LITHOSTRATIGRAPHY AND DEPOSITIONAL ENVIRONMENT OF THE ARCHAEAN NSUZE GROUP, PONGOLA SUPERGROUP.

PART 1

E.G. COLE
1994

LITHOSTRATIGRAPHY AND DEPOSITIONAL ENVIRONMENT OF THE ARCHAEAN NSUZE GROUP, PONGOLA SUPERGROUP.

by
EDWARD GEORGE COLE

Dissertation

submitted in fulfilment of the requirements

for the degree of

MASTER OF SCIENCE

in

GEOLOGY

in the

Faculty of Science

RAND AFRIKAANS UNIVERSITY

Supervisor: Professor N. J. Beukes
Co-supervisor: Professor L. Ashwal

DECEMBER 1994

Abstract:

The ≈ 3,0 Ga old volcano-sedimentary Nsuze Group, which forms the base of the Pongola Supergroup, outcrops as scattered inliers within a 100 km wide zone extending from southern Swaziland to northern Natal on the south-eastern part of the Kaapvaal craton. The Nsuze Group is significant in that it forms part of probably the oldest intracratonic sequence in the world, being deposited at a time when Archaean granite-greenstone sequences were being emplaced elsewhere.

Lithostratigraphic profiles have been constructed along selected traverses throughout the Nsuze basin. Data from these profiles, in addition to published Nsuze lithostratigraphic data, have been ultized to establish regional inter-profile correlations which ultimately contributed to the establishment of a new regionally-applicable stratigraphic framework for the Nsuze Group. The Nsuze Group has been subdivided into eight regionally recognisable formations. Three of those formations are dominantly volcanic (Pypklipberg, Agatha and Ekombe), with four being dominantly sedimentary (Mantonga, White Mfolozi, Langfontein / Vutshini and Mkuzane). One formation, the volcaniclastic Nzimini Formation, is restricted to the southern domain with it's exact stratigraphic position uncertain. A Nsuze Group outcrop map has been constructed, showing regional outcrop distribution in terms of the new stratigraphic nomenclature.

Nsuze Group lithologies have been subjected to a complex series of alteration processes. An initial phase of post-emplacement alteration effected the volcanics, while the entire Nsuze sequence bears the imprint of regional burial-induced low grade metamorphism. Post-Pongola age granitoid emplacement has locally caused hornblende-hornfels facies contact metamorphism.

The Nsuze Group is at present preserved as isolated folded inliers enveloped by pre- and post-Pongola granitoids. A full appreciation of the structural overprint is critical in conducting lithostratigraphic profiles in the Nsuze basin.
These structural complexities have been recorded and interpreted during fieldwork. Geophysical evidence suggests a much wider Nsuze Group subcropping distribution than that seen to be outcropping.

Geochronological, lithostratigraphic and geochemical data suggest a correlation between the Nsuze and Dominion Groups. A large portion of the Dominion Group has been removed by the pre-Witwatersrand unconformity, with only the lower portion of the original Dominion sequence preserved.

One hundred and twelve Nsuze lava and pelite geochemical analyses (major, minor and trace elements) are presented. These data have been combined with published geochemical data to produce a stratigraphically-constrained Nsuze database. These data have yielded information concerning factors such as the provenance of the Nsuze Group, the tectonic setting of the Nsuze Group and the chemical classification of Nsuze lavas. The database is particulary suitable for future geochemical applications.

Progressive subsidence of the Nsuze basin has contributed to an evolution in depositional environments ranging from a sandy braided fluvial environment during Mantonga Formation times, through a tide - dominated depositional environment during White Mfolozi Formation times, to a shallow marine shelf environment during Mfenyana Subgroup times. The volcanic formations also reflect increasingly subaqueous conditions of emplacement. Sedimentation throughout the Nsuze Group was characterised by occasional syn-sedimentary tectonism, instability and pyroclastic volcanism. However in general the Nsuze Group reflects deposition under stable cratonic conditions, possibly in an intracratonic basin.

This study summarizes the lithostratigraphy of the Nsuze Group, in so doing placing the work done by previous Nsuze Group workers in localized areas in a regional stratigraphic framework. It is hoped that this study will stimulate further research on the Nsuze Group.

UITTREKSEL:

Die ≈ 3,0 Ga oue vulkaniese-sedimentologiese Nsuze Groep gesteentes vorm die basis van die Pongola Opeenvolging. Die Nsuze Groep dagsoom as verspreide insluitsels binne 'n 100 km wye sone wat strek vanaf suidelike Swaziland tot noord Natal op die oostelike gedeelte van die Kaapvaal Kraton. Die Nsuze Groep word belangrik geag omrede dit deel uitmaak van die oudste intrakratoniese opeenvolging in die wêreld. Die Groep is gelyktydig afgeset met die Argeiese graniet/groensteen opeenvolgings elders in die wêreld.

Lithostratigrafiese profiele is saamgestel deur voorkeur lokaliteits profiele in die Nsuzekom. Korrelasies tussen die profiele is verkry deur die samestelling van die opgemete profiele, gepubliseerde profiele en gepubliseerde literatuur. Verkryde inligting is gebruik om 'n nuwe Nsuze Groep stratigrafiese raamwerk op te stel wat regionaal toegepas kan word. Die Nsuze Groep kan onderverdeel word in agt regionaal uitkenbare formasies. Drie van die bogenoemde formasies is hoofsaaklik vulkanies van aard nl. die Pypklipberg, Agatha en Ekombe Formasies. Die Mantonga, White Mfolozi, Langfontein/Vutshini en die Mkuzane Formasies is hoofsaaklik van sedimentêre oorsprong. Die vulkaniklastiese Nzimini Formasie is beperk tot die suidelike gebied met stratigrafiese posisie onseker. Volgens die nuwe Nsuze stratigrafiese nomenklatuur is 'n nuwe Nsuze Groep dagsoomkaart saamgestel wat regionale verspreiding uitwys.

Die Nsuze Groep is onderwerp aan 'n ingewikkelde reeks metamorfe en alterasie prosesse. Die vulkaniese gesteentes is onderwerp aan 'n fase van na-inplasing metamorfose, gevolg deur die regionale lae graadse metamorfose van die Nsuze Groep. Die na-Pongola ouderdom intrusiewe graniete het plaaslike hornblende-hornfels metamorfose veroorsaak.

Die Nsuze Groep geplooide insluitsels is gepreserveer en geïsoleer deur omliggende voor- en na-Pongola ouderdom graniete. Strukturele aspekte word waardeer deur die samestelling van lithostratigrafiese profiele verkry in die Nsuzekom. Strukturele aspekte is aangeteken en geinterpreteer gedurende veldwerk. Geofisie inligting bewys dat die ondergrondse verspreiding van die Nsuze Groep die dagsoom verspreiding ver oortref.

'n Korrelasie tussen die Nsuze Groep en die Dominion word verkry uit geokronologiese, lithostratigrafiese en geochemiese inligting. Die onderste gedeelte van die oorspronklike Dominion opeenvolging is gepreserveer as gevolg van die voor-Witwatersrand diskordansie wat die bo-liggende formasies geerodeer het.

Eenhonderd en twaalf Nsuze lawa en peliet geochemiese ontledings word verskaf. Gepubliseerde Nsuze geochemiese data is gekoppel aan die bogenoemde geochemiese ontledings om 'n stratigrafiese - gekoppelde Nsuze databasis te ontwikkel.

Bogenoemde geochemiese data verleen inligting tot die volgende: provenansie van die Nsuze Groep, tektoniese omgewing en 'n geochemiese klassifikasie van die Nsuze lawas. Die databasis is veral geskik vir toekomstige geochemiese toepassings.

Verskeie unieke afsettings omgewings in die Nsuzekom is teweeg gebring deur die progressiewe versakking van die komvloer. Die komvloer afsettings omgewings sluit in: die sanderige gevlegte fluviale omgewing van die Mantonga Formasie, 'n gety-gedomineerde afsettings omgewing gedurende die White Mfolozi Formasie en 'n vlak marine plat omgewing gedurende die Mfenyana Subgroep. Die vulkaniese formasie inligting verkry dui op 'n onderwaterse afsettings omgewing. Sedimentasie in die Nsuze Groep is gekenmerk deur aktiewe vulkaniese prosesse wat onstabiele toestande en piroklasties vulkanisme insluit. Die Nsuze Groep is in die algemeen afgeset onder redelike stabiele kratoniese toestande, waarskynlik in 'n intrakratoniese kom.

Die studie is 'n samevatting van die lithostratigrafie van die Nsuze Groep. 'n Regionale stratigrafiese raamwerk is saamgestel en vorige lithostratigrafiese werk is in die raamwerk geinkorporeer. Die studie poog om verdere navorsing in die Nsuze Groep te stimuleer.

LIST OF FIGURES

1.1	Map showing the location of the study area and the distribution of the Pongola Supergroup and associated intrusive rocks.
1.2	Pongola Supergroup: Provisional correlation of stratigraphic nomenclature.
2.1	Simplified stratigraphic subdivisions of an idealized "complete" Nsuze Group succession compiled from regional studies showing type areas for each lithostratigraphic component.
3.1	Simplified geological map of the northern part of the Gem Vuleka Synform, northwest of Nkandla, illustrating the interpreted lithostratigraphy in relation to structure. (Modified from Groenewald, 1984).
3.2	Imbricate thrust zone patterns within a mature grey-white quartzite unit in the White Mfolozi Formation in the Buffalo River Inlier.
3.3	Simplified logsheet and suggested lithostratigraphic subdivision of drillhole NQ2, Nqutu district.
3.4	Remnant total Nsuze isopach contour plan.
4.1	Detailed lithostratigraphy of the Mantonga Formation, showing a type profile and lateral variations within the Nsuze Basin.
4.2	The immediate surrounds of the type profile for the Mantonga Formation. The Mantonga River on the farm Saaiplaas, Western Hartland Basin. Demarcated are approximate facies contacts. (Photograph looking south).
4.3	Sub-angular-to-subrounded chert and vein quartz pebbles in a matrix-supported conglomerate in the basal portion of the Mantonga Formation. Mantonga River traverse, Western Hartland Basin.
4.4	Thin olig~~i~~omictic conglomerate at the base of the Mantonga Formation, overlying granitic basement, White Mfolozi River Inlier.
4.5	Immature green diamictite at the base of the Mantonga Formation along the Mazebeko profile, Buffalo River Inlier, overlain by an oligiomictic conglomerate and a unit of coarse quartz arenites. Notice late-stage, high angle cross-cutting normal fault.
4.6	Well-developed flat beds in coarse-grained arenites at the base of a fining-up cycle. Mantonga Formation, Mantonga River traverse, Western Hartland Basin.
4.7	Small scale trough cross-beds in a medium-grained orthoquartzite. Mantonga Formation. Fugitives Drift traverse. Buffalo River Inlier.
4.8	Photomicrograph showing a sericitized angular K-feldspar grain in contact with rounded quartz grains. Sample MR10. Mantonga Formation. Mantonga River traverse. Western Hartland Basin. X5 magnification. Crossed polars.
4.9	Mantonga Formation isopach contour plan, showing palaeocurrent directions.
4.10	Detailed lithostratigraphy of the Pypklipberg Formation, showing a type profile and lateral variations within the Nsuze Basin.
4.11	Flow contact in basaltic lavas near the base of the Pypklipberg Formation. Mantonga River traverse. Western Hartland Basin notice highly amygdaloidal flow top overlain by succeeding flow with pipe amygdales at base.
4.12	Subrounded-to-subangular heterolithologic fragments defining a lava agglomerate within a lava flow. Pypklipberg Formation. White River traverse. Western Hartland Basin.

4.13	Photomicrograph showing a plagioclase phenocryst in relation to a highly altered trachytic groundmass. X10 magnification, crossed polars. Sample AM6. Plagioclase phenocryst zone. Pypklipberg Formation. Amsterdam area.
4.14	Semi-aligned plagioclase phenocrysts within a plagioclase phenocryst zone along the White River traverse. Pypklipberg Formation. Western Hartland Basin.
4.15	Pypklipberg Formation isopach plan.
4.16	Symmetrical ripple marks from the lower shale / siltstone unit of the White Mfolozi Formation, White Mfolozi River Inlier.
4.17	Sharp contact between a dark green sandy diamictite and the overlaying basal dolomitic portion of the Chobeni member. White Mfolozi Formation. White Mfolozi River Inlier.
4.18	Chertified conical stromatolites from the biohermal stromatolite facies, Chobeni member. White Mfolozi Formation. White Mfolozi River Inlier.
4.19	Dolomitic quartzite nfrom the Chobeni Member. White Mfolozi Formation. Nkandla Central Synform. (Note shear deformation in one bed).
4.20	Quartz-filled desiccation cracks in a medium-grained quartzite immediately overlaying the Chobeni member, White Mfolozi Formation. Sifula traverse, Buffalo River Inlier.
4.21	Regional panoramic overview of the arenaceous White Mfolozi Formation. Nkandla Central synform. Cross-cut by the Nsuze River valley, looking south.
4.22	Photomicrograph showing subrounded quartz and K-feldspar fragments in an altered sericitic groundmass in a volcaniclastic diamictite. Sample WM15. White Mfolozi Formation. White Mfolozi River Inlier. X5 magnification, crossed polars.
4.23	The angular unconformity between the dark green Agatha Formation lava (below) and orthoquartzite of the overlaying Mozaan Group. White Mfolozi River Inlier.
4.24	White Mfolozi Formation isopach contour plan, showing palaeocurrent directions.
4.25	Detailed lithostratigraphy of the Agatha Formation, showing a type profile and lateral variations within the Nsuze Basin.
4.26	Dense quartz-filled amygdaloidal zone demarcating a lava flow contact in Agatha Formation lavas, White Mfolozi River Inlier.
4.27	Photomicrograph of plagioclase crystals being partially replaced by high birefringence epidote ± chlorite in an altered mafic lava. Agatha Formation. Agatha River profile. Sample AS2. X10 magnification. Crossed polars.
4.28	Subrounded-to-subangular chert clasts (silicified lava) in a siliceous, green groundmass. Ntambo Member agglomerate. Western Swaziland traverse.
4.29	Agatha Formation isopach contour map.
4.30	Detailed lithostratigraphy of the Langfontein / Vutshini Formation showing lateral variations within the Nsuze Basin.
4.31	Well-rounded very large pebble, pebble-supported volcanic pebble conglomerate. Roodewal member. Langfontein / Vutshini Formation. Ntombe River traverse. Western Hartland Basin.
4.32	Well-laminated siltstones (reworked tuffaceous ash?) from the Langfontein / Vutshini Formation, Ntombe River profile. Western Hartland Basin.

4.33	Well-rounded quartzite pebble in a massive coarse-grained quartzite. Langfontein / Vutshini Formation. Hohobo River traverse. Magudu area.
4.34	Polymictic, medium-to-large pebble, pebble-supported conglomerate from the Roodewal member, Langfontein / Vutshini Formation. Drillhole NQ2, Nqutu district.
4.35	Well-preserved planar cross-bedding in coarse-grained grey-white quartzites from the middle part of the Langfontein / Vutshini Formation at the Nkandla Central Synform.
4.36	Sharp shale-quartzite contact in the lower part of the Langfontein / Vutshini Formation. Nkandla Central Synform. Note discontinuous thin conglomerate developed along contact.
4.37	Interpretative Mfenyana Subgroup isopach contour plan showing palaeocurrent directions.
4.38	Detailed lithostratigraphy of the Mkuzane Formation along the Mfenyana River traverse, Magudu area.
4.39	Interbedded cordierite (± andalusite) schist and green-grey quartzite from the lower part of the Mkuzane Formation along the Mfenyana River traverse, Magudu area.
4.40	Euhedral andalusite crystals in a quartzitic zone within cordierite schists. Central part of the Mkuzane Formation. Mfenyana River traverse, Magudu area.
4.41	Brown weathered surface and green / grey fresh surface of a volcaniclastic diamictite, showing lapilli-sized, subrounded lithic clasts. Nzimini Formation. Fugitives Drift traverse. Buffalo River Inlier.
4.42	An agglomerate bed displaying subrounded "bombs" of mainly altered volcanics within a volcaniclastic (tuffaceous), coarse-grained altered groundmass. Nzimini Formation Fugitives Drift traverse. Buffalo River Inlier.
4.43	Pitted surface of a volcaniclastic diamictite showing rounded-to-subangular lapilli-sized clasts. Nzimini Formation. Roodeklip traverse. Buffalo River Inlier.
4.44	Angular chlorotic fragments (altered lava?) within a typical volcaniclastic diamictite groundmass. Nzimini Formation. Fugitives Drift traverse. Buffalo River Inlier.
4.45	Photomicrograph displaying quartz and plagioclase grains in a highly-altered groundmass comprising: chlorite, carbonate, sericite, epidote, quartz and opaques. Volcaniclastic diamictite. Nzimini Formation. Nzimini district. Sample NSZ1. X5 magnification. Crossed - polars.
5.1	Photomicrograph of a saussuritized feldspar phenocryst enveloped by a chlorotic rim associated with epidote. Crossed polars. X10 magnification. Sample SW12. Feldspar porphyry. Agatha Formation Southwestern Swaziland.
5.2	Photomicrograph of yellow birefringent epidote replacing sericitized plagioclase laths in a mafic lava groundmass. Crossed polars. X10 magnification. Sample AM6. Pypklipberg Formation. Amsterdam area.
5.3	Photomicrograph of muscovite needles interstitial to and partially cross-cutting quartz grains in an argillaceous quartz arenite. Crossed polars. X10 magnification. Sample Man2. Mantonga Formation. Mazebeko traverse. Buffalo River Inlier.
5.4	Photomicrograph of a green dominantly chlorotic shale containing sub-rounded equigranular quartz grains and subangular opaques. X5 magnification. Sample MD2. White Mfolozi Formation. Nkandla Central Synform.

5.5	Laminated, spotted cordierite hornfels from the Mkuzane Formation. Mfenyana River traverse. Magudu area.
5.6	Photomicrograph showing cross-cutting secondary high relief chloritoid needles in a fine-grained altered groundmass of a cordierite hornfels. X5 magnification. Plane polarized light. Sample MF2. Mfenyana River traverse. Magudu area.
5.7	Tabular andalusite crystals, cross-cut by quartz veinlets, showing a moderate preferred orientation in an andalusite-cordierite schist. Langfontein / Vutshini Formation. Mfenyana River traverse. Magudu area.
5.8	Photomicrograph showing a poikilitic garnet phenocryst in contact with altered hornblende and saussuritized plagioclase. X5 magnification. Plane polarized light. Sample MW8. Hohobo River traverse. Magudu area.
6.1	(Na_2O + K_2O) - (SiO_2) wt % diagram for this study's lava data set (Cox et al, 1979).
6.2	(Na_2O + K_2O) - (SiO_2) wt % diagram for the total Nsuze lava data set. (Cox et al, 1979).
6.3	Log (Zr / TiO_2) - log (Nb/ Y) diagram for this study's lava data set (Winchester and Floyd, 1977).
6.4	Log (Zr / TiO_2) - log (Nb / Y) diagram for the total Nsuze lava data set (Winchester and Floyd, 1977).
6.5	FeO * - (Na_2O + K_2O) - MgO diagram for the total Nsuze data set (Irvine and Barager, 1971).
6.6	FeO * - (Na_2O + K_2O) - MgO diagram for the Pypklipberg Formation data from this study (Irvine and Barager, 1971).
6.7	FeO * - (Na_2O + K_2O) - MgO diagram for the Agatha Formation data from this study (Irvine and Barager, 1971).
6.8	Nb-Zr-Y discrimination diagram for the total Nsuze lava data set (Meschede, 1986).
6.9	Log (Zr / Y) - log Zr (ppm) diagram for the total Nsuze lava data set (Pearce and Norry, 1979).
6.10	Ti-Zr-Y diagram for this study's lava data set (Pearce and Cann, 1973).
6.11	FeO * - MgO - Al_2O_3 diagram for this study's lava data set (Pearce et al 1977).
6.12	AL_2O_3 - Fe_2O_3 - K_2O diagram for the total Nsuze pelite data set.
6.13	Cr - Ni (ppm) diagram for the total Nsuze pelite data set.
6.14	Cr - Ni - V ternary diagram for the total Nsuze pelite data set.
7.1	Oligiomictic pebble-supported, large pebble conglomerate with pebble size ≤ 7 cm (basal Renosterspruit conglomerate on the farm Oorbietjiesfontein, Dominionville area).
7.2	Thin oligiomictic pebble-supported small pebble conglomerate (upper Renosterspruit conglomerate on the farm Oorbietjiesfontein, Dominionville area.
7.3	Photomicrograph showing a tabular plagioclase crystal in a altered green groundmass comprising microlithic plagioclase, quartz, chlorite, carbonate, opaques and minor sericite. 5X magnification. (Syferfontein feldspar porphyry, Dominionville area).
7.4	Oval-shaped large quartz-filled amygdales in a green aphanitic mafic lava of the Renosterhoek Formation. (Doornfontein farm, NNE of Klerksdorp).

7.5	Log (Zr / TiO_2) vs log (Nb / Y) diagram for the Nsuze and Dominion data sets (after Winchester and Floyd, 1977).
7.6	FeO * - (Na_2O + K_2O) - MgO diagram for the Nsuze and Dominion data sets (after Irvine and Barager, 1971).
7.7	Log (Zr / Y) vs log (Zr) diagram for the Nsuze and Dominion data sets (after Pearce and Norry, 1979).
7.8	Nb - Zr - Y ternary diagram for the Nsuze and Dominion data sets (after Meschede, 1986).
7.9	Diagram showing Nsuze-Dominion Group correlation.
8.1	Diagram showing simplified depositional environments and tectonic evolution.

LIST OF TABLES

6.1 Summary of geochemical information used in discrimination plots of Nsuze lavas.
6.2 Summary of samples for chemical analyses of pelites from the Nsuze Group.

LIST OF MAPS (APPENDIX 3)

1.	Outcrop map of the Nsuze Group in northern Natal, Southeastern Transvaal and southwestern Swaziland.
2.	Inter-profile Nsuze Group correlations (comparative profiles).
3a.	Simplified geological map of the area between the Bivane and White Rivers. Western Hartland Basin. (modified from Humphrey, 1913 and Armstrong, 1980).
3b.	Nsuze Group lithostratigraphic composite profile constructed from various traverses in the Western Hartland Basin.
4a.	Geological map of the Archaean terrane surrounding Amsterdam (modified from van Vuuren, 1965 and sheet 2 630 Mbabane).
4b.	Nsuze Group lithostratigraphic subdivision along profile line A - B in the Amsterdam area.
5.	Nsuze Group lithostratigraphic subdivision for a profile described by Hatfield (1990), east of Piet Retief.
6a.	Simplified geological map of the Southwestern Swaziland region around Gege and Mahlangatsha (modified from Swaziland 1:250 000 geological sheet).
6b.	Nsuze Group lithostratigraphic subdivision along profile line A - B in the Gege and Mahlangatsha areas, Southwestern Swaziland.
7a.	Simplified geological map of the pre-Karoo lithologies in the Magudu area. (modified from Geological Survey Sheet 2730 Vryheid).
7b.	Nsuze Group lithostratigraphic subdivision along the demarcated composite profile in the Magudu area.
8a.	Geological map of the central part of the White Mfolozi River Inlier (after Matthews, 1967).
8b.	Nsuze Group lithostratigraphic subdivision along profile line A - B in the White Mfolozi River Inlier.
9a.	Simplified geological map of the Nsuze Group in the Mpongoza Inlier (modified after Preston, 1987 in Hunter and Wilson, 1988).
9b.	Nsuze Group lithostratigraphic subdivision in the Mpongoza Inlier (modified from Preston, 1987).
10a.	Geological map showing the Archaean geology in the Nkandla area (modified from Matthews, 1959-1969).
10b.	Nsuze Group lithostratigraphic subdivision along the demarcated composite profile lines in the Central Synform, Nkandla district.
11a.	Geological map of a portion of the Mhlatuze River Inlier in the Cwezi district, near Nkandla (modified from Gold Fields, 1981).
11b.	Lower Nsuze Group lithostratigraphic subdivision along profile line A-B in the Mhlatuze River Inlier, near Nkandla.
12a.	Simplified pre-Karoo geological map of the Buffalo River Inlier (modified from Dixon, 1992).
12b.	Nsuze Group lithostratigraphic subdivision a profile in the Buffalo River gorge.
13.	Plan and section of a diagrammatic North-South composite profile showing the relationship between fragmented Nsuze lithostratigraphic blocks and the major structural elements in the Buffalo River Inlier.

14.	Diagrammatic cross section along profile lines 1 - 2 and 3 - 4 on the Okhalweni and Mangeni traverses along the Buffalo River.
15.	Detailed lithostratigraphy of the White Mfolczi Formation, showing a type profile and lateral variations within the Nsuze Basin.
16a.	Simplified geological map of the area around Dominionville showing Dominion distribution (modified from Geological Survey sheet 2626).
16b.	Simplified Dominion profiles showing lithostratigraphic subdivisions with proposed Nsuze Group correlates.
17.	Interpretative plan showing Pongola Supergroup outcrop distribution, inferred subcropping Nsuze Group distribution, geophysical trends and simplified structural trends within the Pongola basin on the southeastern portion of the Kaapvaal craton.

CONTENTS

CHAPTER 1: INTRODUCTION

PAGE

1.1 Statement of problem 1

1.2 Location and extent of the study area 2

    1.2.1 Northwestern domain

    1.2.2 Northeastern domain

    1.2.3 Central domain

    1.2.4 Southern domain

1.3 Previous work 5

    1.3.1 Northwestern and Northeastern domain

    1.3.2 Central domain

    1.3.3 Southern domain

1.4 Objectives and Methods 9

CHAPTER 2: REGIONAL GEOLOGY AND LITHOSTRATIGRAPHIC SUBDIVISION

2.1 Introduction 11

2.2 Pre-Nsuze Group lithologies 11

2.3 Post-Nsuze Group intrusives 12

    2.3.1 Ultramafic and mafic intrusions

    2.3.2 Post-Nsuze Granitoids

2.4 Composite Profile of the Nsuze Group 13

2.5 Lateral distribution of major rock units 18

CHAPTER 3: GEOLOGY AND LITHOSTRATIGRAPHIC SUBDIVISIONS IN DIFFERENT DOMAINS AND REGIONAL CORRELATION

3.1 Introduction 20

3.2 Northwestern Domain
    3.2.1 Hartland Synform 20
        3.2.1.1 Geology
        3.2.1.2 Lithostratigraphy
    3.2.2 Amsterdam Area 22
        3.2.2.1 Geology
        3.2.2.2 Lithostratigraphy.
    3.2.3 Area east of Piet Retief 23
        3.2.3.1 Geology
        3.2.3.2 Lithostratigraphy
    3.2.4 Southwestern Swaziland 25
        3.2.4.1 Geology
        3.2.4.2 Lithostratigraphy
3.3 Northeastern Domain (Magudu Area)
    3.3.1 Geology 26
    3.3.2 Lithostratigraphy
3.4 Central Domain
    3.4.1 White Mfolozi River Inlier 28
        3.4.1.1 Geology
        3.4.1.2 Lithostratigraphy
    3.4.2 Mpongoza Inlier 30
        3.4.2.1 General
        3.4.2.2 Lithostratigraphy
3.5 Southern Domain
    3.5.1 Nkandla Area 31
        3.5.1.1 Geology
        3.5.1.2 Lithostratigraphy

3.5.2 Mhlatuze River Inlier 34
    3.5.2.1 Geology
    3.5.2.2 Lithostratigraphy
3.5.3 Buffalo River Inlier 35
    3.5.3.1 General
    3.5.3.2 Lithostratigraphy
3.5.4 Drillhole NQ2 38
3.6 Regional Lithostratigraphic correlation 38

CHAPTER 4: DETAILED LITHOSTRATIGRAPHY

4.1 Introduction 43
4.2 Mantonga Formation 43
    4.2.1 Distribution
    4.2.2 Type profile
    4.2.3 Lateral variation
    4.2.4 Palaeocurrent directions
4.3 Pypklipberg Formation 54
    4.3.1 Distribution
    4.3.2 Type profile
    4.3.3 Lateral variations
4.4 White Mfolozi Formation 61
    4.4.1 Distribution
    4.4.2 Type profile
    4.4.3 Lateral variation
    4.4.4 Palaeocurrent directions
4.5 Agatha Formation 71
    4.5.1 Distribution
    4.5.2 Type profile
    4.5.3 Lateral variation

4.6 Langfontein / Vutshini Formation 82
    4.6.1 Distribution
    4.6.2 Type profile
    4.6.3 Lateral variation
    4.6.4 Palaeocurrent directions
4.7 Mkuzane Formation 92
    4.7.1 Distribution
    4.7.2 Type profile
4.8 Ekombe Formation 96
    4.8.1 Distribution
    4.8.2 Type profile

4.9 Nzimini Formation 96
    4.9.1 Distribution
    4.9.2 Type profile, lateral variation and general characteristics

CHAPTER 5: METAMORPHISM AND ALTERATION

5.1 Introduction 103
5.2 Alteration and regional low grade metamorphism ... 103
    5.2.1 Lavas
    5.2.1.1 Mafic and Felsic lavas
    5.2.2 Siliciclastics
5.3 Contact Metamorphism 107

CHAPTER 6: GEOCHEMISTRY

6.1 Lavas of the Nsuze Group 111
    6.1.2 Introduction
    6.1.2 Results
    6.1.3 Summary

6.2 Pelites of the Nsuze Group 121

6.2.1 Introduction

6.2.2 Results

CHAPTER 7: COMPARISON BETWEEN THE NSUZE AND DOMINION GROUPS

7.1 Introduction 127

7.2 Geochronology 127

7.3 Lithostratigraphic comparisons 129

7.4 Geochemical comparisons 131

CHAPTER 8: DISCUSSION

8.1 Introduction 137

8.2 Depositional environment 137

8.3 Nsuze evolution and tectonic setting 145

CHAPTER 9: SUMMARY AND CONCLUSIONS

9.1 Distribution 153

9.2 Lithostratigraphic sub-divisions 153

9.3 Structure and metamorphism 153

9.4 Geochemistry 154

9.5 Correlation with the Dominion Group 155

9.6 Depositional environment and tectonic setting .. 155

ACKNOWLEDGEMENTS 157

Reference List.................................. 158

APPENDICES:

Appendix 1:

Chemical Analyses

Table 1 a:	Chemical analyses of lavas from the Pypklipberg Formation.
Table 1 b:	Chemical analyses of lavas from the Agatha Formation.
Table 1 c:	Chemical analyses of volcanics from 'other' formations in the Nsuze Group.
Table 2:	Chemical analyses of Nsuze Group pelites.
Table 3:	Selected chemical analyses from the Dominion Group.

Appendix 2:

Summarized thin section descriptions (60 samples).

Appendix 3:

Large maps

CHAPTER 1: INTRODUCTION

1.1 STATEMENT OF PROBLEM

The Archaean Pongola Supergroup, which comprises a lower volcano-sedimentary Nsuze Group and an upper predominantly sedimentary Mozaan Group, outcrops in isolated, but laterally extensive, areas within a zone about 100 km wide, in southern Swaziland and northern Natal (fig. 1.1). The Pongola, as a stratigraphic term, was introduced by Humphrey (1912), who used it as a "Series" name for a succession of lavas and sediments he located along the Pongola River in the southeastern Transvaal. The name Nsuze was initially introduced as the Insuzi Series by Hatch (1910). He used it to describe a succession of quartzites, conglomerates, grits and schists encountered in a valley of that name west of Nkandla in northern Natal.

Recent isotopic age dating has placed the age of the Pongola Supergroup between that of the pre-Pongola granites (3107 ±4 Ma, U-Pb single zircon from southern Swaziland, Kamo et al., (1990)) and the post-Pongola intrusive Ushushwana Complex (2871 ±30 Ma Sm-Nd, whole rock pyroxenite, Hegner et al. 1984). Single zircon grains from Nsuze Group rhyolites from southern Swaziland yield concordant ages with a mean value of 2984 ± 2,6 Ma (Hegner et al, 1993). These ages emphasize the geological significance of the Pongola Supergroup, which probably represents the oldest intracratonic sequence in the world, deposited on the southeastern part of the Kaapvaal craton in southern Africa during a time when typical Archaean granite-greenstone sequences were being formed elsewhere ie. Zimbabwe, Western Australia and North America.

Surprisingly little regional work has been conducted to date on the Nsuze Group. Studies have been largely confined to localized general geological mapping, with no serious attempt made to establish regional correlations of different units in the Nsuze Group or to recognise the lateral variations within the succession. The result is a confusing array of Nsuze stratigraphic nomenclature with limited regional applicability (Fig. 1.2). This study addresses these problems through lithostraphic studies of the entire outcrop area of Nsuze strata, attempting to place the work done by various workers within a regional lithostratigraphic framework. A new lithostratigraphic nomenclature, which can be applied regionally, is proposed for the Nsuze Group.

Burke et al (1985) have suggested that the Pongola Supergroup (of which the Nsuze Group forms the base) displays many characteristics of rocks deposited in ancient rifts. This concept suggests that the Nsuze Group records the oldest known rift. However, Burke et al (1985) present no detailed regional data to support their proposals. It is believed that regional basinal analysis such as that undertaken in this study is essential for making such interpretations.

1.2 LOCATION AND EXTENT OF STUDY AREA

The study area, which covers all Nsuze Group exposures, extends southwards from southern Swaziland to northern Natal as a zone about 100 km wide (east-west) and 250 km long (north-south) (Fig. 1.1). Several Nsuze outcrop domains are recognised. Each domain is defined by specific structural and outcrop patterns.

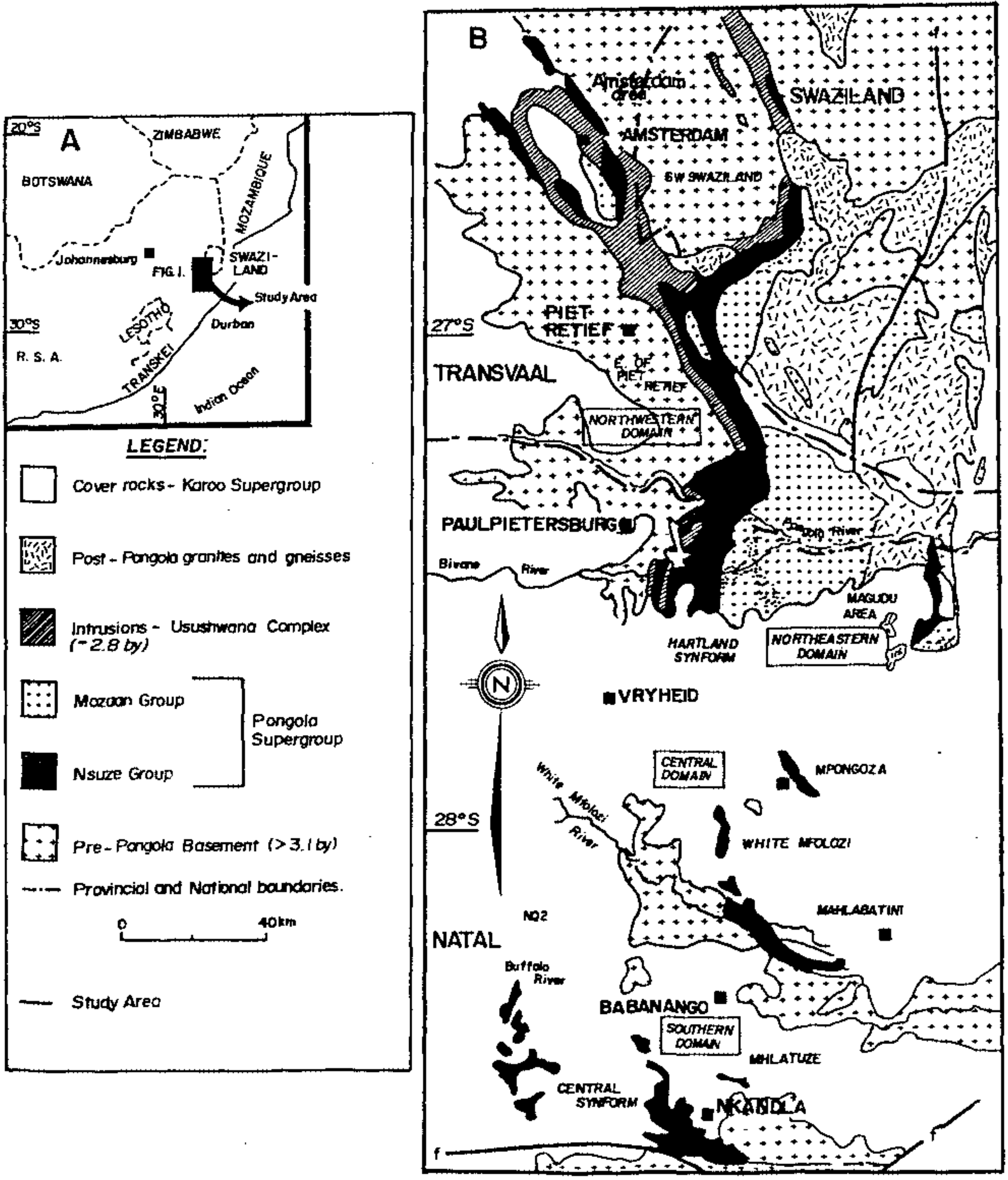
1.2.1 Northwestern Domain

This domain hosts the thickest known sequence of Nsuze Group strata and includes inliers near Amsterdam, the Hartland Basin area (east of Paulpietersburg), an area east of Piet Retief and another in southwestern Swaziland (Fig. 1.1). This domain is characterized by large open synclines with the Nsuze Group unconformably overlain by the Mozaan Group.

1.2.2 Northeastern Domain

This domain includes Nsuze Group strata west of Magudu (Fig. 1.1). Strata have been deformed into an anticlinal structure and have been intruded by post-Pongola granites. The granites have left a significant contact metamorphic imprint on the Nsuze succession in this area.

FIGURE I.1 MAP SHOWING THE LOCATION OF THE STUDY AREA (A) AND THE DISTRIBUTION OF THE PONGOLA SUPERGROUP AND ASSOCIATED INTRUSIVE ROCKS (B).



GROUP	FORMATIONS								
	AMSTERDAM AREA (SACS 1980)	PIET RETIEF–HARTLAND AREA (BEUKES AND CAIRNCROSS 1991)		VRYHEID–PIET RETIEF AREA (SACS 1980)	HARTLAND W (LINSTRöM 1987) (a)	HARTLAND E (LINSTRöM 1987) (a)	MAGUDU (LINSTRöM 1987) (a)	WHITE MOFOLOZI AREA (SACS 1980)	NKANDLA AREA (SACS 1980)
Mozaan Group		Nkoneni Subgroup	Ntanyana	Nkoneni	Nkoneni	Nkoneni			
			Gabola						
			Bongaspoort						
		Odwaleni Subgroup	Khiphunyawa	Odwaleni					
			Delfkom				Lubanjana		
							Mpushana		
			Hlashana	Hlashana		Mkaya	Mkyaya		
		Dwaalhoek Subgroup	Thalu	Ceba		Langfontein	Mkuzane		
				Thalu			Langfontein		
	Redcliff		Ntombe	Ntombe		(intrusive granite)		Qwasha	
								Mapunga	
	Skurwerant		Sinqeni	Sinqeni				Mandova	
				Ozwana					
Nsuze Group		Ozwana			Roodewal		Maswili	Taka	Mankane
	Bivane	(not mapped)		Bivane	Bivane		(intrusive granite)	Bivane	Vutshini
									Qudani
									Mdlelanga
	Mantonga	(not mapped)		Mantonga	Mantonga			Chobeni	Msukane
									Dlaba
									Mome
									Mabeleni
								Thambeni	
								Nhlebela	Hlathini
								Bomvu	

NOTE: Units of Nkandla area not correlated with other areas above the basal tectonic contact of the Mdlelanga Formation.

FIGURE 1.2: PONGOLA SUPERGROUP PROVISIONAL CORRELATION OF STRATIGRAPHIC NOMENCLATURE (FROM WATKEYS, PERS. COM., 1993)

1.2.3 Central Domain

The White Mfolozi and Black Mfolozi Rivers have incised through thick Karoo cover in the Central Domain to expose several isolated Pongola inliers. The largest two are known as the White Mfolozi and Mpongoza inliers (fig. 1.1). A system of southwesterly-tilted fault blocks, comprising basement overlain unconformably by Pongola strata (Matthews, 1990), is apparent in this domain. The Nsuze Group is overlain, with a marked angular unconformity, by the Mozaan Group.

1.2.4 Southern Domain

This domain includes several inliers of deformed Nsuze Group strata, including the Central Synform (west of Nkandla), the Mhlatuze River inlier (north-east of Nkandla) and the Buffalo River inlier (south of Dundee). The domain is geographically adjacent to the Natal thrust front (at the southern edge of the Kaapvaal craton), which has contributed to the structural deformation of the sequence.

Access to exposures in the study area is through a network of primary roads, farm roads and tracks. The best exposures are usually confined to topographically rugged river and stream courses. Most lithostratigraphic profiles were measured along such river or stream sections.

1.3 PREVIOUS WORK

Previous work on the Nsuze Group will be summarized briefly under the various geographical domains.

1.3.1 Northwestern and Northeastern Domains

Most work to date has been done in the northwestern domain. The earliest recorded work on the Nsuze Group in this domain dates back to regional reconnaissance surveys carried out in 1898 by Molengraaf (1902).

Humphrey (1912) described two formations in the south-eastern Transvaal as the lower and upper Pongola Series, the lower consisting of bands of quartzite and phyllite separated by lavas of intermediate and basic composition and the upper of quartzite and shales. Du Toit (1931) equated the lower Pongola Series of Humphrey (1912) with the Insuzi Series.

Humphrey and Krige (1931) described the Insuzi Series in the Paulpietersburg and Piet Retief areas as comprising a thick basal quartzite succession overlain by predominantly andesitic lavas (with acid and more basic varieties as rare occurrences). Humphrey and Krige (1931) suggested that the Nsuze-Mozaan contact could be both unconformable or conformable, depending on the locality, and also noted that the Nsuze rocks to the east had been assimilated by younger granite.

Truter (1950) applied the term Insuzi Series to incorporate all the rocks of the lower Pongola Series. He referred to the predominantly sedimentary upper Pongola unit as the Mozaan Series. Subsequently the term Insuzi was changed to Nsuze and given group status (SACS, 1980).

The Swaziland Geological Survey began reconnaissance mapping of the Pongola rocks in Swaziland during 1946 (Mehliss, 1961). Hunter (1961) described the occurrence of andesitic lavas and minor felsic volcanics within the Nsuze Group in Swaziland.

Davies et al., (1964) described the economic potential of a number of small pyrophyllite deposits within the Nsuze Group in Swaziland. Matthews and Scharrer (1968) described a graded unconformity north-east of Paulpietersburg where granitic rocks pass gradationally upwards into a zone of structureless gritty argillaceous rocks, which is in turn overlain by stratified Nsuze sediments.

Mapping by van Vuuren (1965) near Amsterdam has shown the Pongola Supergroup to be partially preserved in a synclinal trough. In this area the Nsuze Group lavas and sediments were shown to be dismembered by the intrusion of the Usushwana Complex.

Hammerbeck (1977), who concentrated on the Usushwana Complex in southeastern Transvaal, described the basaltic and andesitic rocks of the Nsuze Group in the Amsterdam - Piet Retief area and suggested that the acid lavas and pyroclastics here are extrusive phases of the Ushushwana Complex. This suggestion has been questioned by Armstrong (1980) and Hatfield (1990).

Watchorn and Armstrong (1980) described the arenaceous sediments at the base of the Nsuze Group in the Paulpietersburg region, suggesting deposition in a distal braided stream environment which derived sediment from a granitic source located to the west.

The first detailed lithostratigraphic study and sedimentological analysis of the Nsuze Group in Hartland Basin area was made by Armstrong (1980). He mapped an area in the vicinity of the Pongola and Bivane Rivers in northern Natal and southeastern Transvaal. The Nsuze Group is subdivided into a lower sedimentary-volcanic unit, a middle volcanic unit with minor intercalations of volcaniclastic and sedimentary rocks, and an upper volcaniclastic - sedimentary unit (Armstrong et al., 1982).

The geology and structure of the Pongola Supergroup east of Piet Retief was described by Hatfield (1990). He recognised, within the Nsuze Group, a basal sedimentary unit overlain by a felsic volcanic unit which is separated from an uppermost unit of andesitic and minor basaltic andesites by a pyroclastic volcaniclastic unit.

Recent work done in the northeastern domain by the Geological Survey, as part of their broad scale regional mapping programme, was reported in the 1988 edition of the Vryheid 2730 1:250 000 geological map by Linström (1987a).

1.3.2 Central Domain

The Nsuze Group in the White Mfolozi inlier was described by Matthews (1967) as two basaltic volcanic units separated by a sequence of banded shale and quartzitic dolomite. Matthews (1967) and SACS (1980) describe the overall succession here in some detail. Resting with an unconformable contact on granitic basement, the Nsuze Group comprises six formations (SACS, 1980) with a total thickness probably exceeding 3500 m (Linström 1987b).

Biogenic stromatolite structures occurring within White Mfolozi inlier carbonates were documented by Von Brunn and Mason (1977), Mason and von Brunn (1977) and Beukes and Lowe (1989).

Von Brunn (1974) described a succession of alternating argillaceous and arenaceous sedimentary rocks in the Mpongoza inlier. Von Brunn and Hobday (1976) discussed the sedimentary sequences of the White Mfolozi and Mpongoza inlier suggesting that they were deposited in a predominantly shallow marine, tidal flat environment with temporary influxes of fluvial sediments.

The Mpongoza inlier has been studied in detail by Preston (1987) who recognised a lower 2560 m thick volcanic unit, a 260 m thick middle clastic sedimentary unit and an 720 m thick upper volcanic unit.

1.3.3 Southern Domain

Du Toit (1931) proposed a six-fold subdivision of the Nsuze Group into alternating quartzite and volcanic units, which he correlated with the lower Pongola series recognised by Humphreys (1912) in the Utrecht-Vryheid area.

Other early work on the Nsuze Group inliers around Nkandla is restricted to a report by Hatch (1910), on the mines and minerals of Natal, reference to the area by Matthews, (1959) in a description of the post-Ntingwe thrust belt and the unpublished mapping of Matthews (1979).

Matthews (1979, unpublished work cited in SACS, 1980), proposed a subdivision of the Nsuze Group into nine formations. The lower five formations correspond to units recognised by du Toit (1931). The upper four formations are suggested to be unique to the Central Nsuze synform.

In the area studied by Groenewald (1984), centred around the Central Nsuze synform, the stratigraphic subdivisions of SACS (1980) were used with the addition of one new formational name. Groenewald (1985) suggested a correlation between some of the formations in the southern domain with those in the northern and central domains.

The lithostratigraphy of the Pongola succession in the Buffalo River gorge has been studied by Dixon.(1993). He suggests a unique Nsuze-aged sequence in this area, with no regional correlatives elsewhere.

1.4 OBJECTIVES AND METHODS

The main objective of this study was to regionally re-assess the lithostratigraphy of the Nsuze Group by conducting detailed lithostratigraphic profiles across carefully selected traverses throughout the Nsuze basin. Along each profile the inter-relationships and field occurrences of the different Nsuze strata were recorded as accurately as possible to assess the possibility of inter-profile correlations, and ultimately to test the validity of a single Nsuze stratigraphic column applicable to Nsuze strata throughout the basin.

Mapping along each traverse was performed with the aid of 1:10 000 orthophotographs. These maps were then used in constructing lithostratigraphic profiles. Various marker units were identified. These formed the basis of the correlations and enabled the recognition of lateral variations within correlatable lithostratigraphic units.

Sedimentological analysis of sedimentary strata was undertaken to identify the major environments of deposition throughout the basin. Sedimentary structures are usually very well preserved and only occasionally are they obscured by metamorphic or structural overprints.

A study of the petrography of selected volcanic and sedimentary rock samples was undertaken to gain some understanding of the mineral assemblages, textural features and the effect of post-depositional structural and metamorphic alteration.

A comprehensive literature study was undertaken to relate previous work done to the data generated in this study, and to incorporate all previous locally-derived data in the construction of the new regional Nsuze framework.

Stratigraphic samples of Nsuze sedimentary rocks and lava (a total of 112 samples), from the entire field area, were submitted for major, minor and trace element analysis by X-ray fluorescence to establish the nature and extent of the chemical variations in these rocks. Geochemical data from the lavas provide the basis for discussion of magma type, tectonic setting and petrogenesis. Geochemical data from this study are combined with data from other studies and are used in making geochemical interpretations. All available Nsuze geochemical data are documented in this study. It is hoped that this could serve as a database for future studies.

Basic field work on the Nsuze Group again emphasized the structural complexities associated with the Pongola Supergroup. This factor was carefully considered during lithostratigraphic studies. Structural complexities were recorded and taken into account in construction of the lithostratigraphic profiles. It is hoped that the lithostratigraphic knowledge gained during this study can further help unravel the structural complexities in the sequence. This study has revealed that major structural deformation is largely confined to fault and shear zones. However, within fault and shear zone-bounded blocks, lithostratigraphic sequences and sedimentary structures are often perfectly preserved. Lithostratigraphic profiles were measured within such 'undeformed' fault blocks.

Beukes and Cairncross (1991) have suggested a regional correlation between the overlying lower Mozaan Group and the West Rand Group in the Witwatersrand basin. The West Rand Group is underlain by the Dominion Group and similar age constraints between the Nsuze and Dominion Groups have suggested a possible correlation between these two groups. This possibility is further investigated in this study. The type profile of the Dominion Group was studied in order to be able to do such a comparison.

This study serves as a summary of the current status of our knowledge of the stratigraphy and depositional environment of the Nsuze Group. A new map of the Nsuze Group is supplied illustrating regional correlations and the new stratigraphic nomenclature; summarizing the results of this study.

CHAPTER 2: REGIONAL GEOLOGY AND LITHOSTRATIGRAPHIC SUB-DIVISION:

2.1 INTRODUCTION

In this chapter a summary description will be given of a composite profile constructed for the Nsuze Group compiled from stratigraphic data from the lithostratigraphic profiles traversed in this study. The lateral and vertical relationships between these major lithostraphic units will be discussed. In addition to profiles from this study, reference will be made of sequences in the Mpongoza inlier (as reported by Preston, 1987) and from a study east of Piet Retief (as reported by Hatfield, 1990). An interesting core intersection from a drillhole near Nqutu, northern Natal, will be referred to, with reference to it's possible correlation with the Nsuze Group. Each lithostratigraphic profile is briefly discussed in chapter 3.

Ultimately the correlations between the profiles will be shown and a new regionally-applicable Nsuze Group stratigraphic nomenclature proposed. More detailed discussion of the newly proposed formations follows in chapter 4, where type profiles for each formation will be discussed with reference to lateral variations within the formation.

Mention will also be made in this chapter of those lithologies directly associated with the Nsuze Group viz.:

i. Pre-Nsuze lithologies, constituting the basement to the Nsuze Group and

ii. Post-Nsuze granitic and mafic intrusives. Younger intrusive lithologies, particulary pre-Karoo mafic dykes and post-Karoo doleritic intrusives will not be discussed here, although their intrusive positions and thicknesses are demarcated on each lithostratigraphic profile.

2.2 PRE-NSUZE GROUP LITHOLOGIES

Early Archaean, pre-Nsuze Group basement largely comprises an assemblage of granitoids in which are preserved remnants of metavolcanic/metasedimentary supracrustals with greenstone affinities (distribution shown in Fig. 1.1). Studies in the eastern Transvaal and Swaziland on a wide range of granitic rock types (Hunter 1957, 1970, 1973 and 1979 and Wilson 1982) have emphasized the complexity of this pre-Nsuze granitic terrane with no consensus on the regional correlation of these rocks.

Five lithologically and geographically distinct Archaean, supracrustal sequences have been recognised by the Archaean Research Group at the University of Natal at Pietermaritzburg (Hunter and Wilson, 1988) in the basement of the Nsuze Group. These sequences, with greenstone belt affinities, are:-

a. the Dwalile metamorphic suite,

b. the Assegaai supracrustal suite,

c. the De Kraalen remnant,

d. the Commondale supracrustal suite and

e. the Nondweni supracrustal suite.

Sequences (a) - (d) outcrop in the northern domain while sequence (e) occurs in the central and southern domains.

A main component of the post-greenstone early Archaean granitoids are hornblende tonalites and leucocratic tonalites which represent some of the oldest phases of granite activity in the study area (Anhausser and Robb, 1981).

A widespread intrusion of granites occurred at ± 3,1 Ga, represented by the multiphase Lochiel (Mpuluzi) batholith, which essentially cratonised the previously mobile eastern part of the Kaapvaal area (Anhaeusser and Robb, 1981). According to Weilers (1990) the Pongola sequence was deposited in a basin on the eastern flank of the Lochiel batholith after intrusion of the batholith.

Recent single zircon U-Pb dating of the Lochiel (Mpuluzi) granite in Swaziland by Kamo et al (1990), yield a radiometric age of 3107 ± 4 Ma. The Nsuze Group must thus be younger than this.

2.3 POST-NSUZE GROUP INTRUSIVES

2.3.1 Ultramafic and mafic intrusions

Subsequent to Pongola volcanism and sedimentation, the stratigraphically lowest formations of the northern outcrops of the Nsuze Group were intruded by magmas of primarily ultramafic and mafic composition. Hunter (1950) first recognised these intrusive rocks in the vicinity of the Usushwana River in southwestern Swaziland. The intrusive suite, which comprises gabbros, quartz gabbros, quartz-diorites, granophyres, granodiorites and microgranites (Armstrong, 1980) has been termed the Usushwana Complex (Hunter, 1950). It

RAV 1

is recognised in the area from east of Paulpietersburg to west of Mbabane and even north of Amsterdam in the Transvaal (distribution shown in Map 1).

The Nsuze Group in the southern domain, particulary in the Nkandla area, has been intruded by a series of differentiated sills, each comprising alternating layers of peridotite, pyroxenite, olivine gabbronorite and gabbro. These intrusives, which predate the main penetrative deformation event here (related to the ~ 1000 Ma Natal tectonothermal event), are allocated to the Hlagothi Suite (Groenewald, 1984).

2.3.2 Post-Nsuze Granitoids

Granitoids, of primarily potassic composition, intrude the northern outcrops of the Pongola Supergroup in southeastern Transvaal, northern Natal and in southern Swaziland (distribution shown in Map 1). These granitoids were emplaced as gneiss domes, tabular bodies and discordant plutons (Hunter and Wilson, 1988). Hunter and Wilson (1988) suggest that these granitoids were emplaced towards the centre of the Pongola depo-basin, possibly representing crystallization products of magmas generated by partial melting of the sialic basement to the Pongola Supergroup. This suggestion could explain the poorly-constrained Rb/Sr isotopic data for these granites which yield only errorchrons (Barton et al., 1988).

The post-Nsuze granitoids are described in detail by Matthews (1985), Robb and Meyer (1991), Wilson and Jackson (1988), and Anhaeusser and Robb (1981). Matthews (1985) stresses the need for additional studies on the late-stage granitoid plutons in the area covered by this study. A study of the deformational and contact - metamorphic effects of these late-stage granitoids on Pongola-age strata would be of particular significance.

2.4 COMPOSITE PROFILE OF THE NSUZE GROUP

During this study it was found that a number of localities exist from which the regional stratigraphy of the Nsuze Group can be understood. The basic ingredient to understanding the regional stratigraphy was the construction of a regional Nsuze Group outcrop map on a scale of 1:250 000. This map (Map 1) was constructed from data generated in this study combined with existing larger scale Nsuze maps published by other workers. Another vital ingredient in understanding the regional stratigraphy was the recognition of profiles that could be used as "reference" profiles containing characteristic key rock units essential for regional correlations.

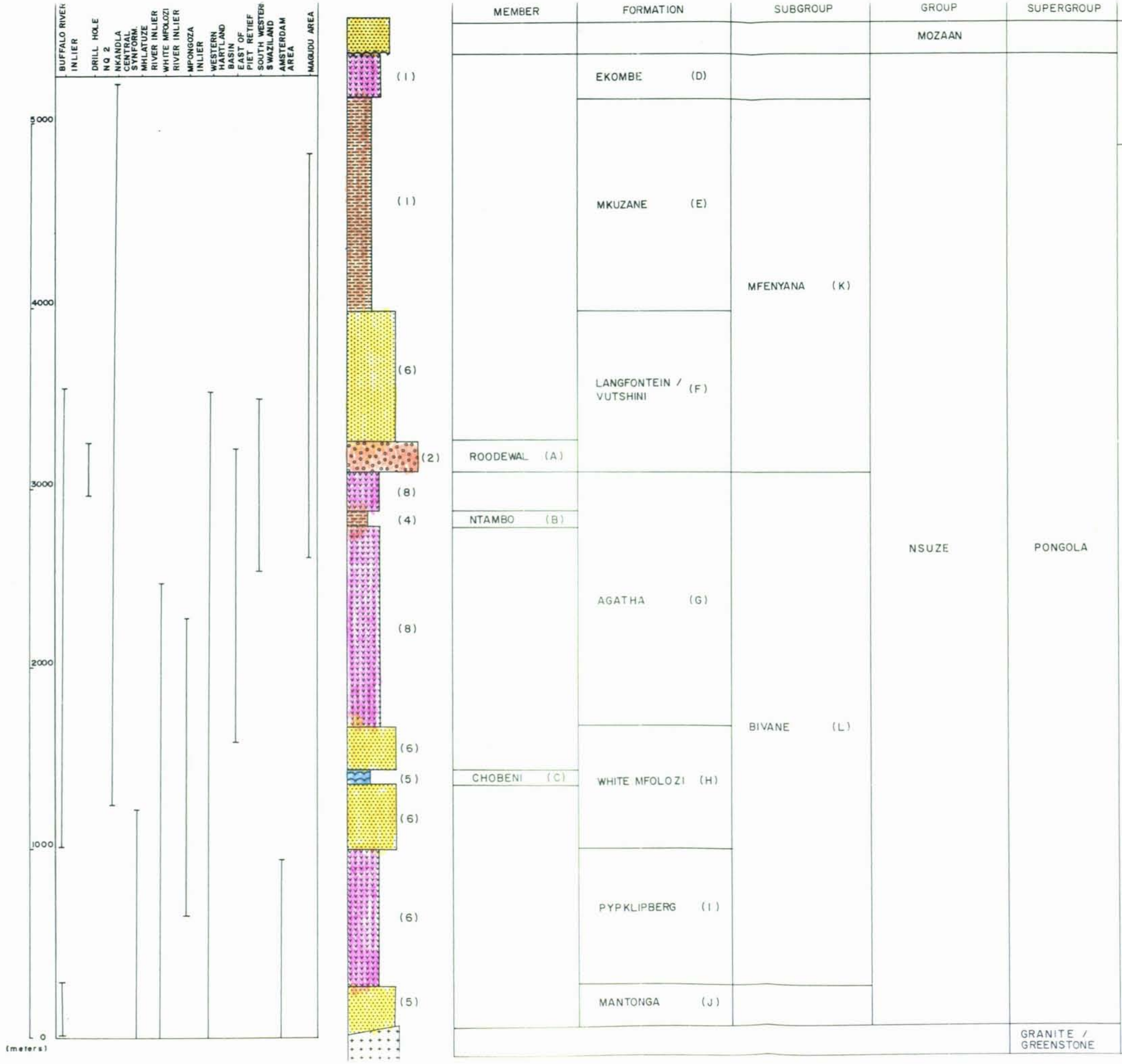
The lithostratigraphic profiles constructed during this study (combined with stratigraphic data described by Preston, 1987 and Hatfield, 1990) are summarized in Map 2. The recognition of "reference" profiles within Map 2 and the mapping of correlatable unmistakable key units within these profiles has enabled the establishment of a new stratigraphic nomenclature for the Nsuze Group. This new nomenclature is illustrated in Fig. 2.1. It displays an idealised "complete" Nsuze Group succession and indicates type areas for each lithostratigraphic unit.

Lithostratigraphic studies across the Nsuze basin have shown the Nsuze Group to be composed of several regionally correlatable lithostratigraphic units. In many cases it was merely necessary to combine all existing data on a regional map of the Nsuze Group to recognise the major lithostratigraphic units which can be traced over very wide areas (refer to Map 2). The general lithostratigraphic subdivision constructed in this way can be summarized as follows:

a) A basal sedimentary unit composed primarily of quartzite, with subordinate shale, diamictite and conglomerate (Fig. 2.1). This unit has been termed the Mantonga Formation after Matthews (1979). The type locality for the Mantonga Formation is the farm Mantonga 44 HU in the Western Hartland basin (traversed in profile 7, Map 2).

b) A lower dominantly mafic amygdaloidal lava, termed the Pypklipberg Formation after Armstrong (1980) (Fig. 2.1). The type locality for the Pypklipberg Formation is the farm Pypklipberg in the western part of the Hartland basin. (traversed in profile 7, Map 2).

c) A middle sedimentary unit composed mainly of quartzite and shale with subordinate siltstone, diamictite and a characteristic regional carbonate marker bed. It has been named the White Mfolozi Formation (Fig. 2.1) after of the excellent exposures in the White Mfolozi River gorge (traversed in profile 5, Map 2). The carbonate marker bed has been given Member status and is termed the Chobeni Member. Matthews (1967) introduced the term Chobeni as a formation name for the carbonate-bearing unit, named after a hill on the farm Welgevonden 527 in the White Mfolozi River valley.



SIMPLIFIED STRATIGRAPHIC SUBDIVISION OF AN IDEALIZED "COMPLETE" NSUZE GROUP SUCCESSION COMPILED FROM REGIONAL STUDIES, SHOWING TYPE AREAS FOR EACH LITHOSTRATGRAPHIC COMPONENT.

TYPE AREAS:

(A)	NTOMBE RIVER TRAVERSE WESTERN HARTLAND BASIN.
(B)	NTAMBO RIVER TRAVERSE SOUTH-WESTERN SWAZILAND.
(C)	WHITE MFOLOZI RIVER INLIER.
(D)	NKANDLA CENTRAL SYNFORM.
(E)	MFENYANA RIVER TRAVERSE, MAGUDU AREA.
(F)	NKANDLA CENTRAL SYNFORM/MFENYANA RIVER TRAVERSE, MAGUDU AREA.
(G)	AGATHA STREAM TRAVERSE WESTERN HARTLAND BASIN.
(H)	WHITE MFOLOZI RIVER INLIER.
(I)	MANTONGA RIVER TRAVERSE WESTERN HARTLAND BASIN.
(J)	MANTONGA RIVER TRAVERSE WESTERN HARTLAND BASIN.
(K)	MFENYANA RIVER TRAVERSE, MAGUDU AREA.
(L)	WESTERN HARTLAND BASIN.

LEGEND

LITHOLOGICAL

🟪	MAINLY VOLCANICS
🟨	MAINLY ARENITES
🟫	MAINLY ARGILLITES
🟦	MAINLY CARBONATES
🟧	MAINLY CONGLOMERATES
⁚	GRANITE / GREENSTONE

OTHER

(B)	TYPE AREA REFERENCE
(5)	NUMBER OF LITHOSTRATIGRAPHIC REFERENCE PROFILES MEASURED

Figure 2.1

d) A middle lava unit, within which a shale-rich sub-unit is developed, in the northern domains. The lava unit is termed the Agatha Formation (Fig. 2.1) after excellent exposures along the Agatha stream in the Western Hartland basin (traversed in profile 7, Map 2). The shale unit is accorded Member status and is named the Ntambo Member. The type locality for this member is along the Ntambo River in southwestern Swaziland (traversed in profile 9, Map 2). The Pypklipberg lavas, the White Mfolozi Formation sedimentary rocks and the Agatha lavas are grouped into the Bivane Subgroup (Fig. 2.1). The Bivane, as a stratigraphic term, was originally introduced by Matthews (1979) as a formation name for a succession of lavas in the Western Hartland basin. The name is derived from the Bivane River, east of Paulpietersburg.

e) An upper sedimentary unit which comprises a basal largely arenaceous Vutshini / Langfontein Formation and an overlying largely argillaceous Mkuzana Formation (Fig. 2.1). These two formations are very well developed in particulary the northeastern domain (Magudu area) and together comprise the Mfenyana Subgroup (Fig. 2.1). The base of the Vutshini/Langfontein Formation is characterised by a laterally extensive sedimentary / volcaniclastic unit termed the Roodewal Member (Map 2) which is well developed in the Western Hartland basin. The Vutshini Formation is the southern correlate of the Langfontein Formation. The term Langfontein was introduced as a formation name in the Magudu area by Linström (1987). The Vutshini, as a formation name was introduced by Matthews (1979) after the Vutshini River, which is a tributary of the Nsuze River in the Nkandla area (traversed in profile 3, Map 2). The Roodewal Member was originally proposed as a group by Armstrong (1980), after well preserved volcaniclastics in the Western Hartland basin. The Mkuzana Formation was originally introduced by Linström (1987 a), after well-preserved exposures west of Magudu. Both the Langfontein and Mkuzana Formations are well preserved along the Mfenyana River west of Magudu, hence the origin of the term Mfenyana Subgroup (traversed in profile 11, Map 2).

f) An upper lava unit, which is only preserved at the top of the Central Synform in the Nkandla area, termed the Ekombe Formation (Fig. 2.1). This stratigraphic name was introduced by Groenewald (1984), after mapping in the Central Synform. This unit was traversed in profile 3 (Map 2).

g) An interesting diamictitic unit was recorded in the southern domain (see distribution in Map 1). This unit has its type locality near Nzimini store, close to the town of Nqutu, hence the name Nzimini Formation. The stratigraphic position of this formation is uncertain (Map 2).

The general stratigraphic column of the Nsuze Group discussed above can essentially be understood by paying special attention to three "type" areas viz.:

a) the White Mfolozi River inlier;

b) the Western Hartland basin area and

c) the Magudu area.

When combined, stratigraphic profiles in these three areas give the idealized "type" profile for the Nsuze Group (profiles 5, 7 and 11 in Map 2).

The White Mfolozi inlier provides an excellent record of the succession from the basal Mantonga Formation, which rests unconformably on granitic basement, to the Agatha Formation. The latter is unconformably overlain by Mozaan Group sediments, so that the upper formations are missing here. An important marker unit in the White Mfolozi inlier is the Chobeni Carbonate Member which outcrops widely in the southern and central domains. The profile from the western Hartland basin provides the most complete, continuous record of the Nsuze sequence preserved anywhere, recording the succession from the basal Mantonga Formation to the Langfontein / Vutshini Formation near the top. Of local significance are the well-preserved argillaceous Ntambo Member and volcaniclastic Roodewal Member here. Record of the upper Langfontein / Vutshini and Mkuzana Formations is best preserved in the Magudu area. The only formation not preserved in these three "type" areas is the upper volcanic Ekombe Formation, which is only preserved in the Nkandla area (Fig. 2.1 and Map 10 a).

The other areas where profiles were traversed (such as the Amsterdam area and southwestern Swaziland) in the northern and central domains provide information on lateral variations in the formations well represented by the above three "type" areas.

The southern domain yielded structurally-complex profile areas. These are:

a) the Buffalo River inlier;

b) the Central Synform (Nkandla area) and

c) the Mhlatuze River inlier.

An insight into the broad regional Nsuze lithostratigraphy gained from the combined three "type" areas has enabled recognition of Nsuze Group units within those complex areas and progress has been made in unravelling the structural elements here. It was also found that structural complexities are largely confined to fault and thrust zones, with strata within fault blocks well preserved.

2.5 LATERAL DISTRIBUTION OF MAJOR ROCK UNITS

The lateral distribution of major rock units (including the components of the Nsuze Group and pre-and-post-Nsuze lithologies) is illustrated on Map 1. The recognition of Nsuze Group components throughout the Pongola basin has highlighted major structural trends.

The lateral continuity of Nsuze formations between the northern domains and the central domain is indicated on Map 1, with the Nsuze units in the White Mfolozi inlier being a southward extension of those in the Hartland synform and in southwestern Swaziland. The Nsuze lithologies in the Amsterdam area form a detached structural basin, largely cut by Usushwana intrusives (Map 1). The Nsuze units in the southern domain are separated from those in the central domain by pre-Pongola granites, and are structurally complex. In the Nkandla area broad synformal structures are recognised, while in the Buffalo River inlier a refolded synformal structure is recognised (refer to section 3.5).

Map 1 shows that Nsuze Group units are traceable over large distances. The basal quartzitic Mantonga Formation is mappable over the entire study area, with maximum thickness in the Hartland synform (Map 1). The volcanic Pypklipberg Formation thins drastically to the south with maximum exposed accumulation in the northwestern domain. The Pypklipberg Formation is actually not developed in the Buffalo River inlier area, with the White Mfolozi Formation resting directly on the Mantonga Formation (Map 1). The sedimentary White Mfolozi Formation is better developed in the southern and central domains, thinning to a continuous lenticular unit in the northwestern domain (Map 1). The diagnostic carbonate Chobeni Member is also only preserved in southern and central domains with excellent exposures in the White Mfolozi and Buffalo River inliers. Nsuze formations above the Pypklipberg lavas in the Amsterdam area have been removed by the pre-Mozaan unconformity (Map 1).

The volcanic Agatha Formation is well-developed throughout the study area, even being recognised in the northeastern domain (Magudu area) where it represents the lowermost exposed unit (Map 1). The argillaceous Ntambo Member is only developed in the northern domains, especially in the northwestern domain, where it forms a laterally continuous unit extending northwards from southeast of Paulpietersburg to southeast of Mankaiana in southwestern Swaziland (Map 1). The Langfontein/Vutshini Formation is exposed throughout the study area, with maximum preservation in the Magudu area and in the Nkandla area. The preserved thickness of the Langfontein/Vutshini Formation is largely controlled by the Mozaan unconformity. The unit was removed by erosion in the White Mfolozi inlier prior to deposition of the Mozaan Group. The volcaniclastic Roodewal Member, which forms the base of the Langfontein / Vutshini Formation, has only been recognised in the Hartland synform, southwestern Swaziland and the Buffalo River inlier. The argillaceous Mkuzane Formation is only preserved in the Magudu area (Map 1). The uppermost preserved unit of the Nsuze Group, the volcanic Ekombe Formation is only preserved in the Nkandla area (Map 1). The enigmatic volcaniclastic Nzimini formation is only preserved in the southern domain, forming an elliptical outcrop pattern between the Buffalo River inlier and the Nkandla area (Map 1).

CHAPTER 3: GEOLOGY AND NSUZE LITHOSTRATIGRAPHIC SUBDIVISIONS IN EACH DOMAIN AND REGIONAL CORRELATION

3.1 INTRODUCTION

The geology of each area where lithostratigraphic profiles were measured will be briefly discussed in this section. In addition a simple lithostratigraphic subdivision for each domain will be presented. Lastly a regional correlation will be given.

3.2 NORTHWESTERN DOMAIN

3.2.1 Hartland Synform

3.2.1.1 Geology

The thickest succession of Nsuze strata crops out in the area north of Vryheid and east of Paulpietersburg (Figure 1 and Map 1). Detailed mapping by Watchorn (1978) has revealed two structural basins, one in the northeast called the Piensrand "basin" and another in the southwest termed the Hartland "basin". In this study, the term "synform" is preferred to "basin" and will be applied. The two synforms are separated by a faulted antiform known as the Altona antiform (Matthews, 1990).

The Nsuze Group is exposed on the gently dipping western limb of the southeasterly-plunging Western Hartland synform. A simplified geological map of the area between the Bivane and White Rivers, on the western part of the Hartland synform, modified from Humphrey (1912) and Armstrong (1980), is presented in Map 3a. Geological mapping in this area is hindered by the scarcity of suitable outcrop. Consequently a composite profile was constructed across the area from carefully selected outcrop areas, usually along stream or river sections.

The components of the composite profile provides a more realistic summary of the lithostratigraphic package here. The sedimentary units mapped out as "lenticular" units within the thick lava pile, are suggested to be continuous, defining mappable and correlatable stratigraphic units.

3.2.1.2 Lithostratigraphy

The composite thickness of the Nsuze sequence in this area is about 4 570 m (this contrasts with the 8 000 m thickness documented by Armstrong, 1980, which possibly included duplicated portions of the succession). The lithostratigraphic subdivision, as proposed by Linström (1987), is compared with the regionally-applicable nomenclature proposed in this study for the composite profile, as shown in Map 3b.

The basal Mantonga Formation overlies granitoid basement with a graded unconformity (as reported by Matthews and Scharrer, 1968). The Mantonga Formation along the Mantonga River traverse is about 800 m thick and comprises chiefly of quartzite, quartz-wacke and occasional arkosic arenite. The lower part of the formation is characterised by thin conglomeratic beds, while argillaceous units are occasionally interbedded. Diamictitic units, of possible volcanic origi~~s~~n, are developed throughout the formation. Armstrong (1980) records a ± 300 m thick discordant unit of basaltic volcanic rocks with a thin arenaceous base towards the north of the area shown in Map 3 a. He suggests that this reflects an early depositional phase of the Nsuze Group. The exact relationship of this unit (termed the Wagendrift Formation by Armstrong (1980)) to the Mantonga Formation is uncertain. The Wagendrift Formation is dislogged from the main outcrop area of Nsuze strata by the Usushwana Complex. It may thus merely represent a faulted fragment of the lower part of the Pypklipberg Formation.

The Pypklipberg Formation, as traversed along the Mantonga River and White River profiles, comprises a sequence of mafic lavas including basalts, basaltic andesites and andesites, some 1 500 m thick. It is not possible without geochemical data to distinguish between these different types of lava in the field.

Along the Nkemba traverse a 230 m thick succession of sedimentary rocks, composed of quartzite, wacke, shale and subordinate diamictite and gritstone, are present at the top of the Pypklipberg Formation (Map 3 a). The contact with the overlying lavas is faulted. This sedimentary unit is correlated with the White Mfolozi Formation, bearing lithostratigraphic similarities with the type area in the White Mfolozi inlier.

The Agatha Formation, as traversed along the White River and Agatha stream profiles, comprises an approximately 1 700 m thick pile of altered and occasionally amygdaloidal basalt, basaltic andesite, andesite, dacite and even rhyolites (Armstrong, 1980). Within the Agatha Formation, a persistent, but poorly exposed argillaceous unit, is developed. This unit, which is about 20 m thick along the Balmoral profile, comprises phyllitic shale overlain by an erratically-developed thin agglomerate. It represents a regionally mappable unit over a wide area, and is correlated with the Ntambo Member (with its type section in southwestern Swaziland (Map 6 a).

The top of the Nsuze Group in the Hartland synform is formed by an almost 200 m thick sequence of wackestone and argillite underlain by volcanic sandstone and volcanogenic conglomerate in the Ntombe River traverse (Map 3 a). The basal volcaniclastic unit is defined as the Roodewal Member, which locally forms the base of the Langfontein/Vutshini Formation. (type area in the Magudu area).

3.2.2 Amsterdam Area

3.2.2.1 Geology

Mapping by van Vuuren (1965) near Amsterdam indicated that part of the Pongola Supergroup is preserved in a synclinal structure (Map 4 a). The central axial region of the structure is covered largely by Karoo strata. The Mozaan and Nsuze Groups have been intruded and dismembered by mafic to ultramafic intrusives of the Usushwana Complex (Map 4 a). The northwest-trending synclinal structure in the Pongola strata is outlined in map 9(a), with dips rarely exceeding 30°.

3.2.2.2 Lithostratigraphy

A lithostratigraphic profile of the Nsuze Group was measured on the farm Merriekloof 420 IT (Map 4 a). The simplified lithostratigraphic succession encountered along this traverse is shown in Map 4 b. The sequence is some 1 950 m thick in total.

The contact between the basement granite and the overlying Mantonga Formation is not exposed. The Mantonga Formation is about 365 m thick and comprises chiefly quartzites, with intercalations of siltstone and wackestone and subordinate shale and conglomerate. Thin (± 5 m thick) diamictitic units, of possible volcaniclastic origin, are also present. Van Vuuren (1965) reports basaltic lava of some 30 m thick in the Mantonga Formation in the southwestern portion of the area.

The Mantonga Formation is overlain by a pile of mafic, commonly amygdaloidal, lava some 1 585 m thick. This lava unit is correlated with the Pypklipberg Formation. The lavas are intruded by some coarse-grained mafic sills correlated with the Usushwana Complex (Map 4 b).

The Mozaan Group rests unconformably on the Pypklipberg Formation. This indicates that all the upper units of the Nsuze Group have been removed by erosion prior to deposition of the Mozaan Group.

3.2.3 Area East of Piet Retief

3.2.3.1 Geology

Hatfield (1990) mapped and described attenuated Pongola Supergroup strata east of Piet Retief in the southeastern Transvaal, immediately adjacent to the Swaziland border. He essentially examined the development of a northwesterly-striking foliation in this area, which contrasts sharply with the northeasterly strike which predominates in Nsuze lithologies in northern Natal and southwestern Swaziland. However he also described the lithostratigraphy of the Nsuze Group. Hatfield's (1990) lithostratigraphic sequence compares well with adjacent profiles from this study. Nsuze Group lithostratigraphic subdivisions for the profile described by Hatfield (1990) is shown in Map 5.

3.2.3.2 Lithostratigraphy

A total thickness of about 4 000 m of Nsuze strata is exposed in Hatfield's (1990) study area. The base of the sequence is intruded by granophyres of the Usushwana Complex. The sequence is unconformably overlain by the Mozaan Group (Map 5).

The basal sedimentary unit is discontinuous and disrupted by the Usushwana Complex. This unit, considered a correlative of the White Mfolozi Formation, attains a maximum thickness of 100 m and comprises quartz wacke with subordinate argillite and tuff. The White Mfolozi Formation here is clearly a northern extension of this formation in the Hartland synform, with the lower formations being intruded by the Usushwana Complex (Map 1). However Hatfield (1990) correlated this unit with the Mantonga Formation. Inspection of the regional map (Map 1) clearly indicates that this is not the case. The White Mfolozi Formation is overlain by about 2 300 m of felsic lavas with subordinate intercalations of highly weathered pyroclastic beds. The felsic lavas are reported to be rhyolitic with minor dacitic flows (Hatfield, 1990) which suggests correlation with the lower part of the Agatha Formation.

The Agatha felsites are overlain by a 300 m thick succession dominated by pyroclastic rocks. This succession, which is ascribed to the Ntambo Member of the Agatha Formation, separates underlying felsic volcanics from overlying andesitic lavas. Although highly variable in stratigraphy, the lower part of the Ntambo Member is represented by argillites overlain by a succession of tuffs with minor agglomerate. The upper part of the Ntambo Member is dominated by tuffs with interbedded argillites and subordinate heterolithic sediments and agglomerates (Map 5). The uppermost agglomerate reaches a thickness of about 5m. It is noteworthy that the Ntambo Member contains less volcaniclastic beds towards southwestern Swaziland being more argillaceous there. Subordinate lava flows occur within the Ntambo Member.

The upper part of the Agatha Formation is composed of a monotonous sequence of andesitic lavas with minor interbeds of basaltic andesites and basalts (Map 5). The lavas become more amygdaloidal towards the top of the unit, which is some 1 200 m thick. The Agatha Formation is overlain by a 50 m thick zone of volcanic breccias and tuffs intercalated with siltstone and mudstone. This unit correlates with the lower part of the Langfontein Formation, with the volcanic breccias being a possible correlative of the Roodewal Member (Map 1).

3.2.4 Southwestern Swaziland

3.2.4.1 Geology

Nsuze strata outcrop around Mahlangatsha in southwestern Swaziland. The outcrops are referred to as the Mahlangatsha Belt (Hunter, 1961). The Nsuze Group is intruded by rocks of the Usushwana Complex and are unconformably overlain by the Mozaan Group. It was difficult to construct a good profile because of poor outcrop and severe tectonic deformation in some areas, especially towards the north. However a lithostratigraphic profile was measured (Map 6 b) across the entire sequence about 10 km north of Gege (Map 6 a).

3.2.4.2 Lithostratigraphy

The Nsuze sequence is some 1 100 m thick in the area (Map 6 b). A xenolithic fragment of quartzite with minor phyllite, outcrops in the Usushwana Complex north of Mahlangatsha. This unit is possibly a correlative of the White Mfolozi Formation (Map 6 a). The Nsuze strata along profile line A - B in Map 6 a are situated stratigraphically above the White Mfolozi Formation (Map 6 b).

The lower part of the Nsuze Group is composed of tectonised felsic lavas which are some 170 m thick. The felsites are overlain by the Ntambo Member, which is some 150 m thick here and consists of phyllitic argillites with occasional pyrophyllite deposits. Andesitic lava and a discontinuous agglomerate bed are developed in the middle part of the Ntambo succession. (Map 6 b). Thin quartzite beds occur near the top of the Ntambo Member.

The Ntambo Member is overlain by andesitic amygdaloidal lavas of the Agatha Formation which are some 780 m thick here. The Agatha Formation is overlain by an approximately 100 m thick sedimentary unit composed of coarse-grained, sometimes conglomeratic quartzite with intercalated shale and wackestone. The sedimentary sequence is composed of three quartzite and two shale beds, correlated with the lower part of the Langfontein Formation (Map 6 b). This sedimentary unit was considered part of the Mozaan Group by Hunter (1961). The sedimentary unit is, however, discordantly overstepped by the basal Singeni quartzite of the Mozaan Group (Nelson, pers. com., 1994) and is therefore considered part of the Langfontein Formation of the Nsuze Group.

3.3 NORTHEASTERN DOMAIN (MAGUDU AREA)

3.3.1 Geology

Pongola strata have been deformed into a doubly-plunging anticlinal structure to the west of Magudu (Map 7 a). Strata dip in general to the east and to the south. The western limb of the anticline has been intruded by discordant post-Pongola granites (Spekboom granite, after Matthews, 1985). The eastern part of the structure is faulted down against the post-Karoo Koppie Alleen fault (Map 7 a).

Although large parts of the Pongola Supergroup are Karoo-covered, several major rivers crosscut the area, resulting in excellent exposures as Pongola strata in river valleys (Map 7 a). Two lithostratigraphic profiles were measured in the area namely :-

a) along the Hohobo River in the north and

b) along the Mfenyana River in the south. (Map 7 a).

Lithostratigraphic data from the two profiles were linked to produce a composite lithostratigraphic profile for the Nsuze Group in the Magudu area (Map 7 b).

The base of the Mozaan Group is formed by the Singeni orthoquartzite sequence, previously known as the Mkaya Formation (Nelson, pers. com., 1994). The sedimentary units below that, named the Langfontein and Mkuzana Formations, thus forms part of the Nsuze Group and not part of the Mozaan Group as suggested by Linström (1987 a). This correlation is further supported by the fact that lavas are present at the base of the Langfontein Formation (Hohobo River profile) and these can be correlated with the Agatha Formation (Map 7 b).

Sedimentary rocks of the Langfontein and Mkuzana Formations have undergone contact metamorphism in proximity to the post-Pongola intrusive Spekboom granites, leading to the presence of abundant andalusite hornfels in the area.

3.3.2 Lithostratigraphy

The lowermost preserved units of the Nsuze Group in the area, in contact with intrusive granite, comprises a 600 m thick metavolcanic pile correlated with the upper part of the Agatha Formation (Map 7 b). The contact with the post-Pongola granitoids is not exposed along the Hohobo River traverse. The basal 300 m of the sequence, in close proximity to the Spekboom intrusive granite, appear felsic in composition. It may, however, merely represent mafic lavas that have been silicified by the intrusion of the granite. The felsic (silicified?) lavas are overlain by a metapelite unit composed of biotite ± andalusite ± garnet-bearing schists and correlated with the Ntambo Member of the Agatha Formation. The Ntambo Member is in turn overlain by altered mafic lavas (Map 7 b).

The Agatha Formation is overlain by a sequence of metasediments some 2800 m thick (Map 7 b). These rocks represent the Langfontein and Mkuzana Formations described by Linström (1987 a). The Langfontein Formation is much more arenaceous than the overlying dominantly argillaceous Mkuzana Formation. Along the Mfenyana River traverse the Langfontein Formation consists of interbedded quartzite, andalusite schist and quartz-sericite schist with rare cordierite ± garnet-bearing schist. The Langfontein Formation is about 1 400 m thick here.

The Mkuzana-Formation is about 1 450 m thick and composed mainly of interbedded cordierite and andalusite schist. Thin interbeds of quartzite and quartz-sericite schist are present (Map 7 b). For purposes of regional correlation, metapelite is shown as shale and quartzite-sericite schist as wacke/siltstone on map 7 b.

This is the only area known in the whole of the Nsuze basin where such a thick sequence of sedimentary rocks is preserved above the Agatha Formation. This emphasizes the importance of differential erosion prior to the deposition of the Mozaan Group in determining the thickness of Nsuze strata preserved in the outcrop area of Nsuze Group.

3.4 CENTRAL DOMAIN

3.4.1 White Mfolozi River Inlier

3.4.1.1 Geology

The White Mfolozi structure can be considered as an 80 km southerly extension (beneath extensive Karoo cover) of the arcuate belt of Pongola strata outcropping north of Vryheid (Map 1).

A geological map of the central part of the White Mfolozi inlier (modified from Matthews, 1967) is presented in Map 8 a. Various ~~duplicatiens~~ duplications of strata by faulting were recognised along the profile line. These have not been recorded earlier.

The Nsuze Group overlies granitic gneiss basement with a marked unconformity. Contact relationships are however not well preserved due to the intrusion of a younger post-Pongola granite along the contact. This younger intrusive granite has not previously been recognised.

The Nsuze Group is overlain by the Singeni Formation of the Mozaan Group with an angular disconformity. The Nsuze strata dip between 15° - 35° towards the northeast, whereas the Mozaan Group dips at 5° - 15° east-northeast. The basal Singeni quartzite of the Mozaan Group rapidly oversteps different stratigraphic members of the Nsuze Group over a small distance of 3 to 4 km in the White Mfolozi inlier, emphasizing the unconformable relationship between the Nsuze and Mozaan Group. Matthews (1967) has estimated that the progressive south-easterly directed overstep of Mozaan strata has eliminated approximately 1200 m of Nsuze strata. This elimination has obvious implications for regional Nsuze lithostratigraphic correlations and the construction of a composite reference profile.

3.4.1.2 Lithostratigraphy

The Nsuze Group attains a thickness of approximately 1 070 m along the White Mfolozi lithostratigraphic profile (Map 8 b). Matthews (1967) estimated a thickness of 1 890 m, but did not take into account some duplication of strata by faulting.

The White Mfolozi profile (Map 8 b) represents one of the best Nsuze reference profiles preserved, not only because of a virtually 100 per cent exposure, but also because the basal four rock units (from the Mantonga Formation through the Pypklipberg and White Mfolozi Formations into the Agatha Formation) are present.

The Mantonga Formation is composed of orthoquartzite with a conglomerate zone at the base. This zone is disrupted by the post-Pongola granite that intruded along the basal contact with basement granitic gneiss. The Mantonga Formation varies in thickness between 4 m and 60 m, perhaps illustrating an irregular floor at the time of deposition. The Pypklipberg Formation rests with a sharp contact on the Mantonga Formation. It is composed of dark green aphanitic, usually amygdaloidal, lavas with a thickness of some 130 m. The lavas are intruded by dolerite sills, resulting in an apparent greater thickness of "lava" preserved (Map 8 b).

The White Mfolozi River inlier is the type location for the White Mfolozi Formation (the middle sedimentary sequence), which here comprises alternating shale, siltstone, quartzite, diamictite, tuffaceous sandstone and dolomite. A stromatolitic carbonate unit, in the middle part of the White Mfolozi Formation, has been named the Chobeni Member. The Agatha Formation overlies the White Mfolozi Formation with a sharp contact. It is composed of dark green amygdaloidal lava. The Agatha Formation is overlain, with an angular unconformity, by coarse-grained orthoquartzite of the Singeni Formation of the Mozaan Group (Map 8 b).

Although not exposed in profile A-B, along the course of the White Mfolozi River, due to (Map 8a) the Mozaan Group overstepping Nsuze strata in a southerly direction, Matthews (1967) reports a succession of ferruginous shale with intercalated quartzite up to 530 m thick above the lavas of the Agatha Formation, but below the Singeni quartzite of the Mozaan Group. This unit, termed the Taka Formation (SACS, 1980) is most probably a lateral equivalent of the Langfontein/Vutshini Formation. There is also some possibility that it represents part of the Ntambo Member of the Agatha Formation. This unit is however normally much thinner and contain little or no quartzite interbeds. The Ntambo Member is however also believed to become more quartzitic to the south (compare with Buffalo River inlier).

3.4.2 Mpongoza Inlier

3.4.2.1 Geology

The Mpongoza inlier is situated northeast of the White Mfolozi inlier and although not traversed in this study, it has been studied in detail by Preston (1987). His findings will be summarized here. Mapping and the correlation of the various volcanic units in the inlier are difficult because of lateral discontinuity and poor exposure. Outcropping Nsuze strata in the Mpongoza inlier define an elongate outcrop pattern (Map 9 a). Nsuze strata have a general NW-trending strike, with a younging direction to the southwest (Map 9 a).

3.4.2.2 Lithostratigraphy

Preston (1987) has informally subdivided lithologies in the Mpongoza inlier into a lower volcanic unit (approximately 2560 m thick), a middle clastic sedimentary unit (approximately 260 m thick) and an upper volcanic unit (approximately 270 m thick). This informal subdivision, although not to scale, is shown in Map 9 b.

The lower lava unit, correlated with the Pypklipberg Formation, is subdivided into a northern and southern facies, both comprising amygdaloidal mafic lavas overlain by felsic volcaniclastic rocks. The amygdaloidal lavas reach a maximum thickness of about 300 m in the northern area, while the felsic volcaniclastics reach a maximum thickness of 1 420 m in the southern area.

The middle siliciclastic White Mfolozi Formation comprises two quartzite units with interbedded mudstones and siltstones (von Brunn, 1974). According to Von Brunn (1974) vertical facies arrangements are similar to that in the White Mfolozi Formation in the White Mfolozi inlier. However the Chobeni carbonate Member is absent.

The upper volcanic unit, correlated with the Agatha Formation (Map 9 b), is composed of mafic lavas overlain by an felsic volcanic rocks. The felsic volcanics could partially be a product of silicification (Preston, 1987).

3.5 SOUTHERN DOMAIN

3.5.1 Nkandla Area

3.5.1.1 Geology

The Nsuze Group in the southern domain, near Nkandla, outcrops as several discrete inliers (Map 10 a). The domain is characterised by E-W trending folds with associated zones of thrust faults. A dominant deformation event resulted in large scale isoclinal folding, which is probably related to the 1000 Ma Namaqua-Natal tectonogenesis at the edge of the Kaapvaal craton in Natal (Groenewald, 1985). This deformation event resulted in the formation of 3 large synformal structures in the Nkandla area. Possibly a more correct term for these synformal structures are synclinoria. The folds have wavelengths of 3-5 km, with numerous associated smaller parasitic folds. The 3 large synformal structures are termed the Gem-Vuleka, Central and Southern synforms (Map 10 a). The synformal structures are separated by large tectonic shear zones.

Matthews (1979, cited in SACS, 1980) proposed a nine-fold subdivision of the Nsuze Group in the Nkandla area, of which the lower five formations correspond to the units of du Toit (1931). The upper four formations are apparently stratigraphically unique to the Central synform. The scarcity of good outcrop and structural complexities prohibits the construction of detailed profiles at each of the synforms. In this study, a detailed composite lithostratigraphic profile could only be constructed in the Central synform. (See Map 10 a for the position of the profile).

Apart from field work in the Central synform, outcrops in the Gem-Vuleka synform were also examined (Map 10 a). Lithostratigraphic elements from the Central synform were recognised in the Gem-Vuleka synform, although the latter is structurally more complex. A simplified geological map of the northern part of the Gem-Vuleka synform (modified from Groenewald, 1984) is shown in Fig. 3.1. It illustrates the structural complexity of this area, the lithostratigraphic components, and the known outcrop distribution of the enigmatic Nzimini Formation (which chiefly comprises of volcaniclastic diamictite). The Nzimini Formation is also present in the northern part of the Buffalo River inlier and to west of Babanango in the vicinity of the Nzimini store. It is referred to as the Ndikwe Formation by Groenewald (1984). It was decided to change the formation name to Nzimini, in recognition of the wider distribution of this unit than was

SIMPLIFIED GEOLOGICAL MAP OF THE NORTHERN PART OF THE GEM–VULEKA SYNFORM, NORTH-WEST OF NKANDLA, ILLUSTRATING LITHOSTRATIGRAPHY IN RELATION TO STRUCTURE. (GEOLOGY MODIFIED FROM GROENEWALD, 1984)

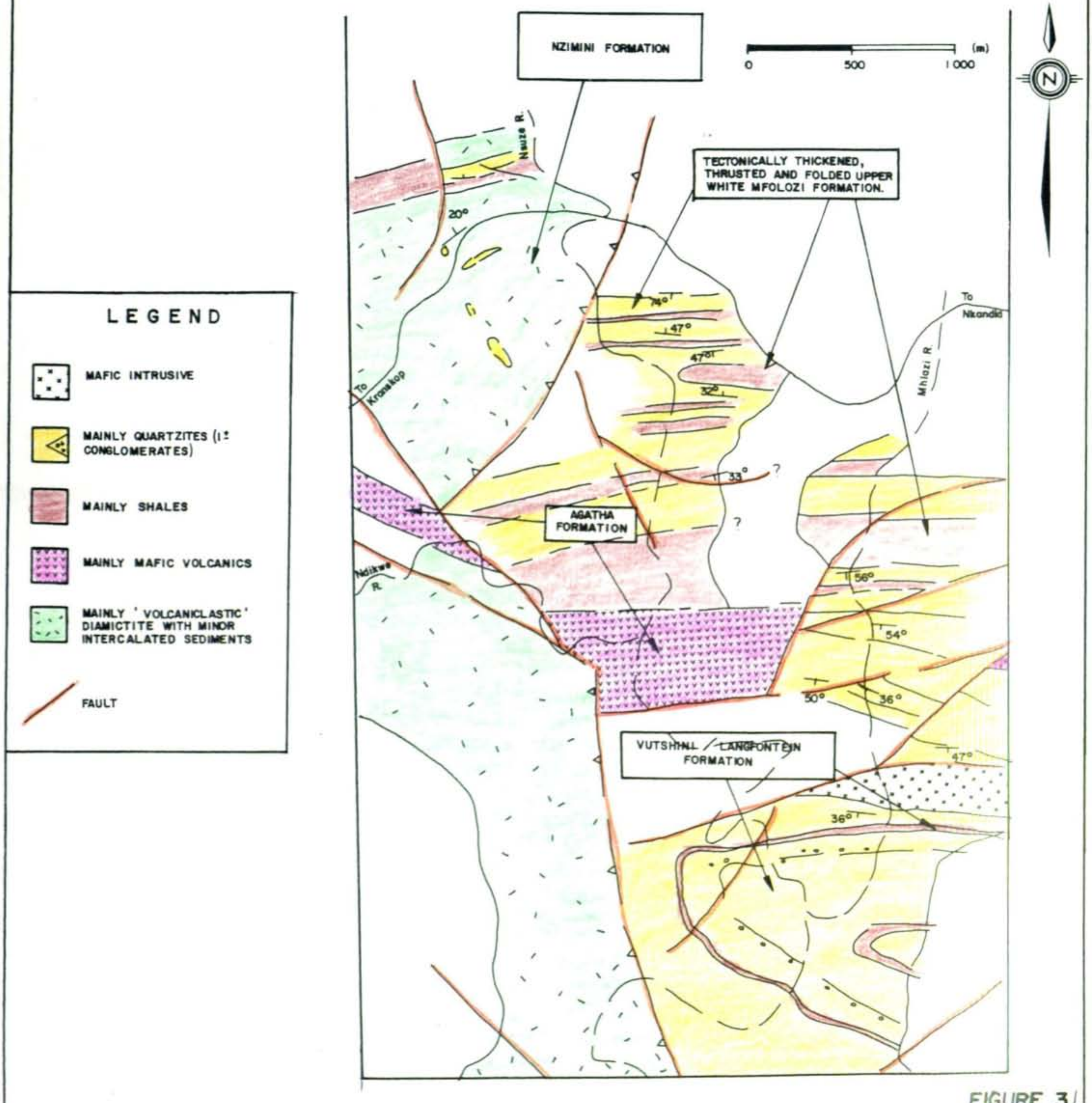


FIGURE 3.1.

previously recognised and after the excellent exposures near Nzimini store.

Matthews (1990) suggests that the southern domain is largely composed of two major structural units. The upper "Nsuze Nappe" is an extensive slightly folded allochthonous thrust sheet with a complex imbricate internal structure consisting of folded and faulted Nsuze Group formations. The lower unit is an extensive pre-Pongola granite-greenstone segment containing two E-W trending structural wedges of down-folded and downfaulted Nsuze formations (i.e. the Mhlatuze and Enome synclinal wedges).

3.5.1.2 Lithostratigraphy

A volcano-sedimentary succession, some 3150 m thick, is preserved in the Nkandla Central synform. The composite profile (which was constructed from outcrops along major streams) is simplistically illustrated and compared with lithostratigraphic subdivisions of SACS (1980) in Map 10 b. Key marker units recognised in the profile are carbonates of the Chobeni Member of the White Mfolozi Formation and the thick upper lava unit correlated with the Agatha Formation.

The basal part of the White Mfolozi Formation is in tectonic contact with a major melange (Map 10 a). The preserved part of the White Mfolozi Formation is about 1 200 m thick and comprises a thick accumulation of recrystallized quartzite with minor quartz wacke, siltstone and shale. The Chobeni Member is about 90 m thick and composed of calc-arenite underlain by a schistose metadiamictite. This diamictite may be equivalent to the volcaniclastic diamictite directly underlying the Chobeni Member in the White Mfolozi inlier (Map 8 b). The overlying Agatha Formation is some 650 m thick and comprises lavas ranging in composition from basaltic andesite to dacite (Groenewald, 1984).

The Vutshini Formation unconformably overlies the Agatha Formation and consists of a 1100 m thick sequence of alternating arenaceous and argillaceous metasediments, becoming more arenaceous upwards. The lower quartzites are gritty with a thin conglomerate developed at the base. Conglomerates are also developed near the top of the formation (Map 10 b). This formation is tentatively correlated with the Langfontein Formation further to the north. The Vutshini Formation is overlain by the Ekombe Formation (Groenewald, 1984), being exposed in the core of the Central synform (Map 10 a). It is composed of amygdaloidal mafic lava. A lava mapped in the core of the Gem-Vuleka synform by Matthews, 1959-1969 (Map 1) is most probably a correlative of the Ekombe Formation (Map 10 a). The Ekombe Formation may represent one of the highest preserved units in the Nsuze Group (Figure 2.1).

3.5.2 Mhlatuze River Inlier

3.5.2.1 Geology

The Mhlatuze River inlier, situated north-east of Nkandla, consists of a tightly folded E-W trending system of anticlines and synclines, displaced by later faults and intruded by multiple diabase sills and dykes. Although excellent exposure exists along the Mhlatuze River, structural complexities militate against construction of complete long lithostratigraphic profiles.

The Nsuze Group is wedged between greenstone-age units in the north and pre-Nsuze granite basement in the south (Map 11 a). A lithostratigraphic profile could be constructed for the lower approximately 600 m of the Nsuze Group (Map 11 a). Folding has duplicated strata in the inlier.

Matthews (1990) refers to the area as the Mhlatuze fault belt and considers the Nsuze Group to have been thrusted over the greenstone belt in the north (Map 11 a).

3.5.2.2 Lithostratigraphy

Three units, namely the Mantonga, Pypklipberg and White Mfolozi Formations were identified with confidence in the area (Map 11 b). The basal Mantonga Formation is about 30 m thick and composed of recrystallized quartz arenites. It unconformably overlies granitic basement. A 5 m thick granular arkosic arenite separates the quartz arenite of the Mantonga Formation from the granitic basement. Bedding is very steep, occasionally overturned.

The Pypklipberg Formation is about 250 m thick and composed of dark mafic lavas with occasional amygdaloidal beds. Excellent fresh outcrop of the lava is present along the Mhlatuze River. The lower part of the White Mfolozi Formation is composed of phyllite overlain by thick quartzite with interbedded phyllite (Map 11 b).

Diabase sills, up to 10 m thick, intrude the White Mfolozi Formation. The strata of the Nsuze Group in the Mhlatuze River inlier compares well with that along the White Mfolozi River, indicating a direct correlation across the post-Pongola Melmoth arch (Map 1).

3.5.3 Buffalo River Inlier

3.5.3.1 Geology

The Buffalo River in northern Natal has incised through flat-lying Karoo cover and exposed the Archaean basement in certain areas along it's course. Excellent outcrops of Nsuze Group are exposed as an inlier in Karoo strata in the gorge of the Buffalo River to the east of Pomeroy in northern Natal (Maps 1 and 12 a).

Recent mapping by Dixon (1993) has shed light on the structural and lithostratigraphic complexities of the area. A 1:50 000 geological base map provided by Dixon was used to select suitable localities for constructing lithostratigraphic profiles (Map 12 a).

Dixon (1993) is of the opinion that various units of the Nsuze Group in the Buffalo River inlier cannot be correlated with other areas. However, a number of units were found that could be directly correlated with units in the White Mfolozi inlier some 60 km to the east. With the aid of these marker beds, the stratigraphy of the Nsuze Group in the Buffalo River inlier could be unravelled.

Recognition of key lithostratigraphic units in the area and correlation between fault blocks enabled better understanding of the structure. In essence Nsuze strata are folded into a large synclinorium, with subordinate anticlinal and synclinal structures (Map 13). After folding the structure was disrupted by a system of normal faults into a series of fault blocks (Maps 13 and 14). Evidence of northward and southward - directed thrusting is present, (Fig. 3.2) most probably related to the period of fold deformation. Normal faults strike mainly in northeasterly and northwesterly directions (Map 12 a).

One of the main observations made was that the sequence is intensely block faulted. However, within the fault blocks, successions are well-preserved and by the recognition of marker beds a composite profile could be constructed, working from one fault block to the other (Map 12 b).

FIGURE 3.2 Imbricate thrust zone patterns within a mature grey-white quartzite unit in the White Mfolozi Formation in the Buffalo River Inlier.

Key lithostratigraphic units recognised, enabling regional correlation are the basal Mantonga Formation, the Chobeni carbonate member of the White Mfolozi Formation and the Agatha lava formation.

3.5.3.2 Lithostratigraphy

Careful mapping along eight traverses in the area (Map 12 a) allowed construction of a composite lithostratigraphic profile (Map 12 b). The sequence is some 4 050 m thick but some tectonic thickening may be present, a factor very difficult to quantify.

Nsuze strata unconformably overlie greenstone, basement comprising largely mafic and ultramafic metavolcanics, with banded chert and iron-formations. The greenstones are thought to be intruded by two ages of granitoids thought to be pre-Pongola in age (Dixon, 1990). The Mantonga Formation has a polymictic diamictite at its base in the Mazebeko area. The diamictite is overlain by about 150 m of quartzites with associated gritstone and conglomerates.

The Pypklipberg Formation is apparently absent in the area and the White Mfolozi Formation follows directly on the Mantonga Formation. The base of the White Mfolozi Formation is formed by a volcanic diamictite which may be up to 500 m thick (Map 12 b). The possibility of tectonic thickening in such a massive sedimentary unit is however difficult to assess. The unit thins drastically to about 20 m in the south.

The diamictite is overlain by a succession of quartzite, shale and wackestone some 1 000 m thick (Map 12 b). Excellent examples of the Chobeni carbonate member, with internal stratification exactly similar to that in the White Mfolozi inlier, are present at a number of localities i.e. the Roodeklip, Buffelshoek, Sifula, Mazebeko and Mangeni traverses (Map 12 a).

The Agatha Formation is composed of mafic lavas with a 150 m thick quartzite interbedded along the Mazebeko traverse (Map 12 b). This quartzite may be a correlative of the Ntambo Member. The Agatha Formation is estimated to be about 2 000 m thick. The Agatha Formation is overlain by the Langfontein Formation. This formation has a basal volcanic diamictite correlated with the Roodewal Member (Map 12 b). It is overlain by about 250 m of quartzite, gritstone and shale.

3.5.4 Drillhole NQ2

Diamond drillhole core NQ2, drilled by Gold Fields Mining and Development, near the town of Nqutu (southeast of Dundee, Map 1), to a depth of 2 120 m intersected an interesting volcano-sedimentary sequence. The succession is unconformably overlain by Dwyka diamictite to a depth of 285 m (Fig. 3.3).

The sequence intersected below Karoo cover is composed of interbedded volcanic pebble conglomerate, with diamictite towards the top and mafic lavas towards the base (Fig. 3.3). The mafic amygdaloidal lavas, at the base is in turn underlain by felsic lavas. The lavas are correlated with the Agatha Formation (Fig. 3.3).

3.6 REGIONAL LITHOSTRATIGRAPHIC CORRELATION

Each lithostratigraphic profile discussed in the previous section is placed into a broad regional lithostratigraphic context in Map 2. Some interesting points arising from the regional correlation are that:-

a. The overall Nsuze sequence comprises three volcanic and four sedimentary formations;

b. despite structural complications and breaks in outcrop, correlations of various units are possible over virtually the entire regional outcrop area of the Nsuze Group;

c. the Pypklipberg Formation apparently pinches out towards the Buffalo River inlier;

d. the carbonate Chobeni Member is restricted to the Southern and Central domains of the Nsuze Group;

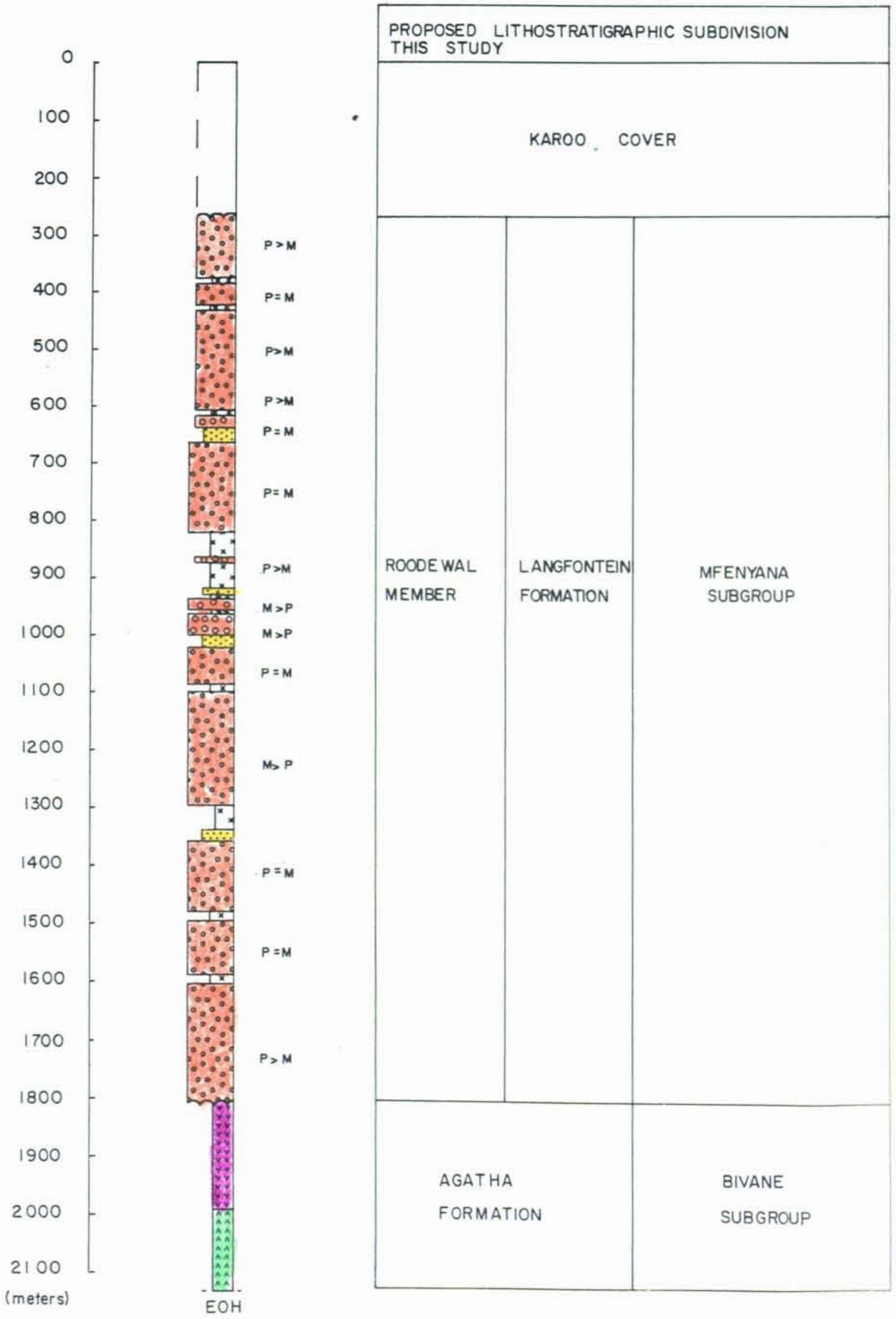
e. the volcaniclastic Nzimini Formation has a localized distribution in the Southern domain;

f. the argillaceous Ntambo Member is possibly restricted to the Northern domain (except for a possible quartzite correlate along the Mazebeko traverse in the Buffalo River Area);

g. large parts of Nsuze strata have been removed by erosion prior to the deposition of the Mozaan Group;

h. one of the most "complete" successions of the Nsuze Group is preserved in the western part of the Hartland basin;

SIMPLIFIED LOGSHEET AND SUGGESTED LITHOSTRATIGRAPHIC SUBDIVISION OF DRILLHOLE NQ 2 , NQUTU DISTRICT.



LEGEND

LITHOLOGICAL

☐ KAROO COVER

⁙ DIABASE INTRUSION

🟨 QUARTZITE

🟧 CONGLOMERATE (± INTERCALATED QUARTZITES)

🟪 MAFIC LAVA

🟩 FELSIC LAVA

SYMBOLS

〰 UNCONFORMITY

EOH END OF HOLE

P > M PROPORTION OF PEBBLE - SUPPORTED TO MATRIX - SUPPORTED CONGLOMERATES

Figure 3.3

i. the Magudu profile only represents strata from the upper part of the Nsuze Group. The Langfontein and Mkuzana Formations are best preserved here;

j. the Pypklipberg and Agatha volcanic formations thicken to the north;

k. conglomerates and diamictites intersected in drill core NQ2 may represent a very thick equivalent of the Roodewal Member of the Langfontein Formation;

Summarizing it can thus be stated that despite apparent local lithostratigraphic complexities encountered along the traverses, the Nsuze Group can confidently be subdivided into three dominantly volcanic (Pypklipberg, Agatha and Ekombe) and four dominantly sedimentary (Mantonga, White Mfolozi, Langfontein/Vutshini and Mkuzane) Formations. Each lithostratigraphic traverse in this study represents only a portion of the "complete" Nsuze Group succession. No individual lithostratigraphic traverse represents the "complete" Nsuze Group succession, due to factors like:-

i. incomplete exposure (cover by younger sequences),

ii. structural dismembering of the succession,

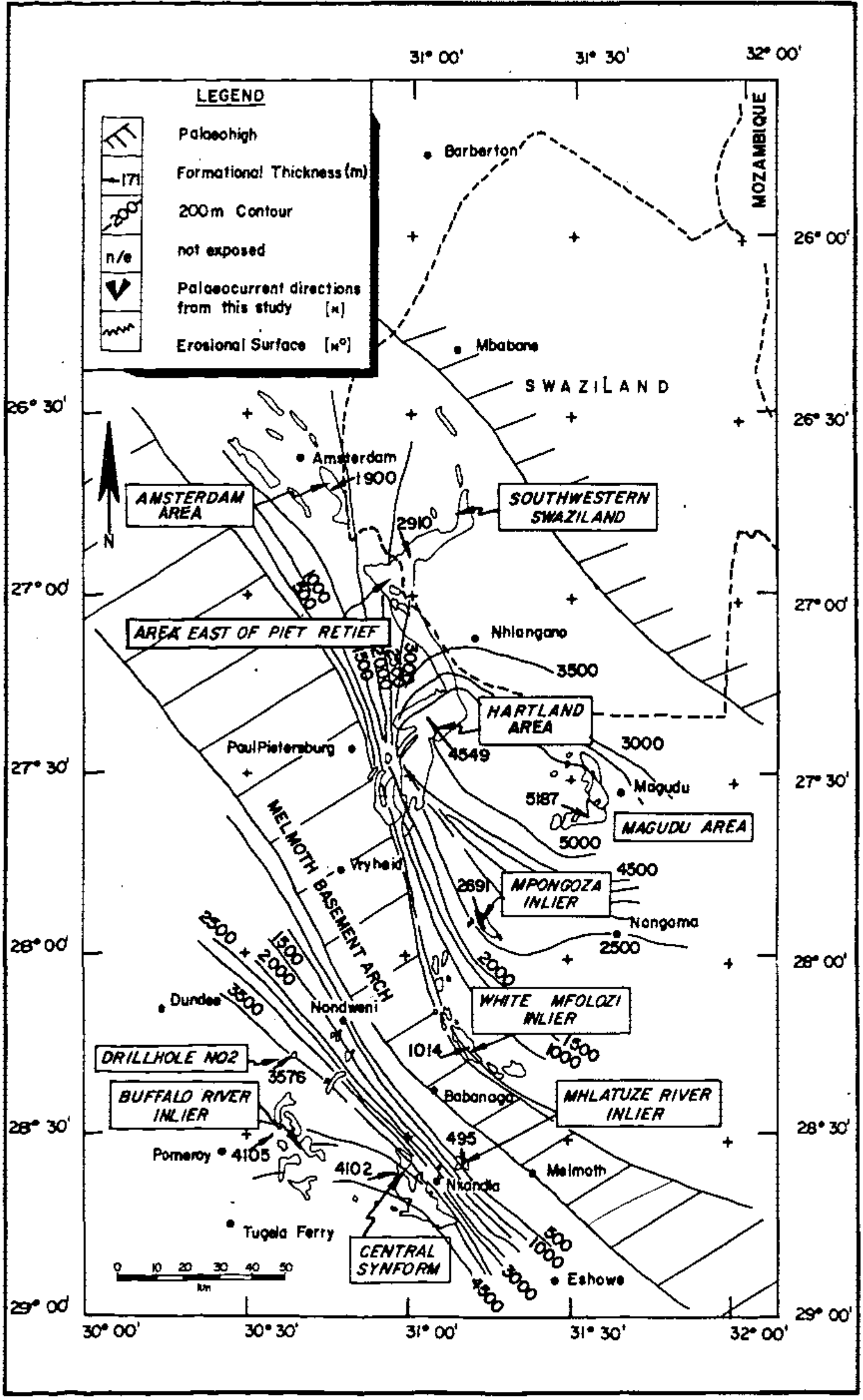
iii. large scale unconformities have ~~removed~~ parts of the succession,

iv. complications due to late-stage intrusives and

v. possible non-deposition of certain formations in certain parts of the Nsuze depobasin.

A composite stratigraphic column for the Nsuze Group is shown in Fig. 2.1, the formational thicknesses being determined from the average of all the correlates of each particular formation. This composite stratigraphic column could be seen as an idealized "complete" Nsuze Group succession. Figure 2.1 also shows the type areas for each lithostratigraphic component in the composite stratigraphic column. The Nzimini Formation has not been incorporated in this composite stratigraphic column due to uncertainties of it's exact stratigraphic position.

The remnant total preserved thicknesses of the Nsuze Group, have been used to construct the remnant total Nsuze isopach contour map (Fig. 3.4). The Nsuze Group has maximum preserved thicknesses in the northern domains, in the Magudu area (5 189 m) and the Hartland basin (4 549 m). Thick accumulations also occur in the southern domain close to Nkandla and in the Buffalo River inlier. It should be emphasized that these recorded Nsuze thicknesses are remnant thicknesses only, the primary Nsuze Group packages



ADDITIONAL LEGEND:

[n] (n = No. of readings).
[n°] (Pre-Mozaan).

FIGURE 3.4 - REMNANT TOTAL NSUZE ISOPACH CONTOUR PLAN

could have been much thicker. The isopach contours are sub-parallel to the Melmoth basement arch, which may therefore in part be a syndepositional structure activated again in post-Pongola times.

CHAPTER 4: DETAILED LITHOSTRATIGRAPHY

4.1 INTRODUCTION

In this chapter each of the formations of the Nsuze Group will be discussed. Each formation has a characteristic type profile after which the formation was named. These type profiles are usually well exposed and are thought to best represent the formation concerned. Discussions of formations will consequently concentrate on the type profiles. Brief reference will also be made to the lateral variations that exist within each formation, referring only to selected features. These lateral variations are critical when assessing palaeoenvironments of deposition and the tectonic evolution of the Nsuze sequence. The formations will be discussed with reference to their distribution, sedimentology (if applicable), petrography, lithostratigraphy and general field characteristics.

4.2 MANTONGA FORMATION

4.2.1 Distribution

The regional outcrop distribution of the dominantly clastic Mantonga Formation is illustrated on Map 1. Five reference profiles were measured through the Mantonga Formation. The formation reaches a maximum known thickness of about 806 m along the Mantonga River profile and a minimum known thickness of 5 m along the White Mfolozi River profile (Fig. 4.1).

4.2.2 Type profile

The type profile is along the Mantonga River in the western part of the Hartland basin (Map 1). A composite panoramic photograph of the profile is given in Fig. 4.2. Along the profile the contact between the underlying granitoid basement and the overlying basal quartzite of the Mantonga Formation is characterised by a 5 m zone of poorly-sorted arkosic sandstone which contains thin (0,1 m - 1 m) mudstone layers. This basal zone, which Matthews and Scharrer (1968) describe as a palaeoregolith derived from the underlaying granitoid basement, fines upwards (Fig. 4.1 (2))..

The arkosic sandstone is overlain by a 70 m thick poorly-sorted unit of pebbly, coarse-grained quartzite with associated matrix-supported conglomerate (unit B in Fig. 4.2). Subrounded to subangular chert and vein quartz pebbles up to 5 cm in diameter typify the conglomerates (Fig. 4.3). Thin shales are sometimes draped over the tops of upward fining facies successions. Poorly-preserved trough and planar cross

General legend applicable to the lithostratigraphic Columns in Figures 4.1, 4.10, 4.25, 4.30, 4.38, and Map 15.

LEGEND

LITHOLOGIES:

☐	NO EXPOSURE
⁘	MAFIC INTRUSIVE
🟥	CONGLOMERATE (± QUARTZITE, WACKE)
🟨	QUARTZITE (± WACKES, GRITSTONE, SHALE)
🟦	CARBONATE (± QUARTZITE)
▤	SHALE (± WACKE, QUARTZITE)
🟧	SILTSTONE / WACKE (± QUARTZITE, SHALE)
⁘	DIAMICTITE (RANGING FROM 'REWORKED' VOLCANIC SANDSTONE TO AN AGGLOMERATE)
🟩	FELSIC VOLCANIC (± TUFF, AGGLOMERATE)
🟪	MAFIC VOLCANIC (± INTERMEDIATE VOLCANICS)
+ + +	GRANITE / GREENSTONE

SYMBOLS

〰	UNCONFORMITY
—F—	FAULT
FIG 32←	THESIS PLATE REFERENCE LOCATION
MHL 2 ←	PETROGRAPHICAL SAMPLE
Q.V	QUARTZ VEIN
⌒	DESICCATION
⌣	TROUGH CROSS BEDDING
////	PLANAR CROSS BEDDING
≡	FLAT BEDDING
LAM	LAMINATED
∧	SYMMETRICAL RIPPLES
⌒	ASYMMETRICAL RIPPLES
→→	HERRINGBONE CROSS BEDDING
∿	CONTORTED
▭	RIP-UP CLAST
Ø	CLAST SIZE
DEW	DEWATERING STRUCTURES
MPC	MEDIUM PEBBLE CONGLOMERATE
SPC	SMALL PEBBLE CONGLOMERATE
LPC	LARGE PEBBLE CONGLOMERATE
P	PEBBLE- SUPPORTED
M	MATRIX SUPPORTED
PL < 1m	PLANAR SET< 1m
Tr < 1m	TROUGH SET< 1m
⋯⋯	GRIT ZONE
UC (C)	UPWARD COARSENING CYCLE
UF (C)	UPWARD FINING CYCLE
X	DIABASE
BAND	BANDING (FLOW)
AGGLOM	AGGLOMERATE
OO	PILLOWS
SPH	SPHEROIDAL STRUCTURES
PLAG	PLAGIOCLASE PHENOCRYSTS
VESS	AMYGDALES / VESICLES
GRAD	GRADATIONAL CONTACT
SHARP	SHARP CONTACT
E.O.H	END OF HOLE
BR	BRECCIA
↓	FINING UPWARD
↑	COARSENING UPWARD
—·—	SILTSTONE
—	SHALE
△	DIAMICTITE

SIZE CLASSIFICATION OF CROSS-BEDDING

CROSS-LAMINATION	<5cm HIGH
VERY SMALL	5-10cm HIGH
SMALL	10-20cm HIGH
MEDIUM	20-50cm HIGH
LARGE	50-100cm HIGH
VERY LARGE	100-200cm HIGH

SIZE CLASSIFICATION OF GRAVEL CLASTS

●	BOULDER	256-2048 mm
⊙	COBBLE	64-256 mm
◎	VERY LARGE PEBBLE	32-64 mm
◎	LARGE PEBBLE	16-32 mm
⊗	MEDIUM PEBBLE	8-16 mm
○	SMALL PEBBLE	4-8 mm
∘	GRANULE / GRIT	2-4 mm

DETAILED LITHOSTRATIGRAPHY OF THE MANTONGA FORMATION SHOWING A TYPE PROFILE AND LATERAL VARIATIONS WITHIN THE NSUZE GROUP BASIN.

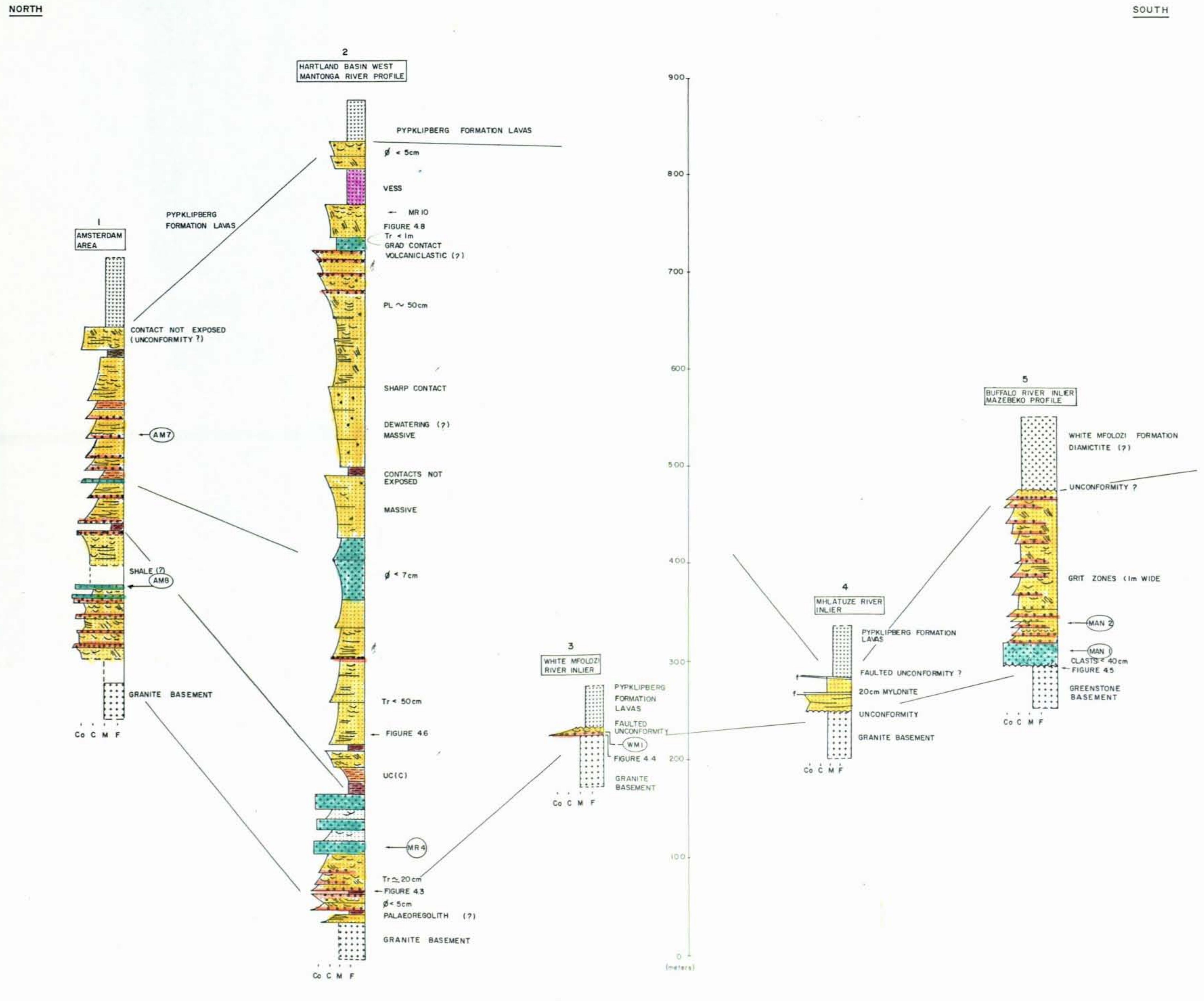


Figure 4.1

FIGURE 4.2 The immediate surrounds of the type profile for the Mantonga Formation. The Mantonga River on the farm Saaiplaas, Western Hartland Basin. Demarcated are approximate facies contacts. (Photograph looking south)

MANTONGA FORMATION FACIES SUBDIVISIONS

J Mixed lava / sediment unit
I Upper diamictite unit
H Coarse to gritty unit
G Massive quartzite unit
F Middle diamictite unit
E Well - stratified unit
D Transgressive shale unit
C Basal diamictite unit
B Conglomeratic unit
A Basement granite

beds are encountered with an average set thickness of 20 cm.

The conglomeratic unit is overlain by a 60 m thick diamictitic unit (unit C in Fig. 4.2). This unit is characterized by immature, green, polymictic diamictite. Clasts in the diamictite are subangular to subrounded and include quartzite, chert, vein quartz, granite and other lithic fragments. The diamictite contains interbeds of coarse-grained immature quartz wackes. Microscopically, the Mantonga Formation diamictites are composed of subrounded quartz grains (≤ 2 mm in diameter) set in a fine-grained, altered green chlorite / sericite matrix (accessory amount of epidote and opaques are present - see Appendix 2). The diamictitic unit is overlain with a sharp contact by a 30 m thick unit of dark green laminated shale. The shale coarsens upwards into a quartz wacke (Fig. 4.1 (2)). This argillaceous unit is referred to as unit D in Fig. 4.2.

The shale unit is overlain by a 160 m thick unit of medium-to-coarse grained well cross-stratified arenites (unit E in Fig. 4.2). The unit displays a characteristic cyclic repetition of sedimentary structures. The coarse basal parts of upward fining cycles are characterized by flat bedding and scattered well-rounded quartzite pebbles. It is succeeded by a subzone noted for small-to-medium scale trough cross-bedding (<50 cm sets) (Fig. 4.7). The top of upward fining cycles are marked by clay drapes. Small scale rip-up clasts are present near the top of the unit. Soft sediment deformation structures are present throughout.

A 60 m thick coarse to very coarse-grained massive, green quartzitic diamictite overlies the well-stratified arenite unit (Unit F in Fig. 4.2). Well-rounded quartz grains are a common constituent of the groundmass of the diamictite. The diamictite coarsens upwards from the base and then fines towards the top (Fig. 4.1 (2)). Scattered angular-to-subangular chert fragments (up to 7 cm in diameter) are abundant towards the top of the lower upward coarsening unit.

The diamictite is overlain by two massive upward coarsening quartzite beds separated by a thin shale (5 m thick). Unit G in Fig. 4.2. The unit is about 150 m thick, with quartz pebbles scattered throughout. It is unclear whether the massive structure of the quartzite is a primary feature or the product of later dewatering processes. The quartzites display spheroidal weathering. The interstitial shale is green in colour and finely laminated.

FIGURE 4.3 Sub-angular-to-subrounded chert and vein quartz pebbles in a matrix-supported conglomerate in the basal portion of the Mantonga Formation. Mantonga River traverse, Western Hartland Basin.

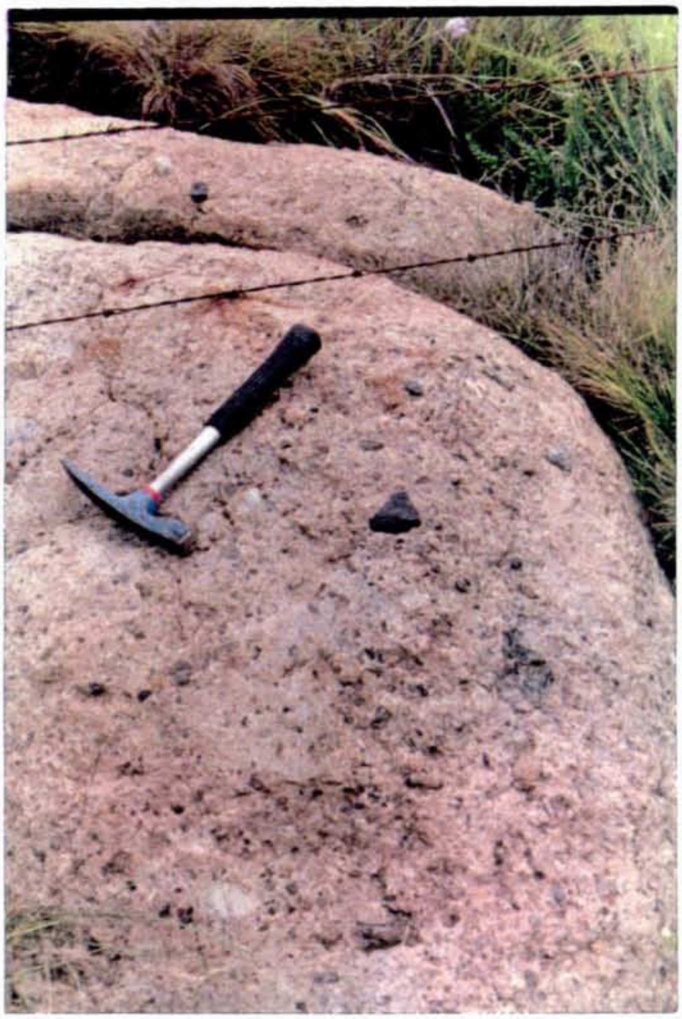


FIGURE 4.4 Thin oligiomictic conglomerate at the base of the Mantonga Formation, overlying granitic basement, White Mfolozi River Inlier.

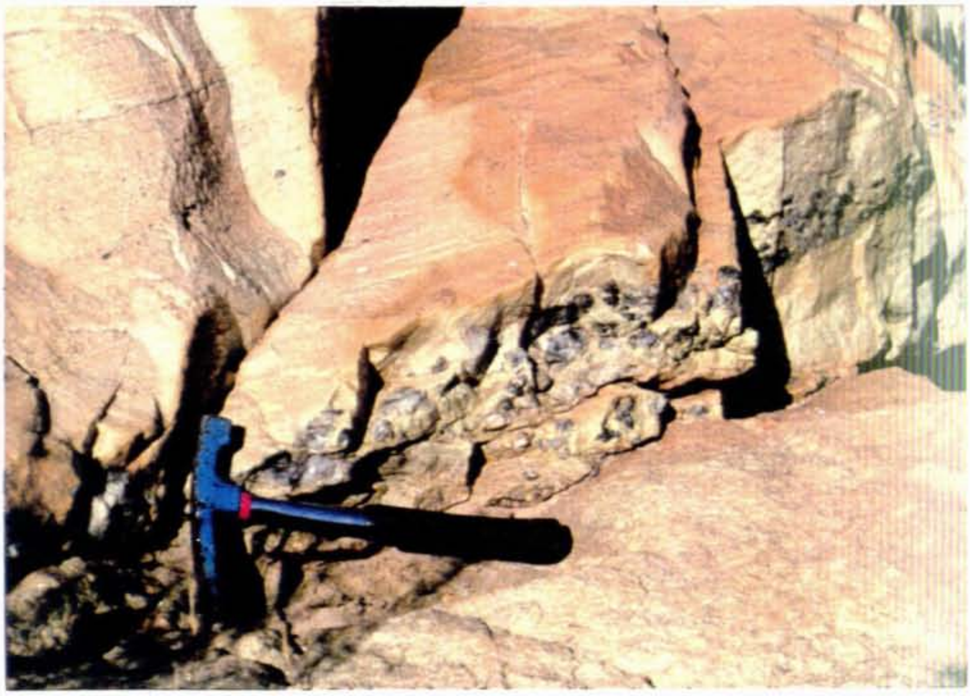


FIGURE 4.5 Immature green diamictite at the base of the Mantonga Formation along the Mazebeko profile, Buffalo River Inlier, overlain by an oligiomictic conglomerate and a unit of coarse quartz arenites. Notice late-stage, high angle cross-cutting normal fault.

FIGURE 4.6 Well-developed flat beds in coarse-grained arenites at the base of a fining-up cycle. Mantonga Formation, Mantonga River traverse, Western Hartland Basin.

The massive quartzite unit is overlain with a sharp contact by flat bedded quartzite. (unit H in Fig. 4.2, see also Fig.4.1). Subordinate medium-scale planar cross-bedding is present. The quartzite coarsens upwards with thin gritstone beds common near the top. The gritty quartzite zone becomes more massive upwards with scattered sub-to-well rounded quartzite pebbles up to 7 cm in diameter. Poorly preserved planar cross bed sets are present with an average height of 50 cm.

The gritty subzone is overlain by a thin (<10 m) diamictite, characterised by polymictic clasts in an immature green chloritic matrix. (unit I in Fig. 4.2). The diamictite grades upwards into a coarse-grained quartzite with a green tinge. This quartzite has well-developed planar and trough cross-beds, with sets up to 1 m high. Scattered sub-rounded to subangular quartzite and vein quartz clasts occur throughout the quartzite. Microscopically the quartzite is poorly-sorted. Highly sericitized subangular potassium feldspar grains are present and may constitute up to 15 percent of the grains (as in sample MR10 shown in Fig. 4.8).

The coarse-grained quartzite is overlain by a 35 m thick unit of amygdaloidal mafic lava which weathers negatively and is poorly exposed (unit J in Fig. 4.2). The lava is succeeded by another zone of coarse-grained quartzite, similar to that below the lava. The quartzite is 20 m thick, immature with well-developed planar and trough cross bedding, with sets in the order of 0,5 - 1,0 m high. Scattered rounded quartzite pebbles (up to 5 cm in diameter) occur throughout the quartzite. This quartzite marks the top of the Mantonga Formation along the Mantonga River traverse and is sharply overlain by mafic lavas of the Pypklipberg Formation.

4.2.3 Lateral Variation

The Mantonga Formation unconformably overlies granite/greenstone basement and is sometimes capped by another unconformity (sometimes faulted). Preserved formation thicknesses are shown in fig. 4.1. A Mantonga Formation isopach contour map in fig. 4.9 illustrates formational thickening away from the Melmoth Basement arch, with maximum preserved accumulation east of Paulpietersburg.

FIGURE 4.7 Small scale trough cross-beds in a medium-grained orthoquartzite. Mantonga Formation. Fugitives Drift traverse. Buffalo River Inlier.

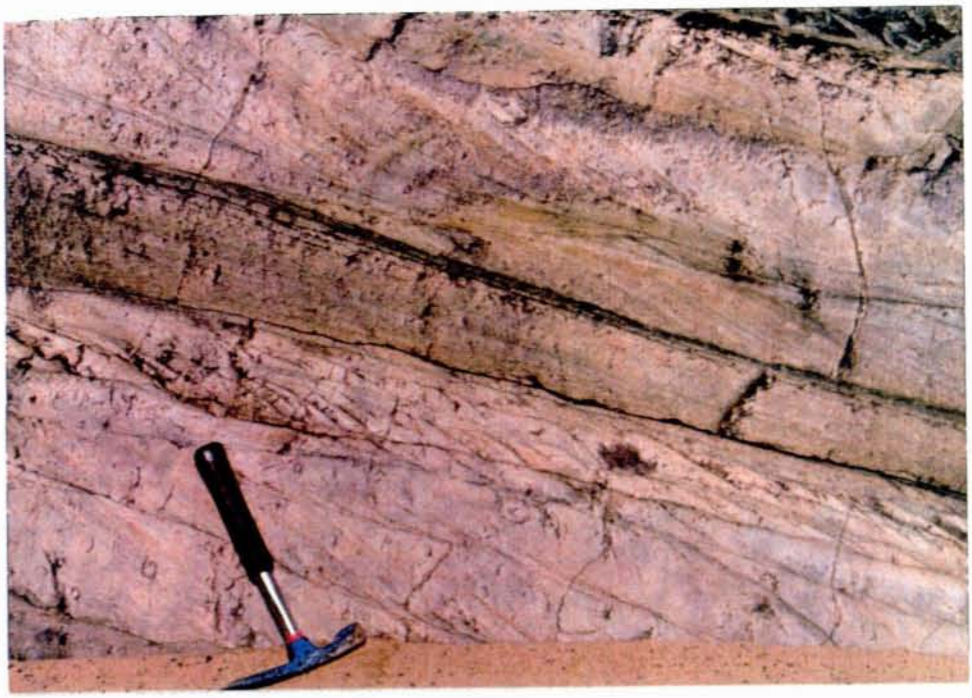


FIGURE 4.8 Photomicrograph showing a sericitized angular K-feldspar grain in contact with rounded quartz grains. Sample MR10. Mantonga Formation. Mantonga River traverse. Western Hartland Basin. X5 magnification. Crossed polars.

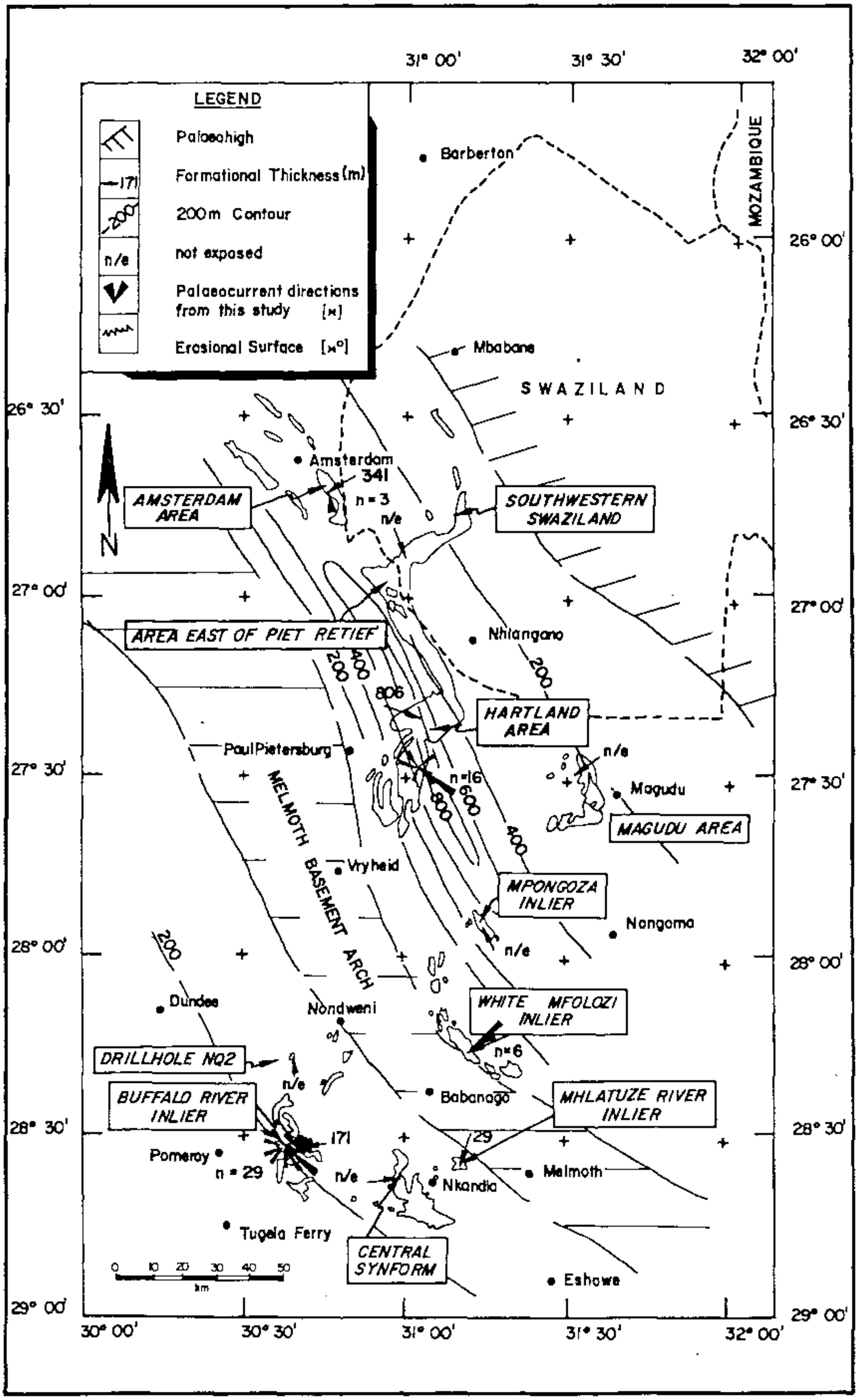
Although the basal portion of the Mantonga Formation along the type profile is entirely siliciclastic, Armstrong (1980) describes a 300 m thick sequence of basaltic volcanics with an irregular, basal sedimentary layer intervening between granitic basement and the overlying sedimentary sequence to the north of the Mantonga River. It is uncertain whether these volcanics are allochthonous (possibly related to the Pypklipberg Formation) or if these lavas reflect an earlier, but volumetrically limited extrusive event.

The coarse-grained often conglomeratic basal unit is typical of the Mantonga Formation throughout the Nsuze basin. Fig. 4.4 illustrates a thin oligomictic conglomerate developed at the base of the Mantonga Formation, overlying granitic basement in the White Mfolozi River inlier (Fig. 4.1 (3)). Similar poorly-sorted, coarse-grained quartzites alternating with thin conglomeratic beds are present in this basal portion along the Amsterdam traverse (Fig. 4.1 (1)).

The base of the Mantonga Formation in the Buffalo River inlier is characterised by a similar diamictite to that described from unit C (Fig. 4.2) in the type profile (Fig. 4.1 (5)). This unit contains clast constituents largely derived from the local greenstone basement (such as altered volcanics and banded cherts). The diamictite is overlain by a poorly developed, 20 cm thick, conglomerate which forms the base of a coarse, gritty quartzite (Fig. 4.5). The flat bedding described in unit E (Fig. 4.2) from the type profile also characterises a similar stratigraphic zone in the Amsterdam profile (Fig. 4.1 (1)).

4.2.4 Palaeocurrent directions

Paleaocurrent data available from the Mantonga Formation are summarized in Fig. 4.9 (corrected for tectonic dip). A wide dispersion of palaeoflow directions is indicated, with the bulk of the flow directions ranging from northeast to southeast. Watchorn and Armstrong (1980) record similar trends and ascribe the angular discordance in directional data from trough forsets with that from planar crossbeds to the lateral growth of transverse bars. The major palaeoflow directions are parallel-to-subparallel to the isopach contours in Fig. 4.9, with only the White Mfolozi River inlier data showing a unimodal trend perpendicularly away from the Melmoth Basement arch.



ADDITIONAL LEGEND:

[x] (n = No. of readings).
[x°] (Pre-Mozaan).

FIGURE 4.9 - MANTONGA FORMATION ISOPACH CONTOUR PLAN, SHOWING PALAEOCURRENT DIRECTIONS.

4.3 PYPKLIPBERG FORMATION

4.3.1 Distribution

The regional outcrop distribution of the volcanic Pypklipberg Formation of the Bivane Subgroup is illustrated on Map 1. The Pypklipberg Formation is best developed in the western part of the Hartland basin. It thins towards the south (Fig. 4.15).

4.3.2 Type Profile

The type profile was measured along the Mantonga and White River profiles in the western part of the Hartland basin. Poor outcrop and exposure, coupled with extreme alteration (Chapter 5) of the volcanic rocks, made field volcanic hand specimen identification practically impossible without geochemical backup. These factors militated against detailed field descriptions of the volcanic rocks. Considering that this study is not petrographic in emphasis, descriptions of the volcanic rocks given are only general in nature.

The lavas are green-grey in colour, aphanitic and often very amygdaloidal or vessicular. Sometimes the lavas are so vessicular that they resemble pumice. The vesicular zones are usually thin (<5 m thick), indicating some form of differential vessiculation in the lava flow. These highly vesicular (the gas-formed cavities are sometimes filled with quartz or calcite) zones grade into non-amygdaloidal / vesicular zones (Fig. 4.10). Amygdales are up to 10 cm in diameter. It seems likely that Pypklipberg lavas were mainly extruded under subaerial conditions, although pillow structures were encountered near the base of the type profile along the Mantonga River and also in the White Mfolozi River inlier (also recorded by Matthews, 1967) indicating some subaqueous extrusion.

Poor exposure usually prevents the determination of the dimensions and shapes of single lava flows. However, near the base of the type profile, flow contacts could be observed, with individual flows about 10 m thick. Fig. 4.11 illustrates a flow contact where a highly amygdaloidal flow top is succeeded by another flow with pipe amygdales at its base. Armstrong (1980) reports a complex interfingering relationship amongst flows of both similar and different compositions in this lava sequence. Within the type profile, and also in the Amsterdam profile (Fig. 4.10) at approximately the same stratigraphic level in the lower half of the Pypklipberg Formation, a sequence of lavas is

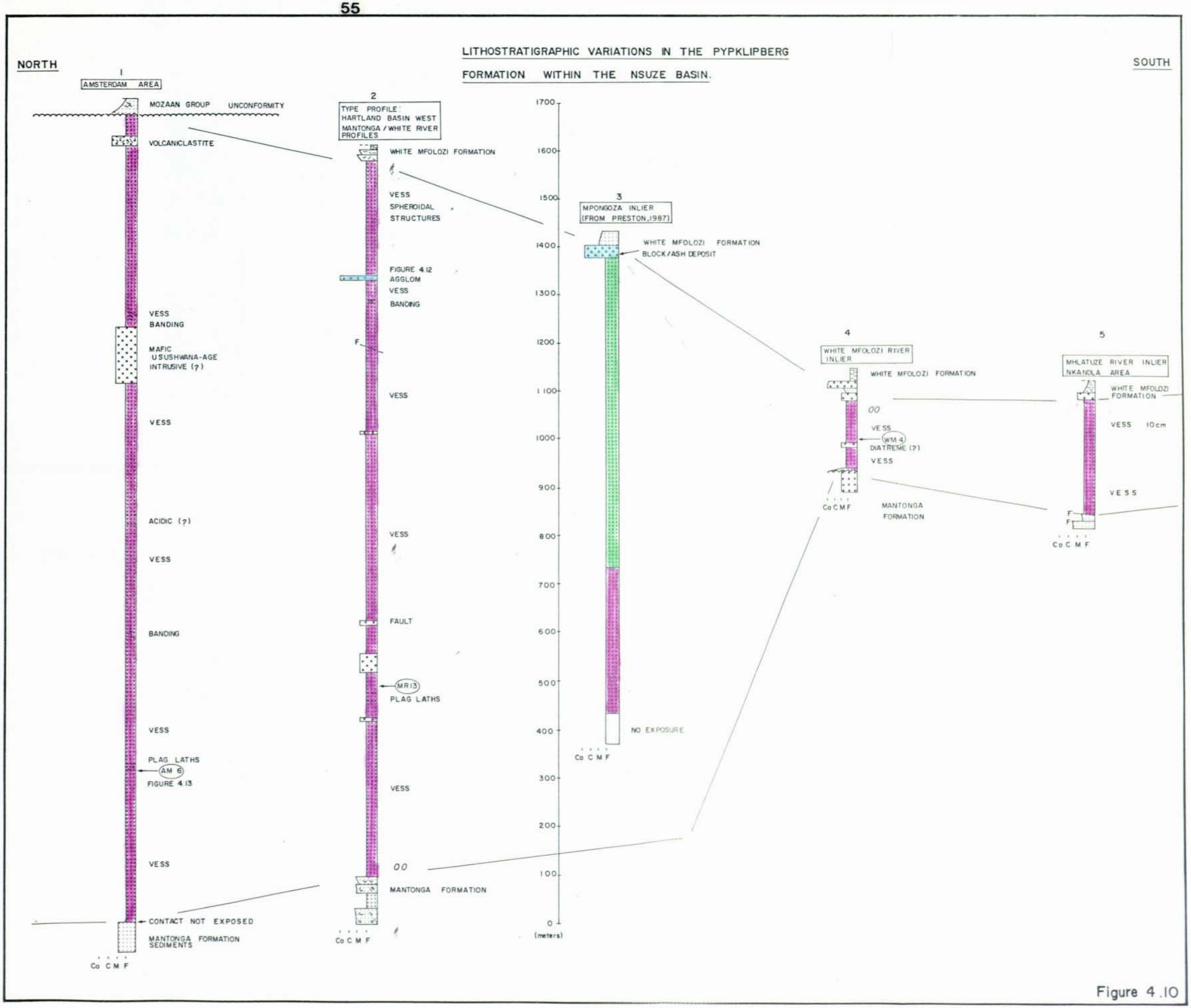

LITHOSTRATIGRAPHIC VARIATIONS IN THE PYPKLIPBERG FORMATION WITHIN THE NSUZE BASIN.
NORTH
SOUTH
1
AMSTERDAM AREA
MOZAAN GROUP
UNCONFORMITY
VOLCANICLASTITE
VESS
BANDING
MAFIC USUSHWANA-AGE INTRUSIVE (?)
VESS
ACIDIC (?)
VESS
BANDING
VESS
PLAG LATHS
AM 6
FIGURE 4.13
VESS
CONTACT NOT EXPOSED
MANTONGA FORMATION SEDIMENTS
Co C M F
2
TYPE PROFILE: HARTLAND BASIN WEST
MANTONGA / WHITE RIVER PROFILES
WHITE MFOLOZI FORMATION
VESS
SPHEROIDAL STRUCTURES
FIGURE 4.12
AGGLOM
VESS
BANDING
F
VESS
VESS
FAULT
MR 13
PLAG LATHS
VESS
00
MANTONGA FORMATION
Co C M F
1700
1600
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
(meters)
3
MPONGOZA INLIER (FROM PRESTON, 1987)
WHITE MFOLOZI FORMATION
BLOCK/ASH DEPOSIT
NO EXPOSURE
Co C M F
4
WHITE MFOLOZI RIVER INLIER
WHITE MFOLOZI FORMATION
00
VESS
WM 4
DIATREME (?)
VESS
MANTONGA FORMATION
Co C M F
5
MHLATUZE RIVER INLIER NKANDLA AREA
WHITE MFOLOZI FORMATION
VESS 10cm
VESS
F
F
Co C M F

Figure 4.10

FIGURE 4.11 Flow contact in basaltic lavas near the base of the Pypklipberg Formation. Mantonga River traverse. Western Hartland Basin notice highly amygdaloidal flow top overlain by succeeding flow with pipe amygdales at base.

FIGURE 4.12 Subrounded-to-subangular heterolithologic fragments defining a lava agglomerate within a lava flow. Pypklipberg Formation. White River traverse. Western Hartland Basin.

developed containing prominent plagioclase phenocrysts (Fig. 4.14). These phenocrystic zones are also developed to a lesser degree near the top of the White River traverse. The plagioclase phenocrysts are typically between 1 cm and 3 cm in length and arranged randomly or poorly aligned throughout the zone. The phenocrystic zones are up to 20 m thick. Microscopically the phenocrysts are situated in a saussuritized trachytic groundmass with abundant cross-cutting epidote (Fig. 4.13). The plagioclase phenocrysts are commonly partially replaced by chlorite.

Armstrong (1980) uses the non-genetic descriptive term "spheroidal structure" to describe various subspherical structures observed within Pypklipberg lavas. Although their origin is somewhat uncertain, Armstrong (1980) suggests that these structures owe their origin to silicate liquid immiscibility. Near the top of the White River traverse, on the farm Umkoonyan, large silica-rich "spheroids" are preserved in an altered mafic matrix (Fig. 4.10 (2)). These "spheroids" are up to 1 m in diameter and subrounded in shape. These unusual structures occur intermittently over a zone of 300 m thick. Spheroidal structures are more common in the type profile than elsewhere.

Along the White River traverse, 220 m below the top of the the Pypklipberg Formation, an 8 m thick agglomerate bed is present (Fig. 4.10 (2)). It is composed of subangular-to-subrounded heterolithologic fragments (<40 cm size) within a lava flow (Fig. 4.12). However, most of the fragments are composed of different types of lava with occasional quartzite clasts.

The fragments display a poorly defined preferred orientation. Flow banding is seen in some lavas. These impart an irregular laminated fabric to a lava flow and are an indicator of primary lava flow directions. Sometimes vesicles and amygdales are elongated parallel to the flow banding orientation.

Petrographic descriptions of Pypklipberg Formation samples MR13, WM6 and AM6 (stratigraphic positions shown on Fig. 4.10) are given in Appendix 2. The lavas are highly altered with high proportions of chlorite, epidote, sericite and even calcite developed at the expense of the primary plagioclase and tremolite / actinolite.

FIGURE 4.13 Photomicrograph showing a plagioclase phenocryst in relation to a highly altered trachytic groundmass. X10 magnification, crossed polars. Sample AM6. Plagioclase phenocryst zone. Pypklipberg Formation. Amsterdam area.

FIGURE 4.14 Semi-aligned plagioclase phenocrysts within a plagioclase phenocryst zone along the White River traverse. Pypklipberg Formation. Western Hartland Basin.

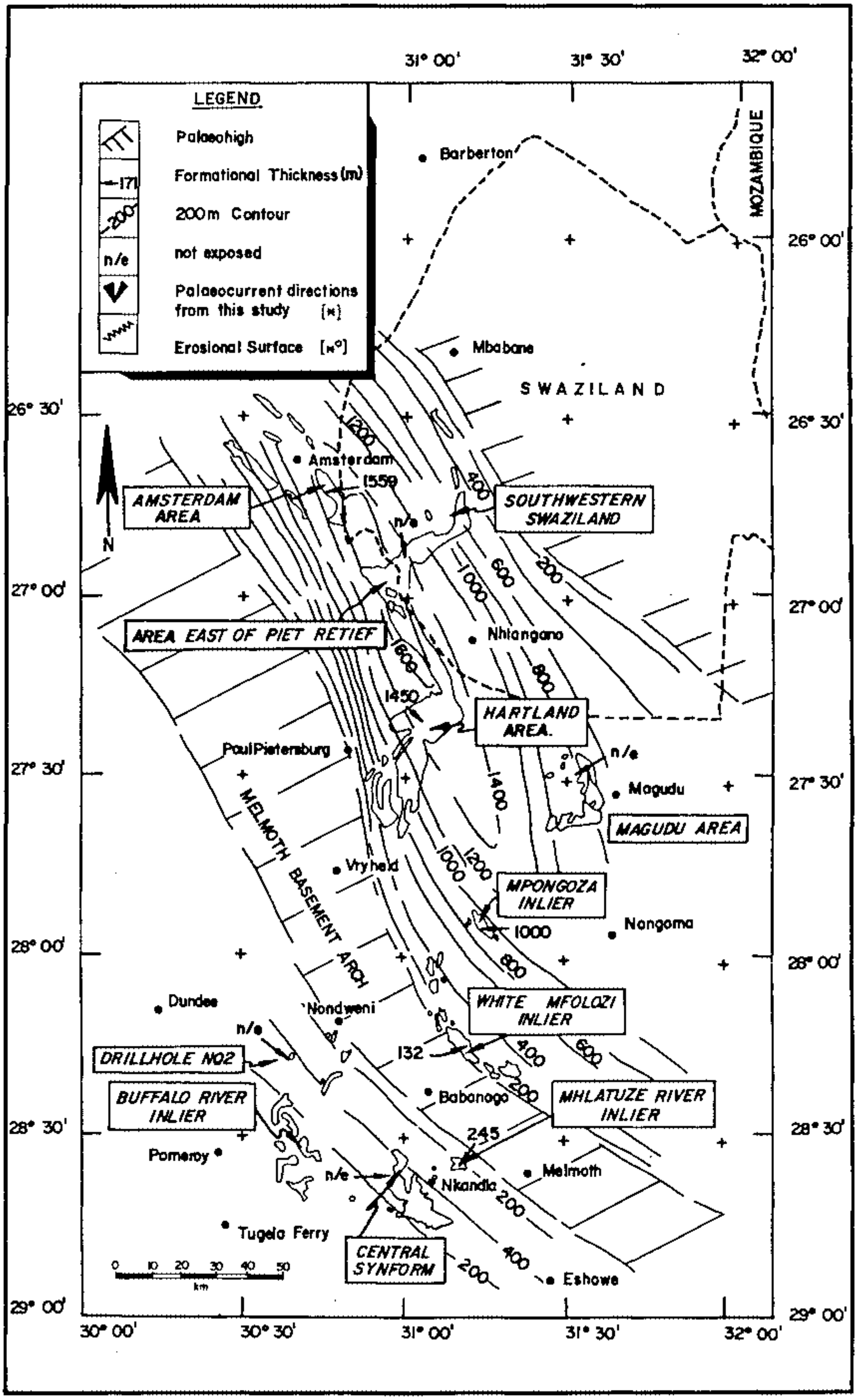
4.3.3 Lateral variation

The Pypklipberg Formation is best developed in the western part of the Hartland basin and in the Amsterdam area in the northern domains, with thinner accumulations preserved south of the Melmoth Basement arch (Fig. 4.15). The Pypklipberg Formation is not preserved in the Buffalo River inlier, where the White Mfolozi Formation is superimposed onto the Mantonga Formation. In the Pypklipberg Formation isopach map in Fig. 4.15, a rapid formational thickening away from the northwest-trending Melmoth Basement arch and from the inferred palaeohigh in southwestern Swaziland can be seen. The five lithostratigraphic correlates of the Pypklipberg Formation traversed in this study are illustrated in Fig. 4.10.

Excellent petrographic studies of the Pypklipberg Formation volcanic rocks were made by Preston (1987) in the Mpongoza inlier, by Armstrong (1980) in the western part of the Hartland basin and by van Vuuren (1965) in the Amsterdam area.

In addition to lava flows of varying composition, various volcaniclastites occur within the Pypklipberg Formation. The term "volcaniclastite" includes a variety of fragmental volcanic rocks of different origin, emplaced in various physiographic environments or mixed with non-volcanic particles in various proportions (Fisher, 1966). Armstrong (1980) describes various examples of volcaniclastites from the Nsuze Group in the western part of the Hartland basin. These include pyroclastites, epiclastites, autoclastites and hyaloclastites (these terms refer to different mechanisms of fragmentation). The most common type of volcaniclastite is pyroclastite, which is a term used to describe rocks derived directly from explosive volcanic processes. Pyroclastite is mainly represented by airfall tuffs, but also include some agglomeratic phases in the Pypklipberg Formation (Watchorn and Armstrong, 1980).

In contrast to the type profile, the Pypklipberg Formation in the Mpongoza inlier is composed of a lower mafic lava unit, with a thick upper felsic volcanic unit (Preston, 1987). The latter includes tuffs and agglomerates. The volcaniclastite/pyroclastite component of the Pypklipberg Formation in the Mpongoza inlier far exceeds that of other Pypklipberg Formation in other areas (Fig. 4.10). A feature of the volcaniclastites described by Armstrong (1980), in the western part of the Hartland basin, is their discontinuity.



ADDITIONAL LEGEND:

[x] (n = No. of readings).
[x°] (Pre - Mozaan).
era (eroded away)

FIGURE 4.15 - PYPKLIPBERG FORMATION ISOPACH CONTOUR PLAN

The Pypklipberg Formation is intruded by a large volume of post-Pongola age mafic intrusives. The majority of these intrusives are coarse-grained diabase sills and dykes which, when fine-grained, can easily be misidentified as a non-amygdaloidal lava. A 110 m thick coarse-grained ancient mafic intrusive of probable Usushwana-age was intersected along the Amsterdam traverse (Fig. 4.10 (1)). Quartz veins, often in swarms, cross-cut Pypklipberg volcanics.

4.4 WHITE MFOLOZI FORMATION

4.4.1 Distribution

The regional outcrop distribution of the largely sedimentary White Mfolozi Formation is illustrated in Map 1. Although this Formation is recognised throughout the Nsuze basin, the thickest accumulations are developed south of the Melmoth basement arch, with the thickest sequences preserved in the Buffalo River inlier (tectonically fragmented) and in the Central Synform in the Nkandla district. The White Mfolozi Formation is a key formation in the Nsuze Group; its wide distribution between two volcanic formations (viz. the Pypklipberg and Agatha Formations) allows assessment of the facies variations within the formation.

Seven regional lithostratigraphic profiles from the White Mfolozi Formation are presented and compared in Map 15. Five of those profiles were constructed during this study, while two were compiled from existing work i.e. from Preston (1987) and Hatfield (1990).

4.4.2 Type Profile:

The type profile of the White Mfolozi Formation is in the White Mfolozi River inlier (Map 15 (4)). Faulting has duplicated Nsuze Group strata along the White Mfolozi River traverse. The profile shown in map 15 (4) has been corrected for fault duplication and the estimated thickness of 480 m is much thinner than previous estimates in the area by Matthews, (1967).

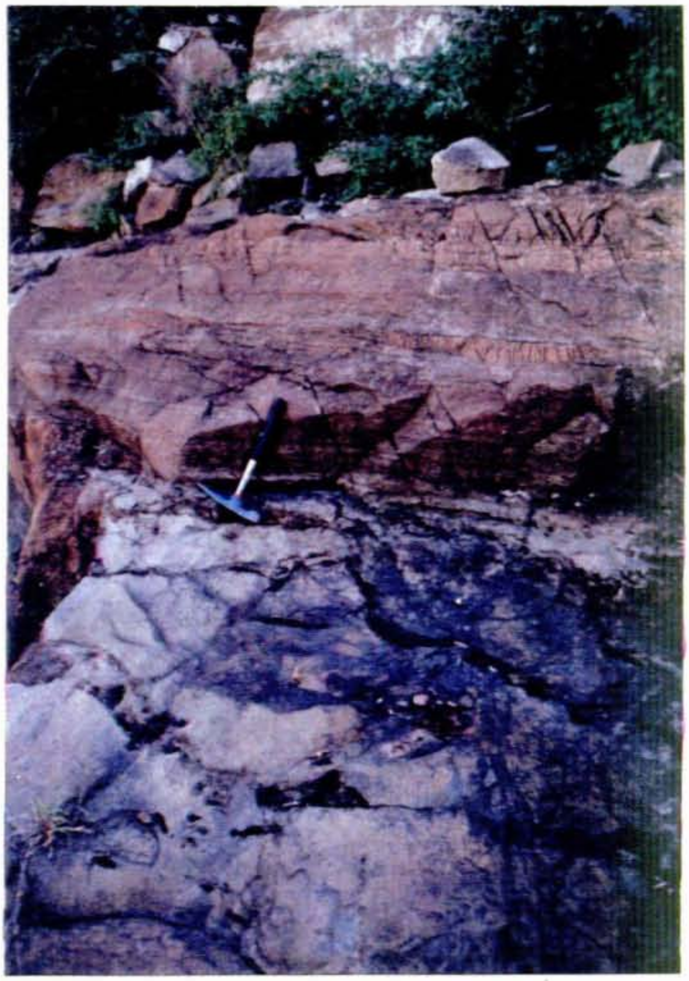
The base of the formation is formed by a poorly exposed quartzite, intruded at its base by a 15 m thick coarse-grained dolerite sill. Overlying the basal quartzite is a 14 m thick diamictite. The diamictite is composed of angular to subrounded clasts supported by a green coloured chloritic muddy matrix. The clasts are composed of vein quartz, quartzite, chert, shale, granite and altered volcanic fragments. Maximum clast sizes observed are on the order of 20 cm. Quartz sand grains are dispersed in the matrix.

The diamictite is overlain with a sharp contact by a 65 m thick unit of finely-laminated green-grey shale. Lenticles and wavy laminae of light grey siltstone are present. The lower 35 m of the unit is composed essentially of shale which passes upwards into interlaminated shale and siltstone, with siltstone dominant near the top. The basal shale is characterised by small scale ripple-drift cross-lamination (Matthews, 1967), while the upper siltstone is characterised by asymmetrical and symmetrical ripple marks (Fig. 4.16). The unit has a banded appearance due to alternating dark grey shale and light green siltstone laminae.

The shale/siltstone unit grades upwards into a quartzite with quartz arenitic composition. The quartzite is some 165 m thick. It is composed of a lower quartzite unit, a middle alternating arenite/argillite/carbonate-rich arenite unit and an upper quartzite unit. The lower 10 m of the lower quartzite unit is represented by a quartz wacke which coarsens up into a well-bedded medium to coarse-grained quartzite. The lower quartzite is grey-green in colour with prominent trough cross bedding (15 cm - 150 cm high) and planar cross bedding (10 -30 cm high). The quartzite is composed of stacked fining upward facies successions. These successions are on the order of 2 - 5 m thick with gritty units at their base. Rare herringbone cross-bedding sets are present in this quartzite. Thin (< 20 cm thick) black shale interlayers occur in the quartzite. In addition to gritty layers, black shale rip-up clasts are encountered in the coarse-grained quartzite.

FIGURE 4.16 Symmetrical ripple marks from the lower shale / siltstone unit of the White Mfolozi Formation, White Mfolozi Rive Inlier.

FIGURE 4.17 Sharp contact between a dark green sandy diamictite and the overlaying basal dolomitic portion of the Chobeni member. White Mfolozi Formation. White Mfolozi River Inlier.



The middle portion of the quartzite unit is composed of stacked fining upward facies successions comprising alternating quartzite-siltstone-shale with carbonate-bearing arenites near the top. There are gradational contacts between these lithologies. The quartzites are dark grey, medium-grained and contain angular dark silicified shale rip-up clasts. Asymmetrical and symmetrical ripple marks are common in the siltstone beds with small scale trough cross-bedding preserved in the quartzite. Desiccation cracks, infilled with quartzite, are present in the argillites. The upper carbonate-bearing beds are up to 2 m thick, dark grey in colour with small scale (5 cm) trough cross-bedding developed. Oolites are sometimes present in the carbonate-bearing beds.

The upper 40 m of the quartzite is similar in composition to the lower quartzite unit. It is grey-green in colour and well-bedded. Bands of gritstone are common. Medium to fine-grained quartzite alternates with very coarse-grained quartzite. Planar and trough cross-beds are developed with sets usually 10 - 50 cm high. Flat bedding is well developed. Angular silicified shale rip-up clasts, up to 20 cm long, are common.

The quartzite is overlain with a sharp contact by a 14 m thick massive dark grey sandy diamictite. Matthews (1967) refers to the diamictite as a tuffaceous sandstone. This diamictite displays poorly-defined flat stratification. It is composed of subrounded to angular quartz grains, lithic (volcanic?) and potassium feldspar grains set in a fine-grained chloritic matrix. The matrix is partially replaced by carbonate. In some cases carbonate clasts, up to 10 cm in diameter, are present. The sandy diamictite is overlain with a sharp contact by the Chobeni carbonate member (Fig. 4.17). The carbonate unit is 20 m thick in the type profile and comprises a succession of quartzitic dolomite, dolomitic quartzite, carbonate-bearing siltstone and partly silicified light-grey dolomite. The dolomites can be subdivided into two types viz. a silicified pisolitic variety and an aphanitic to fine-grained variety.

According to Beukes and Lowe (1989) the top 4,5 m of the Chobeni Member in the type profile is stromatolitic and crops out continuously for about 250 m. Beukes and Lowe (1989) recognise four lithofacies in the stromatolitic zone, their distribution being controlled by specific palaeoenvironment factors. These lithofacies include:

a) stratiform stromatolites,

b) rippled dolarenite / mudstone,

c) biohermal stromatolites (Fig. 4.18) and

d) channelled dolarenite.

The Chobeni Member is overlain by an 8 m thick dark grey very fine-grained carbonate-bearing siliceous wackestone. The wackestone is flat bedded with the carbonate component decreasing upwards in the unit. This unit contains poorly-preserved dessiccation cracks.

The very fine-grained wackestone is overlain with a sharp contact by a 75 m thick coarse-grained well-stratified quartzite. This unit is well cross-bedded with troughs typically in the order of 10 - 40 cm high. The quartzite is usually green-grey in colour with occasional shale partings. Silicified shale rip-up clasts are common, usually aligned along forsets of cross-bedding sets. The shale clasts may be up to 20 cm long. Gritstone lags become more prominent towards the top of the unit.

The quartzite is overlain with a sharp contact by a massive diamictite. Angular clasts in the sandy to muddy matrix are composed of rounded quartz grains (< 5 mm diameter), subrounded to subangular potassium feldspar grains and angular to subangular lithic fragments. Microscopically, the matrix contains sericite, chlorite, quartz and carbonate (Fig. 4.22).

The upper diamictite unit is in turn overlain with a sharp contact by some 27 m of cross-stratified coarse to very coarse-grained quartzite with a composition similar to that of the quartzite immediately below the diamictite. Gritty layers, composed of subrounded chert and quartz grains, are common. Trough cross-bed sets are in the order of 10 - 70 cm high. The quartzite is overlain by a carbonate-cemented coarse-grained arenite which grades and fines upwards into an aphanitic blue grey dolomite unit. This carbonate unit is 10 m thick and, unlike the Chobeni Member carbonate assemblage, it is non-stromatolitic.

FIGURE 4.18 Chertified conical stromatolites from the biohermal stromatolite facies, Chobeni member. White Mfolozi Formation. White Mfolozi River Inlier.

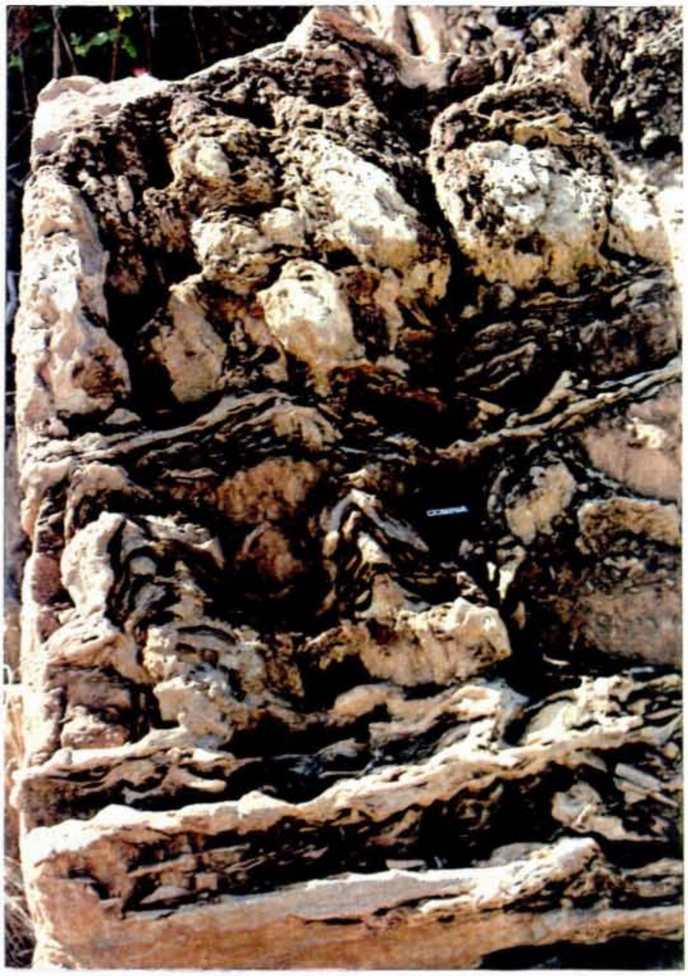


FIGURE 4.19 Dolomitic quartzite from the Chobeni Member. White Mfolozi Formation. Nkandla Central Synform. (Note deformation in one bed).

The dolomite unit grades upwards into a medium to coarse grained dark grey, carbonate-bearing quartzite with poorly-developed flat bedding and trough cross-bedding. The quartzite is overlain by a banded mudstone unit of 5 m thickness which is interlayered with thin fine-grained quartzite layers and the occasional thin (about 10 cm wide) carbonate-rich horizon. Abundant mudcracks are present in this unit.

The top of the White Mfolozi Formation in the type profile comprises a dark grey quartzite, which is coarse-grained at the base but fines upwards into a medium to fine grained quartzite. The quartzite becomes more mature towards the top. Trough cross-bed sets are up to 120 cm high, while planar sets are up to 50 cm high. The White Mfolozi Formation is unconformably overlain by Agatha Formation lavas. The upper quartzite bed of the White Mfolozi Formation is truncated over a short distance along strike by the unconformity.

4.4.3 Lateral variation

The White Mfolozi Formation reaches maximum thickness south of the Melmoth basement arch. This southerly accumulation is illustrated on the isopach map for the White Mfolozi Formation (Fig. 4.24). Some uncertainty exists concerning White Mfolozi Formation thickness in the northern domain, due to the White Mfolozi Formation being partially unexposed (as in the Magudu area) and partially eroded away by pre-Mozaan Group erosive events (as in the Amsterdam area). The thickness of the preserved White Mfolozi Formation in the Nkandla Central Syncline far exceeds that of the type profile (1 300 m preserved with lower contact not exposed). The Central Synform sequence is a monotonous, highly arenaceous sequence probably originating in a different environment to that of the type profile. A regional panoramic overview of the arenaceous sequence of the White Mfolozi Formation in the Central Synform is shown in Fig. 4.21. This formation is referred to as the Mdelange Formation by SACS (1980) and by Groenewald (1984).

At this stage a brief reference to the lateral variation of diagnostic units in the White Mfolozi Formation will be made (as illustrated in Map 15). The thick volcanically-derived diamictite in the Buffalo River inlier could be a proximal correlated the basal diamictite in the White Mfolozi Formation type profile, or it could be an independant unit (the Nzimini Formation). The lower shale / siltstone unit of the type profile is exposed in the faulted lower portion of the White Mfolozi Formation in the Mhlatuze River inlier, with this unit not exposed in the Central Syncline (Map 15). A sandy diamictite, similar to that found below the Chobeni Member along the type profile, is found in the Buffalo River inlier and in the Central Syncline, making this diamictite / carbonate succession a regional marker bed. In the Buffalo River inlier the sandy diamictite is conformably overlain by a 40 m thick amygdaloidal lava unit (Buffelshoek traverse).

Matthews (1967) estimates the carbonate-bearing lithologies (the Chobeni Member) in the White Mfolozi River valley to have a localized strike extension of less than 4 km. However the Chobeni Member has now been proven to have a regional distribution (with its volcanically-derived base) in the southern and central domains (excluding the Mhlatuze River inlier and the Mpongoza inlier).

Stromatolitic carbonates are only present in the Chobeni Member of the type profile and of the Buffalo River inlier. The Chobeni Member of the Central Syncline comprises largely dolomitic quartzites. Fig. 4.19 shows a stratified dolomitic quartzite from the Central Syncline. Overlying the Chobeni Member in the Sifula traverse, Buffalo River inlier, is a medium-grained quartzite with well-preserved quartzite-filled desiccation cracks similar to the one in the type profile (Fig. 4.20).

The upper diamictite in the type profile has a correlate in the Mangeni traverse in the Buffalo River inlier. This diamictite possibly also correlates with the one present at the top of the White Mfolozi Formation along the Nkemba profile in the western part of the Hartland basin (Map 15 (6)).

FIGURE 4.20 Quartz-filled desiccation cracks in a medium-grained quartzite immediately overlaying the Chobeni member, White Mfolozi Formation. Sifula traverse, Buffalo River Inlier.

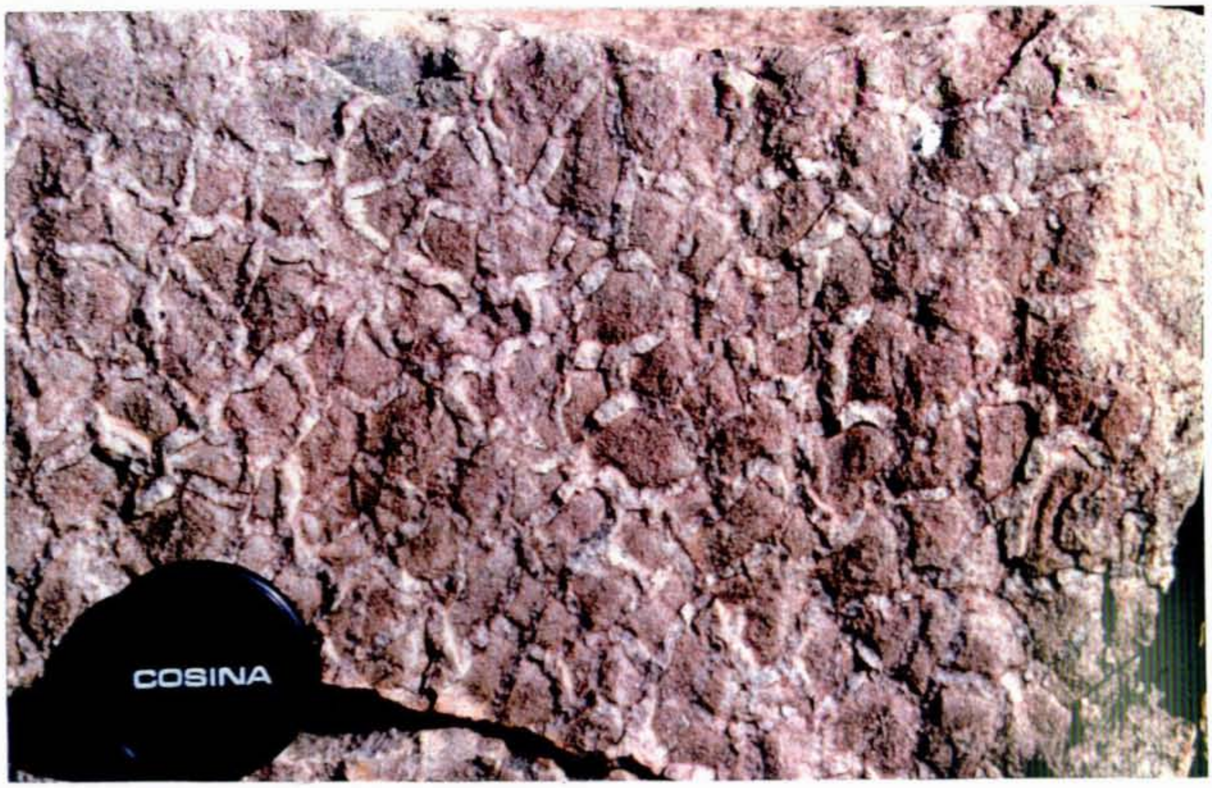


FIGURE 4.21 Regional panoramic overview of the arenaceous White Mfolozi Formation. Nkandla Central synform. Cross-cut by the Nsuze River valley, looking south.

FIGURE 4.22 Photomicrograph showing subrounded quartz and K-feldspar fragments in an altered sericitic groundmass in a volcaniclastic diamictite. Sample WM15. White Mfolozi Formation. White Mfolozi River Inlier. X5 magnification, crossed polars.

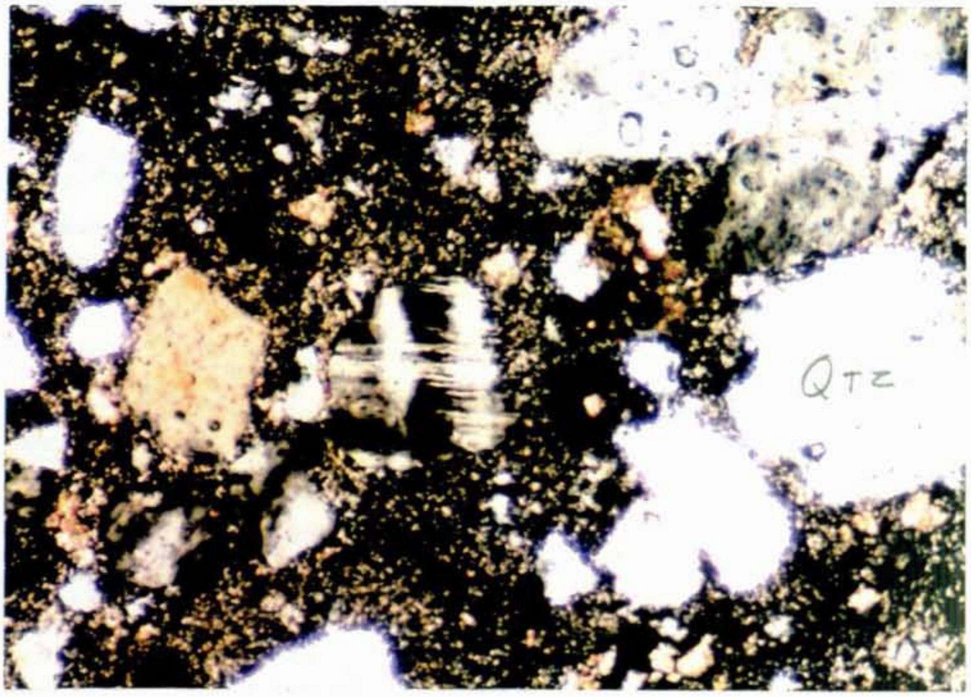
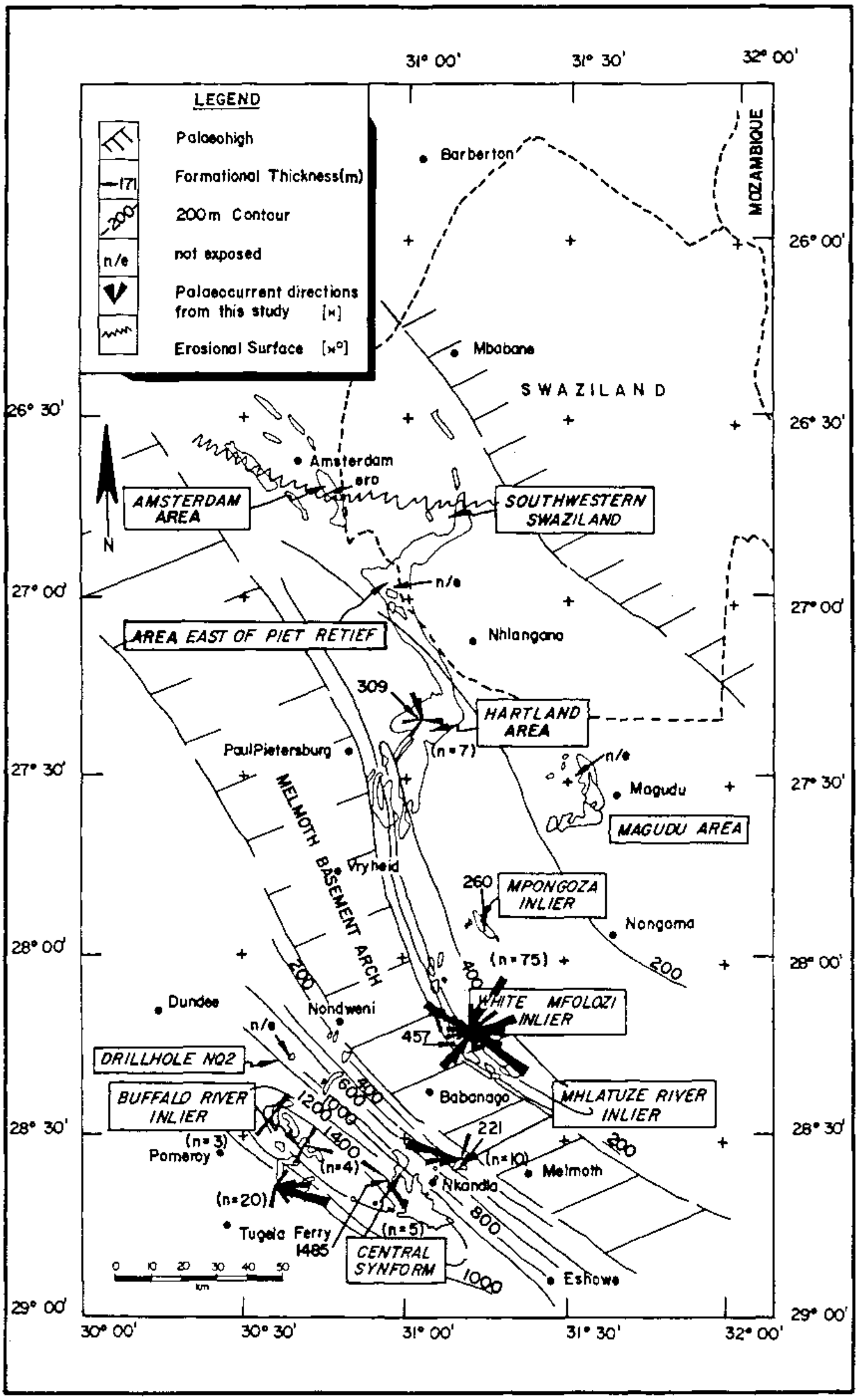


FIGURE 4.23 The angular unconformity between the dark green Agatha Formation lava (below) and orthoquartzite of the overlaying Mozaan Group. White Mfolozi River Inlier.



ADDITIONAL LEGEND:

[×] (n = No. of readings).
[×°] (Pre-Mozaan).
ero (eroded away)

FIGURE 4.24 - WHITE MFOLOZI FORMATION ISOPACH CONTOUR PLAN, SHOWING PALAEOCURRENT DIRECTIONS.

4.5.2 Type Profile:

Each measured profile of the Agatha Formation has unique characteristics with no individual profile adequately demonstrating all of the characteristics of the formation. The 'type' profile in the western part of the Hartland basin will be briefly discussed here, while in the next section (4.5.3) other profiles will be referred to in an attempt to demonstrate the full spectrum of lateral variations in the Agatha Formation (Fig. 4.25).

The type profile of the Agatha Formation in the western part of the Hartland basin consists of a 1 800 m thick sequence of basalt, basaltic andesite, andesite, dacite and rhyolite (refer to Map 3 a) with similar petrographical and field characteristics to that described for the underlying Pypklipberg Formation. The lavas are usually amygdaloidal, with quartz-filled amygdales often having irregular shapes being up to 20 cm in diameter. The lavas are fine-grained to aphanitic, usually dark green with occasional silicified leucocratic zones.

It is difficult to distinguish between the various lava-types in the field. Petrographically the amygdales are filled with quartz ± epidote ± chlorite. The plagioclase porphyries are usually partially to totally replaced by epidote ± chlorite (Fig. 4.27), with the trachytic groundmass comprising plagioclase, epidote, sericite and chlorite ± quartz (see Appendix 2 - samples AS2, WR1). The Ntambo Member is situated some 350 m from the top of the Agatha Formation along the type profile. In Fig. 3 a, it can be seen that the Ntambo Member is seemingly discontinuous; this is probably a function of variable deposition and poor present outcrop. Along the Balmoral traverse, the Ntambo Member comprises largely dark green, non-magnetic well-stratified argillites, which Armstrong (1980) interprets as reworked tuffs and other volcaniclastics. The 20 m thick Ntambo Member is capped by a thin discontinuous lava agglomerate, comprising elliptical altered lava clasts (≤ 5 cm) in a medium-grained siliceous matrix.

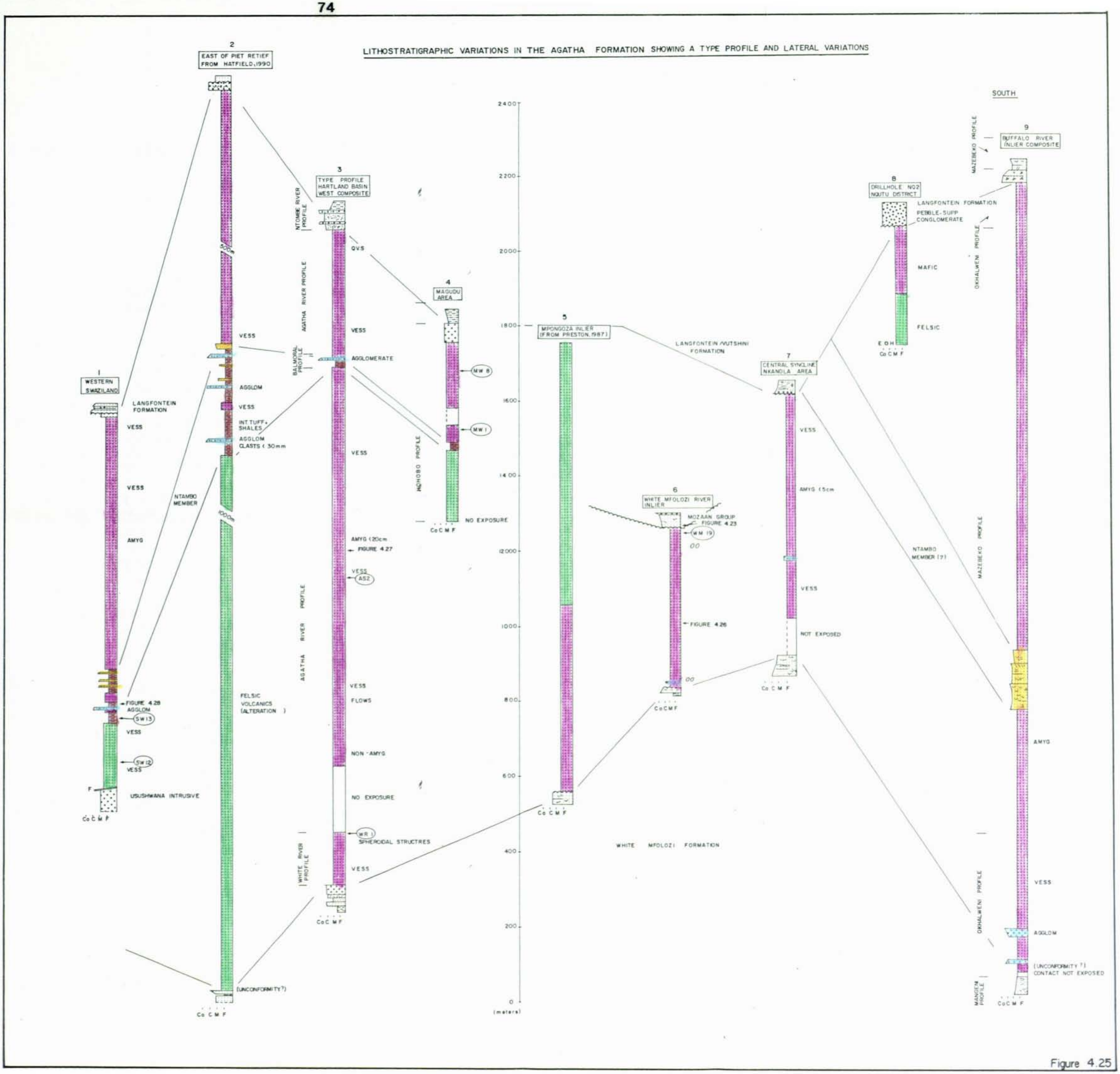

LITHOSTRATIGRAPHIC VARIATIONS IN THE AGATHA FORMATION SHOWING A TYPE PROFILE AND LATERAL VARIATIONS

Figure 4.25

4.5.3 Lateral Variation

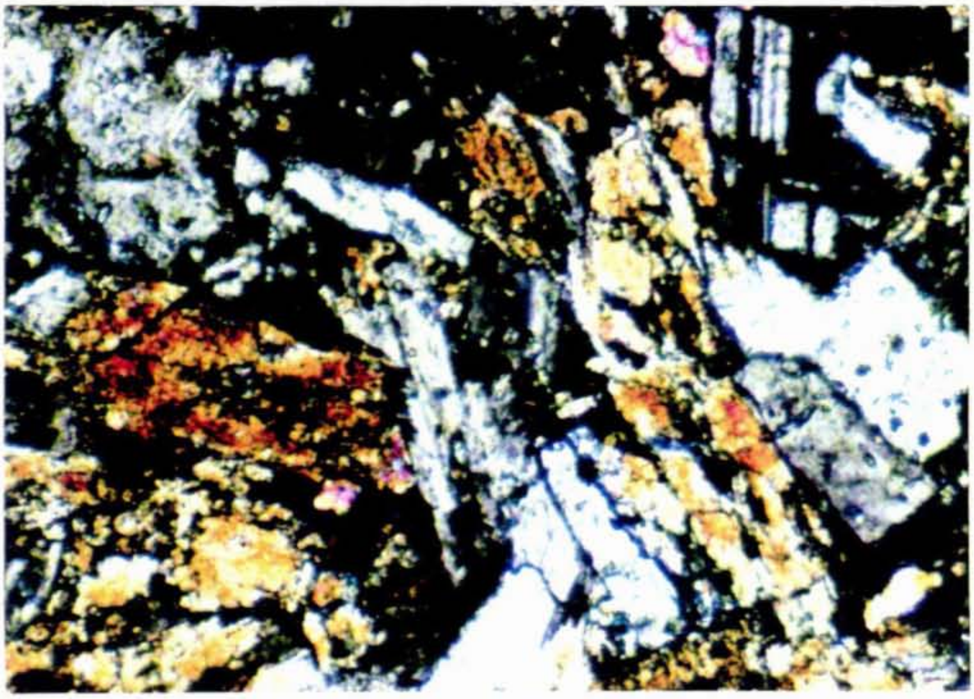
Nine lithostratigraphic correlates of the Agatha Formation are illustrated in simplified columns in Fig. 4.25, of which seven of these were traversed in this study. Preserved and exposed Agatha Formation stratigraphic thicknesses have been used to compile the interpretative Agatha Formation isopach map in Fig. 4.29. Thick accumulations of Agatha Formation lavas (and minor clastics) are preserved in the northern and southern domains of the Nsuze basin. The Agatha Formation in the Amsterdam area was removed by erosion, prior to Mozaan Group deposition.

As demonstrated on a Zr / TiO_2 vs Nb / Y diagram (after Winchester and Floyd, 1977) in Fig. 6.4, chapter 6), Agatha Formation lavas have a geochemical signature ranging from basalt to rhyolite. The Agatha Formation lavas in the White Mfolozi River Inlier are 420 m thick and are unconformably bound at the base by the White Mfolozi Formation clastics and unconformably overlain by the Mozaan Group (Fig. 4.23). The lavas are light to dark green and generally amygdaloidal. Different flows can be distinguished by the development of densely amygdaloidal zones near their bases and tops. Fig. 4.26 illustrates such a dense quartz-filled amygdaloidal zone. Amygdales do not exceed 3 cm in diameter. Pillow structures are developed near the base and near the top of the formation. The pillow structures are elongate, up to 1 m wide and typically have chilled margins which are slightly darker than the normal lava colour. These pillows are also closely associated with flow top breccias. Matthews (1967) records a 0 - 40 m thick wedge of green and grey quartzite about 360 m above the base of the lavas in the N.E. corner of the farm Welgevonden 527 (for location, see Map 8 a) in the White Mfolozi Inlier. Linström (1987) documents inliers of ferruginous shale with intercalated quartzite (the Taka Formation) in the Taka River Valley nearby, which he places above the Agatha Formation lavas. The Taka Formation could however also be a greenstone correlate. If the Taka Formation does overlie the Agatha Formation, it would correlate with the base of the clastic Langfontein/Vutshini Formation.

The Agatha Formation correlate in the Nkandla Central Syncline is 679 m thick, situated unconformably below the clastic Vutshini Formation (Fig. 4.25 (7)). The green, fine to medium-grained lavas commonly contain quartz, calcite epidote or chlorite-filled amygdales. The amygdales are usually < 5 cm in diameter. No pillow structures were observed in these lavas. These

FIGURE 4.26 Dense quartz-filled amygdaloidal zone demarcating a lava flow contact in Agatha Formation lavas, White Mfolozi River Inlier.

FIGURE 4.27 Photomicrograph of plagioclase crystals being partially replaced by high birefringence epidote ± chlorite in an altered mafic lava. Agatha Formation, Agatha River profile. Sample AS2. X10 magnification. Crossed polars.



lavas are sometimes silicified, which causes irregularly-shaped leucocratic banding and patches. Groenewald (1984) reports lava flow thicknesses ranging from 1 - 16 m here with an average of 2 - 4 m. Groenewald (1984) describes basaltic andesites, andesites and dacites from this volcanic package, with a predominance of the andesitic lava variety. An unusual, possible altered volcaniclastite horizon (5 m wide) was observed about 250 m above the base of the formation.

Preston (1987) reports that the upper volcanic unit in the Mpongoza Inlier (Agatha Formation correlate overlying White Mfolozi Formation tidalites) is similar to the lower volcanic unit there (Pypklipberg Formation), comprising mafic lavas unconformably overlain by felsic volcaniclastic rocks with a minimum stratigraphic thickness of 1 160 m. The lower mafic lavas are green-grey to dark grey in colour, aphanitic, and display various concentrations of randomly dispersed quartz-filled amygdales. Preston (1987) also recognises a vertical zonation of the mafic lavas from an amygdaloidal base, overlain by an amygdale-poor central zone which is in turn overlain by an amygdale-rich zone. The felsic sub-unit represents the youngest eruptive phase exposed in the Mpongoza Inlier, consisting primarily of ash tuffs, dust tuffs and a block and ash deposit (Preston, 1987). This sub-unit has been simplistically subdivided into a lithophysae-rich ignimbrite zone overlain by a lithophysae-poor ignimbrite zone (see Map 9 a) after Preston, 1987 in Hunter and Wilson, 1988).

The composite profile for the Agatha Formation from the Buffalo River inlier is interpreted to be in excess of 2 000 m thick (Fig. 4.25 (9)). Duplicated packages of Agatha Formation lavas occupy a large portion of the central part of the Archaean Buffalo River Inlier exposures (refer Map 12 a). The Agatha Formation here consists primarily of mafic amygdaloidal lavas with a significant 150 m thick arenite member near the middle of the Formation. The quartzite member, has been tentatively linked with the Ntambo Member (which is more argillaceous in the northern domain). This arenite is a well-stratified, medium to coarse-grained, grey-white arenite. Dixon (1991) reports mafic lava flows here to be 20 m thick on average. Dixon (1991) also reports a mafic lava mineralogy here of:- amphibole - plagioclase - chlorite - epidote ± quartz. Two agglomerate horizons (maximum 20 m wide) are developed near the base of the Agatha Formation along the Okhalweni profile (Fig. 4.25 (9)). These agglomerates comprise subrounded to subangular clasts of volcanic fragments, quartzite and vein quartz set in a green chloritic matrix with rounded quartz grains in it. Dixon (1991) documents tuffaceous lithologies and pillow-shaped structures from these lavas.

Drillhole NQ2, in the Nqutu district, (location on Fig. 4.29) intersected a 325 m thick volcanic pile unconformably beneath a thick conglomeratic clastic wedge (a proximal correlate of the Langfontein / Vutshini Formation). This Agatha Formation correlate has an upper 180 m thick mafic amygdaloidal portion and a lower felsic portion. This felsic to mafic transition upwards is common in the northern domain, where these two lava types are separated by the Ntambo Member. The clastic Ntambo Member is not developed in NQ2.

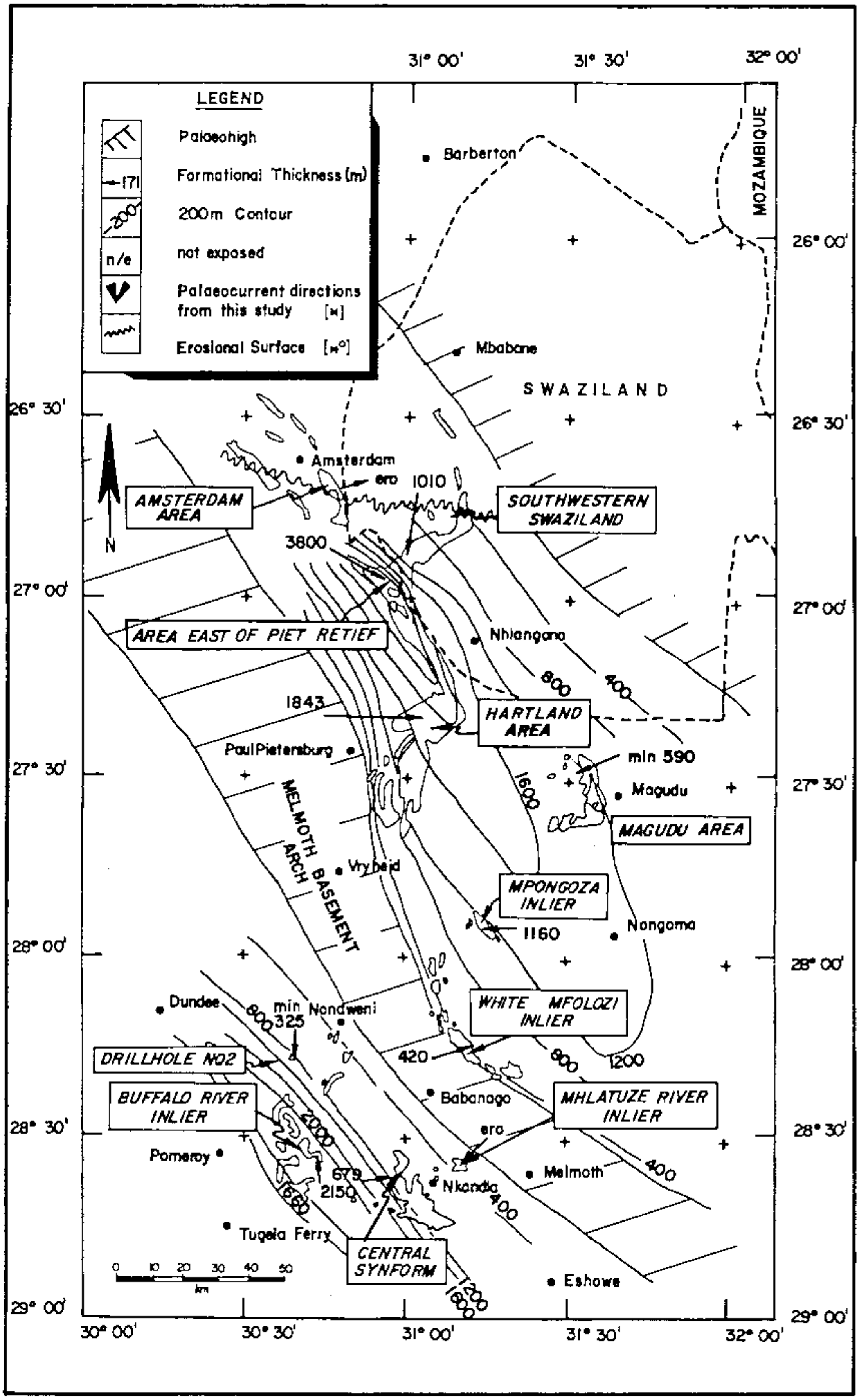
In the Magudu area, a 450 m thick package of metavolcanics is exposed beneath a metasedimentary package correlatable with the Langfontein / Vutshini Formation. The upper metamafic lavas here are separated from the lower metafelsic lavas by a 10 m thick unit of metapelites, which correlate with the Ntambo Member. The Ntambo Member consists of muscovite-garnet-andalusite schists, with andalusite crystals up to 2 cm in size. No obvious volcanics could be detected associated with these metapelites. The mafic metalavas are highly altered, silicified in particular. Petrographically, primary hornblende has largely been altered, primary plagioclase phenocrysts are now highly poikilitic, and poikilitic garnet crystals are up to 5 mm in size. Magudu area petrography and mineralogy is discussed in more detail in chapter 5 (also see Appendix 2). Linström (1987 a) interprets these altered volcanics as intermediate to acid tuffs.

In Western Swaziland a 1 000 m thick Agatha Formation profile was traversed (Fig. 4.25 (1)). A package of mafic lavas separated from underlying felsic lavas by a 140 m argillaceous Ntambo Member is unconformably overlain by Langfontein Formation clastics. The felsic volcanics are cut by coarse-grained Usushwana Complex intrusives. The mafic volcanics are separated from the overlying clastics by a thin unit of brown-weathering coarse-grained volcanic arenite, which is an immature sediment with volcanic fragments in the matrix. The mafic lavas are fine-grained to aphanitic, often highly amygdaloidal. The Ntambo Member is highly argillaceous comprising brown / grey laminated phyllites, which are sometimes ferruginous. Some thin interbedded arenites and pyrophyllitic schists are interbedded with the phyllites. Highly amygdaloidal altered lavas are also associated with

FIGURE 4.28 Subrounded-to-subangular chert clasts (silicified lava) in a siliceous, green groundmass. Ntambo Member agglomerate. Western Swaziland traverse.

the Ntambo Member here. A thin lower lava unit here is capped by an unusual agglomerate with chert and amygdaloidal lava sub-rounded clasts (in a green siliceous groundmass). Fig. 4.28 illustrates this agglomerate. The lower felsic volcanic is grey and porphyritic, with dense layers of vesicles and amygdales (< 20 m in size). Petrographically plagioclase phenocrysts are up to 7 mm in length and highly saussuritized to sericite, quartz and epidote. The felsics have been silicified, with a late phase of chloritization also being evident (sample SW12).

East of Piet Retief, Hatfield (1990) documented an approximately 4 000 m thick volcano-sedimentary package, which correlates well with the Agatha Formation. The main features of this package are illustrated in Fig. 4.25 (2). The base of the package is a succession of felsic volcanics within which are a number of tuffaceous beds commonly interlayered with subordinate clastic sedimentary layers (Hatfield, 1990). The felsites are overlain by a persistent pyroclastic - volcanosedimentary unit (Ntambo Member), which is in turn overlain by a sequence of intermediate volcanics. The felsic basal part comprises mainly felsic lavas, which are mostly rhyolitic, with minor dacitic flows. Hatfield (1990) describes the petrography and field characteristics of these felsics in his thesis. Hatfield (1990) also recognises that his volcano-sedimentary unit (Ntambo Member) continues into southwestern Swaziland. The Ntambo Member east of Piet Retief is up to 300 m thick, comprising chiefly interbedded tuffs and shales with associated thin, discontinuous lenses of amygdaloidal intermediate volcanics, agglomerates, pyrophyllite schist and felsic volcanics. Hatfield (1990) notices that the pyroclastic - volcano - sedimentary unit (Ntambo Member) in southwestern Swaziland contains a higher proportion of sedimentary lithologies than east of Piet Retief. The overlying intermediate volcanic unit consists of a sequence of andesitic lavas, with minor intercalations of basaltic andesites and basalts. These lavas are grey-green in colour and commonly amygdaloidal. Hatfield (1990) reports a unit of pyroclastic breccias, tuffs, agglomerates with intercalated sedimentary layers at the top of the intermediate volcanic unit, this could correlate with the overlaying Roodewal Member at the base of the Langfontein Formation.



ADDITIONAL LEGEND:

[n] (n = No. of readings).
[n°] (Pre-Mozaan).
ero (eroded away)

FIGURE 4.29 - AGATHA FORMATION ISOPACH CONTOUR MAP

4.6 LANGFONTEIN/VUTSHINI FORMATION

4.6.1 Distribution

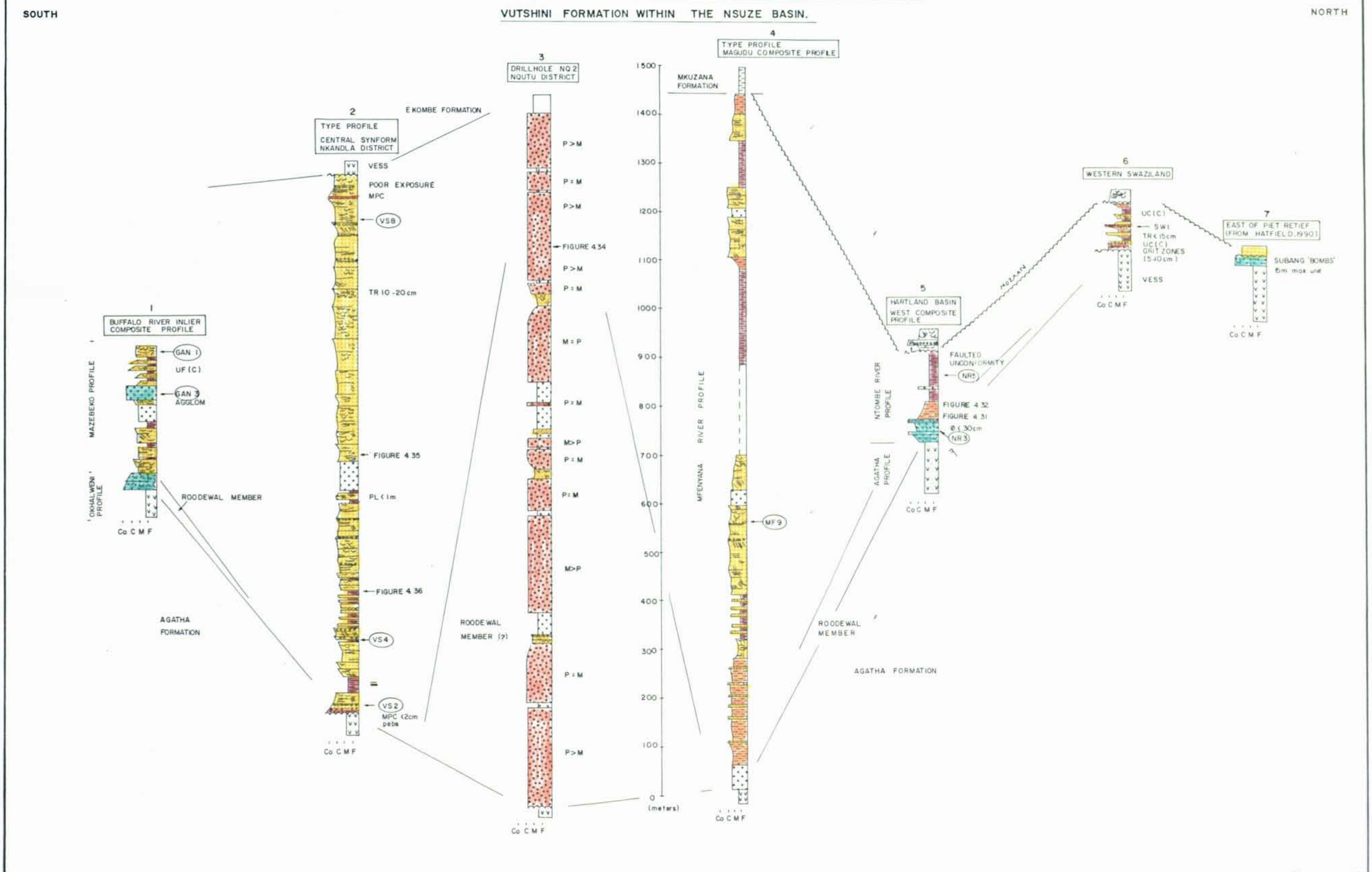
The Mfenyana Subgroup comprises the two uppermost sedimentary formations of the Nsuze Group viz. the lower largely arenaceous Langfontein / Vutshini Formation (abbreviated as the L/V Formation in this section) and the upper largely argillaceous Mkuzane Formation. The Mkuzane Formation is only preserved in the Magudu area. Correlates of the L/V Formation have been recognised throughout the Nsuze basin, six of which were traversed in this study. The regional distribution of the L/V Formation is shown in Map 1.

Although the preserved L/V Formation thicknesses have largely been influenced by the Mozaan Group unconformity, the thickest accumulations are preserved in the northern domain centred around the Magudu area (Fig. 4.30). Thinner, but substantial, accumulations are also preserved in the southern domain (1 435 m in drillhole NQ2).

4.6.2 Type Profile

Each correlate of the L/V Formation is a unique clastic succession reflecting widely contrasting depoenvironments after Agatha Formation volcanism. The profiles in the Magudu area and in the Nkandla Central Synform are thought to lithologically best represent this highly variable formation. These two profiles will be discussed briefly in this section, with the other profiles in Fig. 4.30 referred to in the following section (4.6.3).

The L/V Formation correlate along the Mfenyana River traverse, Magudu area is a 1 375 m thick succession of alternating arenaceous and argillaceous metasediments (Fig. 4.30 (4)). The L/V Formation comprises quartz-sericite schist, quartzite, andalusite schist and minor andalusite-cordierite schist. These sediments have been thermally contact-metamorphosed by local post-Pongola-age granite intrusives (see Map 7 a) for intrusive granite distribution). The quartzite is coarse-to-medium-grained, grey-green in colour, usually with poorly-preserved cross-stratification. These often form prominent resistant ridges. Occasionally the quartzite is highly immature and gritty, sometimes hosting scattered rounded quartzite pebbles (Fig. 4.33). The andalusite and sericite schist weathers negatively and are commonly intercalated. The andalusite schist is grey in colour and highly fissile. Schist becomes more prominent higher in the profile. Andalusite porphyroblasts are up to 2 cm in size.



DETAILED LITHOSTRATIGRAPHIC VARIATIONS IN THE LANGFONTEIN/ VUTSHINI FORMATION WITHIN THE NSUZE BASIN.

Figure 4.30

The petrography of the metasediments of the Mfenyana Subgroup are discussed further in chapter 5. The schist is interbedded with thin quartzite layers (<2 m wide) towards the base of the formation.

The L/V-correlate in the Nkandla Central Syncline is a 1 100 m thick sedimentary sequence unconformably overlying the Agatha lavas (Fig. 4.30 (2)). The sedimentary sequence contains three different rock units. The lower 450 m comprises of alternating shale and quartzite, the middle 500 m comprises of well-stratified immature quartzite with rare shale intercalations, and the upper part of the coarse-grained quartzite which is sometimes gritty and conglomeratic. The total package is overlain by lavas of the Ekombe Formation (the Mkuzane Formation is not preserved or was not developed here). The base of the lower part of the L/V Formation consists of a single pebble (≤ 2 cm) oligomictic quartz pebble conglomerate. The lower part consists essentially of multiple ferruginous laminated (occasionally weakly magnetic) shale-quartzite intercalations (Fig. 4.36 shows a sharp shale - quartzite contact). The quartzite is usually grey-white in colour, medium-to-coarse grained with well-preserved planar and trough cross-bed sets (sets usually < 0,8m high). Sometimes thin small-pebble conglomerates, mark the contacts between shale and overlying quartzite beds. Petrographically the quartzite is poorly-sorted and composed of inequigranular subangular to subrounded quartz grains with interstitial mica minerals.

The middle part of the L/V formation in the Central synform consists of grey-white, coarse-grained, mature quartzite with well-preserved cross-stratification. Trough cross-bed sets are usually 10-20 cm high, while planar cross-bedding sets are 30-80 cm in high (Fig. 4.35). Flat bedding is also present. Occasional discontinuous thin gritstone layers are present. Rare, thin argillaceous intercalations are sometimes developed between quartzite beds. The upper part of the L/V Formation is also well-stratified, but is coarser than the middle part. Well-developed gritstone zones are developed, with a single 30 cm-thick small to medium pebble conglomerate developed near the top of the formation. This conglomerate is auriferous, oligomictic and has pebbles 0,5 - 1 cm in diameter. Petrographically the host quartzite is poorly-sorted, composed of highly strained subrounded, medium to very coarse quartz grains.

FIGURE 4.31 Well-rounded very large pebble, pebble-supported volcanic pebble conglomerate. Roodewal member. Langfontein / Vutshini Formation. Ntombe River traverse. Western Hartland Basin.

FIGURE 4.32 Well-laminated siltstones (reworked tuffaceous ash?) from the Langfontein / Vutshini Formation, Ntombe River profile. Western Hartland Basin.

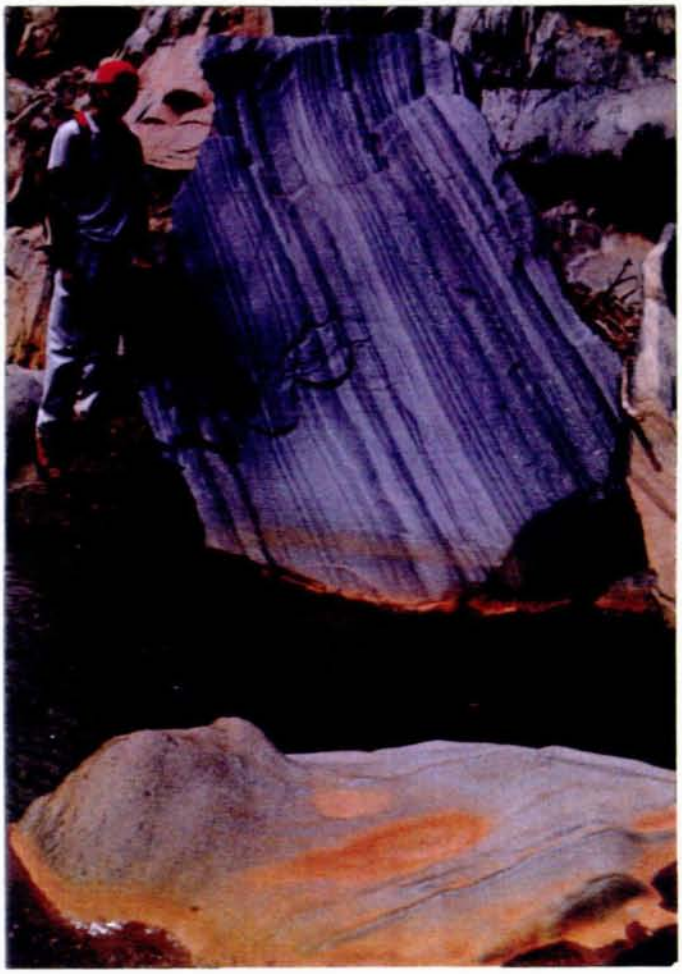


FIGURE 4.33 Well-rounded quartzite pebble in a massive coarse-grained quartzite. Langfontein / Vutshini Formation. Hohobo River traverse. Maqudu area.

FIGURE 4.34 Polymictic, medium-to-large pebble, pebble-supported conglomerate from the Roodewal member, Langfontein / Vutshini Formation. Drillhole NQ2, Nqutu district.

Groenewald (1984) has recognised similar sedimentary rocks to that described above in the lower part of the L/V formation here in the Gem-Vuleka Syncline, which is a structural syncline just north of the Central Syncline in the Nkandla area (refer to Map 10 a and Fig. 3.1).

4.6.3 Lateral Variation

Lateral variations in the L/V Formation are shown in Fig. 4.30. Preserved stratigraphic thicknesses of the Mfenyana Subgroup, as measured throughout the Nsuze basin, have been used to construct an isopach map plan (Fig. 4.37). Maximum preserved thicknesses are present in the Magudu area and also in the southern domain.

Along the Ntombe river profile, in the western part of the Hartland basin, the L/V Formation comprises a 180 m thick sequence of volcaniclastic-sedimentary lithologies, unconformably below Mozaan Group sediments (Fig. 4.30 (5)). The upper portion is dominated by fine-grained argillaceous rocks, with the lower 40 m represented by the Roodewal Member. The Roodewal Member consists of volcanic arenite, which is dark green in colour and coarse-grained with well-developed sedimentary structures. Structures include flat bedding, small scale planar cross-bedding and interference ripplemarks. Petrographically the volcanic arenite consists of equigranular quartz grains (≤ 2 mm) cross-cut by chlorite flakes in an altered sericitic matrix. Scattered quartz vein and lava fragments are present in the matrix. Two prominent cobble-to-boulder-size polymictic conglomerates (maximum 8 m thick) are interbedded with the volcanic arenites . Clasts are usually ≤ 30 cm in size and consist of well-rounded lava, quartz vein and quartzite constituents (Fig. 4.31). The volcanic arenites are interpreted by Armstrong (1980) to be tuffaceous in origin, while the conglomerates are interpreted to be epiclastic volcanoclastites. The volcanic arenites and conglomerates along the Ntombe River are overlain by well-laminated grey siltstones (Fig. 4.32) which gradually fine upwards into dark finely-laminated phyllites, with occasional thin quartzite intercalations (< 2 m thick). Petrographically the phyllite laminations are caused by alternating laminae of sericite-rich mudstone and quartz-rich siltstone (sample NR5). The contact with the overlying Mozaan Group is marked by a 10 m-thick, quartz-veined and brecciated tectonic unconformity.

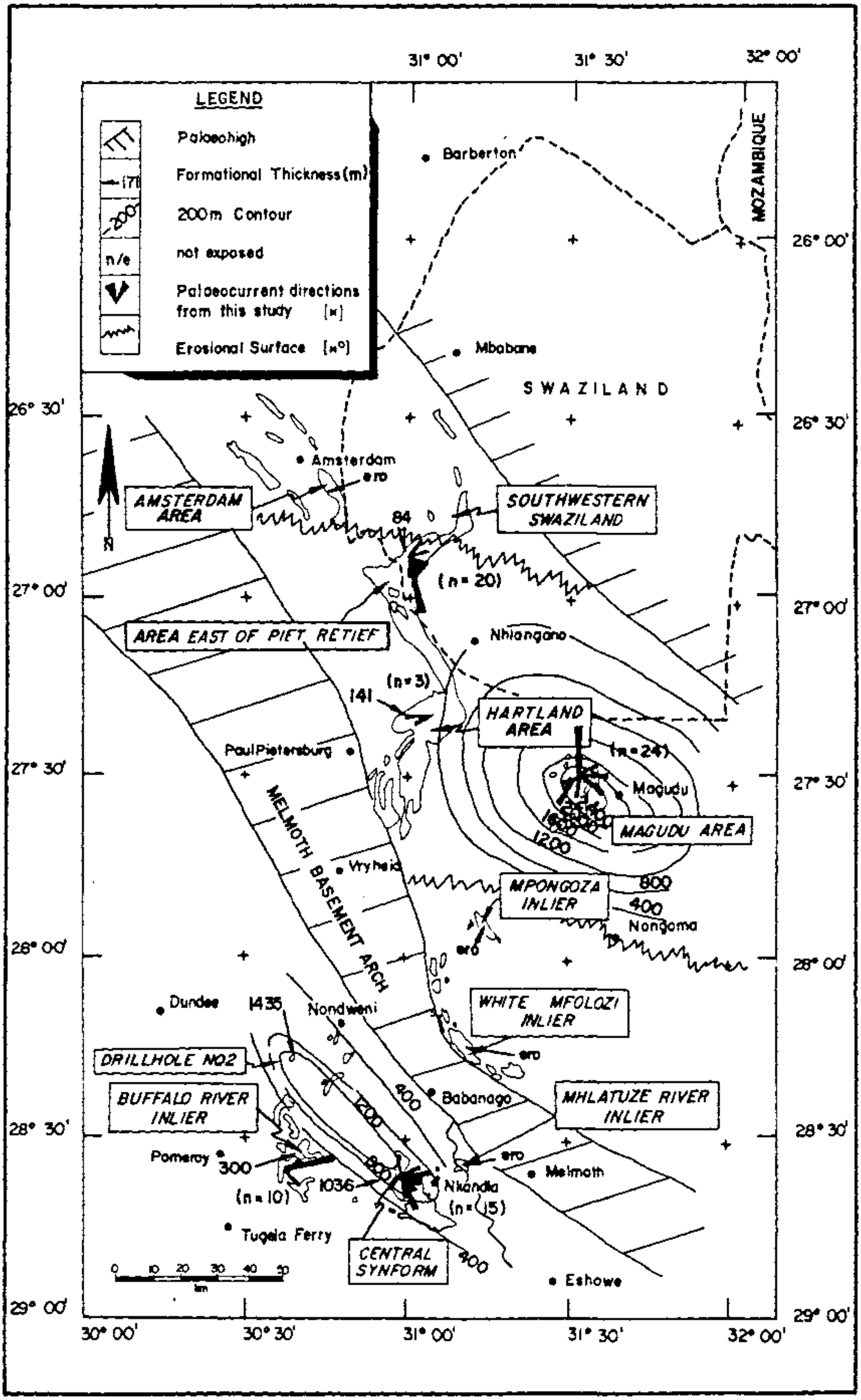
FIGURE 4.35 Well-preserved planar cross-bedding in coarse-grained grey-white quartzites from the middle part of the Langfontein / Vutshini Formation at the Nkandla Central Synform.

FIGURE 4.36 Sharp shale-quartzite contact in the lower part of the Langfontein / Vutshini Formation. Nkandla Central Synform. Note discontinuous thin conglomerate developed along contact.

East of Piet Retief, Hatfield (1990) describes pyroclastic breccias containing a high concentration of angular to subangular volcanic bombs set in a tuffaceous matrix. The breccias overlie intermediate amygdaloidal lava of the Agatha Formation. Siltstone and mudstone, which possibly represent reworked air-fall tuffs, are intercalated with the lavas. This mixed volcano-sedimentary zone most probably is a correlative of the Roodewal Member, and is unconformably overlain by the Mozaan Group (Fig. 4.30 (7)).

In southwestern Swaziland the L/V Formation is 84 m thick. It is unconformably overlain by the Mozaan Group (Fig. 4.30 (6)). The contact with the Agatha Formation intermediate lavas at the base is tectonic. The L/V Formation comprises upward-coarsening sedimentary cycles. Each cycle is composed of ferruginous shales, immature wackes through coarse grained, well-stratified arenites (with thin grit layers) to matrix-supported conglomerates at the top. The arenites display abundant sedimentary structures including wavy ripple marks, trough and planar cross-beds with sets usually 10 - 15 cm high. Petrographically the arenite consists of poorly-sorted quartz grains (≤ 4 mm size) with sutured grain boundaries set in a matrix of sericitic material. These arenites are partially recrystallized (sample SW1). The gritstone layers in the arenites are < 10 cm thick. Occasional scattered rounded quartzite pebbles are found in the arenites. The conglomerates are discontinuous with well-rounded-to-subrounded quartzite, quartz vein and chert pebbles (up to 2 cm in diameter).

Drill hole NQ2, drilled in the Nqutu area, intersected a 1 435 m-thick coarse clastic succession overlying possible correlatives of Agatha Formation lavas. The sequence is interpreted as a very proximal-correlate of the Roodewal Member at the base of the L/V Formation. It is unconformably overlain by the Dwyka Formation. The sequence comprises alternating polymictic, matrix-supported and pebble-supported conglomerate with interstitial thin zones of medium-to-coarse grained immature volcaniclastic quartzites (Fig. 4.30 (3)). Conglomerate pebbles are subangular-to-subrounded comprising largely altered lava with subordinate vein-quartz, quartzite and chert (silicified lava?) (Fig. 4.34).



ADDITIONAL LEGEND:

[x] (n = No. of readings).
[x°] (Pre-Mozaan).
ero (eroded away)

FIGURE 4.37 - MFENYANA SUBGROUP ISOPACH CONTOUR PLAN, SHOWING PALAEOCURRENT DIRECTIONS (PRESERVED THICKNESS)

A composite Langfontein / Vutshini profile has been constructed from the fragmented lithostratigraphic Nsuze fault blocks in the Buffalo River inlier. A composite profile, 300 m thick, has been assembled from the Okhalweni and Mazebeko traverses (Fig. 4.30 (1)). The Roodewal Member at the base consists of angular to subangular clasts of quartzite and altered lava in a grey coarse-grained diamictitic groundmass. Clasts are ≤ 40 cm in size. The coarse diamictitic unit fines upwards into a green coarse-grained volcaniclastic ("tuffaceous") arenite. The Roodewal Member is very similar in composition here to that along the Ntombe River traverse in the Western Hartland basin. The Roodewal Member, is overlain by a succession of alternating shale and quartzite, with a single 25 m thick diamictite unit developed along the Mazebeko profile. The quartzite is medium-to-coarse grained, grey-white and well cross-stratified. Planar cross-bedding sets are typically 50 cm - 100 cm high, while trough cross-bedding sets are up to 1 m high. Petrographically the quartzite is composed of subrounded to subangular well-sorted quartz grains (≤ 2 mm size) in a fine-grained quartz-muscovite-sericite ± chlorite matrix. There are usually sharp shale-quartzite contacts, with the shale dark grey/green in colour laminated and moderately ferruginous. This mixed shale-quartzite zone is similar to the lower L/V formation at the Nkandla Central Syncline. The shale possibly forms the tops of fining-upwards cycles. The upper diamictite is dark green in colour with scattered subrounded clasts of quartzite and lava. Petrographically, the groundmass contains rounded quartz grains (< 1 mm in diameter) and lithic fragments constituents largely replaced by chlorite, sericite and quartz (as in sample Gan 3).

Summarizing all the L/V profiles, (Fig. 4.30) an idealised 'composite' L/V Formation succession can be constructed. This ideal succession would have the coarse Roodewal Member at the base, a central unit of alternating quartzite and shale overlain by an upper dominantly quartzite unit.

4.6.4 Palaeocurrent Directions

The regional distribution of palaeocurrent directions from the Mfenyana Subgroup are shown regionally in rose diagram format in Fig. 4.37. The palaeocurrent directions in the northern domain are widely dispersed, especially those from the Magudu area. In the southern domain however, an easterly-directed trend emerges, indicating a general provenance direction from the west. Detailed palaeocurrent studies by Groenewald, (1984) in the Nkandla area indicate a predominately southeastwards palaeoslope, which is consistent with the easterly-directed trend in this study.

4.7 MKUZANE FORMATION

4.7.1 Distribution

The Mkuzane Formation, which is the upper formation of the Mfenyana Subgroup, is composed of mainly argillaceous metasediments overlaying the L/V Formation in the immediate Magudu area. This limited outcrop distribution is illustrated in Map 1. It is uncertain whether this limited distribution is due to non-deposition over the major part of the Nsuze basin, or due to removal by particularly pre-Mozaan erosive events. It is likely that both factors have played a role.

4.7.2 Type Profile

The Mkuzane Formation has been traversed along the Hohobo and Mfenyana Rivers, west of Magudu. Exposures in latter traverse are the best. The Mkuzane - L/V Formation contact has been placed above the last major quartzite unit characteristic of the L/V Formation (Fig. 4.38).

Along the Mfenyana River, the Mkuzane Formation is represented by a 1 450 m thick metasedimentary sequence of cordierite hornfels and cordierite-andalusite hornfels with subordinate quartzite and quartz-sericite hornfels. The lower part of the formation comprises finely interlayered quartzite and cordierite (± andalusite) hornfels (the quartzite layers are ≤ 3 m thick). The cordierite hornfels is dark-grey in colour, with prominent dark porphyroblasts of cordierite (≤ 2 cm size). Such quartzite-cordierite hornfels intercalations are shown in figure 4.39. The quartzites in the lower part of the formation are grey-green in colour, well-sorted and medium to fine-grained. The hornfels-quartzite contacts are very sharp (Fig. 4.39).

DETAILED LITHOSTRATIGRAPHY OF THE MKUZANE FORMATION ALONG THE MFENYANA RIVER TRAVERSE, MAGUDU AREA.

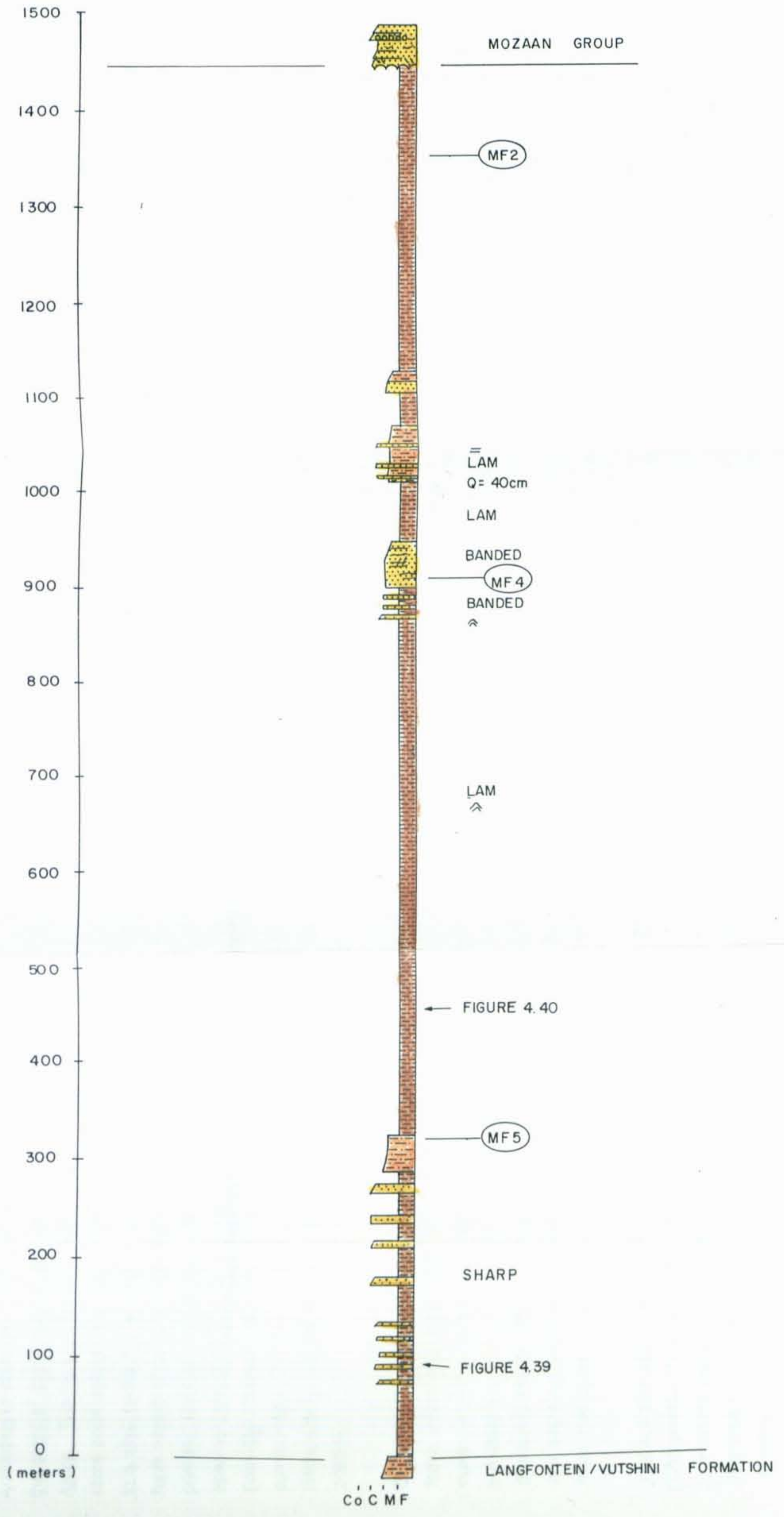


Figure 4.38

The central part of the formation comprises largely of cordierite hornfels with a 35 m thick quartz-sericite hornfels at the base. The quartz-sericite hornfels is brown-grey in colour and petrographically comprises of equigranular grains of quartz (< 0,1 mm size) with sutured outlines in a matrix of sericite and quartz (sample MF5). The cordierite hornfels are usually finely laminated, occasionally displaying symmetrical ripple marks. Within the cordierite hornfels, andalusite-rich layers are found usually in a more quartzitic groundmass. Andalusite crystals are usually euhedral in shape, similar to that seen in the L/V Formation (Fig. 4.40). The upper part of the Mkuzane Formation is also a fine-grained dark-grey cordierite hornfels unit, displaying light (quartzitic) and dark (micaceous) discontinuous layering. Cordierite crystals are less than ½ cm in length in the upper zone.

About 300 m below the top of the formation a 250 m-thick mixed zone of cordierite hornfels, quartzite and quartz-sericite hornfels are developed. The quartzitic layers often display small scale planar cross-bedding and flat bedding. The contacts between different rock types in this mixed zone are gradational. Altered cordierite-andalusite hornfels from this mixed zone may contain rotated, cordierite porphyroblasts in a quartz-sericite matrix. It is interesting to note the presence of large volumes of chloritoid needles (< ½ mm long) in these upper cordierite hornfels (samples MF2, MF4, Appendix 2).

The upper cordierite hornfels is unconformably overlain by mature, coarse-grained Mozaan Group quartzite. This unconformity reduces the Mkuzane Formation thickness from 1 450 m along the Mfenyana River traverse to about 600 m along the Hohobo River traverse, 16 km to the north indicating apparent northwards-directed downcutting. It is however uncertain how much of this decreased thickness is due to structural thinning (Map 7 a).

FIGURE 4.39 Interbedded cordierite (± andalusite) schist and green-grey quartzite from the lower part of the Mkuzane Formation along the Mfenyana River traverse, Magudu area.

FIGURE 4.40 Euhedral andalusite crystals in a quartzitic zone within cordierite schists. Central part of the Mkuzane Formation. Mfenyana River traverse, Magudu area.

4.8 EKOMBE FORMATION

4.8.1 Distribution

The Ekombe Formation is the uppermost formation in the Nsuze Group. This Formation is thought to unconformably overlie the Mfenyana Subgroup and is only seen outcropping in the Nkandla area in the southern domain. The Ekombe Formation is composed of mafic lava with its original extent being uncertain, largely as a result of removal by post-Nsuze erosive events. The formation name was proposed by Groenewald (1984), who recognised this volcanic unit in the centre of the Central Synform traverse in the Nkandla area. It is the same unit as the Mankana Formation described by Matthews (1979) in the Nkandla area.

4.8.2 Type Profile

The Ekombe Formation type profile unconformably overlies the Langfontein / Vutshini Formation in the Nkandla Central Syncline, (refer to Map 10 a for location) where the Mkuzane Formation has not been preserved (or not deposited). The outcrop area is very limited due to Phanerozoic cover. It is estimated that a thickness of only 25 m is present. The lavas are highly weathered and altered, with a purplish colour in outcrop. They are fine-grained and highly amygdaloidal, the amygdales being small, rounded and quartz-filled. The lava is composed of white mica (40 %), quartz and albite (50 %) and sphene (5 %) according to Groenewald (1984).

4.9 NZIMINI FORMATION

4.9.1 Distribution

A localized distribution of coarse-grained volcaniclastics, with subordinate intercalated sediments outcrop in the southern domain. Outcrops are present in the northern part of the Buffalo River Inlier (Map 12 a) in the west, the northern part of the Nkandla area (Map 10 a) particulary within the Gem-Vuleka Synform in the southeast, and in the Nzimini district between Babanango and Nqutu in the north (Map 1).

This unique lithological unit has provisionally been named the Nzimini Formation, after the excellent exposures in the Nzimini district. This formation comprises a unique lithostratigraphic assemblage, with no exposed correlates in the northern domain. As mentioned earlier, the exact stratigraphic position of this formation within the general Nsuze lithostratigraphic framework created in this study is uncertain. It seems most likely that it is unique to the southern domain and although further work is still required, on this enigmatic formation, it will be briefly discussed here.

4.9.2 Type profile, lateral variation and general characteristics

Excellent exposures of the Nzimini Formation in the Nkandla area are found in the Nsuze River valley, north of it's intersection with the Ndikwe River (refer to Fig. 3.1). These exposures and other local outcrops of the formation are well-documented by Groenewald (1984), who introduced the name Ndikwe Formation for the local occurrence of this formation in the Nkandla area. The Nsuze River valley exposures can be regarded as the 'type area' for the Nzimini Formation.

Groenewald (1984) estimates a maximum thickness of 1 500 m for this formation, along the Nsuze River valley. The unit is composed of volcaniclastics, volcanogenic sediments, arenites and argillites. The formation is highly deformed and disrupted by gabbroic intrusions of the Hlagothi Complex. Groenewald (1984) also reports subordinate intercalations of amygdaloidal lava and banded iron formation within the formation. Sheared volcaniclastics constitute the greater part of the formation, being usually green-grey in colour with lapilli and occasional volcanic bombs (up to 20 cm) characterising the volcaniclastics, which Groenewald (1984) interprets as pyroclastic tuffs. The groundmass is reported to be heterogeneous with angular fine-grained lithic fragments dispersed in it. Groenewald (1984) also reports crystal tuffs and crystal-bearing lapilli tuffs to be common here. Other volcaniclastic lithologies reported here are agglomerates, tuffaceous greywacke and ash-tuffs.

The arenites here include thin units of quartz arenite, quartz wacke and lithic wacke. The quartz arenites are coarse to fine-grained rocks composed of rounded to subangular quartz grains set in a sericitic and/or chloritic matrix. The argillites here vary from light brown pelites to dark grey phyllitic rocks. (Groenewald, 1984).

FIGURE 4.41 Brown weathered surface and green / grey fresh surface of a volcaniclastic diamictite, showing lapilli-sized, subrounded lithic clasts. Nzimini Formation. Fugitives Drift traverse. Buffalo River Inlier.

FIGURE 4.42 An agglomerate bed displaying subrounded "bombs" of mainly altered volcanics within a volcaniclastic (tuffaceous), coarse-grained altered groundmass. Nzimini Formation Fugitives Drift traverse. Buffalo River Inlier.

A very thick sequence of similar diamictitic volcaniclastics, with minor intercalated amygdaloidal lavas, arenites and argillites is exposed in the northern part of the Buffalo River inlier (from the Fugitives Drift traverse in the north to the Roodeklip traverse in the south (refer Map 12 a). Dixon (1991) suggests that these diamictitic lithologies are pyroclastic in origin, similar to that in the Nkandla area. The pyroclastics are reported to include; lapilli and crystal tuffs and agglomerates. The diamictites are grey-green in colour with a brown weathered surface (Fig. 4.41). The diamictites comprise primarily coarse-grained volcaniclastic arenites (altered and reworked tuffaceous deposits) with scattered lithic clasts. The volcaniclastic arenites often grade into thin agglomeratic beds usually < 20 m in thickness. Subrounded-to-subangular lithic agglomerate "bombs" up to 40 cm in size are seen, usually composed of altered lava. Clasts of quartzite, banded iron formation and vein quartz have also been recorded. An agglomeratic bed is shown in Fig. 4.42. Agglomerate clasts are set in a coarse-grained, green chloritic groundmass, often displaying visible interstitial rounded quartz grains.

The clasts within the volcaniclastic arenites are rounded to angular, as illustrated in Figs. 4.43 and 4.44. The composition of clasts are similar in composition to that in the agglomeratic beds. The volcaniclastites in the Nzimini district are similar to that recorded in the northern part of the Buffalo River Inlier. A volcaniclastic diamictite from the Nzimini district (sample NSZ 1 Appendix 2 is composed of a chlorite-sericite-quartz groundmass, hosting sub-angular plagioclase and subrounded quartz grains with cross-cutting mineral phases of carbonate, epidote and chlorite (Fig. 4.45).

The Nzimini Formation is highly tectonised. A prominent SE-NW-trending axial planar cleavage is developed. The contact between the Nzimini Formation and the White Mfolozi Formation sediments in the northern part of the Buffalo River inlier is usually faulted. Within the Nzimini Formation itself, many NE-SW and SE-NW-striking late-stage faults have been recorded. It is also possible that the volcaniclastic package here has been extensively tectonically-thickened. Within the Gem-Vuleka Syncline in the Nkandla area the Nzimini Formation displays evidence of extreme shear deformation and are highly dissected by gabbroic intrusions of the Hlagothi Complex.

It is possible that the thick diamictitic unit of the Nzimini Formation in the northern part of Buffalo River inlier thins to the south and correlates with the well-established diamictite at the base of the White Mfolozi Formation (Map 15). This unit was only in the region of 10 - 15 m thick along the Mazabeko traverse in the south. This option was selected when the composite stratigraphic column for the Nsuze Group in the Buffalo River inlier (refer to Map 12 a) was constructed - hence the thick diamictite at the base of the White Mfolozi Formation in this area (Map 12b).

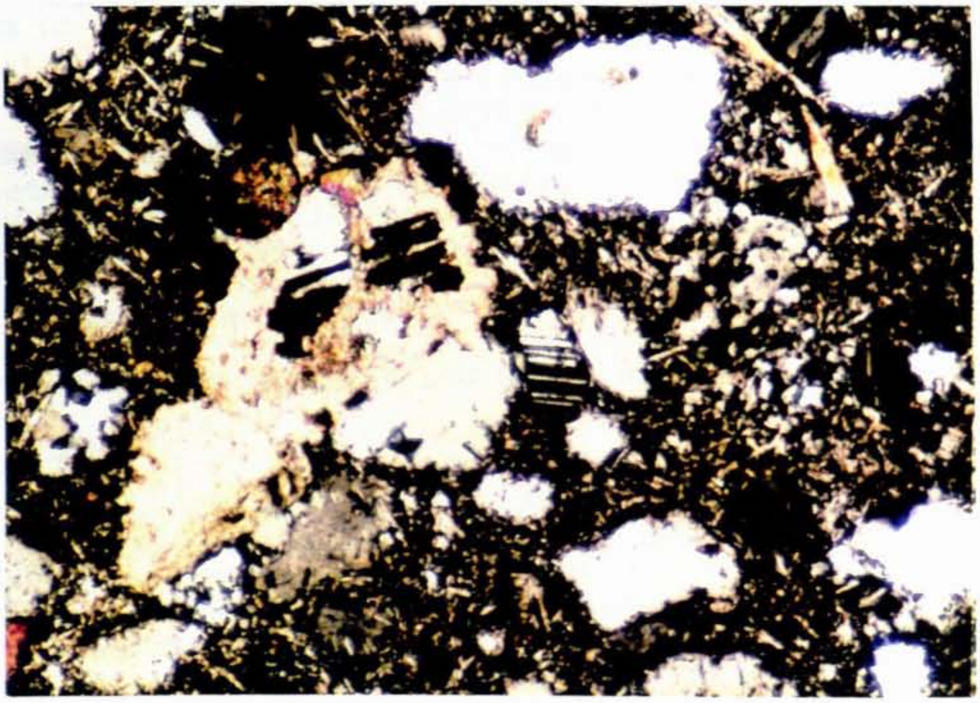
FIGURE 4.43

Pitted surface of a volcaniclastic diamictite,showing rounded-to-subangular lappilli-sized clasts.Nzimini Formation.Roodeklip traverse.Buffalo River Inlier.

FIGURE 4.44

Angular chloritic fragments (altered lava ?) within a typical volcaniclastic diamictite groundmass.Nzimini Formation.Fugitives Drift traverse.Buffalo River Inlier.

FIGURE 4.45 Photomicrograph displaying quartz and plagioclase grains in a highly-altered groundmass comprising: chlorite, carbonate, sericite, epidote, quartz and opaques. Volcaniclastic diamictite. Nzimini Formation. Nzimini district. Sample NSZ1. X5 magnification. Crossed - polars.



CHAPTER 5: METAMORPHISM AND ALTERATION

5.1 INTRODUCTION

The rocks of the Nsuze Group have been subjected to a number of alteration processes. The volcanics were exposed to an initial post-emplacement period of alteration, during which hydrothermal and deuteric alteration processes were active (recognised by Preston, 1987 through detailed petrographic studies of volcanics in the Mpongoza inlier).

The entire Nsuze Group bears the imprint of regional low-grade metamorphic alteration, which has been superimposed on the earlier alteration products. This metamorphic imprint could be due to pressure and temperature increases related to burial by younger cover sequences. The secondary minerals arising from these two alteration events are very similar and it is difficult to distinguish between them on petrographic grounds.

In addition to regional low grade metamorphic alteration, the sequence has also locally been affected by contact metamorphism and tectonic shear deformation. This is especially the case in the Magudu area, where post-Pongola granites intrude the sequence. The contact metamorphic imprint pre-dates the low-grade regional metamorphic imprint, (with the latter superimposed on the former as a retrogressive overprint).

5.2 ALTERATION AND REGIONAL LOW GRADE METAMORPHISM

5.2.1 Lavas

Due to a wide range of alteration processes (including metamorphic effects and subaerial and even subaqueous alteration effects), Nsuze volcanics no longer display their initial primary mineralogical composition. The present Nsuze volcanic mineralogical composition is a function of factors such as bulk rock composition, the relevant P-T conditions and even on the availability of H_2O and CO_2. (Preston, 1987). Petrographic examination of Nsuze lavas from the entire outcrop area reveal varying degrees of chloritization, calcitization, silicification, sericitization and epidotization. Each of these alterations will be briefly described here (descriptions of thin sections are summarized in Appendix 2).

5.2.1.1 Mafic and Felsic lavas

Chlorite is commonly developed in all the Nsuze lavas examined, often as cross-cutting stringers closely associated with sericite dissecting both the feldspar phenocrysts (when developed) and the altered groundmass.

Plagioclase phenocrysts and the trachytic plagioclase groundmass in most Nsuze lavas show varying degrees of sericitization (Fig. 5.1). Sericitization can be interpreted to involve the leaching of alkalies and calcium as well as the release of silica as quartz (Preston, 1987). Sericite often occurs in association with epidote, quartz and chlorite as replacement minerals pseudomorphous after plagioclase. The released calcium is often accommodated in secondary calcite which occur throughout the trachytic groundmass, partially replacing plagioclase phenocrysts. Calcium is also released during the recrystallization of more calcic plagioclase to form albite at low metamorphic grades (Armstrong, 1980). This results in the replacement of the original calcium-rich plagioclase by varying proportions of calcite and epidote.

Epidotization is a common alteration process in Nsuze lavas. Epidote, in conjunction with the other replacement minerals mentioned above, commonly occurs interwoven with sericitized plagioclase. Fig. 5.2 illustrates yellow epidote partially replacing plagioclase in a felty sericitic groundmass. Armstrong (1980) describes larger-scale (0,2 - 1,0 m diameter) light green epidote alteration patches from Nsuze lava in the Piet Retief area. Although macroscopic in scale, the textures described by Armstrong (1980) are similar to that observed microscopically here.

Varying degrees of silicification occur in some Nsuze lavas. This silicification could either be due to the post-magmatic introduction of silica-rich fluids to the system or could even be due to selective leaching of other components leaving a silica-rich quartz residue (Siems, 1984). Equigranular, fine-grained mosaic quartz overgrowths are good evidence of secondary silicification.

FIGURE 5.1 Photomicrograph of a saussuritized feldspar phenocryst enveloped by a chloritic rim associated with epidote. Crossed polars. X10 magnification. Sample SW12. Feldspar porphyry. Agatha Formation Southwestern Swaziland.

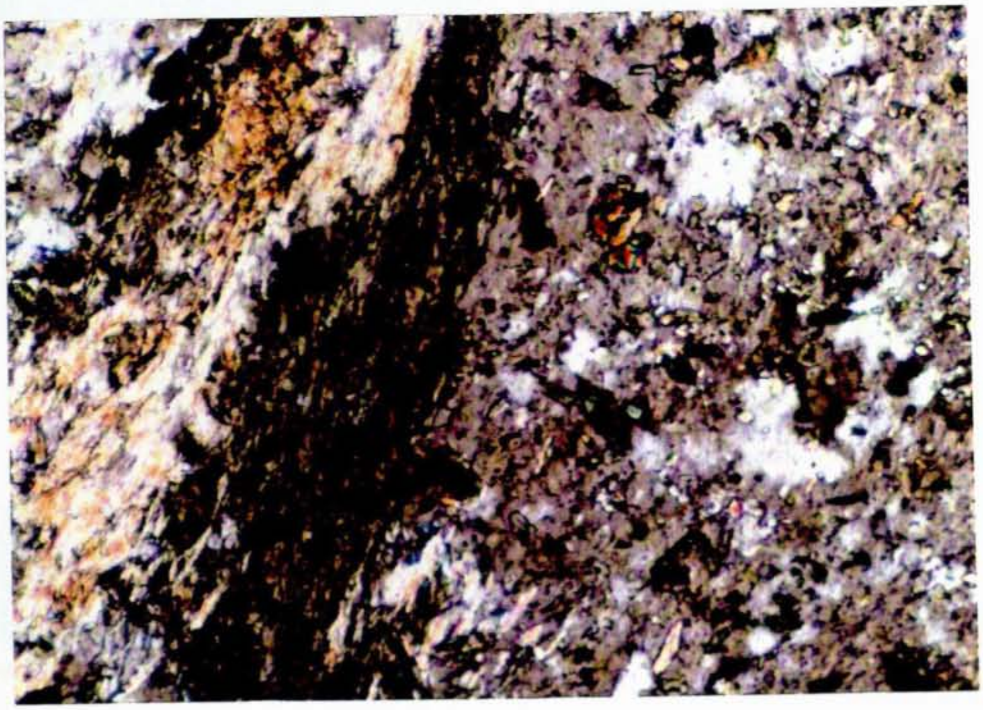


FIGURE 5.2 Photomicrograph of yellow birefringent epidote replacing sericitized plagioclase laths in a mafic lava groundmass. Crossed polars. X10 magnification. Sample AM6. Pypklipberg Formation. Amsterdam area.

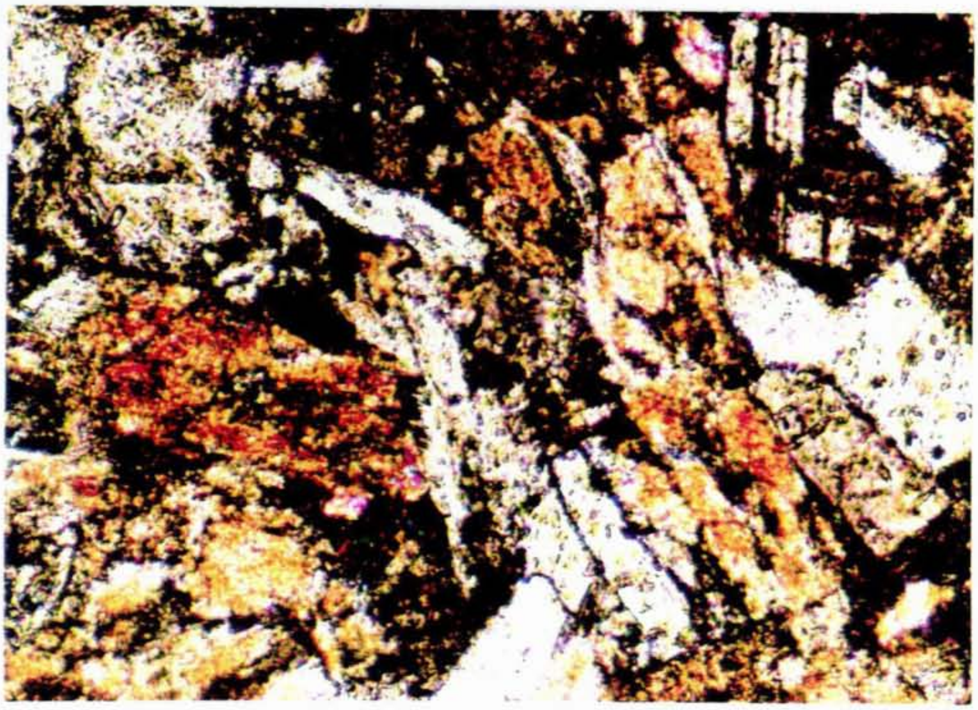


FIGURE 5.3 Photomicrograph of muscovite needles interstitial to and partially cross-cutting quartz grains in an argillaceous quartz arenite. Crossed polars. X10 magnification. Sample Man2. Mantonga Formation. Mazebeko traverse. Buffalo River Inlier.

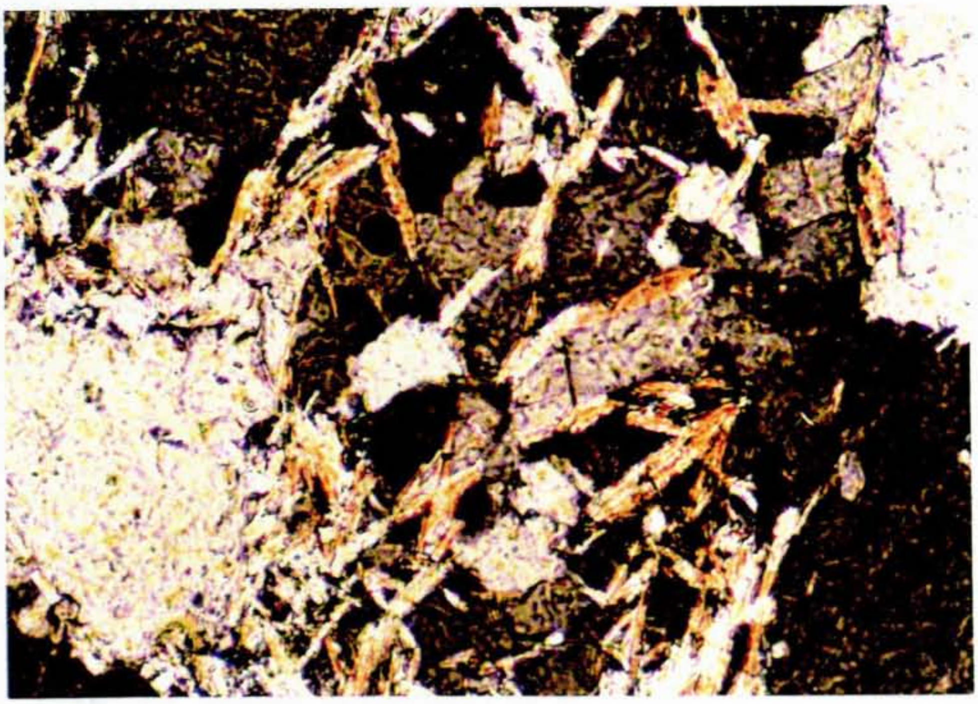
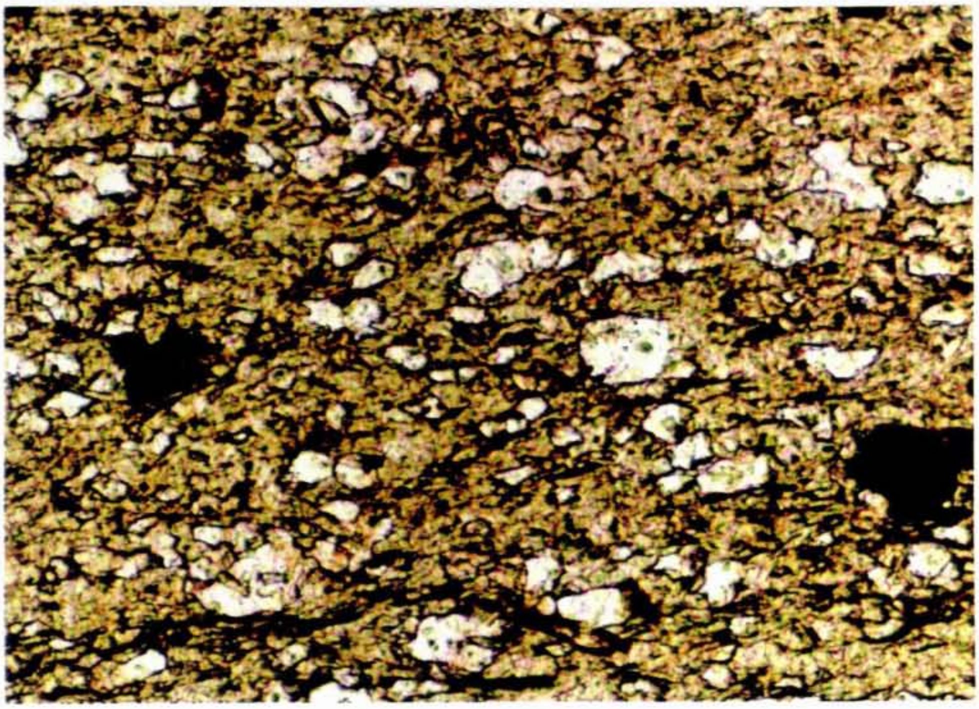


FIGURE 5.4 Photomicrograph of a green dominantly chloritic shale containing sub-rounded equigranular quartz grains and subangular opaques. X5 magnification. Sample MD2. White Mfolozi Formation. Nkandla Central Synform.



5.2.2 Siliciclastics

Nsuze Group arenites commonly comprise strained, sometimes recrystallized, quartz grains with muscovite ± chlorite in the matrix (Fig. 5.3). Descriptions of thin sections are summarized in Appendix 2.The Nsuze argillites are usually highly chloritic, often containing fine-grained equigranulaur quartz grains with varying proportions of micaceous minerals. The secondary chlorite has often totally obliterated primary textures, but has enhanced a fine lamination in most shales (Fig. 5.4).

5.3 CONTACT METAMORPHISM

The Nsuze Group lithologies in the Magudu area bear a contact metamorphic imprint, because of the intrusion of post-Pongola granitoids in this area (refer to Map 1 for distribution of these intrusive granitoids). These cross-cutting granitoids represent Anhaeusser and Robb's (1981) third magmatic cycle, being typically coarse-grained and porphyritic in places. These granitoids in the northern domain are classified as the Spekboom, Godlwayo and Kwetta granites (Matthews, 1985). The thermal metamorphic effects of this intrusive granitoid complex has briefly been examined along the Hohobo and Mfenyana River traverses. Field observations and petrographic results from this area will be summarized here.

The examination of the contact metamorphic aureole around the post-Pongola granitoid complex west of Magudu is complicated by later burial-induced low grade regional metamorphic facies assemblages (including, chlorite, epidote and chloritoid). In places the initial prograde contact metamorphic assemblage has been totally obliterated by the retrogressive overprint.

Diagnostic prograde minerals in argillaceous units in the Langfontein and Mkuzane Formations are cordierite and andalusite. The two minerals frequently co-exist. Cordierite is seen as ovoid phenocrystic crystals (1-3 cm in diameter) (Fig. 5.5). Andalusite occurs frequently as euhedral phenocrysts up to 4 cm in size, sometimes bearing a chiastolite pattern. Fig. 5.7 illustrates unusual tabular andalusite crystals cross-cut by thin quartz veinlets. These two diagnostic minerals occur throughout the full thickness of the Nsuze Group in the area up to the contact with the Mozaan Group in the Mfenyana traverse which is over 4 km from the contact with the intrusive granite (see Map 7 a).

FIGURE 5.5 Laminated, spotted cordierite hornfels from the Mkuzane Formation. Mfenyana River traverse. Maqudu area.

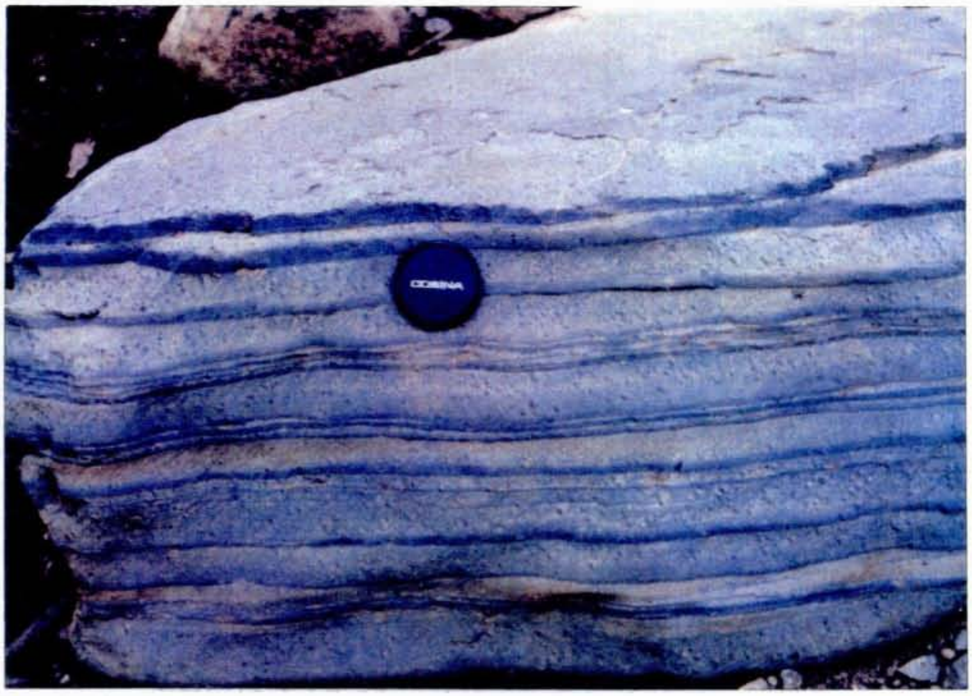
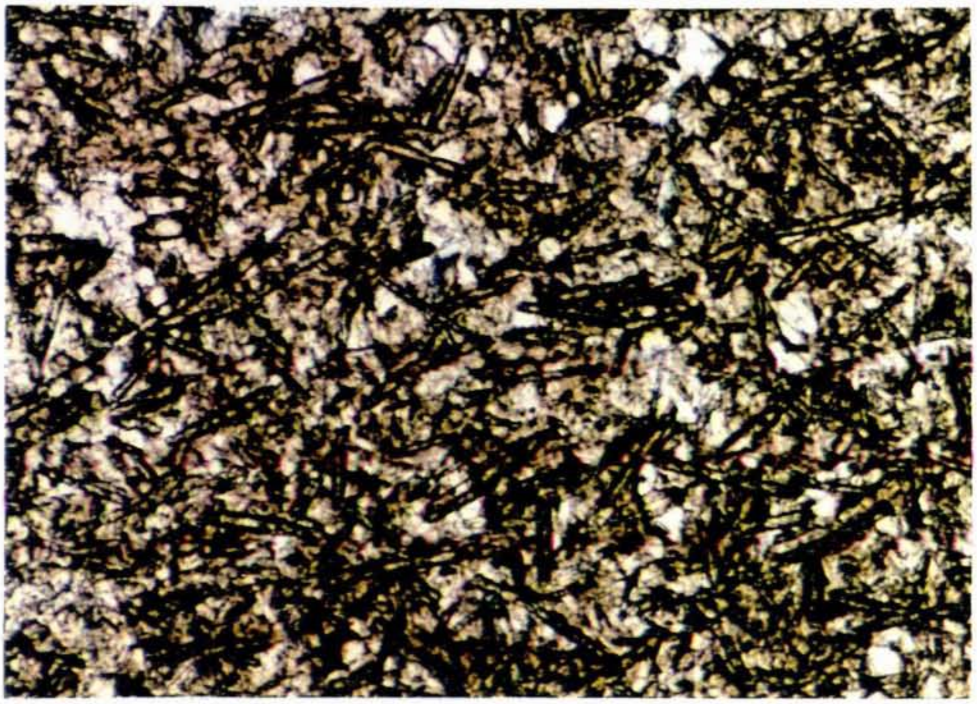


FIGURE 5.6 Photomicrograph showing cross-cutting secondary high relief chloritoid needles in a fine-grained altered groundmass of a cordierite hornfels. X5 magnification. Plane polarized light. Sample MF2. Mfenyana River traverse. Maqudu area.

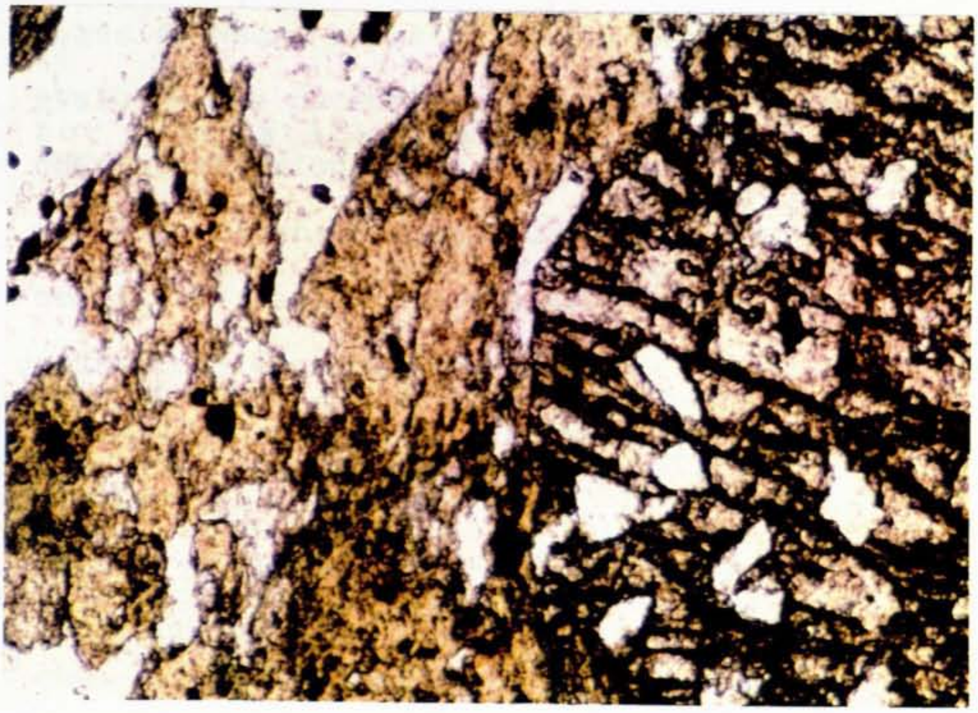


The diagnostic prograde assemblage in samples MW1 and MW8 (Appendix 2) is plagioclase (highly altered) and garnet. Poikilitic garnet crystals are < 1 cm in diameter (Fig. 5.8), usually co-existing with hornblende, quartz and secondary minerals like epidote, chlorite and biotite.

Hornblende-hornfels facies mineral assemblages have been largely overprinted by mineral assemblages attributable to the regional low grade burial metamorphic event. In the pelites these minerals include chlorite, muscovite/sericite and chloritoid, while in the basic rocks these include chlorite, quartz, epidote and occasionally biotite (Appendix 2). Chloritoid is a relatively common constituent of aluminium and ferric -rich regionally metamorphosed pelitic sediments (Deer et al. 1980). Chloritoid in pelites of the Mkuzane Formation along the Mfenyana traverse commonly occurs as cross-cutting needles, up to 0,5 mm in length (Fig. 5.6).

FIGURE 5.7 Tabular andalusite crystals, cross-cut by quartz veinlets, showing a moderate preferred orientation in an andalusite-cordierite schist. Langfontein / Vutshini Formation. Mfenyana River traverse. Magudu area.

FIGURE 5.8 Photomicrograph showing a poikilitic garnet phenocryst in contact with altered hornblende and saussuritized plagioclase. X5 magnification. Plane polarized light. Sample MW8. Hohobo River traverse. Magudu area.



CHAPTER 6: GEOCHEMISTRY

6.1 LAVAS OF THE NSUZE GROUP

6.1.1 Introduction

An attempt was made to compile a regional geochemical data set for lavas of the Nsuze Group. An unpublished set of 73 geochemical analyses of Nsuze Group lavas from throughout the Nsuze basin has been made available for this study by Gold Fields Mining and Development. The data set includes major, minor and trace element analyses by X-ray fluorescence done at Gold Fields Laboratories, Johannesburg. Sample positions are indicated on Map 1. Data from previous studies by Armstrong (1980), Armstrong et al. (1982,1986) and Hatfield (1990) in the northern domain, Preston (1987) in the central domain and Groenewald (1984), Tunnington (1981) and Brown (1982) in the southern domain were combined with the new data. The actual analyses are given in tables 1a, b and c in Appendix 1.

The geochemical analyses were undertaken to:

a) produce a lithostratigraphically-constrained geochemical database for the Nsuze Group;

b) make a geochemical comparison between the Agatha and Pypklipberg formations;

c) evaluate the degree of alteration of Nsuze lavas;

d) classify Nsuze lavas on geochemical grounds;

e) evaluate the potential of geochemistry as a tool for stratigraphic correlation or characterization;

f) apply published discrimination diagrams for evaluation of the magmatic affinity and tectonic setting of lavas from the Nsuze Group.

The geochemical data set of the Nsuze lavas needs to be evaluated in the context of the effect of secondary alteration that may have affected the rocks. The mobility of elements during alteration and metamorphism has been studied by a number of researchers such as Floyd and Winchester (1978). Many major, minor and trace elements become mobile during alteration but high field strength elements (HFS) like Ti, Zr, Y, Nb and P have high ~~charge/ionic~~ size ratios and are regarded by various authors to be relatively resistant to the processes of alteration and metamorphism. However, these authors also warn that differential mobility of HFS elements is possible under conditions of extreme alteration. Therefore combinations of discrimination plots based on mobile as well as immobile elements are necessary to fully appreciate the implications of geochemical data sets.

Lava geochemistry is thought by many writers (including Pearce et al, 1977 and Floyd and Winchester, 1975) to be related to the tectonic setting in which these lavas were generated. Consequently several discrimination diagrams have been devised, mainly for Mesozoic volcanics erupted in known plate tectonic settings. Although the applicability of such discrimination diagrams to Nsuze Group lavas is debatable, limited application of such diagrams have been made in this study in an attempt to cast light on the tectonic setting of the depository of the Nsuze Group.

A summary of the geochemical information used in discrimination plots of Nsuze lavas is given in table 6.1. The geochemical data referred to in table 6.1 are tabulated in table 1a (Pypklipberg Formation), table 1b (Agatha Formation) and table 1c (other Nsuze Formations) in Appendix 1.

FIGURE 6.1 (Na2O + K2O) – (SiO2) wt% diagram for this study's lava data set (diagram from Cox et al., 1979)
[○ Agatha Formation ✳ Pypklipberg Formation]

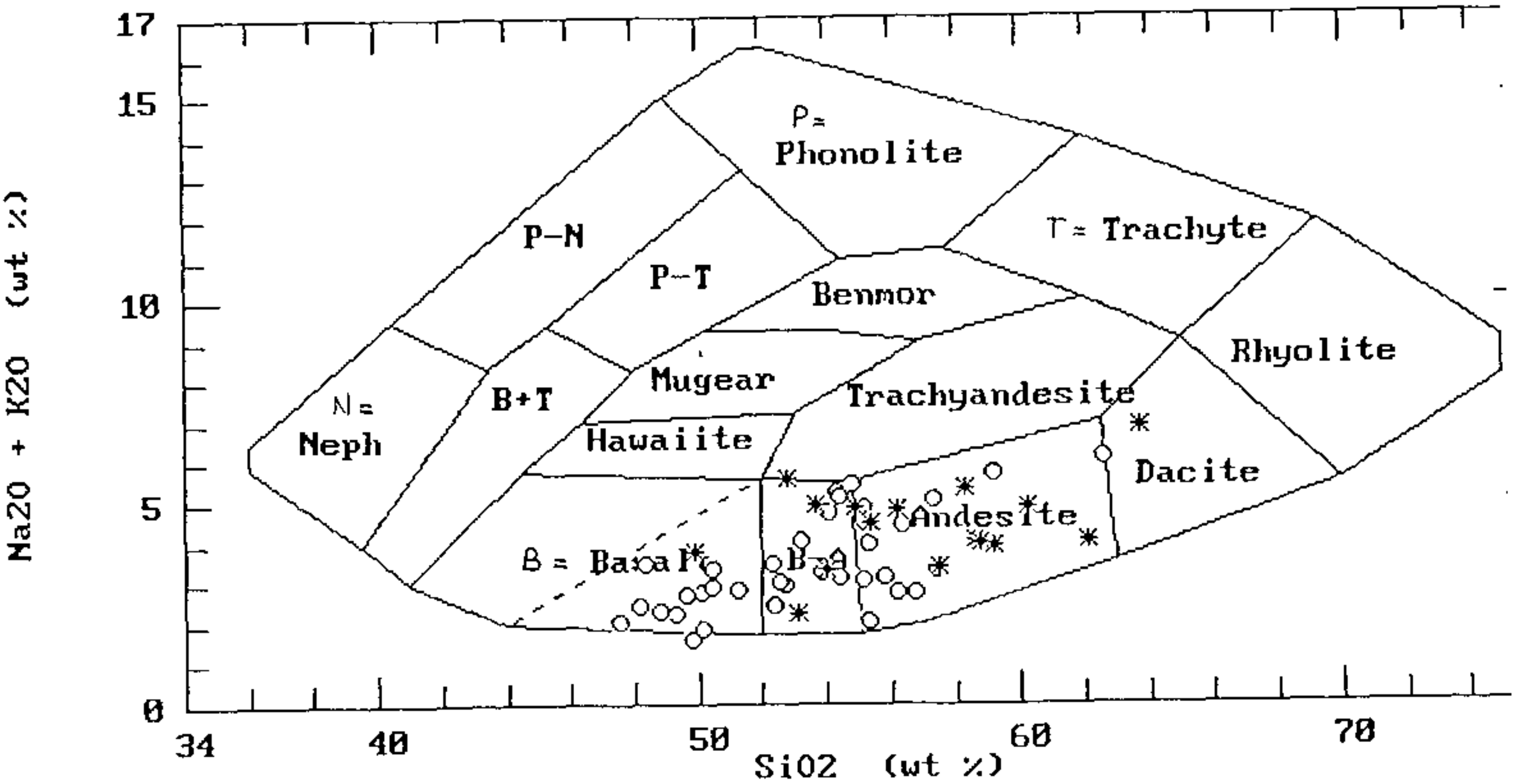


FIGURE 6.2 (Na2O + K2O) – (SiO2) wt% diagram for the total Nauze lava data set . (diagram from Cox et al , 1979)
[○ Agatha Formation ✕ Pypklipberg Formation]

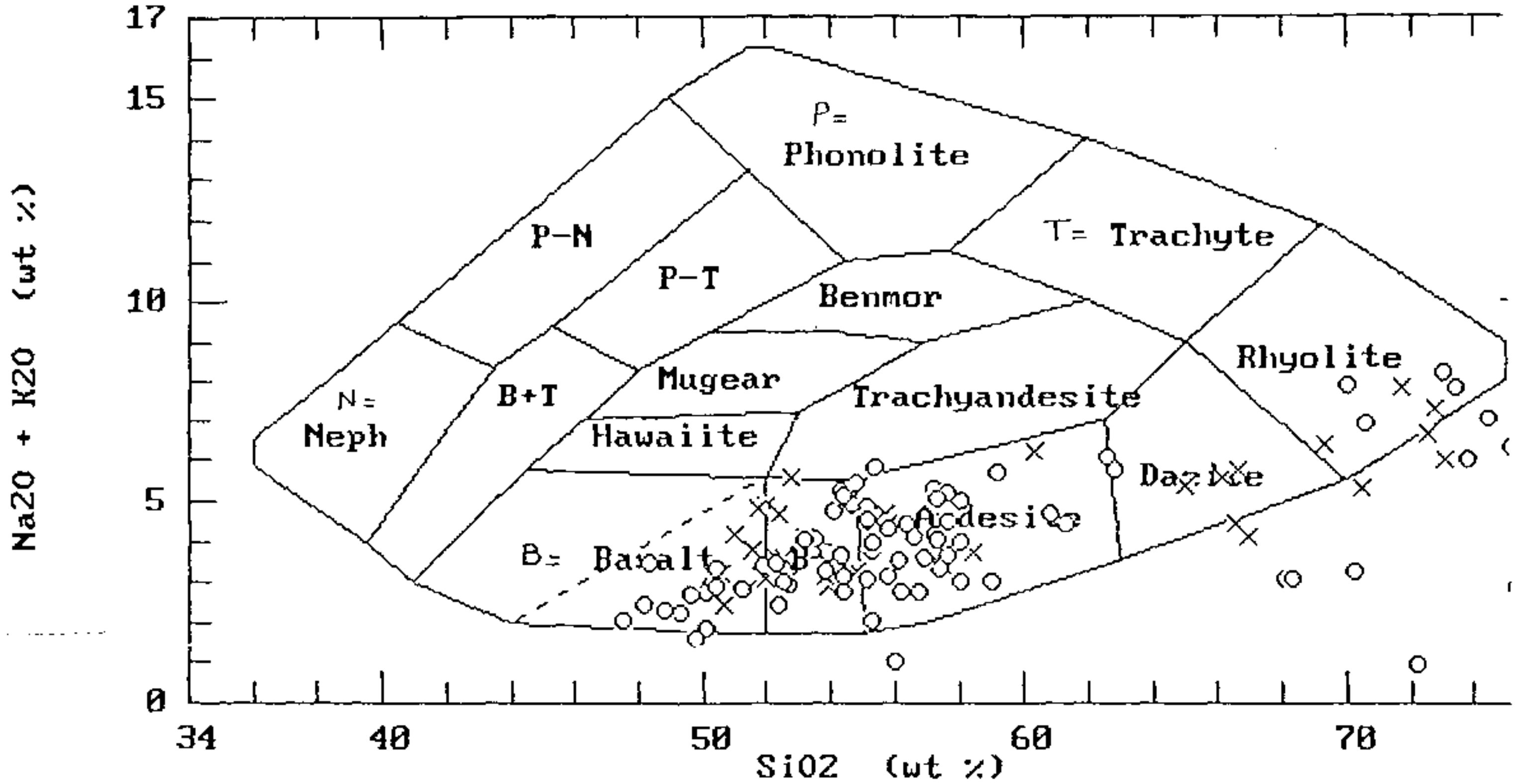


TABLE 6.1:

SUMMARY OF GEOCHEMICAL INFORMATION USED IN DISCRIMINATION PLOTS OF NSUZE LAVAS

Pypklipberg Formation	
a. Western Hartland basin	i. Armstrong (1980) (n=32) ii. this study (n=5)
b. Mpongoza inlier	i. Preston (1987) (n=41)
c. White Mfolozi inlier	i. this study (n=8)
d. Mhlatuze River inlier	i. this study (n=3)
Agatha Formation	
a. Western Hartland basin	i. Armstrong (1980) (n=16) ii. Hatfield (1990) (n=13) iii. this study (n=6)
b. Mpongoza Inlier	i. Preston (1987) (n=10)
c. White Mfolozi Inlier	i. this study (n=10)
d. Central Synform (Nkandla)	i. this study (n=6) ii. Groenewald (1984) (n=6) iii. Tunnington (1981) (n=8) iv. Brown (1982) (n=8)
e. Buffalo River inlier	i. this study (n=11)
f. Drillhole NQ2	i. this study (n=24)

(n = number of samples analysed)

6.1.2 Results

All new analyses of Pypklipberg and Agatha lavas from this study were plotted on a conventional diagram of SiO$_2$ versus total alkalis (Na$_2$O + K$_2$O) for chemical classification purposes (Fig. 6.1). Nsuze lavas display a spectrum of chemical compositions, ranging from basalt to dacite, with lavas of intermediate composition predominant. The Agatha lavas apparently tend to be more basaltic in composition in contrast to the Pypklipberg lavas which appear to be more andesitic in composition. However when all the available data are plotted, including those from

FIGURE 6.3 Log (Zr/TiO2) - log (Nb/Y) diagram for this study's lava data set . (diagram from Winchester and Floyd , 1977) [○ Agatha Formation ▲ Pypklipberg Formation]

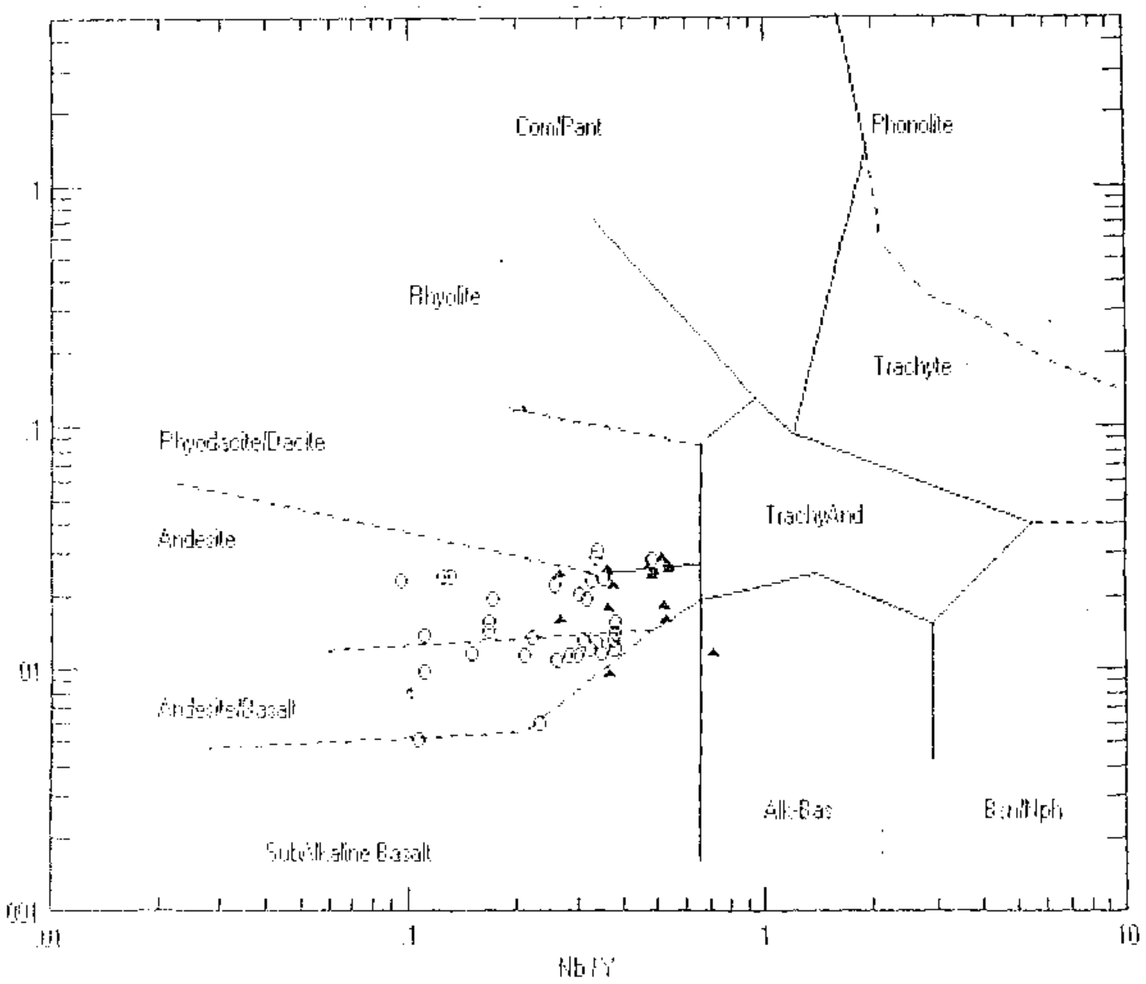
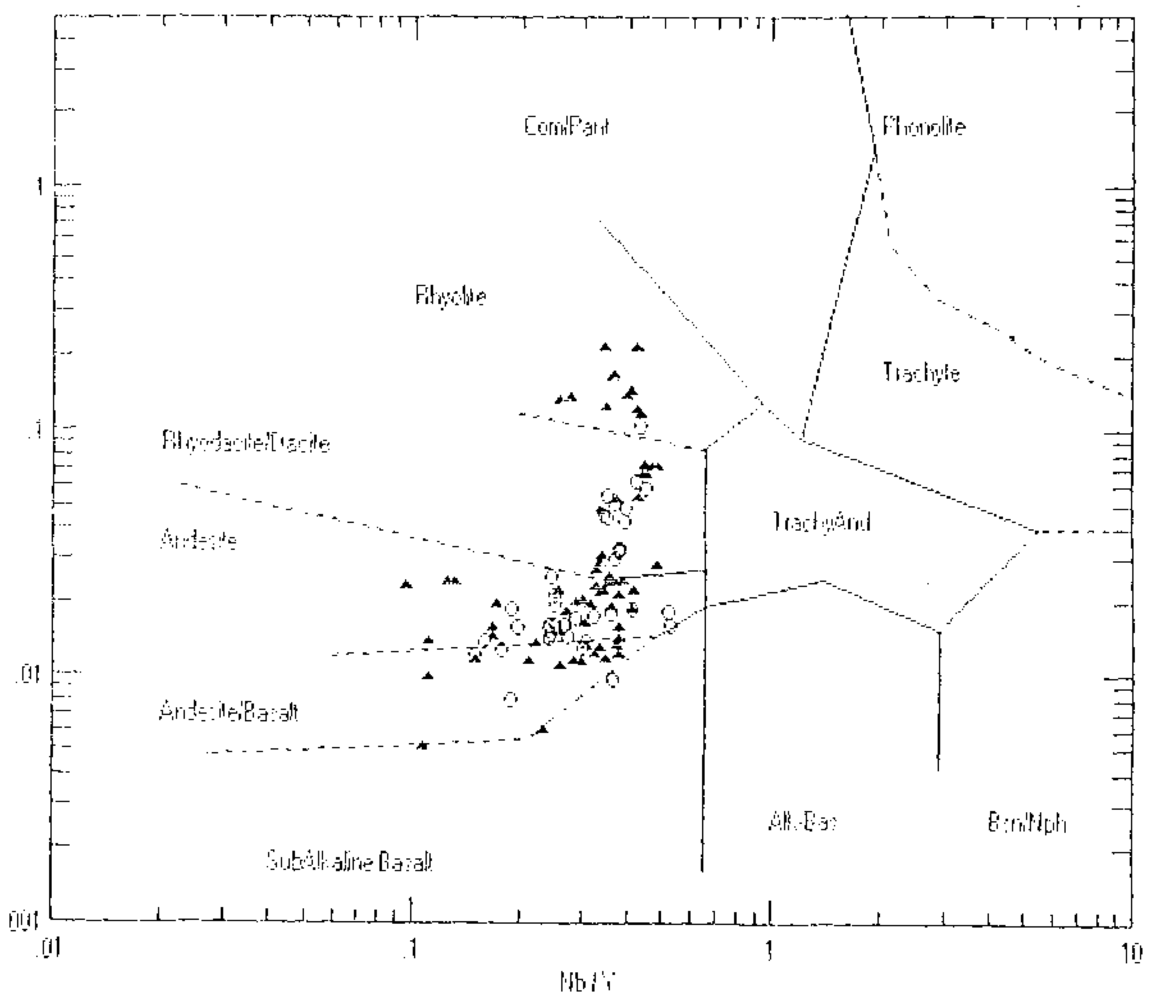


FIGURE 6.4 Log (Zr/TiO2) - log(Nb/Y) diagram for the total Nsuze lava data set . (diagram from Winchester and Floyd , 1977). (Excludes data from Preston , 1987) [▲ Agatha Formation ○ Pypklipberg Formation]



previous studies (Fig. 6.2), the differentiation between the Agatha and Pypklipberg lavas disappear. A very large number of the available data plot in the basalt to andesite compositional range. Many samples are also of dacitic to rhyolitic composition. Some samples plot outside the field of lavas, being high in silica and low in alkalis. This phenomenon may reflect secondary silification. Most of the data plotting outside the lava compositional fields in Fig. 6.2 are ascribed to the data of Preston (1987) from the Mpongoza inlier. He ascribes it to redistribution due to post-emplacement alteration.

On a plot of immobile element ratios, log (Zr/TiO_2) versus log (Nb/Y), after Winchester and Floyd (1977), the new data set indicates Pypklipberg lavas to fall closer to the trachy-andesite and alkali basalt field than that of the Agatha Formation (Fig. 6.3). However when all the available data are plotted, this differentiation disappears but many lava samples display rhyodacite/dacite and rhyolitic compositions (Fig. 6.4).

The magmatic affinity of the Nsuze lavas may also be assessed by using the FeO^*-Na_2O+K_2O-MgO diagram of Irvine and Barager (1971). The lavas from the Agatha and Pypklipberg Formations (total data set) overlap both the calc-alkaline and tholeiitic fields (Fig. 6.5). The general trend is similar to that recognised by Armstrong (1980) for western Hartland basin Nsuze lavas viz. a general trend of iron enrichment from the basalts to basaltic andesites to andesites followed by a decrease in iron and an increase in alkalis through the dacites into the field of rhyolites. Armstrong (1980), working in the Hartland basin in the northern domain, found his data set on lavas to have a dominantly tholeiitic trend. In contrast Groenewald (1984) working with a data set from the southern domain, found lava samples to overlap both the tholeiitic and calc-alkaline fields in equal numbers.

If data are restricted to these of this study, Pypklipberg lavas are evenly distributed between the tholeiitic and calc-alkaline fields (Fig. 6.6). In contrast, lavas from the Agatha Formation plot in the tholeiitic field with only samples from the Buffalo River inlier plotting in the calc-alkaline field (Fig. 6.7).

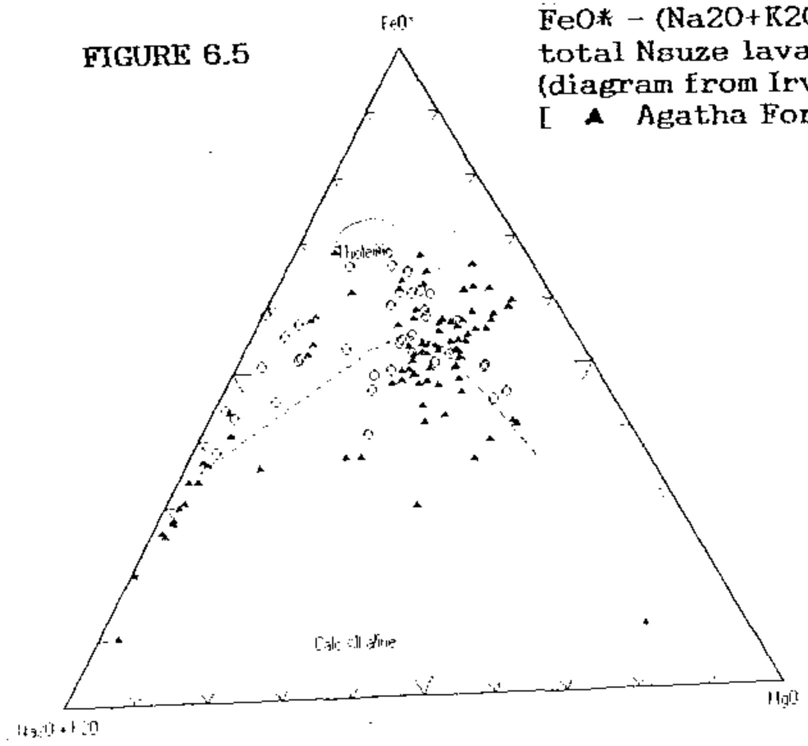
On a Nb-Zr-Y diagram (after Meschede, 1986) most lavas plot within field C (Fig. 6.8). Within this field, tholeiitic basalts from within-plate environments (WPT) are predominant (volcanic arc basalts also plot in field C). Meschede (1986) states that ancient continental tholeiites would fall in the within-plate tholeiite field. Interestingly, of the few analyses not falling within Meschede (1986)'s within-plate tholeiite field, 4 come from the Agatha Formation in the Buffalo River inlier (low Nb contents).

The discrimination diagrams involving the high field strength (high charge/radius ratio) elements Ti, Zr, Y and Nb which are highly immobile during alteration processes should be more applicable to the ancient Nsuze Group lavas. Peace and Norry (1979) observe that these elements vary systematically with tectonic setting of eruption. In a plot of the Zr/Y ratio relative to the index of fractionation i.e. Zr, most of the Nsuze database plot within the region of field A (within-plate basalt) (Fig. 6.9). Agatha and Pypklipberg formation data are similarly distributed Fig. 6.9. The plots outside the defined fields in figure 6.9 could possibly be attributed to extreme alteration.

In a discrimination diagram using Ti, Zr and Y (after Pearce and Cann, 1973) the lavas sampled during this study plot in field C, which are ascribed to calc-alkali basalts (Fig. 6.10). There is a slight enrichment in Zr in certain analyses of the Pypklipberg Formation from the Buffalo River inlier.

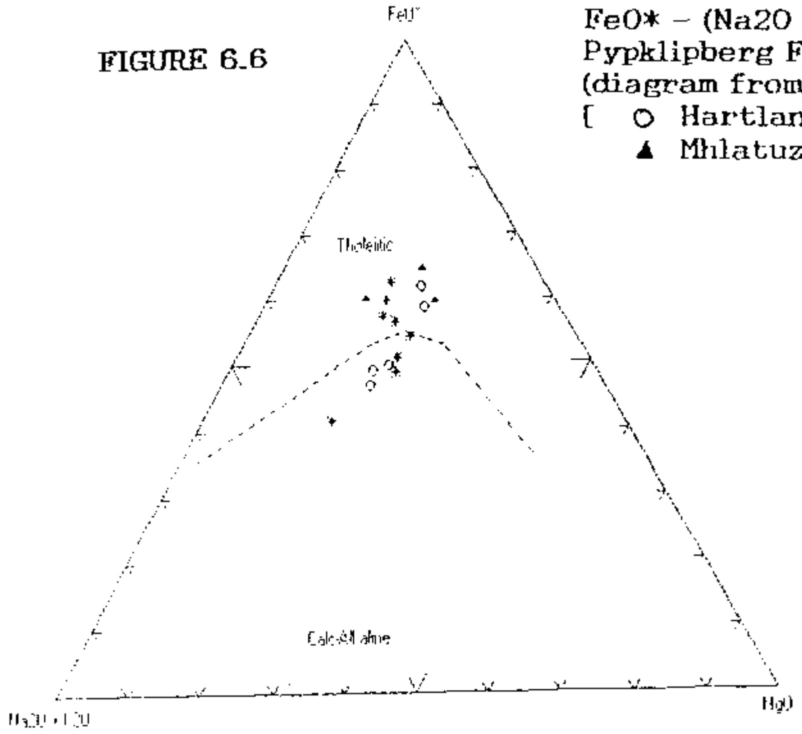
Pearce et al (1977) have found that a simple ternary plot of MgO-FeO (total) - Al_2O_3 may be used to distinguish between five Phanerozoic tectonic settings of lavas. The majority of the analyses of lavas sampled during this study plot within the field of the continental environment (Fig. 6.11). Scatter is caused mainly by samples of the Agatha Formation from the Buffalo River inlier and a few from the Pypklipberg Formation in the Hartland basin. A similar continental setting emerges when all available data are ploted on such a diagram.

FIGURE 6.5



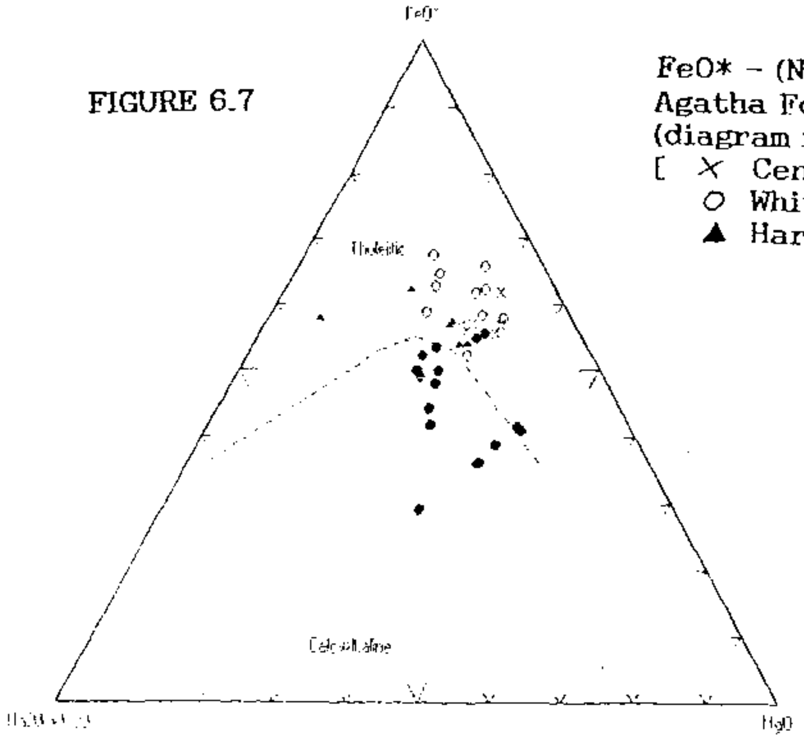
FeO^* – (Na_2O+K_2O) – MgO diagram for the total Nsuze lava data set.
(diagram from Irvine and Barager , 1971)
[▲ Agatha Formation ○ Pypklipberg Formation]

FIGURE 6.6



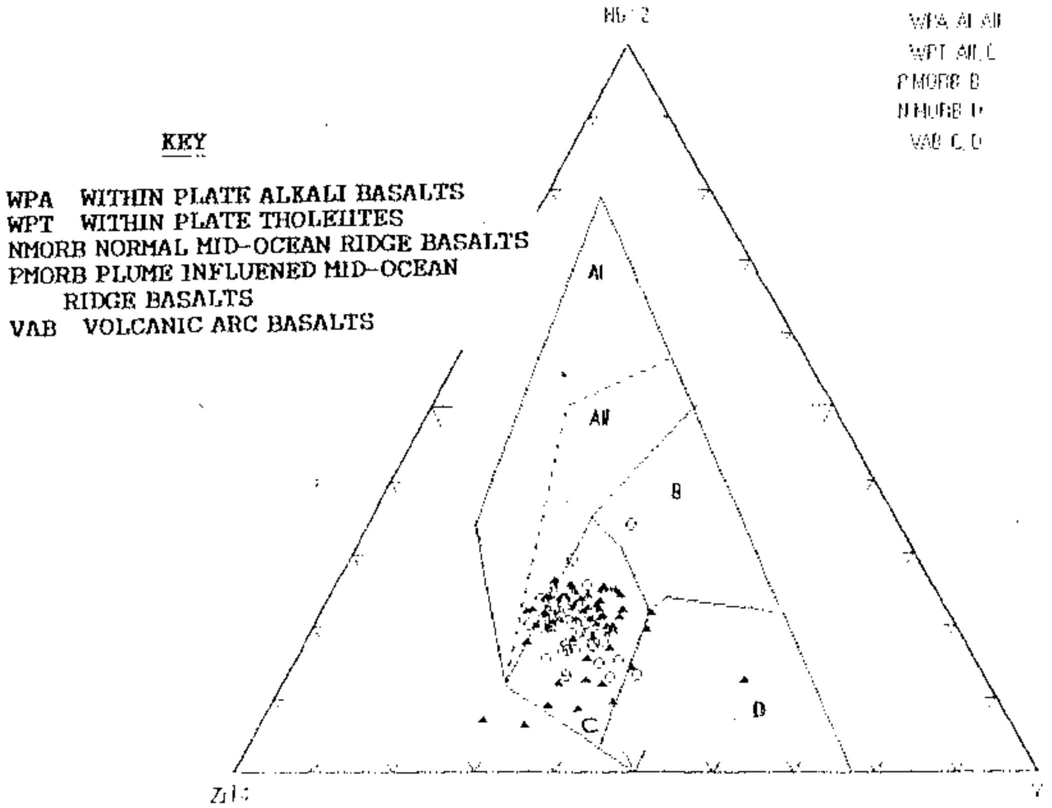
FeO^* – (Na_2O + K_2O) – MgO diagram for the Pypklipberg Formation data from this study.
(diagram from Irvine and Barager ,1971)
[○ Hartland Basin * White Mfolozi R. Inlier
▲ Mhlatuze River Inlier]

FIGURE 6.7



FeO^* – (Na_2O + K_2O) –MgO diagram for the Agatha Formation data from this study.
(diagram from Irvine and Barager ,1971)
[× Central Syncline ● Buffalo R.Inlier
○ White Mfolozi R. Inlier
▲ Hartland Basin]

FIGURE 6.8 Nb - Zr - Y discrimination diagram for the total Nsuze data set .(diagram from Meschede, 1986)
[▲ Agatha Formation ○ Pypklipberg Formation]


KEY

WPA WITHIN PLATE ALKALI BASALTS
WPT WITHIN PLATE THOLEIITES
NMORB NORMAL MID-OCEAN RIDGE BASALTS
PMORB PLUME INFLUENED MID-OCEAN RIDGE BASALTS
VAB VOLCANIC ARC BASALTS

FIGURE 6.9 Log (Zr/Y) - log Zr (ppm) diagram for the total Nsuze lava data set . (diagram from Pearce and Norry , 1979)
[▲ Agatha Formation ○ Pypklipberg Formation]

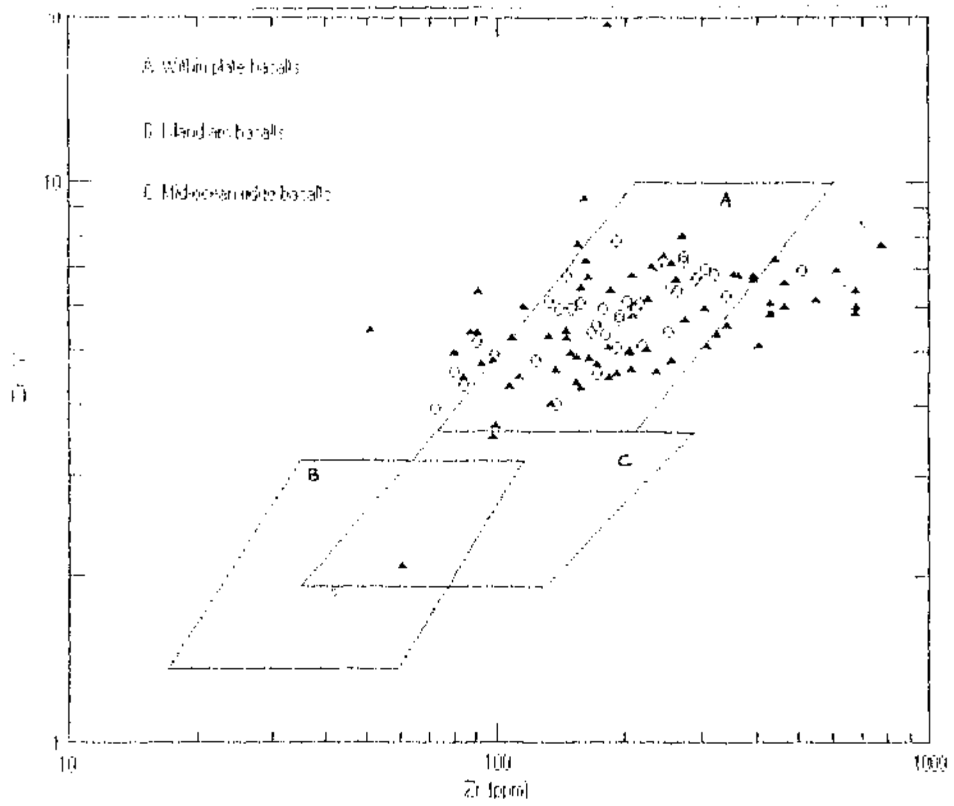


FIGURE 6.10 Ti – Zr – Y diagram for this study's lava data set. (diagram from Pearce and Cann , 1973.)
[o Agatha Formation ▲ Pypklipberg Formation]

KEY

WPB	WITHIN PLATE BASALTS
OFB	OCEAN FLOOR BASALTS
LKT	LOW POTTASIUM THOLEIITES
CAB	CALC ALKALI BASALTS

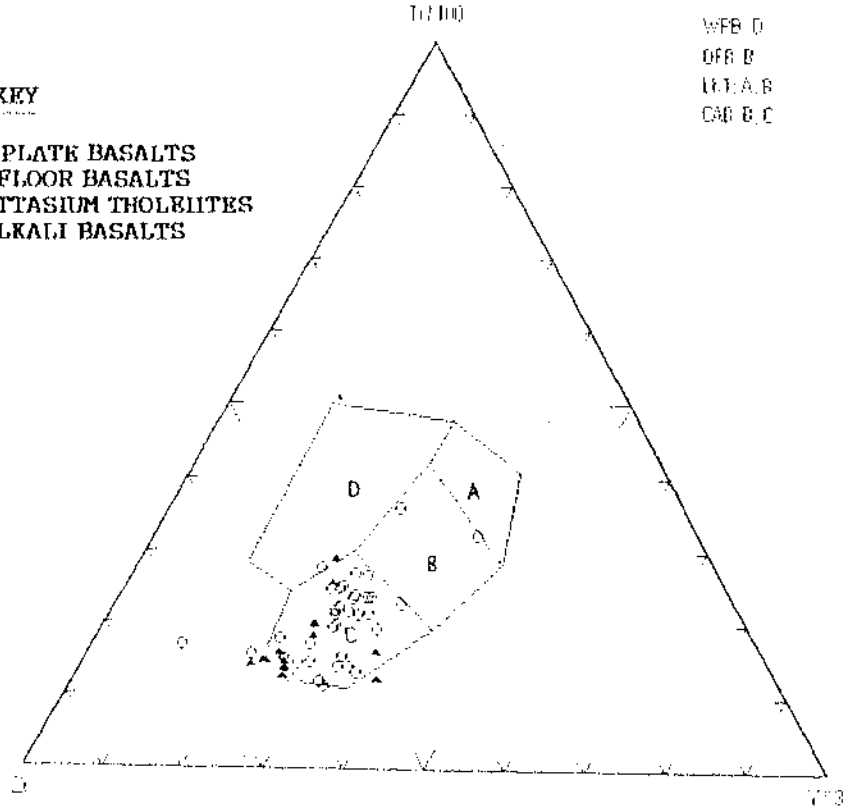
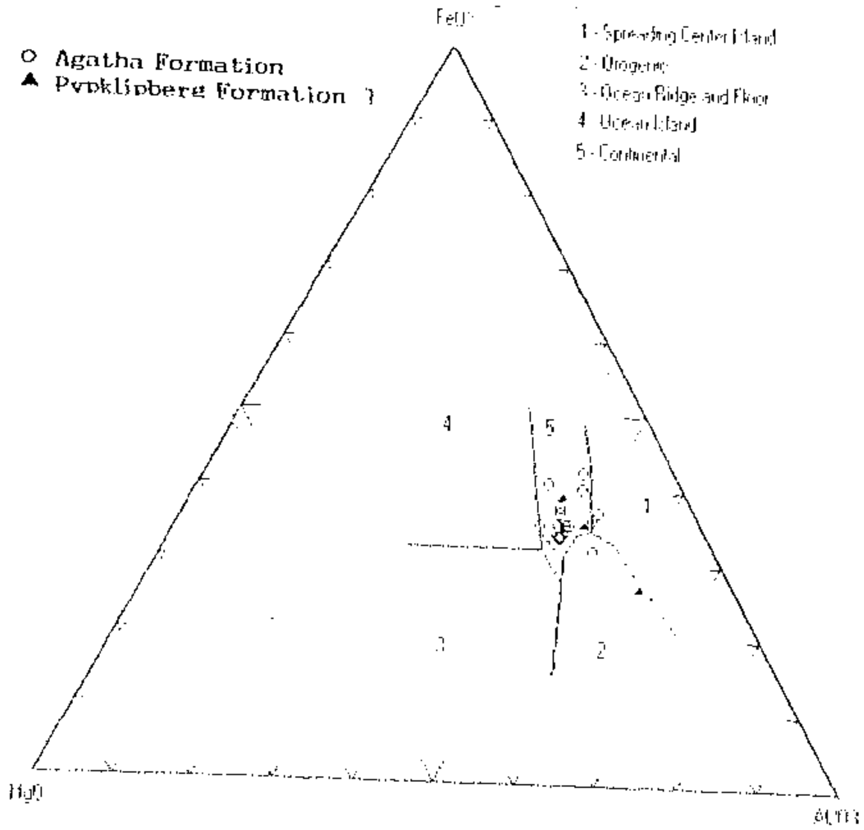


FIGURE 6.11 Fe2O* – MgO – Al2O3 diagram for this study's lava data set. (diagram from Pearce et al 1977)

[o Agatha Formation
▲ Pypklipberg Formation]



6.1.3 Summary

Nsuze lavas display a continuous compositional spectrum from basalt to rhyolite, with no compositional gaps. Agatha and Pypklipberg Formation volcanics display a combination of both tholeiitic and calc-alkaline affinities. Data suggest the tectonic setting of the Nsuze Group to be tholeiitic, within a continental plate, although a Ti-Zr-Y diagram re-emphasizes a calc-alkaline affinity.

The Pypklipberg and Agatha Formations have similar geochemical signatures. The two formations therefore probably extruded under similar tectonic conditions.

Although visibly subjected to at least regional greenschist grade metamorphism, it is thought that post-emplacement processes have not greatly altered the geochemical signatures of the lavas sampled during this study. For example all lavas plot on acceptable compositional fields in the total alkali-SiO_2 diagram (Fig. 6.1). However, some of the lavas sampled in other studies may have been altered, especially those from Preston (1987) in the Mpongoza inlier and some samples of this study from the Buffalo River inlier.

The application of discrimination diagrams based on high field strength immobile element ratios also helped to evaluate the possible effect of any post-emplacement alteration. Most of the data again plot in acceptable lava compositional fields with those from the study of Preston (1987), and some from the Agatha Formation in the Buffalo River inlier again being anomalous.

6.2 PELITES OF THE NSUZE GROUP

6.2.1 Introduction

The chemical composition of pelites can provide information on the composition, tectonic setting and evolutionary growth of the early continental crust (McLennan and Taylor, 1983). The Nsuze Group is one of the oldest and best-preserved supracrustal successions in the world and particulary its pelitic constituent could provide clues to the nature of the Kaapvaal lithosphere during this early part of crustal evolution.

An unpublished set of 39 chemical analyses of pelites from the Nsuze Group (shales and siltstones) was made available for this study by Gold Fields Mining and Development (major, minor and trace elements by X-ray fluorescence). Sample positions are indicated on Map 1. The analyses from this study were combined with published analyses to produce a stratigraphically-constrained Nsuze pelite database (Table 6.2). The original data are given in table 2 of Appendix 1.

TABLE 6.2:

SUMMARY OF SAMPLES FOR CHEMICAL ANALYSES OF PELITES FROM THE NSUZE GROUP

A. Langfontein / Vutshini Formation	
i. Western Hartland basin	a. this study (n=3)
ii. Central Syncline (Nkandla)	a. this study (n=14) b. Wronkiewicz and Condie (1989)
B. White Mfolozi Formation	
i. Mpongoza inlier	a. Wronkiewicz and Condie (1989) b. McLennan and Taylor (1983)
ii. White Mfolozi inlier	a. this study (n = 5) b. Wronkiewicz and Condie (1989)
iii. Mhlatuze River inlier	a. this study (n=4)
C. Mantonga Formation	
i. Buffalo River inlier	a. this study (n=13)

(n = number of samples analysed)

Geochemical investigations of pelites of the Pongola Supergroup by Wronkiewicz and Condie (1987, 1989) and Mclennan and Taylor (1983) have provided clues to the provenance of the Pongola Supergroup. The application of pelite geochemistry to gain an insight to Nsuze Group provenance is fairly problematic, open to the influence of many unpredictable variables. Although source composition is the dominant factor controlling the composition of fine-grained terrigenous clastic sediments, a complex combination of other factors such as weathering, hydraulic sorting during transport, element adsorption onto clay particles, tectonic setting, diagenesis and even metamorphism can also have an influence (Wronkiewicz and Condie, 1989). Bearing in mind these restrictions, a limited geochemical analysis is made here to investigate the provenance of the material and to determine if any stratigraphic geochemical variations exist.

6.2.2 Results

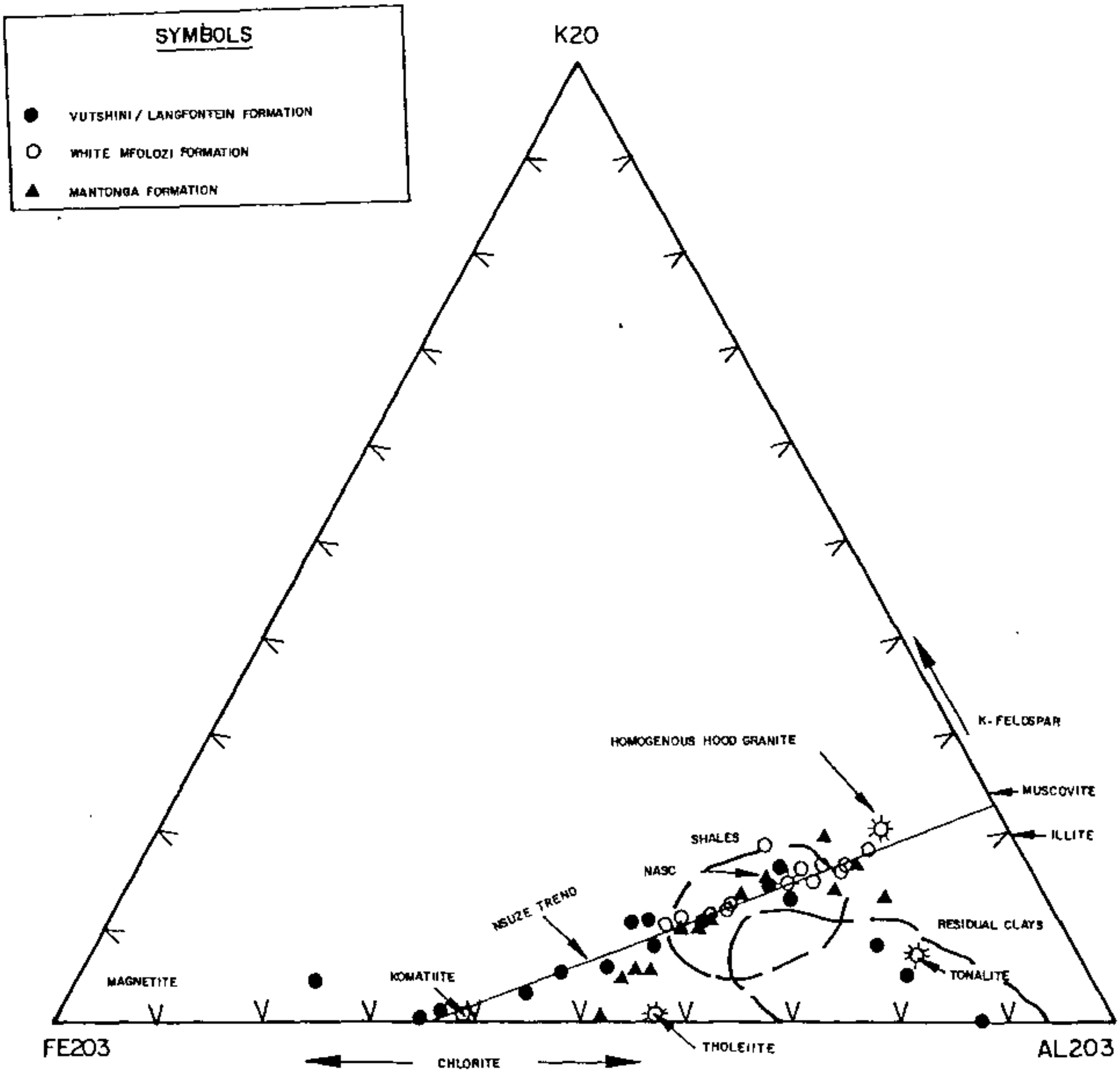
X-ray diffraction analyses of Pongola pelite samples by Wronkiewicz and Condie (1989) have shown Nsuze pelites to have relatively constant mineral compositions, with muscovite (illite) and chlorite the major constituents, and minor amounts (< 10 %) of pyrophyllite, potassium-feldspar, quartz and kaolinite.

The entire pelite database, from all formations and geographic locations, plotted on a K_2O-Fe_2O3-AL_2O_3 ternary diagram, define a mixing line between the chlorite and illite/muscovite end members (Fig. 6.12). Data from the Langfontein/Vutshini Formation define a spread of points along the entire trend, while data from the White Mfolozi Formation are clustered around the Phanerozoic North American Shale Composite (NASC, Fig. 6.12). Three Vutshini/Langfontein samples plot in the residual clay field and are thought to reflect the effects of modern weathering.

With the exception of a few analyses from the Vutshini/Langfontein Formation in the Hartland basin and from the Mantonga Formation in the Buffalo River inlier, Nsuze pelites are substantially enriched in Ni and Cr relative to NASC (Fig. 6.13). Wronkiewicz and Condie (1989) also recognised that Pongola pelites differ from other Archaean pelites in having high Cr/Ni ratios and positive Cr anomalies on NASC-normalized diagrams.

The geochemical observations of Wronkiewicz and Condie (1989) from a study of 36 Nsuze pelites suggest that, relative to the NASC, most Pongola pelites have similar concentrations of large ion lithophile elements (K, Pb, Sr, Ba, Th, U, Pb) high field strength elements (Y, Zr, Ti, Nb, Hf, Ta), rare earth elements, V and Sc. The Nsuze analyses of some of those elements from this study are compared to that of the NASC in table 2 (Appendix 1) showing marked similarities.

FIGURE 6.12 AL2O3 – Fe2O3 – K2O diagram for the total Nsuze Group pelite data set.



(☼ additional geochemical plots from Wronkiewicz and Condie, 1989).

Nsuze pelites show marked inter-formation and geographic variations in some major and trace elements. Such geographic variations often produce a large data scatter in some binary and ternary diagrams. A Cr-Ni-Y plot illustrates this, with some pelites from the Langfontein/Vutshini Formation in the western part of the Hartland basin and the Mantonga Formation in the Buffalo River inlier for example having very low Cr and Ni values relative to the rest of the Nsuze pelites (Fig. 6.14). This scatter may indicate local source heterogeneities.

FIGURE 6.13 Cr – Ni (ppm) diagram for the total Nsuze Group pelite data set.
[● Vutshini /Langfontein Formation
○ White Mfolozi Formation
▲ Mantonga Formation (Buffalo River Inlier)
✳ NASC]

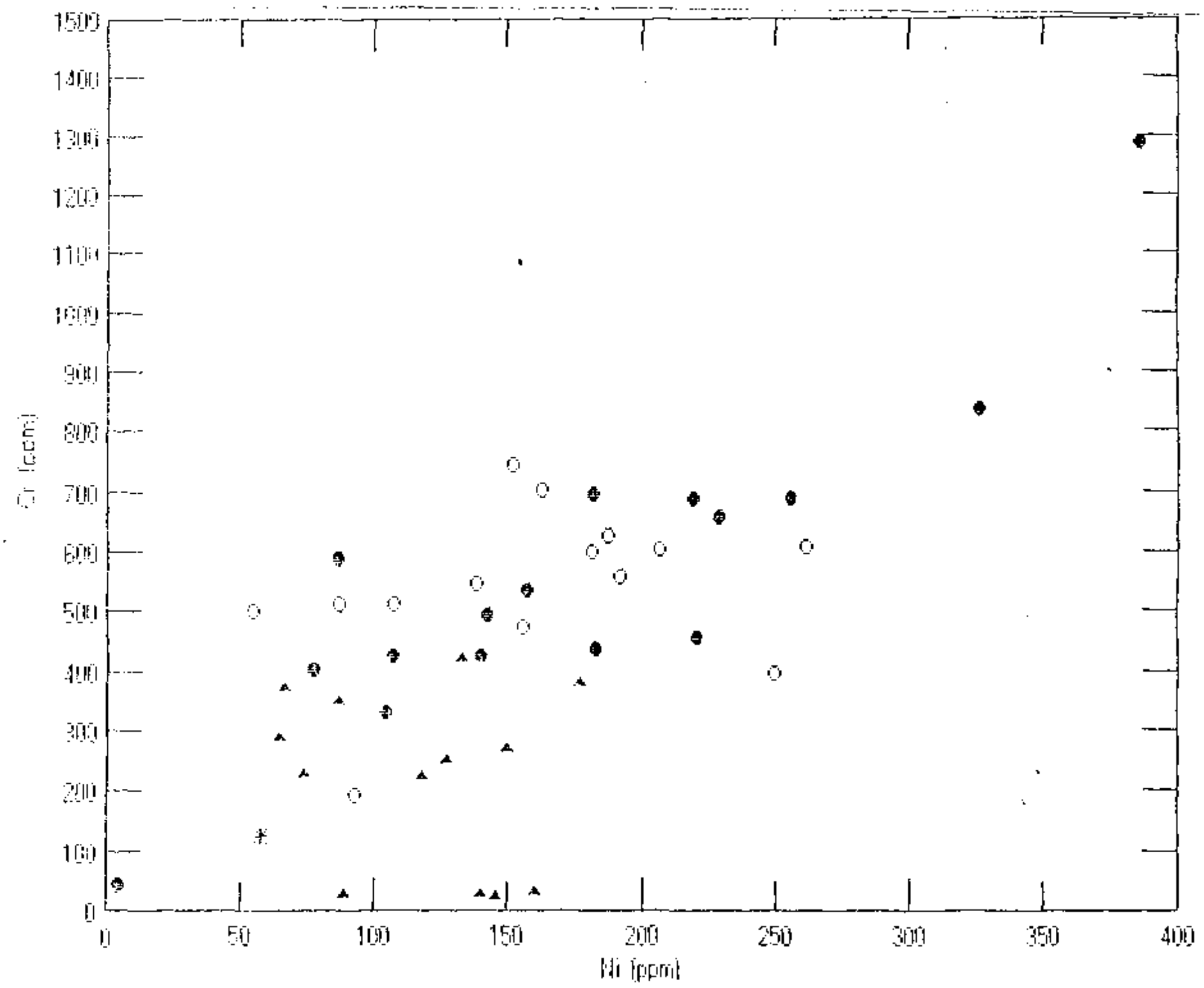
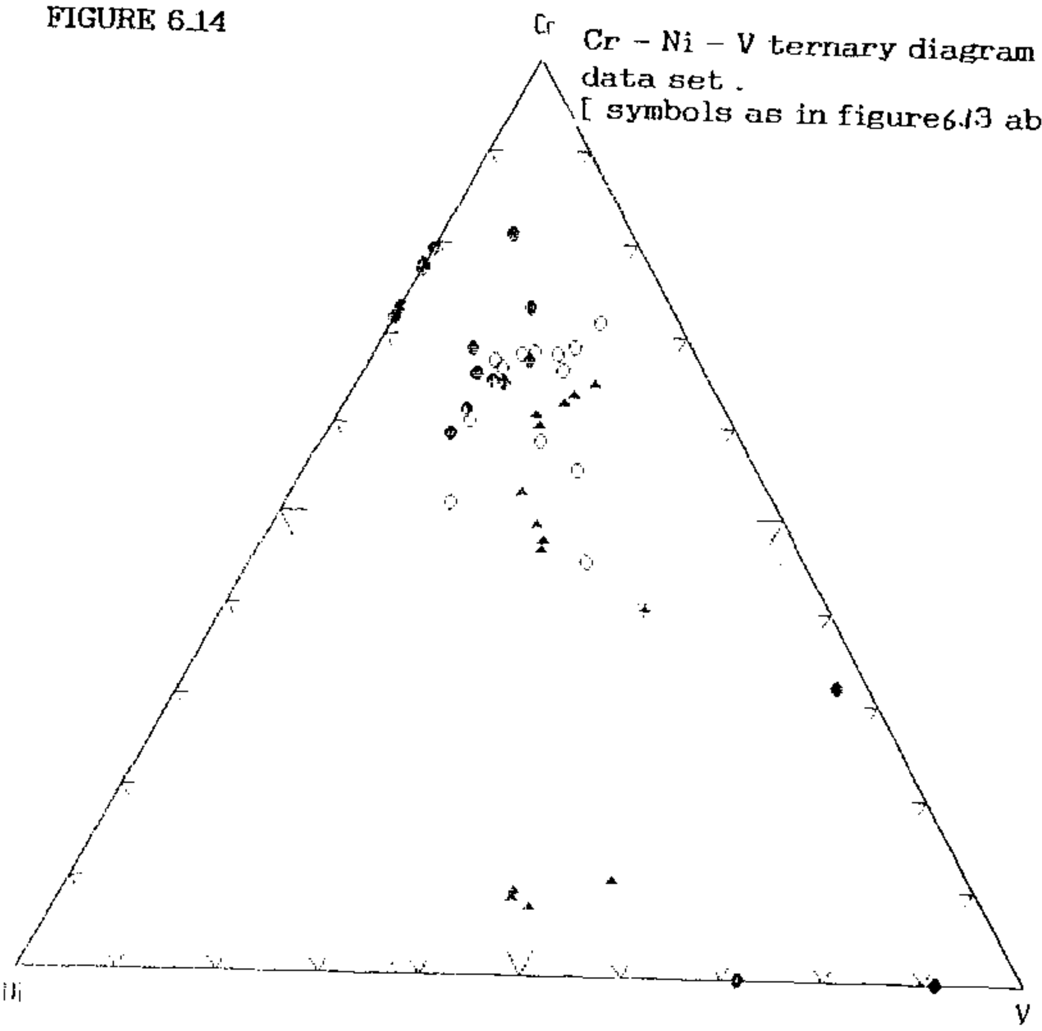


FIGURE 6.14 Cr – Ni – V ternary diagram for the total Nsuze pelite data set.
[symbols as in figure 6.13 above)



CHAPTER 7: COMPARISON BETWEEN THE NSUZE AND DOMINION GROUPS

7.1 INTRODUCTION

The Dominion Group is a volcano-sedimentary sequence of Archaean-age unconformably underlying the Witwatersrand Supergroup and overlying granite/greenstone basement in the Western Transvaal and Northern Orange Free State. Exposure is best to the west of Klerksdorp and in the Ottosdal district. Here the sequence consists of a basal clastic sedimentary unit, the Rhenosterspruit Formation, overlain by mafic amygdaloidal lavas, the Rhenosterhoek Formation and capped by massive felsic volcanics, the Syferfontein Formation (stratigraphic subdivision after SACS, 1980).

Due to poor surface exposure, the Dominion Group has not been studied in detail and its sub-outcrop extent is not well known. Dominion Group borehole intersections south of Welkom greatly increases the potential original extent of the Dominion basin (Jackson, 1992), suggesting that the Dominion Group once occupied a vast area, in contrast to it's limited surface outcrop extent.

The recent regional correlation of the Witwatersrand Supergroup with the Mozaan Group of the Pongola Supergroup (Beukes and Cairncross, 1991), coupled with the fact that the Nsuze Group stratigraphically underlies the Mozaan Group, re-emphasizes the possibility that the Nsuze Group is a regional correlate of the Dominion Group. This possibility will be briefly assessed here in terms of geochronology, lithostratigraphy, geochemistry and inferred tectonic settings.

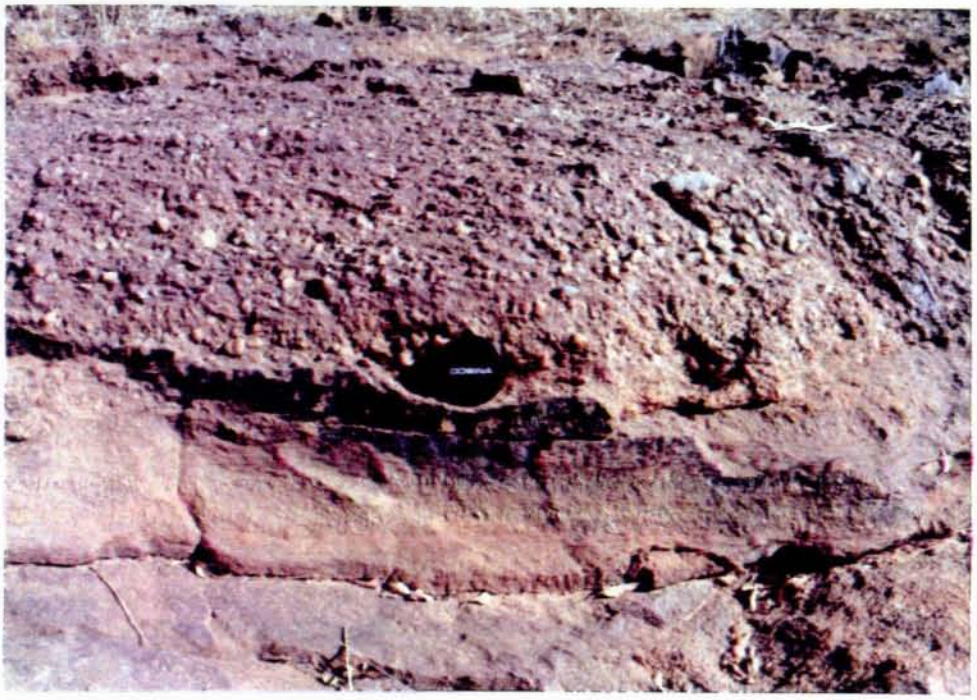
7.2 GEOCHRONOLOGY

The Nsuze Group is broadly bracketed between 3 107 ± 4 Ma (basement granite, Swaziland, U-Pb single zircon, Kamo et al, 1990) and 2 871 ± 30 Ma (Usushwana pyroxenite, Sm-Nd, Hegner et al (1984). A recent U-Pb single zircon age for an upper Agatha Formation rhyolite in Swaziland by Hegner et al (1993) is 2 984 ± 2,6 Ma. Burger and Coertze (1973) report a Rb/Sr age of 3 090 ± 90 Ma for a lava in the Nsuze Group.

In the Hartbeesfontein area, two granites unconformably underlying the Dominion Group have been dated at 3 120 ± 5 Ma (Armstrong et al, 1990) and 3 174 Ma (Robb et al, 1991) (both U-Pb zircon dates). Recent U-Pb single zircon dating from Syferfontein Formation quartz porphyry has yielded an age of 3 074 ± 6 Ma based on 5 concordant and 4 discordant analyses (Armstrong et al. 1990).

FIGURE 7.1 Oligiomictic pebble-supported, large pebble conglomerate with pebble size ≤ 7 cm (basal Renosterspruit conglomerate on the farm Oorbietjiesfontein, Dominionville area).

FIGURE 7.2 Thin oligiomictic pebble-supported small pebble conglomerate (upper Renosterspruit conglomerate on the farm Oorbietjiesfontein, Dominionville area).



In summary, the Nsuze and Dominion Groups appear to fall in about the same age bracket.

7.3 LITHOSTRATIGRAPHIC COMPARISONS

A lithostratigraphic profile of the Dominion Group was measured in the type area near Dominionville, west of Klerksdorp in order to compare it with that of the Nsuze Group (Map 16 a). The locality of the profile is also indicated on Map 16 a.

The granitoid basement is poorly exposed in the type locality near Klerksdorp and Ottosdal, but is reported to consist of older light grey homogeneous granitoids becoming schistose towards the base of the Dominion Group (Button and Tyler, 1981). This schistose zone is similar to that occasionally seen immediately below the Nsuze Group (western part of the Hartland basin and Mhlatuze River inlier), possibly representing a deformed palaeosol (Matthews and Scharrer, 1968).

The reference profile of the Dominion Group near Dominionville is simplistically illustrated in Map 16 b. It is also compared with a profile by von Backström (1952, 1962) from the Ottosdal area. A much thicker volcano-sedimentary pile is preserved in the Ottosdal area (only a portion shown in Map 16 b). It may be due to differential rates of basin subsidence as suggested by Watchorn (1980), or merely reflect removal of more material by erosion in the Dominionville area relative to the Ottosdal area before deposition of the Witwatersrand Supergroup.

The basal Rhenosterspruit Formation is well exposed on the farm Oorbietjiesfontein. It is some 35 m thick and comprises a sequence of coarse arkosic quartzite, gritstone, conglomerate and rare sericitic schist with variable thicknesses. Two well-documented auriferous conglomerate beds occur at the base of the formation. The lower conglomerate (Map 16 b) contains large pebbles and is up to 1,0 m thick. The upper conglomerate is a thin small pebble conglomerate separated from the lower conglomerate by a quartzite a few meters thick (Fig. 7.1).

The overlying Rhenosterhoek Formation is some 600 m thick, composed mainly of mafic amygdaloidal lavas (Fig. 7.4) with a few interbeds of tuff and felsic porphyry (Watchorn, 1980). The lavas are green to grey in colour. Microscopic studies indicate it to be metamorphosed to at least greenschist facies. The overlying Syferfontein Formation is some 1100 m thick and comprises massive quartz-feldspar porphyry (Fig. 7.3), with occasional amygdaloidal textures, and rare intercalations of mafic to intermediate lavas on the farm Syferfontein 303. It is unconformably overlain by orthoquartzite of the Orange Grove Formation of the

FIGURE 7.3 Photomicrograph showing a tabular plagioclase crystal in an altered green groundmass comprising microlithic plagioclase, quartz, chlorite, carbonate, opaques and minor sericite. 5X magnification. (Syferfontein feldspar porphyry, Dominionville area).

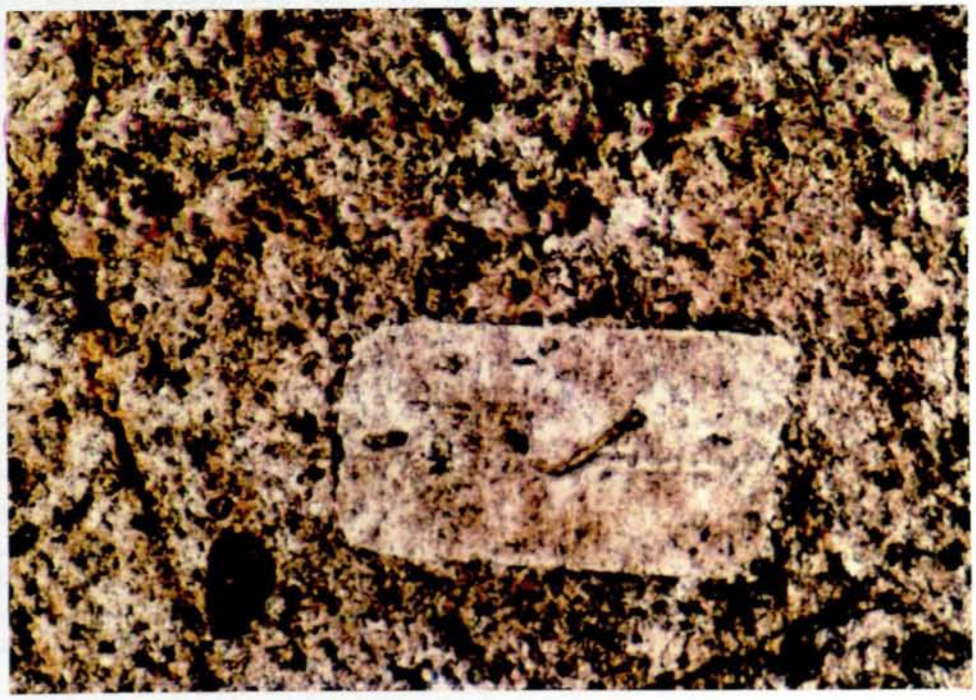


FIGURE 7.4 Oval-shaped large quartz-filled amygdales in a green aphanitic mafic lava of the Renosterhoek Formation. (Doornfontein farm, NNE of Klerksdorp).

Hospital Hill Subgroup of the Witwatersrand Supergroup. In the Ottosdal area the Syferfontein Formation contains some thin (up to 70 m thick) pyrophyllite-rich units locally known as 'wonderstone'. These units are thought to represent altered volcaniclastic sedimentary units (Nel et al, 1937).

Compared to the Nsuze Group the Rhenosterspruit Formation can be correlated with the Mantonga Formation (Fig. 7.9). The Rhenosterhoek and Syferfontein Formations would then collectively form a correlate of the Pypklipberg Formation of the Nsuze Group (Fig. 7.9). This implies that large parts of the Dominion Group has been removed by erosion prior to deposition of the Witwatersrand Supergroup (Fig. 7.9). Recent work by Van der Merwe (1994) indicated that a major unconformity exists between the Dominion Group and the West Rand Group. This correlation also indicates that isotopic age dates cannot be directly correlated. It would be important to date felsites from the Pypklipberg Formation for a more meaningful direct comparison to the Dominion Group (Fig. 7.9).

To summarize, both the Dominion and Nsuze Groups are underlain by similar age granitoid basement (i.e. 3107 Ma to 3120 Ma), providing similar maximum ages to both groups. The Syferfontein age of 3074 Ma represents the lower Nsuze-correlate volcanic, which has not been accurately dated in the Nsuze Group. A poorly-constrained date of 3083 ± 150 Ma was reported by Burger and Coetzee (1973) for a Nsuze felsite (Rb-Sr whole rock). The Agatha Formation, which is not preserved in the Dominion Group, is dated at 2984 Ma. The 2871 Ma Usushwana age can be taken as a minimum age to Nsuze/Dominion Group emplacement. An excellent geochronological match thus exists between the two Groups, constraining their evolution to the period 3107/3120 to 2871 Ma. Age dating thus supports the interbasin lithostratigraphic correlations proposed here.

7.4 GEOCHEMICAL COMPARISONS

A comprehensive Dominion Group geochemical database is provided by Crow and Condie (1987), Bowen (1984) and Bowen et al (1986). A selection of Dominion Group lava analyses from both the Rhenosterhoek and Syferfontein Formations (from data published by the above workers) for comparison with the Nsuze Group database is given in table 3 (Appendix 1). The database of Dominion lavas come mainly from borehole samples in the Klerksdorp area.

FIGURE 7.5 Log (Zr / TiO2) vs log (Nb / Y) diagram for the Nsuze and Dominion data sets.
(diagram from Winchester and Floyd ,1977)
[symbols as in figure 7.6 below]

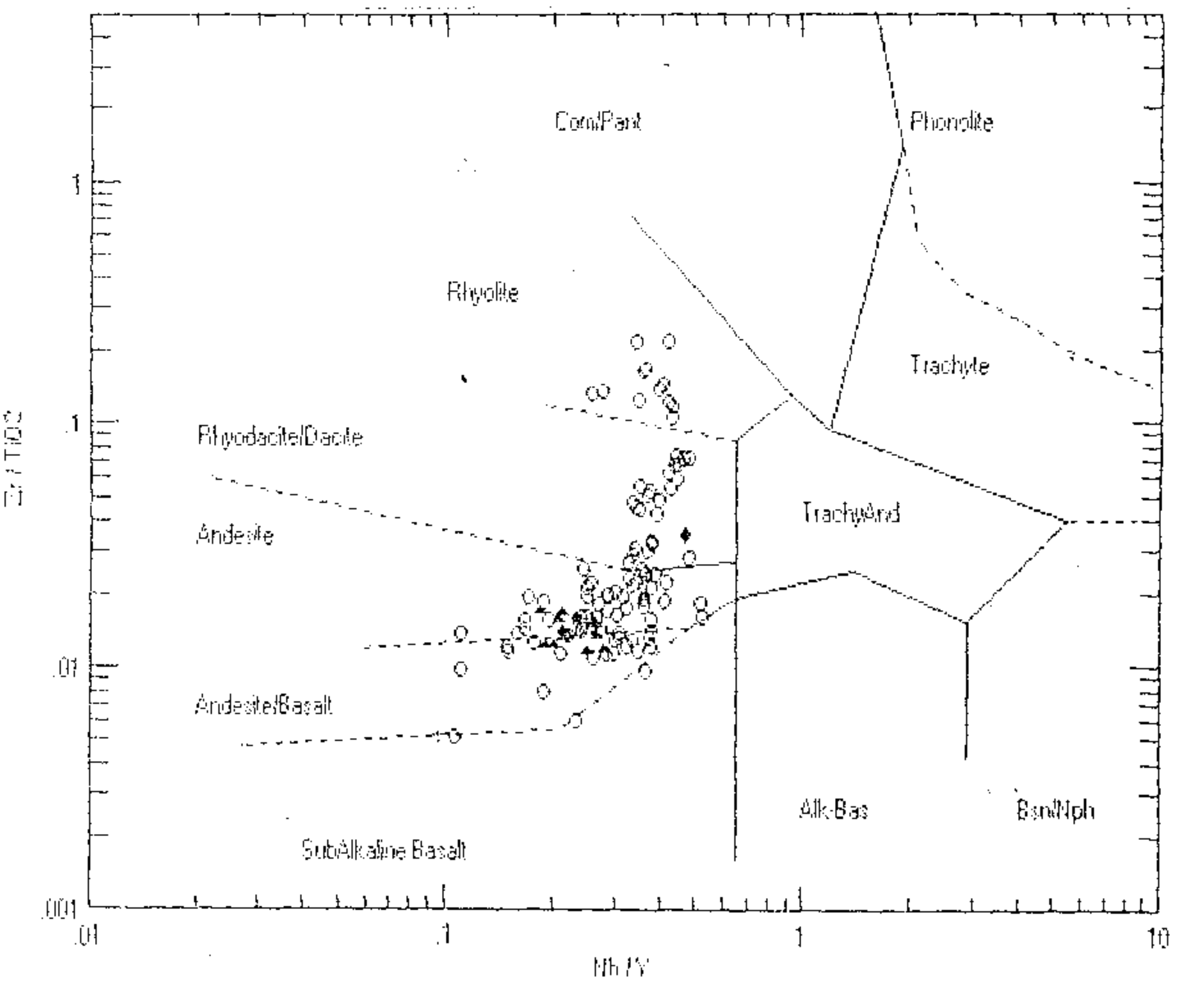
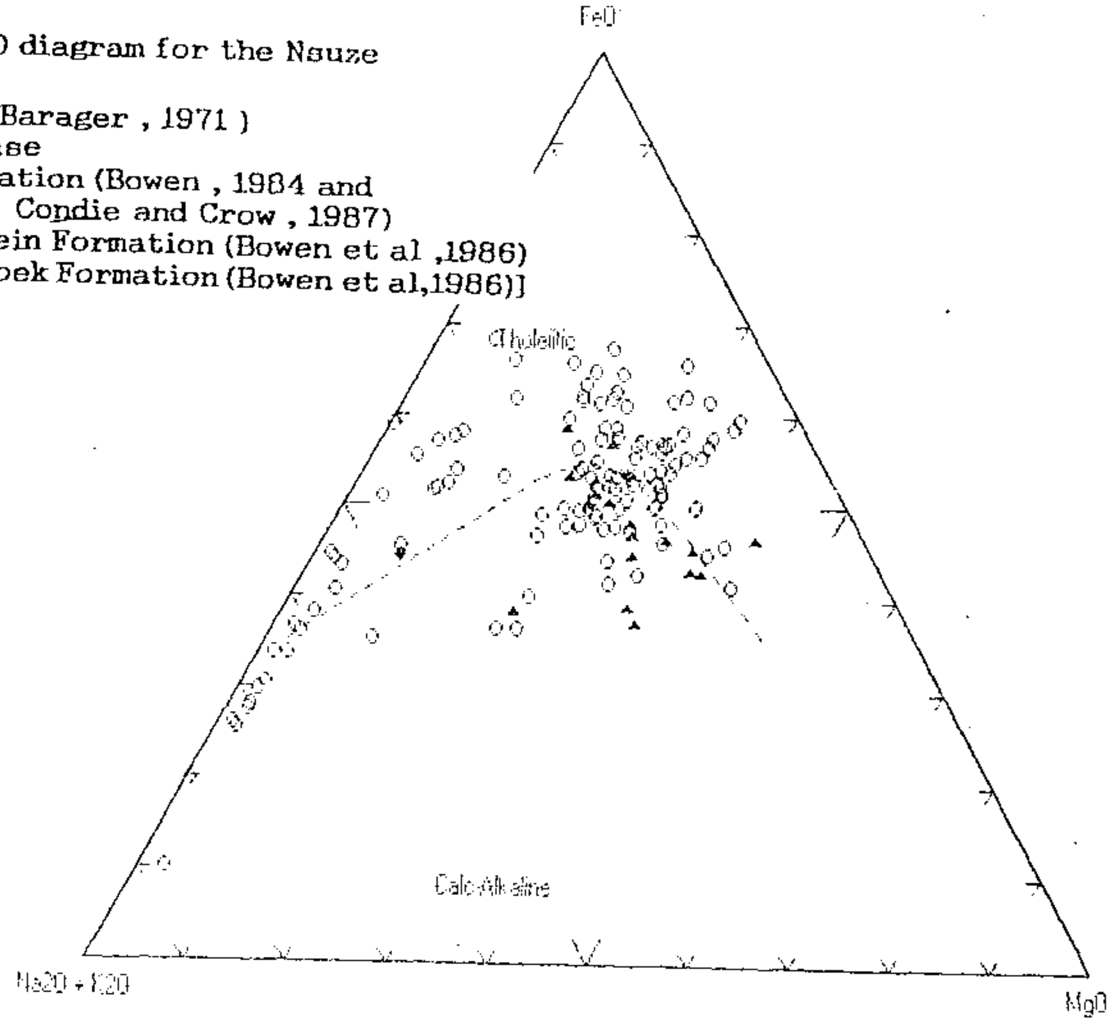


FIGURE 7.6

FeO* – (Na2O + K2O) – MgO diagram for the Nsuze and Dominion data sets.
(diagram from Irvine and Barager , 1971)
[o Total Nsuze database
▲ Renosterhoek Formation (Bowen , 1984 and Condie and Crow , 1987)
♦ Average Syferfontein Formation (Bowen et al ,1986)
✳ Average Renosterhoek Formation (Bowen et al,1986)]



The total Nsuze database and the selected Dominion analyses from table 3 are plotted on a log (Zr/TiO_2) vs log (Nb/Y) diagram (after Winchester and Floyd, 1977) in figure 7.5. The Dominion lavas have a bimodal nature with the Rhenosterhoek lavas having a well-constrained andesitic composition. In contrast, the average Syferfontein porphyry analyses plot in the rhyodacite/dacite field. This appears to be in contrast to the continuum of compositions defined by lavas of the Nsuze Group.

Similar to lavas of the Nsuze Group, the Dominion lavas have both tholeiitic and calc-alkaline compositions on a AFM diagram (Fig. 7.6, after Irvine and Barager, 1971).

The Dominion lavas are also very similar to Nsuze lavas if other elements are compared. On a log (Zr/Y) vs log (Zr) variation diagram both the Nsuze and Dominion data show a similar spread of data concentrated around the within-plate basalt field (Fig. 7.7). On a Nb-Zr-Y ternary plot (Fig. 7.8) both groups are concentrated in the C-field (and AII field) suggestive of a within-plate tholeiite.

A correlation between the Dominion and lower part of the Nsuze Group (Mantonga and Pypklipberg Formations) thus seems a distinct possibility. The geological evidence in support of this statement can briefly be summarized as follows:

a) The similar stratigraphic sequence of the two groups (i.e. clastic sedimentary rocks overlain by mafic/felsic volcanics).

b) Both groups are underlain unconformably by granitoid basement (sometimes with a possible deformed palaeosol at the contact) and unconformably overlain by arenaceous sedimentary rocks of the Mozaan and West Rand Groups. The West Rand Group has been rigidly correlated with the lower part of the Mozaan Group (Beukes and Cairncross, 1991).

c) The two groups have approximately similar radiometric ages.

d) The geochemical signatures of the Nsuze volcanics are very similar to those of the Dominion volcanics with data plotting in close proximity on most variation diagrams. In particular, the concentration of immobile incompatible trace elements are very similar.

e) Both groups have a similar alteration and metamorphic overprint, possibly indicating a similar geological history.

FIGURE 7.7 Log (Zr/Y) vs log Zr diagram for the Nauze and Dominion data sets . (diagram from Pearce and Norry , 1979)
[symbols as for figure 7.8 below]

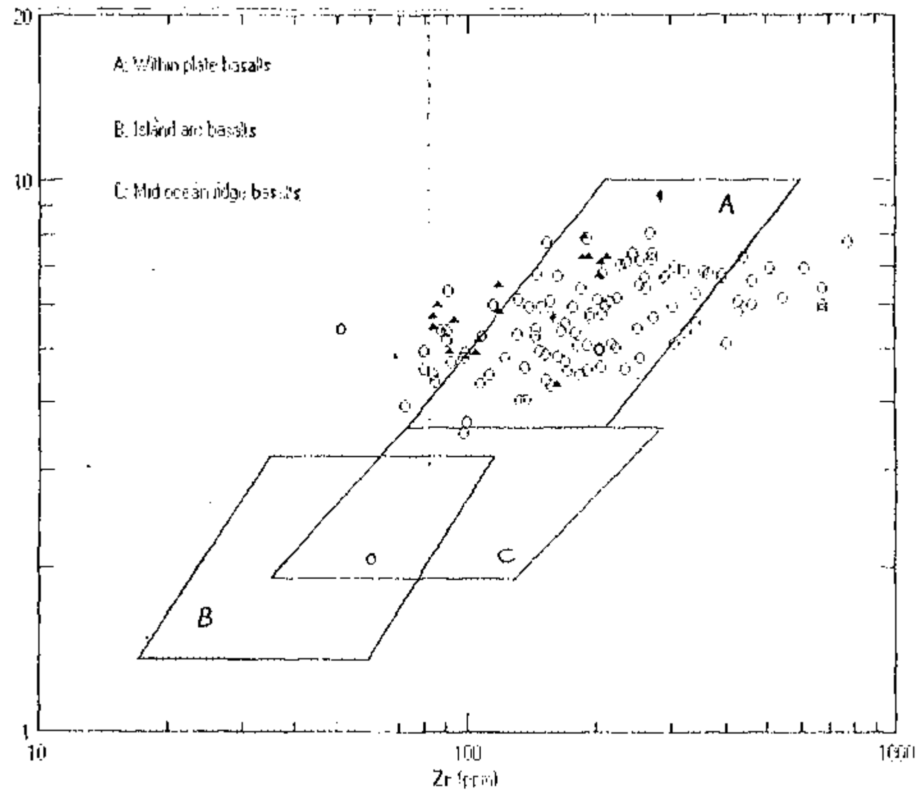
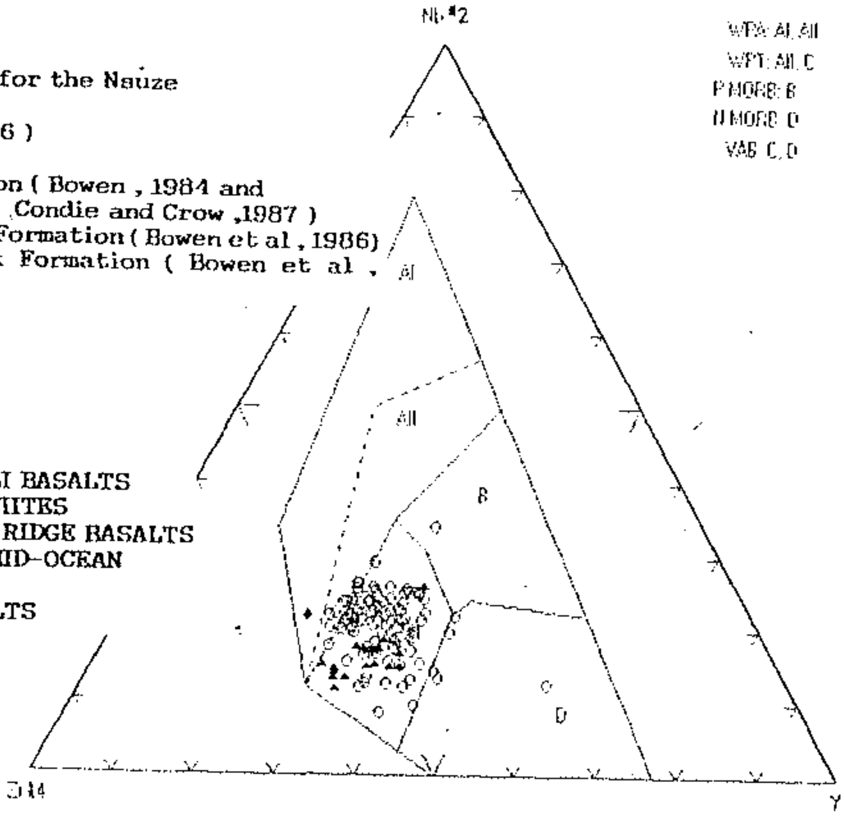


FIGURE 7.8

Nb – Zr – Y ternary diagram for the Nauze and Dominion data sets.
(diagram from Meschede , 1986)
[○ Total Nauze Group
▲ Renosterhoek Formation (Bowen , 1984 and Condie and Crow ,1987)
◆ Average Syferfontein Formation (Bowen et al , 1986)
✳ Average Renosterhoek Formation (Bowen et al , 1986)]



KEY

WPA WITHIN PLATE ALKALI BASALTS
WPT WITHIN PLATE THOLEIITES
NMORB NORMAL MID-OCEAN RIDGE BASALTS
PMORB PLUME INFLUENED MID-OCEAN RIDGE BASALTS
VAB VOLCANIC ARC BASALTS

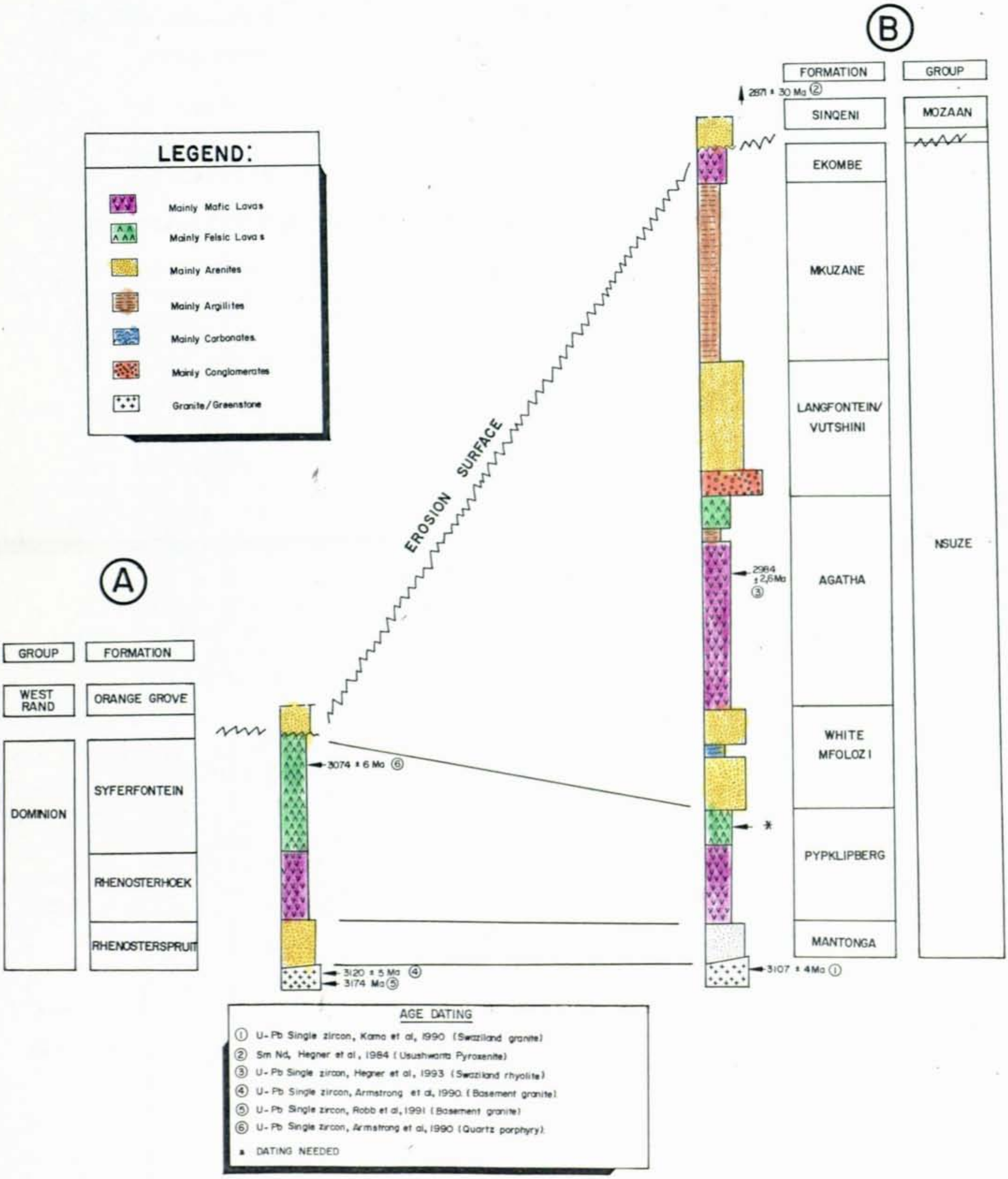
f) The provenance for Dominion conglomerates consisted mainly of granite with subordinate contributions from mafic to ultramafic lavas and older arenites (Reimer, 1986). This provenance is similar to that proposed for the Nsuze Group.

g) Reimer (1986) proposes that Witwatersrand conglomerates were partially derived from arenaceous sequences in the Dominion Group, implying that the latter had a much wider geographic distribution. Thus it may well have been part of the Nsuze Group depository.

h) Dominion geochemistry suggests deposition in a failed continental rift-basin tectonic setting (Bickle and Eriksson, 1982; Clendenin et al, 1988; Stanistreet and McCarthy, 1991), this scenario is similar to that proposed for the Nsuze Group (Armstrong et al 1982, 1986, Burke et al. 1985).

FIGURE 7.9

DIAGRAM SHOWING NSUZE DOMINION GROUP CORRELATION



Not to Scale

CHAPTER 8: DISCUSSION

8.1 INTRODUCTION

In this chapter the depositional environment of the Nsuze Group will be discussed. Once this is established, an attempt will be made to place the sequence into some type of tectonic setting.

8.2 DEPOSITIONAL ENVIRONMENT

The lithostratigraphic sequence along the Mantonga River traverse is thought to be representative of the spread of depositional environments in the Mantonga Formation. The conglomeratic zone at the base of the Mantonga Formation most probably indicates a high energy fluvial depositional environment. The overall nature of the sedimentary rocks in the Mantonga Formation suggests deposition in a distal sandy braided stream environment (Figure 8.1). It is suggested that the Mantonga Formation has features similar to the sandy braided systems of the South Saskatchewan (Cant and Walker, 1978) and Platte River (Smith, 1970). This interpretation is supported by Watchorn and Armstrong (1980). The overall small scale of cross-stratification (< 1,0 m high) and the relative absence of significant shale units suggests shallow water conditions with rapid lateral migration of channels. The shale units near the base of the formation are transgressive, possibly indicating periods of marine flooding between fluvial depositional events.

The diamictitic units within the dominantly arenaceous Mantonga Formation need special explanation. The massive nature of the diamictites suggest rapid deposition. One must also account for the polymictic clast population in the diamictites, which range from granite to quartzite to volcanic fragments. A mixed epiclastic/pyroclastic origin for the diamictites is thus envisaged. Pyroclastic material probably became mixed with fluvial detritus (including rounded clasts) in a tectonically unstable environment to produce the diamictitic units. It is possible that unconsolidated pyroclastic or tuffaceous accumulations flowed downslope to mix with fluvial material and to be partially reworked under fluvial conditions on braided alluvial plains. Pyroclastic and tuffaceous material could also have been erupted to land directly on the braided alluvial plains where it become mixed with fluvial detritus. Watchorn and Armstrong (1980) diagrammatically-propose such a palaeoenvironmental model for the Mantonga Formation. Point count analyses on arenites from the Mantonga Formation (plotted during this study) suggest a craton interior provenance on a Qm-F-Lt diagram (after Dickinson and Suczek, 1979).

Eventual denudation of the granitic provenance area apparently caused a decline in fluvial activity towards the upper part of the Mantonga Formation. Sedimentation was succeeded by the extrusion of large volumes of mafic lavas representing the lower part of the Pypklipberg Formation.

The Mantonga Formation in the Amsterdam profile (Fig. 4.1) has a similar basal conglomeratic zone to that in the Mantonga River profile succeeded by diamictitic beds. Here the middle and upper parts of the Mantonga Formation are dominated by upwards - fining arenite successions and flat bedding. Such structures could indicate high energy shallow water depositional conditions on a braided fluvial plain. Two major shale units may again indicate marine transgressions.

The well-bedded orthoquartzites with basal conglomerate and sporadic arkosic grit layers at the base of the Mantonga Formation in the White Mfolozi River inlier most probably represents a thin marine transgressive deposit (Matthews, 1967) (Fig. 8.1).

Palaeocurrent directions in the Mantonga Formation throughout the Nsuze basin suggest a flow direction from the northeast (as in the White Mfolozi River inlier) to the southeast (as in the western part of the Hartland basin). The variation in palaeocurrent directions may reflect an initial irregular palaeotopography over which the braided streams flowed or may be due to a variety of marine currents in orthoquartzite units (Figs. 4.9 and 8.1)

The Pypklipberg Formation is characterised by lavas, being dominated by basalts, basaltic andesites and andesites. The formation is also characterised by subordinate explosive volcanic activity (locally significant at the Mpongoza inlier). The Pypklipberg lavas (excluding the felsic volcaniclastics of the Mpongoza inlier) were mainly extruded under subaerial conditions. This can be deduced from the proposed presence of braided fluvial sediments in the basal Mantonga Formation, indicating continental deposition. The scarcity of pillow structures or other evidence of subaqueous deposition, also points towards subaerial deposition. Poorly-developed pillow structures were observed at the base of the Mantonga River profile section and within the White Mfolozi River inlier (Fig. 4.10), but these are not typical of the Pypklipberg Formation. Armstrong (1980) suggests that the lack of any sedimentary intercalations within this formation also points towards a dominantly subaerial extrusion (Fig. 8.1).

Geochemically the lavas of the Pypklipberg Formation plot in the continental field of the FeO*-MgO-AL_2O_3 discrimination diagram of Pearce et al. 1977, which may also indicate subaerial extrusion. The extrusion of the Pypklipberg lava flows probably took place from a large number of vents, considering the wide distribution of the lavas.

The composition of the Pypklipberg Formation in the Mpongoza inlier, as reported by Preston (1987), differs from that in other areas (refer to Fig. 4.10 (3)). The Pypklipberg Formation here comprises a lower mafic lava sequence, which was extruded in a similar fashion to that described above, overlain by a felsic volcaniclastic sequence. Preston (1987) suggests that the felsic volcanics represent ignimbrite or pyroclastic flow units. Preston (1987) could not determine the nature of the eruption centre for these flows i.e. whether it was a single vent, a cluster of vents or a fissure. Considering the localized nature of this felsic pyroclastics within the Pypklipberg Formation, a single vent seems probable. Subsequent to the pyroclastic (or ash) flows there was a period of quiescence during which time the eruption centre became saturated (Preston, 1987) by ash material. This resulted in a short period of explosive volcanicity at the top of the Pypklipberg Formation in the Mpongoza inlier (Fig. 4.10 (3)).

Subsequent to deposition of the Pypklipberg Formation, widespread basin subsidence occurred creating favourable conditions for the accumulation of the sedimentary sequence of the White Mfolozi Formation. The type profile of the White Mfolozi Formation (in the White Mfolozi River inlier) comprises a succession of alternating siliciclastics, volcaniclastic diamictites and carbonate sedimentary rocks. The succession is thought to have been deposited in a tide-dominated environment of an epicontinental sea (Fig. 8.1). A tide-dominated depositional environment produces characteristic sedimentary structures depending on the position within a tidal flat (Klein, 1977). Sedimentary deposits of tidal flats are characterised by the following features, many of which are found within the White Mfolozi Formation, i.e. symmetrical and asymmetrical ripple marks, cross-stratification, wavy bedding, flaser bedding and lenticular bedding, shrinkage cracks, interlaminated silt and mud, and thin rhythmic lamination in the finer sedimentary layers (von Brunn, 1974; Klein, 1977). The banded shales near the base of White Mfolozi Formation, which grade upwards into interbedded shales and siltstones could represent distal marine shelf deposits.

The thick dominantly arenaceous sequence, overlying the argillaceous unit, comprises alternating subtidal and intertidal facies with characteristics similar to that described by Klein (1972). The succession probably formed by the progradation of tidal-flat (inter-tidal) sediments across sub-tidal environments (Tankard et al, 1982) controlled by sea level rise and fall. The intertidal sediments are characterised in particular by shale rip-up clasts, symmetrical and asymmetrical ripple marks, desiccation cracks and well-developed cross-stratification. The mature, medium-to-coarse grained well-bedded quartzites in the White Mfolozi Formation, which show well-rounded quartz grains and the absence of any features indicative of subaerial emergence, are likely to have formed in a subtidal depositional environment (in particular the thick quartzite units in the Nkandla Central Synform). The occasional thin shale units, within the formation, are likely to reflect an upper tidal flat depositional environment (especially if they contain mud cracks).

The carbonate units in the White Mfolozi Formation contain similar sedimentary structures to that in the siliciclastic sediments, suggesting a similar depositional environment. Von Brunn and Mason (1977) report the occurrence of stromatolitic chip conglomerates in the carbonate units suggesting that the biogenic structures were subjected to occasional emergence, desiccation and subsequent erosion. A study on the environmental control on diverse stromatolite morphologies from the thick dolomitic unit in the type profile by Beukes and Lowe (1989), indicate that the various stromatolite facies formed in tidal environments. Stratiform stromatolites formed in upper intertidal environments, domal stromatolites in middle intertidal environments, columnar stromatolites in lower intertidal environments and conical stromatolites in high energy subtidal channel environments.

The various partly volcanogenic diamictite units within the White Mfolozi Formation most probably reflect syn-sedimentary volcanic events. The diamictites sometimes contain quartzite, vein quartz, granite and altered volcanic clasts set in a chloritic matrix with dispersed semi-rounded quartz grains in it, most probably reflecting the volcano-sedimentary nature of the units.

The vertically recurring subtidal to intertidal deposits within the White Mfolozi Formation could be due to intermittent tectonic subsidence coupled with continued progradation due to a continued supply of sedimentary material (Von Brunn and Mason, 1977). Sedimentation rate and subsidence rates began to wane towards the top of White Mfolozi Formation. A period of erosion probably occurred before the commencement of Agatha Formation volcanism as indicated by the unconformity between the White Mfolozi and Agatha Formations along the type profile.

The lavas of the Agatha Formation display geochemical signatures ranging from basalt to rhyolite, with a significant volcaniclastic contribution. The sequence displays contrasting volcanic styles in different areas. A few profiles of the Agatha Formation will be briefly discussed to give an indication of the spectrum of volcanic conditions that prevailed during deposition.

In the southern domain the Agatha Formation (excluding the sequence at the Mpongoza inlier) is largely composed of amygdaloidal mafic lava with minor volcaniclastic interbeds. Pillow structures have been observed near the base of the succession in the Buffalo River inlier (Dixon, 1991) and at the base and top of the succession in the White Mfolozi River inlier (also recorded by Matthews, 1967). These structures, although uncommon, indicate that some of the lavas extruded under water. A series of volcanic vents are envisaged, with a continuous eruption of lavas resulting in complexly interdigitated lava flows of varying composition. The 150 m thick arenite member in the middle of the sequence in the Buffalo River inlier must represent a period of volcanic quiescence. It is correlated with the Ntambo Member, which is mainly argillaceous in the northern domain. The source area of the siliciclastics was thus most probably to the south (Fig. 8.1). The Agatha Formation in the north differs from that in the south in that it contains a lower felsic portion, separated from a mafic upper portion by a widespread argillite ± volcaniclastic (Ntambo Member). In the western part of the Hartland basin mafic lavas dominate below and above the Ntambo Member.

In southwestern Swaziland and east of Piet Retief, deposition of the White Mfolozi tidalites was followed by large scale felsic volcanism. Hatfield (1990) suggests that these felsic lavas were extruded from a number of volcanic centres, considering the high viscosity of felsic lavas and their wide distribution. Hatfield (1990) documents minor quartz wackes and argillites within the felsic succession east of Piet Retief, which he suggests to represent fluvial sediments deposited during brief periods of volcanic quiescence. The end of felsic volcanism in the northern domain was characterised by intermittent explosive pyroclastic activity (Hatfield, 1990), the products of which were deposited in the argillaceous Ntambo Member which succeeded felsic volcanism. The Ntambo Member possibly represents a period of basinal subsidence in the northern domain, with resultant deposition of a marine shale unit. Deposition of the shale was interrupted by deposition of pyroclastic debris and localised thin lava flows.

The mode of formation of the pyrophyllite schists within the Ntambo Member is unresolved at this stage (Hatfield, 1990). Deposition of the Ntambo Member was followed by extrusion of a large volume of lavas with intermediate composition. The lavas were probably erupted under similar conditions to that of the Agatha Formation in the southern domain, with subaerial conditions and localized depressed areas in which pillow lavas formed in subaqueous environments (Fig. 8.1).

In some areas the Agatha Formation is capped by reworked pyroclastic / volcaniclastic material, indicating a period of explosive volcanism terminating the Agatha volcanic event. The products of this explosive volcanism form part of the Roodewal Member, which forms the base of the clastic Langfontein / Vutshini Formation (Fig. 8.1).

The Mfenyana Subgroup essentially represents a major period of clastic sedimentation, following the period of Agatha volcanism. The Mfenyana Subgroup in some localities comprises a basal Roodewal Member (Fig. 4.30), which varies in thickness from in excess of 1 200 m (NQ2 drillhole) to about 10 m (east of Piet Retief). The thick conglomeratic Roodewal Member intersected in NQ2 is interpreted as evidence for a tectonically-active depositional environment. It may have formed along a fault scarp. Continuous uplift of a dominantly volcanic source (probably Agatha Formation volcanics) provided the volcanic detritus for the Roodewal Member, which is seen in NQ2 as a proximal portion of a clastic wedge thinning away from a steep uplifted source. Similar, but much thinner, volcanic pebble conglomerates are found in the Roodewal Member in the western part of the Hartland basin locally interbedded with and overlain by fine-grained rock types, which Armstrong (1980) terms volcanogenic sediments. These volcanogenic sediments are interpreted by Armstrong (1980) to include epiclastic volcaniclastites, airfall tuffs, accretionary lapilli tuffs and arenaceous and argillaceous lenses with some minor lava flows. The Roodewal Member thus also locally represents the last pulses of Agatha volcanism.

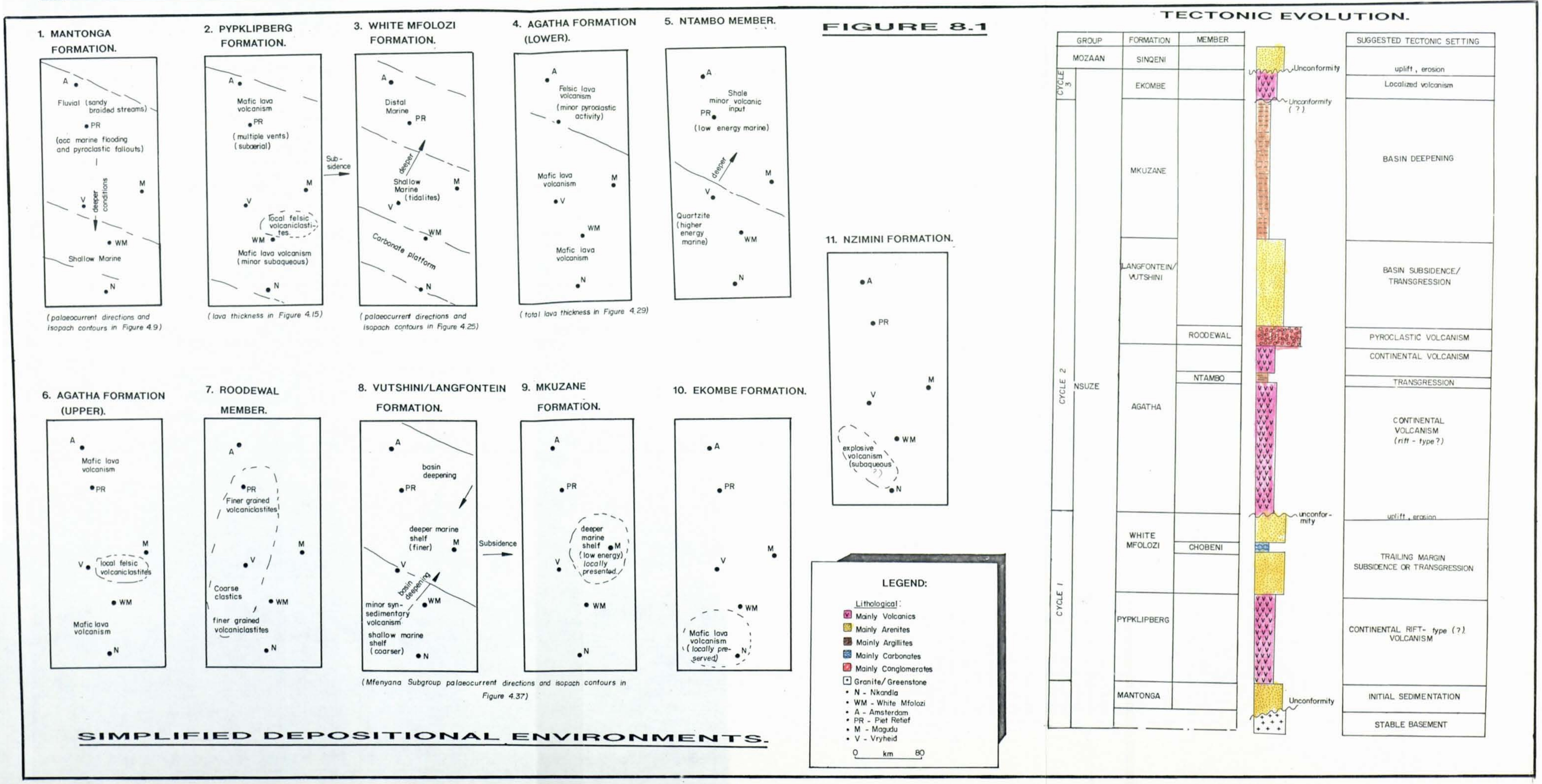
It may be significant that the Roodewal Member is not preserved throughout the Nsuze basin. This could be due to either non-deposition or post-depositional removal prior to the deposition of the thick overlying sedimentary rocks of the Langfontein/Vutshini Formation. A conglomerate with pebbles up to 2 cm in diameter at the base of the Langfontein/Vutshini Formation probably marks an unconformity in the Nkandla Central Syncline. Strata of the Langfontein/Vutshini and Mkuzane Formations, overlying the Roodewal Member, were most probably deposited in a shallow marine shelf environment. The Mfenyana Subgroup constitutes a series of upward coarsening progradational packages with shales at the base coarsening up through the transitional zone shales, with intercalated quartzites, into shoreface arenites at the top. Similar progradational sequences are reported by Reineck and Singh (1980) to be relatively common in the geological record. The thick quartzite successions in the Nkandla Central Synform reflect shallower shoreface deposits relative to that in the Magudu area. The basin thus most probably deepened from Nkandla towards Magudu (Fig. 8.1).

It is interesting to note that the diamictite unit in the Langfontein/Vutshini Formation in the Buffalo River inlier (Fig. 4.30), probably reflects local syn-sedimentary volcanism here i.e. localized volcaniclastic massflow deposits.

The Mfenyana Subgroup is overlain by the volcanic Ekombe Formation, which is only preserved in the core of the Nkandla Central Synform. It represents a third episode of volcanism in the basin. Towards the north it has apparently been removed by erosion prior to deposition of the Mozaan Group.

The Nzimini Formation (its correlation is uncertain) in the southern domain comprises mainly volcaniclastics, with subordinate arenites, argillites and amygdaloidal lavas. The volcanic lithologies are interpreted to be pyroclastic in origin (Groenewald, 1984; Dixon, 1991). The wide elliptical distribution of the Nzimini Formation (Map 1) may reflect a significant eruption column height. The thick pyroclastic units could be the function of several explosive events which resulted in deposition of ejecta over a wide area. Large boulder-sized (> 64 mm) clasts within the Nzimini Formation (Fig. 4.42) could represent ballistic clasts (Cas and Wright, 1987) deposited near to explosive vents. The larger proportion of the pyroclastic deposits are tuffaceous (lithified ash derived from fall deposits) with grain size < 2 mm. The highly polymictic clast assemblage in certain units, the occasional rounded shape of these clasts, the large proportion of rounded quartz grains and rare poorly-preserved stratification suggests a certain amount of reworking of the sedimentary material in a subaqueous environment.

DIAGRAM SHOWING SIMPLIFIED DEPOSITIONAL ENVIRONMENTS AND TECTONIC EVOLUTION



8.3 NSUZE EVOLUTION AND TECTONIC SETTING

It is increasingly recognised that a wide variety of domains, including continental margins, back arc basins and within- plate rifts are preserved in the Archaean record (Hunter, 1991) and that plate tectonic processes must have operated since Archaean times (Thomas et al, 1993). The Archaean-Proterozoic boundary is conventionally drawn at the time of cratonic stabilization, which resulted from a decrease in heat flow and an increase in the thickness of continental crust (Thomas et al, 1993). The Nsuze Group is of special significance as it represents a Proterozoic-style volcano-sedimentary basin accumulation, yet it is dated at about 2,9 - 3,0 Ga. The Archaean-Proterozoic boundary has traditionally been drawn at about 2,5 Ga (Miall, 1984). The Pongola Supergroup is suggested by Matthews (1990) to represent the oldest intracratonic sequence in the world and was formed before the granite-greenstone phase of crustal evolution had ended in other Archaean-age lithosphere segments (for example; the central part of the Kaapvaal craton, within which the Nsuze basin is sited, attained tectonic stability about 600 Ma earlier than the Zimbabwe craton - Thomas et al. 1993).

This suggests that cratonisation was a continuous process which began early in the Kaapvaal craton through the emplacement of tabular granitic batholiths which resulted in a relatively stable, high standing sialic-crust, capable of sustaining volcano-sedimentary basin accumulations such as the Nsuze Group.

Hunter (1991) notes that the lithologies of the Pongola (and Witwatersrand) Supergroup are important for two reasons, irrespective of their tectonic setting. Firstly, the often tholeiitic lavas in the Pongola Supergroup are dramatically different to the high-Mg komatiitic flows that characterised the immediately proceeding greenstone-type volcanism (the tholeiitic lavas are time-equivalents of komatiitic volcanism in other Archaean environments). Secondly, the great Pongola-age thicknesses of clastic sediments imply that extensive continental crust existed by ≈ 3,0 Ga. The development of the Pongola (and the Dominion, Witwatersrand and Ventersdorp) basin in the central and southern parts of the Kaapvaal craton was contemporaneous with the accretion of the Late Archaean granite-greenstone terranes in the western and northern Kaapvaal craton (Thomas et al. 1993).

It has long been recognised that the detrital composition of clastic rocks is related to the tectonic setting of their source area (Miall, 1984). Point count analyses of detrital grains from clastic units in the Mantonga, White Mfolozi and Langfontein/Vutshini Formations in this study have been complicated by varying degrees of recrystallization in these units. Despite this complication, continental block or craton interior provenances are indicated (using diagrams after Dickinson and Suczek, 1979) for Nsuze Group clastic sediments. These sediments are noted for high quartz and very low lithic fragment contents, probably reflecting a derivation from crystalline Precambrian granitic sources. This craton interior, granitic continental block provenance now needs to be interpreted in terms of plate tectonics. The volume of the Pongola basin has been estimated by Hunter (1991) to be in the region of 75 000 - 100 000 km^3 within the present limits of uncertainty. The regional correlations shown in this study for the Nsuze Group and its possible correlation with the Dominion Group, suggests that the volume of the Pongola basin far exceeds the estimation of Hunter (1991).

Before any conclusions regarding the tectonic setting of the Nsuze Group can be made, a further statement regarding conditions during the Precambrian is required. At present very little is known about genesis of magma in the Precambrian and it seems likely that many of the variables controlling present day magma formation have changed with time. A few of these variables are suggested by Pearce and Cann (1973) to be:-

a. Precambrian mantle would have undergone less melting episodes and therefore might have been more enriched in incompatible elements

b. higher Precambrian heat flow could have resulted in partial melting at a shallower level than at present and involved different liquidus phases

c. factors like degree of partial melting and the partitioning of trace elements are unknown for the Precambrian

d. major tectonic influences on magma composition, such as mantle recycling processes, rate of plate movement and even the nature of the tectonic regimes themselves, are unknown for the Precambrian.

The interpretation of Precambrian-age volcanic rocks using geochemical tectonic discrimination diagrams applicable to Phanerozoic age volcanic rocks should be made considering the above reservations.

The geochemical composition of lavas support a within-plate continental tectonic setting for the Nsuze Group. Armstrong (1980) also suggests that the depository of the Nsuze Group was intiated in a continental setting on a cratonic crustal segment.

In terms of plate tectonics, the setting of the Nsuze Group is thought to best be correlated with intraplate volcanism and sedimentation (Armstrong, 1980). Armstrong (1980) suggests that this setting does not find an exact analogue in modern day environments.

Geochemical similarities between Nsuze pelites and Phanerozoic NASC shales, suggest that the Nsuze (and Pongola) source was very similar in composition to average Phanerozoic upper continental crust. The primarily granitic basement to the Nsuze Group throughout the basin supports Wronkiewicz and Condie's (1989) suggestion that K_2O-rich granites were a major sediment source during Pongola sedimentation. Veizer and Jansen (1979) propose that mafic to felsic transitions in the chemical composition of sediments occurred from 3,0 to 2,0 Ga, reflecting major continental crust processes. The Pongola pelites are more felsic than the Moodies Group pelites (> 3,3 Ga, McLennan and Taylor, 1983).. This compositional transition is thought to be related to the intrusion of widespread K_2O-rich granitic plutons on the Kaapvaal craton between 3,2 and 2,9 Ga (Anhaeusser and Robb, 1981). These granitic plutons are post-Greenstone belt in age and frequently form the basement to the Nsuze Group (see Figure 1 for granite distribution).

Wronkiewicz and Condie (1989) have isotopically shown that these K_2O-rich granites are in fact the major Nsuze sediment source. Large volumes of magma were generated during this magmatic event and is considered by Annhaeusser and Robb (1981) to also represent the main event contributing to formation of the Kaapvaal craton. The earliest mafic to felsic upper crustal cycle is recorded from the deposition of the Moodies (~ 3,3 Ga) to the ~ 3,0 Ga Pongola successions. The sediments of the Dominion Group and the Orange Grove Formation of the Witwatersrand Supergroup can also be included in the felsic-rich portion of this cycle.

Burke et al (1985) has suggested that the rocks of the Pongola Supergroup (of which the Nsuze Group forms the base) display many features that are characteristic of rocks deposited in continental rifts (i.e. a divergent margin basin in a plate tectonic context). These features include: rapid lateral variations in thickness and character of sediments, volcanic rocks which are bimodal in silica content, coarse basement-derived conglomerates, and thick sequences of shallow water sedimentary facies.

This study only partially agrees with the criteria used by Burke et al (1985). The Nsuze Group has volcanics showing both tholeiitic and calc-alkaline affinities with a whole continuum in the silica content (not only bimodal). There is indeed a substantial variation in strike thickness within the Nsuze Group Formations introduced here, however the influence of unconformities and post- depositional tectonic events on presently preserved formational thicknesses should not be discounted. Also, the large scale correlations demonstrated here, suggest similar depositional conditions throughout the Nsuze basin. The immature nature of some of the basal Mantonga Formation sediments demonstrates they were derived, at least partially, from a locally uplifted granitic source. The variable thickness of the Mantonga Formation can also partially be attributed to fluvial deposition over an uneven basement floor.

Matthews (1990) presented a plate tectonic model in support of that of Burke et al (1985), suggesting that the Pongola sequence was deposited in a continental rift environment. Matthews (1990) proposes that the Pongola Supergroup was deposited within two connected, but contrasting structural domains. The N-S trending northern structural domain evolved as a major half-graben syndepositional rift basin or aulacogen, while the E-W trending southern structural domain evolved originally as part of an epicratonic basin situated at the southern end of the Pongola aulacogen which broadened out southward as part of a subsiding continental margin. He also infers that this margin was located along part of a transform plate boundary with a major ocean basin. Matthews (1990) also proposes that the Pongola Supergroup was subsequently subjected to a post-depositional deformational history of alternating periods of extensional and compressional tectonics, which accounts for the present Pongola Supergroup outcrop pattern. In support of his model Matthews (1990) refers to palaeomagnetic evidence quoted by Piper (1983) in which the present southern margin of the Kaapvaal craton and the associated late Archaean Pongola Supergroup would have been located along part of an extensive continental margin.

The original southern limit of the Pongola basin has been disrupted by the Natal thrust front (Map 1). The Natal Province is actually a younger allochthonous terrane emplaced upon the southern portion of the Kaapvaal craton as a series of nappes at a suture zone about 1,0 Ga ago (Matthews, 1981). It seems likely then that the Nsuze basin extended further southward than presently exposed, being buried under the Natal mobile belt. It is possible that the enigmatic Nzimini Formation originates from such a southern provenance. It may have been transported by thrusting to its present position in the southern domain. Dixon (1993) suggests that the Nzimini Formation in the Buffalo River inlier is allochthonous, representing a previously unrecognised western extension of the Nsuze nappe, a term introduced by Matthews (1990) for the Nkandla area. Dixon (1993) also suggests that the Nzimini district belongs to the northern margin of this nappe structure. This nappe interpretation introduces the concept that the Nzimini Formation originated elsewhere (to the south of present day Nsuze Group outcrops) and that it could not be Nsuze in age. This could explain the localized distribution of the Nzimini Formation, with no correlates in the northern domain. To date the question of whether the Nzimini Formation lithologies are allochthonous or autochthonous has not been be resolved.

At this stage it is appropriate to comment on the metamorphic grade of the Nsuze Group, as revealed by thin section studies. This information may provide clues to the evolution of the Nsuze strata. The Nsuze Group has been subjected to regional low-grade metamorphism. Nsuze mafic/intermediate lavas are generally characterized by the mineral assemblage: plagioclase (albite?) + sericite + chlorite + quartz ± tremolite/actinolite ± epidote ± calcite ± other accessory minerals. In the felsic volcanics, the mineral assemblage is similar except for a marginally higher quartz content and for the presence of biotite and saussuritized plagioclase phenocrysts. Nsuze Group argillites are characterized by the assemblage chlorite + quartz + sericite / muscovite ± epidote. According to Winkler (1979), low grade metamorphism is characterized by the mineral assemblage: chlorite + zoisite / clinozoisite ± actinolite ± quartz. The minerals chlorite, actinolite, white mica, Fe-rich epidote and others are already present in rocks of very low grade. The minerals identified as epidote in this study could well include non-Fe-rich epidotes ie. clinozoisite. In addition to Fe-rich epidote Groenewald (1984), also recognises substantial amounts of clinozoisite in pelites and volcanics from the Nsuze Group in the Nkandla area. The absence of minerals diagnostic of very low grade metamorphism (viz. limonite, prehnite, pumpellyite, lawsonite, etc) and the absence of minerals diagnostic of medium grade conditions (including cordierite and staurolite) coupled with observed low grade assemblages in this study (excluding assemblages from the Magudu area which have also been subjected to contact metamorphism) allows a confident conclusion that Nsuze Group volcano-sedimentary assemblages have been subjected to low grade greenschist facies regional metamorphic conditions.

The regional correlations established for the Nsuze Group and for the Lower Mozaan Group (Beukes and Cairncross, 1991), and their likely correlations with the Dominion and West Rand Groups respectively, emphasize the potential sizes of the primary Nsuze - Dominion and Lower Mozaan - West Rand basins. It is significant to note that Nsuze strata can be correlated across the Melmoth basement arch. This may suggest that most of the upwarping of this structure occurred in post-Nsuze times.

It is possible that initial upwelling of hot mantle below the recently created stable cratonic conditions in the southeastern Kaapvaal craton induced initial localized uplift and horizontal tensional stresses. This created the depositional setting for the 'divergent margin' Nsuze basin (Fig. 8.1). Extensional tectonics here was associated with thick lava flows (the three volcanic formations of the Group) and occasional syn-depositional pyroclastic volcanism (the diamictites now preserved within the siliciclastic formations of the Group).

Initial sedimentation rates in the Nsuze basin were most probably rapid (presented by the largely fluvial Mantonga Formation), but gradually basin subsidence rates began to exceed sedimentation rates with the clastic Nsuze formations reflecting increasingly deeper water depositional conditions. The White Mfolozi Formation represents a tide-dominated depositional-environment, with the Mfenyana Subgroup reflecting deposition in a shallow marine shelf environment (Fig. 8.1). The volcanic formations also reflect increasingly deeper depositional conditions, with the upper part of the Agatha Formation displaying pillow lavas. The thick accumulation of the shallow marine sediments of the Mfenyana Subgroup in the Magudu area suggests that this area subsided rapidly. Pre-Mozaan uplift and erosion however could have removed Mfenyana Subgroup lithologies from other areas within the Nsuze basin, making this assumption difficult to substantiate.

An attempt will now be made to summarize the tectonic evolution of the Nsuze Group using the data accumulated in this study. The tectonic evolution summary will commence at the Mantonga Formation and end at the lower part of the Mozaan Group (refer to Fig. 8.1).

1. The Mantonga Formation could represent an initial rifting phase (extensional tectonics), with sedimentation taking place over an irregular granitic basement within an intra-continental basin.

2. A period of uplift followed, possibly caused by thermal updoming. Thermal tensional stresses prevailed. Associated with the uplift was a period of erosion, prior to Pypklipberg volcanism (inferred unconformity between Mantonga and Pypklipberg Formation).

3. Pypklipberg Formation lava flows, possibly from a large number of vents. Local explosive volcanism (as at Mpongoza inlier).

4. Nsuze basin subsidence, probably caused by the weight of the Pypklipberg lavas and due to the heat loss after volcanism. White Mfolozi Formation sedimentation and transgression. Localised syn-depositional tectonic instability (as marked by various diamictite units).

5. After White Mfolozi sedimentation another thermal uplift event occurred with associated tensional stresses. An erosional period occurred as indicated by the unconformity between the White Mfolozi and Agatha formations.

6. Agatha Formation lava flows formed under similar conditions to the Pypklipberg Formation. The Ntambo Member represents local periods of volcanic quiescence, in particulary the northern domain. Local explosive volcanism (Fig. 8.1).

7. Period of tectonic instability and extensional stresses. This period signifies the end of Agatha volcanism and is a precursor to Langfontein/Vutshini Formation basin subsidence. The locally significant Roodewal Member is a record of this period of tectonic instability.

8. Another period of basin subsidence, again probably induced by the weight of the Agatha volcanics and heat loss after volcanism. Langfontein/Vutshini Formation transgressive sedimentation.

9. Continued localized subsidence allowed Mkuzane Formation sedimentation.

10. Further thermally induced uplift with associated tensional stresses. A period of erosion followed (inferred unconformity at the base of the Ekombe Formation - Fig. 8.1).

11. Ekombe Formation lava flows. Possibly restricted to southern domain.

12. A period of subsidence probably followed Ekombe volcanism (similar to that after the Pypklipberg and Agatha Formations). This subsidence could also have been localized, with the sediments deposited not being preserved. End of Nsuze deposition.

13. Large scale uplift, probably also driven by thermal updoming. Large scale erosion occurred, removing varying amounts of Nsuze strata throughout the basin. Magma did not reach the surface (as during Nsuze times). This period of erosion is marked by the Nsuze-Mozaan unconformity (Fig. 8.1).

14. Large scale basin subsidence with subsequent Mozaan Group transgression.

The Nsuze Group deposition can possibly be subdivided into three cycles. A cycle commences with a thermal uplift phase (volcanism) and ends in a subsidence phase (sedimentation) (Fig. 8.1). The top of the upper third cycle has been effected by the Mozaan unconformity.

The lower Mozaan Group is devoid of any volcanics, has a higher shale: quartzite ratio and is less deformed than the Nsuze Group. A substantial time gap thus most probably separates the Nsuze Group from the Mozaan Group as manifested by the low-angle unconformity between the two groups (Beukes and Cairncross, 1991). Bickle and Eriksson (1982) suggest that the Mozaan sequence represents the thermal subsidence phase of the Pongola basin. Thermal subsidence is characterised by broad crustal down-warping due to thermal cooling and contraction. It followed the initial rift phase during which Nsuze strata were deposited.

Pongola deposition was followed by a period of mafic plutonism in the northern domain around 2 870 Ma, represented by the Usushwana mafic suite. Basalt and basaltic andesite volcanism (Ventersdorp Supergroup) occurred around 2 700 Ma over the Witwatersrand part of Pongola - Witwatersrand basin. The period 2 500 - 2 800 Ma saw the intrusion of potassic granites (referred to as post-Pongola granites in this study), which left a marked tectonic and metamorphic imprint on adjacent Pongola lithologies as seen in the Magudu area (Hunter 1991).

CHAPTER 9: SUMMARY AND CONCLUSIONS

9.1 DISTRIBUTION

The volcano-sedimentary Nsuze Group crops out in several areas in southwestern Swaziland, southeastern Transvaal and northern Natal. This study has investigated all major Nsuze Group exposures in the area. An attempt was made to delineate the full extent of the Nsuze Group (Map 17). Aeromagnetic and gravity geophysical trends (shown in Map 17) have been used in association with known surface geology to estimate the total preserved distribution of the Nsuze Group. Generally speaking, aeromagnetic highs are expected to coincide with the highly ferruginous lower Mozaan strata, although some smaller aeromagnetic highs could also be attributed to magnetic sedimentary rocks in greenstone belts. Gravity lows are attributed to granitic bodies (post and pre-Pongola in age), while gravity highs are thought to represent dense, thick volcano-sedimentary accumulations. These simplistic geophysical guidelines apply well to outcropping geology shown in map 17 and suggest a wide suboutcrop distribution of the Nsuze Group in the southeastern part of the Kaapvaal craton. The inferred suboutcrop distribution of the Nsuze Group to the west of known distribution of Nsuze outcrops dramatically increases the potential size of the Nsuze basin. It is important because it may provide a link with the Dominion Group which is exposed further to the west.

The thickest remnant of Nsuze strata occurs in the northern domain, centred in the Magudu area and the Hartland basin.

9.2 LITHOSTRATIGRAPHIC SUBDIVISION

The Nsuze Group is subdivided into eight formations. Three of those formations are dominantly volcanic (Pypklipberg, Agatha and Ekombe formations) and four of them are dominantly sedimentary in origin i.e. the Mantonga, White Mfolozi, Langfontein/Vutshini and Mkuzane Formations. The Nzimini Formation, being largely composed of diamictite is enigmatic in that its exact stratigraphic position is uncertain. These formations can be correlatated over very wide areas and simplify the existing stratigraphic subdivision of the Nsuze Group by SACS (1980) significantly.

9.3 STRUCTURE AND METAMORPHISM

The entire Nsuze Group bears the imprint of low grade burial-induced metamorphism. Post-Pongola granitic intrusive rocks have left localized effects of contact metamorphism on Nsuze lithologies, especially in the northeastern part of the outcrop area in southwestern Swaziland, the Magudu area and the eastern part of the

Hartland basin.

Mafic to intermediate lavas of the Nsuze Group are generally characterised by the mineral assemblage plagioclase + sericite + chlorite + quartz ± tremolite/actinolite ± epidote ± calcite ± accessory minerals. The argillites are characterised by the mineral assemblage chlorite + quartz + sericite/muscovite ± epidote, diagnostic of low grade greenschist facies regional metamorphism. The regional low grade burial-induced metamorphic mineral assemblage overprints the hornblende-hornfels facies of contact metamorphism.

This study has not concentrated on structural deformation aspects of Nsuze strata. However, a full appreciation of the structural imprint was necessary in order to produce meaningful lithostratigraphic profiles. It was found that deformation is mainly fault-controlled and that within fault blocks stratigraphic relations are very well preserved. Contributions have been made by other investigations, particulary those of Matthews (1990) and Dixon (1991) towards a better understanding of the structural evolution of the Pongola basin. Simplified structural trends, modified from all previous structural mapping in the Pongola basin, are illustrated relative to the distribution of various lithostratigraphic units and geophysical trends on Map 17. The regionally applicable lithostratigraphic correlations in the Nsuze Group, made during this study, should allow fuller appreciation of the structural complexities within the Nsuze basin and provide insights into the importance of some of the structures involved.

9.4 GEOCHEMISTRY

One hundred and twelve chemical analyses of lava and argillites from the Nsuze Group are presented in this study. The data were combined with published geochemical data to produce a stratigraphically- constrained Nsuze database. It represents the most comprehensive Nsuze Group database yet to be compiled. Nsuze lavas display a complete spectrum of chemical compositions, ranging from basalt to rhyolite with lavas of intermediate composition being predominant. Agatha and Pypklipberg Formation lavas display both calc-alkaline and tholeiitic magmatic affinities. A within-plate continental setting is suggested by the range in composition of the lavas.

The composition of the pelites provide information on the provenance of the Nsuze Group as well as clues concerning the evolutionary growth of the early continental crust. The entire pelite database plotted on a K_2O-Fe_2O_3-AL_2O_3 diagram defines a broad trend falling along the mixing line defined by the chlorite and illite/muscovite end members. Nsuze pelites display marked inter-formational geographic variations in some major and trace elements. The pelites appear to have been derived from a granite-enriched source with minor contributions from tonalitic and komatiitic sources.

9.5 CORRELATION WITH THE DOMINION GROUP

Geochronological, lithostratigraphic and geochemical evidence, compiled during this study, suggests a correlation between the Nsuze and Dominion Groups. It is proposed that the Rhenosterspruit Formation of the Dominion Group can be correlated with the Mantonga Formation of the Nsuze Group. Collectively the Rhenosterhoek and Syferfontein Formations of the Dominion Group are stratigraphic correlatives of the Pypklipberg Formation of the Nsuze Group. The units fall into the same radiometric age bracket. Recent age dating constrains the evolution of the two groups to the period 3107/3120 to 2871 Ma. In addition the chemical composition of Nsuze and Dominion lavas are very similar, especially with reference to the immobile incompatible trace element contents.

9.6 DEPOSITIONAL ENVIRONMENT AND TECTONIC SETTING

The basal Mantonga Formation was deposited over an uneven granitic surface in a dominantly sandy braided fluvial environment with subordinate marine incursions represented by shales and orthoquartzites. Diamictites suggest periodic unstable conditions and rapid sedimentation in the form of debris flows. Lavas of the Pypklipberg Formation appear to have erupted from a large number of volcanic vents, under subaerial conditions. Volcanic conditions in the Mpongoza inlier area were dominated by pyroclastic volcanism, unlike the more widespread effusive lava volcanic style in the rest of the Nsuze basin.

Pypklipberg volcanism was followed by large scale basinal subsidence creating favourable conditions for the accumulation of the White Mfolozi Formation sedimentary sequence (Fig. 8.1). The White Mfolozi Formation displays classic examples of tidalites and also contain a carbonate platform succession. Thin diamictite units within the tidalites possibly reflect syn-sedimentary volcanic events. Volcanism that formed the Agatha Formation was widespread with locally unique volcanic styles, partially under subaqueous conditions. The Ntambo Member in the northern domain marks a period of volcanic quiescence, with subsequent argillaceous transgressive marine deposits. The Roodewal Member, at the base of the Langfontein/Vutshini Formation indicates the end of Agatha volcanism (Fig. 8.1).

The Mfenyana Subgroup suggests regional subsidence and deposition within a shallow marine shelf environment. Mfenyana sedimentation was followed by a final volcanic event, represented by lava of the Ekombe Formation, which although, only exposed in the Nkandla area, could have had a far wider original distribution (Fig 8.1).

The Nzimini Formation, the exact stratigraphic position of which is uncertain, is largely pyroclastic in origin. The pyroclastic debris has been subjected to variable degrees of epiclastic reworking, possibly under subaqueous conditions.

The siliclastic rocks of the Nsuze Group were derived from a craton interior provenance. In terms of a plate tectonic basin classification, the Pongola basin is an example of a divergent 'passive' margin basin. The basin shows certain features attributable to an ancient rift basin. The Nsuze Group distribution is too widespread to have originated in a classical graben-type basin.

ACKNOWLEDGEMENTS:

I am indebted to Gold Fields of South Africa Limited for the financial and logistical support given to this project, without which this thesis would not have been possible. I am also grateful for the raw data made available by Gold Fields of South Africa Limited for this study.

I am grateful for the support given by Prof. N.J. Beukes of the Department of Geology, Rand Afrikaans University who supervised this project. His insight into previously overwhelming regional concepts has greatly benefited this study. I also acknowledge the support given by Rand Afrikaans University staff and students, especially Profs. L. Ashwal and C. Roering, Drs. M. Buxton and B. Cairncross and Jan Nelson towards this project. John Dixon is thanked for his guidance in the complex Buffalo River inlier and for making various of his unpublishing mapping available for this study.

I thank George and Stella Craig, of the farm Vaalkrans in the Glückstadt district, for logistical and other support provided during the field-based period of this study. Megan van Gent and Marina Strydom are thanked for their support with the draughting and typing respectively.

Finally I wish to thank my father and of course Astrid for continued encouragement and support throughout this study.

REFERENCES

Anhaeusser, C.R. and Robb, L.J., (1981). Magmatic cycles and the evolution of the Archaean granitic crust in the eastern Transvaal and Swaziland. Spec. Publ. Geol. Soc. Austr., 7, 457-467.

Armstrong, N.V., (1980). The geology and geochemistry of the Nsuze Group in Northern Natal and Southeastern Transvaal. Ph. D. thesis (unpubl), University of Natal, Pietermaritzburg, 386 pp.

Armstrong, N.V., Hunter, D.R. and Wilson, A.H., (1982). The stratigraphy and petrology of the Archaean Nsuze Group, Northern Natal and Southeastern Transvaal, S. Africa. Precamb. Research, 19, 75-107.

Armstrong, N.V., Wilson, A.H. and Hunter, D.R., (1986). The Nsuze Group, Pongola Sequence, S. Africa. Geochemical evidence for Archaean volcanism in a continental setting. Precamb. Research, 34, 175-203.

Armstrong, R.A., Retief, E., Compston, W. and Williams, I.S., (1990). Geochronological constraints on the evolution of the Witwatersrand Basin, as deduced from single zircon U/Pb ion microprobe studies. Abstracts, Geocongress 1990, Geological Soc. S. Africa, Cape Town, 24-27.

Barton, J.M., Roering, C., Barton, E.S., Van Reenen, D.D. and Smit, C.A., (1988). The late Archaean - early Proterozoic evolution of the Limpopo belt and it's possible relationships to the Kaapvaal craton. Abstracts, Geocongress 1988, Geological Soc. S. Africa.

Beukes, N.J. and Cairncross, B., (1991). A lithostratigraphic - sedimentological reference profile for the late Archaean Mozaan Group, Pongola Sequence: application to sequence stratigraphy and correlation with the Witwatersrand Supergroup. S. Afr. J. Geol., 94., 44-69.

Beukes, N.J. and Lowe, D.R., (1989). Environmental control on diverse stromatolite morphologies in the 3000 Myr Pongola Supergroup, S. Africa. Sedimentology, 36, 383-397.

Bickle, M.J. and Eriksson, K.A., (1982). Evolution and subsidence of early Precambrian sedimentary basins. Phil. Trans. R. Soc. Lond, A305, 225-247.

Bowen, M.P., (1984). The petrogenesis of the volcanic rocks of the Witwatersrand Triad in the Klerksdorp area, Transvaal. M.Sc. Thesis (unpubl.), Rhodes University, Grahamstown, 204 pp.

Bowen, T.B., (1984). The geochemical stratigraphy of volcanic rocks of the Witwatersrand Triad in the Klerksdorp area, Transvaal. M.Sc. Thesis (unpubl.), Rhodes University, Grahamstown, 222 pp.

Bowen, T.B., Marsh, J.S. Bowen, M.P. and Eales, H.V., (1986). Volcanic rocks of the Witwatersrand Triad, S. Africa. I. Description, classification and geochemical stratigraphy. Precamb. Research, 31, 297-324.

Brown, G.J., (1982). The geology of the pre-Natal formations of the area to the west of the Nkandla forest reserve. Unpubl. B.Sc. (Hons) Thesis. (unpubl.), University of Natal, Pietermaritzburg, 78 pp.

Burger, A.J. and Coetze, F.J., (1973). Radiometric age measurements on rocks from southern Africa to the end of 1971. Bull. Geol. Surv. S. Africa, 58, 46 pp.

Burke, K., (1977). Aulacogens and continental breakup. Ann. Rev. Earth Planet. Sci., 5, 371-396.

Burke, K., Kidd, W.S.F. and Kusky, T.M., (1985). The Pongola structure in southeastern Africa: the world's oldest preserved rift? Jour. Geodynamics, 2, 35-49.

Button, A, (1981). The Pongola Supergroup, 501-510, In: Hunter D.R. (ed.) Precambrian of the Southern Hemisphere,. The cratonic environment. Elsevier, Amsterdam, 882 pp.

Button, A. and Tyler, N., (1981). The character and economic significance of Precambrian palaeoweathering and erosion surfaces in southern Africa. Econ. Geol., 75th Anniv. Vol., 676-699.

Cant, D.J. and Walker, R.G., (1978). Fluvial processes and facies sequences in the sandy braided South Saskatchewan River, Canada. Sedimentology, 25, 625-648.

Cas, R.A.F. and Wright, J.V., (1987). Volcanic successions modern and ancient. A geological approach to processes, products and successions. Allen and Unwin, London.

Clendenin, C.W., Charlesworth, E.G. and Maske, S., (1988). Tectonic style and mechanism of early Proterozoic successor basin development, southern Africa. Tectonophys, 156, 275-291.

Condie, K.C., Macke, J.E. and Reimer, T.O., (1970). Petrology and geochemistry of early Precambrian greywackes from the Fig Tree Group, S. Africa. Bull. Geol. Soc. Am., Vol. 81, 2759-2776.

Cox, K.G., Bell, J.D. and Pankhurst, R.J., (1979). The interpretation of igneous rocks. George Allen and Unwin, London, 450 pp.

Crow, C. and Condie, K.C., (1987). Geochemistry and origin of late Archaean volcanic rocks of the Rhenosterhoek Formation, Dominion Group. S. Africa. Precamb. Research, 37, 217-229.

Davies, D.N., Vrie, J.G., Jones, D.H. and Winter, P.E., (1964). The alumina, pyrophyllite and silica deposits in the Insuzi series, Mahlangatsha, Mkopeleli, Shiselweni and Manzini districts. Bull. Geol. Surv. Mines Dept. Swaziland, 4, 5-22.

Deer, W.A., Howie, R.A. and Zussman, J., (1980). An introduction to the rock-forming minerals. Longman Group, London, 528 pp.

Dickinson, W.R. and Suczek, C.A., (1979). Plate tectonics and sandstone compositions. Bull. Amer. Assoc. Petrol. Geol., 63, 2164-2182.

Dixon, J.G.P., (1991). Notes on the Archaean Geology of the Buffalo River Gorge, Northern Natal. Unpubl. Gold Fields of S.A. Internal Report. 29pp.

Dixon, J.G.P., (1993). Lithostratigraphy of the Pongola succession in the Buffalo River gorge, Northern Natal. Abstracts, Colloquium of African Geology, Swaziland, 1993. 3 pp.

Dixon, J.G.P., (1993). Polyphase deformation of Archaean greenstones in the Buffalo River gorge, Northern Natal. Abstracts, Colloquium of African Geology, Swaziland, 1993. 2 pp.

Du Toit, A.L., (1931). The geology of the country surrounding Nkandla, Natal. Geol. Surv. S. Africa. An explanation of sheet 109, 111 pp.

Eglington, B.M., Matthews, P.E., Retief, E.A., Walraven, F., Scharer, U., Dixon, J.G.P. and Taima, S., (1993). Isotopic constraints on the age and formation of the Pongola sequence. Abstracts, Colloquium of African Geology, Swaziland, 1993.

Floyd, P.A. and Winchester, J.A., (1975). Magma type and tectonic setting discrimination using immobile elements. Earth. Planet. Sci. Lett., 27, 211-218.

Floyd, P.A. and Winchester, J.A., (1978). Identification and discrimination of altered and metamorphosed volcanic rocks using immobile elements. Chem. Geol., 21, 291-306.

Fisher, R.V., (1966). Rocks composed of volcanic fragments and their classification. Earth. Sci. Rev., 287-298.

Gold Fields of South Africa Ltd, (1981). Unpubl. internal report on the Nkandla project: 1980-1981.

Groenewald, P.B., (1984). The lithostratigraphy and petrogenesis of the Nsuze Group northwest of Nkandla, Natal. M.Sc. thesis (unpubl.), University of Natal, Pietermaritzburg, 323 pp.

Hammerbeck, E.C.I., (1977). The Usushwana complex in southeastern Transvaal with special reference to it's economic mineral potential. D.Sc. Thesis (unpubl.), Univ. Pretoria, 226 pp.

Hatch, F.H., (1910). Report on the mines and minerals of Natal. Clay, London, 155 pp.

Hatfield, R.A., (1990). The geology and structure of the Pongola sequence east of Piet Retief, southeastern Transvaal. M.Sc. Thesis. (unpubl.), University of Natal, Pietermaritzburg. 109 pp.

Hegner, E., Tegtmeyer., A. and Kröner, A., (1981). Geochemie und Petrogenese archaischer Vulkanite der Pongola - Gruppe in Natal Südafrika. Chem. Erde, 40, 23-57.

Hegner, E., Kröner, A. and Hofmann, A.W., (1984). Age and isotope geochemistry of the Archaean Pongola and Usushwana Suites in Swaziland, SE Africa - a case for crustal contamination of mantle - derived magma. Earth Planet. Sci. Lett., 70, 267-279.

Hegner, E., Kroner, A. and Hofmann, A.W., (1993). Trace elements and isotopic constraints of the origin of the Archaean Pongola and Usushwana Igneous Suites in Swaziland. Abstracts. Africa Geocongress, Swaziland, 1993.

Humphrey, W.A., (1912). The geology of a portion of northern Natal between Vryheid and the Pongola River. Ann. Rep. Geol. Surv. Union of South Africa, 19-23.

Humphrey, W.A. and Krige, L.J., (1931). The geology of the country south of Piet Retief. Expl. of sheet 68 (Piet Retief), Geol. Surv. S. Africa, 72 pp.

Hunter, D.R., (1950). Pongola fieldwork Annual Report Geol. Surv. Dept. Swaziland., p 40-41.

Hunter D.R., (1957). The geology, petrology and classification of Swaziland granites and gneisses. Trans. Geol. Soc. S. Africa, 60, 85-120.

Hunter D.R., (1961). The geology of Swaziland. Swaziland Geol. Surv. An explanation of the 1:125 000 geological map, 104 pp.

Hunter D.R., (1970). The ancient gneiss complex in Swaziland. Trans. Geol. Soc. S. Africa, 73, 107-150.

Hunter D.R., (1973). The granitic rocks of the Precambrian in Swaziland. Spec. Publ. Geol. Soc. S. Africa, 3, 131-145.

Hunter D.R., (1974). Crustal development in the Kaapvaal Craton. I. The Archaean. Precamb. Res., 1, 259-294.

Hunter D.R., (1979). The role of tonalite and trondjemitic rocks in the crustal development of Swaziland and the eastern Transvaal, S. Africa. In: Barker, F. (ed.), Trondhjemites, dacites and related rocks., Elsevier, Amsterdam, 301-322

Hunter D.R., (1991). Field excursion guide book: Pongola sequence in Swaziland. Conference on Precambrian sedimentary basins of Southern Africa. Pretoria, 1991, 17 pp.

Hunter, D.R., (1991). Crustal processes during Archaean evolution of the southeastern Kaapvaal Province. Jour. Afr. Earth. Sci., 13, 13-25.

Hunter, D.R. and Wilson, A.H., (1988). A continuous record of Archaean evolution from 3,5 Ga to 2,6 Ga in Swaziland and northern Natal. S. Afr. J. Geol., 91, 57-74.

Hunter, D.R. and Gold D.J.C., (1993). A re-examination of the stratigraphy of the Pongola Sequence in Swaziland and northern Natal. Abstracts, African Geocongress, Swaziland, 1993.

Irvine, T.N. and Baragar, W.R.A., (1971). A guide to the chemical classification of the common volcanic rocks. Can. Jour. Ear. Sci., 8, 523-548.

Jackson, M.C., (1991). The Dominion Group. A review of the late Archaean volcano-sedimentary sequence and implications for the tectonic setting of the Witwatersrand Supergroup, S. Africa. E.G.R.U. Info. Circ, No. 240.

Jackson, M.C., (1992). Field trip guide book. Wing/Tdogs Excursion to Dominion Group and the Vredefort Dome, 1992.

Kamo, S.L., Davis, D.W. and de Witt, M.J., (1990). U-Pb geochronology of Archaean plutonism in the Barberton region, S. Africa: 800 Ma of crustal evolution. Abstr. 7th Int. Conf. on Geochronology, Cosmochronology and Isotope Geology, Canberra, Australia, p 53.

Klein, G. de V., (1972). Determination of the palaeotidal range in clastic sedimentary rocks. 24th Inter. Geol. Congr., 6, 397-405.

Klein, G. de V., (1977). Clastic tidal facies. Continuing Education Publication Company. Champaign, Illinois.

Linström, W., (1987 a) Die geologie van die gebied Vryheid. Expl. of sheet 2730. Geol. Surv. S. Africa, 48 pp.

Linström, W., (1987 b) The geology of the Dundee area. Expl. of sheet 2830. Geol. Surv. S. Africa, 52 pp.

Marsh, J.S., Bowen, M.P., Rogers, N.W. and Bowen, T.B., (1989). Volcanic rocks of the Witwatersrand triad, S. Africa. II: Petrogenesis of mafic and felsic rocks of the Dominion Group. Precamb. Research, 44, 39-45.

Mason, T.R. and von Brunn, V., (1977). 3 Gyr old stromatolites from South Africa. Nature, 266, 47-49.

Matthews, P.E., (1959). The metamorphism and tectonics of the pre-Cape formations in the post-Ntingwe thrust belt, S.W. Zululand, Natal. Trans. Geol. Soc. S. Africa, p 257.

Matthews, P.E., (1959-1969). Unpublished mapping in the Nkandla area during the period 1959-1969. University of Natal, Durban.

Matthews, P.E., (1967). The pre-Karoo formations of the White Umfolozi Inlier, northern Natal. Trans. Geol. Soc. S. Africa, 70, 40-63.

Matthews, P.E., (1972). Possible Precambrian obduction and plate tectonics in southeastern Africa. Nature, 240, 37-39.

Matthews, P.E., (1979). Unpubl. geological maps. Pongola area. (1:50 000 sheets 2731 AA, AC, CA and CB). University of Natal, Durban.

Matthews, P.E., (1979). Unpubl. geological maps. Nkandla area. (1:50 000 sheets 2830 DB, 2831 CA, and CB). Geol. Surv. S. Africa.

Matthews, P.E., (1981). A new tectonic model for the northern region of the Namaqua - Natal belt in Natal. Abstr. Geocongress 1981. Geol. Soc. S. Africa., pp 150-151.

Matthews, P.E., (1985). Archaean post-Pongola granites in the southeastern Kaapvaal craton. S. Afr. J. Sci., 81, 479-484.

Matthews, P.E., (1990). A plate tectonic model for the late Archaean Pongola Supergroup in southeastern Africa. p 41-72 In: Crustal evolution and orogeny. Editor Synchanthavong, S.P.H. Oxford Publ, New Dehli, 324 pp.

Matthews, P.E. and Scharrer, R.M., (1968). A graded unconformity at the base of the early Precambrian Pongola system. Trans. Geol. Soc. S. Africa, 71, 257-272.

Matthews, P.E. and Silva-Perreira, B., (1978). Geological maps of the Babanango area (1:50 000 sheets 2831 AA, AB) Geol. Surv, open file.

McLennan, S.M. and Taylor, S.R., (1983). Geochemical evolution of Archaean shales from S. Africa. I - The Swaziland and Pongola Supergroups. Precamb. Research, 22, 93-124.

Mehliss, A.T.M., (1961). The geology of a portion of the country between Mankaiana and Hlatikulu, Mankaiana district, Swaziland. Bull. Geol. Surv. Swaziland, 36-55.

Meschede, M., (1986). A method of discriminating between different types of mid-ocean ridge basalts and continental tholeiites with the Nb-Zr-Y diagram. Chem. Geol., 56, 207-218.

Miall, A.D., (1984). Principles of sedimentary basin analyses. Springer, Verlag, New York.

Mootengraaff, G.A.F., (1902). Annual Report. Geol. Surv. S. Africa, (for 1898) 10 pp.

Nel, L.T., (1935). The geology of the Klerksdorp - Ventersdorp area. Expl. of geological map no. 37. Geol. Surv. of S. Africa.

Nel, L.T., Jacobs, H., Allan, J.T. and Bozzoli, G.R., (1937). Wonderstone. Bull., Geol. Surv. S. Africa, 8., 44 pp.

Pearce, J.A. and Cann, J.R., (1973). Tectonic setting of basic rocks using trace element analysis. Ear. Plan. Sci. Lett., 19, 290-300.

Pearce, J.A. and Norry, M.J., (1979). Petrogenetic implications of Ti, Zr, Y and Nb variations in volcanic rocks. Contrib Min. Petr, 69, 33-47.

Pearce, T.H., Gorman, B.E. and Birket, T.L, (1977). The relationship between major element chemistry and tectonic environment of basic and intermediate volcanic rocks. Ear. Planet. Sci. Lett., 36, 121-132.

Phillips, G.N., (1986). Metomorphism of shales in the Witwatersrand Goldfields. Econ. Geol. Res. Unit. Info. Circ., No. 192.

Piper, J.D.A., (1983). Proterozoic palaeomagnetism and single continent plate tectonics. Geophys. J. Astr. Soc., 74, 163-197.

Preston, V.A., (1987). The geology and geochemistry of the Mpongoza Inlier, Northern Natal. Unpubl. M.Sc. Thesis, University of Natal, Pietermaritzburg, 229 pp.

Reimer, T.O., (1986). Comments on the Eu and Th geochemistry of the Archaean continental crust of the Kaapvaal Craton, S. Africa. Precamb. Research, 31, 275-289.

Reimold, W.U., Meyer, F.M., Walraven, F. and Matthews, P.E., (1993). Geochemistry and chronology of the pre- and post-Pongola granitoids from northeastern Natal. Abstracts. Africa Geocongress Swaziland, 1993.

Reineck, H.E. and Singh, ± B. (1980). Depositional sedimentary environments. Springer Verlag. Berlin. Heidelberg. New York.
Robb, L.J., Davis, D.W. and Kamo, S.L., (1991). Chronological framework for the Witwatersrand Basin and environs towards a time - constrained depositional model. S. Afri. J. Geol, 94, 86-95.

Saager, R., Stupp, H.D., Utter, T. and Matthews, H.O., (1986). Geological and mineralogical notes on placer occurrances in some conglomerates of the Pongola sequence. <u>In:</u> Mineral Deposits of S. Africa. (Eds. Vol II. 473-489. Annhaeusser, C.R. and Maske, S).

South African Committee for Stratigraphy (SACS), (1980). Stratigraphy of South Africa Part I (Comp. Kent, L.E.). Lithostratigraphy of the Republic of South Africa, S.W.A., Namibia and the Republics of Bophutsthatswana, Transkei and Venda. Handb. Geol. Surv. S. Africa, 8.

Scheiderhöhn, H., (1961). Die Erzlagerstatten der Erde. Vol II. Die Pegmatite. Gustav Fischer, Verlag, Stuttgart.

Siems, P.L., (1984). Hydrothermal alteration handbook Mineral Exploration workshop. Dept. Geology. University of the Witwatersrand. 528 pp.

Smith, N.D., (1970). The braided stream depositional environment: Comparison of the Platte River with some Silurian clastic rocks, north-central Appalachians. Bull., Geol. Soc. Amer. 81, 2993-3014.

Stanistreet, I.G. and McCarthy, T.S. (1991). Changing tectono-sedimentary scenarios relevant to the development of the late Archaean Witwatersrand Basin. Econ. Info. Circ., Geol. Res. Univ. Witwatersrand, 233, 28 pp.

Tankard, A.J., Jackson, M.P.A., Eriksson, K.A., Hobday, P.K., Hunter, D.R. and Minter W.E.L., (1982). Crustal Evolution of Southern Africa. 3,8 billion years of Earth History. Springer-Verlag, New York, 423 pp.

Thomas, R.J., von Veh, M.W. and McCourt, S., (1993). The tectonic evolution of Southern Africa: An overview. J. Afr. Earth. Sci, 16, 5-24.

Truter, F.C., (1950). A review of volcanism in the geological history of S. Africa. Proc. Geol. Soc. S. Africa, 52.

Tunnington, D.P., (1981). The geology of the Central Nsuze Syncline. B.Sc. (Hons) Thesis. unpubl. Univ. Natal, Pietermaritzburg, 58 pp.

Turner, F.J., (1980). Metamorphic Petrology: Mineralogical, Field and Tectonic aspects. Second Edition, Hemisphere Publishing Corporation, McGraw Hill, 524 pp.

Van der Merwe, R., (1994). The nature of the western margin of the Witwatersrand Basin. Ph. D. Thesis (unpubl.), Rand Afrikaans University.

Van Vuuren, C.J., (1965). Die geologie van 'n gebied suid van Amsterdam, Oos-Transvaal. M. Sc. Thesis. (unpubl.) University of the Orange Free State.

Veizer, J. and Jansen, S.L., (1979). Basement and sedimentary recycling and continent evolution. J. Geol, 87, 341-370.

Von Backström, J.W., (1952). The Dominion reef and the Witwatersrand systems between Woolmaranstad and Ottosdal, Transvaal. Trans. Geol. Soc. S. Africa, 55, 53-71.

Von Backström, J.W., (1962). Die geologie van die gebied om Ottosdal, Transvaal. Toeligting van blaaie 2625D (Barberspan) en 2626C (Ottosdal). Geol. Surv. S. Africa, 1962.

Von Brunn, V., (1974). Tidalites of the Pongola Supergroup (early Precambrian) in the Swart Mfolozi area, northern Natal. Bull. Precambr. Res. Unit, Univ. Cape Town, 15, 107-122.

Von Brunn, V. and Hobday, D.K., (1976). Early Precambrian tidal sedimentation in the Pongola Supergroup of S. Africa. J. Sed. Pet., 46, 670-679.

Von Brunn, V. and Mason, T.R., (1977). Siliciclastic-carbonate tidal deposits from the 3000 My old Pongola Supergroup, S. Africa. Sed. Geology, 18, 245-255.

Walker, R.G. (editor), (1979). Facies Models. Geoscience Canada, Reprint Series 1.

Watchorn, M.B., (1980). Continental sedimentation and volcanism in the Dominion Group of the Western Transvaal: a review. Econ. Geol. Res. Unit, Univ. Witwatersrand. Info. Circ, No. 146, 8 pp.

Watchorn, M.B. and Armstrong, N.V., (1980). Contemporaneous sedimentation and volcanism at the base of the early Precambrian Nsuze Group. S. Africa. Econ. Geol. Res. Unit, Univ. Witwatersrand. Info. Circ, No. 142.

Weilers, B.F., (1990). A review of the Pongola Supergroup and its setting on the Kaapvaal Craton. Econ. Geol. Res. Unit. Univ. Witwatersrand, Info. Circ, No. 228, 69 pp.

Wilson, A.C., (1982). Geological map of Swaziland: 1:250 000 geological summary publ. by Swaziland Government.

Wilson, A.C. and Jackson, M.P.A., (1988). Mantled gneiss domes in southern Swaziland and the concept of 'stable' Pongola cratonic cover. S. Africa. Geol. Tyd., 91, 404-414.

Winchester, J.A. and Floyd, P.A., (1977). Geochemical discrimination of different magma series and their differentiation products using immobile elements. Chem. Geology., 20, 325-343.

Winkler, H.G.F., (1979). Petrogenesis of metamorphic rocks. Springer Verlag, New York, 320 pp.

Wronkiewicz, D.J. and Condie, K.C., (1987). Geochemistry of Archaean shales from the Witwatersrand Supergroup. S. Africa. Source-area, weathering and provenance. Geochim. Cosmochim. Acta, 51, 2401-2416.

Wronkiewicz, D.J. and Condie, K.C., (1989). Geochemistry and provenance of sediments from the Pongola Supergroup, S. Africa. Evidence for a 3,0 Ga old continental craton. Geochim. Cosmochim. Acta, 53, 1537-1549.

LITHOSTRATIGRAPHY AND DEPOSITIONAL ENVIRONMENT OF THE ARCHAEAN NSUZE GROUP, PONGOLA SUPERGROUP.

PART 2

APPENDICES:

E.G. COLE
1994

APPENDICES

APPENDIX 1:

CHEMICAL ANALYSES:

Table	1 (a):	Chemical analyses of lavas from the Pypklipberg Formation.
	1 (b):	Chemical analyses of lavas from the Agatha Formation.
	1 (c):	Chemical analyses of volcanics from "other" formations in the Nsuze Group.
Table	2:	Chemical analyses of Nsuze Group pelites.
Table	3:	Selected chemical analyses from the Dominion Group.

Major and trace elements are listed as a percentage, while trace elements are given in PPM.

APPENDIX 2:

SUMMARIZED THIN SECTION DESCRIPTIONS: (60 SAMPLES)

A. Nsuze Group lavas.

B. Nsuze Group diamictites.

C. Nsuze Group sediments:

Arenites

Argillites

Carbonates

D. Dominion Group lavas.

E. Dominion Group: Other.

The sample locations for these selected thin sections are demarcated on the relevant figures in Chapter 3 and 7. The samples identified by an (*) fall outside the range of these figures.

APPENDIX 1:

CHEMICAL ANALYSES:

TABLE 1 A: GEOCHEMICAL ANALYSES OF LAVAS FROM THE PYPKLIPBERG FORMATION:

WESTERN HARTLAND BASIN

		THIS STUDY (N=5)					ARMSTRONG (1980) (N=32)											
1		WR1	WR2	WR3	WR4	WR5	WR13	HKS29	PKB18	HKS27	WR3	WR8	WR10	WR5	WR12	WR6P	HK531	D38
2																		
3	SiO2	52.8	54.9	55.4	54	57.5	65	66.5	66.1	66.6	70.5	69.3	73.1	55.7	54.8	55.8	58.4	60.3
4	TiO2	0.73	0.84	0.8	1.27	1.96	0.68	0.65	0.82	0.7	0.58	0.62	0.48	1.1	0.67	1.01	0.94	0.59
5	Fe2O3	9.03	8.73	8.88	13.4	11.9	7.8	7.6	8.2	9	5.8	8	5.4	11.8	13.6	10.6	11	[illegible]
6	AL2O3	18.7	19.6	17.6	13.7	14.1	13.2	12.3	12.3	11.7	11.8	12.1	11.2	13.8	15.9	15.2	13.2	14.1
7	MnO	0.08	0.11	0.11	0.19	0.14	0.1	0.2	0.2	0.1	0.15	0.09	0	0.15	0.34	0.18	0.39	0.24
8	MgO	3.63	3.22	3.52	3.98	4.12	1.1	0.68	1.2	0.64	0.9	0.46	0.37	4.2	3.3	3.8	1.3	4
9	CaO	6.02	4.89	6.77	6.34	5.22	3.7	3.7	2.8	2.9	2.7	1.7	1.9	7.4	3.6	5.8	4.8	5.8
10	Na2O	3.7	4.7	3.2	[illegible]	2.2	1.8	1.1	2.7	2.2	2.8	2.5	1.8	3.5	2.3	3.3	2	4.3
11	K2O	1.89	0.19	1.3	1.45	1.19	3.8	3.3	2.9	3.6	2.5	3.9	4.2	1.2	1	1.1	1.7	1.9
12	P2O5						0.15	0.15	0.18	0.21	0.15	0.17	0.09	0.23	0.15	0.21	0.24	0.35
13																		
14	LOI						2.2	4	2.2	2.7	2.8	1.5	0.7	1.4	4.2	3.1	5.2	0.7
15																		
16	Sc	18	17	15	24	18												
17	V	127	123	137	201	172												
18	Cr	116	136	164	89	138	0	0	11	39	5	0	0	124	128	0	39	0
19	Co	19	19	11	42	31												
20	Ni	64	64	48	78	81	13	3	12	10	9	12	15	54	14	58	13	43
21	Cu	23	14	24	40	29	29	15	27	22	17	15	20	37	31	50	29	20
22	Zn	89	77	59	140	120	99	81	60	89	68	88	61	102	116	90	86	63
23	Ga	25	17	15	20	14												
24	As																	
25	Rb	35	3	24	37	27	131	112	112	102	108	146	90	20	22	24	54	42
26	Sr	417	221	288	281	247	147	67	221	69	182	63	181	330	296	381	247	414
27	Y	33	25	21	34	33	53	11	38	32	40	46	43	35	24	32	28	24
28	Zr	133	152	129	206	190	332	[illegible]	247	229	256	316	301	208	143	198	166	189
29	Nb	17	9	11	9	12	21	6	14	12	14	17	18	6.6	6	8	9	9
30	Ag																	
31	Ba						404	334	309	358	538	371	687	294	232	237	275	356
32	La						60	53	46	51	48	62	57	30	13	14	34	34
33	Ce						116	109	92	105	70	99	92	43	43	31	70	69
34	Nd																	
35	P	546	547	517	886	842												

TABLE 1 A: GEOCHEMICAL ANALYSES OF LAVAS FROM THE PYPKLIPBERG FORMATION (CONT.):

WESTERN HARTLAND BASIN

ARMSTRONG (1980) (N=32)

1		WR11	MS35	C19	MS36	WR19	HKS28	MS37	WR4	HKS26	WR1	WR12	MS32	MS34	KB48	HKS30	WR14	WR16
2																		
3	SiO2	72.5	72.8	71.7	53.9	52.7	51.8	52.3	56.9	52.5	51.6	50.7	50.3	50.6	52	53.8	53	53.2
4	TiO2	0.49	0.45	0.48	0.56	0.62	0.62	0.58	1.61	0.75	1.05	1.02	1.19	1.4	1.26	0.53	0.91	1.29
5	Fe2O3	6.2	5.3	12.6	10.5	11.4	11.5	11	7.5	11.1	13	10.4	13.4	13.7	14.4	8.4	11.2	13.9
6	AL2O3	11.4	11.2	4.5	12.6	14.9	13.7	13.8	11.2	14.6	15.1	15.4	14.2	14.8	16	14.6	13.4	14.4
7	MnO	0.09	0	0.12	0.31	0.27	0.23	0.38	0.14	0.33	0.26	0.35	0.21	0.39	0.28	0.22	0.2	0.4
8	MgO	0.19	0.41	0.08	8.2	7.2	7.3	6.6	1.8	5.8	4.7	4.5	4.4	6.2	3.8	4.1	3.2	3.6
9	CaO	1.5	1.3	1.6	9.3	7.8	10.8	8.2	3.8	9.3	9.2	8.7	8.8	8.9	3.2	8.5	7.8	6.4
10	Na2O	2.3	2.2	2.7	2.7	2.8	2.2	2.8	0.89	2.4	3	2.3	2.8	1.7	3.5	2.5	2.9	2.4
11	K2O	4.4	5.1	5.1	0.19	0.45	0.95	0.99	3.2	1.2	0.78	0.16	0.4	1.5	1.4	0.87	0.17	1.7
12	P2O5	0.11	0.09	0.12	0.11	0.14	0.11	0.11	0.2	0.14	0.09	0.33	0.23	0.29	0.23	0.12	0.19	0.26
13																		
14	LOI	0.7	1.2	1.4	1.9	2.2	2.1	1.8	4.1	2.3	1.6	6.6	4.1	2.1	4.3	6.1	7.3	2.7
15																		
16	Sc																	
17	V																	
18	Cr	8	5	0	367	409	494	516	5	135	115	0	56	111	0	107	12	92
19	Co																	
20	Ni	18	10	7	151	116	137	122	6	67	93	142	67	101	34	39	29	59
21	Cu	16	19	13	62	43	57	51	20	44	89	63	59	59	47	30	50	47
22	Zn	61	73	84	80	83	124	73	63	104	107	69	109	125	102	61	83	123
23	Ga																	
24	As																	
25	Rb	131	109	164	3.7	9	22	20	124	26	25	3.3	8	26	35	21	7	30
26	Sr	93	97	69	115	250	293	172	50	318	403	824	602	343	51	368	266	263
27	Y	37	35	72	17	17	20	18	41	25	19	22	32	42	44	20	28	33
28	Zr	268	267	301	78	88	98	71	278	120	83	131	171	215	238	136	156	188
29	Nb	13	18	31	2.7	4.1	3.9	2.7	14	8	3.8	3.9	8.7	10	16	4.9	8	8
30	Ag																	
31	Ba	455	558	545	11	94	200	132	505	250	132	35	123	298	257	95	37	446
32	La	61	52	95	8	17	9	2.1	80	3.2	3.8	28	20	22	34	13	23	18
33	Ce	105	104	184	22	28	40	18	100	34	8	49	42	38	58	42	42	30
34	Nd																	
35	P																	

TABLE 1.A: GEOCHEMICAL ANALYSES OF LAVAS FROM THE PYPKLIPBERG FORMATION (CONT.):

		WESTERN HARTLAND BASIN			MHLATUZE RIVER INLIER			WHITE MFOLOZI INLIER								MPONGOZA INLIER		
		ARMSTRONG (1980) (N=32)			THIS STUDY (N=3)			THIS STUDY (N=8)								PRESTON (1987) (N=41)		
1		MS33	WR7	WR15	NK91	NK93	NK97	WM27	WM28	WM29	WM30	WM31	WM32	WM33	WM34	MI/282	MI/309	MI/312
2																		
3	SiO2	52.4	51.7	51	59.2	53.1	49.9	60.2	58.6	63.7	62.1	53.7	58.3	58.5	56.2	72.95	64.31	[illegible]
4	TiO2	1.25	1.01	1.31	1.01	0.77	2.24	0.9	0.9	0.85	0.82	1.2	0.99	0.85	0.92	1.8	0.49	[illegible]
5	Fe2O3	11.6	13.2	16	10.1	10.2	15.4	10.5	13.2	7.77	10.7	13.1	10.4	11.4	12.3	4.91	7.97	[illegible]
6	AL2O3	14.9	14	15.6	17	12.9	16.4	14.8	13	14.1	12.3	18.9	15.3	13.5	14.5	12.82	17.35	[illegible]
7	MnO	0.28	0.28	0.36	0.11	0.19	0.13	0.08	0.16	0.05	0.13	0.08	0.11	0.14	0.17	0.14	0.07	[illegible]
8	MgO	4.8	4.9	3.2	2.1	2.75	5.46	4.15	3.08	3.09	3.33	4.93	4.52	2.9	3.39	1.13	1.08	[illegible]
9	CaO	7.6	5.6	3.9	3.29	8.68	0.48	0.83	1.66	1.37	1.96	1.38	0.94	3.87	3.06	0.02	0.09	[illegible]
10	Na2O	4.1	2.7	2.8	2.8	1.2	0	0.4	0.4	1.5	0.9	2	0.8	1.7	2.2	1	0.06	[illegible]
11	K2O	0.2	2.1	1.4	1.14	1.02	3.79	4.45	3.84	5.34	3.15	2.95	4.7	2.28	2.61	5.07	8.41	[illegible]
12	P2O5	0.22	0.19	0.37												0.6	0.08	[illegible]
13																		
14	LOI	1.9	4.5	4.8												3.61	2.47	[illegible]
15																		
16	Sc				13	14	21	13	12	10	9	16	19	15	21	12	18	[illegible]
17	V				88	66	160	106	93	52	72	96	100	71	75	1	1	4
18	Cr	116	154	0	38	35	62	34	29	25	33	42	53	23	35	2	3	1
19	Co				19	23	38	26	32	21	24	35	29	29	29			
20	Ni	90	101	30	62	62	67	62	74	44	64	77	45	67	75	2	8	2
21	Cu	58	56	82	98	178	84	122	114	134	76	52	50	125	162	3	2	1
22	Zn	101	141	160	75	97	208	88	92	68	99	113	66	124	123	129	101	[illegible]
23	Ga				16	14	23	23	15	15	16	23	21	19	21			
24	As																	
25	Rb	8	90	48	33	36	62	241	128	93	79	92	172	25	37	145	192	135
26	Sr	276	236	99	60	60	24	40	45	171	105	117	49	148	143	41	12	[illegible]
27	Y	30	36	36	31	26	45	37	27	29	30	35	31	53	34	112	149	[illegible]
28	Zr	162	164	182	259	199	259	252	202	208	213	328	257	210	242	723	1005	747
29	Nb	9	9	11	15	10	32	19	10	14	16	19	15	14	16	39	57	[illegible]
30	Ag																	
31	Ba	160	405	251												1071	937	540
32	La	22	26	20														
33	Ce	35	25	29														
34	Nd																	
35	P				706	555	1157	275	305	358	323	536	412	468	535			

TABLE 1A: GEOCHEMICAL ANALYSES OF LAVAS FROM THE PYPKLIPBERG FORMATION (CONT.):

MPONGOZA INLIER

PRESTON (1987) (N=41)

1		MV314	MV315	MV345	MV347	MV350	MV352	MV354	MV11	MV110	MV111	MV113	MV121	MV123	MV162a	MV162b	MV178	MV179
2																		
3	SiO2	37.67	30.18	60.72	80.67	91.45	61.6	82.76	75.31	76.68	83.12	62.58	57.85	54.85	42.45	80.73	75.4	76.54
4	TiO2	0.63	0.81	2.07	0.31	0.1	0.34	0.34	0.45	0.49	0.49	0.67	2.39	1.71	0.75	0.52	0.54	0.48
5	Fe2O3	15.65	30.74	2.55	3.79	1.13	2.37	0.22	1.86	5.78	0.44	6.89	14.93	13.93	15.7	1.06	4.74	[illegible]
6	Al2O3	26.1	23.53	25.81	1.32	4.73	24.73	13.47	18.43	11.99	12.18	15.68	13.35	22.09	22.1	13.09	13.44	11.07
7	MnO	0.21	0.52	0.07	0.03	0.01	0	0	0.01	0.03	0	0.05	0.19	0.06	0.13	0.01	0.02	0.04
8	MgO	11.18	14.82	0.29	1.36	0.33	0.66	0.02	0.72	2.5	0.27	3.24	2.41	2.33	18.84	1.09	3.34	5.04
9	CaO	0.09	0.05	0.03	0.07	0.01	2.49	0.02	0.04	0.07	0.01	0.15	2.32	0.05	0.17	0.01	0.1	0.05
10	Na2O	0	0	0	0	0	0	0.09	0	0.5	0.5	0	1.46	0.05	0	0.52	0	0
11	K2O	5.31	0.08	7.83	3.27	1.53	8.31	3.36	5.37	2.6	3.84	3.83	3.9	4.35	1.19	3.9	2.79	2.07
12	P2O5	0.13	0.13	6.09	0.06	0	0.08	0.03	0.04	0.07	0.02	0.14	1	0.17	0.32	0.01	0.1	0.07
13																		
14	LOI	7.29	8.63	3.35	2.17	0.76	3.71	1.81	2.46	2.88	1.56	3.3	2.51	6.47	8.36	2.13	3.07	2.92
15																		
16	Sc	22	23	62	10	3	47	12	15	13	13	19	39	46	23	14	16	14
17	V	10	21	367	4	2	27	3	2	5	7	9	35	287	8	4	6	8
18	Cr	0	0	52	12	9	61	3	3	8	6	4	0	44	0	5	2	6
19	Co																	
20	Ni	31	133	9	25	6	11	4	9	25	14	6	0	39	351	83	1	6
21	Cu	0	3	1	0	3	3	0	1	8	4	0	10	16	3	0	2	4
22	Zn	120	201	14	31	6	49	0	17	31	2	38	138	212	49	3	22	19
23	Ga																	
24	As																	
25	Rb	169	2	217	104	56	271	128	192	64	6	109	127	129	27	110	81	[illegible]
26	Sr	7	15	39	8	2	28	65	18	5	6	9	53	21	10	8	7	7
27	Y	187	243	93	97	43	103	101	144	69	6	86	96	73	575	69	73	[illegible]
28	Zr	1535	1400	543	660	267	553	779	962	355	447	465	490	374	502	479	428	385
29	Nb	72	73	25	37	16	45	43	52	27	3	32	26	28	39	27	29	27
30	Ag																	
31	Ba	2820	76	557	300	109	631	52	305	153	209	437	1003	559	70	195	147	[illegible]
32	La																	
33	Ce																	
34	Nd																	
35	P																	

TABLE I A. GEOCHEMICAL ANALYSES OF LAVAS FROM THE PYPKLIPBERG FORMATION (CONT.)

MECIGOZA MEMBER

PRESTON (1987) (N=41)

1		MV125	MV129	MV134	MV138	MV199	MV201	MV203	MV204	MV255	MV182	MV186	MV223	MV224	MV225	MV258	MV288
2																	
3	SiO2	54.17	54.24	75.91	63.27	74.26	73.26	75.61	62.38	41.58	55.56	54.64	65.65	60.17	60.29	78.6	75.82
4	TiO2	2.61	2.91	0.46	0.32	0.31	0.32	0.31	1.65	0.77	1.9	2.31	0.65	1	1.1	0.5	0.5
5	Fe2O3	16.05	14.41	3.4	0.93	4.43	4.4	5.69	1.57	12.52	10.15	15.05	6.19	4.71	4.45	3.83	4.22
6	AL2O3	13.66	12.1	11.54	12.28	12.97	12.03	13.21	25.61	29.9	20.37	13.17	21.24	25.3	26.77	12.02	12.34
7	MnO	0.13	0.33	0.04	0	0.06	0.06	0.04	0	0.14	0.05	0.2	0.01	0	0	0.05	0.05
8	MgO	8.77	7.67	1.06	0.21	1.19	0.95	1.66	0.44	0.76	6.21	4.02	1.47	1.07	0.66	2.03	0.75
9	CaO	0.96	3.96	0.22	0.03	0.09	0.65	0.04	0.03	0.14	0.52	5.87	0.01	0.02	0.03	0.1	0.33
10	Na2O	1.46	1.73	1.74	0	0.5	2.99	0	0.57	0.58	0.45	2.37	0.57	0.09	0.54	0	3.71
11	K2O	0.44	2.26	8.09	3.61	5.17	4.41	3.41	8.02	7.14	4.9	1.16	4.34	6.26	6.19	3.52	2.47
12	P2O5	0.67	0.36	0.08	0.02	0.06	0.06	0.05	0.08	0.25	0.42	0.55	0.04	0.03	0.06	0.09	0.008
13																	
14	LOI	5.24	5.64	1.12	1.72	1.84	1.56	2.69	3.57	6.48	4.65	4.21	4.45	3.37	4.06	2.65	1.06
15																	
16	Sc	47	37	13	10	41	10	9	52	43	52	26	24	31	31	14	14
17	V	289	309	7	5	5	4	2	301	57	470	231	19	27	11	9	6
18	Cr	44	455	3	1	7	6	2	71	0	0	37	6	0	0	1	8
19	Co																
20	Ni	29	143	1	8	0	1	0	18	13	40	30	154	10	46	1	2
21	Cu	2	66	2	1	4	4	3	5	0	4	12	10	0	6	27	7
22	Zn	164	108	66	12	117	153	119	24	104	38	176	7	9	4	30	94
23	Ga																
24	As																
25	Rb	7	57	100	102	206	117	114	247	266	169	52	90	281	146	141	4
26	Sr	36	260	25	4	17	40	7	16	13	10	178	4	13	9	6	35
27	Y	57	34	76	99	105	106	108	89	96	65	68	103	207	326	65	68
28	Zr	298	276	377	685	675	702	832	566	1396	405	327	43	612	774	372	540
29	Nb	17	12	27	40	36	40	41	34	77	27	20	40	53	56	28	2
30	Ag																
31	Ba	81	682	1219	196	763	996	198	263	1020	330	482	117	1104	142	439	54
32	La																
33	Ce																
34	Nd																
35	P																

TABLE 1 A: GEOCHEMICAL ANALYSES OF LAVAS FROM THE PYPKLIPBERG FORMATION (CONT.):

MPONGOZA INLIER

PRESTON (1987) (N=41)

1		MV295	MV299	MV254	MV283	MV291											
2																	
3	SiO2	60.11	75.11	74.98	58.01	73.95											
4	TiO2	2.57	0.47														
5	Fe2O3	4.82	3.53	5.74	5.4	6.62											
6	Al2O3	14.2	12.1	12.21	25.52	13.24											
7	MnO	0.16	0.04	0.08	0.06	0.14											
8	MgO	3.99	0.82	1.05	0.84	1.29											
9	CaO	1.12	0.21	0.14	0.03	1.1											
10	Na2O	0.56	0.53	1.56	0	0											
11	K2O	2.11	7.53	4.17	7.95	3.33											
12	P2O5	0.84	0.08	0.08	0.17	0.1											
13																	
14	LOI	3.64	1.05	1.68	4.19	3.09											
15																	
16	Sc	40	13	12	53	15											
17	V	162	5	5	344	3											
18	Cr	11	10	8	39	5											
19	Co																
20	Ni	86	2	1	23	0											
21	Cu	22	13	5	4	31											
22	Zn	24	23	155	84	120											
23	Ga																
24	As																
25	Rb	78	240	92	286	127											
26	Sr	21	28	22	25	18											
27	Y	81	88	101	80	109											
28	Zr	463	387	649	410	700											
29	Nb	23	26	36	27	38											
30	Ag																
31	Ba	800	184	1409	1210	434											
32	La																
33	Ce																
34	Nd																
35	P																

TABLE 1B. GEOCHEMICAL ANALYSES OF LAVAS FROM THE AGATHA FORMATION:

WESTERN LAPLAND BASIN:

ARMSTRONG (1980) (N=16)

1		AS25	AS23	AS24	PKR20	WR17	AS22	OS42	OS39	NS47	NS46	OS43	OS40	WR18	AS21	OS41	OS44
2																	
3	SIO2	51.9	54.2	53.9	55.3	56.6	57.2	57.2	61.3	60.8	62.8	73.8	70	70.6	78.3	73.4	54
4	TIO2	0.98	1.02	94	1.5	1.01	1.02	1.57	0.91	0.92	0.91	0.38	0.31	0.59	0.31	0.37	0.8
5	Fe2O3	10.9	11.8	10.6	14	10.3	11.3	13.7	7.2	13.9	8.9	4	5.2	6.3	2.4	4.5	10
6	AL2O3	15	13.8	14.4	12.8	13.6	14	12.2	13	11.8	13.5	12.7	13.2	11.9	11.2	12.1	14.2
7	MnO	0.26	0.42	0.22	0.25	0.16	0.2	0.41	0.57	0.26	0.1	0.009	0.21	0.14	0.003	0.17	0
8	MgO	5.9	5	5.9	3.4	4	3.6	2.2	1.1	1	1.4	0.22	0.39	0.29	0.04	0.10	5.4
9	CaO	9.6	8.5	8.3	7.3	4.9	7.3	3.9	5.9	2.6	3.2	0.84	0.91	1.5	0.44	0.66	9.1
10	Na2O	2.4	2.2	2.6	2.1	3.9	2.9	3	2	1.5	2.8	0.91	2.3	2.9	1.4	3.3	2.2
11	K2O	1	1.3	1.1	1.7	0.2	1.3	2.3	2.4	3.2	3	5.1	5.6	4	7.3	4.5	0.57
12	P2O5	0.2	0.21	0.21	0.21	0.2	0.19	0.35	0.24	0.2	0.21	0.05	0.12	0.19	0.08	0.09	0.2
13																	
14	LOI	2.7	1.7	1.9	1.3	5.2	1.3	3.1	5.8	3.9	2.9	1.9	1.7	1.6	0.7	0.8	2.1
15																	
16	Sc																
17	V																
18	Cr	49	5	32	8	0	10	5	5	13	31	8		10			
19	Co																
20	NI	47	42	63	16	23	25		7	16	17	8	8	9	14	10	60
21	Cu	55	57	55	35	30	46		22	33	30	12	11	16	15	16	50
22	Zn	91	105	89	132	64	99		55	100	83	119	63	122	103	102	90
23	Ga																
24	As																
25	Rb	34	35	43	71	46	49	97	86	129	85	196	213	132	171	137	22
26	Sr	188	155	198	187	75	121	109	157	103	265	80	68	159	84	48	197
27	Y	33	41	37	50	42	52	49	31	37	31	85	86	59	69	78	3
28	Zr	160	187	175	229	194	230	292	230	249	220	532	599	430	456	455	177
29	Nb	10	11	10	13	15	19	20	11	12	12	34	37	26	28	32	10
30	Ag																
31	Ba	229	207	239	271	0	177	310	408	379	420	936	554	606	732	390	12
32	La	25	38	24	38	32	41	59	52	47	56	88	100	64	81	99	2
33	Ce	7	74	51	62	66	57	105	93	72	104	190	253	117	160	203	50
34	Nd																
35	P																

TABLE 1.B. GEOCHEMICAL ANALYSES OF LAVAS FROM THE AGATHA FORMATION,

WESTERN HARTLAND BASIN;

ARMSTRONG (1980) (N = 15)

1		AS25	AS23	AS24	PKR20	WR17	AS22	OS42	OS39	NS47	NS48	OS45	OS40	WR18	AS21	OS41	OS44
2																	
3	SiO2	51.9	54.2	53.9	55.3	56.6	57.2	57.2	61.3	60.8	62.8	73.8	70	70.6	76.3	[illegible]	54.4
4	TiO2	0.98	1.02	94	1.5	1.01	1.02	1.57	0.91	0.92	0.91	0.38	0.51	0.59	0.31	0.57	0.82
5	Fe2O3	10.9	11.8	10.6	14	10.3	11.3	13.7	7.2	15.9	8.9	4	5.2	6.3	2.4	4.5	10.6
6	AL2O3	15	13.6	14.4	12.8	13.6	14	12.2	15	11.6	13.5	12.7	13.2	11.9	11.2	12.1	14
7	MnO	0.26	0.42	0.22	0.25	0.18	0.2	0.41	0.57	0.26	0.1	0.009	0.21	0.14	0.003	0.17	0.1
8	MgO	5.9	5	5.9	3.4	4	3.6	2.2	1.1	1	1.4	0.22	0.39	0.29	0.04	0.19	5.4
9	CaO	9.6	8.5	8.3	7.3	4.9	7.3	3.9	5.9	2.6	3.2	0.84	0.91	1.5	0.44	0.66	9.1
10	Na2O	2.4	2.2	2.8	2.1	3.9	2.0	3	2	1.5	2.8	0.91	2.3	2.9	1.4	3.3	2.7
11	K2O	1	1.3	1.1	1.7	0.2	1.3	2.3	2.4	3.2	3	5.1	5.8	4	7.3	4.5	0.57
12	P2O5	0.2	0.21	0.21	0.21	0.2	0.19	0.35	0.24	0.2	0.21	0.05	0.12	0.19	0.05	0.09	0.2
13																	
14	LOI	2.7	1.7	1.9	1.3	5.2	1.3	3.1	5.8	3.9	2.9	1.9	1.7	1.8	0.7	0.8	2
15																	
16	Sc																
17	V																
18	Cr	49	5	32	8	0	10	5	5	13	31	8		10			
19	Co																
20	Ni	47	42	63	16	23	25		7	16	17	8	6	9	14	10	60
21	Cu	55	57	55	35	50	46		22	33	30	12	11	16	15	18	50
22	Zn	91	105	89	132	84	99		55	100	83	119	83	122	103	102	90
23	Ga																
24	As																
25	Rb	34	35	43	71	46	49	97	85	127	85	196	213	132	171	137	2
26	Sr	186	155	198	187	75	121	109	157	103	285	90	68	159	84	48	197
27	Y	33	41	37	50	42	52	49	31	37	31	85	86	59	89	78	35
28	Zr	160	167	175	229	194	250	292	230	249	220	532	599	430	456	455	17
29	Nb	10	11	10	13	15	19	20	11	12	12	34	37	26	28	32	10
30	Ag																
31	Ba	229	292	239	271	0	177	310	406	379	420	938	564	606	732	390	120
32	La	25	36	24	38	32	41	59	52	47	56	88	100	84	81	99	21
33	Ce	7	74	51	62	66	57	105	93	72	104	180	253	117	160	203	5
34	Nd																
35	P																

TABLE 1 B: GEOCHEMICAL ANALYSES OF LAVAS FROM THE AGATIJA FORMATION (CONT.):

		EAST OF PIET RETIEF:		WHITE MFOLOZI RIVER INLIER:										MPONGOZA INLIER:			
				THIS STUDY (N = 10)										PRESTON (1987) (N = 10)			
1		GG25	GG26	WM12	WM13	WM14	WM15	WM16	WM17	WM18	WM19	WM20	WM21	MV214	MV219	MV318	MV321
2																	
3	SiO2	56	56	49.8	55.3	50.1	47.5	49.3	48.3	52.3	50.1	50.4	52.7	76.22	76.85	68.05	81.36
4	TiO2	0.9	1	0.84	1.02	0.93	0.91	1	1.22	0.8	1.76	1.28	1.62	0.91	0.59	1.39	0.35
5	Fe2O3	7.6	9.5	14.4	14.7	12.8	12.6	12	11.5	11.8	13.3	12.2	15.3	4.55	4.09	8.57	0.53
6	AL2O3	15	14	13.6	15.2	14.4	13.9	14.6	14.6	14.2	14.1	15.2	15	10.5	12.52	15.19	13.8
7	MnO	0.1	0.1	0.37	0.14	0.18	0.19	0.18	0.15	0.17	0.18	0.14	0.11	0.04	0.03	0.08	0
8	MgO	5	5	5.13	5.9	6.43	4.9	5.44	3.8	8.06	5.71	3.6	3.85	1.21	2.22	3.57	0.13
9	CaO	10	10	4.9	0.53	4.8	8.11	5.45	8.75	8.67	7.02	7.57	3.59	0.41	0.17	0.29	0.02
10	Na2O	2	1	0.4	1.6	1.7	1.6	1.9	2.7	2.8	2.5	2.8	2.4	0	0.46	0.02	0
11	K2O	1	0	1.18	0.46	0.17	0.48	0.37	0.78	0.85	0.26	0.3	0.56	6.22	5.66	3.05	4.11
12	P2O5	0	0											0.22	0.11	0.28	0.02
13																	
14	LOI													1.43	2.56	3.51	1.86
15																	
16	Sc	29	31	26	43	30	33	31	20	31	28	19	21	28	17	44	12
17	V			138	142	132	112	124	99	111	107	105	105	175	7	542	3
18	Cr		43	89	66	80	67	69	111	166	110	119	104	13	5	3	5
19	Co			41	45	41	35	41	35	32	39	35	37				
20	Ni	82	46	112	97	107	106	109	105	104	113	105	106	4	1	9	6
21	Cu	41	43	21	6	67	82	45	59	56	68	72	49	6	3	8	1
22	Zn	68	87	150	151	135	132	133	104	102	112	96	141	24	20	63	2
23	Ga			19	24	17	16	16	20	20	118	14	22				
24	As																
25	Rb	21	12	29	15	8	17	14	16	14	6	6	8	124	115	96	116
26	Sr			41	41	109	112	77	165	266	231	245	56	20	8	11	15
27	Y	32	35	30	26	27	24	27	32	24	29	34	34	41	58	60	100
28	Zr			121	137	125	130	134	140	105	141	146	196	204	395	306	776
29	Nb	8	7	5	8	8	9	10	9	8	11	10	11	14	26	20	42
30	Ag																
31	Ba													768	330	381	193
32	La	23	25														
33	Ce																
34	Nd																
35	P			491	581	517	617	574	719	55	668	673	882				

TABLE 1 B: GEOCHEMICAL ANALYSES OF LAVAS FROM THE AGATHA FORMATION (CONT.):

		MPONGOZA INLIER:						NKANDLA CENTRAL SYNFORM:								
		PRESTON (1977) (N = 10)						THIS STUDY (N=6)						BROWN (1982) (N = 3)		
1		MI/323	MI/329	MI/330	MI/334	MI/335	MI/339	NK18	NK21	NK24	NK43	NK46	NK49	NK61-1	NK61-2	NK61-6
2																
3	SiO2	80.48	80.68	72.17	70.23	68.33	75.35	48.2	50.4	52.5	48.8	51.2	76.6	57.84	55.39	57.62
4	TiO2	0.31	0.5	0.83	0.64	1.29	0.52	1.13	1.11	0.81	1.82	0.85	0.35	0.88	0.97	0.59
5	Fe2O3	4.93	2.97	11.33	7.53	8.54	5.02	12.8	13.1	12.2	14	12.7	7.46	10.69	11.37	8.74
6	AL2O3	11.34	11.59	9.64	14.28	13.36	12.71	14.6	16	14.7	14.2	15.3	5.50	14.54	15.11	15.14
7	MnO	0.02	0.01	0.09	0.05	0.06	0.04	0.24	0.18	0.19	0.22	0.14	0.08	0.13	0.17	0.14
8	MgO	0.39	1.77	5.83	4.29	5.19	3.1	6.75	5.62	5.56	7.29	5.74	3.28	4.61	5.17	6.1
9	CaO	0.04	0.09	0.16	0.1	0.3	0.11	9.93	6.67	7.62	6.17	8.29	0.84	6	5.83	6.89
10	Na2O	0	0	0.44	0	0.51	0.12	1.6	2.1	2.2	0.9	2.4	0.4	3.51	3.23	3.72
11	K2O	2.59	2.87	0.54	3.25	2.56	2.76	0.63	1.22	0.82	1,38	0.43	0.45	1.69	2.59	0.78
12	P2O5	0.04	0.08	0.14	0.13	0.25	0.11							0.32	0.2	0.29
13																
14	LOI	2.16	2.26	3.9	3.06	4.09	3.15									
15																
16	Sc	11	16	27	187	41	15	33	23	21	34	24	14			
17	V	2	8	177	6	296	7	177	141	116	200	128	61			
18	Cr	8	3	7	2	6	8	238	161	126	191	107	50			
19	Co							32	45	44	46	52	21			
20	Ni	14	17	1	0	50	37	116	110	65	76	105	29			
21	Cu	10	2	3	2	73	1	81	31	36	133	107	19			
22	Zn	31	12	76	76	45	25	170	133	112	102	110	141			
23	Ga							17	20	18	20	16	5			
24	As															
25	Rb	68	86	18	109	63	74	22	11	23	21	16	11			
26	Sr	9	6	4	8	16	6	319	210	309	203	330	38			
27	Y	105	52	29	71	46	54	28	35	24	26	27	9			
28	Zr	673	357	166	431	273	358	58	216	127	96	95	42			
29	Nb	36	25	12	31	16	25	3	6	4	6	7	1			
30	Ag															
31	Ba	95	172	81	330	273	202									
32	La															
33	Ce															
34	Nd															
35	P							505	747	602	795	493	250			

TABLE 1.B: GEOCHEMICAL ANALYSES, ii) LAVAS FROM THE AGATHA FORMATION (CONT.):

NKANDLA CENTRAL SYNFORM

		GROENEWALD (1984) (N=6)						TUNNINGTON (1981) (N=8)										
1		BG160	BG183	BG184	BG156	BG157	BG159	N27-4	N21-5	N27-7	N27-9	N27-10	N27-11	N27-12	N27-13			
2																		
3	SiO2	71.49	61.6	62.34	56.78	53.29	65.51	56.06	54.65	56.88	53.52	54.32	57.6	55.73	57.3			
4	TiO2	1.03	0.76	0.78	1.02	1.3	1.05	0.99	0.94	1.04	1.1	1.16	1.02	1	1			
5	Fe2O3	8.71	7.98	7.68	10.76	17.45	11.06	11.9	10.64	11.24	11.97	11.63	10.59	11.25	10.48			
6	AL2O3	15.52	14.73	15.03	12.54	15	12.42	13.69	13.09	15.55	14.96	14.67	14.23	14.73	14.44			
7	MnO	0.11	0.15	0.12	0.15	0.2	1.16	0.7	0.16	0.15	0.18	0.16	0.15	0.18	0.16			
8	MgO	0.12	3.47	3.3	1.07	2.78	1.13	6.12	5.01	3.8	6.65	6.45	4.95	5.06	4.55			
9	CaO	0.25	6.87	6.66	3.17	5.12	5.09	7.11	5.22	7.32	6.53	6.5	7.46	7.08	7.49			
10	Na2O	0.16	2.43	3.24	3.93	3.34	3.75	3.34	2.92	2.63	3.78	3.49	3.5	3.85	3.77			
11	K2O	4.42	2.51	1.71	0.16	0.36	0.4	0.72	2	0.79	0.20	0.17	0.13	0.43	0.27			
12	P2O5	0.05	0.2	0.19	0.5	0.63	0.52	0.43	0.4	0.45	0.46	0.49	0.47	0.46	0.44			
13																		
14	LOI																	
15																		
16	Sc	34	19	17	19	24	22											
17	V	217	134	125	7	11	7											
18	Cr	41	84	96	38	12	2											
19	Co																	
20	Ni	19	32	33	5	0	0											
21	Cu	7	19	15	3	2	13											
22	Zn	36	82	83	172	275	175											
23	Ga																	
24	As																	
25	Rb	91	36	26	4	12	15											
26	Sr	6	514	638	220	219	275											
27	Y	35	25	24	47	47	46											
28	Zr	200	193	195	235	278	236											
29	Nb	10	8	9	12	14	13											
30	Ag																	
31	Ba	258	840	474	149	172	218											
32	La	21	26	24	37	43	44											
33	Ce																	
34	Nd																	
35	P																	

TABLE 1.B: GEOCHEMICAL ANALYSES OF LAVAS FROM THE AGATHA FORMATION (CONT.):

		BUFFALO RIVER INLIER:											DRILLHOLE NOZ (NQUTU DISTRICT):					
		THIS STUDY (N= 11)											THIS STUDY (N=24) (MAFIC)					
1		B2	BR1	BR3	BR5	BR7	BR6	BR9	BR2	BR5	BR8	BR 10	VPN1	VPN2	VPN3	VPN4	VPN5	VPN6
2																		
3	SIO2	53.2	54.6	54.1	54.3	52.4	49.6	55.1	54.4	55.1	56.7	57.3	46.5	47.1	50.7	51.5	48	46.5
4	TIO2	0.75	0.84	0.82	0.82	0.88	0.89	0.54	0.78	0.74	0.55	0.49	0.94	0.83	0.8	0.82	0.97	0.73
5	Fe2O3	11.4	11.6	11.6	11.4	11.4	11.2	8.94	11.3	11.2	8.27	8.49	8.04	8.65	8.41	7.5	9.45	11.5
6	AL2O3	17.2	14.9	14.3	14.5	14.4	14.5	15	14.7	14.4	13.8	1.48	14.8	14.5	14.5	14.6	15.5	13.7
7	MnO	0.16	0.13	0.11	0.16	0.13	0.14	0.11	0.12	0.12	0.06	0.09	0.11	0.11	0.11	0.11	0.1	0.14
8	MgO	4.9	5.48	4.85	5.04	5.75	5.57	5.3	5.97	5.54	7.73	5.62	3.4	4.2	4	3.9	4.3	5
9	CaO	3.29	5.02	6.59	6.39	5.48	6.77	5.85	6.01	6.55	3.89	6.06	7.76	7.2	6.37	6.22	6.19	7.11
10	Na2O	3.9	2.9	3.9	4.3	2	2.6	2.9	2.8	3.6	2.6	2.2	2.3	2.2	2.2	2.5	2.5	2.3
11	K2O	0.13	2.55	0.83	0.96	0.41	0.08	1.95	2.31	0.96	0.19	2.85	2.33	1.83	1.55	1.68	1.49	1
12	P2O5	0.14	0.1	0.1	0.12	0.1	0.09	0.14	1.16	1.1	1.6	1.2						
13																		
14	LOI	4.87	1.76															
15																		
16	Sc	27	29	16	29	35	27	27	20	30	25	21	24	22	30	27	13	35
17	V	180	156	154	144	172	192	116	126	128	118	98	86	81	81	95	93	136
18	Cr	43	51	51	43	61	55	23	53	56	24	23	44	47	46	51	46	73
19	Co	42	30	36	38	31	38	32	40	44	39	44	23	20	24	23	30	44
20	NI	171	114	101	106	84	60	109	120	110	108	108	62	58	55	38	48	63
21	Cu	65	94	104	110	33	156	55	159	113	40	57	59	8	10	0	0	21
22	Zn	174	103	84	91	122	103	70	97	97	93	71	81	112	121	99	142	131
23	Ga	22	17	11	16	19	15	17	14	11	26	8	23	21	22	22	22	25
24	As																	
25	Rb	3	76	26	33	9	17	40	76	37	195	20	90	77	63	74	59	49
26	Sr	109	127	183	176	76	78	614	177	159	79	237	213	219	224	262	255	218
27	Y	19	14	18	20	19	23	18	16	18	23	19	26	21	22	24	22	22
28	Zr	147	89	81	96	100	103	86	79	86	156	114	112	106	103	103	104	86
29	Nb	6	0	2	3	4	8	6	0	0	11	0	11	13	10	10	11	5
30	Ag																	
31	Ba	140																
32	La	27																
33	Ce	48																
34	Nd	11																
35	P																	

TABLE 1.B: GEOCHEMICAL ANALYSES O_ LAVAS FROM THE AGATHA FORMATION (CONT.):

DRILLHOLE N° 2 (NQUTU DISTRICT):

		MAFIC:					THIS STUDY (N=23) (FELSIC):												
1		VPN7	VPN8	VPN9	VPN10	VPN26	VPN15	VPN16	VPN17	VPN18	VPN19	VPN20	VPN21	VPN22	VPN23	VPN24	VPN25	VPN27	VPN28
2																			
3	SiO2	48.3	47.6	45.8	48.3	45.5	71.6	71	71.7	69	70.3	68.8	72.4	70.5	69.8	72.4	70	71.4	69.4
4	TiO2	0.78	0.8	0.84	0.82	0.61	0.29	0.3	0.32	0.5	0.29	0.32	0.32	0.29	0.27	0.3	0.31	0.34	0.3
5	Fe2O3	9.48	7.77	7.16	8.3	10.7	3.52	3.46	4.27	3.71	3.79	3.01	3.43	3.88	3.75	3.39	4.06	2.94	4.01
6	AL2O3	15	14.6	16	15.5	13.2	13.4	13.3	14.2	13.5	13.5	13.1	14.1	13.4	13.4	14.1	13.5	13.8	13.7
7	MnO	0.11	0.15	0.11	0.13	0.19	0.02	0.04	0.01	0.08	0.04	0.02	0.05	0.02	0.05	0.02	0.06	0.02	0.04
8	MgO	3.9	3.8	4.4	4.1	3.12	0.85	0.82	0.7	0.49	0.44	0.24	0.43	0.27	0.32	0.47	0.45	0.29	0.39
9	CaO	6.19	7.22	8.26	6.44	7.26	1.69	1.83	1.07	2.5	1.99	2.7	0.95	2.03	2.05	0.88	2.45	1.96	2.18
10	Na2O	2	2.3	3.4	2.8	1.2	2.5	2.5	0.5	2.4	2.3	4.1	0.9	2.5	3	1.3	3.2	3.9	3.4
11	K2O	1.74	2.17	0.94	1.69	3.14	2.2	2.34	3.17	2.56	2.84	1.7	4.35	5.01	2.48	3.95	2.54	1.78	2.28
12	P2O5																		
13																			
14	LOI																		
15																			
16	Sc	18	25	21	19	28	10	6	5	8	3	8	15	17	3	5	3	11	3
17	V	82	89	98	83	127	0	1	0	0	5	3	0	2	2	0	0	0	0
18	Cr	48	45	48	50	115	10	11	14	15	11	20	15	11	15	5	7	14	14
19	Co	26	25	20	23	8	0	0	0	0	0	0	0	0	0	0	1	2	0
20	Ni	71	36	32	53	31	1	0	5	0	0	0	1	0	0	0	0	0	0
21	Cu	4	21	6	14	12	2	19	17	7	2	15	3	12	9	0	14	36	13
22	Zn	102	77	68	98	218	36	27	59	32	44	42	55	59	47	54	48	511	21
23	Ga	22	22	19	19	20	22	21	56	23	21	26	22	24	22	22	24	23	20
24	As																		
25	Rb	72	87	39	68	104	82	72	136	92	103	89	146	119	93	126	100	71	93
26	Sr	197	217	299	189	258	69	78	54	119	107	155	81	24	121	58	148	182	128
27	Y	28	27	25	24	19	45	42	51	45	45	53	44	44	47	45	46	46	49
28	Zr	116	106	109	112	74	353	321	335	339	350	365	352	369	357	355	365	382	355
29	Nb	11	9	13	11	10	20	15	22	18	21	24	19	21	18	20	20	23	19
30	Ag																		
31	Ba																		
32	La																		
33	Ce																		
34	Nd																		
35	P																		

TABLE 1.C: GEOCHEMICAL ANALYSES OF VOLCANICS FROM "OTHER" FORMATIONS IN THE NSUZE GROUP:

		NZIMINI FORMATION:										WHITE MFOLOZI FORMATION:							
		CENTRAL SYNCLINE (NKANDLA AREA):										BUFFALO RIVER INLIER:							
		GROENEWALD (1984) (N=10):										THIS STUDY (N=3):							
1		BG128	BG129	BG130	BG131	BG147	BG152	BG268	BG267	BG238	BG257	B52	B11	BR57					
2																			
3	SiO2	58.14	57.94	54.43	60.98	50.16	57.76	55.29	57.73	71.57	74.04	61.7	63.3	53.8					
4	TiO2	1.42	1.44	1.63	1.5	1.59	0.97	1.69	1.55	0.28	0.34	0.8	1.06	0.73					
5	Fe2O3	11.39	11.48	1, 84	10.99	13.79	10.79	15.38	12.87	6.7	3.49	9.92	11.2	8.71					
6	Al2O3	13.93	13.87	25.43	13.55	19.37	14.53	15.97	14.95	8.51	8.76	12	12.5	18.2					
7	MnO	0.15	0.16	0.15	0.14	0.06	0.13	0.21	0.04	0.1	0.07	0.16	0.2	0.14					
8	MgO	3.91	3.67	2.87	5.62	6.69	4.94	9.59	11.95	7.18	5.38	4.59	2.02	2.56					
9	CaO	4.98	6.33	7.51	2.31	1.51	4.88	1.05	0.28	4.59	3.53	3.69	1.86	5.41					
10	Na2O	4.22	4.43	3.18	1.66	5.94	5.12	0.24	0.06	0.98	3.39	2.1	3.4	3.5					
11	K2O	1.61	1.73	2.33	3.57	0.55	1.66	1.24	0.59	0.68	0.9	2.66	0.35	2.68					
12	P2O5	0.19	0.22	0.22	0.24	0.27	0.2	0.23	0.21	0.03	0	0.06	0.14	0.12					
13																			
14	LOI																		
15																			
16	Sc	20	20	21	15	49	30	29	2[illegible]	21	23	21	21	43					
17	V	201	203	219	197	363	205	242	21[illegible]	116	112	129	132	129					
18	Cr	63	57	62	68	65	193	216	69	1239	496	46	21	19					
19	Co											34	45	25					
20	Ni	51	45	49	50	112	84	99	112	190	126	118	118	118					
21	Cu	45	45	12	22	56	16	102	0	36	78	88	63	25					
22	Zn	115	99	102	105	122	86	182	[illegible]	48	35	72	52	86					
23	Ga											10	17	17					
24	As																		
25	Rb	57	62	72	102	9	57	36	11	20	17	69	36	10					
26	Sr	177	213	391	129	150	134	0	[illegible]	63	87	58	307	293					
27	Y	31	33	33	35	28	12	32	22	29	16	17	20	14					
28	Zr	201	209	225	222	240	162	228	211	92	81	86	137	95					
29	Nb	12	12	12	12	9	6	11	12	4	6	5	12	7					
30	Ag											7							
31	Ba	384	402	493	642	184	517	126	[illegible]	493	253	720							
32	La	16	19	18	19	25	20	18	[illegible]	12	14	12							
33	Ce											3							
34	Nd											0							
35	P																		

TABLE 2: GEOCHEMICAL ANALYSES OF NSUZE GROUP PELITES:

		WESTERN HARTLAND BASIN:			MPONGOZA INLIER:		WHITE MFOLOZI RIVER INLIER:						MHLATUZE RIVER INLIER:						
		LANGFONTEIN FORMATION:			WHITE MFOLOZI FORMATION:		WHITE MFOLOZI FORMATION:						WHITE MFOLOZI FORMATION:						
		PHYLLITES ALONG NTOMBE PROFILE			AVE. SHALE	SHALE	SHALES					AVE. SHALE	SHALES AND GREYWACKES						
		THIS STUDY (N=3):			WRONKIEWICZ AND CONDIE (1989)	MCLENNAN AND TAYLOR (1983)(N=1)	THIS STUDY (N=5)					WRONKIE-WICZ AND CONDIE(1989)	THIS STUDY (N=4)						
1		HB14	HB17	HB18	AVERAGE	PO1034	WM22	WM23	WM24	WM25	WM26	AVERAGE	NK81	NK82	NK86	NK88			
2																			
3	SIO_2	64.5	57.1	55.7	56.23	58.96	61.4	58.2	58.1	55.3	56.9	58.75	63.6	59.4	59.7	55.4			
4	TIO_2	0.91	1.41	1.58	1.19	1	0.87	0.8	0.82	0.81	0.84	0.76	0.78	0.77	0.64	0.79			
5	Fe_2O_3	10.6	5.55	8.03	8.22	4.66	6.01	5.9	9.53	10.7	10.1	6.57	6.15	10.3	14.4	11.7			
6	AL_2O_3	13.2	26.1	26.1	24.45	22.84	17.9	20	18.6	19	19.4	20.62	16.2	16	13.4	16.8			
7	MnO	0.12	0.04	0.11	0.04	0.02	0.08	0.02	0.02	0.11	0.02	0.06	0.08	0.08	0.16	0.11			
8	MgO	1.21	1.61	1.74	1.1	0.71	3.45	4.57	3.6	3.64	3.53	3.26	4.53	5.06	5.32	5.53			
9	CaO	1.54	0.25	0.21	0.03	0.08	0.64	0.35	0.11	0.31	0.05	0.04	0.04	0.01	0.01	0.01			
10	Na_2O	0.1	0.7	0.8	0.36	0.56	0.4	0.2	0.2	0.2	0.2	0.19	0	0	0	0			
11	K_2O	2.77	1.84	2.77	5.98	6.03	4.5	5.12	3.91	3.8	3.9	4.7	4.02	3.22	1.56	3.27			
12	P_2O_5	1.37	1.59	1.13	0.04							0.09							
13																			
14	LOI				4.47	5.16						4.64							
15																			
16	Sc	26	54	45	27	23	17	24	33	26	17	24	12	28	14	14			
17	V	83	207	222	223	195	120	113	139	143	138	190	107	121	100	124			
18	Cr	41			455	530	377	521	488	463	477	709	574	593	574	559			
19	Co	19	27	10	19	10	21	13	17	14	11	19	18	14	22	18			
20	Ni	4	82	21	149	182	238	132	83	101	52	144	173	178	197	245			
21	Cu	67	37	31		148	60	50	60	71	26		12	60	48	83			
22	Zn	130	69	83			86	78	97	120	104		41	62	95	95			
23	Ga	17	33	33		15	20	21	24	22	26		16	19	11	26			
24	As																		
25	Rb	84	65	97	200		150	156	111	126	123	162	141	110	60	114			
26	Sr	39	62	71	25		17	35	49	44	48	50	4	1	2	4			
27	Y	30	55	66	43		37	25	34	30	32	33	22	25	15	22			
28	Zr	239	309	351	229	156	206	154	157	156	150	144	321	266	199	216			
29	Nb	10	17	18	19	17	16	16	16	15	15	17	9	7	4	6			
30	Ag																		
31	Ba				260	264						446							
32	La				43	31						47							
33	Ce				83	62						87							
34	Nd					28													
35	P						293	382	636	778			78	77	85	36			

TABLE 2. GEOCHEMICAL ANALYSES OF NSUZE GROUP PELITES (CONT.);

CENTRAL SYNCLINE (NKANDLA AREA);

LANGFONTEIN / VUTSHINI FORMATION;

		SHALES;														AVERAGE SHALE;			
		THIS STUDY (N=14);														WRONKIEWICZ AND CONDIE (1989);			
1		NK1	NK3	NK5	NK9	NK11	NK13	NK26	NK28	NK31	NK34	NK35	NK17	NK36	NK37	AVERAGE			
2																			
3	SIO2	60.1	70.6	63.1	58.3	55.7	43.7	67.5	49.9	60.1	51.8	54.6	63.6	45.1	52.9	70.71			
4	TIO2	0.55	0.49	0.51	0.5	0.68	0.36	0.69	0.85	0.59	0.59	0.54	0.56	0.67	0.95	0.46			
5	Fe2O3	15	5.1	11	15.1	10.9	28.6	5.88	24.2	13.7	22.2	19.2	10.1	2.07	24.4	5.59			
6	AL2O3	14	13.7	14.9	13.1	18.7	9.05	15.4	14	15.3	11.9	12.5	13.6	14.6	11.3	13.56			
7	MnO	0.1	0.02	0.05	0.08	0.24	4.97	0.05	0.13	0.08	0.05	0.08	0.11	0.08	0.08	0.04			
8	MgO	39.3	3.08	2.73	5.48	4.47	3.63	2.59	4.21	3.81	0.59	0.54	5.13	0.67	0.95	1.59			
9	CaO	0.04	0.17	0.02	0.01	0.03	0.47	0.01	0.03	0.09	0.04	0.01	0.08	0.03	0.03	0.01			
10	Na2O	0	0.1	0	0	0.1	0	0	0	0.1	0	0	0	0	0	0.35			
11	K2O	1.52	2.72	2.26	0.89	3.53	1.7	4.15	0.38	1.77	0.1	0.03	2.85	0.03	0.03	3.24			
12	P2O5	0.05	0.01	0.01	0.03	0.06	0.06	0.02	0.01	0.08	0.01	0.09	0.03	0.01	0.02	0.02			
13																			
14	LOI															2.47			
15																			
16	Sc	21	13	16	12	28	18	22	22	28	15	15	26	35	17	8			
17	V	97	49	89	83	0	81	97	0	0	97	0	90	0	0	68			
18	Cr	433	566	431	414	657	394	410	780	259	574	433	660	814	487	386			
19	Co	5	9	6	11	18	6	6	22	17	20	19	21	14	12	10			
20	Ni	137	83	209	173	172	130	103	305	245	200	125	211	244	143	74			
21	Cu	56	28	28	15	27	15	26	35	22	24	71	30	33	11				
22	Zn	104	70	83	99	69	55	52	95	57	58	109	58	70	70				
23	Ga	13	10	14	15	17	14	17	20	18	14	14	17	13	15				
24	As																		
25	Rb	59	83	72	40	109	100	117	32	59	10	4	104	6	16	118			
26	Sr	9	17	9	6	14	14	8	0	12	0	0	4	0	0	14			
27	Y	12	11	8	15	24	12	19	11	22	21	12	10	19	15	19			
28	Zr	127	266	163	180	109	71	185	140	101	192	98	135	139	141	186			
29	Nb	7	4	6	6	4	5	9	4	6	9	0	3	10	8	6.9			
30	Ag																		
31	Ba															460			
32	La															27			
33	Ce															51			
34	Nd																		
35	P																		

TABLE 5: SELECTED GEOCHEMICAL ANALYSES FROM THE DOMINION GROUP:

RENOSTERHOEK FORMATION:

BASIC LAVAS FROM:-

BOWEN (1984) AND CROW AND CONDIE (1987) (N = 17):

1		BBS/04	BBS/05	BBS/09	BBS/13	BBS/16	BFT/2	BSF/02	BSF/03	BSF/08	BSF/09	BSF/10	BSF/11	BSF/12	BTF/02	BTF/03	BTF/06	BTF/14
2																		
3	SiO2	53.1	53.7	53.9	52.8	52.8	58.4	52.8	50.5	55.9	54.4	55.3	53.2	50.6	51.7	51.5	52.1	52.4
4	TiO2	0.99	1.01	0.54	1.23	0.83	1.22	1.13	0.66	0.63	1.15	1.19	1.18	0.83	0.68	0.57	0.59	0.8
5	Fe2O3	10.9	11.1	9.2	12.5	11.6	12.4	12.5	10.7	8.6	11.5	12	11.9	12	11	9.9	9.6	4.9
6	Al2O3	14.1	13.8	15.3	15	14.2	13.7	14	13.8	14	14.5	15.6	14.8	13.9	13.1	13.9	14.2	22.9
7	MnO	0.15	0.15	0.15	0.17	0.18	0.12	0.16	0.2	0.15	0.17	0.12	0.17	0.17	0.17	0.15	0.12	0.05
8	MgO	6.01	6.47	7.94	5.87	7.39	4.56	3.45	8.85	6.76	4.92	4.23	5.18	7.88	9.1	7.94	7.14	2.63
9	CaO	8.43	8.93	5.05	3.43	5.71	2.26	5.45	8.76	7.01	6.33	3.39	5.9	8.11	8.74	8.17	8.92	8.26
10	Na2O	3.7	3.72	4.99	3.94	5	3.69	3.93	2.27	5.14	4.34	4.96	4.23	3.63	2.17	2.85	2.47	1
11	K2O	0.86	1.11	1.13	1.22	0.61	0.21	0.59	1.77	0.29	0.53	0.27	1.22	0.94	0.12	1.09	0.93	3.42
12	P2O5	0.18	0.15	0.13	0.38	0.2	0.3	0.26	0.14	0.15	0.36	0.37	0.37	0.2	0.17	0.12	0.15	0.09
13																		
14	LOI	2.26	2.34	2.43	3.24	2.34	3.59	5.62	2.8	2.01	1.93	3.18	2.13	2.16	2.83	4.13	3.35	3.16
15																		
16	Sc																	
17	V	181	189	187	264	247	353	322	192	181	249	279	262	237	195	185	169	157
18	Cr	295	366	556	30	638	3	10	933	678	25	41	22	675	516	588	532	385
19	Co	42	53	47	62	43	36	50	65	53	44	60	39	48	40	42	52	23
20	Ni	284	274	276	94	202	49	24	390	247	98	110	119	344	318	355	289	152
21	Cu																	
22	Zn																	
23	Ga																	
24	As																	
25	Rb	34	47	49	47	24	7	33	80	8	17	10	48	42	10	36	34	196
26	Sr	291	213	236	241	203	90	246	228	410	570	305	503	358	360	375	380	911
27	Y	18	20	15	29	21	26	27	18	14	25	23	26	20	15	14	18	36
28	Zr	117	117	82	198	103	204	193	89	84	182	182	169	104	93	80	90	156
29	Nb	5	5	4	8	4	6	5	4	3	6	6	6	4	4	3	4	13
30	Ag																	
31	Ba	295	570	490	879	362	60	198	774	143	505	99	770	674	52	482	304	970
32	La	10	12	8	29	10	20	30	13	13	23	34	19	11	8	8	12	53
33	Ce	26	29	20	67	26	45	67	30	29	54	80	47	27	20	18	29	175
34	Nd																	
35	P																	

TABLE 3: SELECTED GEOCHEMICAL ANALYSES FROM THE DOMINION GROUP:

					RENOSTERHOEK FORMATION	SYFERFONTEIN FORMATION:			
					AVERAGE COMPOSITION OF BASIC LAVAS:	AVERAGE PORPHYRY COMPOSITION:			
					(FROM BOWEN ET AL 1986)	(FROM BOWEN ET AL 1986)			
1					MEAN	MEAN			
2									
3	SiO_2				56.05	69.78			
4	TiO_2				1.08	0.81			
5	Fe_2O_3				11.82	6.7			
6	AL_2O_3				14.18	12.92			
7	MnO				0.16	0.08			
8	MgO				5.25	1.13			
9	CaO				7.16	2.01			
10	Na_2O				3.02	3.16			
11	K_2O				0.97	3.16			
12	P_2O_5				0.31	0.25			
13									
14	LOI								
15									
16	Sc								
17	V				256	5.4			
18	Cr				328	4.5			
19	Co				61	118			
20	Ni				139	11			
21	Cu				52	13			
22	Zn				110	83			
23	Ga								
24	As								
25	Rb				28	86			
26	Sr				430	187			
27	Y				28	30			
28	Zr				159	282			
29	Nb				7	14			
30	Ag								
31	Ba				453	768			
32	La				21	48			
33	Ce				46	92			
34	Nd				26	40			
35	P								

APPENDIX 2:

SUMMARIZED THIN SECTION DESCRIPTIONS: (60 SAMPLES)

A: NSUZE GROUP LAVAS
PYPKLIPBERG FORMATION.

SAMPLE NO	LOCALITY	ROCK TYPE	TEXTURE	CONSTITUENT MINERALS (IN ORDER OF ABUNDANCE)	COMMENTS
WM4	White Mfolozi River Inlier	Mafic / Intermediate lava	Interpenetrant, twinned plagioclase laths highly saussuritized. (< 2 mm long axis). Resorbed irregular-shaped tremolite/actinolite crystals, secondary calcite and well rounded quartz crystals.	Plagioclase, saussuritized groundmass, tremolite / actinolite, chlorite calcite, opaques, quartz.	Highly altered, covered by a green, chloritic "dusting".
AM6	Amsterdam Area	Mafic / Intermediate lava	Plagioclase phenocrysts < 2 cm long axis. Matrix dominated by interwoven plagioclase laths, secondary epidote occupies < 25 % volume. Extensive saussuritization. Chlorite mimics plagioclase. Thin ,2 mm - wide cross-cutting quartz vein. Amygdales (< 5 mm across) filled with calcite, quartz + chlorite.	Plagioclase, epidote chlorite, brown opaques, quartz.	Opaques occupy < 5 % volume. Extensively altered.
MR13	Western Hartland Basin (Mantonga River traverse)	Mafic / Intermediate lava	Plagiclase phenocrysts < 2 cm. Trachytic saussuritized plagioclase groundmass. Altered to epidote, sericite, calcite, quartz. Subangular quartz grains < 0,8 mm. Amygdaloidal.	Plagioclase, epidote, sericite, calcite, chlorite, quartz, opaques.	Amygdales filled with calcite and quartz. Highly altered.
			AGATHA FORMATION:		
WM19	White Mfolozi River Inlier	Mafic / Intermediate lava	Plagioclase phenocrysts (< 7 mm) set in a cryptocrystalline groundmass comprising replacement calcite, quartz, epidote, chlorite and saussuritized plagioclase. Quartz - filled amygdales.	Plagioclase, calcite, chlorite, epidote, quartz, opaques.	Extensive calcitization. Calcite pseudomorphs primary mineral.

A: NSUZE GROUP LAVAS

AGATHA FORMATION (CONT.):

SAMPLE	LOCALITY NO	ROCK	TEXTURE TYPE	CONSTITUENT MINERALS (IN ORDER OF ABUNDANCE)	COMMENTS
WR1	Western Hartland Basin (White River traverse)	Mafic / intermediate lava	Rounded, interlocking plagioclase porphyries and quartz amygdales in a yellow-brown altered groundmass.	Plagioclase, quartz, epidote, chlorite, biotite, sericite, reddish opaques.	Highly altered, Reduced groundmass.
AS2	Western Hartland Basin (Agatha Stream traverse).	Mafic / Intermediate lava	Amygdales < 4 mm, filled with intergrown quartz and epidote. Trachytic groundmass plagioclase pseudomorphed by epidote, sericite and chlorite.	Plagioclase, epidote quartz, chlorite, sericite.	Quartz rim around amygdales. Plagioclase largely replaced.
SW12	Western Swaziland	Feldspar porphyry.	Feldspar phenocrysts < 7 mm. (Highly saussuritized to sericite and fine-grained mosaic quartz) cross-cutting chloritic "trains". Irregular shaped epidote after plagioclase?	Feldspar, sericite, epidote, quartz, chlorite, opaques, biotite, zircon.	Local silicification, chlorite is the last replacement mineral.
MW8	Magudu area (Hohobo River traverse)	Metalava (Hornfels)	Poikilitic garnet crystals (< 5mm). Late stage epidote + quartz veining (2 mm wide). Secondary undulose inequigranular quartz crystals.	Chlorite, quartz, garnet, hornblende, epidote, opaques, plagioclase(?)	Hornblende reduced wrt. chlorite. Highly altered mineralogy.
MW1	Magudu area (Hohobo River traverse)	Metalava (Hornfels)	Oval porphyritic clusters after altered plagioclase. Anhedral remnant plagioclase often poikilitic (< 3 mm long axis). Secondary biotite laths randomly distributed. Subangular garnet crystal.	Plagioclase, biotite, quartz, epidote, opaques, chlorite, garnet.	Late stage silification. Aphanitic highly altered groundmass.

B. NSUZE GROUP DIAMICTITES
MANTONGA FORMATION:

SAMPLE	LOCALITY NO	ROCK	TEXTURE TYPE	CONSTITUENT MINERALS (IN ORDER OF ABUNDANCE)	COMMENTS
AM8	Amsterdam Area		Equigranular, subrounded quartz grains (4% volume) < 2 mm size. Fine-grained chlorite matrix. Rare anhedral feldspar pseudomorphed by chlorite ± epidote.	Quartz, chlorite, sericite, epidote, feldspar, opaques zircon.	Highly altered volcanic debris flow? Both mono and polycrystalline quartz grains.
MR4	Western Hartland Basin (Mantonga R. traverse)		Fractured, subrounded, mainly polycrystaline quartz grains (60% volume) < 2 mm size. Highly sericitized matrix. Red iron oxide opaque specks in matrix.	Quartz, sericite, opaques.	Pervasive sericitization. Primary crystals totally pseudomorphed.
MAN1	Buffalo River Inlier (Mazebeko R. traverse)		Elongate quartzose clusters in an altered fine-grained chloritic matrix. Chlorite > 60% volume.	Quartz, chlorite, lithics, opaques.	Diamictite overlies greenstone basement. Tectonic microfabric, shearing.

WHITE MFOLOZI FORMATION:

SAMPLE	LOCALITY NO	ROCK	TEXTURE TYPE	CONSTITUENT MINERALS (IN ORDER OF ABUNDANCE)	COMMENTS
WM10	White Mfolozi River Inlier		Immature quartz, lithic and K-feldspar crystals (< 0,4 mm size) in a very fine-grained altered chloritic matrix. Equigranular fine-grained quartz in matrix.	Quartz, K-feldspar, lithics, chlorite, carbonate, biotite, opaques, sericite.	Late stage carbonatisation. Stratigraphically below Chobeni carbonate Member.
WM15	White Mfolozi River Inlier		Very immature. Well rounded quartz (<5 mm) and subangular K-feldspar crystals in a very fine grained matrix comprising secondary sericite, chlorite and quartz.	Quartz, K-feldspar (microcline), carbonate, sericite, chlorite, opaques.	Silicification. Carbonatisation. Mass / debris flow?

B: NSUZE GROUP DIAMICTITES
WHITE MFOLOZI FORMATION (CONT.):

SAMPLE	LOCALITY NO	ROCK	TEXTURE TYPE	CONSTITUENT MINERALS (IN ORDER OF ABUNDANCE)	COMMENTS
FB4	Buffalo River Inlier Mangeni traverse.		Granule size quartz (< 3mm size) and altered lithic fragments occupy ± 60% volume. Yellow-tinge sericitic matrix.	Quartz, lithics, sericite, chlorite, chert, opaques.	Silification. Interwoven chlorite / sericite / quartz pseudomorph original lithic fragments.
VUTSHINI / LANGFONTEIN FORMATION:					
NR3	Western Hartland Basin. Ntombe River traverse.		Equigranular quartz gains < 2 mm size. Green pleochroic chlorite flakes define a foliation. Altered chlorite / sericite matrix.	Quartz, chlorite,sericite, chert, epidote, carbonate, opaques.	Local carbonitisation. Tectonic rotation of quartz grains.
GAN3	Buffalo River Inlier Mazebeko traverse.		Rounded quartz grains < 1 mm size. Monocrystaline. Lithic fragments replaced by quartz, chlorite and sericite. Matrix largely fine grained quartz mosaic.	Quartz, chlorite, sericite, opaques, lithics, hornblende (?)	Recrystallized. Sericitization post dates chloritization? Opaques + 5% volume.
NZIMINI FORMATION:					
• NSZ1	Nqutu District, near Nzimini store.		Whole spectrum of alteration products. Angular twinned K-feldspar fragments with sericitic rims. Quartzo-sericite matrix. Carbonate in contact with all other phases. Clusters of chlorite + epidote crystals.	Quartz, K-feldspar, epidote, carbonate, sericite (muscovite) lithic fragments, chlorite, opaques.	Lithic wacke subjected to a series of alteration processes? Inferred volcaniclastic origin.
ND3	Buffalo River Inlier. Ndweni traverse.		Subrounded undulose extinction quartz grains < 1 mm size. Matrix is fine-grained interlocking quartz, muscovite and chlorite crystals. Dispersed oval epidote crystals < 0,4 mm size.	Quartz, muscovite, (sericitic), chlorite, epidote, opaques.	Pressure solution textures. Mainly monocrystalline quartz, grains highly fractured. Brown staining.

C: NSUZE GROUP SEDIMENTS - ARENITES
MANTONGA FORMATION:

SAMPLE NO.	LOCALITY	ROCK TYPE	TEXTURE	CONSTITUENT MINERALS (IN ORDER OF ABUNDANCE)	COMMENTS
MAN2	Buffalo River Inlier Mazebeko R. traverse.	Argillaceous quartz arenite.	Coarse grained, moderately well-sorted and sub-rounded quartz grains (< 4 mm) Dirty sericite / muscovite inter-quartz grain matrix. Sutured quartz grain contacts.	Quartz, muscovite, sericite.	Mainly polycrystalline quartz grains. Deformed.
MR10	Western Hartland Basin. Mantonga R. traverse.	Feldspathic quartz arenite.	Inequigranular, poorly-sorted arenite. Quartz grains usually < 3 mm size and largely monocrystaline. Pressure solution textures. Sericitized anhedral *K-feldspar crystals < 3 mm size.* (15% volume). Sericitic matrix.	Quartz, K-feldspar, muscovite, sericite, zircon (?)	Strained quartz grains.
WM1	White Mfolozi River Inlier.	Feldspathic quartz arenite.	Equigranular sub-rounded quartz grains <0,5 *mm size.* Subrounded, cross-hatched twinned microcline crystals. (< 10% volume). Subordinate matrix.	Quartz, K-feldspar (microcline), muscovite, sericite.	Stratigraphically overlying granitic basement.
AM7	Amsterdam Area.	Quartz arenite.	Medium-grained, well to sub-rounded quartz grains. Largely monocrystaline. Rare radiating chlorite needle clusters.	Quartz, chlorite, muscovite (sericite), K-feldspar (?)	Pressure solution evidence.
			WHITE MFOLOZI FORMATION:		
NK4	Western Hartland Basin. Nkemba traverse.	Orthaquartzite.	Equigranular interpenetrant quartz grains. No matrix.	Quartz, rare muscovite (sericite).	Recrystallized. Monomineralic.

C: NSUZE GROUP SEDIMENTS - ARENITES
WHITE MFOLOZI FORMATION:

SAMPLE	LOCALITY NO.	ROCK	TEXTURE TYPE	CONSTITUENT MINERALS (IN ORDER OF ABUNDANCE)	COMMENTS
FB7	Buffalo River Inlier. Okhalweni traverse.	Agillaceous arenite.	Medium to coarse-grained, equigranular, well-sorted quartz grains. (+ 65% volume). Muscovite / sericite matrix.	Quartz, muscovite, sericite, opaques.	Quartz, grains highly deformed. Quartz long axii parallel to bedding direction defined by micas.
MHL6	Mhlatuze River Inlier.	Ortho-quartzite.	Equigranular, coarse grained, well-sorted quartz grains. Suture-bundary, interlocking undulose quartz grains. Minor sericite / muscovite, interstitial and cross-cutting to quartz grains.	Quartz, sericite / muscovite.	Highly strained.
FB5	Buffalo River Inlier. Mangeni traverse.	Quartz wacke.	Sub-rounded to subangular, medium-grained quartz grains. Well-sorted. Dirty altered, sericitic matrix. Matrix-dominant.	Quartz, sericite, muscovite, chlorite.	Preferred orientation of quartz grain long axes.
MD4	Central Syncline. Nkandla district.	Quartz wacke.	Sub-rounded quartz grains < 1 mm size, separated by fine-grained quartz / sericite / chlorite zones.	Quartz, chlorite, sericite, opaques.	Recrystalized quartz. Chlorite / sericite "trains" define foliation.
LANGFONTEIN / VUTSHINI FORMATION:					
MF9	Magudu Area. Mfenyana R. traverse.	Orthoquartzite.	Interlocking subangular quartz grains (< 1/2 mm size). Minor cross-cutting fine-grained mica flakes.	Quartz, mica.	Monocrystalline quartz > polycrystalline quartz.

C: NSUZE GROUP SEDIMENTS - ARENITES
LANGFONTEIN / VUTSHINI FORMATION:

SAMPLE	LOCALITY NO.	ROCK	TEXTURE TYPE	CONSTITUENT MINERALS (IN ORDER OF ABUNDANCE)	COMMENTS
MW7	Magudu Area Hlobo River traverse.	Quartz Arenite.	Poorly-sorted, sub-rounded quartz grains (max. 3 mm size). Sutured boundaries. Altered brownish possible hornblende crystals replaced by micas, chlorite.	Quartz, muscovite, biotite, chlorite, hornblende (?), zircon, sphene.	Immature sediment. Highly altered.
SW3	Western Swaziland	Ortho-quartzite.	Sub-rounded to sub-angular equigranular mainly monocrystalline quartz grains. Interlocking sutured boundaries. Reduced quartzo-sericitic matrix.	Quartz, chert, sericite, opaques.	Recrystallized. Mature sediment (?)
SW1	Western Swaziland	Quartz Wacke	Inequigranular, poorly-sorted quartz grains (max. 4 mm size). Interpenetrant, sutured grain-boundaries. Micas interstitial and cross-cutting to quartz grains.	Quartz, muscovite, biotite.	Pressure solution. Recrystallized. Red oxide-staining.
GAN1	Buffalo River Inlier. Mazebeko R. traverse.	Quartz Wacke	Sub-rounded to sub-angular equigranular quartz grains < 2 mm size. Fine-grained quartz-muscovite-sericite matrix.	Quartz, sericite, muscovite, opaques.	Muscovite needles have a preferred-orientation. Quartz mainly monocrystaline.
VS2	Central Synform. Nkandla district.	Quartz Arenite	Poorly-sorted, inequigranular, coarse, sub-angular to sub-rounded quartz grains. (max. 3 mm size). Interstitial 2' quartz and mica.	Quartz, sericite, muscovite.	Pressure solution. Interpenetrant sutured quartz outlines.
VS8	Central Synform. Nkandla district.	Quartz Arenite	Sub-rounded, poorly-sorted, very coarse to medium-grained quartz grains. Poikilitic, high relief (orthopyroxene?) mineral. No matrix.	Quartz, sericite, orthopyroxene (?), cubic opaque (magnetite?)	Recrystallized. Highly deformed rock.

C: INSUZE GROUP SEDIMENTS - ARGILLITES
WHITE MFOLOZI FORMATION:

SAMPLE	LOCALITY NO.	ROCK	TEXTURE TYPE	CONSTITUENT MINERALS (IN ORDER OF ABUNDANCE)	COMMENTS
MD2	Central Syncline Nkandla District.	Chlorite shale	Light green, fine-grained chloritic rock. Equigranular, sub-rounded quartz grains interwoven with biotite and late stage sericite. Rock cross-cut by quartzo-chloritic veins.	Chlorite, quartz, biotite, opaques, mica.	Recrystallized. Finely laminated.
CF2	Buffalo River Inlier Buffelshoek traverse.	Quartzitic wacke	Equigranular, well-sorted sub-rounded quartz grains set in a dirty sericitic matrix. Matrix comprises fine-grained sericitic needles and interpenetrant recrystalized quartz grains. (matrix 60% volume).	Quartz, chert, sericite, biotite, opaques.	Recrystallized. Two generations of quartz. Well-laminated.
NTAMBO MEMBER:					
HS2	Western Hartland Basin. (Balmoral traverse)	Opaque-rich shale	Well-rounded, mature sediment comprising very fine-grained quartz and sericite ± biotite. Scattered chert grains (< 0,1 mm size). Large proportion (10%) cubic opaques.	Quartz, sericite, black opaques, biotite.	Laminated. Weakly magnetic.
SW13	Western Swaziland	Quartzitic wacke	Fine-grained equigranular unstrained quartz grains in a dirty sericitic altered matrix. Cross-cutting fine muscovite laths. Brown-tinge, late-stage, opaques.	Quartz, sericite, muscovite, opaques, epidote.	Recrystallized. Highly fractured rock. Highly altered, possibly by perculating fluids.
YUTSHINI / LANGFONTEIN FORMATION:					
FB10	Buffalo River Inlier Okhalweni Traverse.	Chloritic shale	Well-rounded, recrystallized quartz grains (unstrained), cross-cut by green pleochroic stringers of chlorite, which defines a layering.	Chlorite, quartz, sericite, opaques.	Primary textures destroyed by chloritic overgrowths.

C: NSUZE GROUP SEDIMENTS - ARGILLITES
VUTSHINI, LANGFONTEIN FORMATION:

SAMPLE	LOCALITY NO.	ROCK	TEXTURE TYPE	CONSTITUENT MINERALS (IN ORDER OF ABUNDANCE)	COMMENTS
VS4	Central Synform Nkandla District.	Ferruginous shale.	Unusual, essentially bimineralic, rock comprising fine-grained recrystalized quartz grains with a late stage opaque (magnetite) in the interstices. No sericite.	Opaque (magnetite), quartz, epidote.	Red straining (oxidation). Well-laminated.
NR5	Western Hartland Basin. Ntombe River Traverse.	Quartz Wacke	Alternating layers of thin sericite-rich zones and quartz-rich zones. Late stage opaque overgrowths. Microboundinage textures. Highly deformed. Strained quartz grains.	Quartz, sericite, opaque.	Discordant 1 mm thick quartz veinlet along fracture. Partial recrystallization.

MKUZANE FORMATION:

SAMPLE	LOCALITY NO.	ROCK	TEXTURE TYPE	CONSTITUENT MINERALS (IN ORDER OF ABUNDANCE)	COMMENTS
MW12	Magudu Area Hohobo River Traverse.	Chloritic schist	Fine-grained, sub-rounded grains of mono-and-polycrystalline quartz set in a finer quartz-rich matrix. Poikilitic crystals of chlorite, pseudomorphing primary amphibole (?) - 120 cleavage. Large % secondary muscorite in matrix.	Quartz, chlorite, muscovite, opaques.	Amphibole -> chlorite could indicate a retrogressive imprint.
MF5	Magudu Area Mfenyana R. Traverse.	Quartzitic schist	Well-sorted, fine-grained equigranular quartz grains (< 0,1 mm size) with sutured outlines, set in a finer quartz-sericite matrix.	Quartz, sericite, opaques.	Undulose larger quartz grains.
MF2	Magudu Area Mfenyana R. Traverse.	Cordierite schist	Alternating quartz-rich and mica-rich layers. Scattered < 1/2 mm long needles of high relief chloritoid. Oval "blebs" of 5 mm width of altered and pseudomorphed cordierite. Sericitic rim around "blebs".	Quartz, sericite, muscovite, chloritoid, opaques, cordierite.	Close proximity to intrusive granites. Retrograde alteration over contact hornfels imprint.
MF4	Magudu Area. Mfenyana River traverse.	Altered cordierite-andalusite schist.	As MF2, well layered with ± 5 mm size porphyroblasts of rotated, altered cordierite with pressure shadows. Sericitic rims around porphyroblasts. Chloritoid needles throughout. Highly-altered matrix, largely quartz and muscovite / sericite.	Quartz, sericite, cordierite, muscovite, chlorritoid, opaques (andalusite in hand speciman).	Rotated altered porphyroblasts - microscopic thrusting features.

C: NSUZE GROUP SEDIMENTS - CARBONATES
HOBENI MEMBER:

SAMPLE	LOCALITY NO.	ROCK	TEXTURE TYPE	CONSTITUENT MINERALS (IN ORDER OF ABUNDANCE)	COMMENTS
WM9	White Mfolozi River Inlier		Carbonate-rich and carbonate-poor zones, separated by sharp contact. Carbonate-poor zones quartz-rich with cross-cutting sericite. Carbonate - rich zone comprises mainly interlocking angular to sub-rounded carbonate grains (< 0,1 mm size).	Carbonate, (dolomite ?), quartz, sericite.	Layering defined by carbonate-rich and poor zones.
CF3	Buffalo River Inlier. Buffelshoek traverse.		Carbonate minerals have irregular outlines, partially replaced by a fine-grained carbonate cement with interstitial chert, quartz and micas. Carbonate mineral has multi-inclusion phases. Cross-cut by 4 mm wide quartzose vein. Vein unstrained.	Carbonate, quartz, micas.	Highly silicified. Stratified. Varying degrees of carbonate alteration. A silicified carbonate sand?
MAZ1	Buffalo River Inlier. Sifula traverse.		Quartz-rich and carbonate-rich layering. Quartz-rich layers < 3 mm wide, comprising mainly of unstrained, angular quartz grains (< 0,2 mm size). Minor sericite carbonate-rich layers have an outer single carbonate grain-thick rim and an inner very fine-grained portion of altered carbonate residue.	Carbonate, quartz, sericite, muscorite.	Micro-stratification. Highly silicified.
MD6	Central Syncline. Nkandla Area.		Subangular carbonate grains < 4 mm long axis. Replacement by quartz and mica. Quartz grains sub-rounded, equigranular and unstrained (secondary) matrix comprises fine-grained mosaic of recrystallized quartz and muscovite.	Carbonate, quartz, muscovite, sericite.	Recrystallization. No strained quartz grains. Altered marly-sand?
WM14	White Mfolozi River Inlier.		Equigranular, sub-rounded quartz grains in a dirty fine-grained cherty/ micaceous / carbonate matrix. Carbonate mineral highly altered. Rare sub-rounded K-feldspar fragments (~ 0,5 mm).	Quartz, carbonate, sericite, chert, K-feldspar.	Altered marly arenite?

D: DOMINION GROUP LAVAS: RENOSTERHOEK FORMATION:

SAMPLE	LOCALITY NO.	ROCK	TEXTURE TYPE	CONSTITUENT MINERALS (IN ORDER OF ABUNDANCE)	COMMENTS
DOM1	Hartbeesfontein Area.	Mafic / Intermediate lava.	Highly trachytic and saussuritized groundmass of plagioclase. (< 0,1 mm size laths). Extensive epidotization. Oval amygdales < 5 mm size, usually filled with calcite ± epidote and quartz.	Plagioclase, epidote, sericite, calcite.	Late stage calcitization.
* DOM14	Doornfontein farm. (North of Klerksdorp).	Mafic / Intermediate lava.	Sub-rounded to rounded amygdales (< 1,0 cm size) in a chloritic green felty groundmass. Amygdales filled with calcite, quartz + chlorite. Amygdales have thin quartz rims.	Plagioclase, calcite, chlorite, quartz, opaques.	Near top of Renosterhoek Formation Amygdales in hand speciman up to 20 cm size.
SYFERFONTEIN FORMATION:					
DOM5	Hartbeesfontein Area.	Feldspar porphyry.	Tabular, euhedral feldspar phenocrysts set in an altered microlitic, felty groundmass. Extensive cross-cutting replacement calcite and chlorite.	Plagioclase, calcite, chlorite, sericite, opaques, quartz.	Calcite crystals often seen as interwoven replacement clusters.
DOM7	Hartbeesfontein Area.	Mafic / Intermediate lava.	Dark green, aphanitic, felty, chloritic groundmass hosting sub-rounded amygdales (< 7 mm size) filled with calcite and quartz. Minor primary altered hornblende.	Chlorite, plagioclase, calcite, quartz, opaques, sericite, hornblende.	Interlayered with Feldspar porphyry. Cross-cutting quartz veinlets.
* DOM16	Doornfontein farm. (North of Klerksdorp).	Feldspar porphyry.	Poikilitic plagioclase phenocrysts < 5 mm size. Pilotaxitic, felty groundmass comprising largely of secondary quartz, plagioclase and chlorite.	Plagioclase, quartz, chlorite, opaques, sericite and hornblende.	Silification. Highly altered. Brown alteration-tinge.

D: DOMINION GROUP LAVAS: SYFERFONTEIN FORMATION:

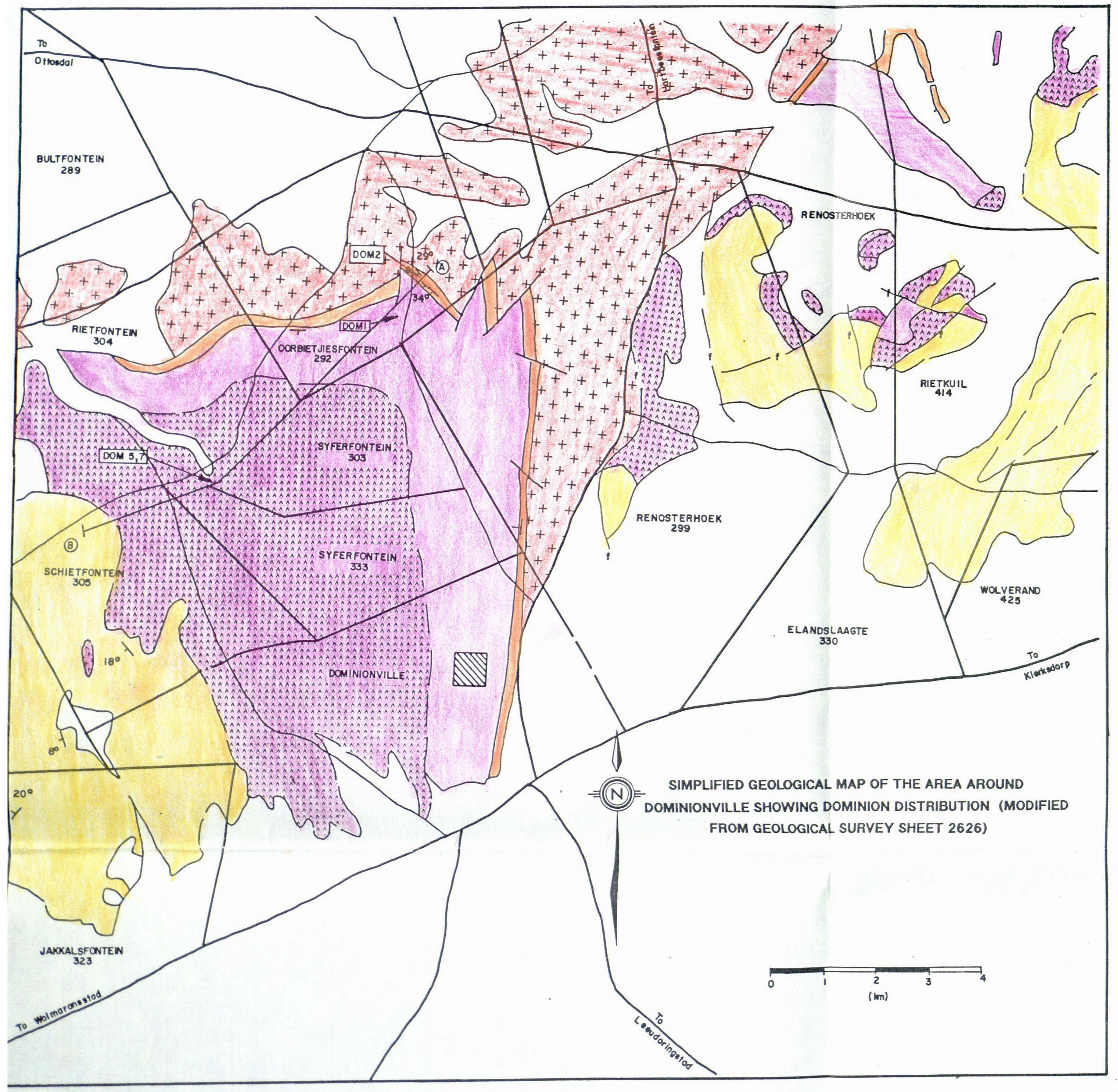
SAMPLE	LOCALITY NO.	ROCK	TEXTURE TYPE	CONSTITUENT MINERALS (IN ORDER OF ABUNDANCE)	COMMENTS
* DOM18	Doornfontein farm. (North of Klerksdorp)	Feldspar porphyry.	Euhedral, poikilitic altered plagioclase phenocrysts up to 7 mm size. Pilotaxitic groundmass, highly chloritic. Secondary carbonate in porphyries and groundmass. Highly amygdaloidal.	Plagioclase, chlorite, carbonate, quartz, sericite, opaques.	Sample taken near tectonic contact with Orange Grove Group.

E: DOMINION GROUP: OTHER:

DOM2	Hartbeesfontein Area.	Coarse-grained arenite. Renosterspruit Formation.	Typically sub-angular, highly-strained quartz grains, < 7 mm size. Matrix comprises finer equigranular quartz grains and cross-cutting small muscovitic / sericite needles. Rare, altered K-feldspar fragments. Poorly-sorted.	Quartz, sericite, muscovite, K-feldspar, opaques.	Quartz both poly- and- monocrystalline. Sampled near to granitic basement contact.
* DOM11	Ottosdal Area.	Granite Basement.	Very coarse grained granite, comprising largely of consertally intergrown K-feldspar and quartz. (< 6 mm size). Two ages of quartz. K-feldspar commonly altered to sericite and epidote.	K-feldspar, quartz, sericite, epidote, opaques.	Possible perthitic textures. Cross-hatched twinning in K-feldspar.

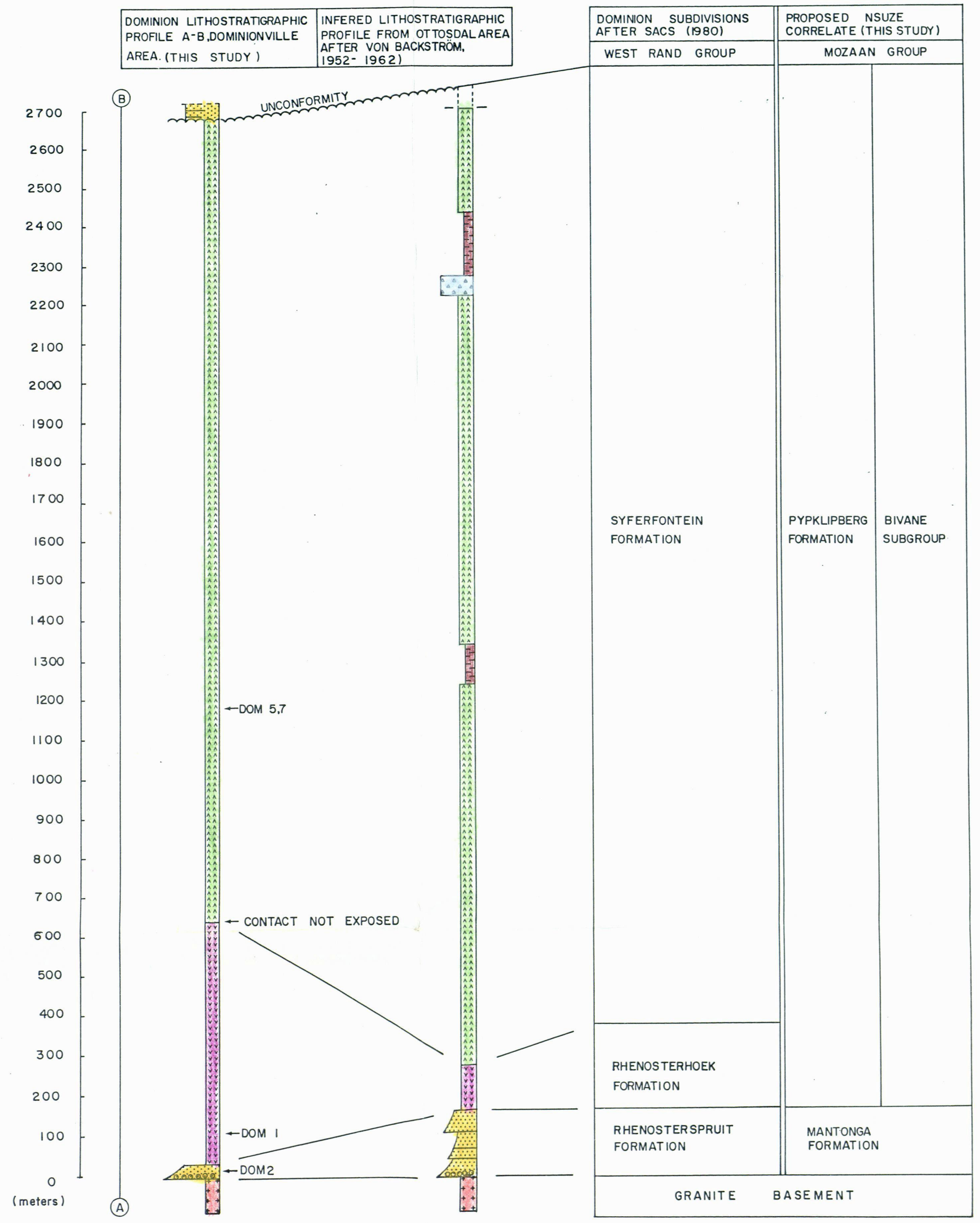
APPENDIX 3:

LARGE MAPS:



SIMPLIFIED GEOLOGICAL MAP OF THE AREA AROUND DOMINIONVILLE SHOWING DOMINION DISTRIBUTION (MODIFIED FROM GEOLOGICAL SURVEY SHEET 2626)

SIMPLIFIED DOMINION PROFILES SHOWING LITHOSTRATIGRAPHIC SUBDIVISIONS WITH PROPOSED NSUZE GROUP CORRELATES.



Map 16 a and b

LEGEND:

GEOLOGICAL MAP (GEOLOGICAL SHEET 2626).

LITHOLOGICAL:

🟨	Ferriginous shale, quartzite, ironstone	Hospital Hill Subgroup	West Rand Group
▨	Porphyritic lava, cherty lava, tuff and schist	Syferfontein Formation	Dominion Group
🟪	Grey andesitic lava, tuff	Rhenosterhoek Formation	
🟧	Quartzite, conglomerate, schist	Rhenosterspruit Formation	
🟥	Undifferentiated granite and gneiss		Basement

SYMBOLS:

37° Dip and strike of bedding

f Fault

Ⓐ—Ⓑ Plan position of lithostratigraphic profile.

← DOM3 Petrographical sample position

LITHOSTRATIGRAPHIC COLUMN:

MAJOR ROCK TYPES:

🟨 Quartzite

🟥 Shale and tuff

▨ Volcaniclastic

🟩 Felsic volcanic

🟪 Mafic volcanic

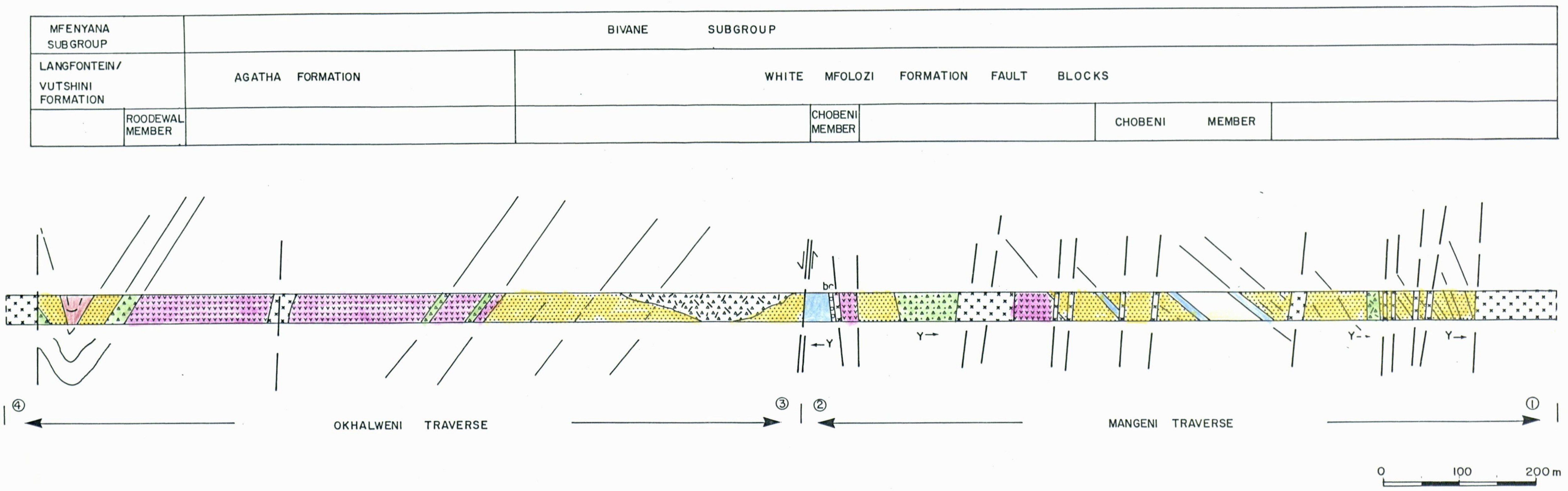
🟥 Granite

SYMBOLS:

〰 Unconformity

← DOM2 Petrographic sample location

DIAGRAMMATIC CROSS SECTION ALONG PROFILE LINES 1-2 AND 3-4 IN THE OKHALWENI AND MANGENI TRAVERSES ALONG THE BUFFALO RIVER



LEGEND

LITHOLOGICAL:

- ☐ ALLUVIUM COVER
- ⁙ DIABASE INTRUSIVE
- ⁙ DWYKA DIAMICTITES

POST - NSUZE

- ▨ QUARTZITE
- ▨ SHALE
- ▨ DIAMICTITE
- ▨ MAFIC LAVA
- ▨ CARBONATE UNIT

NSUZE GROUP LITHOLOGIES (not in stratigraphic order)

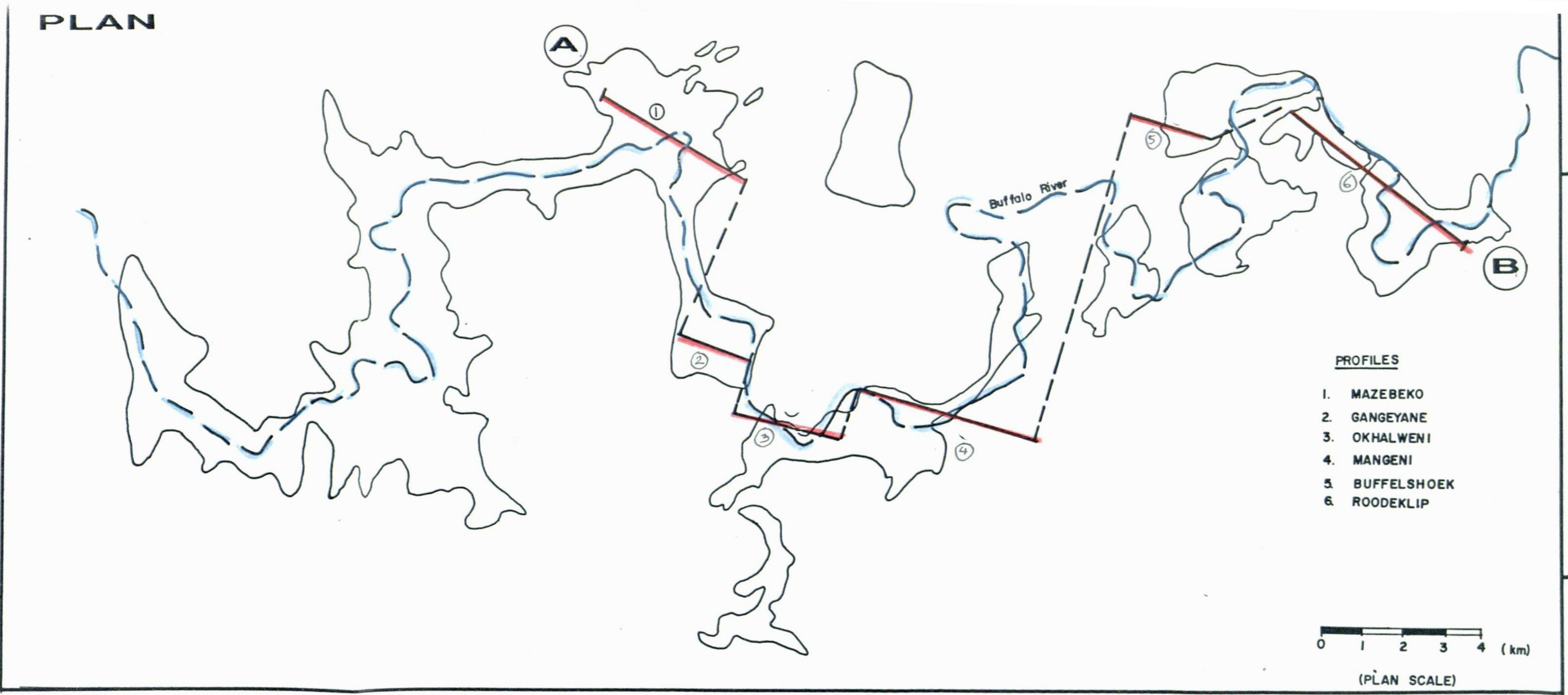
SYMBOLS:

- ⇌ FAULT WITH MOVEMENT DIRECTION
- Y→ YOUNGING DIRECTION
- ③—④ REFERENCE LITHOSTRATIGRAPHIC PROFILE LOCATION
- br BRECCIA

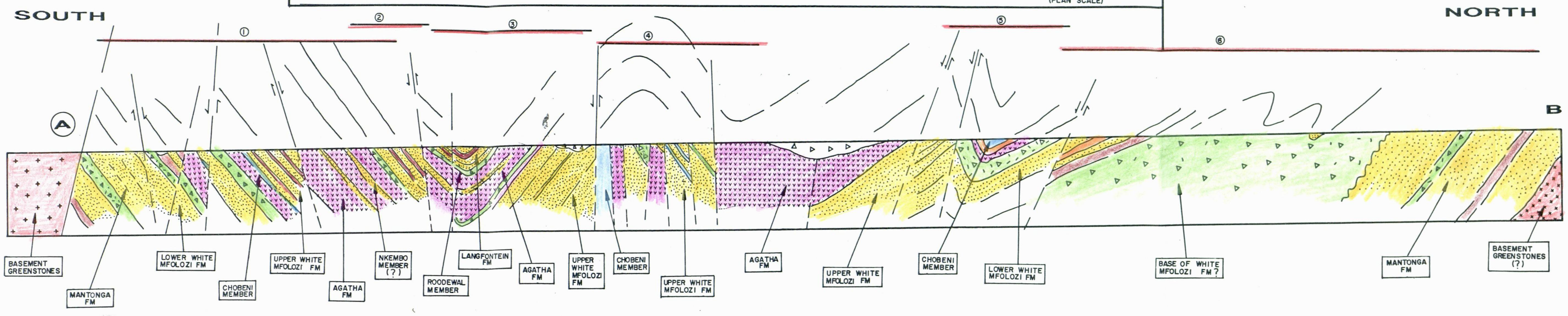
Map 14

PLAN & SECTION OF A DIAGRAMMATIC NORTH–SOUTH COMPOSITE PROFILE SHOWING THE RELATIONSHIP BETWEEN FRAGMENTED NSUZE LITHOSTRATIGRAPHIC BLOCKS & THE MAJOR STRUCTURAL ELEMENTS IN THE BUFFALO RIVER INLIER

PLAN



SECTION



LEGEND:

SECTION:

LITHOLOGY:

MAJOR ROCK TYPES:

△	Dwyka Tillite		Post–Pongola
▨	Quartzite	Nsuze Group	Pongola Supergroup
▨	Siltstone/wacke		
▨	Shale		
▨	Carbonate		
△	Diamictite		
▼	Mafic lava		
+	Greenstone	Basement	Pre–Pongola

SYMBOLS:

Fault with throw direction indicated

⑤ Reference profiles

PLAN:

SYMBOLS:

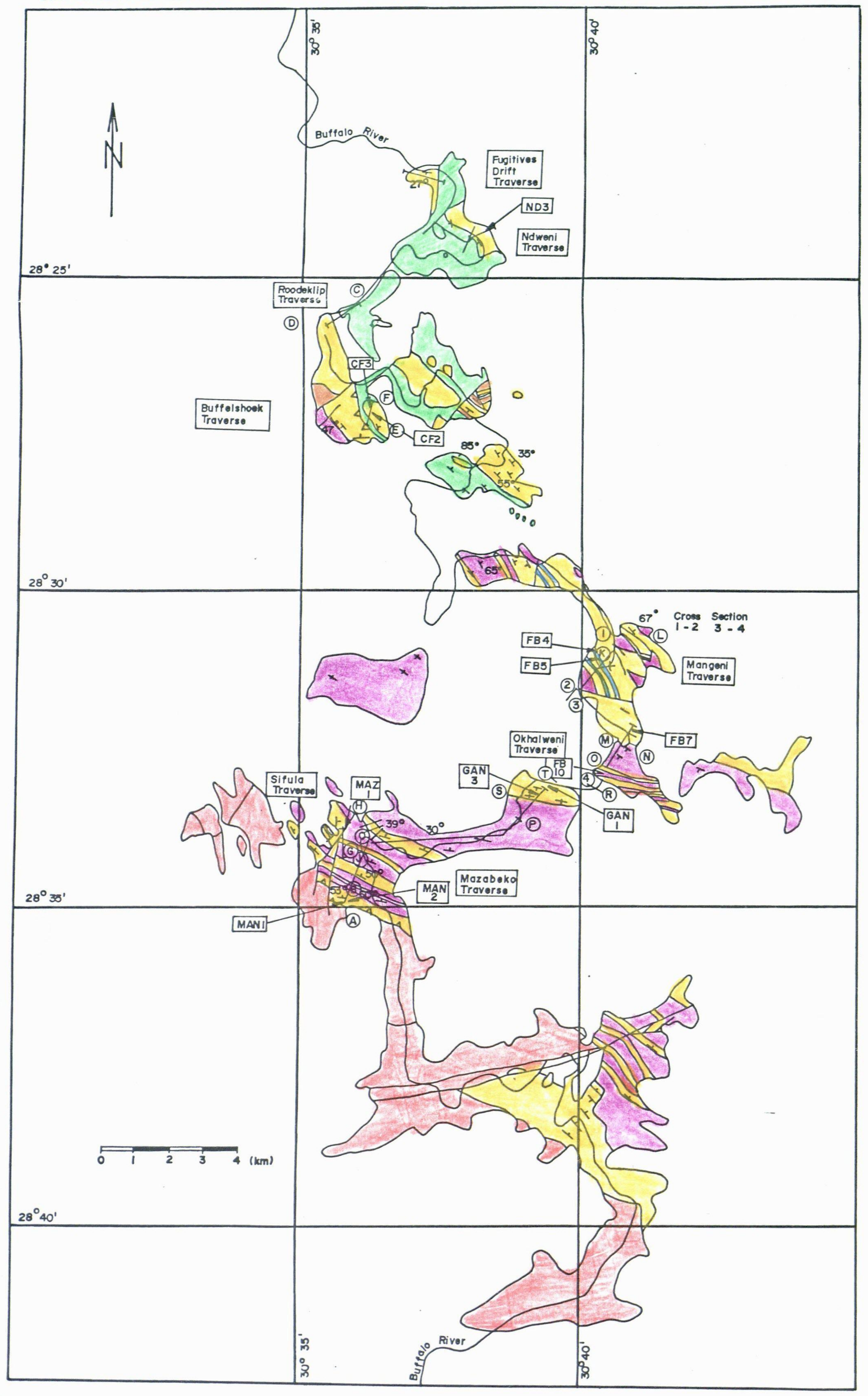
Archaean outcrop (after Dixon, 1992)

Buffalo River

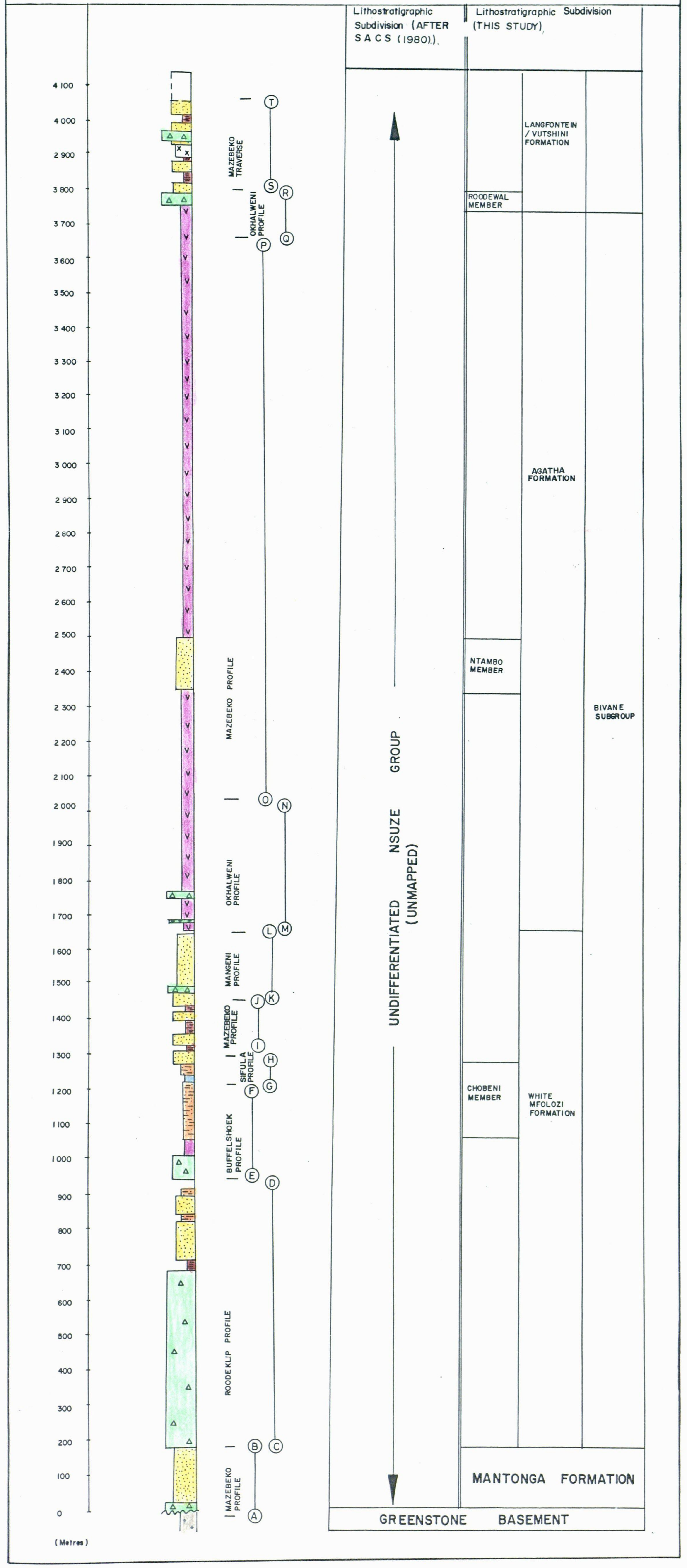
① Lithostratigraphic profile position

Map 13

SIMPLIFIED PRE-KAROO GEOLOGICAL PLAN OF THE BUFFALO RIVER INLIER (MODIFIED FROM DIXON, 1992).



NSUZE LITHOSTRATIGRAPHIC SUBDIVISION ALONG A COMPOSITE PROFILE IN THE BUFFALO RIVER GORGE.



LEGEND:

GEOLOGICAL MAP (AFTER DIXON, 1992).

☐	Karoo Cover	Post–Nsuze
🟨	Quartzite (minor siltstone and shale)	Nsuze Group
🟥	Shale (minor quartzite, siltstone)	
🟦	Carbonate (minor quartzite)	
🟩	Diamictite (volcaniclastic ?)	
🟪	Mafic volcanic (minor felsic)	
🟧	Granite/Greenstone	Pre–Nsuze

SYMBOLS:

45°	Dip and strike of bedding
/	Fault
A–B	Plan position of lithostratigraphic profile
SIFULA TRAVERSE	Lithostratigraphic profile location
①–②	Cross section position
MAN 3 →	Petrographical sample position

LITHOSTRATIGRAPHIC COLUMN:

MAJOR ROCK TYPES:

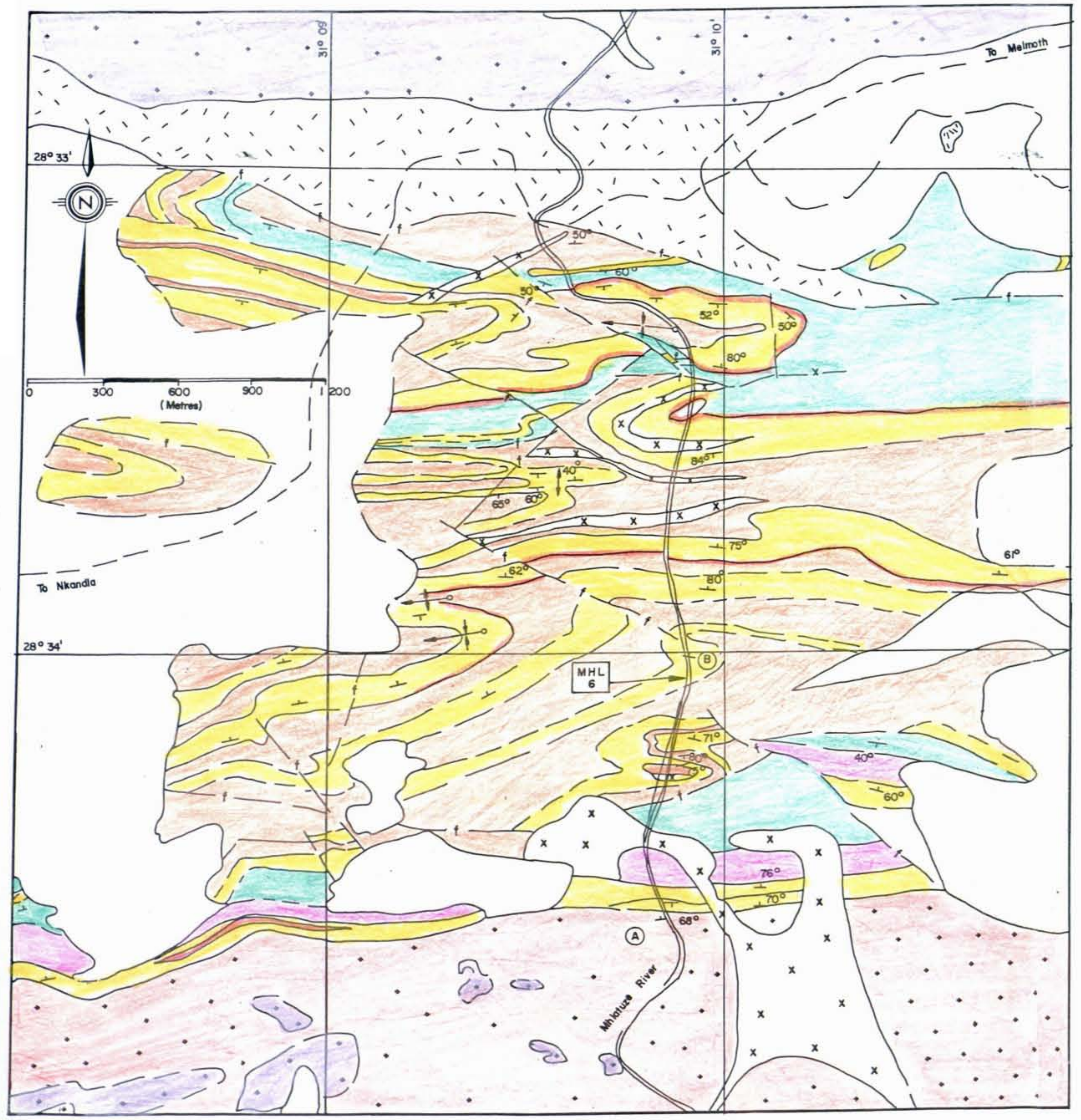
▨	Quartzite
▨	Shale
▨	Siltstone/Wacke
▨	Carbonate
▨	Diamicite
▨	Mafic volcanic
▨	Greenstone

SYMBOLS:

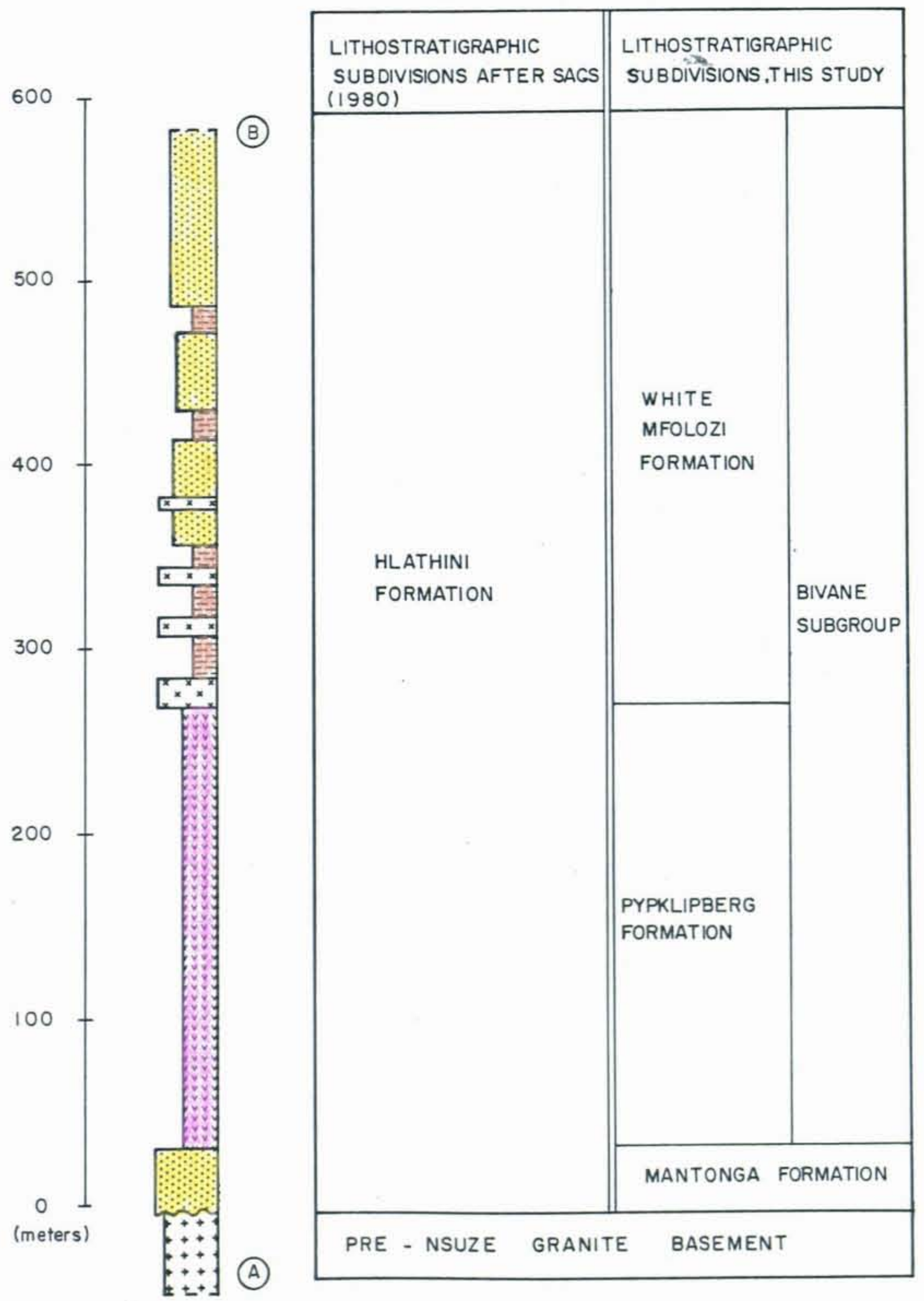
∿	Unconformity
Ⓚ–Ⓛ	Profile reference

Map 12a and b

GEOLOGICAL MAP OF A PORTION OF THE MHLATUZE RIVER INLIER IN THE CWEZI DISTRICT, NEAR NKANDLA
(MODIFIED FROM UNPUBLISHED MAP, GOLD FIELDS, 1981).



LOWER NSUZE LITHOSTRATIGRAPHIC SUBDIVISION ALONG PROFILE LINE A-B IN THE MHLATUZE RIVER INLIER NEAR NKANDLA



Map 11a and b

LEGEND:

GEOLOGICAL MAP (AFTER GOLD FIELDS, 1981).

LITHOLOGICAL:

☒	Dolerite Intrusive	Post–Nsuze
⬜	Post–Pongola Cover	
🟨	Quartzite	Nsuze Group
🟧	Shale/Phyllite	
🟦	Tuff	
🟪	Amygdaloidal lava	
⁘	Serpentinite	Pre–Nsuze
✣	Greenstone	
🟥	Granite	

SYMBOLS:

22° Bedding with dip

Fault

Plunge (anticlinal)

Plunge (synclinal)

Ⓐ Ⓑ Plan position of lithostratigraphic profile

MHL 6 Petrographical sample position

LITHOSTRATIGRAPHIC COLUMN:

MAJOR ROCK TYPES:

☒ Intrusive dolerite/diabase

🟨 Quartzite

🟧 Shale

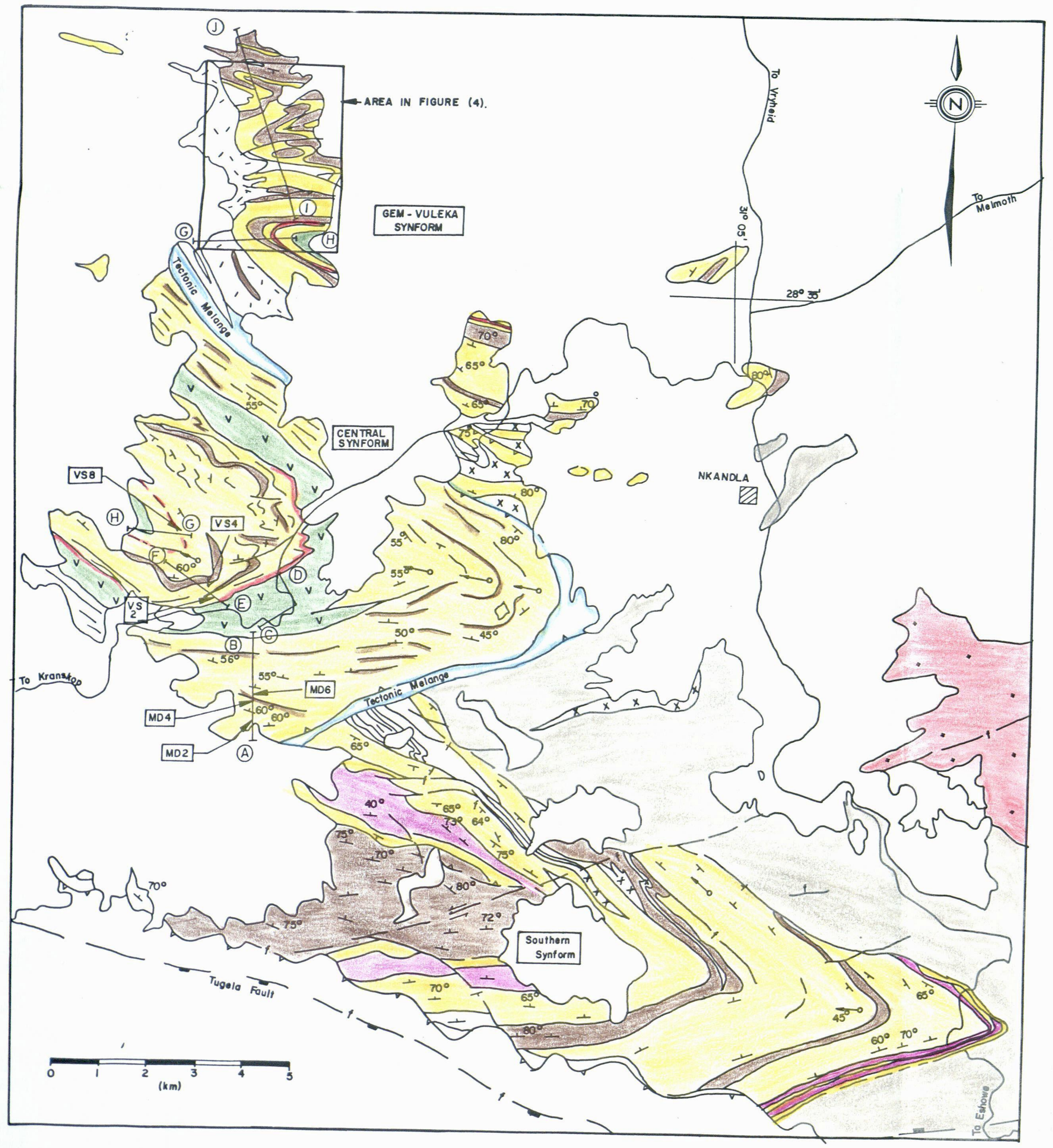
🟪 Mafic lava

🟥 Granite

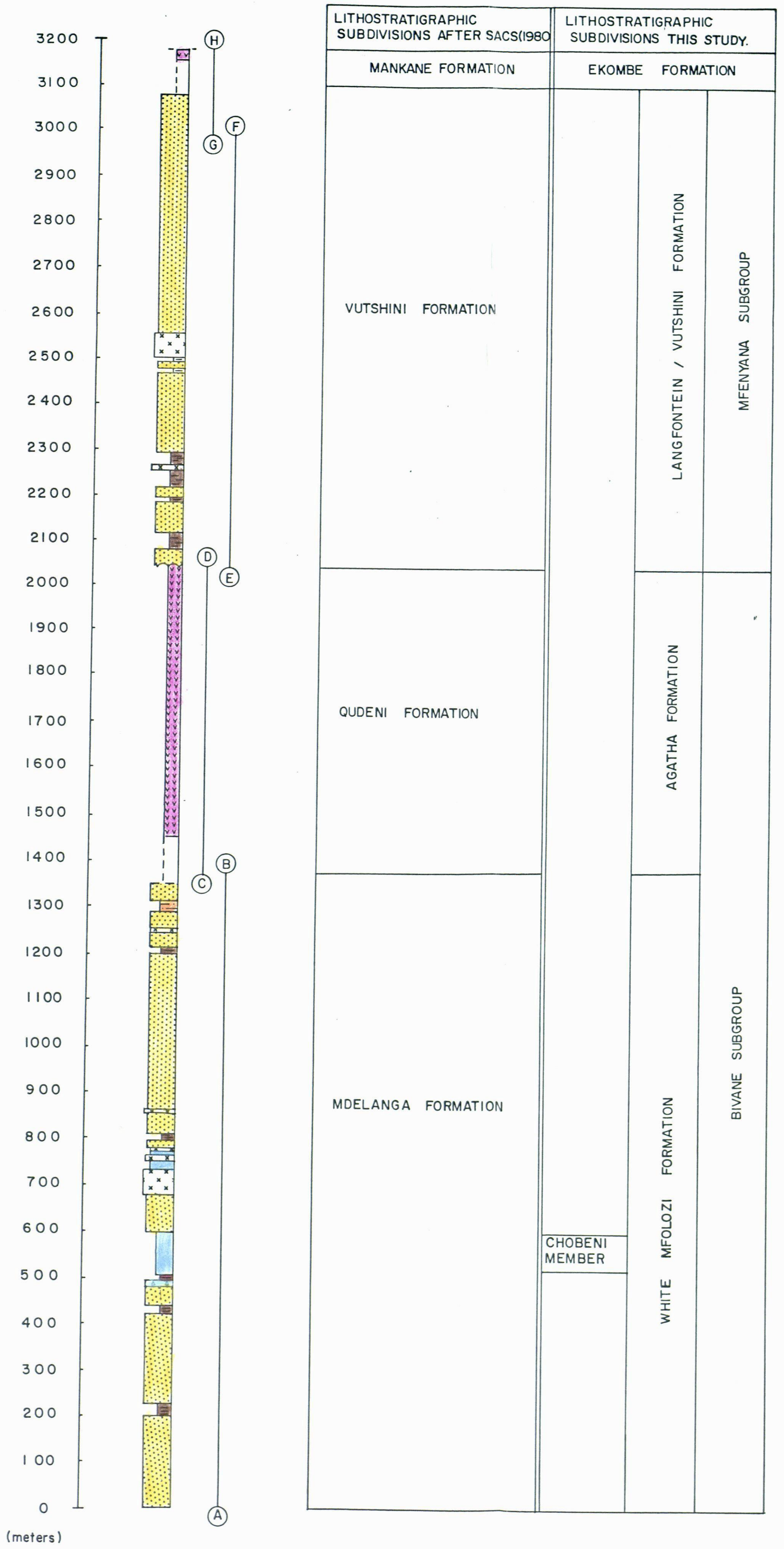
SYMBOLS:

〰 Unconformity

GEOLOGICAL MAP SHOWING ARCHAEAN GEOLOGY IN THE NKANDLA AREA. (MODIFIED FROM P.E. MATTHEWS (1959 – 1969).



NSUZE LITHOSTRATIGRAPHIC SUBDIVISIONS ALONG THE DEMARCATED COMPOSITE PROFILE LINES IN THE CENTRAL SYNFORM, NKANDLA DISTRICT



LEGEND:

GEOLOGICAL MAP (MODIFIED FROM MATTHEWS, 1959–1969).

LITHOLOGICAL:

☐	Cover		Post–Pongola
☒	Diabase intrusive		
🟨	Quartzite with subordinate conglomerate ( ).	Nsuze Group	Pongola Supergroup
🟫	Phyllites and volcanic schists		
🟩	Amygdaloidal lava (Upper unit)		
🟪	Amygaloidal lava (Lower units)		
⁙	'Volcaniclastic' diamictite		
🟥	Granite gneiss	Basement granitoid	Pre–Pongola
⬜	Phyllites, quartzites, quartz–schists banded chert, conglomerates	Greenstone	

SYMBOLS:

⊥ 45°	Dip and strike of bedding
— f —	Major fault (tick on downthrowside)
▲ f ▲	Thrust (tick on upper plate)
○→	Plunge of fold axis
//	Major tectonic zone
Ⓒ——Ⓓ	Plan position of lithostratigraphic profi (this study)
← MD4	Petrographical sample position

LITHOSTRATIGRAPHIC COLUMN: MAJOR ROCK TYPES:

☒	Diabase intrusive
🟨	Quartzite
🟫	Shales/Phyllite
🟧	Siltstone/Wacke
🟦	Carbonate
△	Diamictite
🟪	Mafic Lava

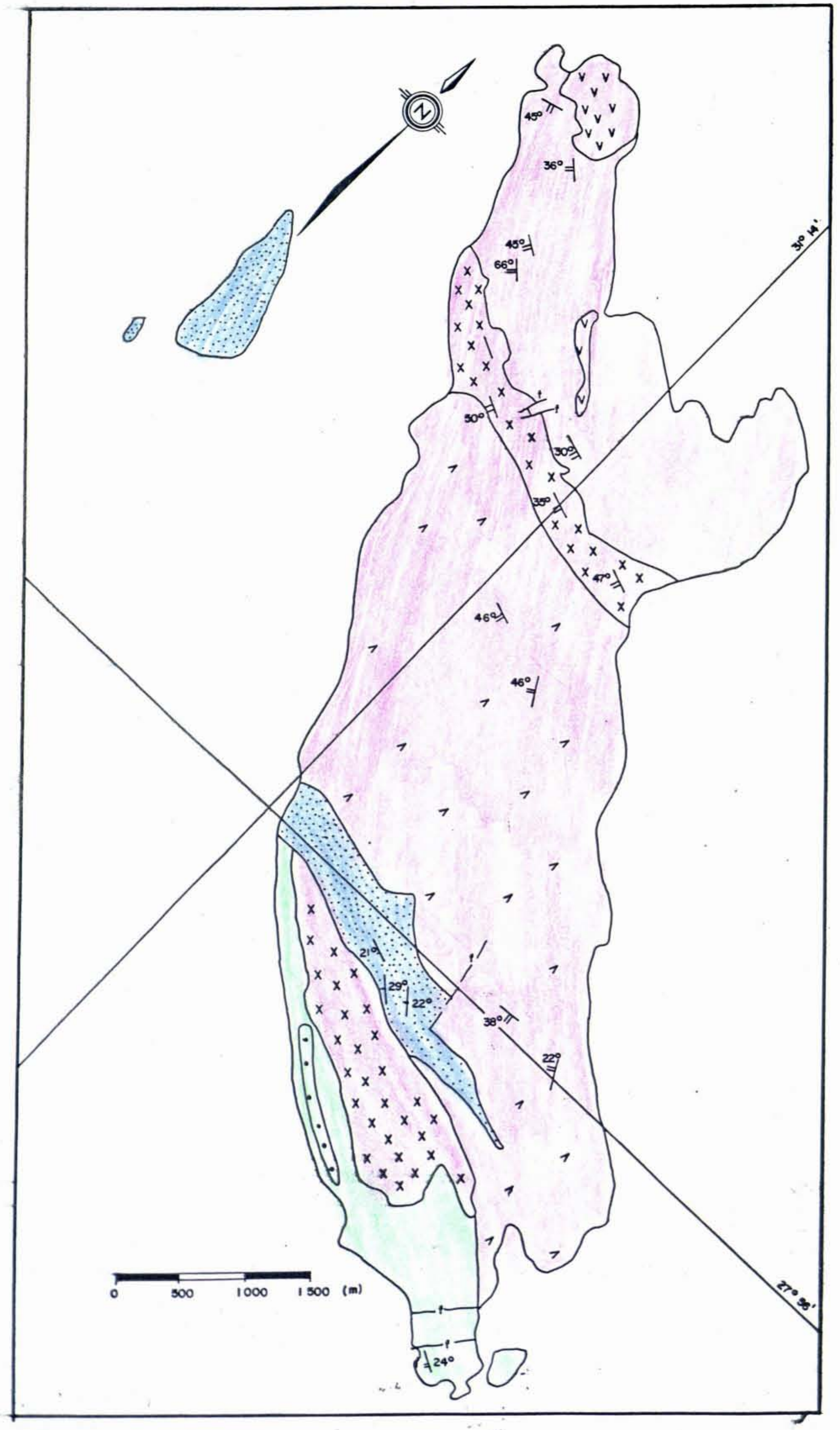
SYMBOLS:

Ⓑ	Lithostratigraphic profile reference point

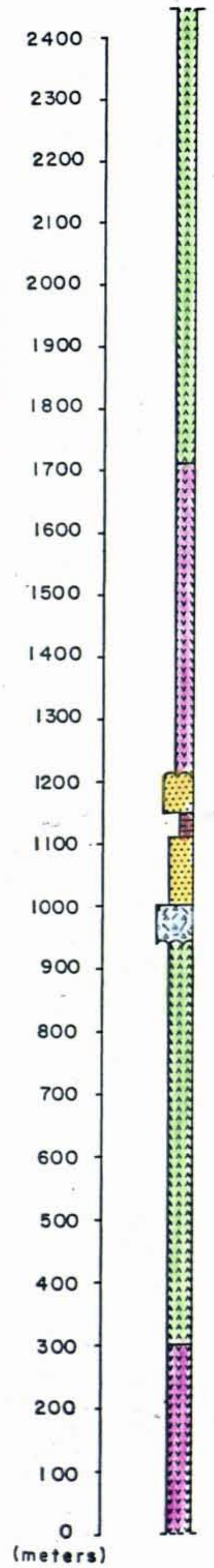
Map 10a and b

SIMPLIFIED GEOLOGICAL MAP OF THE NSUZE GROUP IN THE MPONGOZA INLIER.

(MODIFIED FROM PRESTON, 1987, IN HUNTER & WILSON, 1988).



NSUZE LITHOSTRATIGRAPHIC SUBDIVISION IN THE MPONGOZA INLIER (PROFILE MODIFIED FROM PRESTON, 1987)



LITHOSTRATIGRAPHIC SUBDIVISION, AFTER PRESTON, 1987	LITHOSTRATIGRAPHIC SUBDIVISION, THIS STUDY	
UPPER VOLCANIC UNIT	AGATHA FORMATION	BIVANE SUBGROUP
SEDIMENTARY UNIT	WHITE MFOLOZI FORMATION	
LOWER VOLCANIC UNIT	PYPKLIPBERG FORMATION	

LEGEND:

GEOLOGICAL MAP (After PRESTON, 1987)

LITHOLOGICAL:

🟩	DACITIC BLOCK AND ASH DEPOSIT	UPPER VOLCANIC UNIT	NSUZE GROUP
🟩	LITHOPHYSAE-POOR IGNIMBRITE		
🟦	CLASTIC SEDIMENTS	SEDIMENTARY UNIT	
🟪	LITHOPHYSAE-RICH IGNIMBRITE	LOWER VOLCANIC UNIT	
🟪	MAFIC LAVA		
🟪	LITHOPHYSAE-POOR IGNIMBRITE		
🟪	MAFIC LAVA		

SYMBOLS

21°	STRIKE AND DIP OF BEDDING
42°	STRIKE AND DIP OF FOLIATION
F	FAULT

LITHOSTRATIGRAPHIC COLUMN

MAJOR ROCK TYPE:

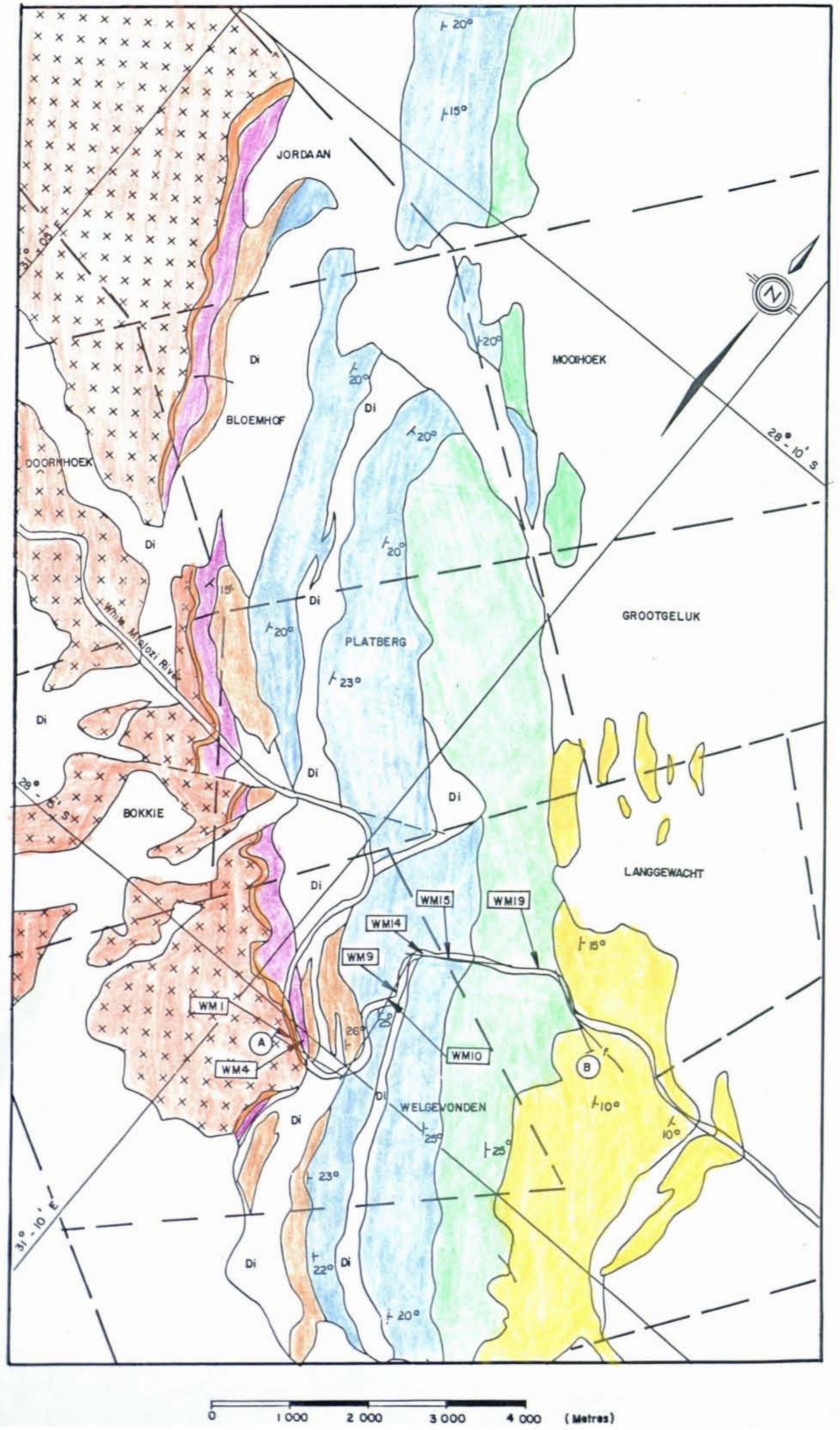
🟥	SHALE
🟨	QUARTZITE
▨	BLOCK AND ASH DEPOSIT
🟩	FELSIC VOLCANICLASTICS
🟪	MAFIC LAVAS

SYMBOLS:

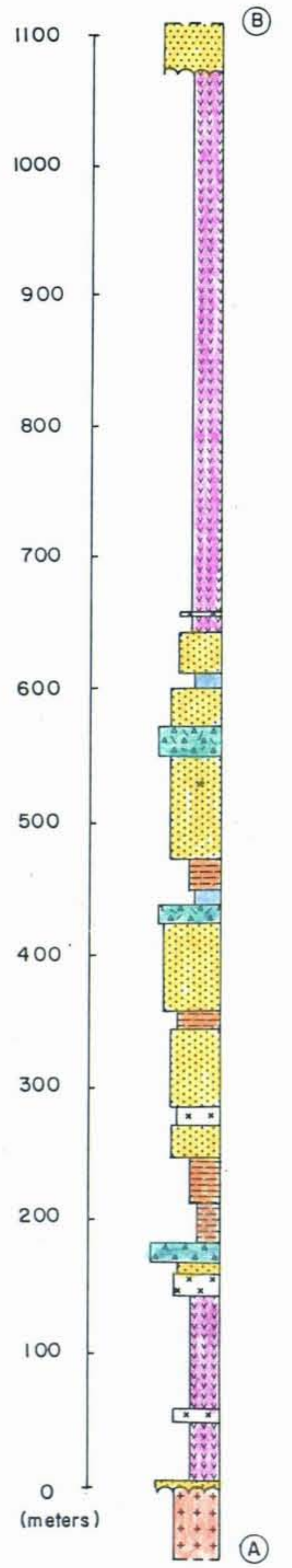
〰 UNCONFORMITY

Map 9a & b

GEOLOGICAL MAP OF THE CENTRAL PART OF THE WHITE MFOLOZI INLIER, (MODIFIED FROM MATTHEWS, 1967)



NSUZE LITHOSTRATIGRAPHIC SUBDIVISION ALONG PROFILE LINE A-B IN THE WHITE MFOLOZI RIVER INLIER.



<table>
<tr><th>LITHOSTRATIGRAPHIC SUBDIVISIONS AFTER MATTHEWS,1967 & SACS,1980</th><th colspan="3">LITHOSTRATIGRAPHIC SUBDIVISIONS, THIS STUDY</th></tr>
<tr><td colspan="4">MOZAAN GROUP</td></tr>
<tr><td>BIVANE FORMATION</td><td colspan="2">AGATHA FORMATION</td><td rowspan="5">BIVANE SUB-GROUP</td></tr>
<tr><td rowspan="3">CHOBENI FORMATION</td><td></td><td rowspan="4">WHITE MFOLOZI FM</td></tr>
<tr><td>CHOBENI MEMBER</td></tr>
<tr><td rowspan="2"></td></tr>
<tr><td>THEMBENI FORMATION</td></tr>
<tr><td>NHLEBELA FORMATION</td><td colspan="3">PYPKLIPBERG FORMATION</td></tr>
<tr><td>BOMVU FORMATION</td><td colspan="3">MANTONGA FORMATION</td></tr>
<tr><td colspan="4">PRE – NSUZE GROUP GRANITES</td></tr>
</table>

LEGEND:

GEOLOGICAL MAP (After MATTHEWS, 1967)

LITHOLOGICAL:

Di	DIABASE		POST- PONGOLA
☐	KAROO COVER		
🟨		MOZAAN GROUP	PONGOLA SUPERGROUP
〰	UNCONFORMITY		
🟩	UPPER VOLCANIC ZONE	NSUZE GROUP	
🟦	QUARTZITE- DOLOMITE ZONE		
🟧	BANDED SHALE ZONE		
🟪	LOWER VOLCANIC ZONE		
🟧	BASAL QUARTZITE UNCONFORMITY		
🟥	GRANITE GNEISS	BASEMENT	PRE - PONGOLA

SYMBOLS:

42	BEDDING WITH DIP
F	FAULT
- -	FARM BOUNDARY
Ⓐ Ⓑ	PLAN POSITION OF LITHOSTRATIGRAPHIC PROFILE (THIS STUDY)
WM4	PETROGRAPHIC SAMPLE POSITION

LITHOSTRATIGRAPHIC COLUMN MAJOR ROCK TYPE:

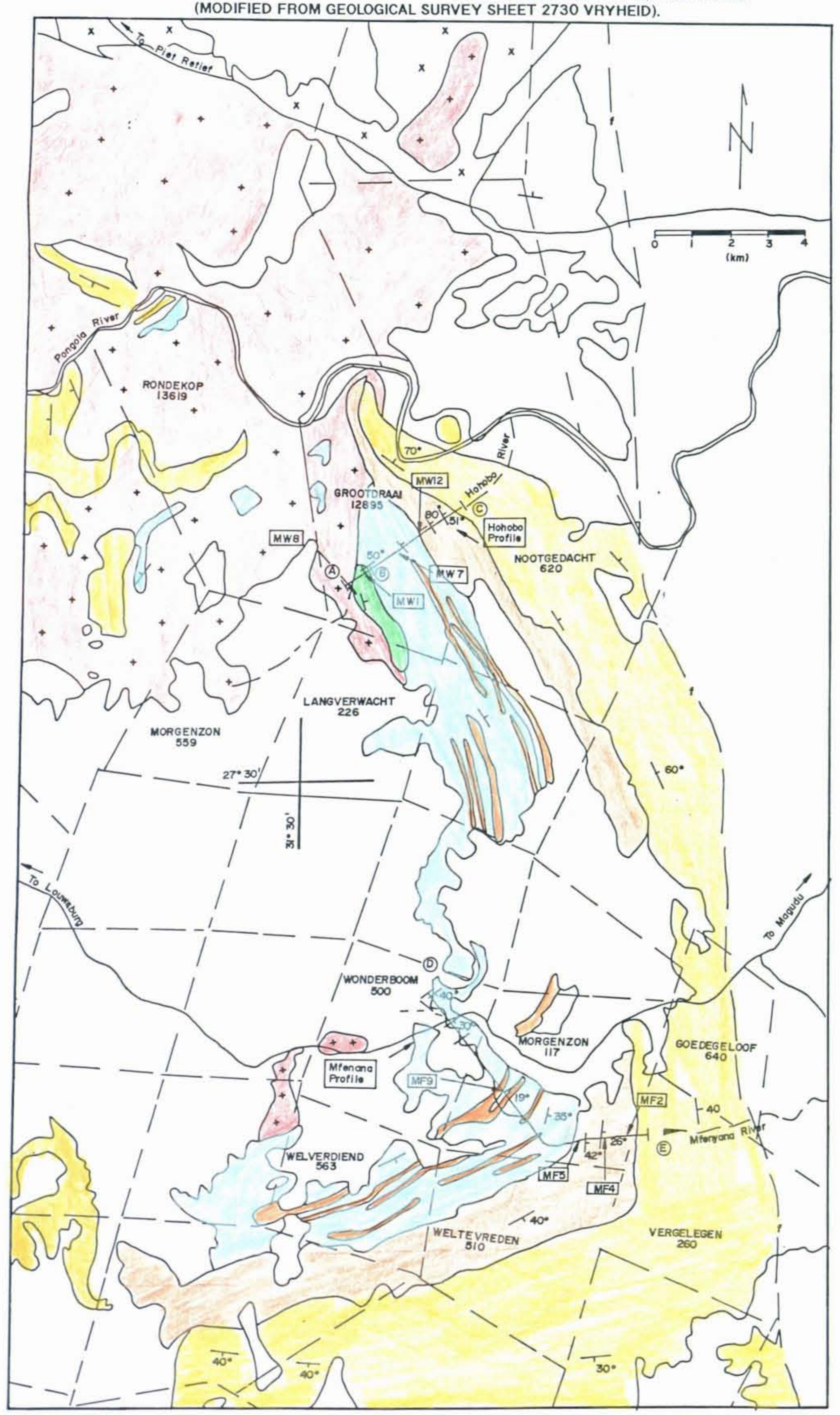
🟨	QUARTZITE
🟪	MAFIC LAVA
🟦	DOLOMITE
🟧	SILSTONE / WACKE
🟧	SHALE
▨	DIAMICTITE
☐	INTRUSIVE DOLERITE
🟥	GRANITE

SYMBOLS:

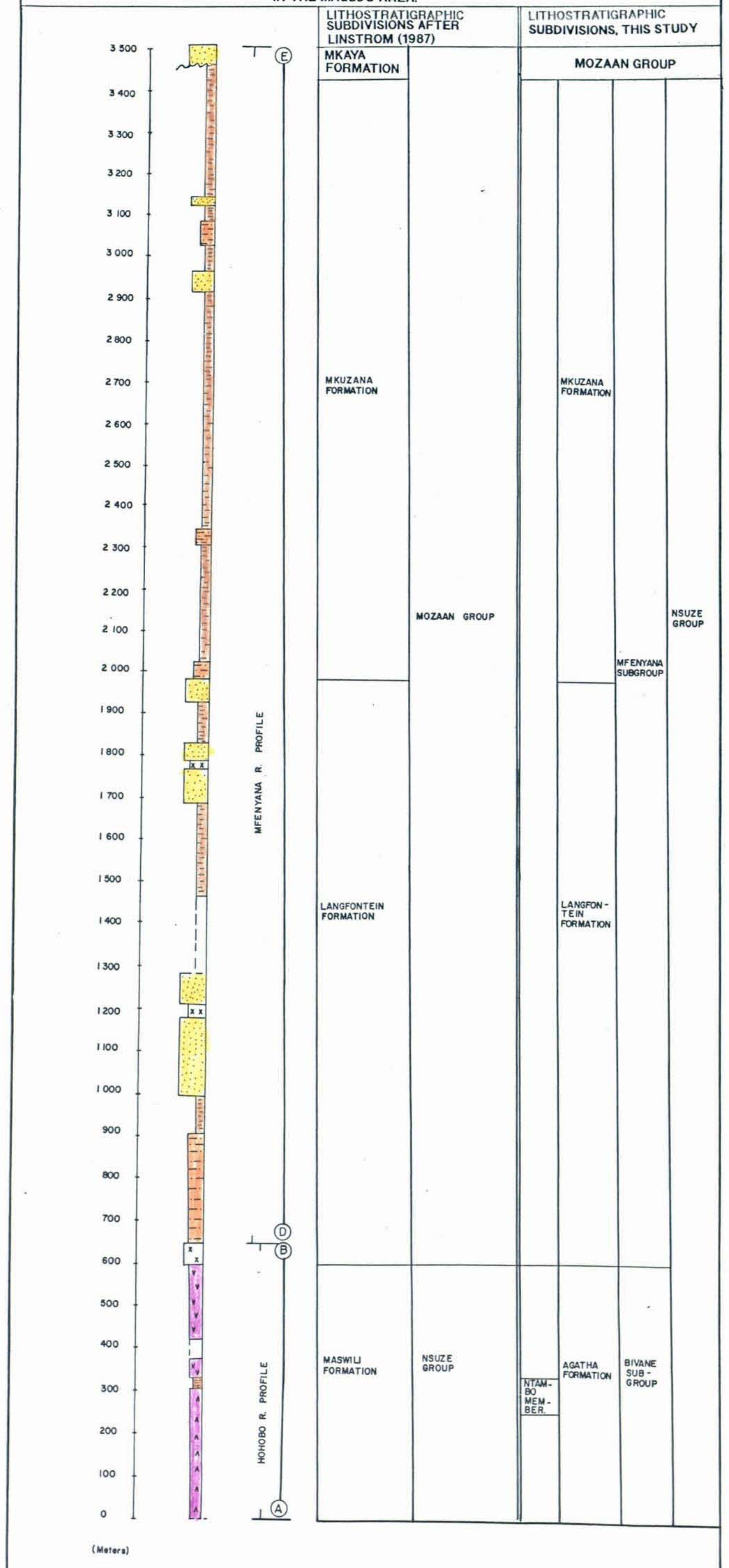
〰	UNCONFORMITY

Map 8a and b

SIMPLIFIED GEOLOGICAL MAP OF PRE-KAROO LITHOLOGIES IN THE MAGUDU AREA
(MODIFIED FROM GEOLOGICAL SURVEY SHEET 2730 VRYHEID).



NSUZE LITHOSTRATIGRAPHIC SUBDIVISION ALONG THE DEMARCATED COMPOSITE PROFILE, IN THE MAGUDU AREA.



Map 7a and 7b

LEGEND:

GEOLOGICAL MAP: (MODIFIED FROM GEOLOGICAL SHEET 2730).

LITHOLOGICAL:

☐	Karoo Cover			Post–Pongola
☒	Diabasic Intrusions			
⊞	Medium grained granite			
🟨	Quartzite, iron-rich shale, thin pelitic schist layers	Mkaya Formation	Mozaan Group	Pongola Super Group
🟧	Cordierite hornfels, minor andalusite schist, quartzite-sericite schist and quartzite	Mkuzane Formation	Nsuze Group	
🟦	Andalusite schist, quartz-sericite schist, amphibolite and quartzite (▬).	Langfontein Formation		
☐	Intermediate to acid tuff	Maswili Formation (Agatha Formation)		

SYMBOLS:

45° Dip and strike of bedding

Ⓐ——Ⓑ Plan position of lithostratigraphic profile (this study)

f Fault

Road (major)

MW8 ⟶ Petrographical sample position

LITHOSTRATIGRAPHIC COLUMN:

MAJOR ROCK TYPES:

☒	Diabase intrusive
🟨	Quartzite
▤	Shale/schist
🟧	Siltstone/wacke/schist
🟪	Mafic lava
🟪	Felsic lava

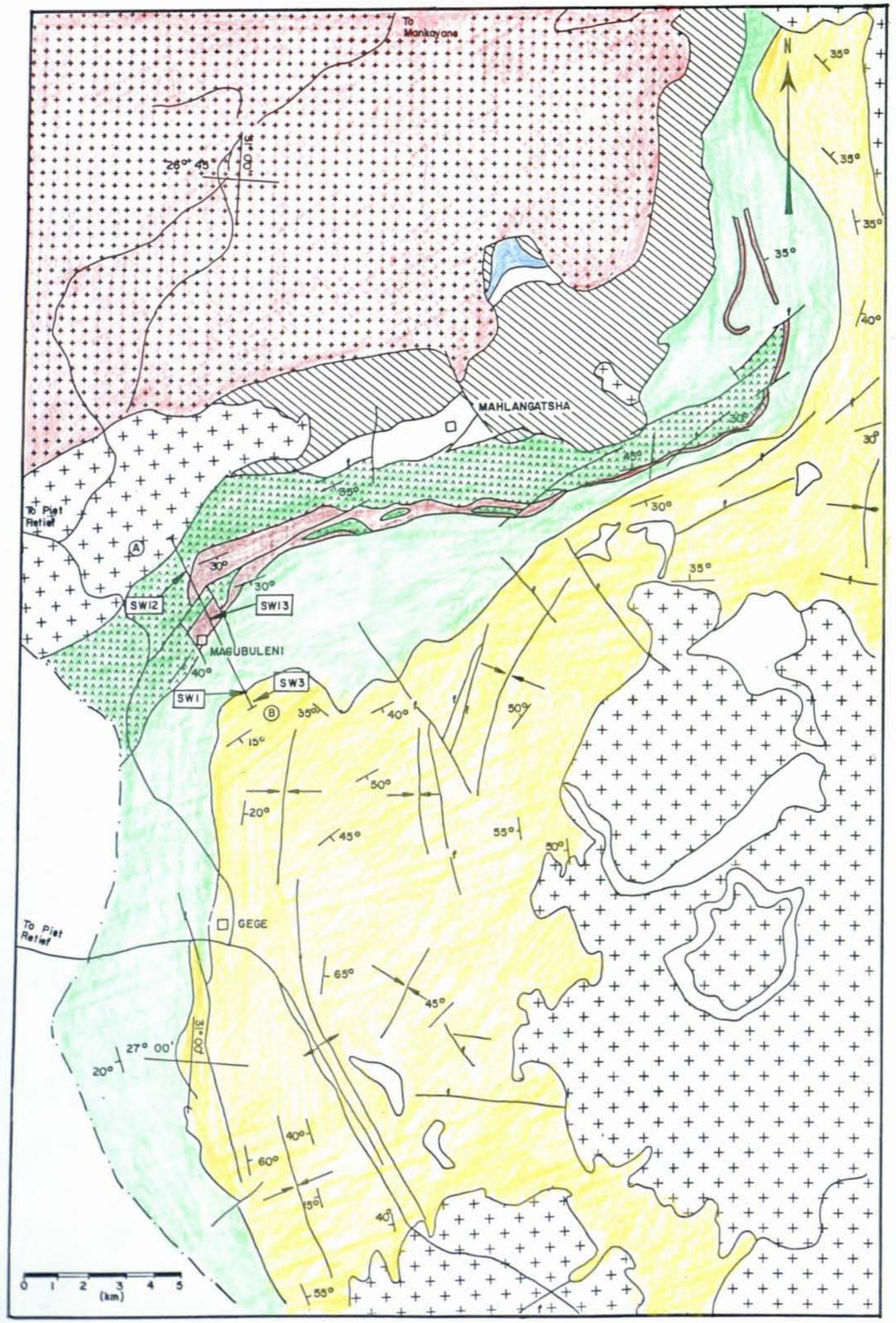
SYMBOLS:

∿ Unconformity

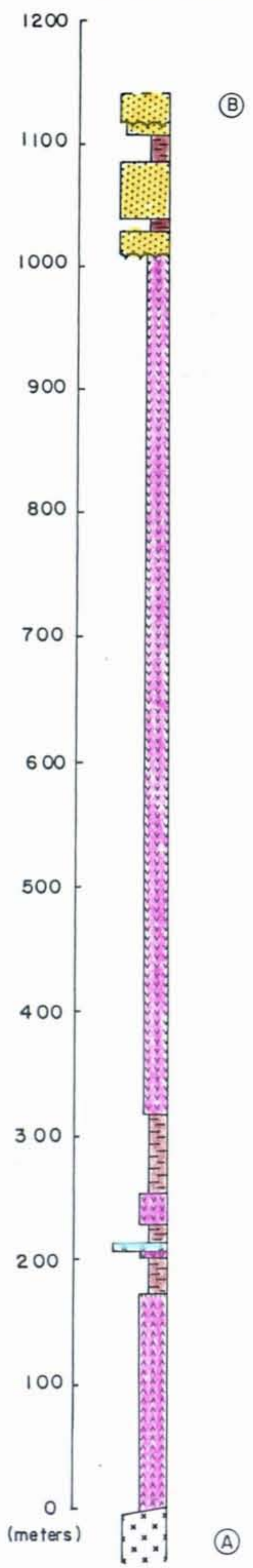
Ⓒ——Ⓓ Lithostratigraphic profile reference

SIMPLIFIED GEOLOGICAL MAP OF THE SOUTHWESTERN SWAZILAND REGION AROUND GEGE & MAHLANGATSHA

(MODIFIED FROM SWAZILAND 1:250 000 GEOLOGICAL SHEET)



NSUZE LITHOSTRATIGRAPHIC SUBDIVISION ALONG PROFILE LINE A-B, IN THE GEGE/MAHLANGATSHA AREA, SOUTHWESTERN. SWAZILAND



LITHOSTRATIGRAPHIC SUBDIVISIONS AFTER SWAZILAND GEOLOGICAL SURVEY AND MINES DEPT (1961 - 1991)	LITHOSTRATIGRAPHIC SUBDIVISIONS THIS STUDY.		
	MOZAAN GROUP		
UNDIFFERENTIATED MOZAAN GROUP	LANGFONTEIN FORMATION		MFENYANA SUBGROUP.
UNDIFFERENTIATED NSUZE GROUP	NTAMBO MEMBER	AGATHA FORMATION	BIVANE SUBGROUP
INTRUSIVE POST - NSUZE GRANITE	USUSHWANA INTRUSIVE COMPLEX		

LEGEND

GEOLOGICAL MAP (FROM SWAZILAND 1:250 000 GEOLOGICAL SHEET)

LITHOLOGICAL :

☐	KAROO COVER		POST-PONGOLA
⊞	POST-PONGOLA GRANITE		
▨	MICROGRANITE, GRANOPHYRE, GABBROS	USUSHWANA COMPLEX	
🟨	QUARTZITES, CONGLOMERATES, SHALES SCHISTS AND IRONSTONES	MOZAAN GROUP	PONGOLA SUPERGROUP
🟩	ANDESITIC LAVA UNDIFFERENTATED INTERMEDIATE LAVAS AND TUFFS	NSUZE GROUP	
🟩	FELSITIC LAVA		
🟦	QUARTZITES AND PHYLLITES		
🟥	PHYLLITE, PYROPHYLLITIC SCHIST		
🟥	TONALITIC GNEISS, SUBORDINATE AMPHIBOLITES		PRE - PONGOLA

SYMBOLS

- ⟋ 50° DIP AND STRIKE OF BEDDING
- — f — FAULT
- ┼ SYNCLINAL AXIS
- ┼ ANTICLINAL AXIS
- Ⓐ——Ⓑ PLAN POSITION OF LITHOSTRATIGRAPHIC PROFILE (THIS STUDY)
- —— ROAD
- —·—·— INTERNATIONAL BORDER
- SW 12 → PETROGRAPHICAL SAMPLE POSITION

LITHOSTRATIGRAPHIC COLUMN MAJOR ROCK TYPE

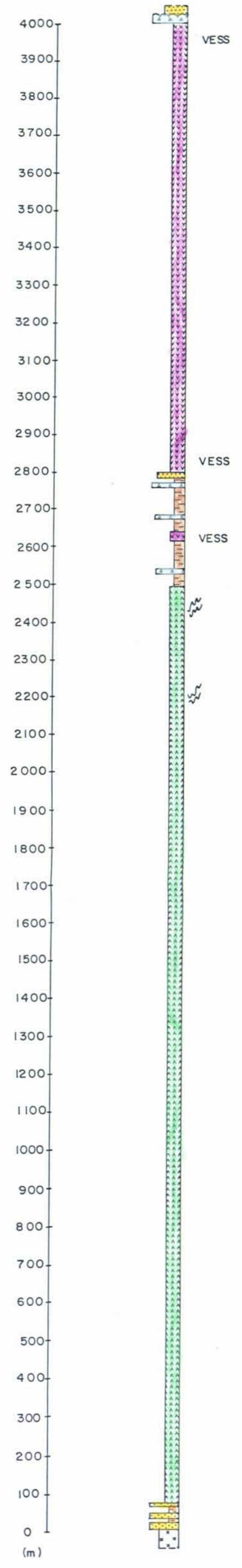
- ☐ MAFIC INTRUSIVE
- 🟨 QUARTZITE
- 🟥 SHALE
- 🟦 AGGLOMERATIC DIAMICTITE
- 🟪 MAFIC LAVA
- 🟪 FELSIC LAVA

SYMBOLS

- 〰 UNCONFORMITY
- Ⓐ LITHOSTRATIGRAPHIC PROFILE REFERENCE POINT

Map 6a and b

NSUZE LITHOSTRATIGRAPHIC SUBDIVISION FOR A PROFILE DESCRIBED BY HATFIELD (1990) EAST OF PIET RETIEF



LITHOSTRATIGRAPHIC SUBDIVISIONS AFTER HATFIELD, 1990	LITHOSTRATIGRAPHIC SUBDIVISIONS THIS STUDY		
MOZAAN GROUP		LANGFONTEIN FORMATION	MFENYANA SUB GROUP
INTERMEDIATE VOLCANIC UNIT (BIVANE FORMATION)	ROODEWAL MEMBER	AGATHA FORMATION	BIVANE SUBGROUP
PYROCLASTIC VOLCANO-SEDIMENTARY UNIT (BIVANE FORMATION)	NTAMBO MEMBER		
FELSIC VOLCANIC UNIT (BIVANE FORMATION)			
BASAL SEDIMENTARY UNIT (MANTONGA FORMATION)	WHITE MFOLOZI FORMATION		
USUSHWANA INTRUSIVE COMPLEX			

LEGEND

LITHOLOGICAL

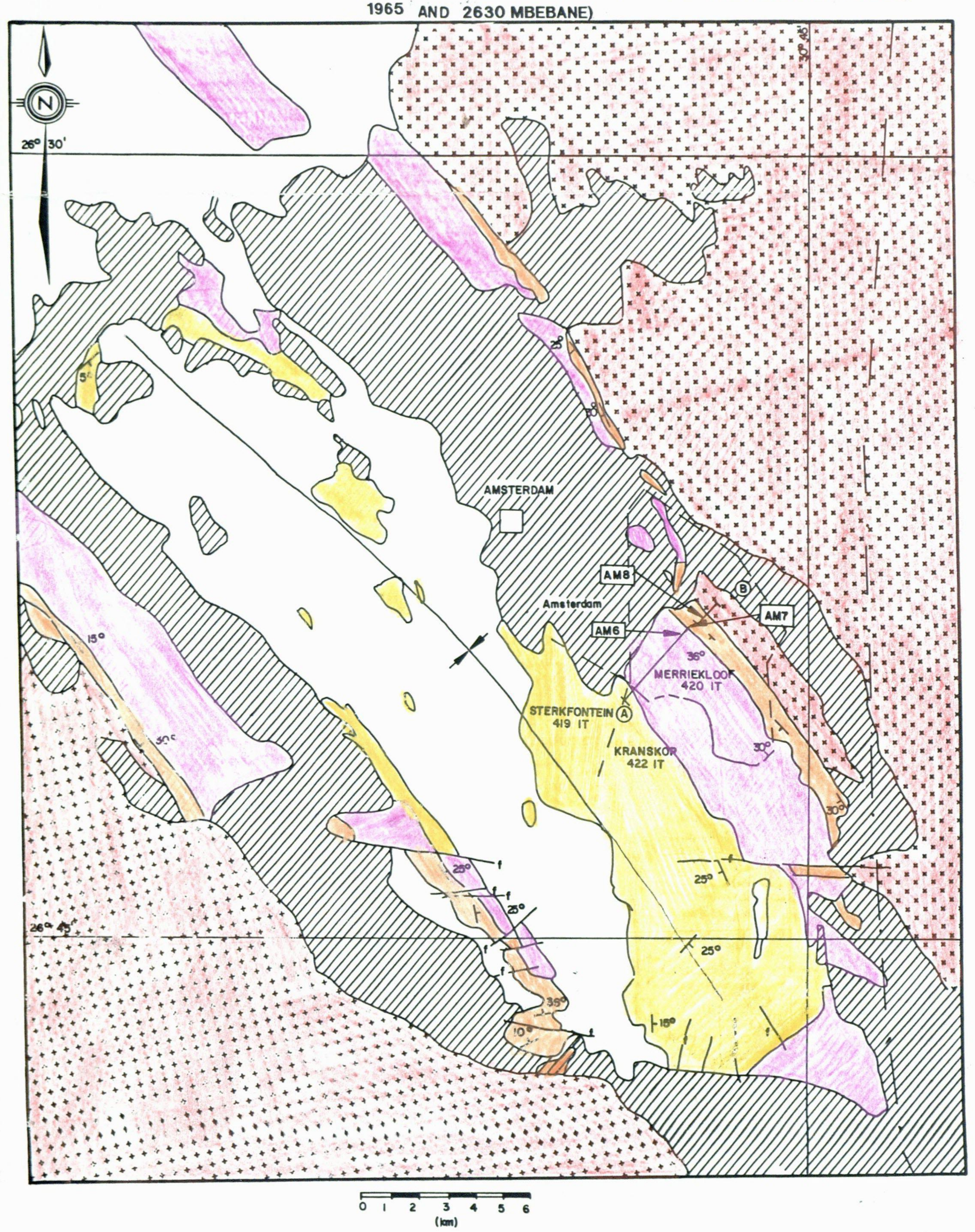
⬜	GRANOPHYRIC GRANITE AND MICROGRANITE
🟨	QUARTZ WACKES (MINOR ARGILLITES)
🟫	ARGILLITE, TUFFS, MINOR QUARTZ WACKES
🟦	AGGLOMERATE
🟪	INTERMEDIATE AND SUBORDINATE MAFIC VOLCANICS
🟩	FELSIC VOLCANIC, MINOR TUFFS AND QUARTZ WACKES

SYMBOLS

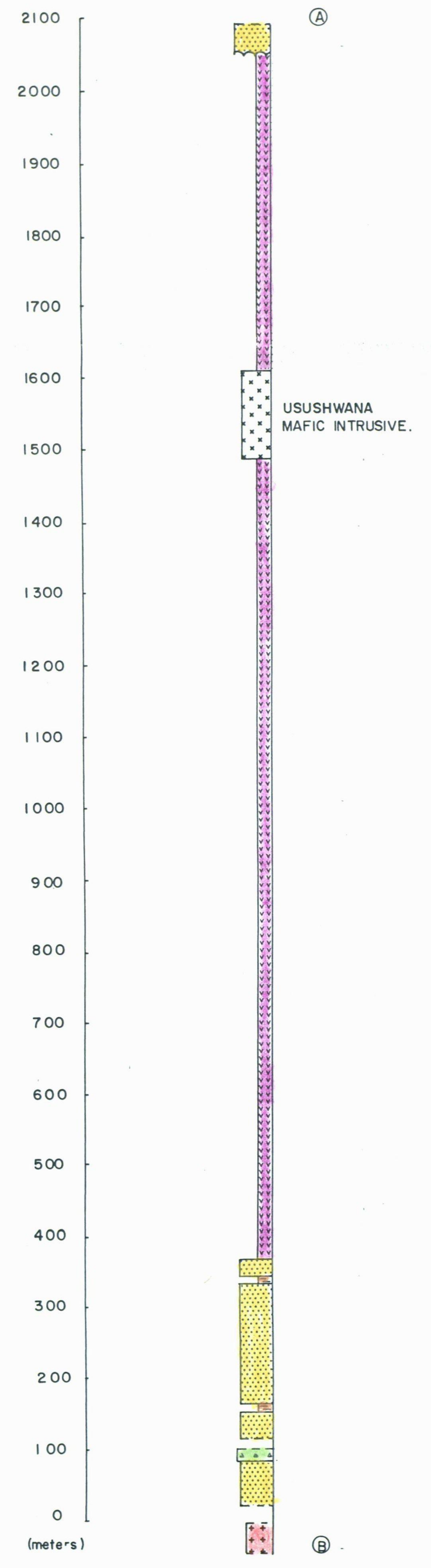
〰	UNCONFORMITY
VESS	VESSICLES AND AMYGDALES
⌇	FLOW BANDING

Map 5

GEOLOGICAL MAP OF THE ARCHAEAN TERRANE SURROUNDING AMSTERDAM (MODIFIED FROM VAN VUUREN, 1965 AND 2630 MBEBANE)



NSUZE LITHOSTRATIGRAPHIC SUBDIVISION ALONG PROFILE LINE A–B IN THE AMSTERDAM AREA



LITHOSTRATIGRAPHIC SUBDIVISION AFTER SACS, 1980	LITHOSTRATIGRAPHIC SUBDIVISION THIS STUDY	
MOZAAN GROUP		
BIVANE FORMATION	PYPKLIPBERG FORMATION	BIVANE SUBGROUP
MANTONGA FORMATION	MANTONGA FORMATION	
PRE-NSUZE GRANITE BASEMENT		

LEGEND

GEOLOGICAL MAP (AFTER VAN VUUREN, 1965)

LITHOLOGICAL:

☐	KAROO COVER		POST-PONGOLA
▨	USUSHWANA INTRUSIVE COMPLEX		
🟨	QUARTZITE, CONGLOMERATE AND SHALE	MOZAAN GROUP	PONGOLA SUPERGROUP
🟪	ANDESITIC LAVA	NSUZE GROUP	
🟧	QUARTZITE, CONGLOMERATE AND SHALE		
🟥	MEDIUM-GRAINED GRANITE	BASEMENT	PRE-PONGOLA

SYMBOLS

↗20°	BEDDING WITH DIP
F —	FAULT
Ⓐ—Ⓑ	PLAN POSITION OF LITHOSTRATIGRAPHIC PROFILE (THIS STUDY)
—·—	INTERNATIONAL BOUNDARY
AM6 →	PETROGRAPHICAL SAMPLE POSITION
— —	FARM BOUNDARY
┼	SYNCLINAL AXIAL TREND

LITHOSTRATIGRAPHIC COLUMN

MAJOR ROCK TYPE

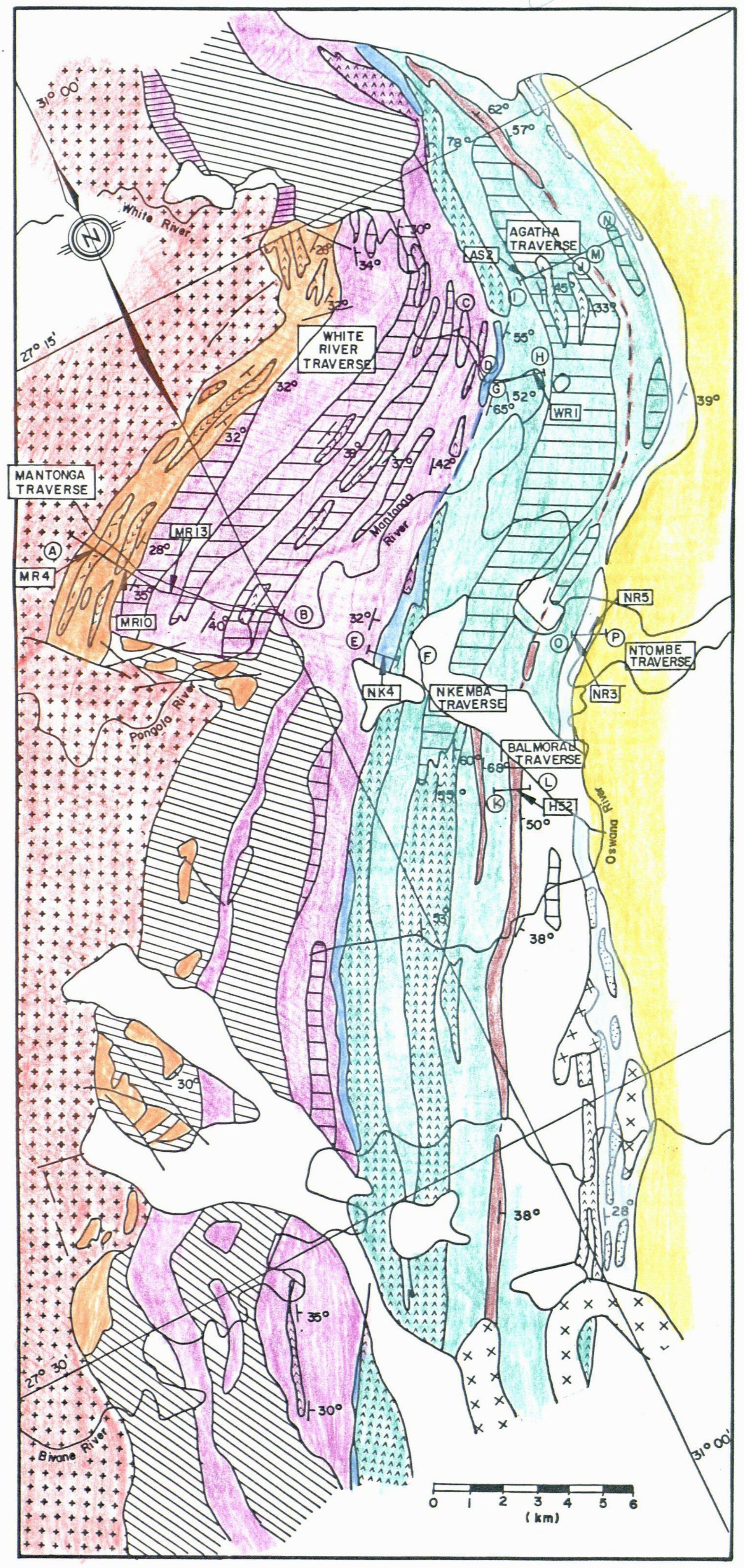
⁘	COARSE MAFIC INTRUSIVE
🟨	QUARTZITE
🟧	SHALE
🟪	MAFIC AMYGDALOIDAL LAVA
🟩	DIAMICTITE
🟥	GRANITE

SYMBOLS

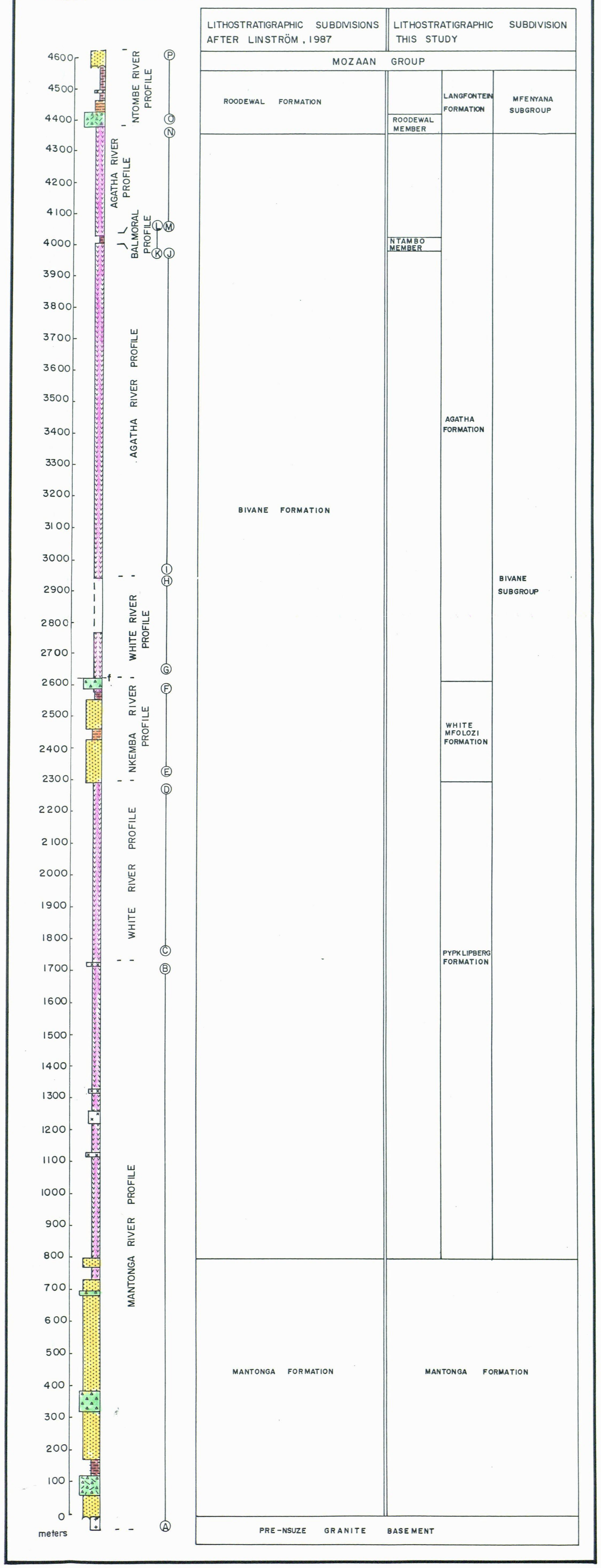
〰 UNCONFORMITY

Map 4a and b

SIMPLIFIED GEOLOGICAL MAP OF THE AREA BETWEEN THE BIVANE & WHITE RIVERS; WESTERN HARTLAND BASIN (MODIFIED FROM HUMPHREY (1913) & ARMSTRONG (1980))



NSUZE LITHOSTRATIGRAPHIC COMPOSITE PROFILE CONSTRUCTED FROM VARIOUS TRAVERSES IN THE WESTERN HARTLAND BASIN.



LEGEND
GEOLOGICAL MAP (After ARMSTRONG,1980)

LITHOLOGICAL

☐	KAROO COVER	KAROO
☐	DIABASE INTRUSIVES	
▨	GRANOPHYRES, MICROGRANITES, QUARTZ DIORITES AND GABBROS	USUSHWANA COMPLEX
🟨	ARENACEOUS, ARGILLACEOUS AND CHEMICAL SEDIMENTS.	MOZAAN GROUP — PONGOLA GROUP
☐	VOLCANIC AND ARGILLACEOUS SEDIMENTS (INTERCALATIONS OF TUFFS, SEDIMENTS AND EPICLASTICS)	NSUZE GROUP — PONGOLA GROUP
🟥	TUFFS, AGGLOMERATES, VOLCANICLASTICS	
🟦	SANDSTONE AND ARGILLITE LENSES	
🟩	BASALTS (UPPER VOLCANIC UNIT)	
🟩	DACITES AND RHYOLITES	
🟩	BASALTIC ANDESITES AND ANDESITES (UPPER VOLCANIC UNIT)	
🟪	BASALTIC ANDESITES AND ANDESITES (LOWER VOLCANIC UNIT)	
🟪	BASALTS (LOWER VOLCANIC UNIT)	
🟧	ARENACEOUS SANDSTONES AND ARKOSIC ARENITES (INTERCALATIONS OF VOLCANOGENIC SEDIMENTS(V)) PYROCLASTICS (▨). BASAL VOLCANIC UNIT (▤)	
🟥	GRANITES , GRANODIORITES AND BANDED GNEISSES.	BASEMENT

SYMBOLS

⟋ 47°	STRIKE AND DIP OF BEDDING
Ⓔ├──┤Ⓕ	PLAN POSITION OF LITHOSTRATIGRAPHIC PROFILE (THIS STUDY)
──	FAULT
NTOMBE TRAVERSE	LITHOSTRATIGRAPHIC PROFILE LOCATION REFERENCE
MR 4 →	PETROGRAPHICAL SAMPLE POSITION

LITHOSTRATIGRAPHIC COLUMN MAJOR ROCK TYPE

☐	DIABASE INTRUSIVE
🟨	QUARTZITE
🟥	SHALE
🟧	SILTSTONE / WACKE
🟩	DIAMICTITE
🟪	VOLCANIC (MAFIC + FELSIC LAVAS)
🟥	GRANITE

SYMBOLS

⌒⌒⌒	UNCONFORMITY
── F	FAULT
A├──┤B	LITHOSTRATIGRAPHIC PROFILE REFERENCE

Map 3a and b