be measured in order to obtain the required data. The grains were predominantly of an ellipsoidal shape and idiomorphic crystals were noticed only occasionally.

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It was found that most of the measured grains plotted between the 1:1 and 1:2 ratio lines on the breadth: length diagram (Fig. 9).

Fifty-one idiomorphic zircon grains from concentrate L.1 of the Loskop System were also plotted on the breadth: length diagram and they are located in exactly the same position as the zircons of felsitic origin (Fig. 10).

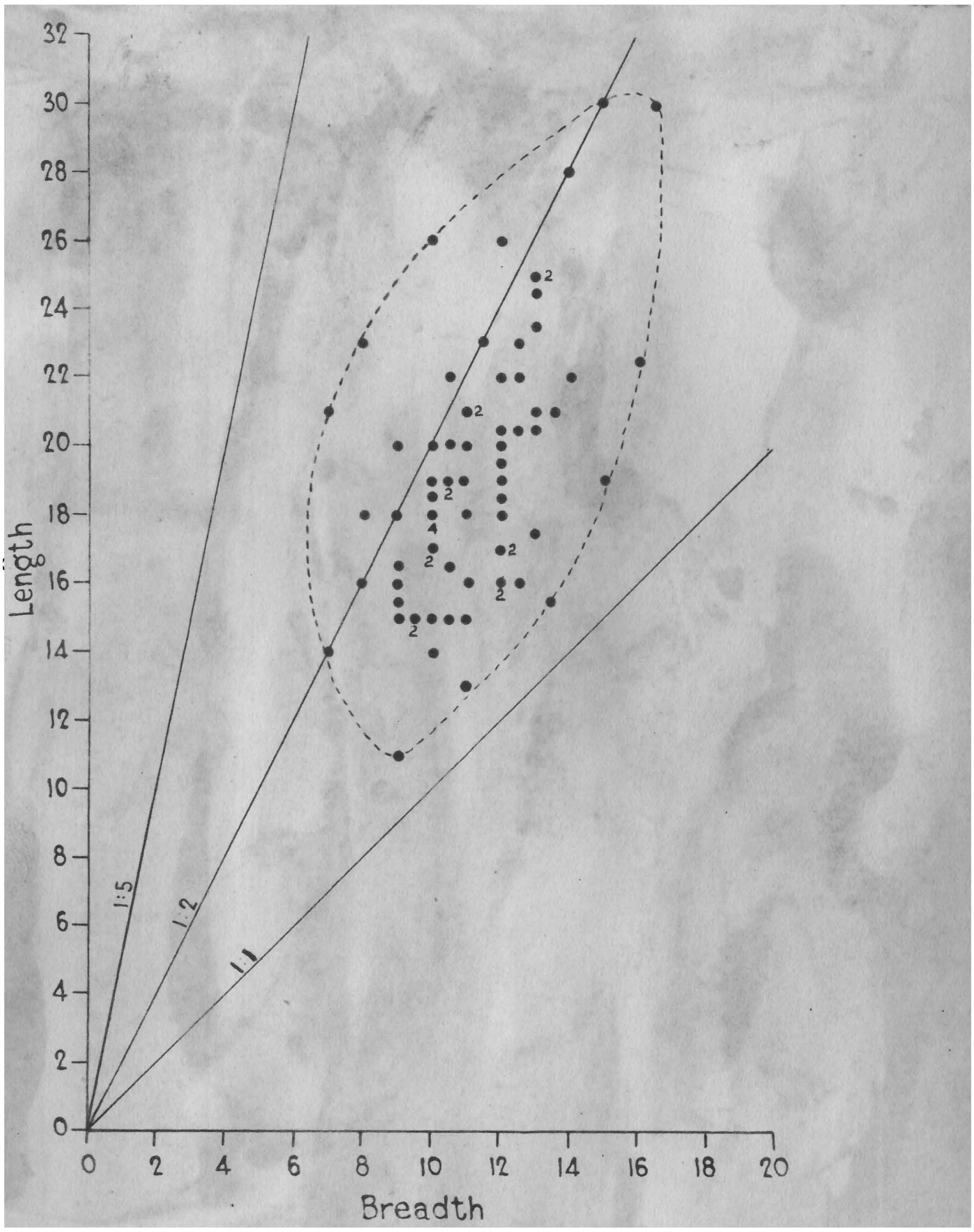

Fig. 9: Length: Breadth Diagram for 70 Zircons from Rooiberg Felsite. (2 Denotes No. of grains having identical measurements)

Coetzee (1941, pp.191-193) infers that the majority of zircon grains derived from sedimentary rocks would be confined to the area between the 1:1 and 1:2 ratio lines whereas zircons from igneous rocks would occupy the area between the 1:2 and 1:5 ratio lines. He uses these data to

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distinguish a granite of supposedly metasomatic origin from one of igneous origin.

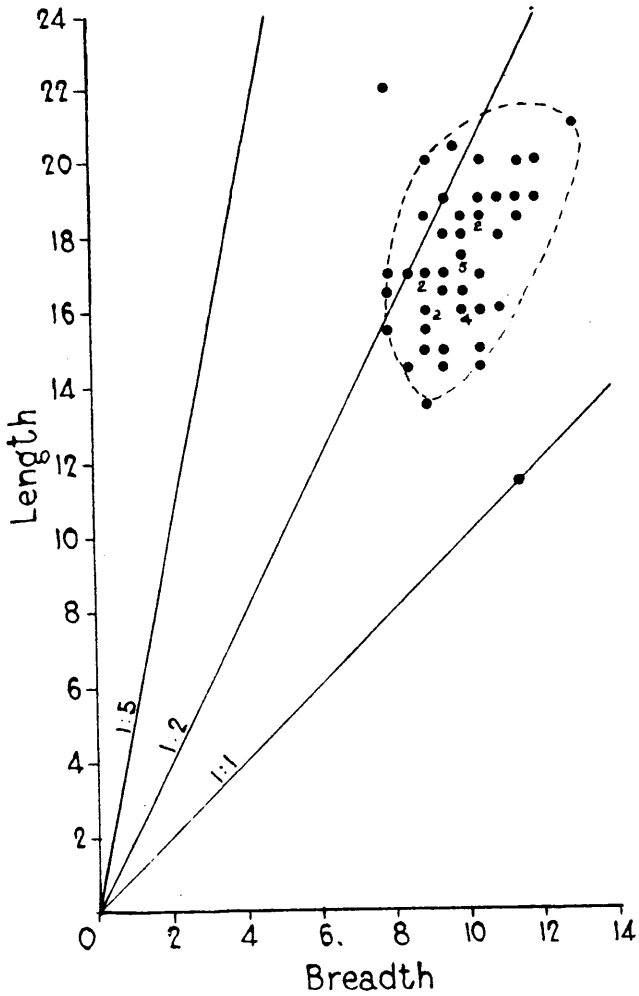

Fig. 10:- Length : Breadth Diagram for 51 Zircons from Sandstone. (2 Denotes No of grains having identical measurements)

It is quite obvious that this method of plotting the size of zircon grains on breadth : length diagrams, in order to determine the igneous or sedimentary origin of a given rock-type, is by no means infallible.

X - INTRUSIVE ROCKS

A. GRANOPHYRIC GRANITE-PORPHYRY (PRE-LOSKOP)

In the north-eastern corner of the area a dyke of granophyric granite-porphyry is intrusive into Rooiberg Felsite. Immediately, west of the dam-wall the same rock-type occurs as a sill above the felsite.

Typically it is a reddish brown rock with macroscopically visible insets up to 8 mm. in length. The phenocrysts consist of quartz, pink

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feldspar and dark green ferromagnesian minerals. The matrix is dense and of a dark colour. Microscopically the rock is composed of deeply corroded individuals of quartz, turbid feldspar and altered biotite set in a matrix of micropegmatite.

The volumetric composition of a specimen (Wo34) from Loskop 104 is as follows:

Micropegmatite	60.3
Plagioclase	5.9
Microperthite	22.8
Quartz	8.8
Biotite	2.4
	100.2

Following Lombaard's classification (1932, p.146) according to which a rock carrying more than 50 per cent micropegmatite is called a granophyre this rock should be designated porphyritic granophyre.

In other specimens from the same body of rock, the interstitial micropegmatite forms less than 50% of the total mineral assemblage and the rock becomes a granophyric granite-porphyry.

The chemical analysis of the porphyritic granophyre is compared with those of common Bushveld granites, granophyres and felsites in Table 9. The chemical analysis of the felsite from Zaagkuil 108 (I, Table 5) is also repeated for comparison.

A comparison of the Niggli-values immediately shows the marked difference between the porphyritic granophyre and the common Bushveld granites, granophyres and felsites. The porphyritic granophyre has a lower al and alk content than any of the other three quartzose types of the Bushveld Complex. This is counterbalanced by higher c and fm in the porphyritic granophyre.

It is perhaps significant that the chemical analysis of this granophyre is remarkably similar to that of a felsite (II, Table 9) collected in the same vicinity.

The two rocks appear to be derived from a common magma - the felsite representing an early extrusive phase and the granophyre a later intrusive phase.

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T A B L E 9

CHEMICAL ANALYSES OF GRANITES, GRANOPHYRES AND FELSITES

	I	II	III	IV	V
SiO_2	72.68	73.84	74.9	72.66	71.77
AL_2O_3	10.11	9.56	11.5	12.18	11.66
Fe_2O_3	1.76	2.06	1.0	1.81	2.42
FeO	3.02	2.87	2.0	2.91	3.28
MnO	0.38	0.23	0.05	0.33	0.22
MgO	0.36	0.47	0.15	0.16	0.10
CaO	2.50	2.02	1.15	1.24	1.30
Na_2O	2.04	2.03	3.25	2.94	3.55
K_2O	4.60	4.70	4.90	4.58	4.41
H_2O+	1.03	1.03	0.65	0.25	0.55
H_2O-	0.17	0.15	0.1	0.69	0.14
TiO_2	0.40	0.35	0.25	0.34	0.52
P_2O_5	0.44	0.25	0.1	0.12	0.13
CO_2	0.18	0.01	-	-	-
	99.67	99.57	100.00	100.21	100.05

Niggli values:

	I	II	III	IV	V
si	397	418	445	392	369
al	32.5	32	40	39	35.5
fm	26	27.5	16	23	25.5
c	15	12.5	7	7	7
alk	27	28	37	31	32
k	0.60	0.60	0.5	0.51	0.55
mg	0.11	0.15	0.1	0.06	0.04

MAGMA TYPES
I. ? (See Text)
II. Si-syenitegranitic
III. Normal alkaligranitic
IV. Rapakiwitic
V. Si-syenitegranitic

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I. Porphyritic granophyre, Loskop 104, Witbank District.
Analyst: A. Kruger

II. Felsite, Zaagkuil 108, Witbank District. Analyst: A. Kruger

III. Average, to nearest .05 per cent, of six Bushveld Granites of the commonest type. (Lombaard, 1934, p.9).

IV. Granophyre, average of six analyses (Hall, 1932, pp.255, 256).

V. Felsite, average of twelve analyses shown in Table 5, p.

The granophyre fails to classify as a specific magmatype. It resembles the si-syenitegranitic type (Niggli, 1936, p.344) except that fm is less than 27.0 instead of in excess thereof. It also conforms to the general requirements of the granitic group but does not correspond to any of the granitic types.

B. DOLERITE (POST-LOSKOP)

There are numerous dolerite outcrops in the region but the most conspicuous is a sill in the souther-eastern quadrant of the area. Striking roughly parallel to the northern margin of the Waterberg System and attaining a thickness of approximately 160 feet, the sill is flanked on its southern side by an escarpment of flat-dipping grit and sandstone (Plate 12).

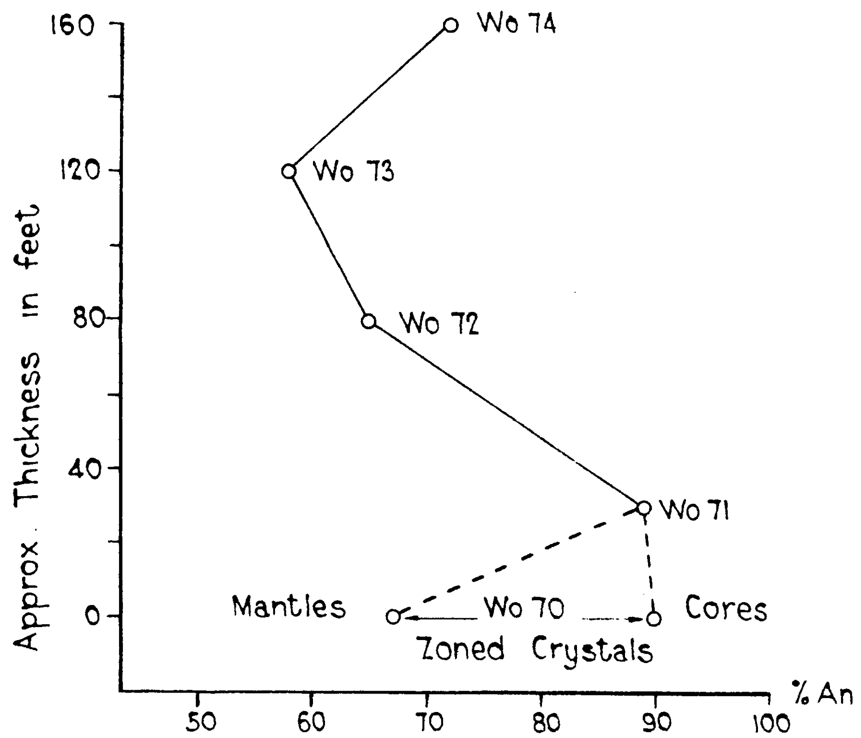

Fig. 11:- Variation in Composition of Feldspar of Dolerite sill.

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The dolerite is a typical dark-greyish, speckled variety, weathering with a reddish crust, frequently spheroidally and giving rise to a reddish-brown clayey soil. Five samples number Wo70 to Wo74 in ascending order, were collected in a traverse across the sill on Voetpadskloof 187.

The typical texture of all specimens is medium grained, holocrystalline, sub-ophitic and the essential constituents are feldspar, pyroxene, micropegmatite and subordinate quartz. The feldspars are usually fresh and clear and their composition is limited to the labradorite - bytownite range, especially in the upper half of the sill (Fig. 11). In the lower portion the trend is towards a more calcic member of the series, viz. $Ab_{11}An_{89}$. The feldspars at the base of the sill show pronounced continuous zoning with cores and mantles varying between extremes of $Ab_{10}An_{90}$ and $Ab_{33}An_{67}$. Roc tourne, albite and carlsbad twins are prevalent.

Ortho-pyroxene ($2V\gamma = 104^\circ \pm 5^\circ$ and $n\gamma = \pm 1.654$) occurs only in samples Wo70 and Wo71. The abnormally low refractive index may be due to the presence of aluminium in the enstenite molecule (Winchell 1951, p.406, fig. 284). Clino-pyroxene has developed in reaction relation to the ortho-pyroxene, often replacing the latter along its edges. The clino-pyroxene is of fairly constant composition. The positive axial angles of between 42° and 46° cover the whole range while the refractive index $n\gamma'$ varies between 1.701 and 1.714. By adopting Hess's revised nomenclature (1949, p.623) and by plotting these data on his optical property curves (1949, pp.633-638) the clino-pyroxene is found to be augite. (Fig. 12). Quartz and micropegmatite are present in all five samples. The micropegmatite is interstitial to pyroxene and feldspar.

The volumetric composition of the five dolerite samples is shown in Table 10.

The variation in the proportion of the different constituents is shown in figure 13.

The sill has had practically no metamorphic effect on the country rock save for a slight recrystallization of the quartz grains in the overlying sandstones.

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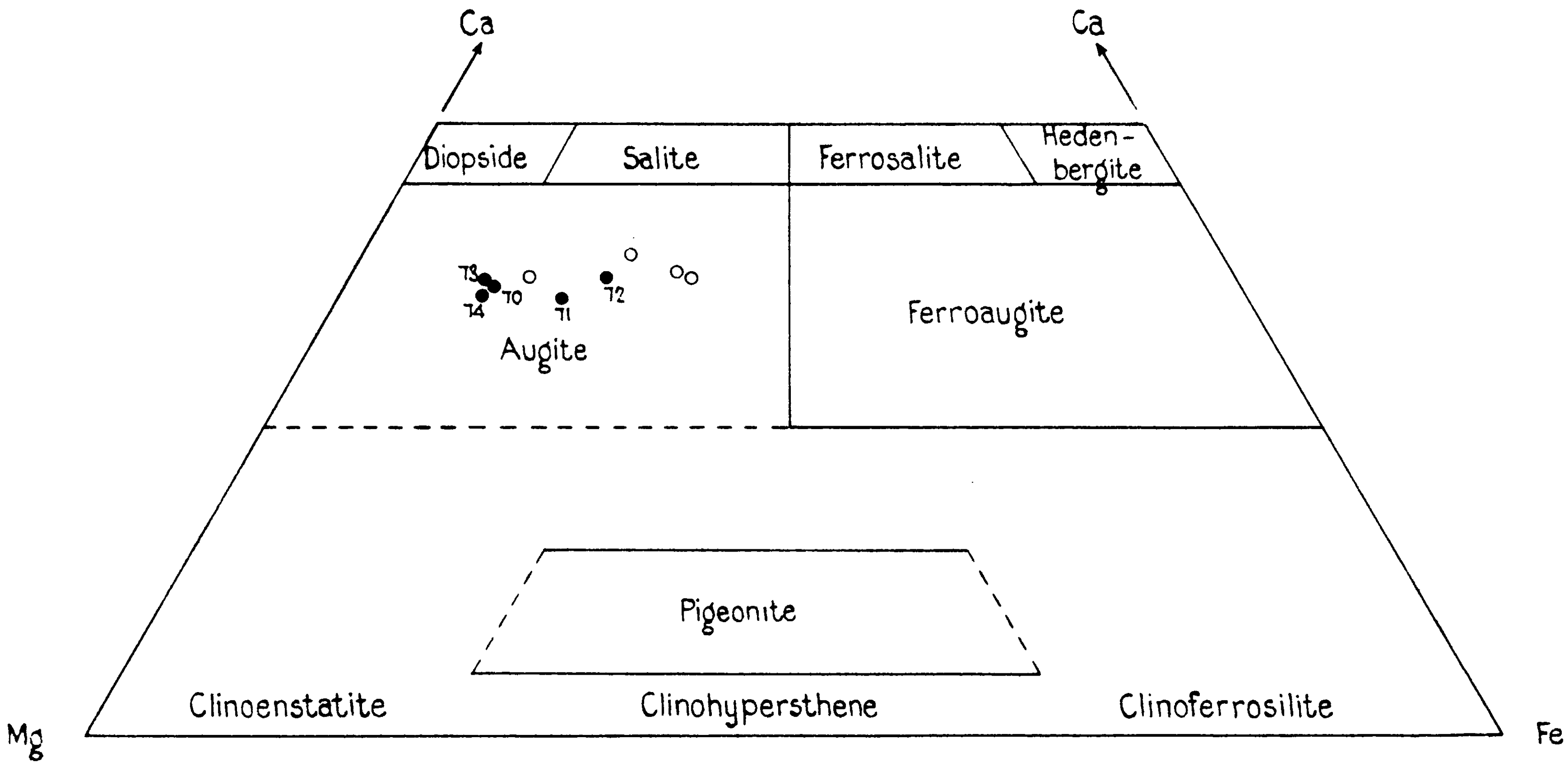

Fig 12 :- Position of clinopyroxenes on diagram expressing the Ca, Mg and Fe atomic percentages (● = Middelburg Dolerite ; o = Karroo Dolerite.)

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T A B L E 10

VOLUMETRIC COMPOSITION OF DOLERITE

	No.70	No.71	No.72	No.73	No.74
Feldspar	44.2	44.1	37.4	26.6	50.1
Clino-pyroxene	22.2	19.4	29.2	39.0	39.3
Ortho-pyroxene	14.8	16.8	-	-	-
Micropegmatite	13.2	15.7	23.5	23.1	2.7
Quartz	4.4	2.8	7.1	5.7	5.1
Ore	1.2	1.0	1.2	2.7	2.8
Amphibole and Epidote	-	0.2	1.6	2.8	-
	100.0	100.0	100.0	99.9	100.0

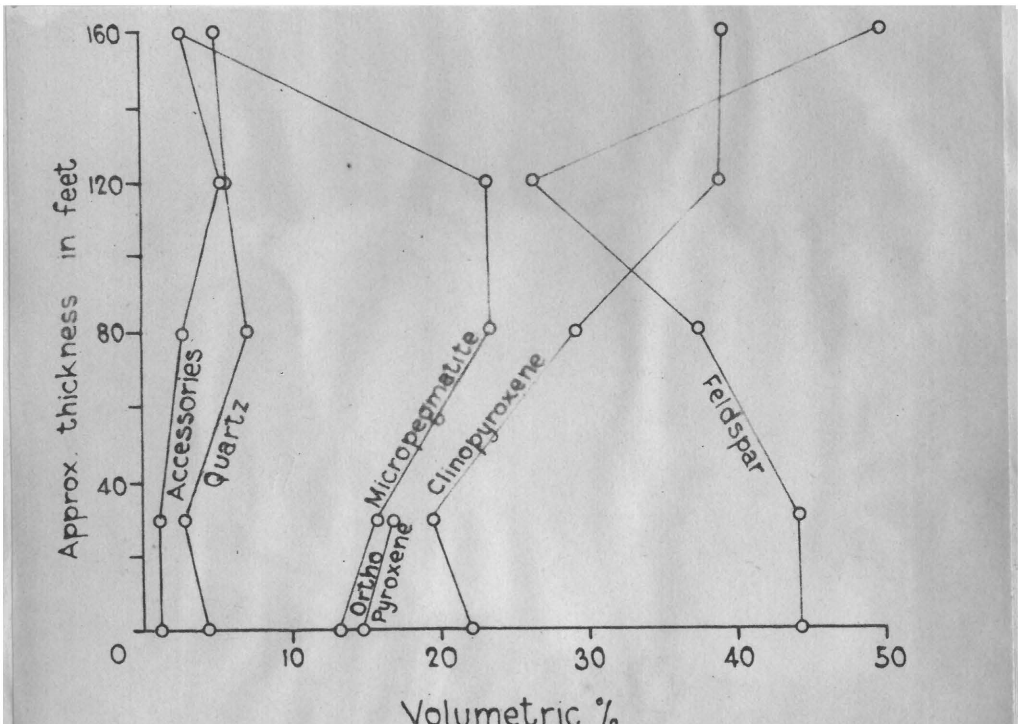

Fig. 13:- Variation in proportion of different constituents of Middelburg dolerite

Strauss (1947) has described a composite sill, also intrusive into rocks of the Waterberg System from the New Belgium Block north-west of Potgietersrust.

The sill is considered to have been formed by the "staccato injection of the residual liquid from a basaltic parent magma during its crystallization somewhere at depth." It is composed of dolerite, quartz-dolerite, tonalite and granophyre - "rock types which are known to occur in other

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parts of the Waterberg Plateau" (Strauss, 1947, p.73).

Save for the presence of rhombic pyroxene in the lower 40 feet, the dolerite sill in the Loskop Dam area exhibits practically no differentiation. It differs from the basic portion (dolerite and quartz-dolerite) of the New Belgium Block sill chiefly in the composition of the feldspar and clinopyroxene. To facilitate comparison, the two intrusions will hereafter be referred to as the Middelburg sill and the New Belgium Block sill. The feldspar of the former is generally more calcic (labradorite-bytownite) than that of the New Belgium Block dolerite and quartz-dolerite (andesine rims and bytownite cores). Pigeonite is recorded in the New Belgium Block dolerite but is absent from the Middelburg dolerite whereas ortho-pyroxene is present only in the basal portions of the Middelburg sill. Augite occurs in the dolerites of both localities.

The positive axial angles of clinopyroxene of the Middelburg dolerite vary between 42° and 46° and those of clinopyroxenes of the New Belgium Block dolerite between 48° and 60°.

The volumetric composition and optical properties of these dolerites are shown in Table 11.

In Table 12 the feldspars and clino-pyroxenes of a number of Karroo dolerites described by Frankel (1942 and 1943) and Poldervaart and Walker (1942) are compared with those of the Middelburg dolerite.

The essential constituents of the Middelburg dolerite are plagioclase, clino-pyroxene, micropegmatite, quartz and ortho-pyroxene. The latter mineral occurs only in the lower portions of the sill (see Fig. 13). The Middelburg dolerite is therefore far more oversaturated in silica than the Karroo dolerites. The feldspars of the latter compare favourably with those of approximately the upper 160 feet of the Middelburg dolerite but are less calcic than the feldspars in the lower portion of the sill.

The position of the clino-pyroxenes of specimens II, VII, VIII and IX of the Karroo dolerites are shown on the Ca Mg Fe diagram (Fig. 12). It is clear that the clino-pyroxenes of the Middelburg dolerite are generally richer in magnesia than their counterparts in the Karroo dolerites.

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TABLE 11.

Volumetric Composition and Optical Properties of the Middelburg and New Belgium Block Dolerite

		Plagioclase	PYROXENE Clino	PYROXENE Rhombic	Micropegm & Quartz	Ore
MIDDELBURG DOLERITE		Labradorite-Bytownite 27-50%	Augite ($2V\gamma$: 42°-46°) 19-39%	Aluminium enstenite ($2V\gamma$=104°) 0-17%	8-31%	1-3%
NEW BELGIUM BLOCK	DOLERITE	Andesine-Bytownite 49-60%	Pigeonite ($2V\gamma$: 24°-44°) 31-40% Augite ($2V\gamma$: 48°-60°)	-	1-7%	2-7%
	QUARTZ DOLERITE	Andesine-Bytownite 48-60%	Pigeonite 23-39% Augite	-	8-18%	2-5%

TABLE 12.

Characteristics of feldspar and clino-pyroxene of different dolerites

	Feldspar Composition (% An)	Clino-pyroxene Refractive Index ($n\gamma$ or $n\gamma'$)	Axial Angle ($2V\gamma$)
I.	An_{58} to An_{90}	1.701 to 1.714	42° to 46°
II.	An_{54} to An_{68}	1.715 ± 0.003	Mantles : 47°(mean value) Cores: 0°-40°(Usually 30°-36°)
III.	-	-	44°
IV.	An_{60}	-	40°
V.	An_{58} - An_{70} (Zoned Grains)	-	42° to 50°
VI.	An_{60}	-	44°
VII.	An_{68}	1.720 ± 0.003	45° to 47°
VIII.	An_{70}	1.721 ± 0.003	45° to 47°
IX.	An_{70}	1.706	50°

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I. "Middelburg" Dolerite.

II. Coarse-grained Main Dolerite, Zanddrift Spruit, O.F.S.

III. Fine-grained Main Dolerite, same locality as II.

IV. Lower margin, younger intrusion, same locality as II.

V. Older Dolerite, Kranskop, Rouxville District, O.F.S.

VI. Older Dolerite, Poortje, Rouxville District, O.F.S.

VII. Younger Dolerite (60 cm-dyke), Kranskop, Rouxville District, O.F.S.

VIII. Younger Dolerite (wider dykes, central portion) Poortje O.F.S.
Specimens II, III and IV after Frankel (1943, pp.48, 49 and 51).
Specimens V to VIII after Frankel (1942, pp.4, 5, 10 and 19)

IX. Picrite from near Middelburg C.P. (Walker & Poldervaart, 1942, p.58).

Of the smaller dolerite dykes and sills in the area under discussion, the majority are located west of the Olifants River. Petrographically they do not differ from the Middelburg dolerite. Noteworthy of the sill on Rhenosterhoek 106 are large idiomorphic feldspar phenocrysts attaining a length of up to 3 cms and a width of 1.5 cms.

XI - ECONOMIC GEOLOGY

A. PHOSPHATE.

A deposit of iron-aluminium phosphates on Kluitjiesfontein 369 bears marked resemblance to the deposits on Zoetendalsvlei 889, Potgietersrust District (Willemse 1949)

A sill of dolerite, partially replaced by phosphate, crops out at the base of a cliff of Waterberg sandstone. These cliffs are frequented by birds of prey and as inferred by Willemse, the offal and droppings that accumulate at the base could serve as the source of phosphatic material. The latter is partially dissolved by rainwater, the solutions then seep into the weathered diabase and replace it. The deposit has been intermittently exploited during the past few years.

B. BARITE.

Small veins of barite, about one inch thick, are exposed at the base of the Waterberg System on Fontein Zonder End 538. The barite occurs alone

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XII - ACKNOWLEDGEMENTS

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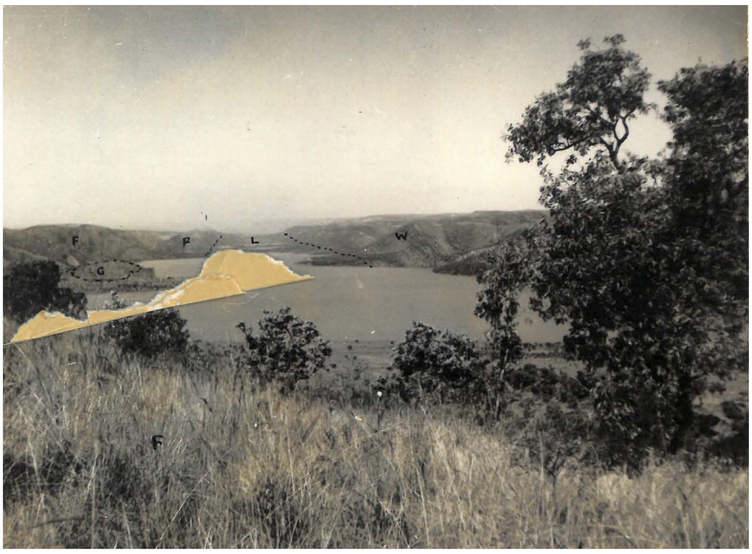

PLATE 3A View eastward across Loskop Dam.
F= Rooiberg Felsite, L=Loskop System,
W=Waterberg System, G=Granite-porphyry.

PLATE 3B. View westward across Loskop Dam.
F=Rooiberg Felsite, L=Loskop System,
W=Waterberg System, G=Granite-porphyry.

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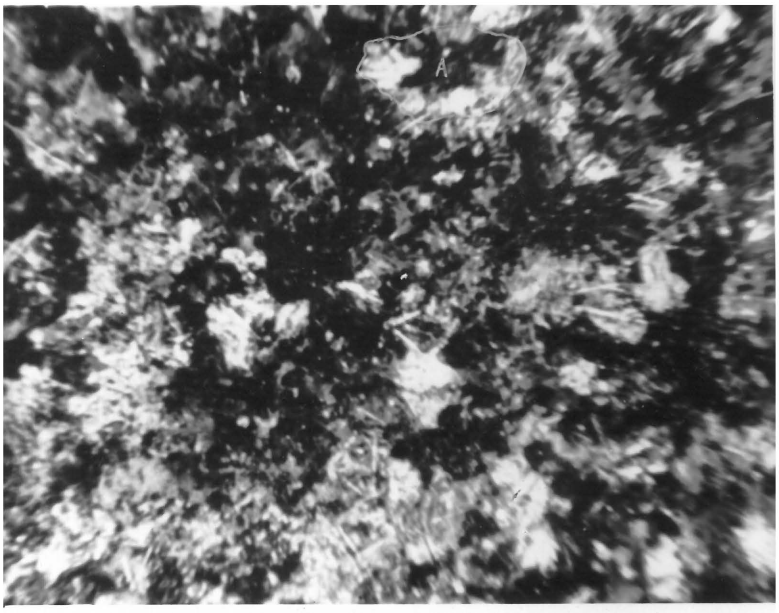

PLATE 4A. Pseudospherulitic granophyric Felsite.
Pseudospherulite (A) situated near
upper right hand corner.
50 X Crossed nicols.

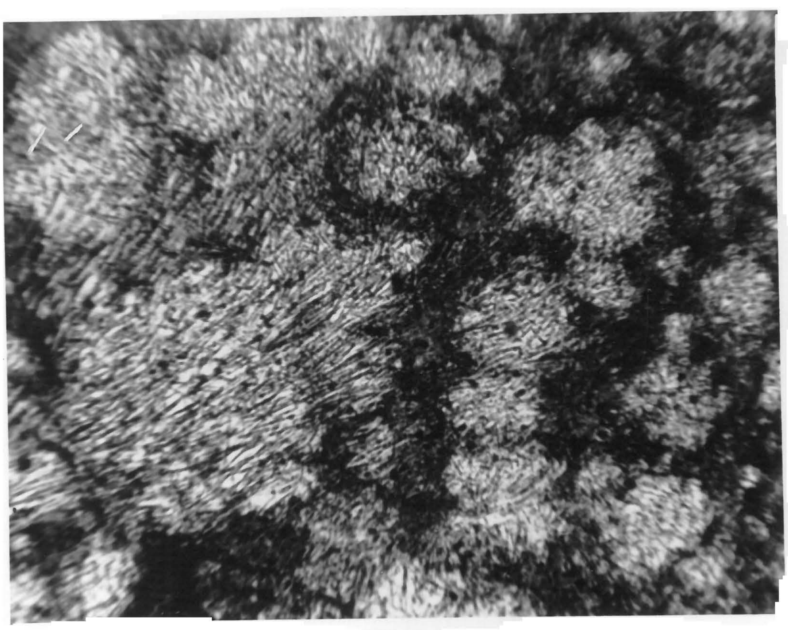

PLATE 4B. Pseudospherulitic Felsite. Crystallites
pass through spherulites in undisturbed
flow - lines.
85 X Ordinary light.

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PLATE 5A. Granophyric Felsite composed of Micrographically intergrown quartz and feldspar.
85 X Crossed Nicols.

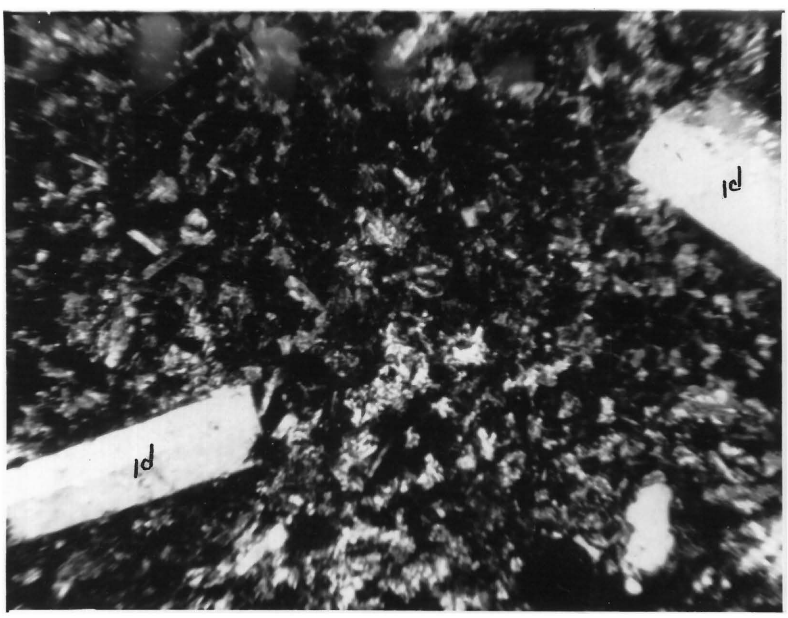

PLATE 5B. Uniformly fine - grained (glassy) felsite containing phenocrysts of plagioclase (pl)
50 X Crossed Nicols.

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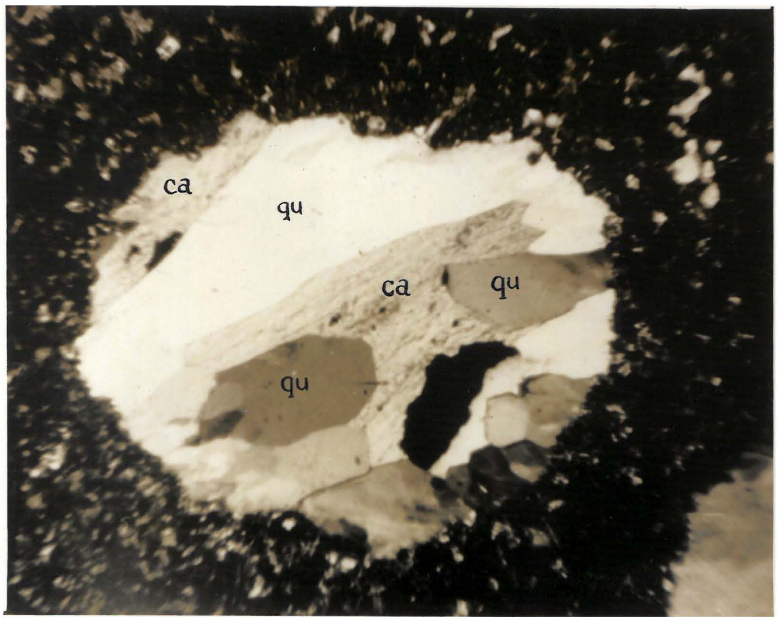

PLATE 6A. Amygdule in Rooiberg Felsite composed partly of calcite (ca) and partly of quartz (qu).
25 X Crossed nicols.

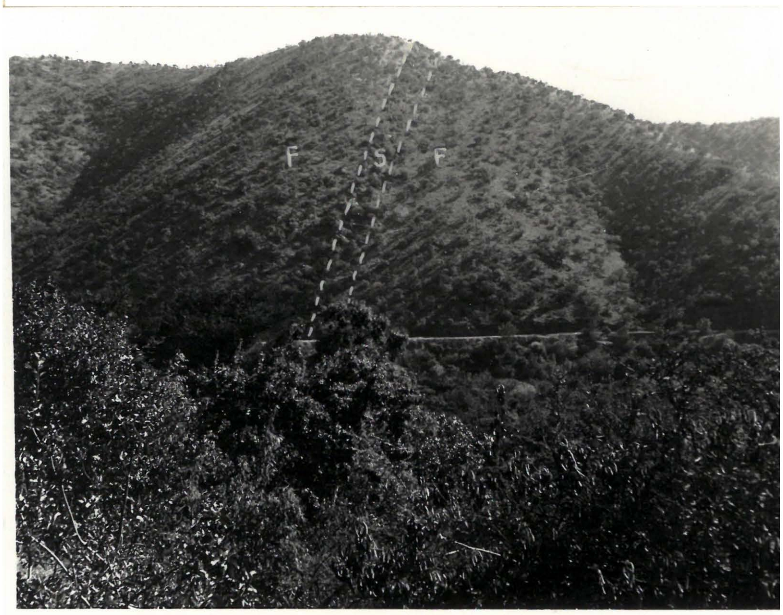

PLATE 6B. Steeply - dipping, interbedded band of sandstone (s) in Rooiberg Felsite(F), Loskop 104.

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PLATE 7A. Steeply-dipping, cross-bedded sandstone of the Loskop System in bed of Krantz Spruit, Rietvallei 92.

PLATE 7B. Basal Conglomerate of the Loskop System overlain by sandstone in bed of Krantz Spruit, Zeekoegat 89.

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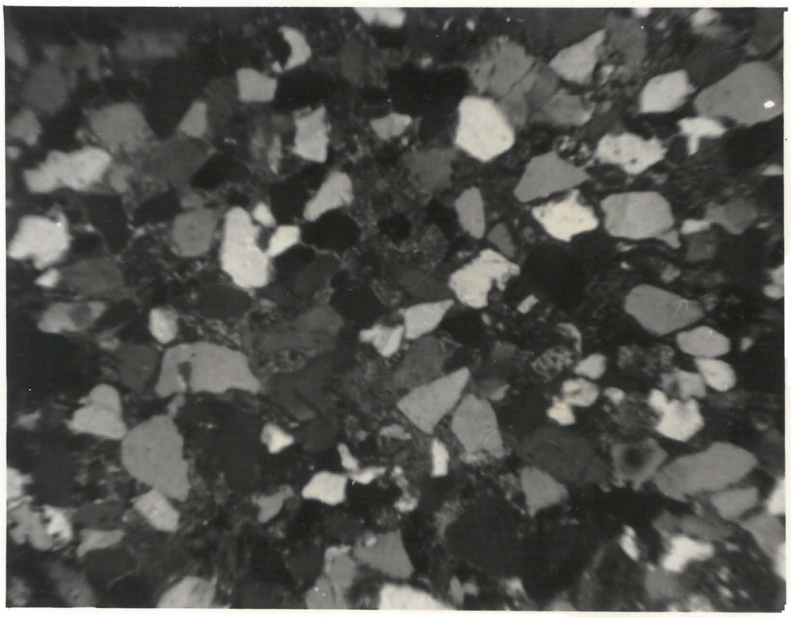

PLATE 8 A. Typical Sandstone of the Loskop System consisting of quartz and chert grains in sericitic ground-mass.
25 X Crossed nicols.

PLATE 8B. Basal conglomerate of the Waterberg System, Rietvallei 92.

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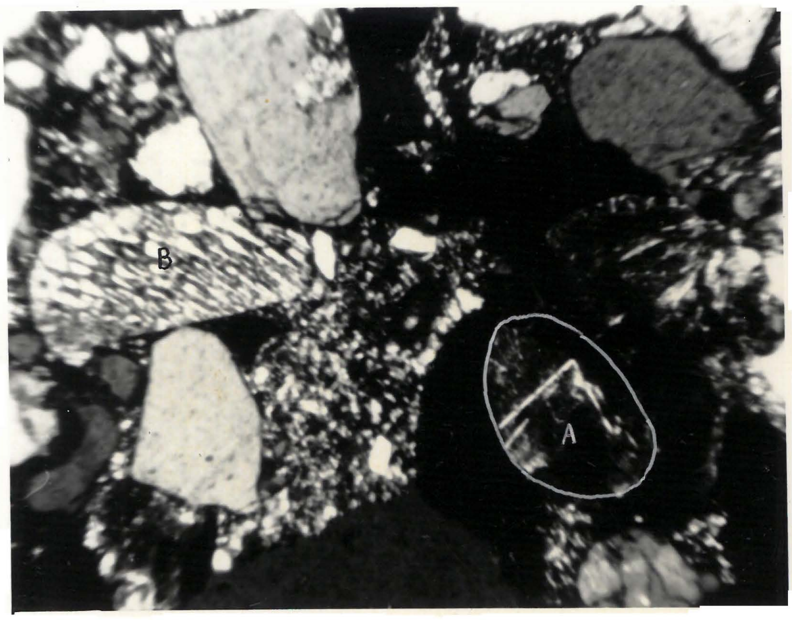

PLATE 9A. Grains of graphic granite (B) and "Premier Mine Type" felsite (A) containing pseudomorphous quartz "needles" in a grit of the Waterberg System; Kliprivier 88.
80 X Crossed nicols.

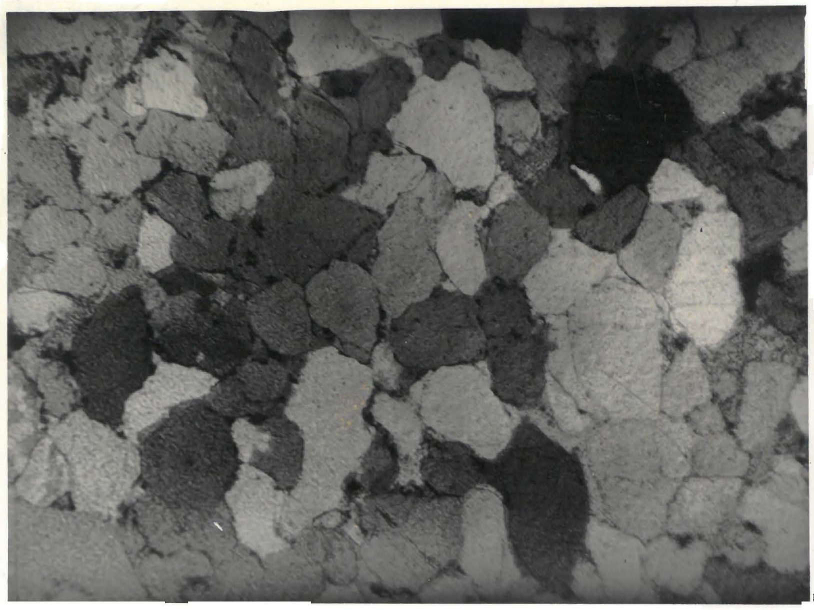

PLATE 9B. Metamorphic Quartzite, Waterberg System; Vergelegen 95,
35 X Crossed nicols.

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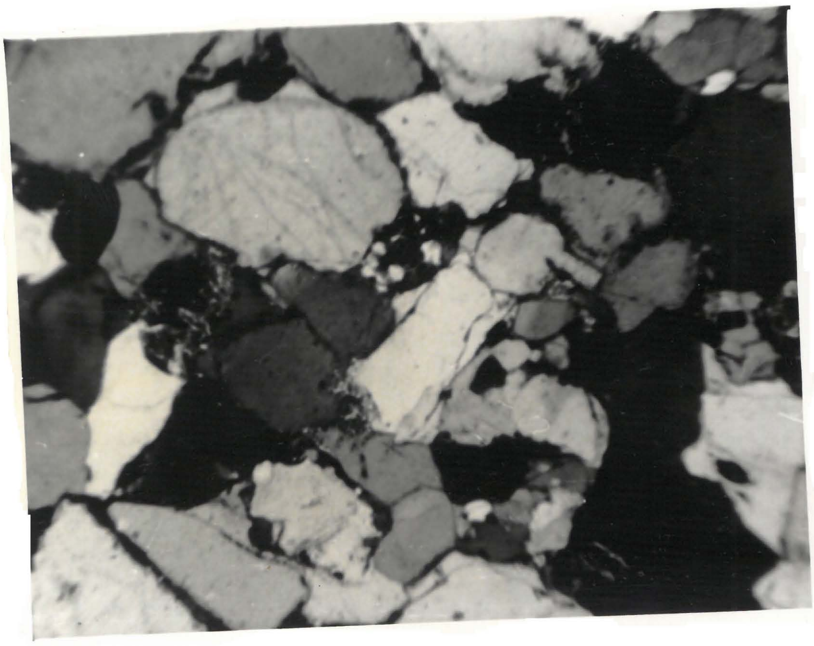

PLATE 10A. Sedimentary Quartzite, Waterberg System, Vergelegen 98. Grains are cemented by secondary silica. Outlines of original grains still distinguishable.
50 X Crossed nicols.

PLATE 10B. Intensely folded strata (A) intervening between normal, gently-dipping strata (B) of the Waterberg System, Polfontein 273.

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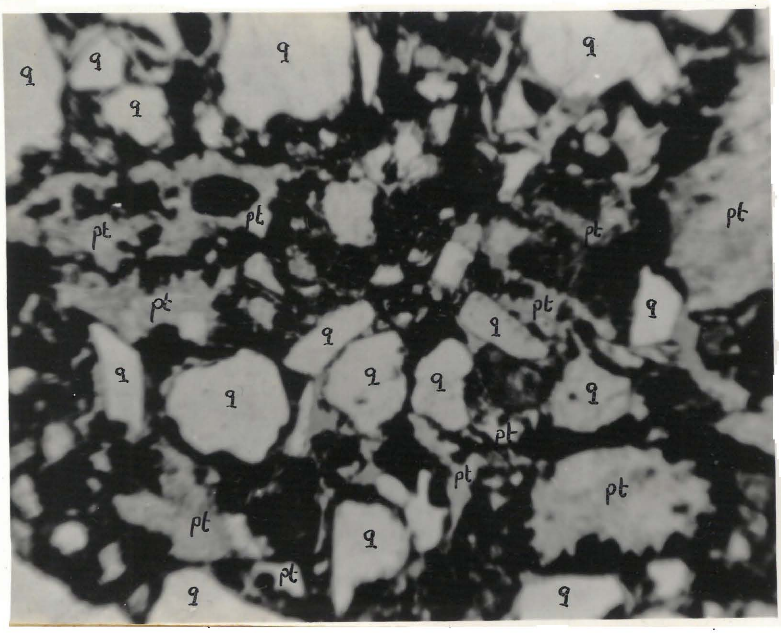

PLATE 11A. Angular glass shards (pt) in tuff from Polfontein 272. The other clastic constituent is quartz (q)
50 X Ordinary light.

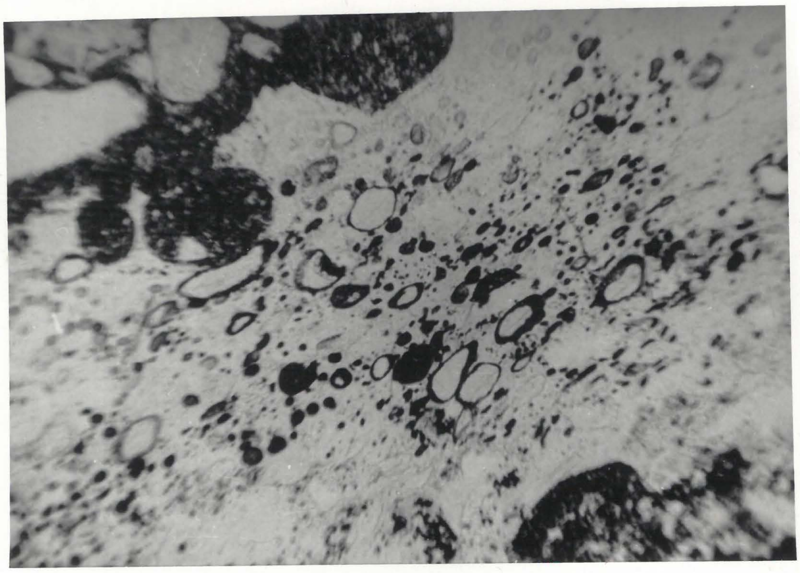

PLATE 11B. Slightly elongated vesicles in shard. from pyroclastics on Polfontein 272.
85 X Ordinary light.

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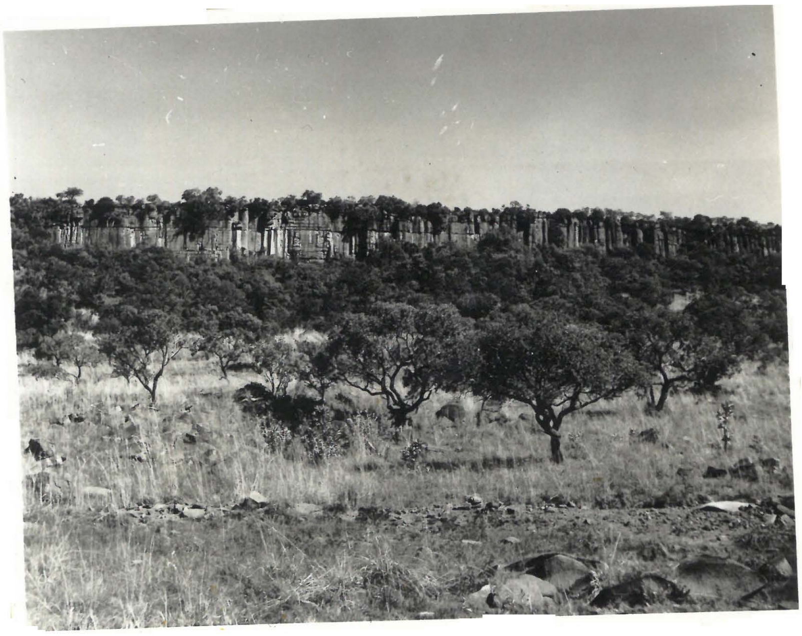

PLATE 12 Dolerite (foreground) ending against an escarpment of sediments of the Waterberg System; Voetpadskloof 87.

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PLATE 2

GEOLOGICAL MAP OF DISTURBED WATERB[damaged]RG STRATA ON POLFONTEIN 272

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