

A GEOLOGICAL INVESTIGATION OF UPPER TRANSVAAL SEQUENCE ROCKS
IN THE NORTHERN PORTION OF THE ROOIBERG FRAGMENT

BY

RALPH JOHN RICHARDS

PRESENTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR
THE DEGREE OF MASTER OF SCIENCE, IN THE FACULTY OF SCIENCE,
UNIVERSITY OF PRETORIA

MAY 1987

A B S T R A C T

A geological investigation of upper Transvaal Sequence rocks in the northern portion, of the Rooiberg Fragment:

BY : Ralph John Richards

PROMOTER : Dr P G Eriksson

CO-PROMOTER: Dr D Twist

DEPARTMENT: Geology

DEGREE : Master of Science

The stratigraphy , sedimentology and geochemistry of the upper Transvaal Sequence rocks in the northern portion of the Rooiberg Fragment are researched.

The Leeuupoort Formation of the Pretoria Group was deposited in a fluvial palaeoenvironment. The basal arkosites in this unit reflect braided stream deposition, whereas the overlying shaly arkosites represent upward-fining cycles of point bar sedimentation. The uppermost main Leeuupoort shale probably formed in a floodplain palaeoenvironment. The overlying Smelterskop Formation arenites indicate high energy flood conditions in a proximal fluvial palaeoenvironment. The extrusion of andesitic lavas acted as an agent of change during the deposition of Smelterskop Formation sedimentary rocks.

The upper and lower contacts of the Smelterskop Formation are disconformable and conformable, respectively. However, non-deposition of the main shale of the upper Leeuupoort Formation and erosion by succeeding Smelterskop sedimentation in some areas, created local disconformities at the base of the Smelterskop Formation.

The scattering of SiO₂ binary plots recorded in the geochemistry of the Rooiberg Group rhyolites indicates extensive alteration of these rocks. Petrogenetic conclusions drawn from the geochemistry must therefore be treated with caution. However, empirical data indicates two lava types, defined by major and trace element geochemistry and geographical position.

C O N T E N T S

	PAGE
1. INTRODUCTION	1
1.1 LOCATION OF STUDY AREA	1
1.2 GENERAL GEOLOGY	1
1.3 SCOPE OF INVESTIGATION	6
1.4 METHOD OF STUDY	6
2. PRETORIA GROUP	9
2.1 LEEUWPOORT FORMATION	9
2.1.1 GENERAL CHARACTERISTICS	9
2.1.2 LITHOLOGY	9
2.1.3 PETROGRAPHY	18
2.2 SMELTERSKOP FORMATION	23
2.2.1 GENERAL CHARACTERISTICS	23
2.2.2 LITHOLOGY	24
2.2.3 PETROGRAPHY	27
2.2.4 GEOCHEMISTRY OF THE LAVAS	29
3. ROOIBERG GROUP	33
3.1 LITHOLOGY	33
3.2 PETROGRAPHY AND MINERALOGY	33
3.3 GEOCHEMISTRY	37
3.3.1 ALTERATION	42
4. INTERPRETATION	47
4.1 SEDIMENTARY ENVIRONMENTS	47
4.1.1 LEEUWPOORT FORMATION	47
4.1.2 SMELTERSKOP FORMATION	53
4.1.3 DISCUSSION	56
4.2 PETROGENESIS OF THE ROOIBERG GROUP	57
4.2.1 LAVA TYPES	57
4.2.2 COMPARATIVE ANALYSIS	61
5. CONTACT RELATIONSHIPS	66
5.1 BASE OF SMELTERSKOP FORMATION	66
5.2 BASE OF ROOIBERG GROUP	68
6. SYNTHESIS	72
7. ACKNOWLEDGEMENTS	74

C O N T E N T S (Continued)

	<i>PAGE</i>
8. REFERENCES	75
9. APPENDIX	80

LIST OF FIGURES

	PAGE
FIGURE 1.1: Regional geological map of the Bushveld Complex showing location of the Rooiberg Fragment	2
FIGURE 1.2: Geological map of the Rooiberg Fragment	3
FIGURE 1.3: Vaalian stratigraphy in the Rooiberg Fragment	4
FIGURE 2.1: Megaripples in the arkosite of the Boshoffsberg Quartzite Member	11
FIGURE 2.2: Convolute bedding in the arkosites of the Boshoffsberg Quartzite Member, Leeuipoort Formation	11
FIGURE 2.3: Rose diagram for palaeocurrent directions measured in the Leeuipoort Formation arkosites	12
FIGURE 2.4: Sedimentary profiles of the Leeuipoort Formation	13
FIGURE 2.5: Well developed slumpballs in the shaly arkosite of the Blaauwbank Shale Member	18
FIGURE 2.6: Flame structures in the shaly arkosite of the Blaauwbank Shale Member	19
FIGURE 2.7: Pseudonodules up to 2m in length in the shaly arkosite of the Blaauwbank Shale Member	19
FIGURE 2.8: Asymmetrical ripple marks in the main shale of the Blaauwbank Shale Member	20
FIGURE 2.9: Symmetrical and interference ripple marks in the Blaauwbank Shale Member	20
FIGURE 2.10: Convolute bedding in the main shale of the Blaauwbank Shale Member	21
FIGURE 2.11: A granoblastic sutured texture in the arkosites of the Leeuipoort Formation (1cm equals 178 microns) - crossed nicols	21
FIGURE 2.12: A granoblastic slightly elongate texture in the arkosites of the Leeuipoort Formation (1cm equals 178 microns) - crossed nicols	22
FIGURE 2.13: A xenomorphic reasonably elongate texture in the shales of the Blaauwbank Shale Member (1cm equals 178 microns) - crossed nicols	22
FIGURE 2.14: Sublithic greywacke with rounded detrital grains set in a chlorite sericite matrix (1cm equals 178 microns) - crossed nicols	24
FIGURE 2.15: Schematic cross-section of the Smelterskop Formation ...	25

LIST OF FIGURES (Continued)

	PAGE
FIGURE 2.16: Typical section through a conglomerate lens in the Smelterskop Formation	26
FIGURE 2.17: Granoblastic to sutured texture in a quartzite of the Smelterskop Formation (1cm equals 178 microns) - crossed nicols	28
FIGURE 2.18: Recrystallized quartzite showing a granuloblastic texture in the Smelterskop Formation (1cm equals 178 microns) - crossed nicols	28
FIGURE 2.19: Geochemical classification of the Smelterskop Formation lavas (Classification System from Cox <i>et al.</i> , 1980, p. 14)	32
FIGURE 3.1: Flow banding in the rhyolites of the Rooiberg Group	34
FIGURE 3.2: Flow banded felsite with accidental lithic clasts, Rooiberg Group	34
FIGURE 3.3: Compositional variation of the feldspar phenocrysts in the porphyritic felsite, Rooiberg Group	38
FIGURE 3.4: Spherulitic texture in the porphyritic felsite of the Rooiberg Group (1cm equals 178 microns) - crossed nicols	38
FIGURE 3.5: Photomicrograph illustrating the intense devitrification in the porphyritic felsite (1cm equals 178 microns) - crossed nicols	39
FIGURE 3.6: Felsitic texture in the porphyritic felsite of the Rooiberg Group (1cm equals 178 microns) - uncrossed nicols	39
FIGURE 3.7: Lithochemical traverses over the Rooiberg Group	40
FIGURE 3.8: The nomenclature of volcanic rocks and classification of the Rooiberg Group rhyolites (Classification System from Cox <i>et al.</i> , 1980, p. 14)	43
FIGURE 3.9: The total alkali-silica diagram of Le Bas <i>et al.</i> (1980) showing Dacitic to Rhyolitic compositions of the Rooiberg Group lavas over the Elandsberg	44
FIGURE 3.10: Major elements binary plots of the rhyolites over the Elandsberg	45
FIGURE 4.1: Representative sedimentary profile of the Leeuwpoot Formation	48
FIGURE 4.2: Proposed depositional model for the Leeuwpoot Formation	52

LIST OF FIGURES (Continued)

	PAGE
FIGURE 4.3: Palaeoenvironmental interpretation of the Smelterskop Formation	55
FIGURE 4.4: Variation of Nb with Zr in the Rooiberg Group - Elandsberg	58
FIGURE 4.5: AFM plot for the Rooiberg Group over the Elandsberg - Rooiberg Fragment	60
FIGURE 4.6: AFM plot for the Rooiberg over the Bushveld Complex	63
FIGURE 4.7: Zr-Nb binary plot for the Rooiberg Group over the Bushveld Complex	64
FIGURE 5.1: Bedding plane measurements for the Leeuwpoort Formation, Smelterskop Formation and Rooiberg Group	67
FIGURE 5.2: Arkosic clasts of Smelterskop Formation embedded in the uppermost shale at the top of the Blaauwbank Shale Member	70
FIGURE 5.3: Schematic stratigraphic section through the Pretoria and Rooiberg Groups using the base of the Rooiberg Group as a conformity	70
FIGURE 5.4: Stratigraphic section through the Pretoria and Rooiberg Groups using the base of the Smelterskop Formation as a conformity	71

LIST OF TABLES

	PAGES
TABLE 1: Chemical Composition of the Smelterskop Formation lavas	31
TABLE 2: Point counts for the phenocrysts/matrix proportion in the porphyritic felsite	35
TABLE 3: Feldspar Microprobe Analyses; porphyritic felsite, Rooiberg Group	36
TABLE 4: Geochemical analyses of the Rooiberg felsites	41
TABLE 5: Total iron compositions over the Elandsberg and those quoted by Cox <i>et al.</i> (1980, p. 402)	59
TABLE 6: Average chemical compositions of the Rooiberg Group over the Bushveld Complex	62

1. INTRODUCTION

1.1 LOCATION OF STUDY AREA

The Rooiberg Fragment, a detached segment of the Transvaal Sequence is situated some 110 km north-west of Pretoria, surrounded by rocks of the Bushveld Complex (Fig. 1.1). The study area covers two farms in the northern portion of the Rooiberg Fragment, namely Welgedacht 514 KQ in the east and Onverwacht 486 KQ in the west (Fig. 1.2). Collectively these farms cover an area of approximately 180 km².

Vegetation in the region is typical Bushveld with coarse grassveld interspersed by low trees of uniform size. The Sekelbos (dichrostachys cinerea), Soetdoring (acacia karroo) and Maroela (scleroearya birrea) tree species are characteristic while Rooigras (therieda triandra) forms most of the undergrowth.

1.2 GENERAL GEOLOGY

The 2200 Ma (Button, 1976; SACS, 1980, p. 195) Rooiberg and Pretoria Groups of the Transvaal Sequence, consisting of sedimentary rocks, volcanoclastics and lavas, are the dominant rock types in the Rooiberg Fragment (Fig. 1.2 and Fig. 1.3). The Lebowa Granite Suite and Rashoop Granophyre Suite of the Bushveld Complex intrude and envelop the Rooiberg Fragment. Tin, in the form of cassiterite, is mined in the area and occurs as replacement and open space-filling orebodies, related to steep fractures and bedded lodes (Leube and Stumpfl, 1963).

The basal unit of the Pretoria Group in the Rooiberg Fragment, the Leeuwoort Formation (Stear, 1976), is an upward-fining sequence of conglomerates, arkosites and shales, which is subdivided into a basal coarser-grained Boshoffsberg Quartzite Member and an overlying finer-grained Blaauwbank Shale Member (Fig. 1.3). The Leeuwoort Formation is unconformably overlain by the Smelterskop Formation (Boardman, 1946), a sequence of alternating layers of quartzite, arkosite, andesitic lava, conglomerate and shale.

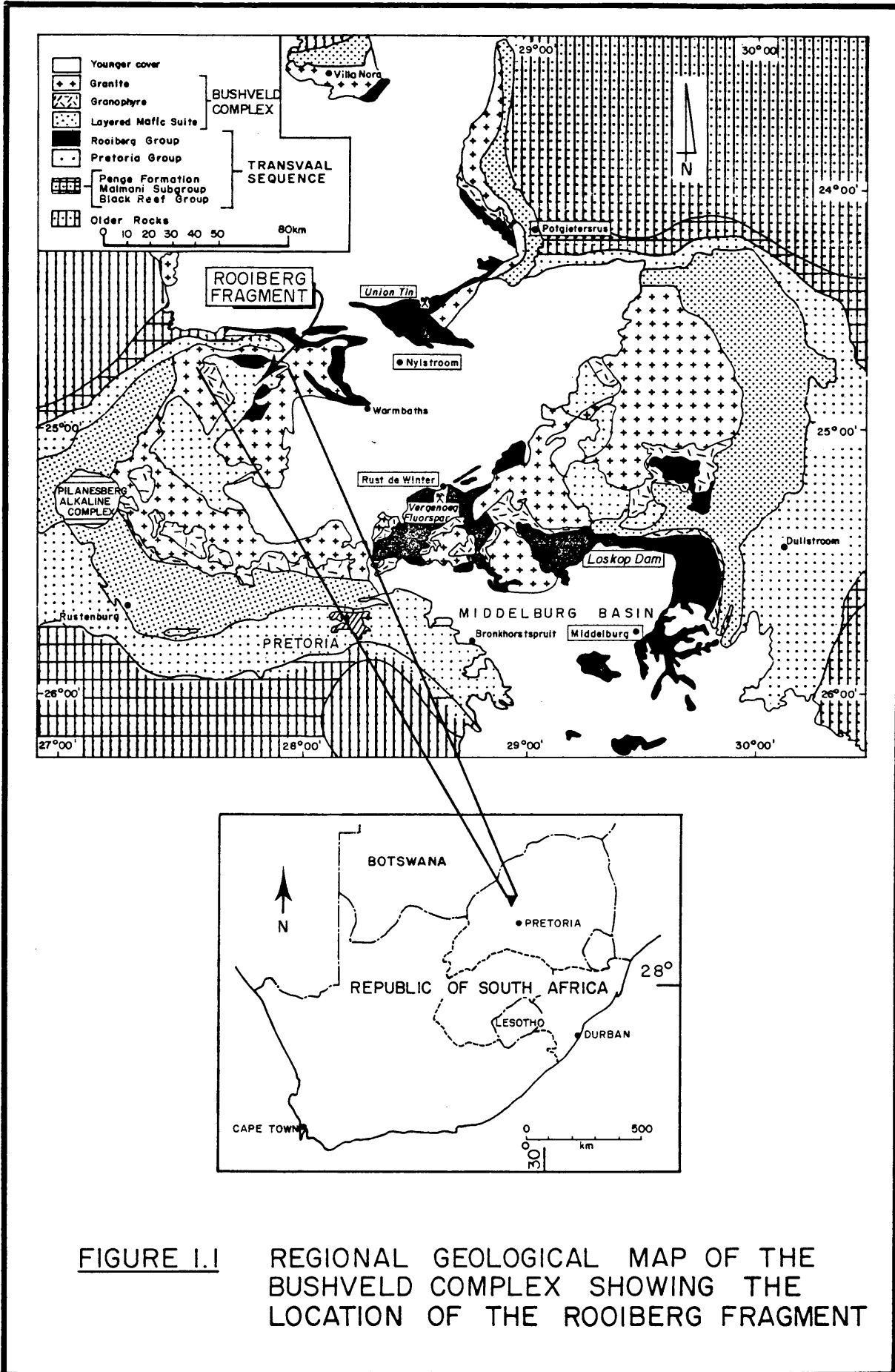


FIGURE 1.1 REGIONAL GEOLOGICAL MAP OF THE BUSHVELD COMPLEX SHOWING THE LOCATION OF THE ROOIBERG FRAGMENT

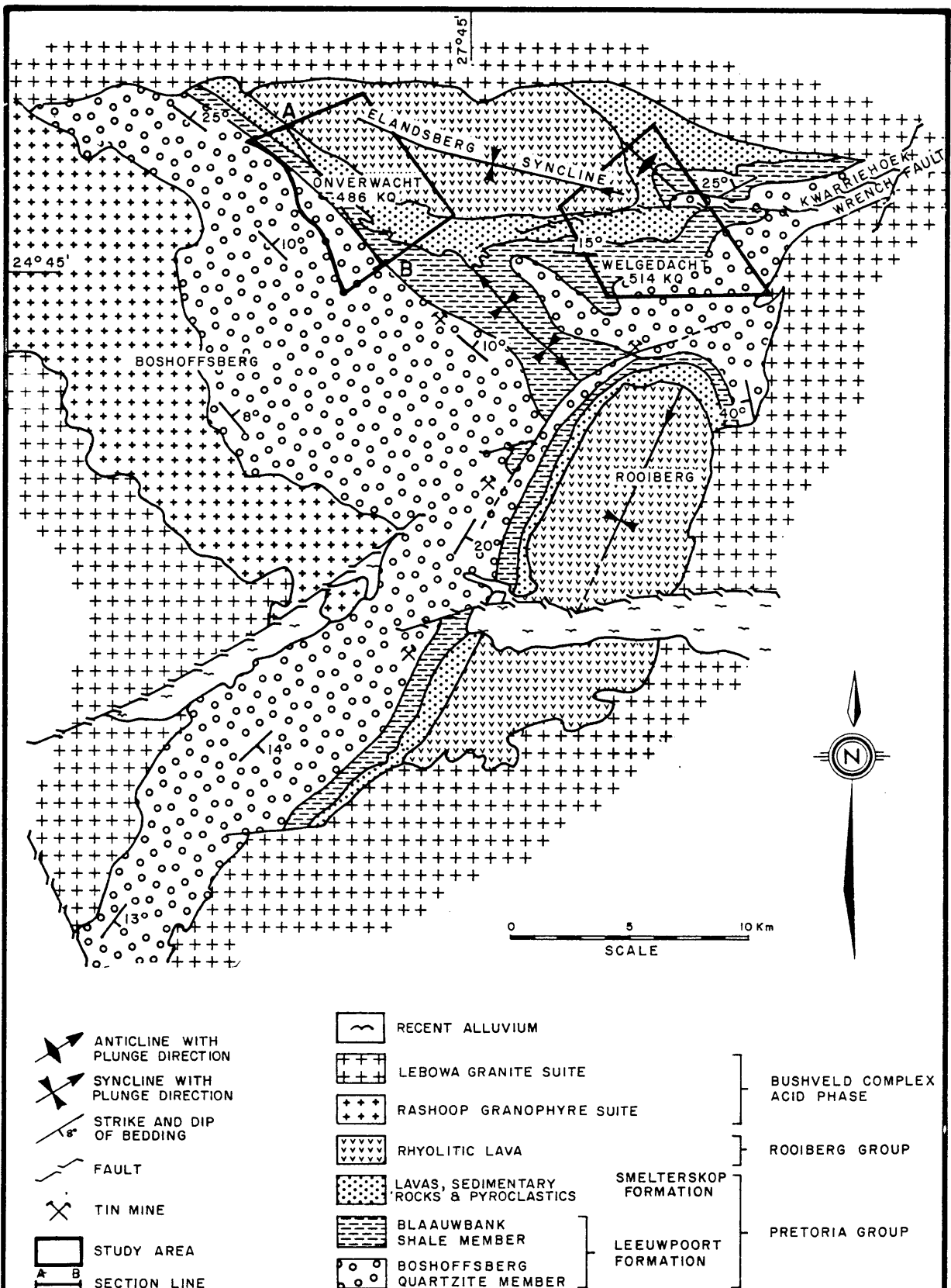
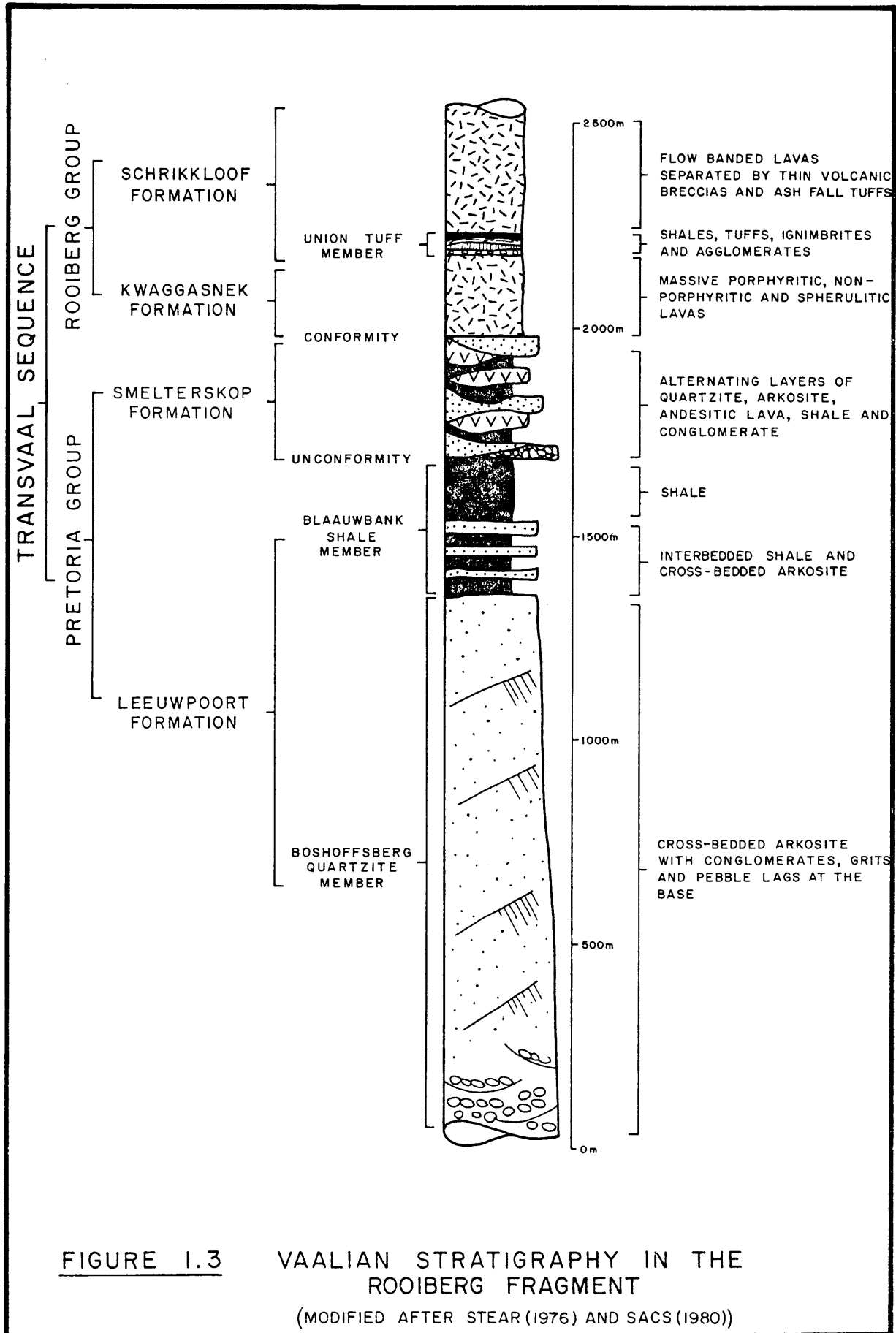


FIGURE 1.2 GEOLOGICAL MAP OF THE ROOIBERG FRAGMENT
(Modified after Marrack (1942) and Phillips (1982))



The Rooiberg Group (Humphrey, 1909) constitutes two formations:

- (a) a basal Kwaggasnek Formation consisting of massive, porphyritic, non-porphyritic and spherulitic lavas, and
- (b) an upper Schrikklouf Formation, comprising massive and flow-banded lavas, separated by thin volcanic breccias and ash fall tuffs, with shales, tuffs, ignimbrites and agglomerates of the Union Turf Member at the base (Fig. 1.3).

The base of the Rooiberg Group is apparently conformable with the Smelterskop Formation (Stear, 1976).

The Leeuwpoort and Smelterskop Formations of the Pretoria Group are correlated with the Rayton Formation in the central Transvaal and the Makeckaan Quartzite Formation in the Marble Hall Fragment (SACS, 1980, p. 203). The Rooiberg Group is equivalent to the Selonsriver and Damwal Formations in the eastern Transvaal (SACS, 1980, p. 203).

The main structural features in the study area are the Elandsberg Syncline and the Kwarriehoek Wrench Fault (Fig. 1.2), which displaces the sedimentary rocks laterally by approximately 2,5 km. Minor low sinuosity folds, normal and reverse faults and doleritic and felsitic dykes are also observed. Leube and Stumpf1 (1963) postulate a major thrust fault at the base of the Rooiberg Group, dipping towards the north. Deformation (folding and faulting) is thought to have occurred during the intrusion of the Bushveld granitoids (Boardman, 1946; Leube and Stumpf1, 1963; Ianello, 1971; Stear, 1976).

Boardman (1946), a pioneer in research within the Rooiberg Fragment, investigated the geology of the north eastern portion of the fragment. Recently, a review of the geology of the fragment was published by Rozendaal *et al.* (1986). Other work on mineralization and sedimentology includes Labuschagne (1970), Dinsdale (1982) and Phillips (1982). Stear (1976, 1977a, 1977b) described the stratigraphy, sedimentology and structure of the Rooiberg Fragment. The mineralogy of the ore deposits has been outlined by Leube and Stumpf1 (1963).

1.3 SCOPE OF THE INVESTIGATION

This thesis incorporates a study of the rocks of the Pretoria Group and overlying Rooiberg Group in part of the Rooiberg Fragment with special reference to sedimentology, contact relationships and geochemistry of the extrusives.

The objectives are:

- (a) to ascertain whether the Rooiberg Group over the northern portion of the Rooiberg Fragment represents the Kwaggasnek or Schrikkloof Formations,*
- (b) to study the sedimentology of the Leeuwpoort and Smelterskop Formations with the view to postulating a depositional model or palaeoenvironment,*
- (c) to ascertain whether the upper and lower contacts of the Smelterskop Formation are conformable, disconformable, unconformable or fault-bounded, and*
- (d) to investigate the litho-geochemistry of the Rooiberg Group and related lavas.*

1.4 METHOD OF STUDY

The study area was mapped as part of a mineral exploration programme. Mapping was carried out with the aid of aerial photographs and 400 m spaced grid lines approximately perpendicular to regional bedding.

Mapping included the following:

- (a) bedding plane measurements which were plotted on Schmidt stereonet projections and contoured according to density per unit area,*
- (b) fault displacement measurements to aid stratigraphic interpretations,*

- (c) detailed observation of the base of the Smelterskop Formation and of the Rooiberg Group,
- (d) sedimentological observations including sedimentary structures, pebble size in conglomerates, grain size variations, palaeocurrent measurements, lenticular beds and lithofacies associations,
- (e) lithological observations, and
- (f) sample collection for petrographic, microprobe and lithogeochemical analysis.

The microprobe analysis of feldspar grains from the Rooiberg Group samples was performed on a JOEL JCSA 773 Electron Microprobe using the following standards at an acceleration voltage of 15 KV; Albite (Na_2O), Pure Quartz (SiO_2), Wollastonite (CaO), Pure Al_2O_3 and Sanidine (K_2O). The lithogeochemical analyses were undertaken by Messrs. Gold Fields Laboratories (Pty.) Ltd. and Bergström and Baker Pty. Ltd., by X-Ray fluorescence. Where modal mineral proportions are given in the text, these were calculated by point-counts of at least 100 points per thin section.

The following definitions for conformable, unconformable and disconformable are used in this thesis. These are taken from the Glossary of Geology (Gary *et al.*, 1972, p. 148 - 149, 201, 765):

(i) *Conformity*: "Said of strata or stratification characterized by an unbroken sequence in which the layers are formed one above the other in parallel order by regular, uninterrupted deposition under the same general conditions"; i.e. there is no significant time period between two different layers.

(ii) *Unconformity*: (a) "A substantial break or gap in the geological record where a rock unit is overlain by another that is not next in stratigraphic succession, such as an interruption in the continuity of a depositional sequence of sedimentary rocks or a break between eroded igneous rocks and younger sedimentary strata. It results from a change that caused deposition to cease for a considerable span of time, and it normally implies uplift and erosion

with loss of the previously formed record. (b) The structural relationship between rock strata in contact, characterized by a lack of continuity in deposition, and corresponding to a period of non-deposition, weathering or especially erosion (either subaerial or subaqueous) prior to the deposition of the younger beds, marked by the absence of parallelism between the strata, strictly, the relationship where the younger overlying stratum does not conform to the dip and strike of the older underlying rocks"; i.e. essentially a time break with different structural attitudes between two layers.

(iii) *Disconformity*: "An unconformity in which the bedding planes above and below the break are essentially parallel, indicating a significant interruption in the orderly sequence of sedimentary rocks, generally by a considerable interval of erosion (or sometimes non-deposition), and usually marked by a visible and irregular or uneven erosion surface of appreciable relief; e.g. an unconformity in which the older rocks remain essentially horizontal during erosion or during simple vertical rising and sinking of the crust (without tilting or faulting)"; i.e. a time break between strata with no structural differences between them.

There is some controversy, however, over the use of the terms *unconformity* and *disconformity* (Tomkeieff, 1962). American researchers recognize *unconformities* and *disconformities* as time breaks irrespective of the structural attitude of the beds while British researchers, in most cases, use the definition of Gary *et al.* (1972).

In spite of petrographic classifications for the sedimentary rocks, the field terms "arkosite", "quartzite" and "shale" are used in this thesis.

2. PRETORIA GROUP

2.1 LEEUWPOORT FORMATION

2.1.1 GENERAL CHARACTERISTICS

The basal Boshoffsberg Quartzite Member, an upward-fining sequence of conglomerates (not exposed in the study area) and arkosites (Fig. 1.3), attains a minimum thickness of 800m in the study area. Thicknesses of 1 400m and 1 300m are quoted by Stear (1977a) and Labuschagne (1970, p. 6), respectively. In outcrop the arkosites display a pink to grey colour and are generally medium-grained. The term arkosite as defined by Leube and Stumpf (1963) is used in this thesis; from petrographic work they are classified as arkosic arenites (Pettijohn, 1975, p. 211).

The upper Blaauwbank Shale Member, locally termed the shaly arkosite (basal unit) and main shale (upper unit), is an upward-fining sequence of interbedded shale and arkosite overlain by finely laminated shale. These arkosites are generally finer-grained than those observed in the Boshoffsberg Quartzite Member. The shaly arkosite attains an average thickness of 208m in the study area, compared to 150m reported by Stear (1977a) and 212m by Labuschagne (1970, p. 10) in other parts of the Rooiberg Fragment. Towards the eastern portion of the study area the main shale and shaly arkosite are separated by a well indurated, medium-grained, pink-coloured arkosite. This unit is lenticular, striking for approximately 1km and thinning out towards the west. The main shale, a dark, black to grey laminated rock, appears to pinch out towards the west, where the Smelterskop Formation lies directly upon the shaly arkosite. A maximum thickness for the main shale of 200m, comparable to Stear's (1976) 150m and Labuschagne's (1970, p. 10) 105m, is found in the eastern portion of the study area. Localised discontinuous quartzite lenses are observed at the top of this shale, especially towards the east.

2.1.2 LITHOLOGY

The arkosites which characterize the basal Boshoffsberg Quartzite Member are medium-grained sandstones with a high feldspar and a

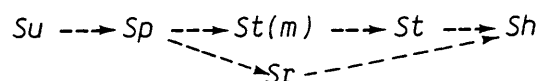
relatively low matrix content. Structures include planar cross-beds, trough cross-beds, horizontal stratification and minor trough cross-lamination. The trough cross-beds are on average 75cm wide and not greater than 30cm deep. Planar cross-beds have an average inclination angle of 25° with laminae thickness not greater than 15mm and set thicknesses of approximately 30cm. Sinuous-crested megaripples (Fig. 2.1) are also common features, formed by the migration of large dunes (Reineck and Singh, 1980, p. 17).

B-C sequences, comprising cross-bedded units overlain by cross-laminated units (Klein, 1970), are fairly common features observed towards the top of the Boshoffsberg Quartzite Member. Other, less important features include convolute bedding (Fig. 2.2) and reactivation surfaces, curved surfaces that truncate planar trough cross-bed sets (Harms *et al.*, 1975, p. 50). Palaeocurrent directions obtained from trough cross-beds in the arkosites of the Leeuwoort Formation are trimodal with north-west, south-west and north-east components, and a vector mean towards the west (Fig. 2.3).

The sedimentary rocks of the Boshoffsberg Quartzite Member can be divided into a number of lithofacies (Fig. 2.4), modified from Miall (1977):

- St Trough cross-bedded arkosite
- St(m) Trough cross-bedded arkosite with megaripples
- Sp Planar cross-bedded arkosite
- Su Undifferentiated arkosite (no structure observed)
- Sh Horizontally laminated arkosite
- Sr Trough cross-laminated arkosite

A Markov Analysis of vertical facies transitions (Fig. 2.4), following the technique of Miall (1973) (Appendix A) indicates a preferential sequence of:



The Blaauwbank Shale Member is an upward-fining sequence of interbedded mudstones and arkosites (shaly arkosite) overlain by mudstones of the



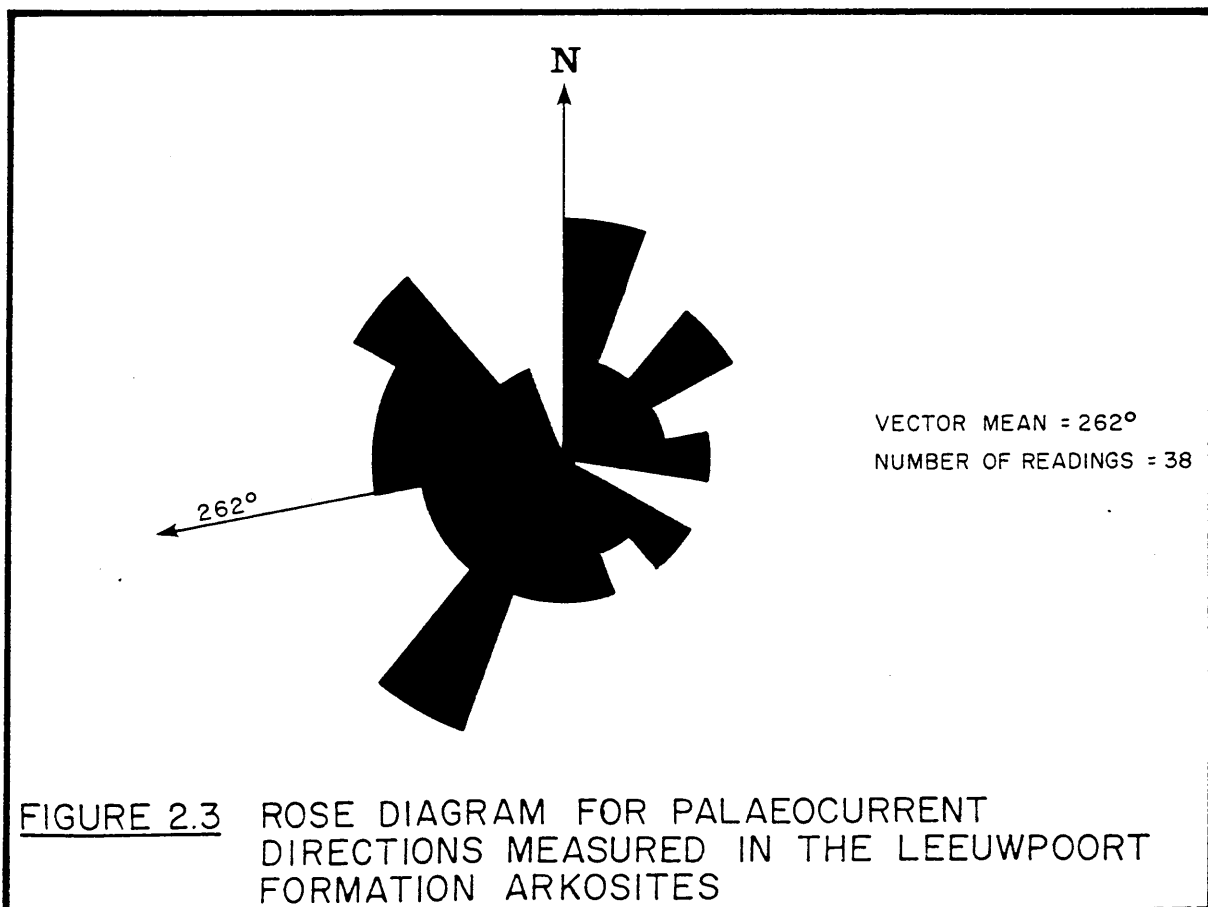
FIGURE 2.1: *Megaripples in the arkosite of the Boshoffsberg Quartzite Member.*



FIGURE 2.2: *Convolute bedding in the arkosites of the Boshoffsberg Quartzite Member, Leeuwpoort Formation.*

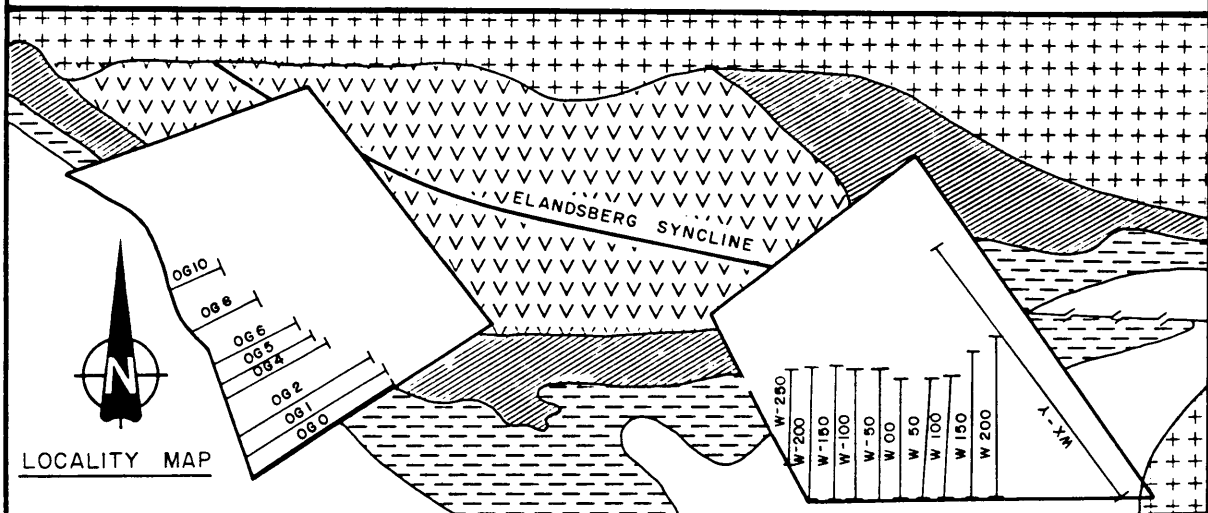
main shale (Fig. 1.3). The shaly arkosite sandstones display planar cross-bedding, trough cross-bedding and horizontal lamination. The mudstones are horizontally laminated and also exhibit trough cross lamination and common soft sediment deformation structures such as slumpballs (Fig. 2.5), flame structures (Fig. 2.6) and pseudonodules (Allen, 1984, p. 359) (Fig. 2.7). Within the shaly arkosites small scale upward-fining sequences are observed (Fig. 2.4). Lithofacies defined in the shaly arkosites include trough cross-bedded arkosite (St), planar cross-bedded arkosite (Sp), horizontally laminated arkosite (Sh), trough cross-laminated mudstone (Fr) and horizontally laminated mudstone (Fh) (Fig. 2.4).

The main shale consists of finely laminated mudstones which also display horizontal and trough cross-lamination and asymmetrical (Fig. 2.8), symmetrical and interference ripple marks (lithofacies Fh and Fr) (Fig. 2.9). Ripples are normally restricted to sandy sediments, but may also occur in mudstones (Reineck and Singh, 1980, p. 14). In addition, convolute bedding (Fig. 2.10) and mudcracks are fairly common features.



LEGEND & FACIES DEFINITIONS

W50	PROFILE NUMBER
F	DOMINANT FACIES (MODIFIED FROM MIALL, 1977)
Po	PALAEOCURRENT DIRECTION
	UNITS OF UPWARD-FINING CROSS-BEDDED ARKOSITE AND SHALE
	SHALE- TROUGH CROSS-LAMINATE (Fr) OR HORIZONTALLY LAMINATED (Fh)
	HORIZONTALLY LAMINATED ARKOSITE (Sh)
	TROUGH CROSS-BEDDED ARKOSITE (St)
	TROUGH CROSS-BEDDED ARKOSITE WITH MEGARIPPLES (St(m))
	PLANAR CROSS-BEDDED ARKOSITE (Sp)
	TROUGH CROSS-LAMINATED ARKOSITE (Sr)
	UNDIFFERENTIATED ARKOSITE (Su) (NO STRUCTURES OBSERVED)
	CONVOLUTE BEDDING (C.B.)
	REACTIVATION SURFACES (Se)
M.C.	MUDCRACKS
SSD	EXTENSIVE SOFT SEDIMENT DEFORMATION FEATURES
	SHALE WITH LOAD STRUCTURES (L.S.)
	BC SEQUENCES (B.C)
	GRADATIONAL CONTACT



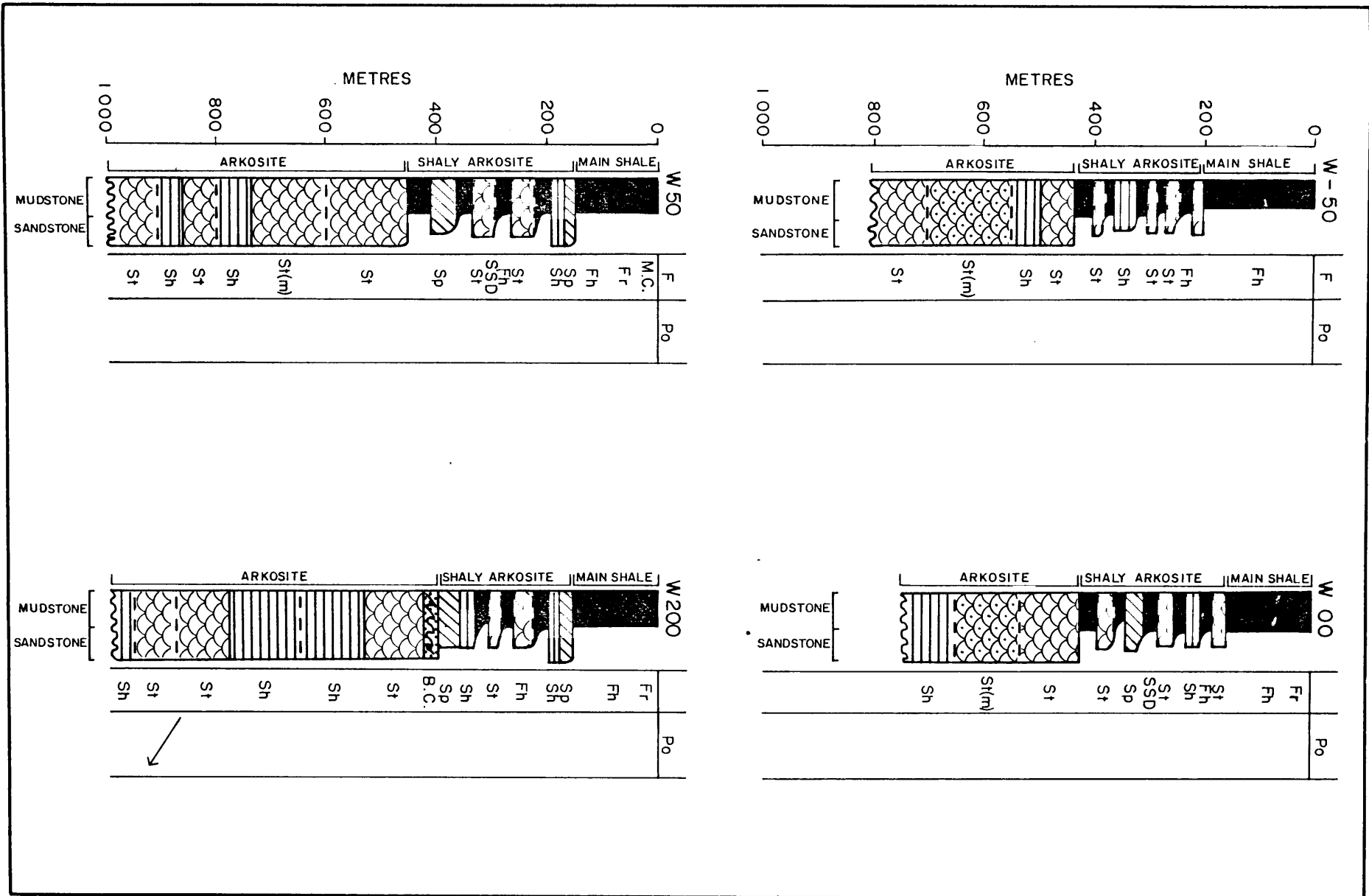
LEGEND

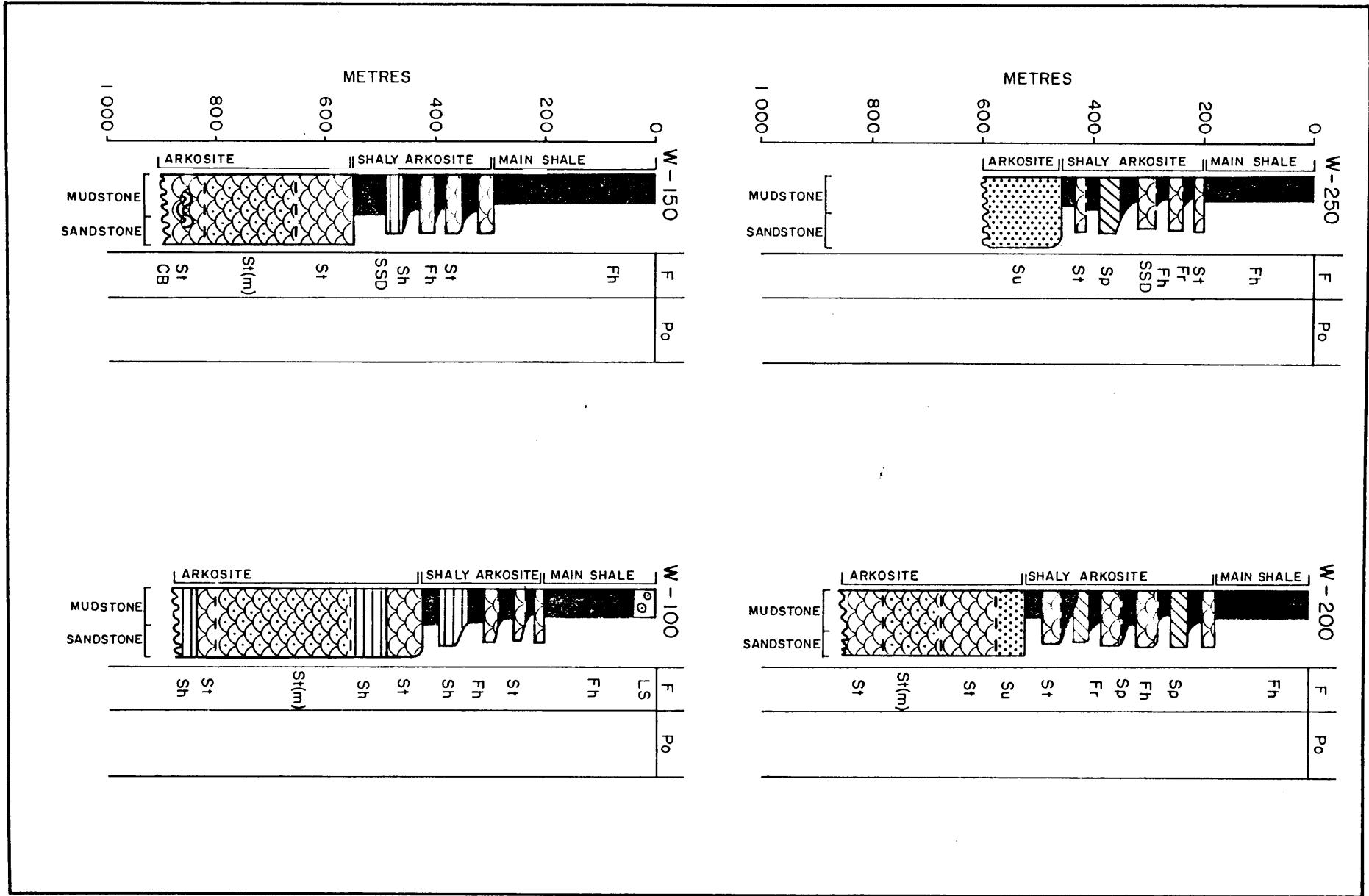
	Bushveld Granite		Blaauwbank Shale Member
	Bushveld Granophyre		Boshoffsberg Quartzite Member
	Rooiberg Group		Profile Line
	Smelterskop Formation		Fault

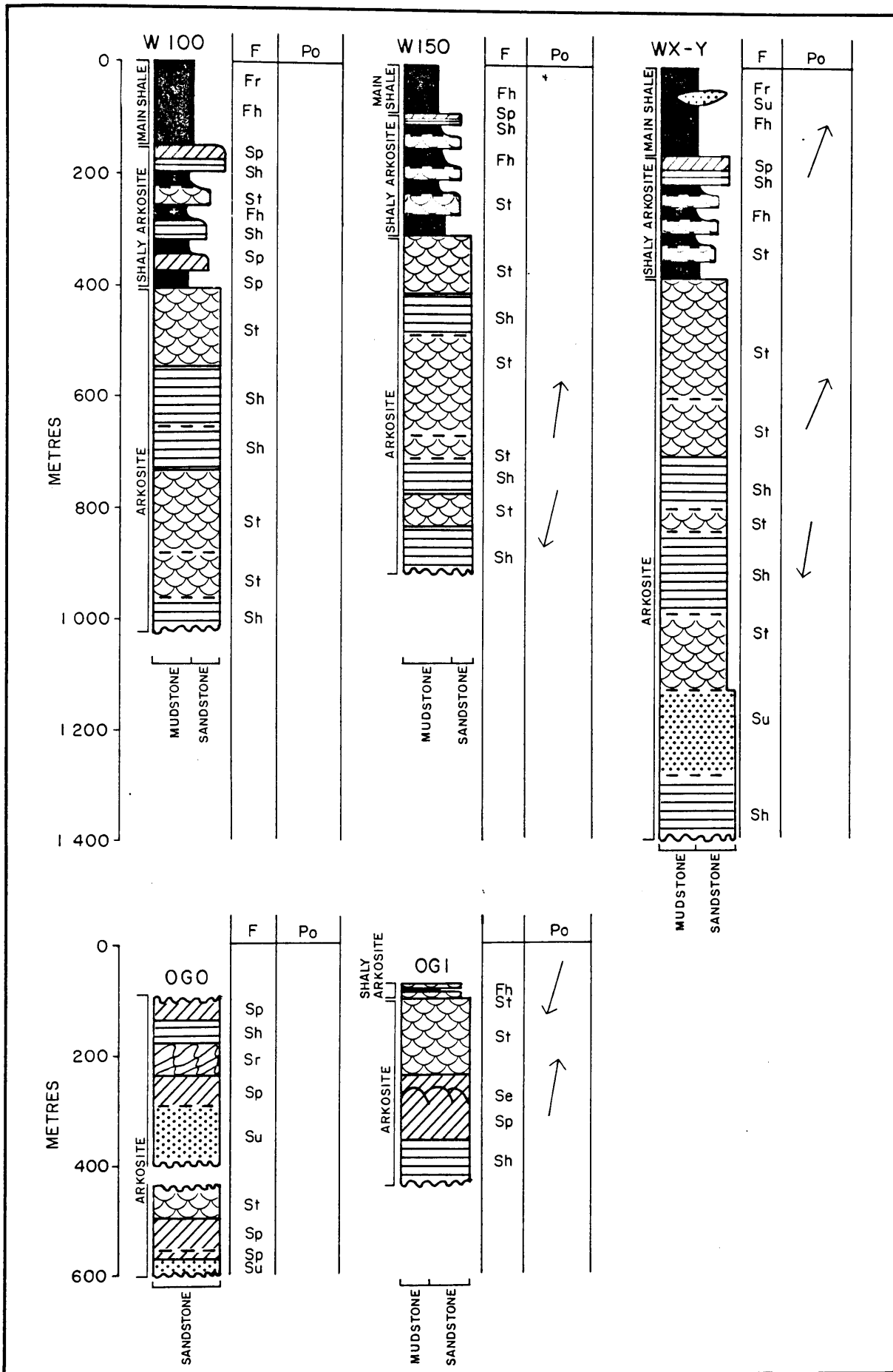


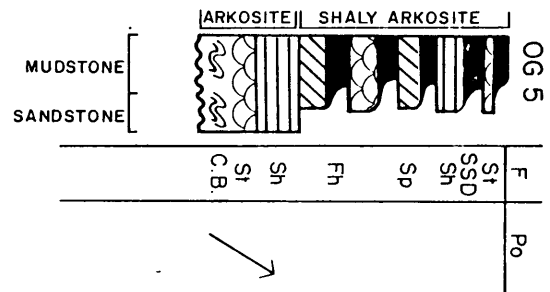
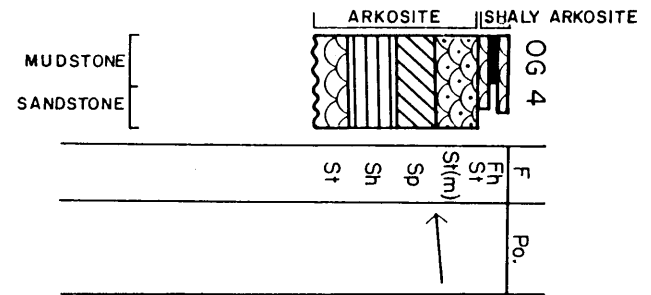
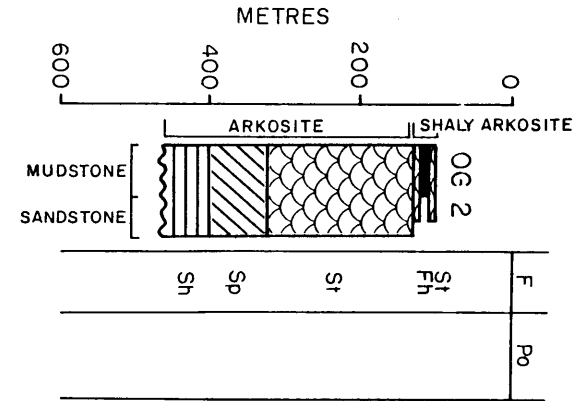
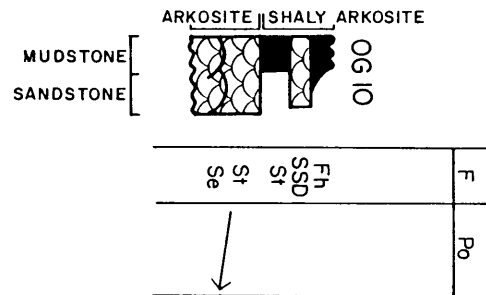
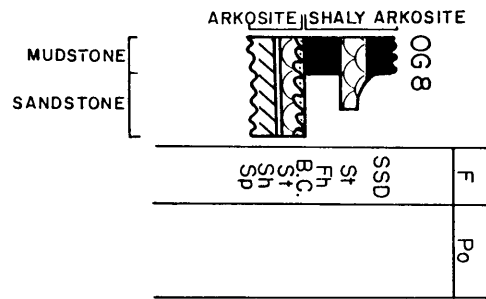
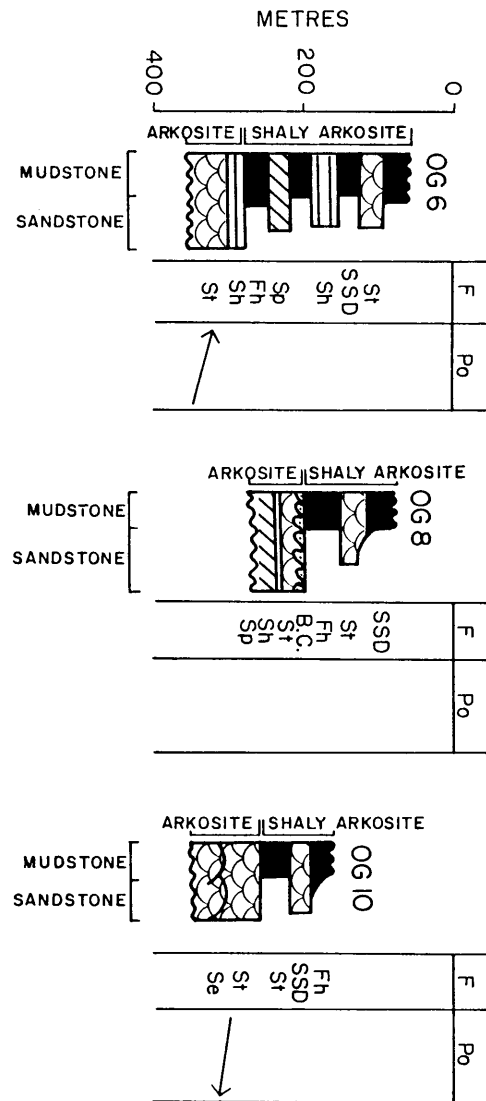
Scale 1:125 000

FIGURE 2.4 SEDIMENTARY PROFILES OF THE LEEUW-POORT FORMATION









2.1.3 PETROGRAPHY

Previous petrographic observations in the Leeuwpoort Formation (Rozendaal *et al.*, 1986) reveal mosaic textures with the presence of chlorite and sericite and absence of primary clay minerals. This suggests an albite-epidote-hornfels grade of contact metamorphism.

The arkosites of the Leeuwpoort Formation are fine- to medium-grained (0,5mm to 0,125mm grain size) rocks with a granoblastic to sutured metamorphic texture (Fig. 2.11). Minerals, with their average modal proportions, include quartz (35%), orthoclase (54%), plagioclase feldspar (5%), microcline (1%), chlorite as matrix (4%) and minor amounts (< 1%) of opaque minerals (probably magnetite), tourmaline, cassiterite and zircon. These rocks are classified in terms of Pettijohn (1975, p. 211) as arkosic arenites. Nebo granites of the Bushveld Complex intrude the arkosites in the south-eastern portion of the study area. This has resulted in an increase in grain size and a slight elongation of quartz and feldspar grains (Fig. 2.12).

In thin section, the shales of the Blaauwbank Shale Member exhibit a xenomorphic, reasonably elongate metamorphic texture (Fig 2.13) of quartz grains set in a matrix of sericite, quartz and chlorite. This is probably the result of metamorphic recrystallization of original mudstones.



FIGURE 2.5: Well developed slumpballs in the shaly arkosite of the Blaauwbank Shale Member.



FIGURE 2.6: Flame structures in the shaly arkosite of the Blaauwbank Shale Member.



FIGURE 2.7: Pseudonodules up to 2m in length in the shaly arkosite of the Blaauwbank Shale Member.



FIGURE 2.8: *Asymmetrical ripple marks in the main shale of the Blaauwbank Shale Member.*

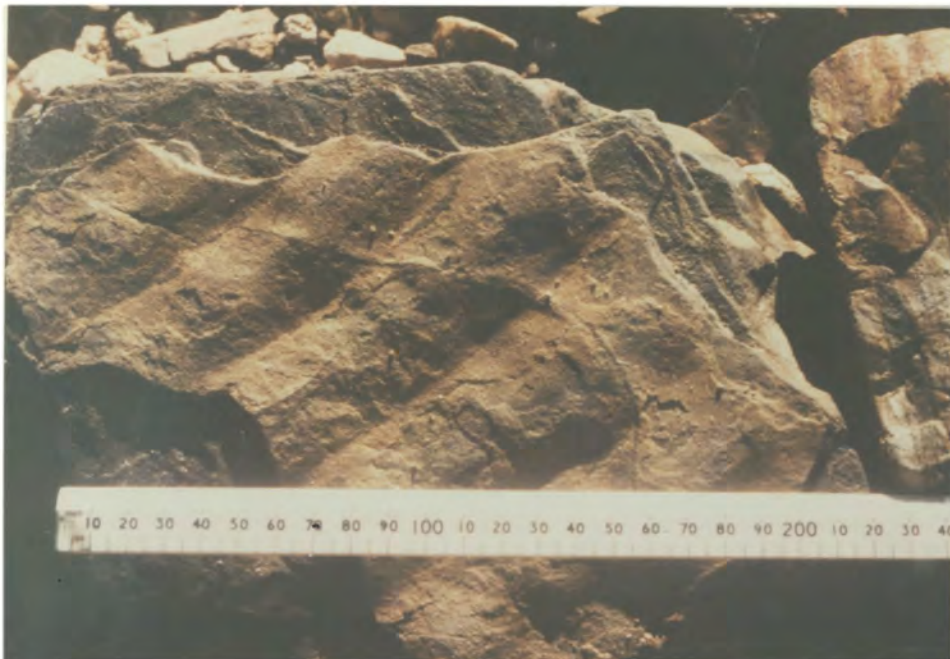


FIGURE 2.9: *Symmetrical and interference ripple marks in the Blaauwbank Shale Member.*



FIGURE 2.10: *Convolute bedding in the main shale of the Blaauwbank Shale Member.*

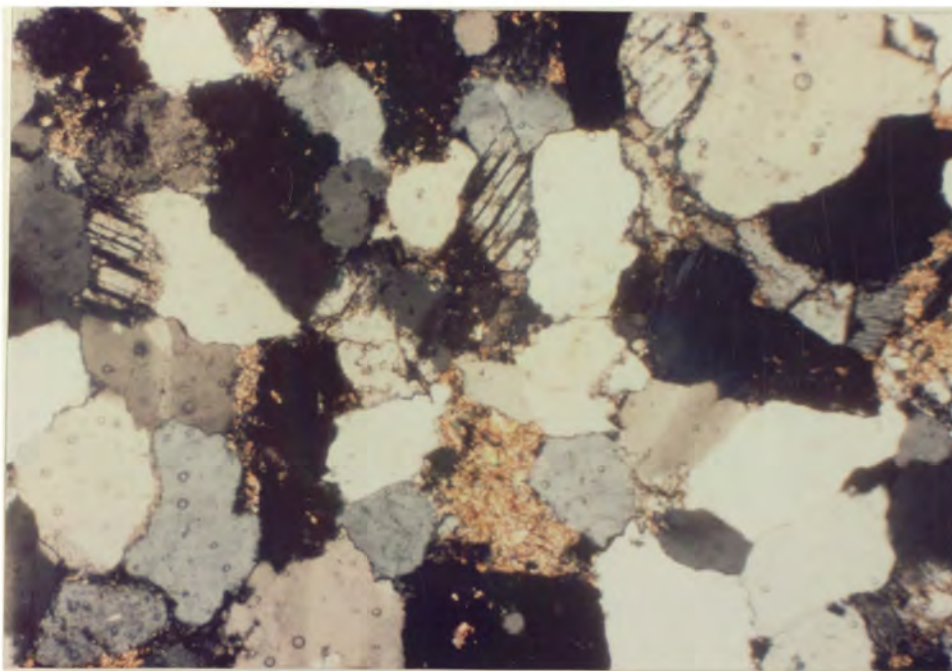


FIGURE 2.11: *A granoblastic to sutured texture in the arkosites of the Leeuwpoot Formation (1cm equals 178 microns) - crossed nicols.*

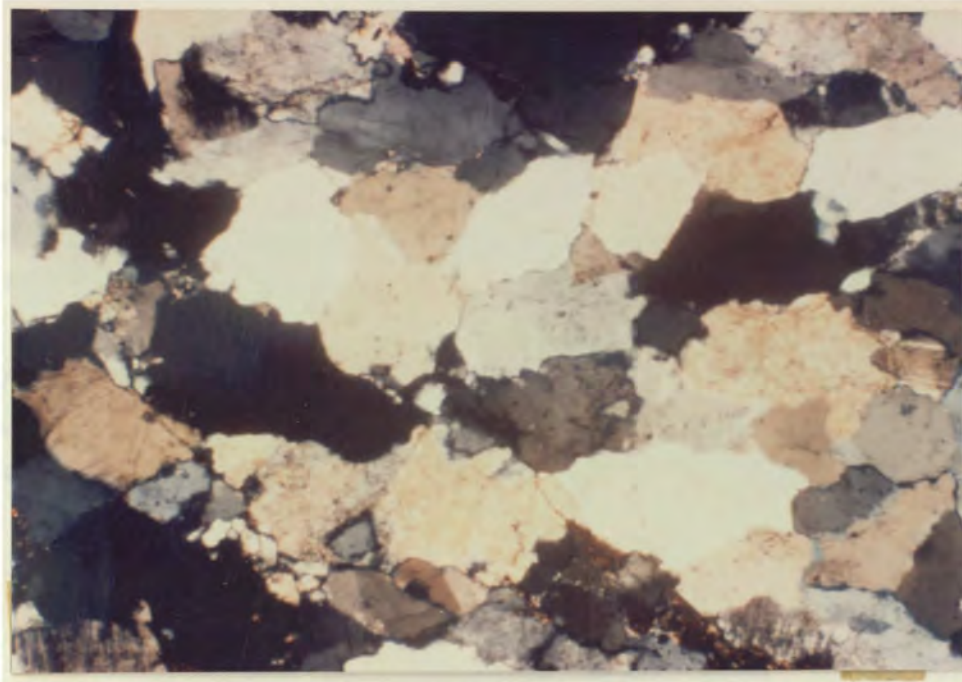


FIGURE 2.12: A granoblastic slightly elongate texture in the arkosites of the Leeuwpoot Formation (1cm equals 178 microns)-crossed nicols

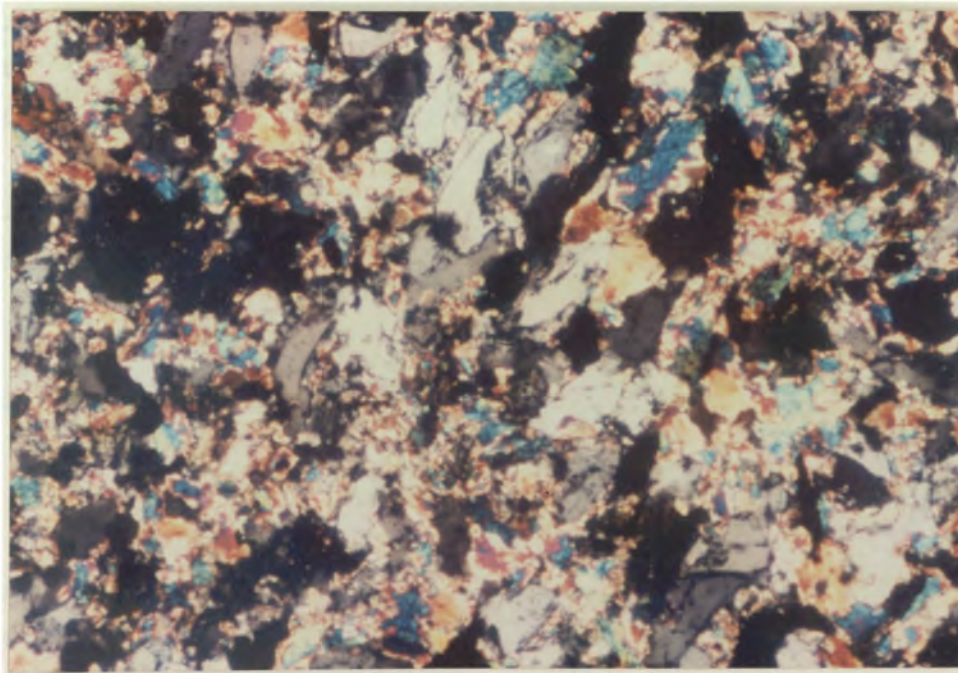


FIGURE 2.13: A xenomorphic reasonably elongate texture in the shales of the Blaauwbank Shale Member (1cm equals 178 microns)-crossed nicols.

2.2 SMELTERSKOP FORMATION

2.2.1 GENERAL CHARACTERISTICS

The Smelterskop Formation consists of andesitic lavas, quartzites, conglomerates, arkosites, minor greywackes and pyroclastic rocks. A lateral variation from finer-grained sedimentary rocks in the west to coarser-grained rocks in the east is observed.

The conglomerates are found at the base of the Smelterskop Formation and outcrop only in the eastern portion of the study area. These occur as lensoid bodies averaging 10m in length and 2m in thickness.

Quartzites are the dominant rock type in the succession and form large lenses up to 2km in length. They are predominant at the base of the succession in the west of the study area, occur throughout the succession in the east, and are present as thin (< 10m thick) lenticular (< 100m strike length) bodies towards the top of the succession in the west. These thin bodies appear to be laterally truncated by the overlying Rooiberg Group.

The arkosites in the Smelterskop Formation are found as lenticular bodies throughout the succession. They are generally similar in character to the arkosites of the Leeuwpoot Formation, but have lower feldspar and matrix contents and a higher degree of recrystallization.

The lavas of the Smelterskop Formation are found throughout the succession but appear to be more dominant towards the west of the study area. This could, however, be due to poor exposure of these lavas as they are highly weathered in outcrop and are usually covered by alluvium or top soil. They have been described by Boardman (1946) and Stear (1976, 1977a) as andesitic in character.

Shale lenses, mostly found in the upper reaches of the formation, display a laminated micro-texture, with quartz being the dominant mineral.

Localised greywackes and pyroclastic rocks are also found, particularly towards the base of the Smelterskop Formation. The greywacke, described by Stear (1976) as an agglomerate, is sublithic in its petrographic character, with rounded to subrounded quartz and rock fragment grains set in a matrix of chlorite and sericite (Fig. 2.14). Large, angular agglomeratic blocks, up to 50cm in size and consisting of fine-grained arkosite and shale are embedded in the greywacke. A pyroclastic rock found in the eastern portion of the study area at the base of the succession consists of small, < 5cm, angular fragments of shale, arkosite/quartzite, conglomerate and lava set in a fine- to medium-grained volcanic tephra. This deposit is analogous to an ash flow in which a "hot particle" flow moves under the influence of gravity and rips up pieces of the underlying formation (Friedman and Sanders, 1978, p. 44).

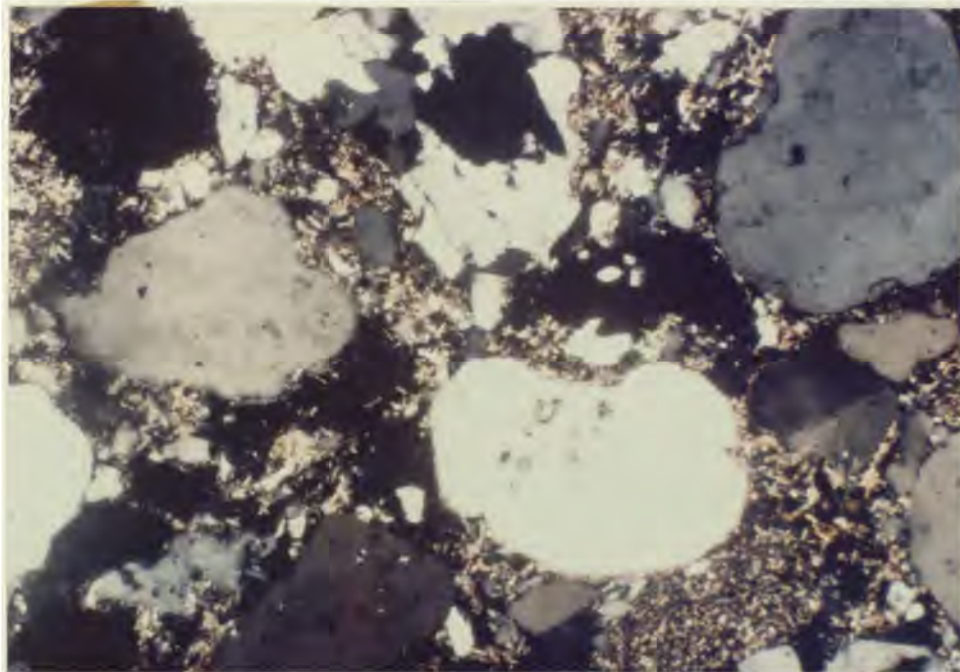
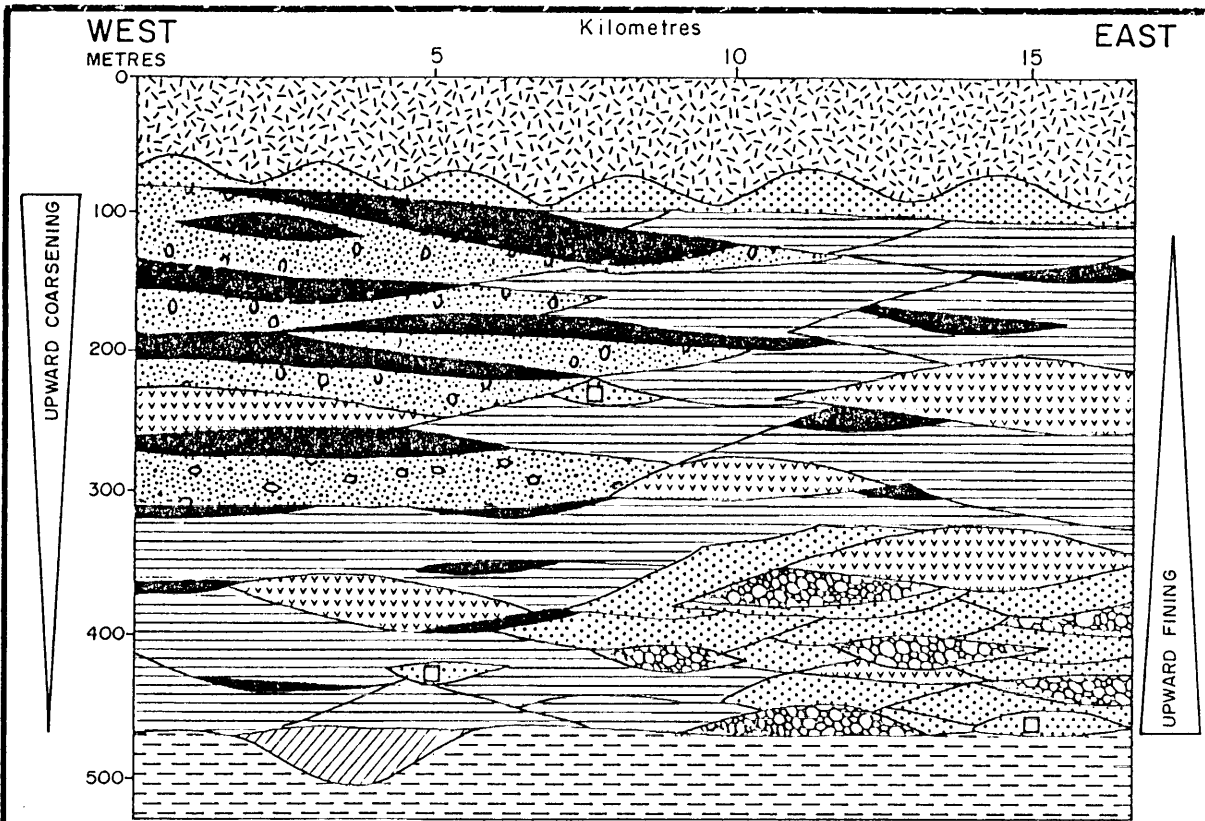


FIGURE 2.14: Sublithic greywacke with rounded detrital grains set in a chlorite/sericite matrix (1cm equals 178 microns) - crossed nicols

2.2.2 LITHOLOGY

The sedimentary rocks of the Smelterskop Formation, comprising conglomerates, arkosites, quartzites and shales, are highly lenticular



LEGEND











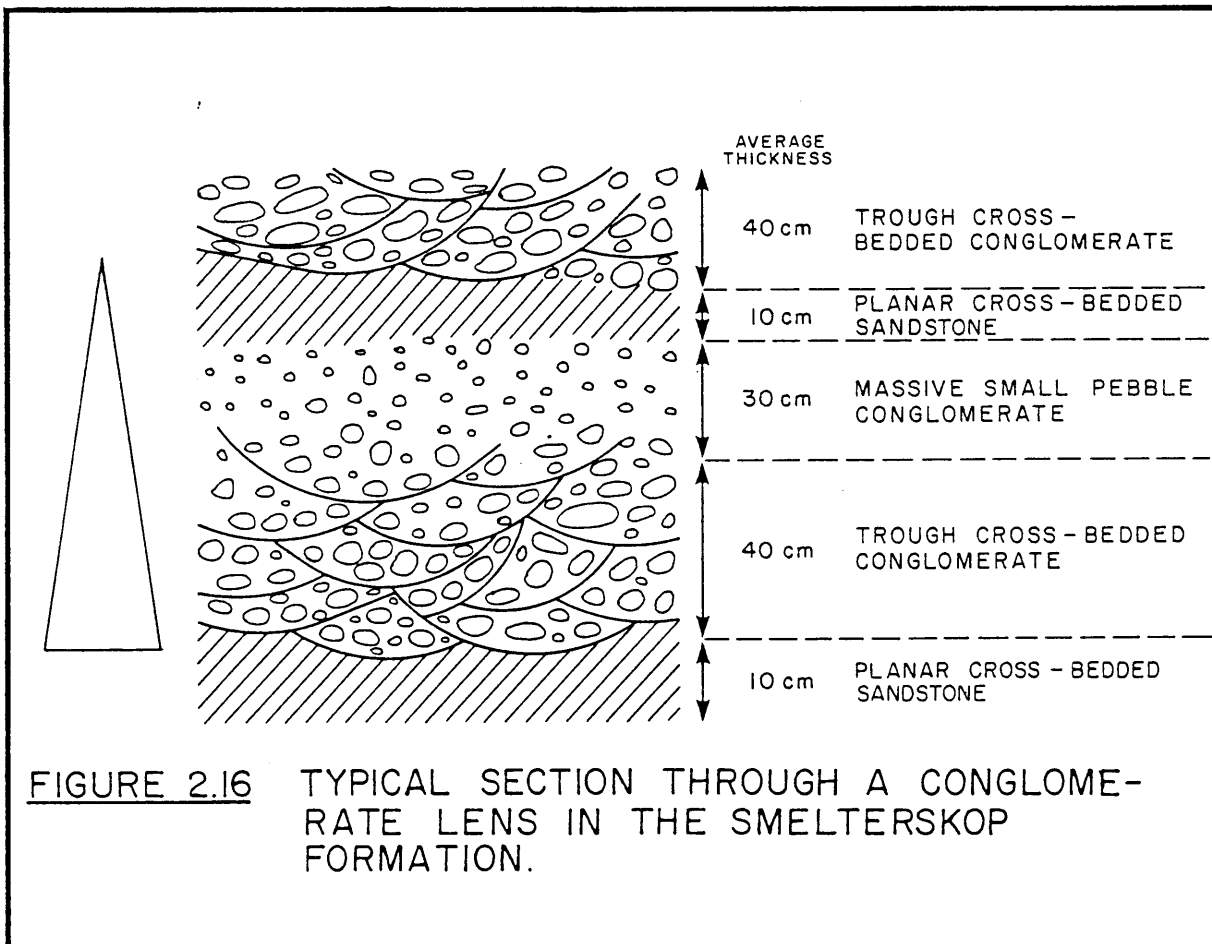
-  SUBLITHIC AGGLOMERATIC GREYWACKE
-  PYROCLASTIC ROCKS
-  CONGLOMERATES
-  SHALES
-  ANDESITIC LAVA
-  TROUGH CROSS-BEDDED AND MASSIVE QUARTZITES + ARKOSITES
-  HORIZONTALLY LAMINATED SANDSTONES
-  MASSIVE COARSE-GRAINED ARKOSITES
-  MAIN SHALE, BLAAUWBANK SHALE MEMBER
-  ROOIBERG GROUP

FIGURE 2.15 SCHEMATIC CROSS-SECTION OF THE SMELTERSKOP FORMATION.

and display few sedimentary structures due to their predominantly massive and coarse-grained field outcrops. Individual units exhibit no traceable lateral correlation. Lithological associations are therefore important in interpreting the sedimentary palaeoenvironment of this sequence. Lateral and lithological changes discussed in the text are depicted in Fig. 2.15.

An upward-fining sequence of conglomerates overlain by arkosites and quartzites in the east, and an upward-coarsening sequence of finer-grained arkosites/quartzites overlain by coarser-grained sedimentary rocks in the west are observed. The feldspar content in the sediments is variable and is not dependent on stratigraphic level or lateral variations.

Sedimentary features of the basal conglomerate lenses include upward-fining sequences of trough cross-bedded conglomerate, massive small pebble conglomerates and planar cross-bedded quartzites and arkosites (Fig. 2.16).



The arkosites and quartzites found throughout the succession are usually massive or horizontally laminated. Minor trough and planar cross-bedded varieties are observed. The massive sandstones are usually coarse-grained (grain size greater than 0.5mm) arkosites and these are predominant in the western portion of the study area, mainly towards the top of the succession (Fig. 2.15). They are usually associated with shale layers which vary in thickness from 5m to 20m. The horizontally laminated sandstones can either be arkosic or quartzitic and are found towards the top of the succession in the eastern portion of the study area, and towards the base in the western part. These are invariably associated with shale layers less than 5m thick (Fig. 2.15).

2.2.3 PETROGRAPHY

Petrographic work on the Smelterskop Formation sedimentary rocks is limited. The grade of metamorphism is however thought to be similar to that observed in the Leeuwpoort Formation.

The quartz content in the quartzites of the Smelterskop Formation ranges from 80% to 99% with an average of one percent opaque minerals and five percent sericite as matrix material. Up to 12% potassic feldspar is observed in some of the quartzites. A granoblastic to sutured metamorphic texture is evident (Fig. 2.17), although in some cases recrystallization with a subsequent granuloblastic texture is observed (Fig. 2.18). These rocks range in classification from quartz wackes to subarkosic wackes (Pettijohn, 1975, p. 211).

The arkosites in this formation display a granoblastic to sutured texture with interlocking grains of quartz and feldspar. Average modal proportions of the different components are:

Quartz	53%	
Potassic feldspar	21%	
Plagioclase feldspar	2%	—
Sericite	21%	MATRIX
Chlorite	3%	

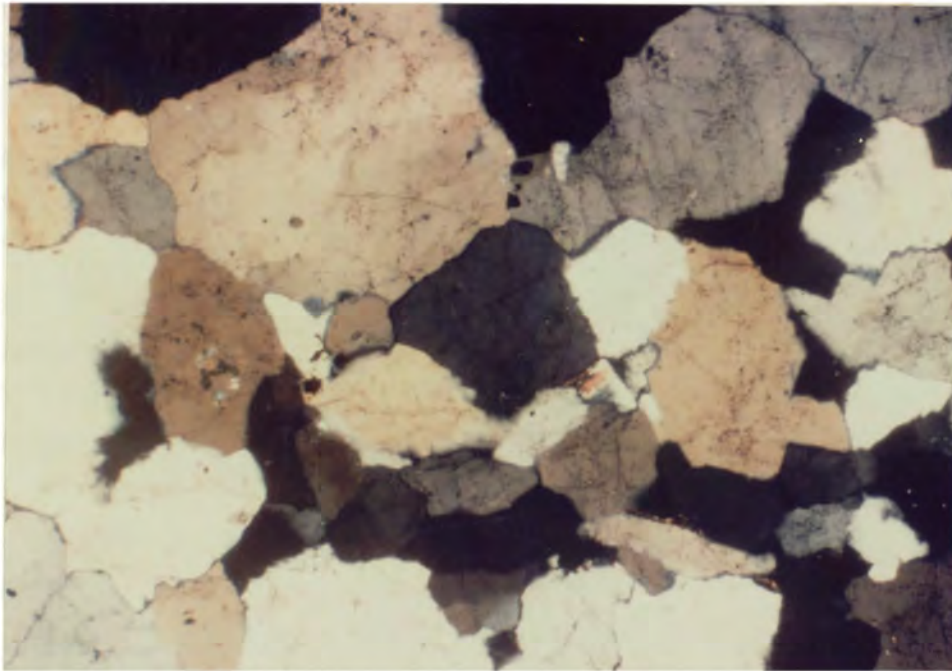


FIGURE 2.17: Granoblastic to sutured texture in a quartzite of the Smelterskop Formation (1cm equals 178 microns)-crossed nicols.

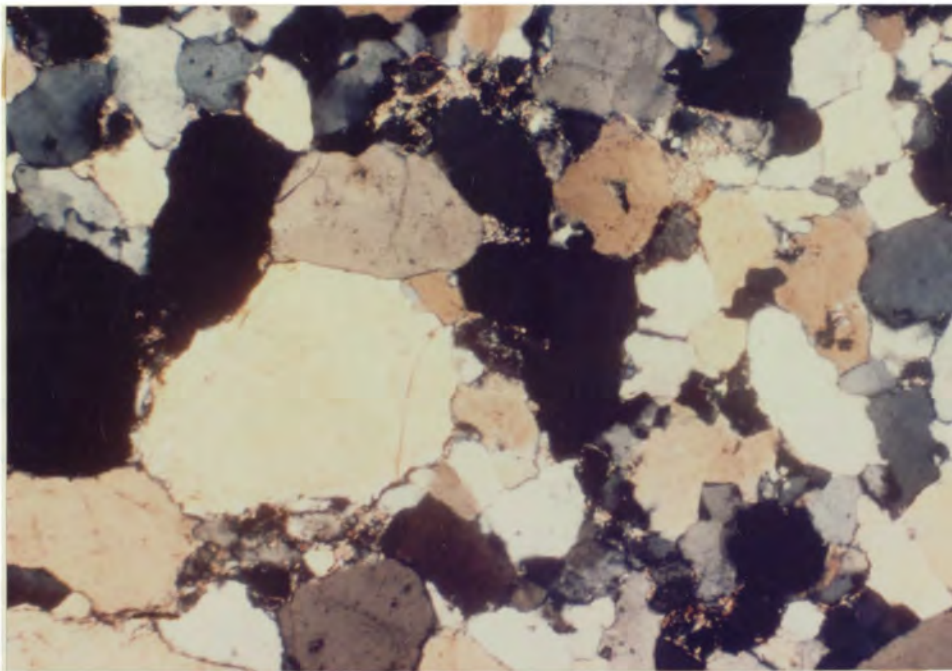


FIGURE 2.18: Recrystallized quartzite showing a granoblastic texture in the Smelterskop Formation (1 cm equals 178 microns) - crossed nicols.

Minor amounts (< 1%) of tourmaline, cassiterite, calcite and microcline are also observed. The different petrography of these arkosites, compared to those of the Leeuwoort Formation, is probably due to (a) a higher degree of reworking causing a lower feldspar and higher matrix content, and (b) a higher silica component, resulting in a greater degree of recrystallization. Some of the matrix may however represent volcanic detritus with the change in sandstone petrography attributed to different source areas. This is expected during an onset of volcanism. Petrographically the lavas are holocrystalline, fine- to medium-grained with an inequigranular sericitic texture. They are texturally similar to the high magnesium lavas of the Rooiberg Group in the south-eastern portion of the Bushveld Complex (Twist, 1985). The mineralogy, although in most cases secondary due to alteration, includes plagioclase feldspar, quartz, biotite, chlorite and amphibole, the latter possibly replacing primary pyroxene. Weathered lava samples consist predominantly of sericite, calcite and chlorite, with minor amounts of remnant quartz, feldspar and biotite.

Pebbles in the conglomerates at the base of the Smelterskop Formation are rounded to subrounded and poorly sorted. From pebble size measurements of 50 pebbles, a mean pebble size of 52mm with a standard deviation of 37,8mm was obtained. Pebble types include vein quartz (67%), pink arkosic quartzite (29%) silicified layered chert (2%) and mafic igneous pebbles (2%).

2.2.4 GEOCHEMISTRY OF THE LAVAS

Two samples of relatively fresh lava obtained from percussion drilling chips were analysed for major and selected trace elements. These analyses, together with analyses obtained on similar material by Phillips (1982) and Lomborg (1985), are shown in Table 1 and Figure 2.19. The samples analysed by Lomborg and Phillips were taken approximately 20km south of the study area; both samples are silica-poor, with highly variable alkali contents. The very low alkali content of Phillips' sample probably indicates alteration accompanied by leaching of sodium and potassium.

The chemical composition of these lavas ranges from basalts (Lomberg, 1985) to alkali poor basaltic andesites (Phillips, 1982) through to andesites (ORS 1 and ORS 2) (Fig. 2.19).

The magnesium content is relatively high for an andesite with concentrations of 8,25% and 8,68% (ORS 1 & ORS 2; Table 1) as compared to 3,33% MgO in average andesite (Cox *et al.*, 1980, p. 403). This feature was also noted by Phillips (1982) who classified his samples as high magnesium basalts.

TABLE 1: CHEMICAL COMPOSITION OF THE SMELTERSKOP FORMATION LAVAS

	ORS 1	ORS 2	LOMBERG (1985)	PHILLIPS (1982)
SiO ₂	59,7	59,6	50,6	52,6
TiO ₂	0,41	0,39	0,38	0,43
Al ₂ O ₃	13,0	12,2	12,4	11,1
* FeO	10,4	10,5	14,7	15,8
MnO	0,16	0,20	0,17	0,17
MgO	8,25	8,68	11,5	15,2
CaO	4,18	4,32	4,93	3,53
Na ₂ O	0,85	1,05	1,11	0,07
K ₂ O	2,94	2,90	4,13	0,99
P ₂ O ₅	0,08	0,08	0,10	0,08
	99,97	99,92	100,02	99,97
Nb	3	3	-	-
Y	13	10	-	-
Zr	63	67	-	-

* FeO : TOTAL IRON

N.D. : NOT DETECTED

- : NOT DETERMINED

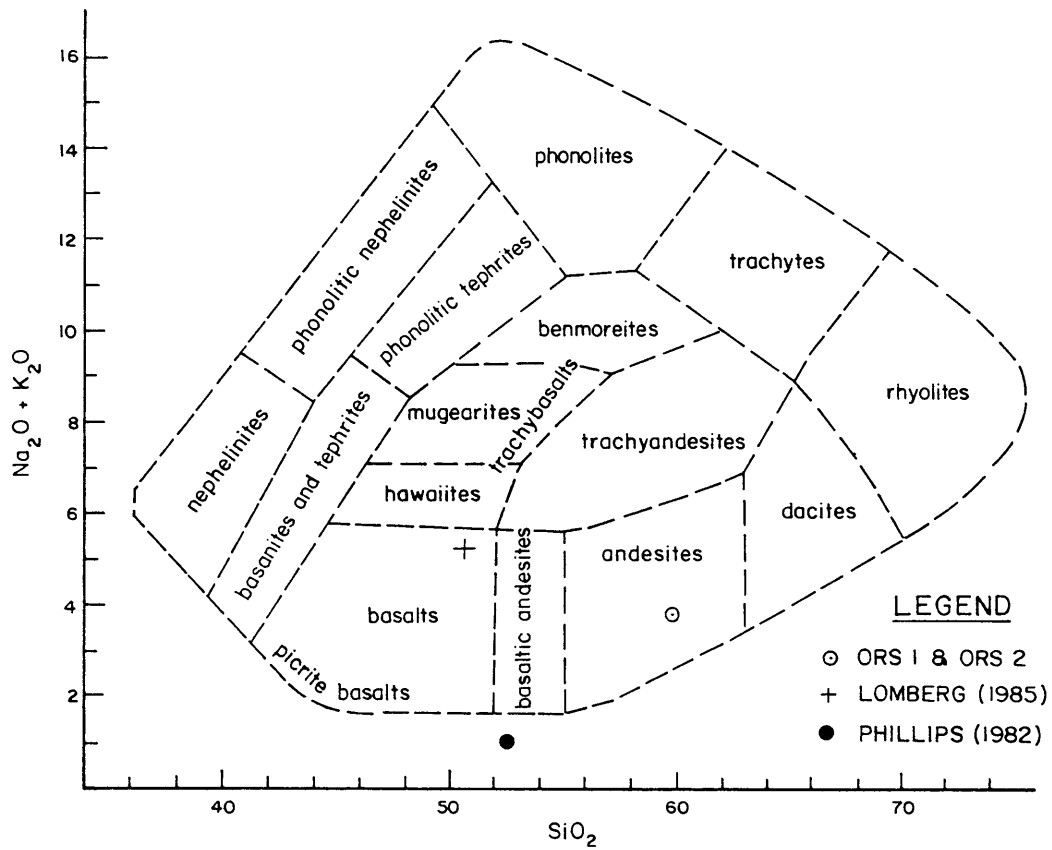


FIGURE 2.19 GEOCHEMICAL CLASSIFICATION OF THE SMELTERSKOP FORMATION LAVAS (CLASSIFICATION SYSTEM FROM COX ET AL., 1980, p.14)

3. ROOIBERG GROUP

3.1 LITHOLOGY

The Rooiberg Group rhyolites, commonly known as the Rooiberg felsites, form the prominent hills of the Rooiberg and Elandsberg (Fig. 1.2). The study area described in this thesis covers only a portion of the Elandsberg. In outcrop these siliceous volcanics weather to a brownish red colour. Columnar jointing, quartz veinlets and conchoidal fracturing are common features. Flow banding is sometimes seen (Fig. 3.1) and amygdales and vesicles are rare. A minimum thickness of 1 350m occurs in the western portion of the study area. This thickness is considerably thicker than the 365m quoted by Boardman (1946).

Two types of felsite have been indentified in the Elandsberg:

1. massive porphyritic felsite,
2. flow banded felsite with accidental lithic clasts.

The massive porphyritic felsite is found throughout the sequence and displays a pink to black colour, depending on the degree of chloritization. In places this rock possesses a sugary texture similar to a sandstone. In thin section, however, it can be seen that this phenomenon is due to extensive devitrification of glassy material to a texture of interlocking quartz grains. The flow banded felsite with accidental lithic clasts (Fig. 3.2) is found close to the top of the Rooiberg Group, as thin (< 20m thick) lenticular bodies, consisting of rounded to angular fragments of felsite set in porphyritic felsite matrix.

3.2 PETROGRAPHY AND MINERALOGY

The texture of the porphyritic felsite is hypocrySTALLINE with phenocrysts of mostly feldspar set in a microcrystalline matrix of quartz, chlorite, biotite, feldspar, magnetite and rare tourmaline.

Phenocryst phases include feldspar, rare quartz and chlorite/ biotite. The phenocrysts range in size from 0,75mm to 1,75mm and make up an



FIGURE 3.1: *Flow-banding in the rhyolites of the Rooiberg Group*



FIGURE 3.2: *Flow banded felsite with accidental lithic clasts, Rooiberg Group.*

average of 1,2% of the rock. The modal proportion of phenocrysts to matrix was obtained by point counting nine thin sections with a total of 8935 point counts (Table 2).

TABLE 2: POINT COUNTS FOR THE PHENOCRYSTS/MATRIX PROPORTIONS IN THE PORPHYRITIC FELSITE

SAMPLE NUMBER	NUMBER OF POINT COUNTS OF PHENOCRYST	NUMBER OF POINT COUNTS OF MATRIX	PERCENTAGE PHENOCRYSTS
WR 160	11	1441	0,76%
WR 176	25	1111	2,25%
WR 161	4	874	0,46%
OTF 19	17	922	1,84%
OTF 7	13	1000	1,30%
OTF 4	7	1073	0,65%
OTF 5	6	813	0,74%
OTF 8	12	724	1,66%
WR 172	10	872	1,15%
TOTAL = 105		TOTAL = 8830	AVER = 1,20%

The feldspar phenocrysts are subhedral to euhedral with chlorite and sericite as common alteration products. Microprobe analysis of three feldspar phenocrysts in the porphyritic felsite show average compositions of:

1. $An_1 Ab_2 Or_{97}$ - Orthoclase - $K(Al, Si)_4O_8$
2. $An_1 Ab_9 Or_{90}$ - Orthoclase - $Na_{0,1} K_{0,8} (Al, Si)_4O_8$
3. $An_1 Ab_{97} Or_2$ - Albite - $Na (Al, Si)_4O_8$

Two separate spot analyses were averaged to calculate the orthoclase- Or_{97} composition while 5 analyses were averaged to calculate the orthoclase- Or_{90} composition. The composition of the albite phenocryst

TABLE 3:

FELDSPAR MICROPROBE ANALYSES; PORPHYRITIC FELSITE, ROOIBERG GROUP

PHENOCRYST NO.	1	1	2	2	2	2	2	2	3	3	3	3	3	3
DISTANCE FROM EDGE OF GRAIN	0	200	0	3	50	200	200	200	0	10	50	100	150	200
SiO ₂	64,69	64,79	63,19	64,82	63,18	64,59	65,03	69,12	68,41	68,77	69,17	68,38	68,44	
Al ₂ O ₃	18,19	18,04	20,43	18,79	19,29	18,43	18,97	19,46	19,55	19,59	19,43	19,78	19,49	
Fe ₂ O ₃	0,12	0,07	0,04	0,10	0,12	0,08	0,15	0,08	0,41	0,09	0,05	0,18	0,07	
CaO	0,04	0,05	0,04	0,01	0,05	0,06	0,12	0,08	0,17	0,07	0,08	0,16	0,13	
Na ₂ O	0,20	0,23	0,31	0,33	0,33	0,27	3,71	11,75	11,58	11,78	11,40	10,57	11,44	
K ₂ O	17,10	16,99	16,67	17,07	16,52	17,04	11,82	0,12	0,21	0,12	0,12	1,80	0,37	
TOTAL	100,34	100,16	100,68	101,12	99,50	100,47	99,80	100,61	100,33	100,42	100,25	100,87	99,94	
(Si + Al) = Z	15,95	15,95	16,10	15,98	16,03	15,60	15,98	16,00	15,97	15,99	16,02	16,00	16,00	
Fe ³⁺	0,02	0,01	0,01	0,02	0,02	0,01	0,02	0,01	0,06	0,01	0,01	0,03	0,01	
Na	0,07	0,08	0,06	0,06	0,12	0,10	1,32	3,96	3,92	3,97	3,85	3,58	3,88	
Ca	<0,01	0,01	0,01	<0,01	0,01	0,01	0,02	0,02	0,03	0,01	0,02	0,03	0,02	
K	4,04	4,02	3,92	4,00	3,93	2,01	2,79	0,03	0,05	0,03	0,03	0,40	0,08	
Mol% [Or	97,7	97,5	98,3	96,8	96,4	94,4	66,9	0,6	1,2	0,7	0,7	9,9	2,1	
[Ab	1,8	2,0	1,4	2,8	2,9	4,5	31,9	98,7	96,6	98,6	98,8	88,7	97,0	
[An	0,5	0,5	0,4	0,4	0,7	1,1	1,1	0,7	2,2	0,7	0,5	1,4	0,9	

is based upon the average of 6 spot analyses. Compositions were calculated on the basis of 32 oxygen atoms per unit cell and are shown in Table 3 and Fig. 3.3.

Rare (<0,1% of the mode) phenocrysts of anhedral quartz and chlorite/biotite are observed in the porphyritic felsite. The chlorite/biotite phenocrysts are probably pseudomorphs after pyroxene (cf. Twist, 1985).

Textures in the matrix include quartz/feldspar spherulites (Fig. 3.4), indicating a late stage devitrification of the glassy component of the rock. This devitrification has become intense in places where interlocking grains of quartz display an inequigranular seriate texture (Fig. 3.5). In hand specimen such rocks tend to show a sugary sandstone-like appearance. A felsitic texture, although relatively rare, of quartz and feldspar laths occurs in the porphyritic felsite (Fig. 3.6). Broad beam microprobe analysis of a lath gave an orthoclase composition of $An_1 Ab_8 Or_{91}$.

Other phases in the matrix of the porphyritic felsite include chlorite, biotite, magnetite and tourmaline. The latter phase, tourmaline, is associated with microfractures in the porphyritic felsite and probably formed during the extensive hydrothermal alteration associated with the tin deposits in the Rooiberg Fragment.

The generally massive and porphyritic nature of the felsite in the Elandsberg and the absence of volcanic breccias and ash fall tuffs (Fig. 1.2) suggest that these porphyritic lavas are the equivalent of the Kwaggasnek Formation of the Rooiberg Group.

3.3 GEOCHEMISTRY

Samples representing the entire sequence of the Rooiberg Group over the Elandsberg were collected and analysed for major and trace elements. One complete sampling traverse through the stratigraphy was made over the western portion of the study area and another more limited sampling traverse was carried out in the east on Welgedacht (Fig. 3.7). Major and selected trace element analyses for these rocks are presented in Table 4.

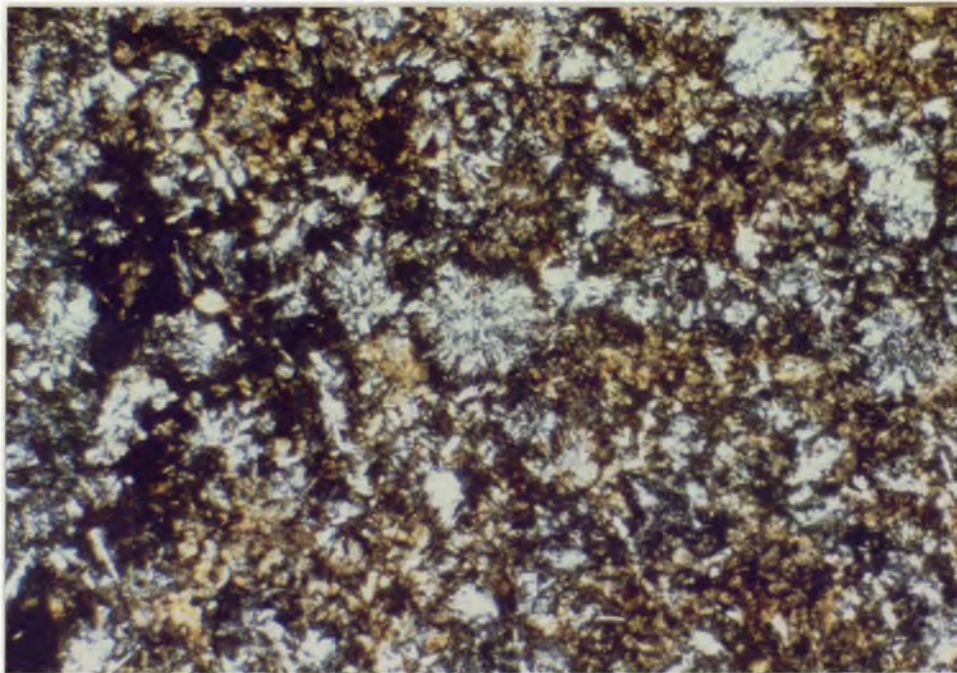
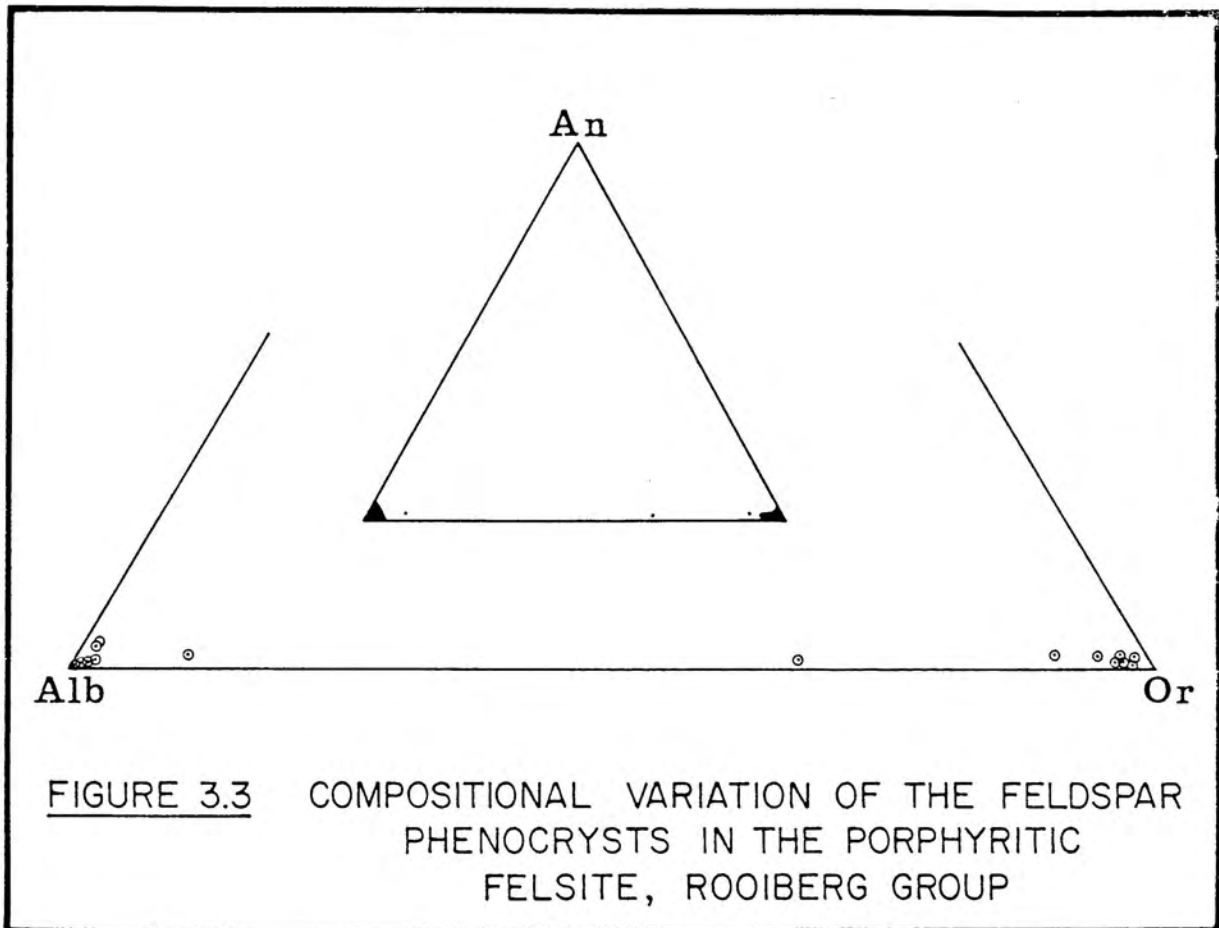


FIGURE 3.4: *Spherulitic texture in the porphyritic felsite of the Rooiberg Group (1cm equals 178 microns) - crossed nicols*

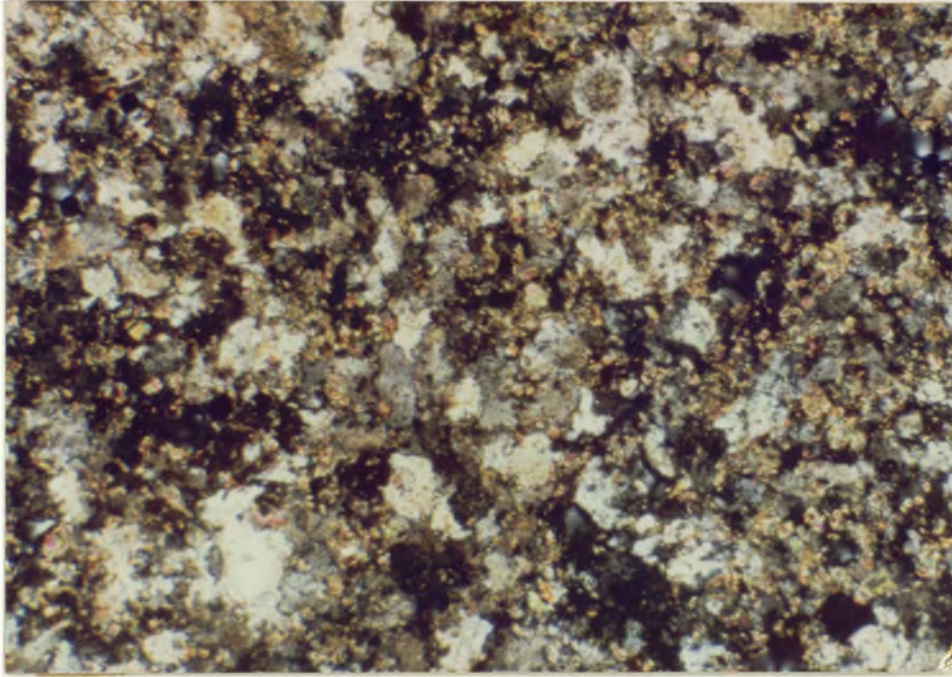


FIGURE 3.5: *Photomicrograph illustrating the intense devitrification in the porphyritic felsite (1cm equals 178 microns) - crossed nicols*

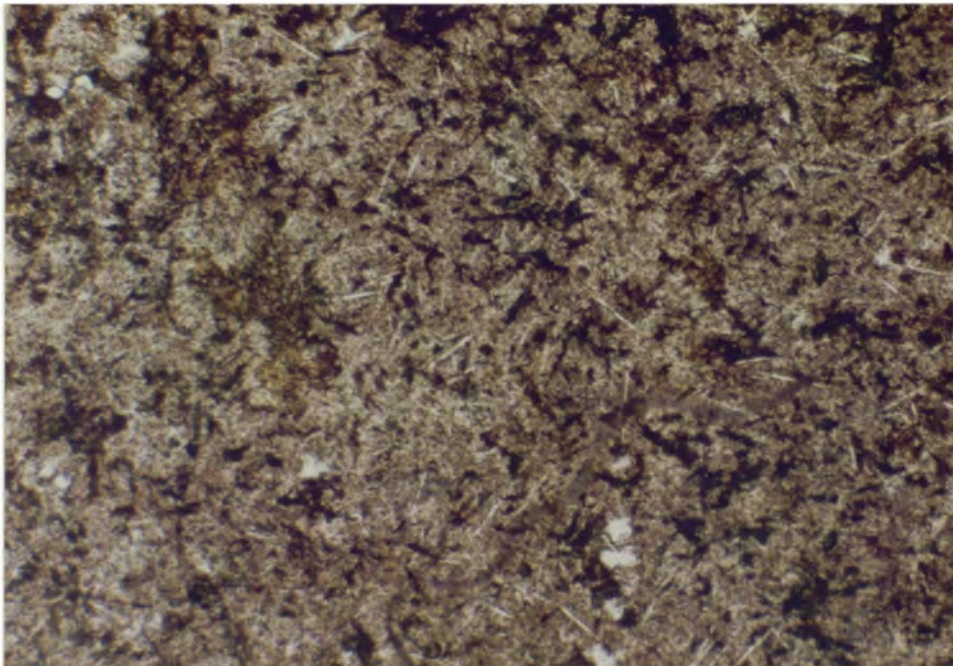


FIGURE 3.6: *Felsitic texture in the porphyritic felsite of the Rooiberg Group (1cm equals 178 microns) - uncrossed nicols*

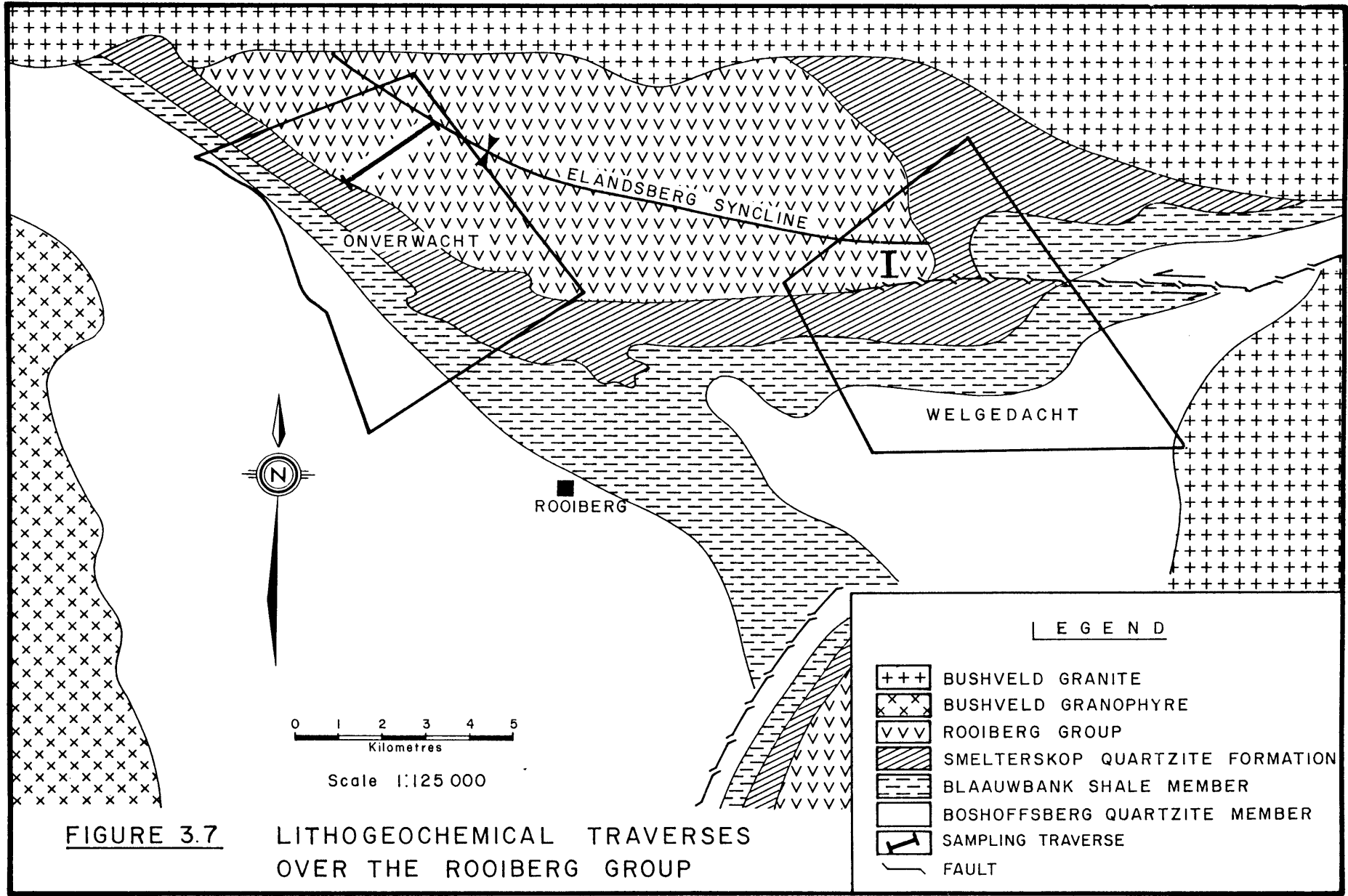


FIGURE 3.7 LITHOGEOCHEMICAL TRAVERSES OVER THE ROOIBERG GROUP

TABLE 4:

GEOCHEMICAL ANALYSES OF THE ROOIBERG FELSITES

	SAMPLE NUMBER	H6 (m)	SiO ₂ %	TiO ₂ %	Al ₂ O ₃ %	FeO*%	MnO%	MgO%	CaO%	Na ₂ O%	K ₂ O%	P ₂ O ₅ %	Nb ppm	Y ppm	Zr ppm	TOTAL
WESTERN TRAVERSE	R16/1	902	66,77	0,31	10,45	12,79	0,12	0,07	0,75	4,54	5,11	0,04	18	52	350	100,95
	R15/2	842	69,94	0,31	9,91	11,24	0,16	1,02	0,72	1,46	5,11	0,05	12	50	292	99,72
	R28/1	786	66,27	0,31	10,38	12,65	0,12	0,04	0,94	5,11	3,61	0,04	17	59	345	99,47
	R29/1	729	69,19	0,35	10,89	11,39	0,06	0,35	0,45	1,29	5,16	0,04	15	46	320	99,17
	R18/1	602	68,74	0,33	10,76	10,89	0,11	0,12	0,63	4,29	5,09	0,03	19	51	345	100,99
	R1/1	515	67,79	0,28	10,58	10,37	0,09	0,94	0,74	2,70	5,25	0,03	17	48	352	98,77
	R19/1	421	65,75	0,31	10,45	12,37	0,11	0,17	0,71	5,04	4,28	0,03	18	48	349	99,22
	R24/1	316	68,47	0,31	10,62	11,94	0,09	0,15	0,47	2,23	6,21	0,03	18	50	347	100,52
	R22/1	256	68,92	0,31	10,13	12,10	0,16	0,26	0,75	1,40	5,11	0,04	14	55	281	99,18
	R22/10	225	69,01	0,28	11,16	12,76	0,13	0,08	0,63	1,03	4,87	0,04	18	67	344	99,99
	R23/1	128	66,82	0,30	10,32	10,97	0,07	0,07	0,88	1,99	6,98	0,04	16	55	346	98,44
	DF 14	10	68,64	0,32	10,80	10,73	0,08	0,11	0,92	3,59	5,46	0,03	18	80	354	100,68
	OR14	0	65,43	0,30	11,24	10,95	0,05	0,19	1,38	3,77	5,59	0,03	17	67	347	98,93
		AVERAGE COMPOS		67,81	0,31	10,59	11,63	0,10	0,27	0,77	2,96	5,22	0,04	17	56	336
EASTERN TRAVERSE	WR163	166	72,77	0,35	10,89	6,46	0,21	0,10	0,11	1,79	5,92	0,02	17	54	376	98,62
	WR161	141	72,87	0,35	11,27	5,79	0,13	0,25	0,62	2,38	5,10	0,01	19	67	382	98,77
	WR159	99	72,68	0,35	10,97	6,82	0,11	0,22	0,14	2,49	4,73	0,02	20	68	375	98,53
	WR157	37	73,21	0,35	11,29	6,09	0,10	0,17	0,27	3,85	2,99	0,09	22	64	388	98,41
	WR151	10	77,39	0,31	9,76	3,60	0,09	0,21	0,08	0,29	7,11	0,01	22	63	347	98,85
	WR172	0	72,49	0,35	10,98	6,25	0,06	0,09	0,49	1,96	6,07	0,03	19	46	363	98,77
	WR6	0	76,78	0,31	10,00	3,50	0,08	0,09	0,57	1,49	5,69	0,04	15	26	362	98,55
		AVERAGE COMPOS		74,03	0,34	10,74	5,50	0,11	0,16	0,33	2,04	5,37	0,03	19	55	370

FeO*%: FeO as total Iron

According to the classification scheme of Cox *et al.* (1980, p. 14) these lavas are rhyolites (Fig. 3.8). However, using a recent modification of the above classification (Le Bas *et al.*, 1986) leads to the conclusion that these lavas also include dacitic compositions (Fig. 3.9). The dacites and trachydacites (Fig. 3.9) only occur in the western portion of the Elandsberg whereas the rhyolitic compositions are restricted to the eastern portion of the area.

3.3.1 ALTERATION

The devitrified textures and the ambiguous presence of chlorite and sericite are the result of post-depositional alteration of the Rooiberg Group rhyolites. Evidence for alteration and hence element mobility in the Rooiberg Group was found by Twist (1984, 1985) in his study of the felsites in the Loskop Dam area (Fig. 1.1). He noted that Si, Fe, Ca, K, Na, Rb and Sr were mobile during alteration processes, whereas Ti, P, Nb, Zr, Y and Sc were immobile. Pearce and Norry (1979) explain the immobility of certain trace elements as a result of their high field strength and charge/radius ratio. They are therefore not usually transported in aqueous fluids except when fluids contain high concentrations of complexing agents.

Element mobility in the Rooiberg Group rhyolites in the Elandsberg is supported by the following line of evidence.

In general, most magmatic rocks show linear trends in Harker diagrams (i.e., binary plots of SiO₂ against other major elements (Cox *et al.* 1980, p. 24)). Such variation is not observed, however, in the Rooiberg Group rhyolites of the Elandsberg (Fig. 3.10). The poorly correlated points on binary variation plots suggest that there has been extensive alteration in these rocks.

The scattering in the SiO₂ binary plots of the rhyolites over the northern portion of the Rooiberg Fragment indicate an extensive phase of post eruptive alteration. For this reason any petrogenetic interpretations drawn from the geochemical analyses must be treated

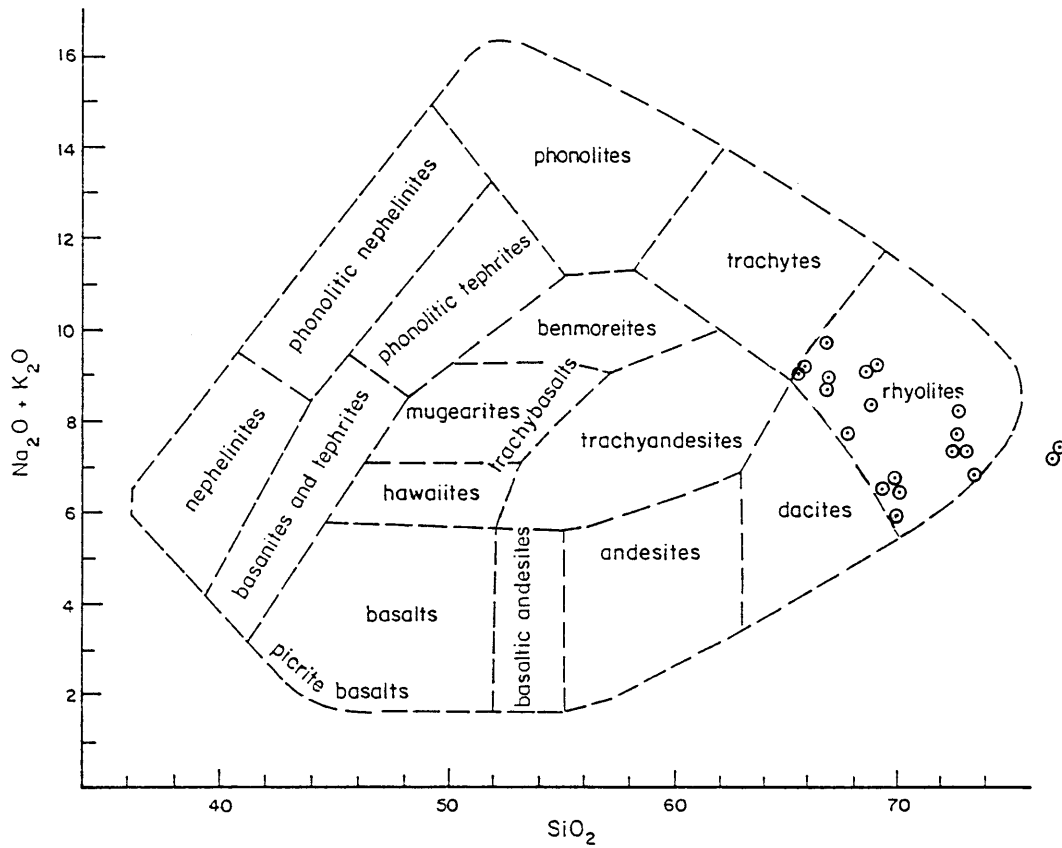


FIGURE 3.8 THE NOMENCLATURE OF VOLCANIC ROCKS AND CLASSIFICATION OF THE ROOIBERG GROUP RHYOLITES (CLASSIFICATION SYSTEM FROM COX ET AL., 1980, p.14)

CHEMICAL CLASSIFICATION OF VOLCANIC ROCKS

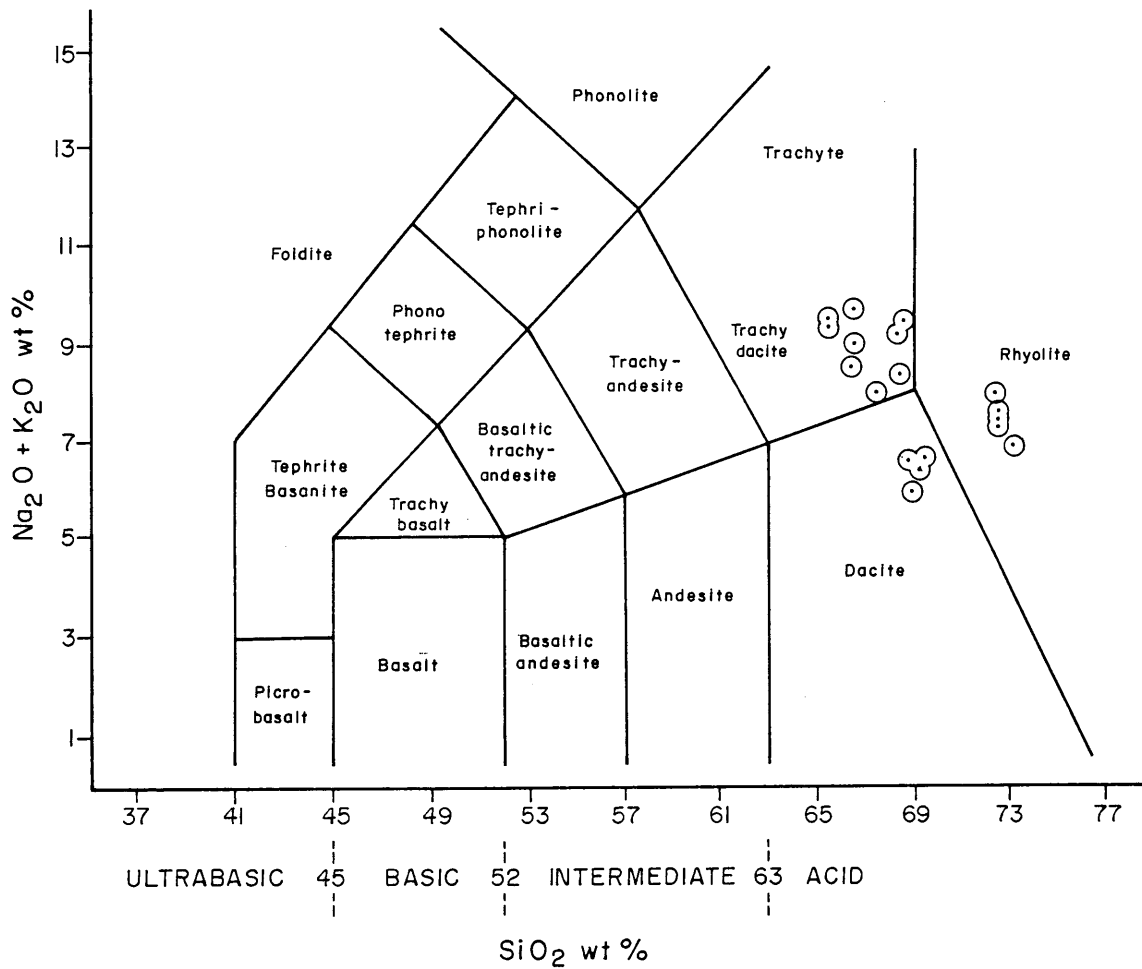
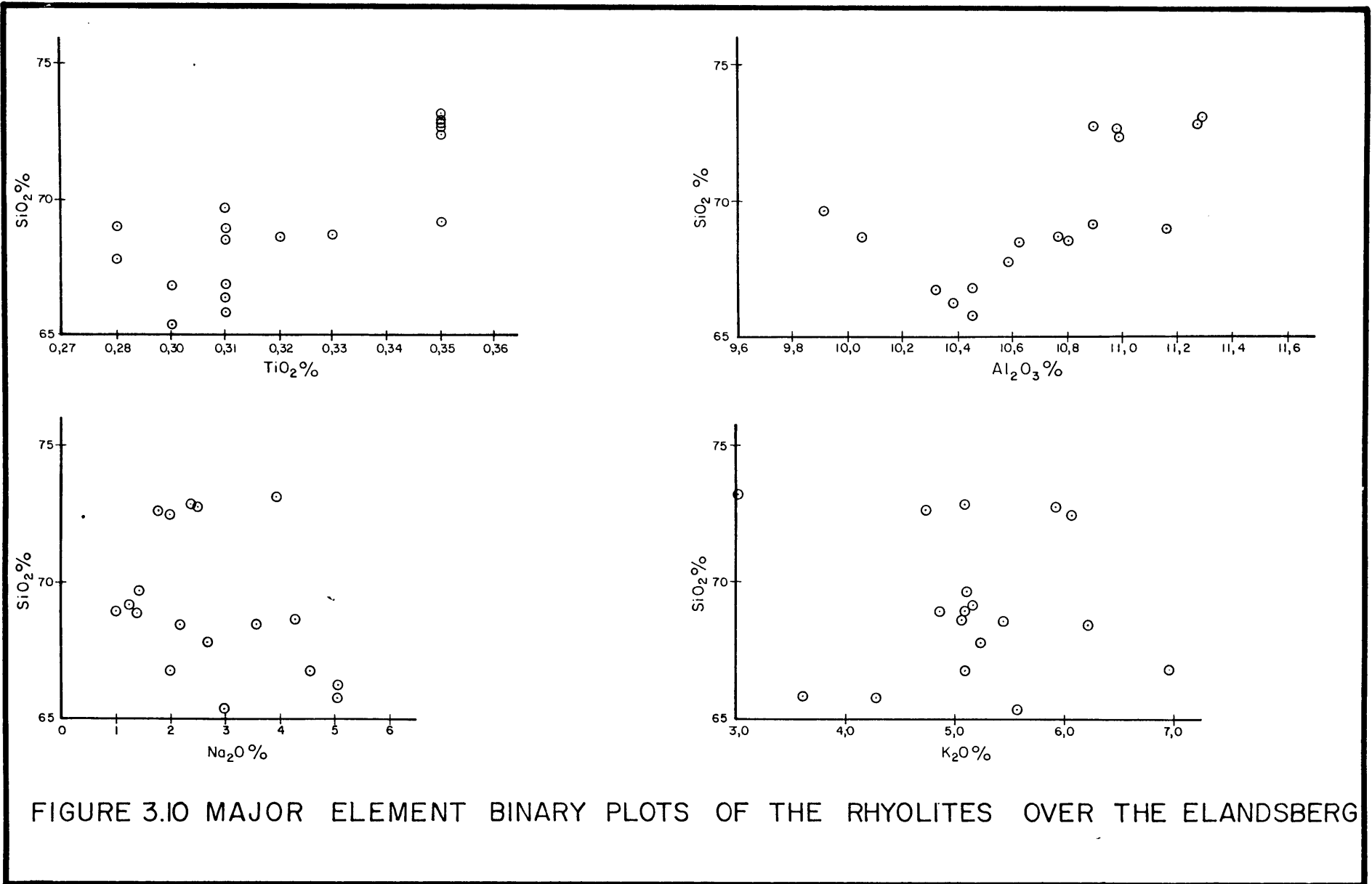


FIGURE 3.9

THE TOTAL ALKALI-SILICA DIAGRAM OF LE BAS ET AL. (1986) SHOWING DACITIC TO RHYOLITIC COMPOSITIONS OF THE ROOIBERG GROUP LAVAS OVER THE ELANDSBERG.



with caution. The type of alteration, however, whether it is hydrothermal alteration, hydration or devitrification, is unclear.

4. INTERPETATION

4.1 SEDIMENTARY ENVIRONMENTS

4.1.1 LEEUWPOORT FORMATION

Eight facies are defined in the Leeuwpoort Formation:

1. Su - undifferentiated sandstones
2. St - trough cross-bedded sandstones
3. Sp - planar cross-bedded sandstones
4. Sh - horizontally laminated sandstones
5. St(m) - trough cross-bedded sandstones with sinuous crested megaripples
6. Fr - trough cross-laminated mudstones
7. Fh - horizontally laminated mudstones
8. Sr - trough cross-laminated sandstones

Additional structures found in the formation include mudcracks, B-C sequences, reactivation surfaces and soft sediment deformation in the form of pseudonodules, slumpballs, flame structures and convolute bedding.

A generalized Leeuwpoort Sequence (Fig. 4.1) drawn up from the sedimentary profiles (Fig. 2.4) with the aid of a Markov Analysis (Appendix A), depicts the lithofacies outlined above and their vertical relationships. With the exception of the main shale of the Blaauwbank Shale Member pinching out towards the west, no lateral variation of facies is observed.

The sedimentary processes that form the structures observed in these lithofacies are briefly outlined below.

Planar cross-bedding (Sp) is produced by migrating bar bedforms, trough cross-bedding (St) and trough cross-lamination (Sr, Fr) by migrating dune bedforms; horizontal lamination (Sh, Fh) normally results either from upper or lower flow regime plane bed transport (Miall, 1977). These facies are found in almost all subaqueous environments. The megaripples in the arkosites indicate large scale dune migration and

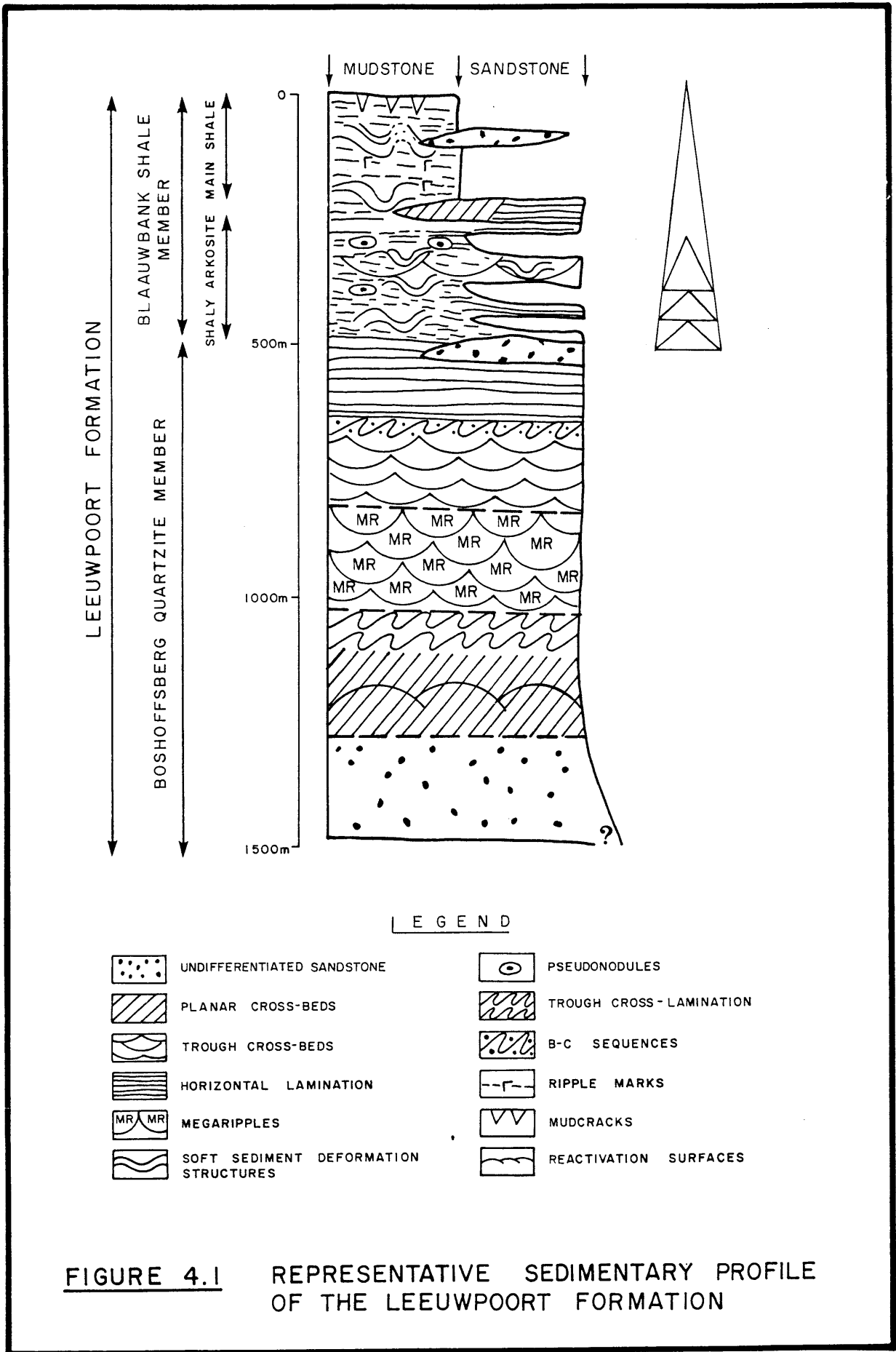


FIGURE 4.1 REPRESENTATIVE SEDIMENTARY PROFILE OF THE LEEUWPOORT FORMATION

commonly form during reworking processes in a tidal flat environment (Reineck and Singh, 1980, p. 17). However, McCabe (1977) attributes similar structures to formation in a fluvial distributary channel environment when they occur as side-attached, alternate bars. The term "side alternate bars" used by McCabe (1977) defines large scale bedforms attached to consecutively opposite banks. Their crestlines extend the full width of the channel and are usually sinuous.

B-C sequences normally form during sudden changes in flow direction in extremely shallow water environments in which the mud overlying the sands is removed (Klein, 1971). These processes commonly occur on a tidal flat during periods of emergent runoff (Klein, 1971, 1977). These structures could, however, reflect a decrease in mean flow velocity (Harms *et al.*, 1975, p. 22), from that forming planar or trough cross-beds to velocities which develop ripples or cross-lamination. It is, therefore, possible for this facies to form in a palaeoenvironment other than a tidal flat.

Reactivation surfaces are erosional surfaces that separate conformable cross-strata and record an interruption in migration of a single bed form (Harms *et al.*, 1975, p. 50). This is caused by changes in flow rate. Although formed in longitudinal and transverse bars in braided stream environments, their highest preservation potential has been recorded in tidal sands in both tidal flats and shallow siliciclastic seas (Johnson, 1979; Elliot, 1979; Klein, 1977). Klein relates reactivation surfaces to time-velocity asymmetry and tidal current bedload transport.

Convolute bedding indicates rapid deposition and plastic deformation of partially unconsolidated sediment (Blatt *et al.*, 1972, p. 173). Wunderlich (1967; *in* Reineck and Singh, 1980, p. 78) describes these features as common on the steep slopes of sand bars in tidal environments. They are, however, also abundant in channel bar sediments of the Brahmaputra fluvial system (Reineck and Singh, 1980, p. 244). Convolute bedding is uncommon in medium- to coarse-grained sediments (Reineck and Singh, 1980, p. 78) like those in the Leeuwpoot Formation. This suggests that deposition of these sedimentary rocks occurred during seismic disturbances at the edge of a depositional basin (Allen, 1986), thereby producing soft sediment deformation

features within coarse-grained sediments. A rapid rate of deposition is in accordance with the high feldspar content of the arkosites.

Slumpballs, flame structures and pseudonodules in the shaly arkosite again suggest rapid deposition. However, in the case of the shaly arkosite, where arkosic sandstones are interbedded with laminated mudstones the density contrast between these sediments would have had a greater influence than seismic events on the creation of soft sediment deformation features. Pseudonodules, essentially large scale slumpballs, are common features in shallow marine and deltaic deposits (Allen, 1984). They have, however, also been ascribed by Eriksson and Vos (1979) to a fluvial palaeoenvironment.

Trough cross-lamination is a common feature in shallow water, lower flow regime deposits. Symmetrical ripples and interference ripples are common in tidal flat environments (Klein, 1977). These ripple types can result from surface wave activity, sometimes operating in conjunction with a current (Collinson and Thompson, 1982, p. 70). They are common in a lacustrine environment (Reineck and Singh, 1980, p. 224), analogous to a distal fluvial floodplain setting. Symmetrical ripples have been described by Greiner (1962) in the Albert Shale Formation lake deposits of New Brunswick, USA. Mudcracks form as a result of aerial exposure in most shallow water environments (Blatt, et al., 1972, p. 193) .

The high feldspar content in the sedimentary rocks of the Leeuwpoot Formation indicates high relief and rapid erosion of the source area, with rapid deposition and burial in the depositional basin (Blatt et al., 1972, p. 279). Hubert (1960) found that a higher proportion of feldspar grains are possible in a fluvial system where rapid erosion of the source area is expected. Deltaic environments with their associated fluvial input systems also deposit their load rapidly with consequential quick burial (Miall, 1979).

The upward-fining nature of the Leeuwpoot sedimentary sequence (Fig. 4.1), the variable multimodal, palaeocurrent directions (Fig. 2.3), and the inferred depositional processes of the lithofacies indicate deposition within a shallow water tidal flat palaeoenvironment. However, the high feldspar content and the very thick

nature of the upward-fining sequence is inconsistent with such a setting. An alternative fluvial model in which most of the above facies, although rare, may occur, takes into account the thick sequence and high feldspar content.

Three palaeoenvironmental facies associations are therefore proposed for the Leeuwpoot Formation (Fig. 4.2). These are:

- (a) **Braided stream association:** Characterized by the rapid deposition of bars and dunes with the formation of B-C sequences and megaripples in active channels. This facies association is analogous to the Platte model (Miall, 1977) in which deposition occurs in a sandy braided river with the most dominant lithofacies being trough and planar cross-bedded sandstones. These proposed braided stream deposits make up the arkosites of the Boshoffsberg Quartzite Member of the Leeuwpoot Formation.
- (b) **Meandering stream association:** Characterized by upward-fining point bar deposits similar to those described by Blatt *et al.* (1972, p. 199), with floodplain sedimentation and crevasse splays in an overbank setting. Deposition is in the form of mudstone and sandstone with the density contrast creating extensive soft sediment deformation features. The shaly arkosite of the Blaauwbank Shale Member is thought to represent this facies association.
- (c) **Floodplain association:** Characterized by the deposition of mudstone and siltstone with the formation of symmetrical, asymmetrical and interference ripples, trough cross-lamination, and mudcracks during times of subaerial exposure. This facies association is represented by the main shale of the Blaauwbank Shale Member.

The lateral and vertical accretion of sandy braided stream deposits in the proximal portion of a fluvial palaeoenvironment is thought to have built up a sequence of trough cross-bedded, planar cross-bedded and horizontally laminated sandstones. Megaripples and B-C sequences reflect the development of side bars and variable flow patterns. Meandering streams in a more distal portion of the proposed fluvial

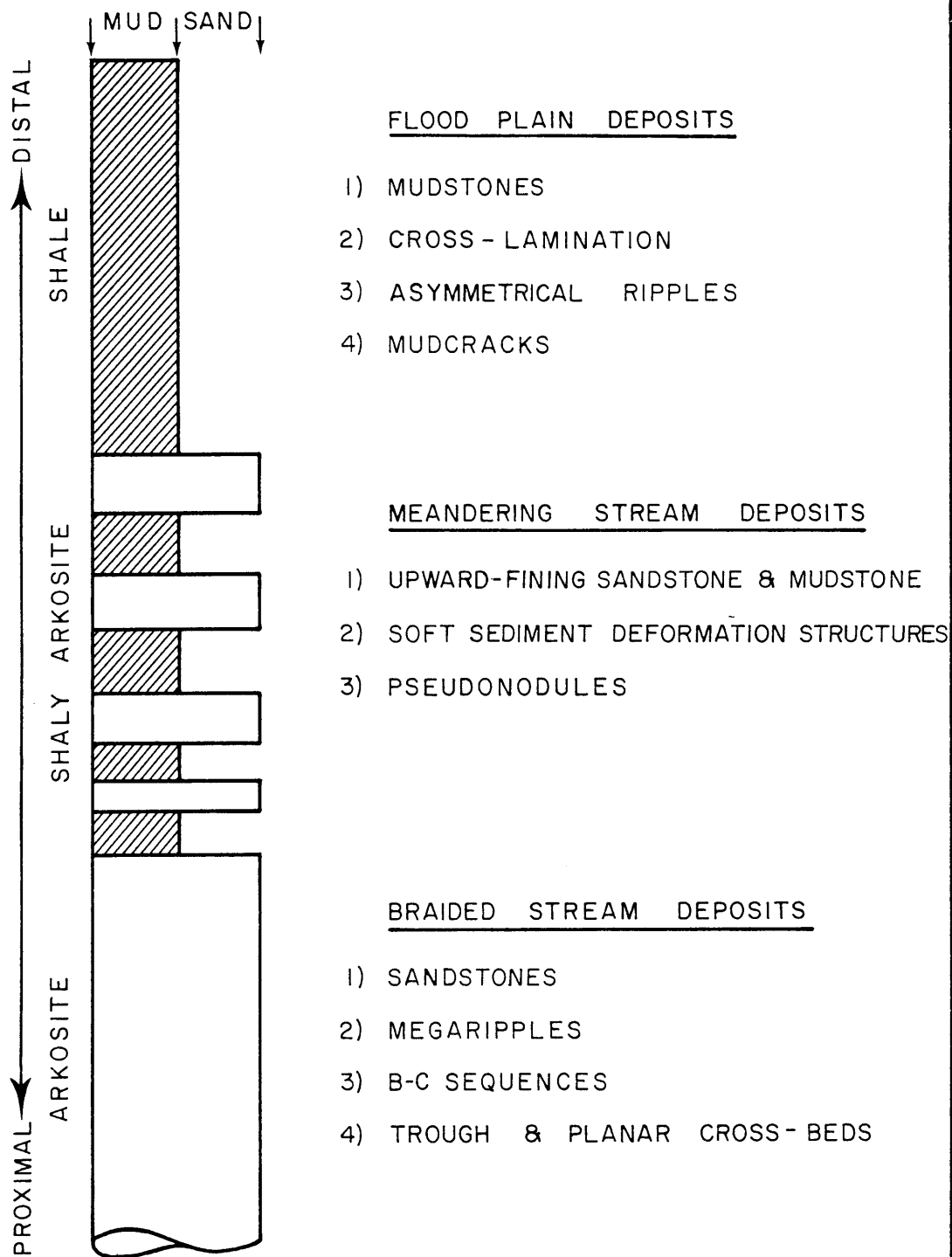


FIGURE 4.2 PROPOSED DEPOSITIONAL MODEL FOR THE LEEUWPOORT FORMATION.

palaeoenvironment built a sequence of upward-fining cycles of trough and planar cross-bedded sandstones overlain by laminated mudstone. A floodplain setting formed in a more distal portion of the palaeoenvironment, where mudstones characterised by trough cross-lamination, ripple structures and local mudcracks were laid down (Fig. 4.2).

The basal conglomerates of the Boshoffsberg Quartzite Member, not exposed in the present study area, but reported by Stear (1977a) from the Rooiberg Fragment, support a fluvial model for the Leeuwpoot Formation; they are not compatible with an alternative tidal setting. The cross-bedded arkosites which characterise the Boshoffsberg Quartzite Member are typical of braided stream environments (Hubert, 1960). The B-C sequences are analogous to the upward-fining arrangement of cross-laminated sandstones in braided river models (Miall, 1977).

Indicators of possible tidal and basin activity, such as reactivation surfaces, symmetrical and interference ripples, may be related to fluviolacustrine influences in the suggested palaeoenvironment. The shaly arkosites may thus represent meandering channel sandstones succeeded by floodplain - lacustrine mudstones. The uppermost mudstones of the main shale of the Blaauwbank Shale Member can be ascribed to a similar floodplain - lacustrine setting. Tectonic instability could have led to proximal low sinuosity fluvial deposition (the Boshoffsberg Member) and to some of the soft sediment deformation features observed in the shaly arkosite.

4.1.2 SMEALTERSKOP FORMATION

The presence of pyroclastic rocks and the absence of pillow lavas in this unit indicates continental deposition. The lenticular bedding of the sedimentary rocks in the Smelterskop Formation and the presence of conglomerates and arkosites suggests possible fluvial deposition. Vertical accretion of overbank and channel deposits, leading to the formation of lenticular mudstone and sandstone deposits is proposed.

Three lithofacies associations can be defined in the Smelterskop Formation (Fig. 4.3):

FACIES ASSOCIATION A

These comprise massive coarse-grained arkosic sandstones associated with thick mudstone layers. They characterise the upper part of the formation in the west of the study area (Fig. 2.15). There is an overall upward-coarsening arrangement of these facies. The sandstones are probably a result of channel-fill deposits formed during a flood event. In the active volcanic region of the Tuego volcano in Guatemala (Davies *et al.*, 1976), where fluvial transport of sediment is in progress, it was found that flood events are the dominant processes controlling the transport of sediment. The massive nature and relatively high feldspar content of the Smelterskop sandstones are probably due to rapid deposition and burial associated with flood deposition. The thick lenticular mud layers are interpreted as levee or floodplain deposits. A decrease in the level of turbulence as the floodwaters moved from channel to the overbank area could have led to deposition of suspended material in the form of levee deposits (Collinson, 1979) (Fig. 4.3) or floodplain deposits.

FACIES ASSOCIATION B

This comprises horizontally laminated finer-grained quartzitic or arkosic sandstones, with relatively low feldspar contents, associated with thin mudstone layers, < 5m thick. This association stretches from the basal western to the upper eastern portion of the field area (Fig. 2.15). The sandstones were most probably formed in the upper flow regime by plane bed transport, possibly in a channel environment. The high energy may again indicate flood deposition. The thin mudstone layers probably represent localised overbank levee or interchannel deposits.

FACIES ASSOCIATION C

This association characterises the basal portion of the Smelterskop Formation in the east of the study area (Fig. 2.15). These thin upward-fining lenses of trough cross-bedded conglomerates and planar cross-bedded sandstone indicate deposition by channel-fills and

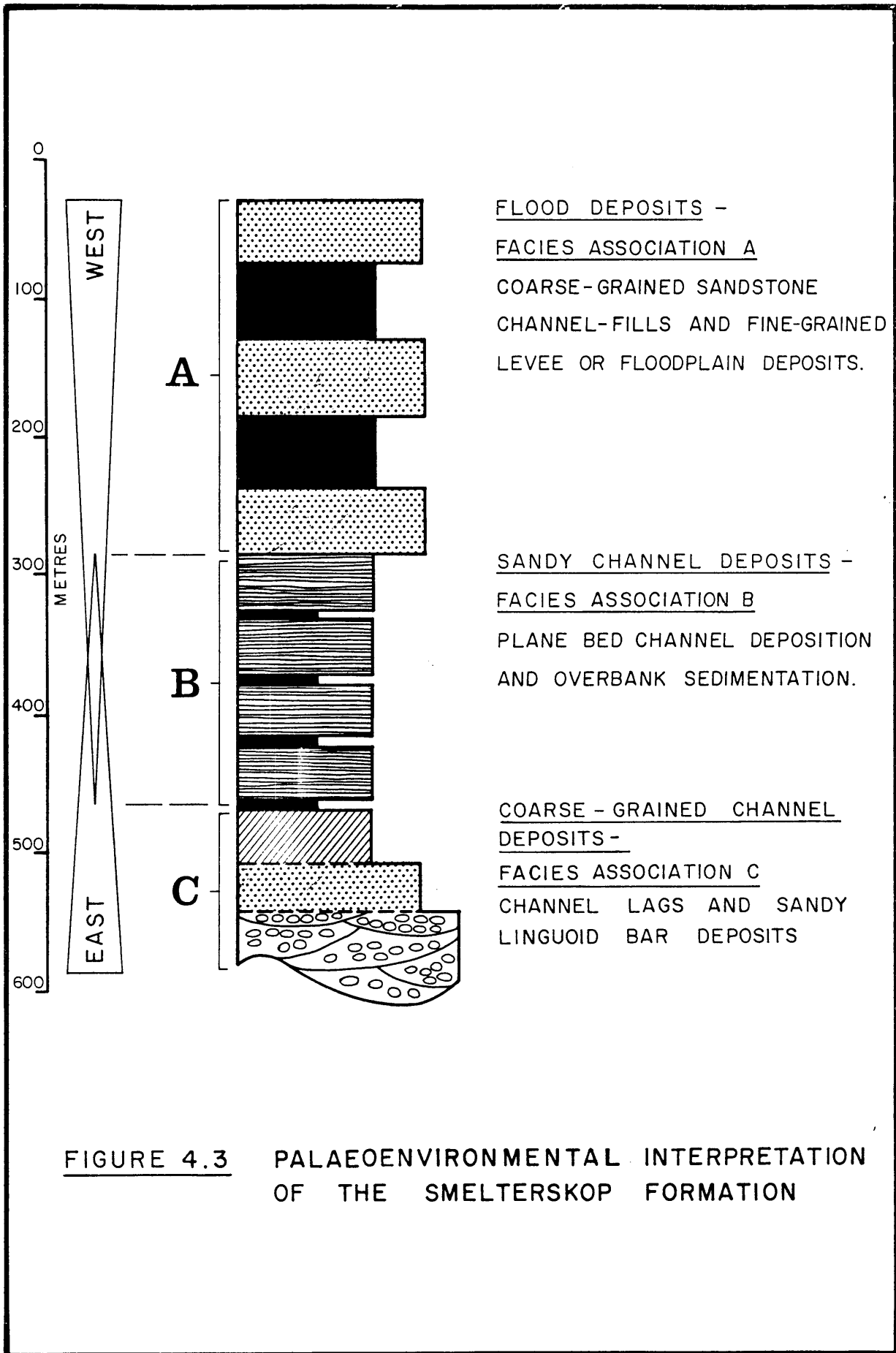


FIGURE 4.3 PALAEOENVIRONMENTAL INTERPRETATION
OF THE SMELTERSKOP FORMATION

linguoid bars (Miall, 1977) in braided streams. The upward-fining nature and cross-bedded sandstones are also indicative of migrating point bars in a meandering stream (Reineck and Singh, 1980, p. 238). However, the absence of regular cyclic sequences, trough cross-bedded sandstones and laminated mudstones points to deposition in a braided rather than a meandering stream palaeoenvironment. The planar cross-bedded sandstone lenses thus presumably represent deposition by linguoid bars migrating over previously deposited conglomeratic channel lags. The poorly sorted nature of the conglomerate lags indicates rapid deposition, probably during flood stages. Similar braided stream deposits on a much larger scale are described by Watchorn and Armstrong (1980) in the Pongola Sequence; they also note the interaction of braided stream deposits with contemporaneous volcanic activity in the Nsuze Group.

Facies B and C are characteristic of the eastern portion of the study area, Facies A and B, of the western portion of the field area (Fig. 2.15). The Smelterskop Formation may thus have been laid down by braided streams, presumably succeeding the flood plain deposits of the uppermost Leeuwpoort Formation. Initial coarse flood deposits in the east were succeeded by finer sandy low sinuosity fluvial sediments which spread towards the west of the field area (Fig. 2.15). Uppermost coarser sandy channel-fill and fine-grained floodplain deposits were laid down in the west as the proposed fluvial system migrated from east to west. Intermittent eruptive volcanic activity and tectonic uplift of portions of the depositional floor probably created unstable conditions and resultant large scale flood events, with major channel and lesser fine-grained overbank deposits.

4.1.3 DISCUSSION

The most authoritative discussions of the sedimentology of rocks within the Rooiberg Fragment are given by Stear (1976, 1977a) and Phillips (1982).

Stear interprets the sediments of the Leeuwpoort Formation as a thick accumulation of immature braided stream deposits overlain by possible tidal flat material. He suggests a fluvial deposition for the

Smelterskop Formation. Phillips postulates braided stream deposits (Boshoffsberg Quartzite Member) overlain by meandering stream deposits (Blaauwbank Shale Member) for the Leeuwoort Formation.

The fluvial model proposed in this study extends the interpretation of Phillips (1982) to include a lacustrine palaeoenvironment for the main shale of the Blaauwbank Shale Member. Lacustrine deposition could also account for the tidal features noted by Stear (1976, 1977a).

The suggested channel and floodplain setting for the Smelterskop Formation is in accordance with Stear's (1976, 1977a) fluvial model.

4.2 PETROGENESIS OF THE ROOIBERG GROUP

4.2.1 LAVA TYPES

It is evident from the classification of Le Bas *et al.* (1986) (Fig. 3.9) that two, possibly three, lava types exist over the Elandsberg. These are:

- (a) Trachydacites - dacites found over the western portion of the Elandsberg with SiO_2 contents ranging between 65% and 70% (Type A lavas).
- (b) Rhyolites found over the eastern portion of the Elandsberg with SiO_2 contents greater than 70% (Type B lavas).

The lavas that fall within the trachydacite - dacite field (type A) could represent two different groups (i.e. dacite and trachydacite). This would be defined by the alkali compositional difference between trachydacite and dacite. However, the poorly correlated points on the SiO_2 -alkali binary plots (Fig. 3.9) indicate that these differences represent an alteration process rather than a different lava type. This group is therefore classified as Dacite.

The Zr-Nb binary plots which are probably not affected by secondary processes and behave in a systematic manner during differentiation (Floyd and Winchester, 1975; Winchester and Floyd, 1977; Pearce and

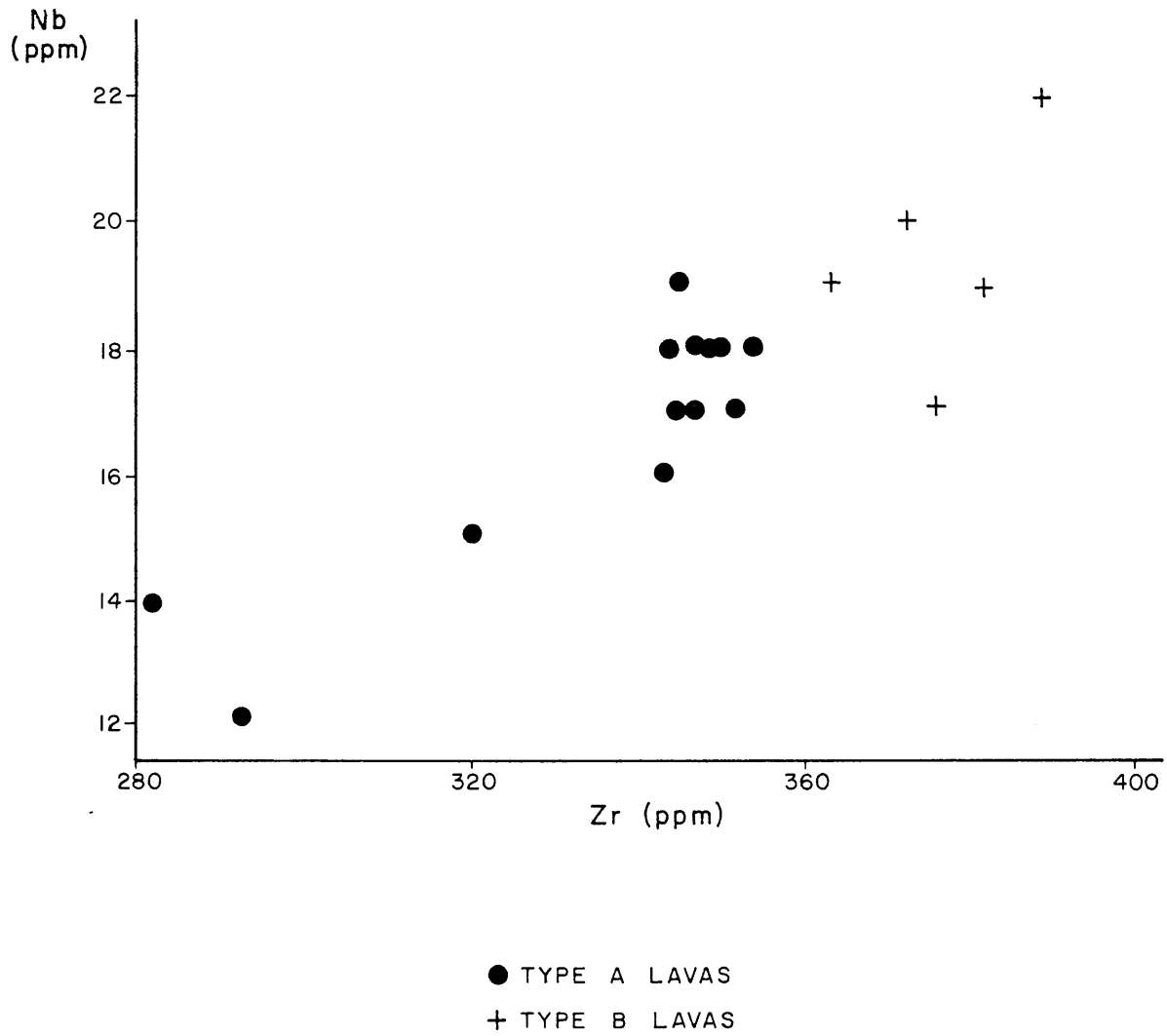


FIGURE 4.4

VARIATION OF Nb WITH Zr IN THE
ROOIBERG GROUP - ELANDSBERG

Norry, 1979) separate the compositional fields of Dacite (type A lava) and Rhyolite (type B lava) over the Elandsberg (Fig. 4.4). Twist (1985) showed that Zr and Nb are concentrated in more evolved felsites. The higher Zr and Nb values of type B lavas therefore indicate a derivative of a more evolved parental magma. This is also reflected in the SiO₂ contents where type B lavas contain greater than 70% SiO₂ and therefore represent a more evolved magma.

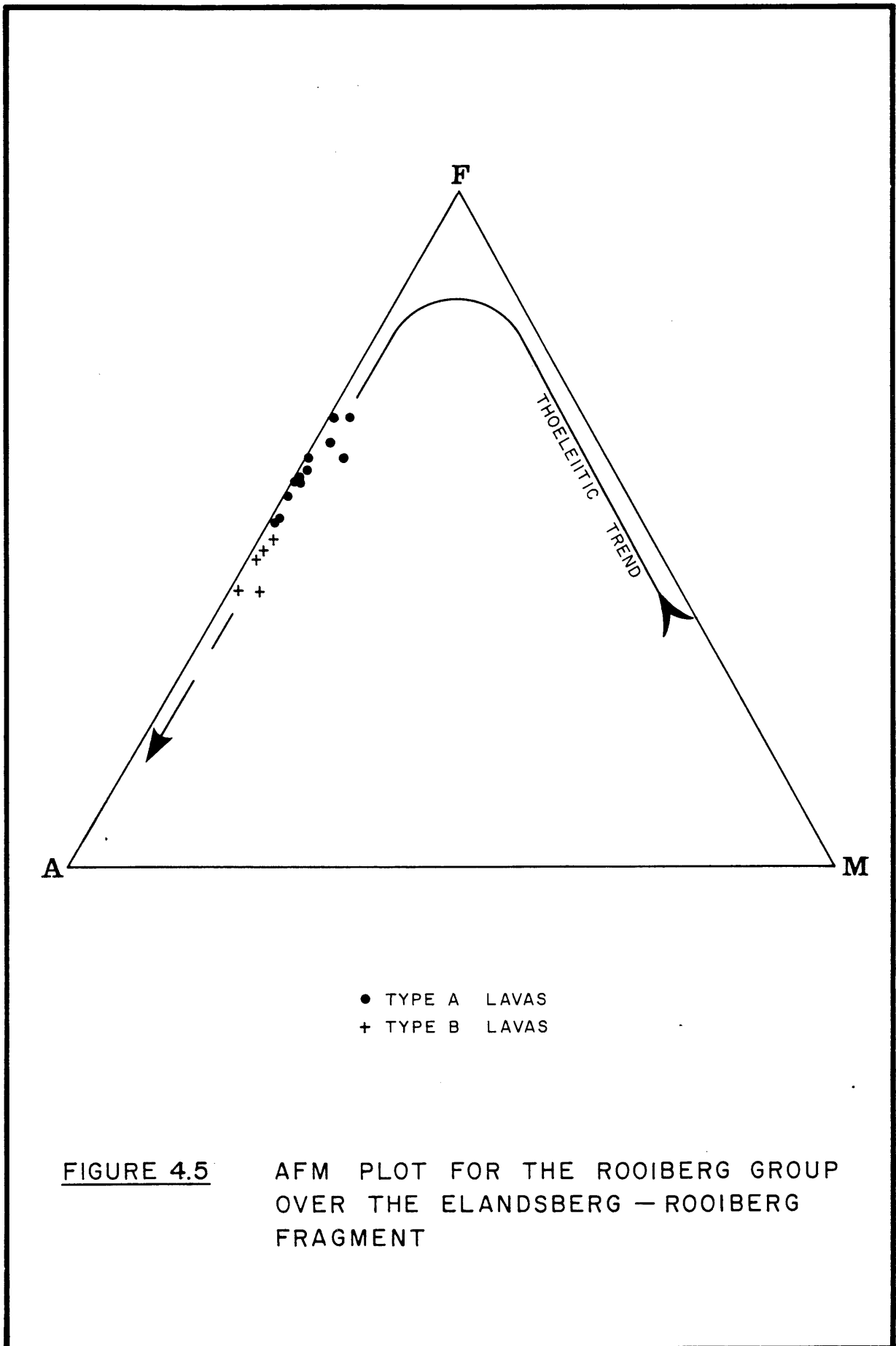
The dacites over the western Elandsberg have anomalously high total iron compositions compared to the rhyolites from the eastern portion of the Elandsberg. Both types are enriched in Fe compared to the average composition quoted by Cox *et al.* (1980, p. 402) (Table 5).

TABLE 5:

TOTAL IRON COMPOSITIONS OVER THE ELANDSBERG AND THOSE QUOTED BY
 COX *et al.* (1980, p. 402)

		TOTAL IRON COMPOSITION
Type A Lavas	Elandsberg	11,63%
Type B Lavas		5,50%
Rhyolite	Cox <i>et al.</i>	2,59%
Dacite		2,73%

These iron anomalies either reflect an alteration event or a primary characteristic of the separation between type A and type B lavas over the Elandsberg. The magnetite noted in petrographic observations does not appear to be secondary. It occurs as individual euhedral grains within the matrix. The high iron content is therefore considered to reflect primary magnetite. Secondly, the evolutionary pattern observed in the Nb-Zr binary plot (Fig. 4.4) is confirmed in the AFM plot (Fig. 4.5). The less evolved type A lavas fall along a tholeiitic trend (Fig. 4.5) with higher relative iron concentrations associated



with the lower Zr and Nb content. The high iron contents, therefore, correspond to the different lava types and do not necessarily represent an alteration event.

4.2.2 COMPARATIVE ANALYSIS

Numerous researchers have undertaken geochemical studies of the Rooiberg Group:

- (a) Fourie (1969); Nylstroom, Potgietersrus, Rooiberg and Rust der Winter areas,
- (b) Coetzee (1970); Nylstroom area,
- (c) Lenthall and Hunter (1977); Potgietersrus area,
- (d) Clubley-Armstrong (1980); Loskop Dam area,
- (e) Vickers (1981); Union Tin Mine area,
- (f) Twist (1985); Loskop Dam area,
- (g) Kleeman (1985); Groblersdal area

The localities are shown in Fig. 1.1 and the average analyses obtained by these researchers are compared with felsites from the Elandsberg in Table 6.

The higher SiO₂ values in type B lavas are similar to those observed in the upper succession of the Rooiberg Group, the Schrikkloof Formation (Table 6; Vickers, 1981), while the lower SiO₂ values of type A lavas are similar to the lower Kwaggasnek Formation in the Union Tin Mine area. This indicates that both formations of the Rooiberg Group may be present over the northern portion of the Rooiberg Fragment. Field evidence (section 3.2), however, suggests that only the lower Kwaggasnek Formation is present.

For comparative purposes the data presented in Table 4 are plotted on an AFM diagram (Fig. 4.6). The high iron contents of type A lavas are similar to the relatively high iron contents from data by Fourie (1969) in the Rooiberg area. This compositional variation might, however, be a result of alteration. To alleviate this, the data points for the Rooiberg Group over the Bushveld Complex were plotted on a Nb-Zr variation diagram (Fig. 4.7) (see section 4.2.1). The high Mg-lavas

TABLE 6 : AVERAGE CHEMICAL COMPOSITIONS OF THE ROOIBERG GROUP OVER THE BUSHVELD COMPLEX

Wt%	FOURIE (1969)				COETZEE (1970)	CLUBLEY-ARMSTRONG (1980)	VICKERS (1981)		TWIST (1985)		ELANDSBERG		KLEEMAN (1985)	LENTHAL AND HUNTER (1977)
	POTGIE-TERSUS	ROOIBERG	NYL-STROOM	RUST DER WINTER	NYL-STROOM	LOSKOP DAM	UNION TIN		LOSKOP DAM		TYPE A	TYPE B	GROBLERS-DAL	POTGIETERS-RUS
							SCHRIK-KLOOF FM	KWAGGAS-NEK FM	HIGH Mg LAVAS	LOW Mg LAVAS				
SiO ₂	72,82	71,84	75,24	75,64	73,21	68,82	74,5	68,2	66,59	71,24	67,81	74,03	69,79	N.D.
TiO ₂	0,37	0,24	0,37	0,25	0,20	0,60	N.D.	N.D.	0,62	0,54	0,31	0,34	0,39	0,39
Al ₂ O ₃	12,10	12,17	12,56	12,66	12,47	13,23	N.D.	N.D.	13,75	12,00	10,59	10,74	11,54	N.D.
FeO (a)	6,31	9,37	4,72	4,02	4,82(b)	7,43	4,7	10,5	6,27	6,76	11,63	5,50	6,21	N.D.
MnO	0,13	0,03	0,23	0,12	0,13	0,14	0,09	0,09	0,23	0,16	0,10	0,11	0,21	N.D.
MgO	0,36	0,44	0,36	0,38	0,73	0,74	N.D.	N.D.	2,54	0,42	0,27	0,16	0,11	N.D.
CaO	0,81	0,12	0,13	0,12	0,87	2,04	0,78	1,43	3,26	2,51	0,77	0,33	1,65	1,03
Na ₂ O	2,85	0,23	0,55	0,19	1,15	2,92	0,29	0,26	3,08	1,77	2,96	2,04	3,72	2,83
K ₂ O	4,18	5,53	5,79	6,60	6,40	3,95	5,3	5,7	3,54	4,48	5,22	5,37	4,38	4,16
P ₂ O ₅	0,06	0,02	0,05	0,03	0,02	0,12	N.D.	N.D.	0,13	0,14	0,04	0,03	0,07	N.D.
PPM														
Nb	18	17	17	18	N.D.	N.D.	N.D.	N.D.	8	16	17	19	21	18(c)
Zr	373	355	392	423	N.D.	N.D.	N.D.	N.D.	200	347	336	370	417	395
Y	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	28	54	56	55	63	36(c)
Zn	277	35	741	152	N.D.	N.D.	142	138	336	226	67(e)	24(d)	145(f)	70
Cu	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	286	326	36	30	119(d)	113(d)	9(f)	175
Ba	1040	1261	1212	1622	N.D.	N.D.	860	513	603	651	845(d)	771	16	1105
No. of Analysis	5	1	3	1	2	23	33	29	28	131	13	7	16	37

a : FeO as Total Iron
b : Suspected Value
c : Average Calculated from 4 Values
d : Average Calculated from 10 Values
e : Average Calculated from 9 Values
f : Average Calculated from 15 Values

N.D.: Not Determined

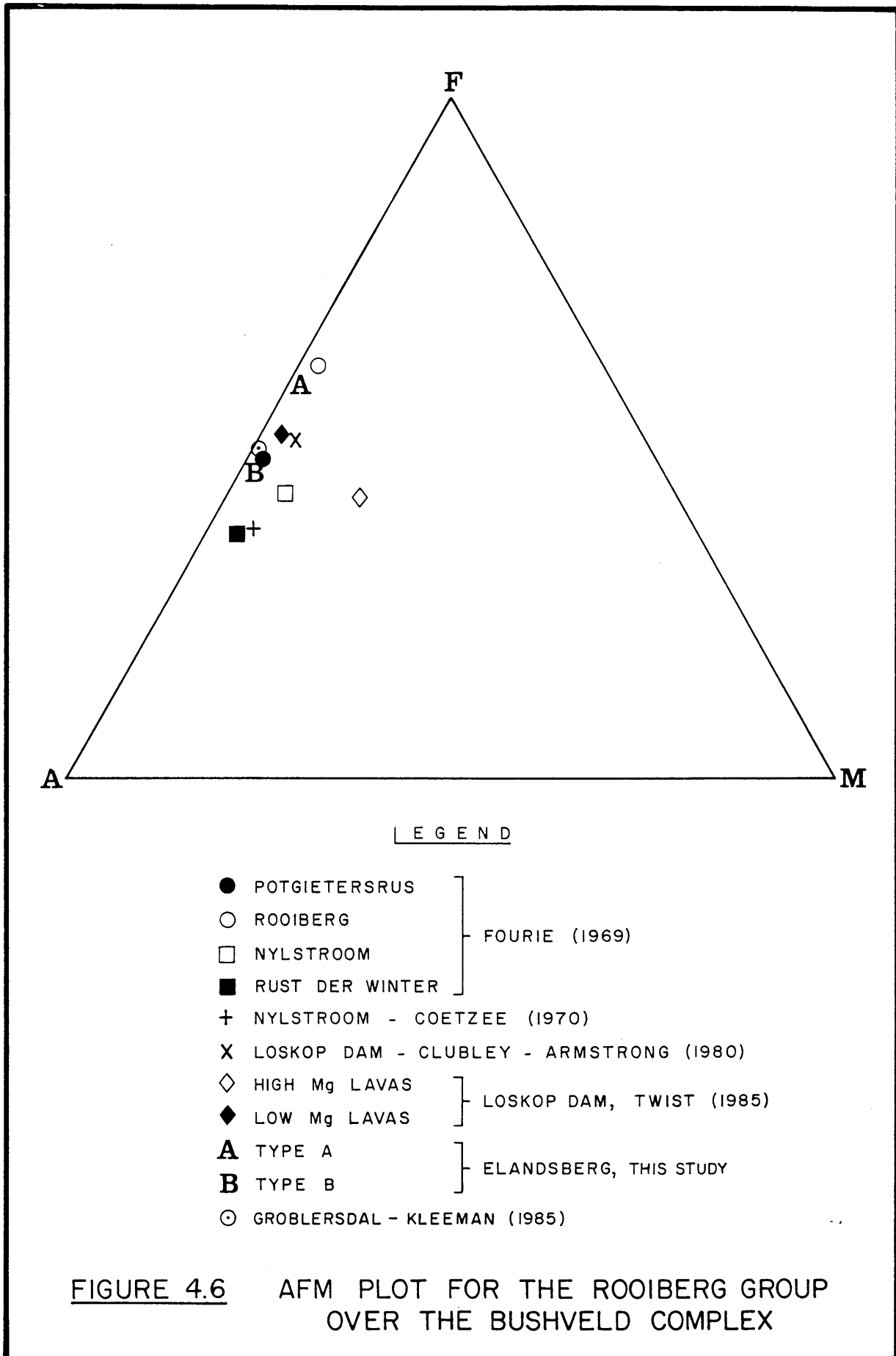
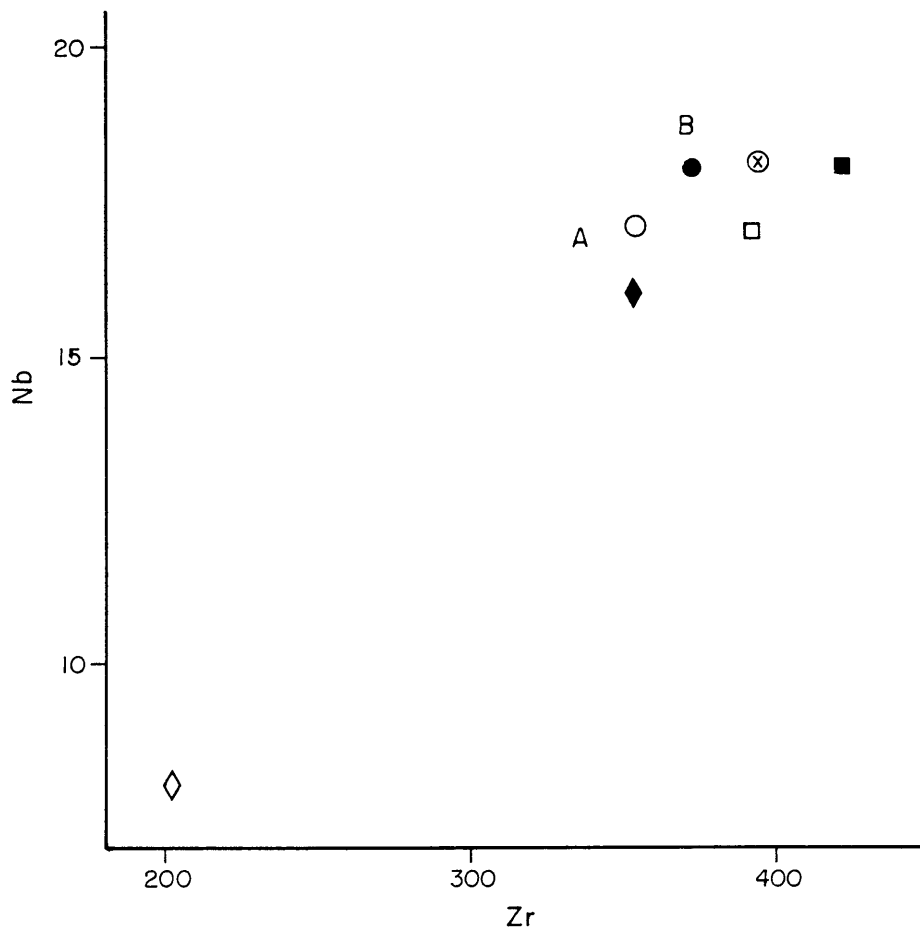


FIGURE 4.6 AFM PLOT FOR THE ROOIBERG GROUP OVER THE BUSHVELD COMPLEX



LEGEND

- | | | |
|---|-----------------|----------------------------|
| ● | POTGIETERSRUS |] FOURIE (1969) |
| ○ | ROOIBERG | |
| □ | NYLSTROOM | |
| ■ | RUST DER WINTER | |
| ◇ | HIGH Mg LAVAS |] TWIST (1985) |
| ◆ | LOW Mg LAVAS | |
| ⊗ | POTGIETERSRUS | - LENTHALL & HUNTER (1977) |
| ⊙ | GROBLERSDAL | - KLEEMAN (1985) |
| A | TYPE A |] ELANDSBERG, THIS STUDY |
| B | TYPE B | |

FIGURE 4.7 Zr - Nb BINARY PLOT FOR THE ROOIBERG GROUP OVER THE BUSHVELD COMPLEX.

described by Twist (1985) clearly fall within a separate compositional field with low Zr and Nb compositions (Fig. 4.7). The remainder of the plots fall within a compositional field of greater than 15ppm Nb and 300ppm Zr. It does, however, appear that the analysis of Kleeman (1985) falls within a separate more evolved compositional field. One data point is insufficient evidence for this separate field.

A relationship between the trend in the AFM diagram (Fig. 4.6) and the trace element binary plot (Fig. 4.7) although subtle, is observed. The high iron, low alkali plots of Fourie (1969) at Rooiberg and type A lavas over the Elandsberg have relatively low Nb-Zr values and are therefore less evolved than other Rooiberg Group lavas in the Bushveld Complex. The converse that low alkali compositions are related to low Nb-Zr is however not observed. This is probably masked by the alkali content which is not anomalously low but of average composition for these rocks.

The chemical composition of the Rooiberg Group over the Elandsberg compares favourably with Rooiberg Group lavas elsewhere in the Bushveld Complex. The high iron contents although anomalous are consistent with the trace element data.

5. CONTACT RELATIONSHIPS

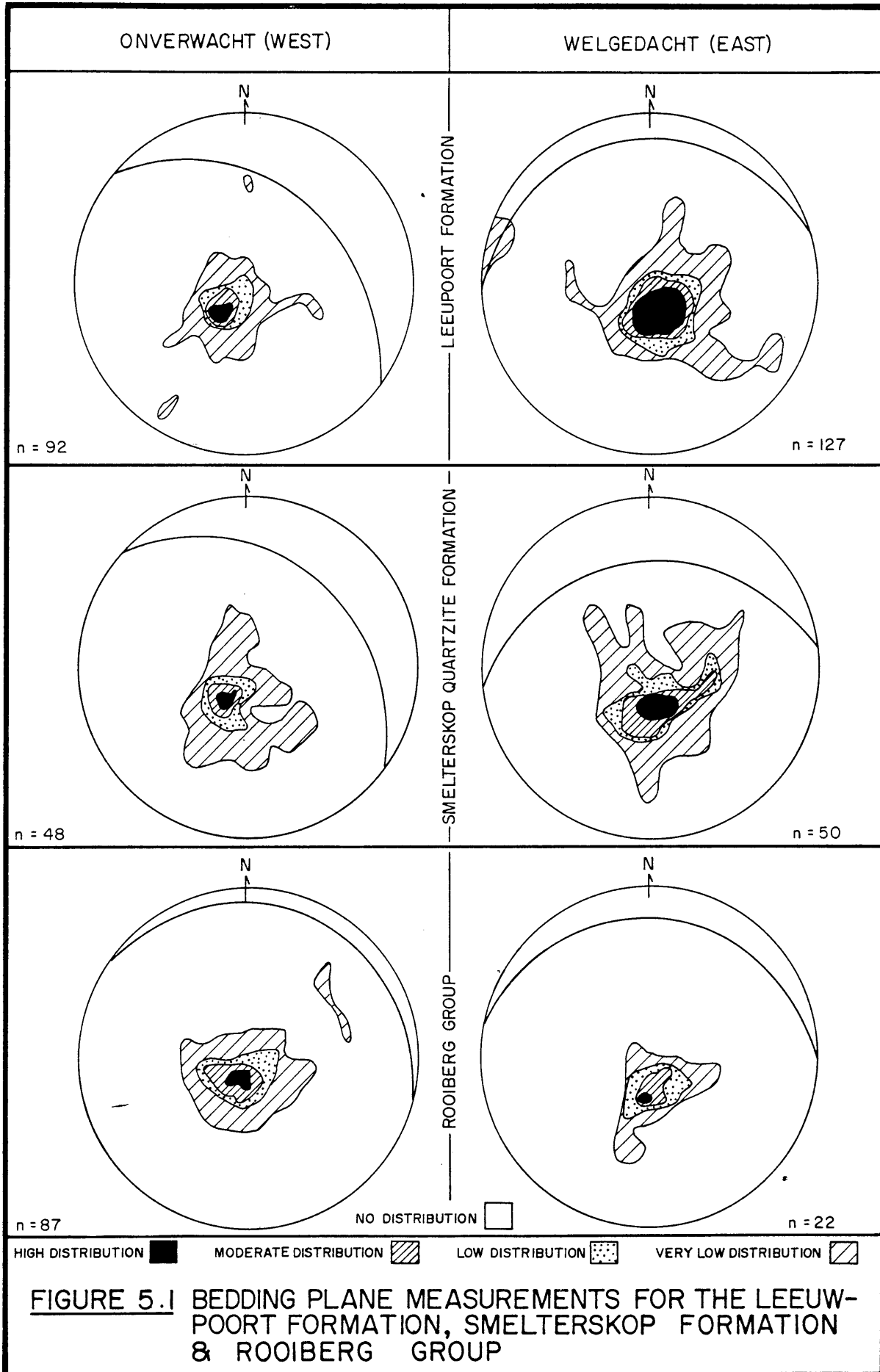
There has been considerable controversy as to whether the basal contacts of the Rooiberg Group and the Smelterskop Formation are unconformable, disconformable, conformable or fault-bounded. In many cases the definitions and interpretations of the above terms have probably been a major problem in this controversy. For this reason the definitions for conformable, unconformable and disconformable contacts are defined in Chapter 1.

An unconformity is present if a time gap exists and if the upper and lower strata have different structural attitudes. Bedding plane orientations for the Leeuwoort Formation, Smelterskop Formation and Rooiberg Group were therefore measured and the poles to bedding plotted on stereographic projections (Fig. 5.1), for the western and eastern portions of the study area. It is obvious from these projections that the attitudes of these three units are similar. The upper and lower contacts of the Smelterskop Quartzite Formation are therefore in no way unconformities and can only be conformable, disconformable or fault-bounded.

5.1 BASE OF THE SMELTERSKOP FORMATION

The base of the Smelterskop Formation has previously been stated as being either conformable (Rozendaal *et al.*, 1986) or unconformable (Stear, 1976) upon the underlying Leeuwoort Formation. The term unconformable as used by Stear implies a disconformable contact in which a time break exists between upper and lower units with the same structural attitude.

Towards the west of the study area the main shale of the Blaauwbank Shale Member pinches out and the Smelterskop Formation overlies the shaly arkosite of the Leeuwoort Formation with an apparent disconformity (Stear, 1976, 1977). Stear also reports shale fragments in a basal agglomerate of the Smelterskop Formation. However, on closer inspection, fine-grained arkosite fragments are also observed in this agglomerate. From petrographic work this agglomerate is defined as a sublithic greywacke (Pettijohn, 1975) (section 2.2.1, p. 24). The



fine-grained arkosite and shale fragments in this greywacke probably indicate clasts derived from the shaly arkosite in the Leeupoort Formation in the sediments of the Smelterskop Formation. This suggests a very strong erosional period in which at least 105m (Labuschagne, 1970) of shale was eroded from the Leeupoort Formation. Evidence for such extensive erosion does not exist at the base of the Smelterskop Formation in the Rooiberg Fragment. This apparent disconformity is therefore postulated to be a local erosive feature in an area where deposition of the main shale of the Blaauwbank Shale Member did not occur. Moreover, coarse clasts of arkosite/quartzite from the Smelterskop Formation (Fig. 5.2) are found embedded in the uppermost shales at the top of the Blaauwbank Shale Member on the farm Welgedacht 514 KQ in the eastern portion of the study area. This indicates that the shales were still fairly unconsolidated during the deposition of the Smelterskop Formation. A large time gap between the Smelterskop Formation and Leeupoort Formation is therefore not evident.

No faulting was observed at the base of the Smelterskop Formation. This, and the presence of Smelterskop clasts at the top of the Blaauwbank Shale Member point to a conformable sequence of Smelterskop Formation sedimentary rocks and volcanoclastics overlying argillaceous and arenaceous rocks of the Leeupoort Formation.

5.2 BASE OF THE ROOIBERG GROUP

The base of the Rooiberg Group in the northern portion of the Rooiberg Fragment comprises a sharp contact in which clastic sedimentary rocks of the Smelterskop Formation are overlain by rhyolitic lavas. It is thought by Stear (1976) and Phillips (1982) to be conformable. However, Hunter and Lenthal (1971) disagree and state that the Rooiberg Group/Smelterskop Formation contact is disconformable. Rhodes (1973) implies a disconformable contact by stating that the felsites only rarely overlie the Transvaal Sequence sedimentary rocks with a normal stratigraphic contact.

To investigate this contact a stratigraphic profile or strike section was drawn using the base of the Rooiberg Group as a time equivalent line or conformity, in other words as a straight and horizontal

contact. This strike section (Fig. 5.3) shows a cross-section of a large scale fold alligned with its axis perpendicular to bedding. There is no field evidence for such folding. The base of the Rooiberg Group can therefore not be used as a conformity. The strike section was redrawn using the base of the Smelterskop Formation as a conformity and a more plausible profile resulted (Fig. 5.4). It is apparent from the section that the base of the Rooiberg Group forms a palaeovalley, indicating erosion prior to the extrusion of the rhyolitic lavas. Field evidence also indicates that the Rooiberg Group truncates well indurated, recrystallized quartzite lenses of the Smelterskop Formation, thus supporting this proposed erosion.

The sublithic greywacke at the base of the Smelterskop Formation discussed in section 2.2.1 appears to form a local erosion channel (Fig. 5.4). This local disconformity is similar to that described by Billings (1972), where at times of flood within a braided stream environment, deep channels may be scoured out and as the flood subsides these channels may become filled with sediment.

Over the eastern portion of the study area the Kwarriehoek Wrench becomes the contact of the Rooiberg Group/Smelterskop Formation. This is believed by Leube and Stumpfl (1963) to be a major thrust fault. This apparent faulted contact is, however, discontinuous and only extends approximately 500m along strike, where it cuts into the felsite.

The entire basal contact of the Rooiberg Group is, therefore, not fault-bounded. The evidence points to this contact having succeeded an erosional period and therefore a time break, creating a subsequent disconformable contact between the Rooiberg Group and Smelterskop Formation.



FIGURE 5.2: Arkosic clasts of the Smelterskop Formation embedded in the uppermost shale at the top of the Blaauwbank Shale Member

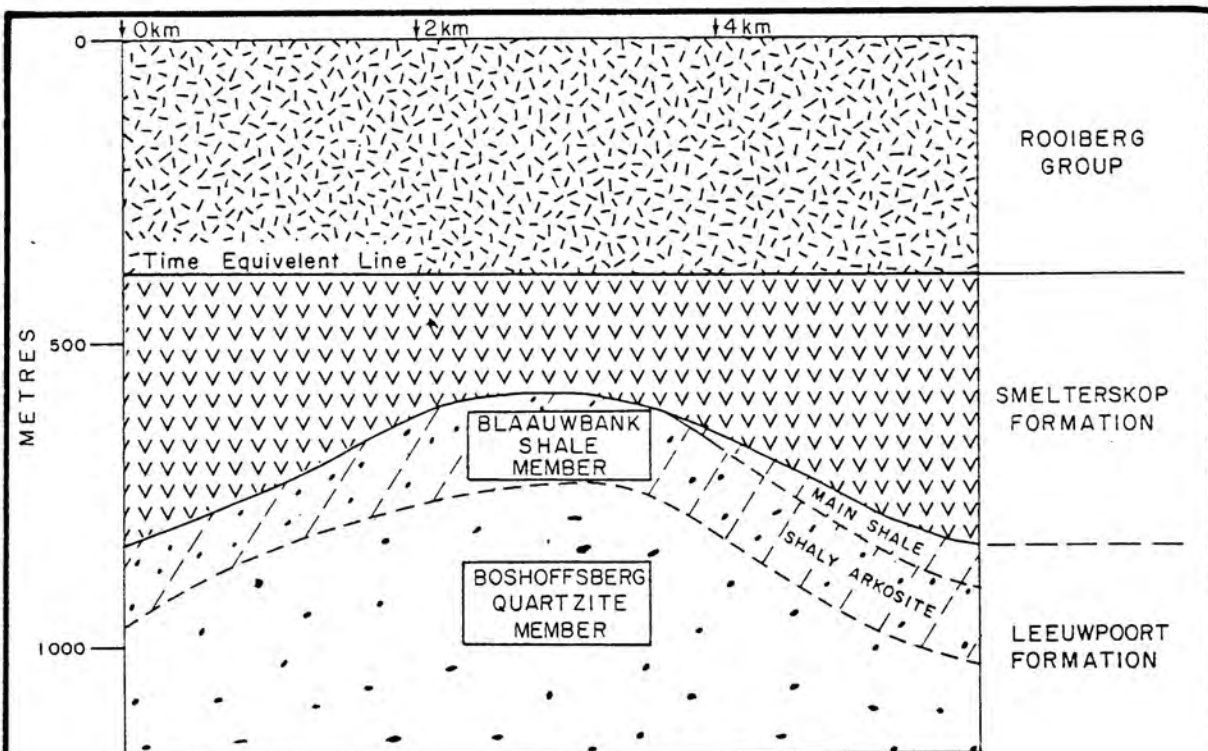


FIGURE 5.3 SCHEMATIC STRATIGRAPHIC SECTION THROUGH THE PRETORIA AND ROOIBERG GROUPS USING THE BASE OF THE ROOIBERG GROUP AS A CONFORMITY.

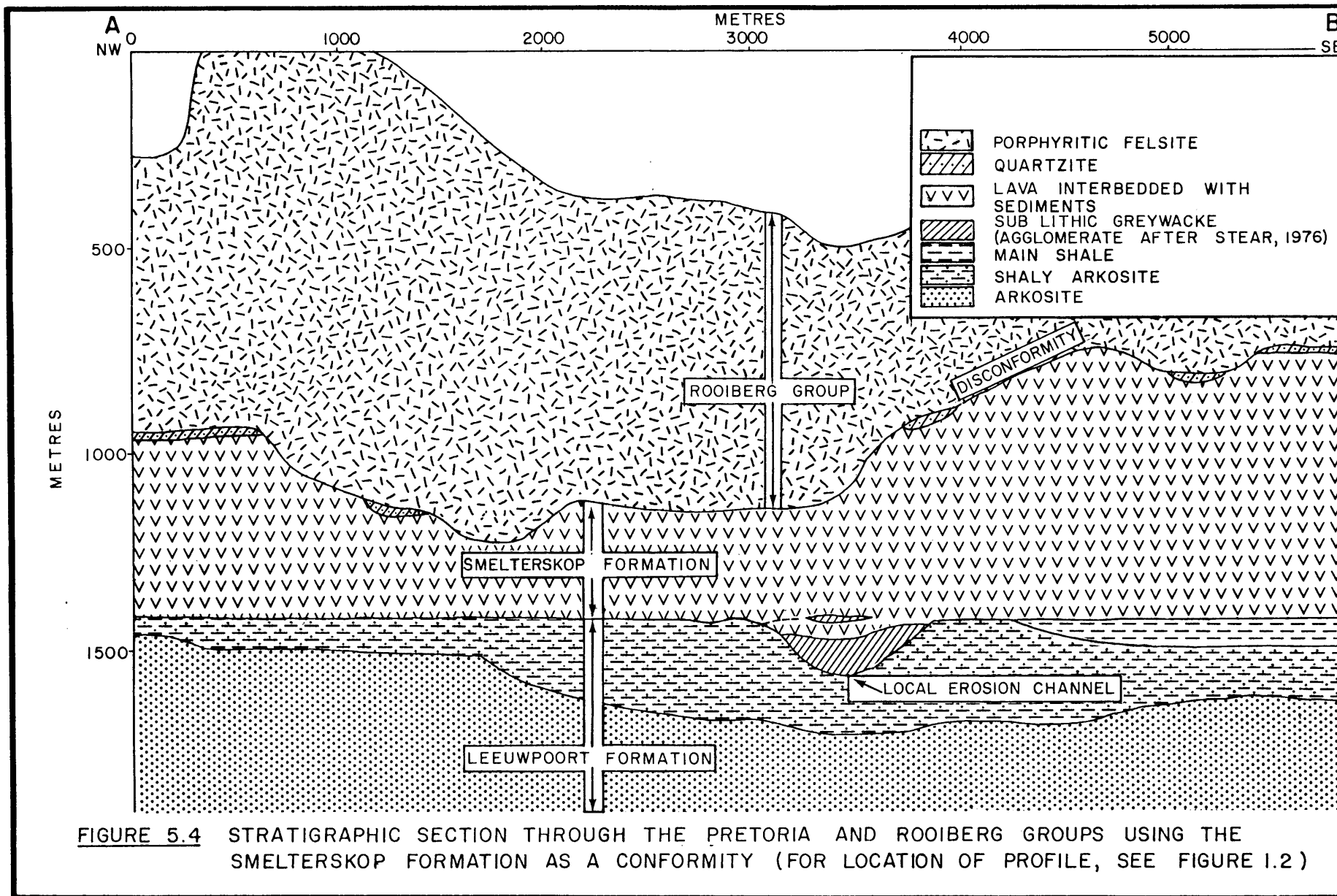


FIGURE 5.4 STRATIGRAPHIC SECTION THROUGH THE PRETORIA AND ROOIBERG GROUPS USING THE SMELTERSKOP FORMATION AS A CONFORMITY (FOR LOCATION OF PROFILE, SEE FIGURE 1.2)

6. SYNTHESIS

The Transvaal Sequence sedimentary rocks in the northern portion of the Rooiberg Fragment point to a fluvial palaeoenvironment situated at the edge of a large Proterozoic basin.

The contemporaneous extrusion of lavas in the upper portions of the sequence had a considerable influence on sediment input. Extrusion of highly siliceous rhyolitic lavas terminated the deposition of the fluvial sequences.

The lower conglomerates and grits of the Leeuwpoort Formation, interpreted by Stear (1976, 1977) as a braided stream system, represent the most proximal portion of the fluvial palaeoenvironment. The overlying arkosites, a finer-grained, more distal lithofacies in this fluvial system, were deposited rapidly and under unstable tectonic conditions by braided river systems. The vertical aggradation of the braided stream deposits lowered the depositional palaeoslope and hence a lower energy meandering river system was formed. The lateral and vertical accretion of upward-fining cycles of sandstone and mudstone in this setting again decreased the depositional palaeoslope. The meandering channels became filled with debris and a very low energy distal fluviolacustrine or floodplain palaeoenvironment resulted, characterised by the deposition of finely laminated mudstones. The braided stream system represents the arkosites of the Boshoffsberg Quartzite Member, Leeuwpoort Formation, whereas, the meandering stream system represents the shaly arkosite of the Blaauwbank Shale Member, Leeuwpoort Formation. The proposed floodplain deposits are correlated with the main shale of the Blaauwbank Shale Member, Leeuwpoort Formation.

Before lithification of the main shales of the Blaauwbank Shale Member was completed, the Smelterskop Formation sedimentary rocks were deposited. Tectonic subsidence of the depositional basin rapidly increased the depositional slope and hence coarse-grained detritus was deposited in the form of channel-fill sediments of the basal Smelterskop Formation. During periods of high discharge and flooding, finer-grained sedimentary rocks were deposited in overbank and floodplain settings. The upward-fining nature of the Smelterskop

Formation over the eastern portion of the study area and the upward-coarsening cycle of the sequence over the western portion, indicates that associated volcanic activity may have had an influence on sediment input and deposition. This activity, caused by the extrusion of the andesitic Smelterskop lavas, created local uplift within the palaeoenvironment and hence local changes in depositional palaeoslope. Variations in grain size distributions are therefore common in the Smelterskop Formation.

A considerable period of erosion and non-deposition followed the deposition of the Smelterskop Formation. The Rooiberg Group lavas extruded as thick sheets of viscous siliceous lava. This extrusion can be correlated with the lower portion of the Rooiberg Group, the Kwaggasnek Formation. The upper Schrikkloof Formation, in the form of flow banded lavas separated by thin volcanic breccias and ash fall tuffs, was probably deposited but subsequently removed by erosion.

Extensive alteration is apparent from the geochemistry of the Rooiberg Group, and was probably due to either the intrusion of the mafic phase of the Bushveld Complex, or intrusion of the related granitoids. However, from empirical data two lava types are observed:

TYPE A: Dacitic composition with high total iron and relatively low Zr-Nb contents.

TYPE B: Rhyolites with relatively high Nb-Zr contents.

7. ACKNOWLEDGEMENTS

Messrs. Gold Fields of South Africa Ltd are thanked for the permission granted to carry out this research. A special appreciation to Dr R P Viljoen for initiating ideas and Messrs. I.C. Pringle, H.M. Meadon and P.D.F. Vickers for constructive criticism.

To Prof. G. von Gruenewaldt, Dr. D. Twist and Dr. P. Eriksson of Pretoria University for their critical reviews and enlightening discussions during the preparation of this manuscript.

Many thanks to the staff of Gold Fields Mining and Development at Vellefontein and the staff of Rooiberg Tin Ltd. for valuable contributions made during the field work.

The draughting and typing services of the ladies at Oberholzer Geological Centre, Carletonville are appreciated.

8. REFERENCES

- ALLEN, J.R.L., 1984. Sedimentary Structures: Their Character and Physical Basis. Elsevier, 663 pp.
- , 1986. Earthquake Magnitude Frequency, Epicentral Distance and Soft Sediment Deformation in Sedimentary Basins. Sedimentary Geology, 46, 67 - 75.
- BILLINGS, M.P., 1972. Structural Geology. 3rd edit., Prentice Hall Inc., 606pp.
- BLATT, H., MIDDLETON, G. AND MURRAY, R., 1972. Origin of Sedimentary Rocks. Prentice-Hall Inc., 634pp.
- BOARDMAN, L.G., 1946. The Geology of a Portion of the Rooiberg Tin-field. Trans. Geol. Soc. S. Afr., 49, 103 - 132.
- BUTTON, A., 1976. Transvaal and Hammersley Basins - Review of Basin Development and Mineral Deposits. Minerals Sci. Engng., 8, 262 - 293.
- CLUBLEY-ARMSTRONG, A.R., 1980. Petrochemistry of the Rooiberg Group and Overlying Loskop Formation, North of Middelburg, South Eastern Transvaal. Ann. Geol. Surv. S. Africa, 14/2, 11 - 28.
- COETZEE, G.L., 1970. The Rooiberg Felsite Series North of Nylstroom. Geol. Soc. S. Afr., Spec. Publ. No. 1
- COLLINSON, J.D., 1979. Alluvial Sediments, 15 - 60. In: Reading, H.G. (Editor), Sedimentary Environments and Facies. Blackwell Scientific Publication, 569pp.
- AND THOMPSON, D.B., 1982. Sedimentary Structures. George Allen and Unwin, 194pp.
- COX, K.G., BELL, J.D. AND PANKHURST, 1980. The Interpretation of Igneous Rocks, George Allen and Unwin, 450pp.
- DAVIES, D.K., VESSEL, R.K., MILES, R.C., FOLEY, M.C. AND BONES, S.B., 1976. Fluvial Transport and Downstream Sediment Modification in an Active Volcanic Region, 61 - 84. In: Miall, A.D. (Editor), Fluvial Sedimentology. Mem. Can. Soc. Petrol. Geol., 5.
- DINSDALE, J.L., 1982. The Development and Control of Pocket-Mineralization in the Rooiberg Quartzites. M.Sc. thesis, Univ. Pretoria, 150pp.

- ELLIOT, T., 1979. Clastic Shorelines, 143 - 177. In: Reading, H.G. (Editor), Sedimentary Environment and Facies, Blackwell Scientific Publication, 569pp.
- ERIKSSON, K.A. AND VOS, R.G., 1979. A Fluvial Fan Depositional Model for Middle Proterozoic Red Beds from the Waterberg, South Africa. Prec. Res., 9, 169 - 188.
- FLOYD, P.A. AND WINCHESTER, J.A., 1975. Magma Type and Tectonic Setting: Discrimination using Immobile Elements. Earth Planet. Sc. Lett., 27, 211 - 218.
- FOURIE, P.J., 1969. Die Geochemie van Granitiese Gesteentes van die Bosveldstollingkompleks. D.Sc. thesis, Univ. Pretoria, 289pp.
- FRIEDMAN, G.M. AND SANDERS, J.E., 1978. Principles of Sedimentology. John Wiley and Sons, 791pp.
- GARY, M., MCAFEE, R. AND WOLF, C., 1972. (Editors), Glossary of Geology, Amer. Geol. Inst. Washington DC, 857pp.
- GREINER, H.R., 1962. Facies and Sedimentary Environments of Albert Shale, New Brunswick. Bull. Am. Assoc. Petrol. Geologists, 46, 219 - 234.
- HARMS, J.C., SOUTHARD, J.B., SPEARING, D.R. AND WALKER, R.G., 1975. Depositional Environments as Interpreted From Primary Sedimentary Structures and Stratification Sequences. Soc. Econ. Pal. Min., 161pp.
- HUBERT, J.F., 1960. Petrology of the Fountain and Lyons Formations, Front Range, Colorado. Calo. School Mines Quart., 55, No. 1, 242pp.
- HUMPHREY, W.A., 1909. On Portions of the Bushveld Bordering the Crocodile River and Including the Rooiberg Tin-field. A Rep. geol. Surv. Transvaal, 1908, 103 - 123.
- HUNTER, D.R. AND LETHALL, D.H., 1971. A preliminary Review of Tin Mineralization with Particular Reference to the Bushveld Igneous Complex. EGRU, Inf. Circ. No. 61, Univ. Witwatersrand.
- IANNELLO, P., 1971. The Bushveld Granites around Rooiberg, Transvaal, South Africa. Geol. Rdsch., 60, 630 - 655.
- JOHNSON, H.D., 1979. Shallow Siliclastic Seas, 207 - 258. In: Reading, H.G. (Editor), Sedimentary Environments and Facies, Blackwell Scientific Publications, 569pp.

- KLEEMAN, G.J., 1985. The Geochemistry and Petrology of the Roofrocks of the Bushveld Complex East of Groblersdal. M.Sc. thesis, Univ. Pretoria, 175pp.
- KLEIN, G, deV., 1970. Tidal origin of a Precambrian Quartzite - The Lower Fine Grained Quartzite (Dalradian) of Islay, Scotland. Jour. Sedimentary Pet., 40, 973 - 985.
- , 1971. A Sedimentary Model for Determining Palaeotidal Range. Geol. Soc. Amer. Bull., 82, 2585 - 2592.
- , 1977. Clastic Tidal Facies. Continuing Education Publication Co., Champaign, Ill., 149pp.
- LABUSCHAGNE, L.S., 1970. The Structure and the Mineralization of the Ore Bodies at Blaauwbank and Nieuwpoort, Rooiberg Tin-field, Transvaal. M.Sc. thesis, Univ. Pretoria, 77pp.
- LE BAS, M.J., LE MAITRE, R.W., STRECKEISEN, A AND ZANETTIN, B., 1986. A Chemical Classification of Volcanic Rocks Based on the Total Alkali-Silica Diagram. Journal of Petrology, 27, 745 - 750.
- LENTHALL, D.H. AND HUNTER, D.R., 1977. The Geochemistry of the Bushveld Granites in the Potgietersrus Tinfield. Prec. Res., 5, 395 - 400.
- LEUBE, A. AND STUMPFL, E.F., 1963. The Rooiberg and Leeuwpoort Tin Mines, Transvaal, South Africa. Econ. Geol., 58, 391 - 418, 527 - 557.
- LOMBERG, K., 1985. A Petrographic and Geochemical Study of Selected Samples from Boreholes CMS 147 ('C' Mine) and V108 (Vellefontein). Unpubl. Rep. Gold Fields of South Africa Limited.
- MARRACK, T., 1942. The Geology of the Rooiberg Tinfield. Unpubl. Rep., Rooiberg Minerals Development Company Limited.
- MIALL, A.D., 1973. Markov Chain Analysis Applied to an Ancient Alluvial Plain Succession. Sedimentology, 20, 347 - 364.
- , 1977. A Review of the Braided River Depositional Environment. Earth Sci. Rev., 13, 1 - 62.
- , 1979. Deltas, 43 - 56. In: Walker, R.G. (Editor), Facies Models, Geosc. Can., Reprint Series, 1, 211pp.
- McCABE, P.J., 1977. Deep Distributary Channels and Giant Bedforms in the Upper Carboniferous of the Central Pennines, Northern England. Sedimentology, 24, 271 - 290.

- PEARCE, J.A. AND NORRY, M.J., 1979. Petrogenetic Indications of Ti, Zr, Y and Nb Variations in Volcanic Rocks. Contrib. Mineral. Petrol., 69, 33 - 47.
- PETTIJOHN, E.J., 1975. Sedimentary Rocks, Harper and Row, 628pp.
- PHILLIPS, A.H., 1982. The Geology of the Leeuwpoort Tin Deposits and Selected aspects of its Environs. M.Sc. thesis, Univ. Pretoria, 297pp.
- REINECK, H.E. AND SINGH, I.B., 1980. Depositional Sedimentary Environments. Springer-Verlag, 549pp.
- RHODES, R.C., 1973. Petrochemical Characteristics of Bushveld Granites and Rooiberg felsite. Trans. Geol. Soc. S. Afr., 77, 93 - 98.
- ROZENDAAL, A.R., TOROS, M.S. AND ANDERSON, J.R., 1986. The Rooiberg Tin Deposits West-Central Transvaal, 1307 - 1328. In: Anhaeusser, C.R. and Maske, S. (Editors), Mineral Deposits of Southern Africa, II, Geol. Soc. of S. Afr., 2335pp.
- SOUTH AFRICAN COMMITTEE FOR STRATIGRAPHY, 1980. Stratigraphy of South Africa. Part I. Lithostratigraphy of the Republic of South Africa, South West Africa/Namibia and the Republics of Bophuthatswana, Transkei and Venda. S. Afr. Geol. Surv. Handbook, No. 8.
- STEAR, W.M., 1976. The Geology and Ore Controls of the Northern Rooiberg Tin-fields, Transvaal. M.Sc. thesis, Univ. Stellenbosch, 89pp.
- , 1977a. The Stratigraphy and Sedimentation of the Pretoria Group at Rooiberg, Transvaal. Trans. Geol. Soc. S. Afr., 80, 53 - 65.
- , 1977b. The Stratabound Tin-Deposits and Structure of the Rooiberg Fragment. Trans. Geol. Soc. S. Afr., 80, 67 - 78.
- THURSTON, P.C. AND FRYER, B.J., 1983. The Geochemistry of Repetitive Cyclic Volcanism from Basalt through Rhyolite in the Uchi-Confederation Greenstone Belt, Canada. Contrib. Mineral. Petrol., 83, 204 - 226.
- TOMKEIEFF, S.I., 1962. Unconformity, an Historical Study. Geologists Association, 73, 383 - 417.
- TWIST, D., 1984. Geochemical Evolution of the Rooiberg Acid Lavas in the Loskop Dam Area, Southeastern Bushveld. Inst. Geol. Res. Bushv. Compl. Res. Rep. 45.

- , 1985. *Geochemical Evolution of the Rooiberg Silicic Lavas in the Loskop Dam Area, Southeastern Bushveld.* Econ. Geol., 80, 1153 - 1165.
- VICKERS, P.D.F., 1981. Lithogeochemical Investigation - Union Tin Mine - Doornhoek 342 KR, Report on Lode and Host Rocks Geochemical Orientation Study. Unpubl. Rep., Gold Fields of South Africa Ltd.
- WATCHORN, M.B. AND ARMSTRONG, N.V., 1980. *Contemporaneous Sedimentation and Volcanism at the Base of the Early Precambrian Nsuze Group, South Africa.* Trans. Geol. Soc. S. Afr., 83, 231 -238.
- WINCHESTER, J.A. AND FLOYD, P.A., 1977. *Geochemical Discrimination of Different Magma Series and their different Products Using Immobile Elements.* Chemical Geology, 20, 325 - 343.

9. APPENDIX

APPENDIX A: MARKOV ANALYSIS OF LITHOFACIES IN THE BOSHOFFSBERG
QUARTZITE MEMBER, LEEUWPOORT FORMATION (AFTER MIALL,
1973)

L E G E N D

St - Trough cross-bedded arkosite
St(m) - Trough cross-bedded arkosite with megaripples
Su - Undifferentiated arkosite
Sh - Horizontally laminated arkosite
Sp - Planar cross-bedded arkosite
Sr - Trough cross-laminated arkosite
Rt - Row total
Ct - Column total

COMBINED COUNT MATRIX

	St	St(m)	Su	Sh	Sp	Sr	RT
St	0	4	2	11	0	0	17
St(m)	4	0	0	2	1	0	7
Su	1	0	0	0	2	0	3
Sh	14	2	1	0	4	0	21
Sp	3	2	0	1	0	1	7
Sr	0	0	0	1	0	0	1
CT	22	8	3	15	7	1	56

COMBINED PROBABILITY COUNT MATRIX

	St	St(m)	Su	Sh	Sp	Sr
St	0,00	0,24	0,12	0,65	0,00	0,00
St(m)	0,57	0,00	0,00	0,29	0,14	0,00
Su	0,33	0,00	0,00	0,00	0,67	0,00
Sh	0,67	0,10	0,05	0,00	0,19	0,00
Sp	0,43	0,29	0,00	0,14	0,00	0,14
Sr	0,00	0,00	0,00	1,00	0,00	0,00

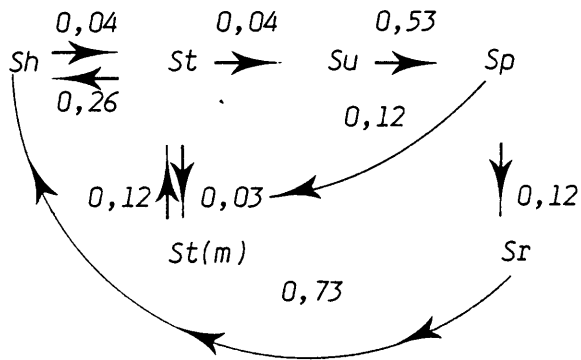
COMBINED INDEPENDENT TRIALS PROBABILITY MATRIX

	St	St(m)	Su	Sh	Sp	Sr
St	0,00	0,21	0,08	0,38	0,18	0,03
St(m)	0,45	0,00	0,06	0,31	0,14	0,02
Su	0,42	0,15	0,00	0,28	0,13	0,02
Sh	0,63	0,23	0,09	0,00	0,20	0,03
Sp	0,45	0,16	0,06	0,31	0,00	0,02
Sr	0,40	0,15	0,05	0,27	0,13	0,00

COMBINED DIFFERENCE MATRIX

	St	St(m)	Su	Sh	Sp	Sr
St	0,00	0,03	0,04	0,26	-0,18	-0,03
St(m)	0,12	0,00	-0,06	-0,02	0,00	-0,02
Su	-0,08	-0,15	0,00	-0,28	0,53	-0,02
Sh	0,04	-0,13	-0,04	0,00	-0,01	-0,03
Sp	-0,02	0,12	-0,06	-0,16	0,00	0,12
Sr	-0,40	-0,15	-0,05	0,73	-0,13	0,00

MARKOV CHAIN



MOST PROBABLE CYCLE

