ZIMBABWE GEOLOGICAL SURVEY

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The Geology of the Country East of Beitbridge

by

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PREFACE

Bulletin No. 87 and accompanying 1:100 000 scale map describes the geology of an area about 1765 km^2 in Beitbridge District. The area is bounded by longitudes 30°00' E to 30°30' E, and latitude 22°00' S, the southern boundary being the Limpopo River. M.P.R. Light carried out the geological mapping between 1973 and 1975, and the map was published in 1981. Publication of the Bulletin text, re-written by T.J. Broderick, was delayed by lack of funds. This publication has been made possible, courtesy of funds provided by Centrum fuer Internationale Migration und Entwicklung (CIM) of Frankfurt, Germany.

The area first described by Carl Mauch in 1871 comprises complexly deformed gneisses and granulites of the Central Zone of the Limpopo Mobile Belt. Rare exposures of enderbites and dioritic gneisses form a basement to the Beitbridge Group deposited as various sediments, limestones and volcanic rocks, but now intensely deformed and metamorphosed to different gneisses and granulites. Karoo sediments lying unconformably on the Beitbridge Group, are preserved in grabens. The whole area is intensely fractured. Most fractures are radial to post-Karoo volcanic centres, and are filled by dykes of various rock types.

Part II of the Bulletin describes the economic geology of the area. Beitbridge West has been subject to numerous Exclusive Prospecting Orders concerned mainly with exploration for base metals, Messina-type copper mineralization in particular. Though few claims were pegged, there has not been any mining of base metals from the area. Recent commissioning of River Ranch diamond mine a few kilometres west of Beitbridge town has attracted huge interests in exploration for kimberlitic diamond deposits in the area.

With a production of over 800 000 tonnes of magnesite, Pande was one of the biggest magnesite mines in the country. Other economic minerals include crystal corundum, limestone, uranium, and semiprecious stones (aventurine, rose quartz, garnet, and epidote). Epidotization of the Bulai gneiss has produced an unakite used for ornamental purposes.

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CONTENTS

PART I - GENERAL GEOLOGY

Page

INTRODUCTION 1
- THE AREA 1
- PHYSICAL FEATURES 2
- PREVIOUS GEOLOGICAL WORK 2
- OUTLINE OF THE GEOLOGY 3
- GEOCHRONOLOGY 7

BASEMENT GNEISSES 8

BEITBRIDGE GROUP 11
- DITI FORMATION 12
  - **Diti Paragneisses** 12
  - **Shakwisa Calcareous Member** 20
  - **Swebebe Ferruginous Member** 27
- NULLI FORMATION 32

SYNTECTONIC INTRUSIVE ROCKS 39
- LAYERED ANORTHOSITE SUITE 39
  - **Lower Group** 41
  - **Upper Group** 42
- ULTRAMAFIC SUITE 47
  - **Ultramafic Granulites, Gneisses and Hornblendites** 47
  - **Serpentinites** 52
- MAFIC GRANULITES 55
  - **Two-Pyroxene Granulites** 55
  - **Metabasic Dykes** 56
- BULAI GNEISS SUITE 58
  - **Singelele and Charnockitic Aureole Gneisses** 58
  - **Bulai Gneiss** 62
- SYNTECTONIC ROSE QUARTZ REEFS 67
- APLITIC RIEBECKITE-GNEISS 67
- FLASER GNEISS AND MYLONITE 68
- PEGMATITES 69
- METASOMATIZED BRECCIAS AND APLITES 71
- QUARTZ REEFS 72

STRUCTURE OF THE BEITBRIDGE GROUP 72

METAMORPHISM OF THE BEITBRIDGE GROUP 73

THE KAROO SYSTEM 77

DOLERITES 78
- COARSE-GRAINED DOLERITES 80
- FINE- TO MEDIUM-GRAINED DOLERITES 81
- GLOMEROPHYRIC DOLERITES 81
- PLATY FELDSPAR DOLERITES 82

Page

POST-KAROO IGNEOUS ROCKS 82
TONALITES AND APLITES 83
MAFIC PORPHYRY DYKES 83
PORPHYRITIC PICRITE DYKES 85
NEPHELINE-SYENITE DYKES 86
LATE FINE-GRAINED DOLERITES 86

FAULTING AND BRECCIATION 87

HYDROTHERMAL ACTIVITY 88

SUPERFICIAL DEPOSITS 88

PART II - ECONOMIC GEOLOGY

EXCLUSIVE PROSPECTING ORDERS 91
ASBESTOS 94
COPPER AND NICKEL 94
CORUNDUM 96
IRON 98
LIMESTONE 99
MAGNESITE 100
SEMI-PRECIOUS STONES 111
SILLIMANITE AND CORDIERITE 111
URANIUM 111

REFERENCES 113

APPENDIX 116

LIST OF ILLUSTRATIONS

FIGURES

1 Landsurfaces east of Beitbridge 3
2 Analysis of the Fe-content for 283 samples of Swebebe Ferruginous Quartzites 28
3 Classification of Gabbroic Rocks containing Hornblende (modified after Streckeisen 1976 and Windley 1973) 38
4 Classification of Ultramafic Rocks containing Hornblende (after Streckeisen 1976) 49
5 Sketch showing dyke relationships 1.5 km south-east of Swebebe Hill 70
6 P-T conditions prevailing during metamorphism of the Beitbridge Group (Light 1979) 76
7 Strike distribution of dolerite dykes east of Beitbridge 79
8 Strike distribution of 88 Breccia zones East of Beitbridge 87
9 Areas reserved under Exclusive Prospecting Orders 90
10 Mat Magnesite Mine – surface plan 101
11 Pande Mine – surface plan 103
12 Pande Mine - Serpentinite and regional structure 104
13 Pande Mine No. 3 plant – heavy separation beneficiation flow sheet 108
14 Pande Mine No. 1 and 2 plants – magnetic and screening plant flow sheet 110

Page

TABLES

1 Geological Formations and Events 5
2 Radiometric ages from the Beitbridge and Messina areas 7
3 Chemical Analyses of Basement Gneisses and Paragneisses 10
4 The lithostratigraphic units defined by the SACS for the rocks in the Messina area compared with the equivalent units as defined in the Beitbridge area 12
5 Chemical Analyses of Beitbridge Group Metasediments and related Igneous Rocks 23
6 Chemical Analyses of rocks of the Layered Anorthosite and Ultramafic Suites 45
7 Chemical Analyses of rocks of the Bulai and Singelele Gneiss 61
8 Summary of the Archaean and Early Proterozoic Geological Events of the Central Zone of the Limpopo Mobile Belt around Beitbridge 74
9 Chemical Analyses of Dolerites and post-Karoo Intrusives 84
10 Exclusive Prospecting Orders – Beitbridge area 91
11 Chemical Analyses of Magnesite and Calcrete – Beitbridge area 100
12 Pande Mine – list of registered claims 102

PLATES

1 Features of basement and Diti Gneisses, in outcrop 19
2 Features of Beitbridge Group meta-sediments, in outcrop 35
3 Features of related intrusive rocks, in outcrop 65
4 Feature of pegmatites and dolerites, in outcrop 107
5 Large-scale fold interference patterns of the main structures .... in pocket
6 The development of porphyroblasts during the metamorpho – tectonic history of the Beitbridge area.. in pocket

PART I – GENERAL GEOLOGY

INTRODUCTION

THE AREA

This bulletin covers an area of 1765 km^2 in the Beitbridge District, and is bounded by the longitudes $30^0 00'$ and 30^0 30'E and the latitude $22^0 00'$ S in the North, the southern boundary being the Limpopo River. The region consists almost entirely of Communal land, the only ranch land being a small triangular section of the Lesanth Ranch in the NE. The boundary between the Diti Communal Land, which forms the eastern third of the area, and the Mtetengwe Communal Land, comprising the western two thirds, runs southwards along the crest of the Nulli Range and then SSW to the Samtete River.

The aerodrome, the new railway station and part of the fenced State Land surrounding Beitbridge lie in the west of the map-area, which is served by the main trunk road from Masvingo to Beitbridge and by the Rutenga to Beitbridge rail link. The town of Beitbridge lies mainly outside the map-area. The Alfred Beit Bridge, constructed in 1929 at the site of Leibig's Drift, links Zimbabwe with the Republic of South Africa.

A wide gravel road, well maintained and with concrete causeways over river crossings runs eastwards from Beitbridge to the Pande Mine. From Lutumba Store, 21 km NE of Beitbridge, a fairly well-maintained gravel road runs eastwards to Tshiturapadsi and westwards to join the Bulawayo to Beitbridge main road.

The area falls within the Lowveld region, with altitudes ranging between 400 and 600 m. The mean annual rainfall is 325 mm, most of which, approximately 100 mm, falls during January. There are frequent drought years. Winter is punctuated by periods of overcast weather and occasional drizzle when the prevailing SE-wind results in precipitation along SE-facing slopes.

The annual average temperature is 23^0 C, but the hottest months are those before the onset of the rains in October-November, when shade temperatures around 42^0 C have been recorded. The winters are warm, dry and sunny, but in mid-winter, night temperatures may drop to freezing point in low-lying areas.

The vegetation consists of three distinctive belts of tree savanna. Thick riverine forest grows along the banks of the Limpopo River and some of its tributaries. *Commiphora* and *Combretum*-tree savanna forms a 7 km-wide belt north of the Limpopo River and on the hills and ridges. The remainder of the area is characterized by Mopani tree-savanna. In the riverine forests the fever tree *(Acacia xanthophloea)* is the dominant tree type and is accompanied by figs *(Ficus spp.)* and pod mahogany *(Afzelia quanzensis.)* The vegetable ivory palm (*Hyphaene ventricosa*) is confined to alluvial drainage channels in which acacias are usually abundant.

The hills and ridges have a thicker cover of paper barks (*Commiphoras*) and mutsviri trees (*Combretum imberbe)* as well as mopani and cassias (*abbreviata* and *petersiana*). Euphorbiae occur along the crests of some quartzite ridges whereas patches of acacia (*erubescens*) fill steep valleys. Occasional sabi stars (*Adenum obesum*) are found on slopes facing N and NE.

The plains have a scrub mopani cover (*Colophosermum mopane*), with concentrations of thorns on the more mafic gneisses, granulites and ironstone horizons. Serpentinites and calcrete areas have an extremely stunted cover of mopani and thorn. The thorns include the Chinese lantern (*Dichrostachys cineria*), blackwoods (*Dalbergia melanoxylon*) and various acacias including the knobby thorn (*Acacia nigrescens*). Baobabs (*Adansonia digitata*) are scattered throughout the area and form clusters of their own.

In general, there is an increase in density of stunted mopani north of an E-W line approximately parallel to the Lutumba to Tshiturapadsi road. This may represent the southerly limit of underlying calcrete horizons, which are fairly abundant in the pan country to the north.

Game is relatively restricted in variety and numbers and is confined to zebra and various types of antelope.

Prospecting activity has been moderately intense, but has failed to find an extension of the South African Messina copper deposit north of the Limpopo River. A thorough search has also been made for further magnesite bodies to replace the now worked-out body at Pande Mine.

A large number of ancient ruins occur throughout the area, the most impressive on the north of Mwanandou hill. At this ruin a herringbone pattern is preserved in one wall and rose quartz was used by the ancients in the construction of parts of the walls elsewhere.

PHYSICAL FEATURES

Drainage

The drainage of the area is controlled by the Limpopo River, which flows ESE and then eastwards along the southern border. It is fed by a number of south-flowing tributaries, the main channels being the Lipani, Etomgwani, Samtete, Pande, Diti and Shakwisa rivers. A 5 km-wide belt on the western border of the area is drained by westward-trending tributaries of the Umzingwani River, which joins the Limpopo River upstream of the Limpopo Gorge to the west of Beitbridge.

Flat pan country showing internal drainage is mainly confined to an area north of an E - W line through Lutumba. The active drainage system of the Limpopo is developed south of this line and the tributaries of the river rise in the centre of the map-area at an altitude between 560 and 600 m above sea level.

The drainage is largely controlled by fracture lines and lithological changes and to a lesser extent by dolerite dykes. The course of the Limpopo River is controlled by ENE- fracture and fault lines and by NW-trending fracture lines which offset the river at intervals of 2 to 20 km. Many of the tributaries have zigzag courses, alternately following fracture lines and lithological changes. In general, the major tributaries flow parallel to the trend of the rocks but their minor streams feeding them are strongly orientated along NW-fracture lines in the ancient gneisses. The ENE-trending dyke swarms cause only minor deflections in river courses.

The drainage pattern of the Bulai granite-gneiss is dendritic in places, owing to local homogeneous zones, though elsewhere paragneiss rafts and fracture lines dictate the stream courses.

Although in winter the tributaries of the Limpopo River dry up, the Limpopo itself contains a little water.

Relief

Most of the ground lies between 465 m and 600 m above sea level, the highest point being Mabezikwe hill (945m) near the centre of the area and lowest point on the Limpopo River where it leaves the eastern border (360 m). Malezikwe hill, to the SW of Mabezikwe hill, is 800 m high, as is Shingwanyana to the south.

Topographically the area consists of a monotonous, featureless plain, an extension of the Transvaal Lowveld, with abrupt sinuous NNE-trending hill ranges, commonly showing well-developed dip and scarp slopes, dependent on the angle of inclination of the strata. These hill ranges rise on average 300 m above the plain. The Shingwanyana, Malezikwe and Nulli hills form a central NNE belt, while an eastern spine is formed by the Malise, Mabana, Shakwisa and Lukumbwe hills. North-west of the central belt of hills only one major NE-trending ridge occurs on the plain, with its highest point at Diriza (645 m). Flat plains also separate the central and eastern ranges, though an irregular group of hills occurs around and north of Pande Mine. In the NE, a ring of hills is found south of and including Bodekwa hill (745 m). Luchewe hill (688 m) forms the peak of a similar ring of hills south of Beitbridge railway station. Rings of low quartzite ridges form the topography east of Shakwisa hill (690 m).

Smaller ridges and koppies of ferruginous quartzite, calc-silicate rocks and dolerite are confined to the flat plains east of the central area.

Four erosion surfaces are preserved in the Beitbridge area. The active Quaternary erosion surface of the Limpopo River system extends northwards to the headwaters of the major tributaries. The flat pan country north of this river system is a Pliocene erosion surface at an altitude of 550 - 620 m above sea level, and formed 4 Ma ago (Lister 1987). An older, higher erosion surface is represented by the flat crests of quartzite hills between 730 and 745 m. This is possibly the Post-African erosion surface formed in Miocene times, 17 Ma ago, on an upfaulted block of ancient gneisses. Mabezikwe rises abruptly above the 800-m contour, and may represent the remnants of a still older erosion cycle (see Figure 1).

PREVIOUS GEOLOGICAL WORK

Carl Mauch (1871), after crossing the Limpopo River 55 km downstream of the present site of Beitbridge, recorded that "the prevalent rocks are metamorphic gneiss frequently mixed with black hornblende", apparently referring to the mafic gneisses found in that area. Molyneux (1899), whilst prospecting for coal 30 km NW of Beitbridge, observed a "series of rocks older than the coal-bearing strata, probably Cambrian, comprising gneiss, schist, tuffs and rocks of volcanic origin. Lightfoot (1938) made a brief excursion into the area, and Tyndale-Biscoe (1949) published results of reconnaissance work east of Beitbridge. Phaup (1949) examined the Mat Claims and in 1951 he made notes on the environs of Beitbridge.

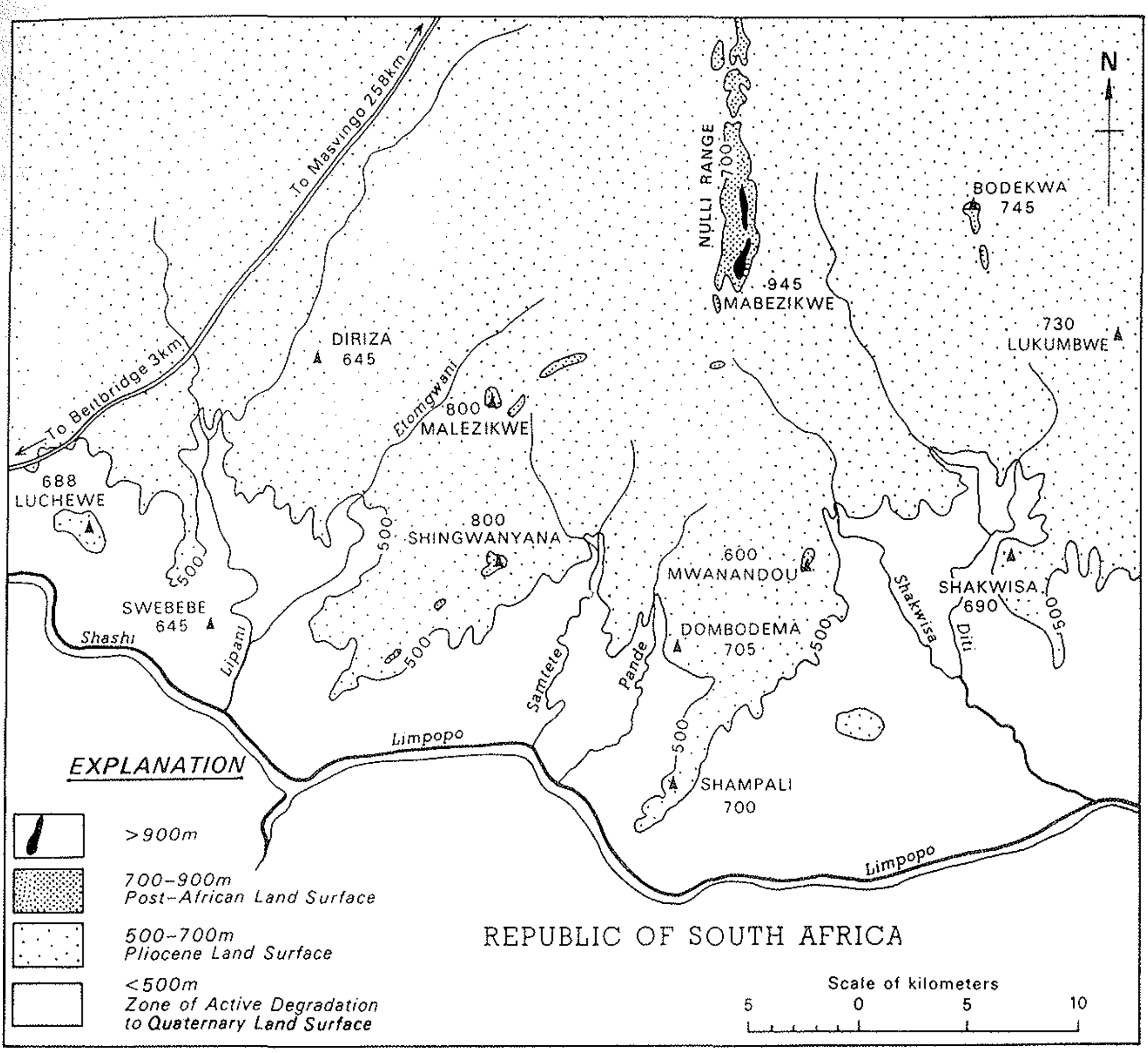


Figure 1: Landsurfaces east of Beitbridge

Goldberg and Short (1964) further investigated the Mat Claims, and notes on the Pande Mine were made by Goldberg (1965). Cox *et al.* (1965) described the rocks of the Nuanetsi Igneous Province.

The Rhodesian Schools Exploration Society briefly described the Archaean gneisses in the extreme west and SE of the area during their examination of rocks in the Karoo System (Robertson 1967 and 1968). Morrison (1968) made a short excursion into the Beitbridge area, and the country east of Beitbridge was mapped by Linnell (1970), who considered the paragneisses to be a basement to the Messina Formation quartzites.

Watkeys (1979) mapped the area west of Beitbridge, and Broderick (1979) covered part of the country south of Mwenezi. Light and Watkeys (1977) summarized the structural and metamorphic history of the Beitbridge area. Chinner and Sweatman (1968) and Schreyer and Abraham (1976) have described unusual cordierite rocks from the Beitbridge area, in an attempt to establish temperature and pressure conditions prevailing at the time of formation.

Numerous Exclusive Prospecting Orders (EPOs) have been granted for various sections of the area, and the final reports for most of them are summarised by Morrison (1974, 1975 and 1978), the remainder being filed with the technical reports of the Geological Survey. The research branch of Johannesburg Consolidated Investment Company Limited has compiled a photogeological map of the country east of Beitbridge (Parsons 1976).

OUTLINE OF THE GEOLOGY

The country East of Beitbridge can be considered to be the type-area for the Beitbridge Group in

Zimbabwe. The map-area lies entirely within the Central Zone of the Limpopo Mobile Belt and encompasses an extension into Zimbabwe of a suite of rocks originally described in the Messina District by Söhnge (1945). The ancient gneisses and granulites of the region have been moulded by a complex interaction of early Precambrian events which appear to have been contemporaneous with many of the adjacent cratonic events.

Enderbites and dioritic gneisses appear to represent the basement to the Beitbridge Group. They are rarely exposed and their exposures are mostly related to that of the Bulai Gneiss in which they occur as inclusions. Similar inclusions within the Diti Paragneisses show evidence for an unconformity. The relationship of these gneisses to the Macuville Group in South Africa is uncertain, but they may be equivalent in age to the Sand River exposures which have been dated at 3 858 Ma. The basement gneisses have been injected by ancient, deformed tholeiitic dykes, the oldest of which do not penetrate the cover sequence.

Rocks of the Beitbridge Group were deposited as widespread arkosic sediments, interbedded with pelites, sandstones, limestones and ferruginous sediments, together with minor lavas and tuffs. The Diti Formation is now composed largely of garnetiferous leucocratic paragneisses, various biotite paragneisses and minor quartzites. Within it the Shakwisa Calcareous Member comprises quartzites, marbles, ophicalcites, calc-silicate rocks and garnetiferous granulites, whilst the Swebebe Ferruginous Member is a series of quartzites, pyroxene granulites, magnetite-quartzites and cordierite-bearing gneisses. The overlying Nulli Formation consists essentially of variable quartzites with intercalated calc-silicate rocks and amphibolite horizons.

Layered anorthosite and ultramafic suites are intrusive into the Beitbridge Group. A variety of related anorthositic gneisses form extensive conformable sheets, and ultramafic granulites, both conformable and plug-like, appear to have been derived from the same magma chamber. Isoclinal recumbent folding (F1) accompanied high grade (granulite) metamorphism prior to the intrusion of a set of mafic dykes into the cover sequence. Further isoclinal folding (F2) was partly concomitant with the Singelele and charnockitic aureole gneisses which originated by palingenesis of the Diti Paragneisses. At much the same time anatexis of the basement appears to have resulted in the intrusion of the Bulai Gneiss 2 690 ± 60 Ma ago. This intrusion was accompanied by migmatization of the surrounding paragneiss and by intrusion of riebeckite-aplite and rose-quartz reefs with attendant soda and boron metasomatism. The intrusion of the Bulai Gneiss caused a gradual decrease from high to medium grade of metamorphism.

During a continued descent to low-grade metamorphic conditions, tight NNE-trending F3 folds, which deform the Bulai Gneiss, were later cross-folded by open NW-trending concentric folds (F4). The rocks were now brittle and subject to cataclastic deformation which resulted in the formation of flaser gneisses, mylonites and breccias related to flat-lying and major ENE-trending fractures. Events during the waning phases of metamorphism took place some 2 000 Ma ago. They included serpentinization of the ultramafic rocks and the intrusion of coarse-grained dolerites, tremolitic dykes, mica pegmatites and quartz reefs.

A long period followed during which extensive erosion took place before Karoo sediments were deposited and downthrown by the reactivated Shurugwe Fault. The fracture system across the Limpopo terrain is intense and this regulated the pattern of intrusion of numerous dykes, many of which are fine- to medium-grained dolerites and platy-feldspar dolerites of Karoo age. Post-Karoo intrusions to the NE were accompanied by radial fractures occupied in part by dykes of tonalite, aplite, mafic porphyry, olivine porphyry, nepheline syenite or late fine-grained dolerite. Copper mineralization apparently accompanied the intense hydrothermal activity related to the acid phase of post-Karoo intrusion. Evidence for this hydrothermal alteration is widespread in rocks adjacent to fracture lines in the Beitbridge area.

North-trending faults have displaced some post-Karoo dykes and a prolonged period of erosion and pediplanation took place to mould the present landscape. The formation of calcrete is widespread across the Pliocene landscape but ferricrete is more localized. A Quaternary landsurface is encroaching along the valley of the Limpopo River where alluvium is best developed. Much of the rock exposure in the map-area is obscured by thick red colluvial soils, but thin residual soils overlie the more dissected country near the Limpopo River.

Table 1 : Geological Formations and Events

RECENT
Colluvial and residual soils, alluvium, calcrete and ferricrete

CREATACEOUS - PLIOCENE
Prolonged erosion and pediplanation. Movement on north-trending faults

POST-KAROO (Jurassic)
Dolerite, nepheline-syenite and olivine-porphyry dykes
Intrusive contacts
Copper mineralization and hydrothermal alteration associated with igneous intrusion
Mafic-porphyry, tonalite and aplite dykes
Intrusive contacts. Radial fracturing related to intrusion of ring dyke complexes (c. 185 Ma)
Reactivation of ENE - fractures. Brecciation of dolerite
Down-faulting and folding of Karoo System

KAROO SYSTEM (Permian – Lower Jurassic)
Platy feldspar and fine- to medium-grained dolerite dykes
Intrusive contacts
ENE-faulting and fracturing
Cross-bedded and massive arkosic grits
Fossiliferous shales

Major unconformity. Prolonged erosion of pre-Karoo land surface

SYNTECTONIC INTRUSIVE ROCKS (Precambrian)
Dolerites, mica pegmatites, aplites and quartz reefs (1 850-2 000 Ma)
Intrusive contacts. Potash metasomatism along breccia zones.

Coarse-grained dolerite and tremolitic dykes (2 265 ± 64 Ma)

Intrusive contacts
Serpentinization of ultramafic rocks
Major ENE-fracturing and shearing. Development of breccia, flaser gneiss and mylonite
Flat-lying cataclastic zones
Low to very low-grade metamorphism
Upright, conical folding with subvertical NE-axes (F_5)
Open, upright, concentric folding with gently to moderately plunging.

NW axes (F_4). Medium-grade metamorphism
Tight, inclined, similar folding with subhorizontal NNE-axes (F_3)
Partial mobilization and retrogression of Singelele Gneiss (2 509 ± 260 Ma)
Gradual decrease from high to medium-grade metamorphism

Aplite and rose quartz reefs

Intrusive contacts. Soda and boron metasomatism
Migmatization of the paragneisses

BULAI GNEISS SUITE (2 690 ± 60 Ma)

Intrusive contact
Anatexis of basement gneisses. Formation of Singelele and charnockitic aureole gneisses by palingenesis of Beitbridge Group paragneisses
Remobilization of some ultramafic rocks into fold noses
Isoclinal, upright, similar folding on subhorizontal NE-axes (F_2)
High-grade (granulite) metamorphism

Mafic dykes (3 128 ± 41 Ma)

Intrusive contacts
Isoclinal, recumbent, similar folding on ESE to SE sub-horizontal axes (F_1) (3 221 ± 48 Ma)

Ultramafic and Layered Anorthosite Suites

Intrusive contacts

BEITBRIDGE GROUP (Early Precambrian)
Nulli Formation: Quartzites, calc-silicate rocks with intercalated amphibolite gneisses. Garnetiferous paragneisses of pelitic and arkosic origin.
Diti Formation: Swebebe Ferruginous Member: Quartzite, ferruginous quartzites, garnet-pyroxene granulite and alumina-rich cordierite-gneiss.
Shakwisa Calcareous Member : Quartzite, marble, sedimentary serpentine and garnet granulite.

Deposition of the Beitbridge group sediments within an elongated basin separating the Kaapvaal and Zimbabwean cratons.
Major unconformity. Erosion
Faulting

Mafic dykes (3 643 ± 102 Ma)

Intrusive contacts
Folding and metamorphism (F_O)

BASEMENT GNEISSES (Early Precambrian)
Banded, migmatitic and enderbitic gneisses (3 858 ± 116 Ma)

GEOCHRONOLOGY

Recent geochronological work has been of great assistance in elucidating the igneous and metamorphic events in the Beitbridge and Messina districts. A summary of age determinations is given in Table 2.

Initially Holmes and Cahen (1957) recognised a c. 2 000 Ma event on the basis of two U-Th-Pb determinations from samples near Beitbridge. This age was confirmed throughout the Limpopo Belt in Zimbabwe. Using the Rb 87/Sr 87 whole-rock isochron method, Van Breemen showed a far greater age of 2 690 ± 60 Ma for remobilization of the Bulai and Singelele gneisses.

Table 2 : Radiometric ages from the Beitbridge and Messina Areas

Rock & Locality	**Sample Material**	**Method**	**Age (Ma)**	**λ (yr^{-1})**	**Reference**
Post-Karoo Intrusives, Mwenezi District, Zimbabwe	Whole rock	Rb-Sr	177 ± 7	1.39×10^{-11}	Manton 1968
Mafic dyke, Artonvilla -Messina, South Africa	Whole rock	K-Ar	185 ± 7	-	Jacobsen *et al.* 1975
Rhyolite, Mwenezi District, Zimbabwe	Whole rock	Rb-Sr	206 ± 13	1.39×10^{-11}	Manton 1968
Messina dyke, Messina District, South Africa	Whole rock	K-Ar	707 ± 28	-	Jacobsen *et al.* 1975
Golf Links dyke, Messina District, South Africa	Whole rock	K-Ar	803 ± 32 1 096 ± 40 1 250 ± 50 1 537 ± 50 1 699 ± 68 1 776 ± 70	-	Jacobsen *et al.* 1975
Messina dyke, Messina District, South Africa	Whole rock	K-Ar	1 840 ± 72	-	Jacobsen *et al.* 1975
Sphene in gneiss, Beitbridge, Zimbabwe	Sphene	U-Th-Pb	1 940 ± 60	-	Holmes & Cahen 1957
Granodioritic gneiss, Mtetengwe River, Zimbabwe	Biotite	Rb-Sr	1 998 ± 50	1.386×10^{-11}	Van Breemen 1968
Pegmatite, Beitbridge, Zimbabwe	Sphene	U-Th-Pb	2 060 ± 60	-	Holmes & Cahen 1957
Diabase dyke, 16 km SE of Messina, South Africa	Whole rock	Rb-Sr	2 265 ± 64	1.39×10^{-11}	Barton & Ryan 1977
Singelele gneiss, near Messina, South Africa	Whole rock	Rb-Sr	2 509 ± 260	1.39×10^{-11}	Barton & Ryan 1977
Bulai & Singele. gneiss Messina District,South Africa	Whole rock	Rb-Sr	2 690 ± 60	1.386×10^{-11}	Van Breemen 1968
Bulai gneiss, W of Messina, South Africa	Whole rock	Rb-Sr	2 772 ± 106	1.39×10^{-11}	Barton & Ryan 1977
Metamorph. mafic dyke Sand River, South Africa	Whole rock	Rb-Sr	3 100 ± 100 3 128 ± 81	1.42×10^{-11} 1.39×10^{-11}	Barton *et al.* 1978, 1977 b
Meta-Anorthosite, Messina District, South Africa	Whole rock	Rb-Sr	3 153 ± 47	1.42×10^{-11}	Barton *et al.* 1978
Metamorph. mafic dyke Sand River, South Africa	Whole rock	Rb-Sr	3 566 ± 100 3 642 ± 102	1.42×10^{-11} 1.39×10^{-11}	Barton *et al.* 1978, 1977 a
Grey gneiss, Sand River, South Africa	Whole rock	Rb-Sr	3 727 ± 57	1.42×10^{-11}	Barton *et al.* 1978
Leucocratic gneiss, Sand River, South Africa	Whole rock	Rb-Sr	3 776 ± 97	1.42×10^{-11}	Barton *et al.* 1978
Grey & leucocr. gneiss, Sand River,South Africa	Whole rock	Rb-Sr	3 786 ± 61 3 858 ± 116	1.42×10^{-11} 1.39×10^{-11}	Barton *et al.* 1978, 1977 a

That these gneisses were derived under separate conditions is suggested by the respective ages of 2 770 and 2 500 Ma determined by Barton and Ryan (1977).

Since late 1973 the Bernard Price Institute for Geophysical Research, in conjunction with the Geology Department at the University of the Witwatersrand, has undertaken a geochronological study of the Messina area as part of the International Geodynamics Project. A good understanding of the field relationships, especially at the Sand River exposures, together with careful sampling techniques, has enabled a number of useful dates to be determined. The basement gneisses in the Messina area may be as old as 3 858 ± 64 Ma (Barton *et al.*1977), whereas deformed mafic dykes reveal ages of 2 265 ± 64 Ma, 3 128 ± 81 Ma and 3 643 ± 102 Ma. Many of these ages have been recalculated using an alternative decay constant for Rb 87. The new dates are slightly younger and may be more realistic (Barton *et al.* 1978). A determination of 3 221 ± 48 Ma was calculated for anorthosite of the Messina Layered Intrusion, but recent lead dating gives an age of c. 3 350 Ma (J.M. Barton, personal communication). This raises the possibility that the original anorthosite age and that for mafic dykes intrusive into it are metamorphic settings imprinted at the time of the F1 fold phase.

Geochronology has also been used in an attempt to clarify the post-metamorphic history of the Limpopo Belt. A primary interest has been to attempt to establish the age of copper mineralization by dating altered and unaltered dolerites at Messina. The mineralization appears to be related to post-Karoo hydrothermal activity which pre-dates the intrusion of the Artonvilla Dyke 185 ± 7 Ma ago (Jacobsen *et al.* 1975). Work has been done on dating the Waterberg Group, the Karoo volcanics and some post-Karoo intrusions of the Nuanetsi Igneous Province (Table 2). In Botswana C_{14} dating has shown calcrete to have originated in the soil profile 10 000 - 34 000 years ago (Key 1977).

BASEMENT GNEISSES

The basement gneisses comprise a variety of non-garnetiferous, mafic orthogneisses and granulites, some of which occur as boulders in the succeeding Diti paragneisses and as xenoliths in the Bulai Gneiss. The gneisses appear to represent the floor of the basin in which the Beitbridge cover sequence was deposited. The South African Committee for Stratigraphy has termed the basement gneisses the Macuville Group, after the farm of the same name which occurs 10 km WSW of Beitbridge. The correlation between gneisses on the Macuville farm and the Sand River Gneisses, 10 km south of Messina, is uncertain as is also their correlation with putative Zimbabwean equivalents which are poorly exposed and limited in outcrop extent. All of these gneisses, including similar tonalitic gneisses at Zanzibar in Botswana (Key 1977), are cut by discordant metamorphosed mafic dykes. The oldest of these dykes do not penetrate the Beitbridge cover and they have been dated at 3 643 ± 102 Ma in the Sand River exposures (Barton *et al.*, 1977a). Rb/Sr whole-rock analyses yield an isochron of 3 858 ± 116 Ma for the Sand River Gneisses which indicates that the basement gneisses in the Beitbridge area could be the oldest rocks yet recognized in Zimbabwe.

Bahnemann (1972) regarded most of the gneisses of the 'Bulai Belt' west of Messina as old Basement rocks. Although the Bulai Gneiss may be equivalent to remobilized basement gneiss, many of the surrounding charnockitic and leucocratic gneisses or granulites can be allocated to the overlying Shanzi Formation in South Africa, or to the equivalent Diti Formation in Zimbabwe. A convincing unconformity between basement gneisses and those of the Beitbridge Group can be seen in the Sand River exposures.

Lithology

Five types of basement gneiss have been distinguished east of Beitbridge. These comprise: a) enderbitic gneisses and granulites, b) dioritic augen gneiss, c) quartz diorite gneisses, d) diorite gneiss and e) orthopyroxene-free gneiss. The last two types occur as inclusions in the Bulai Gneiss.

The enderbitic gneisses and granulites are fairly resistant to weathering and form low koppies and ridges strewn with large rounded and sub-rounded boulders up to a metre across. The boulders are elongated where foliation and mineral alignment is better developed, but mostly the rocks are homogeneous granulites, dark olive green to honey brown, lustrous when broken and with greenish or yellow feldspars of greasy appearance. On weathering the enderbitic rocks develop a dark skin with a reddish hue caused by the decomposition of orthopyroxene. The soils are brown to grey in colour and are covered with a fine scree of pyroxene, hornblende and gneiss fragments. In the foliated varieties, segregation layers of feldspar are separated from more mafic bands composed of pyroxene, hornblende and biotite. The layers are 1-3 mm wide, although in some pegmatitic granulites individual feldspars may be up to 10 mm across.

Mesocratic dioritic augen gneiss was found only at one locality west of the Lipani River. This mottled, dark coloured rock contains deep pink or red feldspar augen which show up as knobs on the black weathered surface. It has a well-developed foliation with irregular, ovoid or lensoid feldspars, 1-20 mm long, orientated between layers of hornblende crystals, 0.5-4.0 mm long. The feldspars have been altered, stained pink and partly epidotised by the action of late stage hydrothermal fluids.

Quartz diorite gneisses are exposed as pavements along the Shakwisa River where the rocks are mottled pink to reddish-grey owing to feldspar alteration. In these fine- to medium-grained rocks a foliation is defined by the alignment of minerals, and by a segregation layering of mafic and felsic components. The minerals are also aligned parallel to lineations trending obliquely across the foliation plane, and layers of biotite and hornblende tend to follow around large intergrowths of quartz and feldspar. These gneisses weather with a brown skin on which are patches of white clay where the feldspars have been decomposed. The rocks are covered by and veined with calcrete, and they produce a red hornblende soil.

The dioritic and orthopyroxene-free gneisses form rafts and inclusions in the Bulai Gneiss where they are exposed as flat pavements, and form low rises. The rocks are even-grained, mesocratic, grey foliated gneisses that often have gradational and indefinite contacts with the Bulai Gneiss. The gneisses have an indistinct planar foliation, owing to segregation layering and the alignment of biotite and hornblende. Porphyroblasts of high temperature patch-perthite apparently replace plagioclase, and concentrations of potash feldspar crystals in the gneiss appears to represent the incipient formation of Bulai Gneiss. Orientated inclusions of quartz apparently represent early secretion pegmatites and these are steeply cross-cut by lensoid micropegmatite dykes. The orthopyroxene-free gneisses are similar in appearance to the enclosing Bulai Gneiss. They contain augen of plagioclase and quartz up to 10 mm long, around which layers of hornblende, biotite and clinopyroxene are wrapped.

Distribution and Field Relations

Basement gneisses are exposed in only two layers, in and around the eastern parts of the Bulai Gneiss and, in the south-east of the map-area, along the Shakwisa River just upstream from its confluence with the Diti River.

South of the major E-trending lobe of Bulai Gneiss, enderbitic gneisses and granulites outcrop in the form of a 'V' with the apex directed to the south. This is part of a complex synformal interference pattern in the core of an F3 antiform separating the two lobes of Bulai Gneiss. The eastern limb of this structure is thickened at its northern end east of the Lipani River. Here the north and south margins dip steeply south and the western edge dips moderately to the west. The eastern limb narrows where it crosses the Lipani River and the rocks swing into a N-trending western limb which lies sub-parallel to the river. This is due to the influence of a NNE-trending synformal cross-fold which causes the rocks in the nose to have steep northerly dips. The western limb is antiformal and the dips along its eastern margin are vertical.

A short distance north of the 'V'-shaped outcrop, and separated from it by Diti Paragneisses, are a series of east-trending belts of enderbitic basement gneiss which appear to be synforms that are refolded in the west by an antiform cross-fold. They are partly in contact with Bulai Gneiss, and the antiform encloses a zone of charnockitic Singelele Gneiss and narrow bands of hornblende. Dips in this structure are steep both to the north and south.

Within the northern lobe of Bulai Gneiss, E-trending rafts of dioritic basement gneiss are poorly exposed. However, at the eastern extremity of this lobe, enderbitic basement gneiss forms a complex north-trending structure which includes dykes of Bulai Gneiss and Mafic granulite. This structure occurs within Diti Paragneisses and charnockitic Singelele Gneisses, and appears to be a repetition of the 'V' - shaped outcrop on the Lipani River. The eastern synformal limb is about 400 m wide and dips moderately eastwards except at its northern extremity where the dip is steeply inclined to the north-west. The western limb is partly rimmed by a dyke of Bulai Gneiss and the dips are moderate or steep towards the west. The limbs converge in the south where they are cross-folded by a NNE-trending antiform. The gneisses here dip steeply to the south and west.

West of the Lipani River no inclusions of basement gneiss were observed in the Bulai Gneiss, except in a small fault block 2.5 km east of Luchewe trigonometrical beacon. Rafts of Diti Paragneiss, however, abound as they do to the west of Beitbridge (Watkeys 1979). This suggests that the northern synformal lobe of Bulai Gneiss has assimilated basement gneisses at a lower level than the western part which also includes rocks of the Diti Formation.

A rounded, fine-grained boulder of enderbitic gneiss was found within highly garnetiferous Diti Paragneiss, 2 km west of the Samtete River (TL

131330) (Plate 2 A). The foliation of this boulder is displaced by an openly folded fault line filled with a secretion quartz veinlet, and it lies oblique to the foliation of the enclosing paragneiss which appears more contorted around the margins of the boulder. A smaller boulder of amphibolitic basement gneiss was found in the Lipani River (TL 011344) where its tightly folded foliation also lies oblique to that of the enclosing biotite paragneiss. These isolated boulders appear to owe their location within the paragneisses to a sedimentary process which took place during the deposition of the Diti Formation, the provenance of which was the basement gneisses.

A small triangular-shaped area on the Shakwisa River, 4 km north-east of Ngwani Hill, is composed of non-garnetiferous tonalitic and quartz diorite gneisses. They are enclosed within quartz-hornblende gneisses of the layered anorthosite suite and they form a synformal structure which encloses a NNW-trending body of quartz-hornblende gneiss. The gneisses are steeply inclined to the west along the western margin of the inlier and in the north-east they dip moderately north. This structure may represent a raft of basement which has been uplifted by the intrusion of quartz-hornblende gneiss.

The structures and rock types of the basement suggest that they were produced by an initial tectonothermal event with medium- to high-grade metamorphic conditions prior to the deposition of the Beitbridge cover sequence. The contrast between the two ages of gneiss is probably best illustrated by the discordant foliation of basement-gneiss boulders within the paragneisses. In these boulders, small rootless folds have been produced by shearing parallel to the foliation, and early fault lines have been filled by cross-cutting secretion-pegmatite veins. The presence of early quartzo-feldspathic dykes and the oldest deformed mafic dykes are regarded as being diagnostic of the basement gneisses which have subsequently been deformed by all the fold phases recognizable in the cover rocks. The later deformation has tended to obliterate any evidence of an unconformity between the two gneiss groups. The Bulai Gneiss appears to have been derived by anatexis and remobilization of basement gneisses during late F2 times owing to an introduction of water and potash. The basement gneisses within the Bulai Gneiss do not contain hypersthene, as this appears to have been replaced by clinopyroxene and hornblende with the addition of water. The addition of potash has also resulted in the widespread replacement of hornblende by biotite.

Table 3 : Chemical analyses of Basement Gneisses and Paragneisses (in %)

Slide No.	25 377	25 378	25 391	25 405	25 406	25 409	25 410
Lab. No.	**017**	**018**	**75/76**	**75/75**	**76/37**	**75/60**	**76/34**
SiO_2	56.26	62.28	55.23	71.61	59.84	73.68	76.01
Al_2O_3	16.93	15.81	23.47	15.25	17.93	14.73	12.66
Fe_2O_3	1.16	1.28	0.50	0.64	1.57	0.10	0.78
FeO	6.14	3.88	9.20	1.61	4.62	1.11	0.78
MgO	3.43	2.83	5.53	0.50	4.59	0.35	0.19
CaO	8.86	6.56	1.70	2.17	2.53	1.01	0.99
Na_2O	3.25	3.25	1.14	4.16	2.13	3.06	2.56
K_2O	1.00	2.00	1.65	3.03	3.35	5.66	5.35
H_2O^+	0.50	0.63	0.66	0.44	0.89	0.32	0.33
H_2O^-	0.07	0.04	0.11	0.11	0.22	0.15	0.19
CO_2	0.06	0.10	tr	0.03	0.25	0.24	0.20
TiO_2	0.95	0.88	0.89	0.24	1.09	0.01	0.22
P_2O_5	1.03	0.89	0.05	0.01	0.08	0.07	0.06
MnO	0.09	0.09	0.10	0.02	0.07	0.05	0.02
Totals	99.73	100.52	100.23	99.91	99.16	100.34	100.34
Specific gravity	2.92	2.83	3.09	1.71	3.10	2.61	2.64

Analysts: B.J. Radclyffe, ZGS: 75/57, 75/60 and 75/66
Dept. Metallurgy : 017 and 018
A.D. Powell, ZGS: 76/34 and 76/37
Rock types and localities: See Appendix

Petrography

Two samples of basement gneiss have been chemically analysed (Table 3, Lab. Nos. 017 and 018). These samples (slides 25 377 and 25 378, see Appendix) are enderbitic and dioritic respectively. The enderbitic gneiss was collected near the Pande Mine road where it crosses the Lipani River and the dioritic variety represents an inclusion in Bulai Gneiss. It is significant that the analyses of these two samples, when compared with analyses of Diti Paragneiss, are not corundum normative. This may be an indication of their igneous origin.

The basement gneisses vary in composition from diorites through quartz diorites to tonalites. Enderbitic gneisses and granulites, in which andesine becomes dominant over microcline, are a common form of basement. The mineral composition of the basement gneisses usually includes various amounts of green-brown or blue-green hornblende, foxy-red to brown biotite, diopsidic augite, hypersthene, enstatite and plagioclase with a composition varying between An_{30} and An_{70}. Biotite is abundant in some samples (slides 25 379 and 25 380), but is nearly absent in others (slide 25 381). Clinopyroxene is partly replaced by hornblende in an inclusion in Bulai Gneiss (slide 25 382), whereas orthopyroxenes are altering to hornblende (slides 25 383 and 25 384). Apatite is abundant in some samples (slides 25 379 and 25 381), whereas another sample (slide 25 385) contains brown allanite and lilac-coloured zircon. A sample of dioritic augen gneiss (slide 25 386) was collected from a point west of the Lipani River. This mesocratic rock contains large pink-stained feldspars which are enclosed in a foliated matrix of green hornblende, epidote, magnetite, apatite, plagioclase and quartz.

A fine-grained enderbitic gneiss (slide 25 387), which occurs as a boulder inclusion in the Diti Paragneiss, has a poikiloblastic elongate to polygonal granular texture with a faint foliation. Olive green to brown hornblende forms as intergranular laths or occurs in aggregates with clinopyroxene and flakes of foxy red biotite. The hornblendes are embayed against the enclosing feldspars, and biotite flakes penetrate both the plagioclase and hornblende grains. The clinopyroxenes form rounded to idioblastic crystals, up to 0.9 mm across, which often contain a core zone with a different orientation. Clinopyroxene granules are intergranular to both hornblende and plagioclase but they contain tiny inclusions of garnet, calcite, quartz and ore. Both clinopyroxene and orthopyroxene are altering to calcite although adjacent hornblende laths are unaltered, these being derived by replacement of the original pyroxenes. Hypersthene forms irregular, equant crystals that are often embayed against other minerals but which are intergranular in relation to feldspar grains. Some hypersthenes contain a core of diopsidic augite but in general they show less alteration to hornblende than do the clinopyroxenes. Numerous granules and crystals of iron ore are associated with the pyroxenes and hornblende. Plagioclase forms irregular poikiloblastic grains containing inclusions of garnet, calcite, iron ore and quartz. The plagioclase shows good albite-and pericline-twinning, indistinct reverse-zoning and undulose extinction. It has a composition of An_{44} to An_{54}. A visual estimate of the rock indicates a composition of 40 % plagioclase, 5 % quartz, 25 % hornblende, 15 % clinopyroxene, 8 % hypersthene, 3 % ore and 4 % garnet.

Another sample of enderbitic gneiss (slide 25 388) has a glomeroporphyritic texture in which irregular aggregates of plagioclase grains, up to 3.5 mm across, are enclosed by intergranular aggregates of hypersthene, augite, hornblende, brown biotite and apatite. The plagioclase, which shows well-formed albite- and pericline-twinning, has the composition of andesine. Hypersthene is pleochroic and forms equant to elongate intergranular crystals up to 1 mm long. Some large sieve-textured crystals are intergrown with plagioclase and contain numerous inclusions of ore, apatite and clinopyroxene. Clinopyroxene also forms small irregular crystals, ribbons and aggregates, which are rimmed by iron ore and hornblende, their alteration products. Hypersthene is also partly altered to irregular patches of hornblende, and a few flakes of foxy-red biotite also occur in the slide. Apatite and a few zircons form the accessory minerals associated with the mafics.

BEITBRIDGE GROUP

Until recently it was believed that most of the rocks in the Central Zone of the Limpopo Mobile Belt were essentially highly metamorphosed equivalents of the cratonic Basement Complex, with a much younger, but complexly infolded series of quartzites and other metasediments of the Messina Formation. Work in South Africa and in Zimbabwe has shown that many of the gneisses, originally thought to be part of the Basement, really form a conformable succession with metasediments of the Messina Formation. This has resulted in a new definition of the stratigraphy for rocks of the Central Zone in both Zimbabwe and South Africa, the comparison between which is made in Table 4.

Table 4 : The lithostratigraphic units defined by the South African Committee For Stratigraphy (SACS) for the rocks in the Messina area compared with the equivalent units as in the Beitbridge area

ZIMBABWE			SOUTH AFRICA		
Syntectonic Intrusive Rocks	Singelele and Charnockitic Gneisses Bulai Gneiss Layered Anorthos. & Ultramafic Suite			Singelele Granitoid Gneiss Bulai Granitoid Gneiss Anorthosite Suite	
Beitbridge Group	Nulli Fm.		Beitbridge Group	Messina Sub-group	Mt. Dowe Metaquartz. Fm. Artonville Cord. Gneiss Fm. Alldays Marble Fm.
	Diti Fm.	Swebebe Ferrug. Member Shakwisa Calc. Member Diti Paragneisses		Shanzi Sub-group	Maryland Leucocr. Gneiss Fm. Vryheid Biot.-Garnet Gneiss Fm.
Basement Gneisses			Macuville Group		

It is now realized that the cover rocks represented by the Beitbridge Group extend over the greater portion of the Central Zone both to the north and south of the Limpopo River. Ancient mafic dykes, which cut across the basement gneisses but not the cover-sequence in the Sand River exposures south of Messina, have been dated at 3 643 ± 102 Ma (Barton *et al.* 1977a). The Messina Layered Anorthosite Intrusion, which trangresses the Beitbridge Group, is dated at 3 221 ± 48 Ma (Barton *et al.* 1977b). This evidence points to the situation in which the cratonic granite-greenstone assemblage lies in direct association with a completely different, but equally Archaean, assemblage formed and modified during much the same time span. That is to say that whilst the Zimbabwean and Kaapvaal cratons are largely volcanic and plutonic igneous terranes, the Beitbridge rocks represent a largely sedimentary succession that was deposited contemporaneously in an intercratonic basin.

DITI FORMATION

The paragneisses and intercalated metasediments of the Diti Formation overlie the basement gneisses with a probable unconformity. The paragneisses are equivalent to the Shanzi Sub-group in South Africa and they are extensively developed as garnetiferous leucocratic and biotitic rocks of arkosic and pelitic origin. Metasediments of the Shakwisa Calcareous Member and the Swebebe Ferruginous Member are intimately associated with the paragneisses, and they are equivalent to the Alldays Marble and Artonvilla Cordierite Gneiss formations in South Africa (Table 4).

Rocks of the Beitbridge Group appear to thicken from the edge of the craton south-eastwards. The most common rocks are arkosic paragneisses, which suggests that the source rocks were various cratonic granites and gneisses. The variety of sediments in the Beitbridge Group was the result of a series of slow transgressions and regressions of the shoreline across a broad arkosic alluvial plain. Rocks of the Shakwisa Calcareous Member were apparently deposited in a stable shelf environment, possibly with a fringing reef, onshore dunes and littoral sands, because marbles and quartzites are now closely associated. The occurrence of graphite and magnetite with the limestone suggests a biogenetic origin, whereas the presence of ophicalcites indicates the deposition of dolomites in shallow back-reef areas. Uplift probably caused the interfingering of continental alluvium and further transgression created a lagoonal environment in which colloidal silica and iron could be deposited to form the ferruginous quartzites. Leaching of the iron offshore created muds rich in magnesium and aluminium, and these now form the cordierite-bearing gneisses of the Swebebe Ferruginous Member. The aluminous muds may have been separated from the lagoonal deposits by sand bars now represented by quartzite. A series of regressions and transgressions of the shoreline apparently allowed for the deposition of quartzites to form the Nulli Formation at the same time that mafic lavas and tuffs were extruded pene-contemporaneously.

Diti Paragneisses

The Diti Paragneisses are widely developed in the northern half of the map-area, especially west of the Nulli Range, where they are best exposed in wells and pans or in borrow pits along the main roads. In the south the various gneisses are better exposed where the leucocratic rocks form low ridges or koppies, and the biotite gneisses are best seen as pavements along river courses. In the north the paragneisses form a monotonous plain with a ubiquitous cover of dark reddish-orange soil that has a granular surface wash of quartz and feldspar fragments, with lighter grey anthills. In the better drained southern regions, sandy soils overlying the leucocratic gneisses are yellow to brown in colour, and they contain a coarse granular scree of quartz and feldspar. The gneisses are covered by stunted mopani and acacia scrub in the north; air photographs have a distinctly darker tone where these gneisses are infolded with mafic granulites which also have darker coloured soils.

The Diti Paragneisses have their greatest extent in the north-west of the area, where they form a broad antiformal structure representing an eastwards continuation of the gneisses described west of Beitbridge (Watkeys 1979). These gneisses are bounded in the east by the Nulli Range, in the south-east by quartzites forming Malezikwe Hill, and in the south by the remobilized Singelele and Bulai gneisses. Dips are generally low to the south and south-east but become steeper near Lutumba Store where a subsidiary synformal axis runs parallel to the main Masvingo road. Rocks of the Shakwisa Calcareous Member are exposed along the Diriza Ridge where dips are steep and to the west. The eastern boundary along the Nulli Range and west of Malezikwe Hill has been quite extensively invaded by rocks of the layered anorthosite suite, the presence of which reflects a more complex structure. Other bands of paragneiss are exposed as windows within the charnockitic Singelele Gneiss; they fill a synformal closure west of Diriza Hill between Mapai Dam and Beitbridge Aerodrome and they occur as inclusions in the Bulai Gneiss. Diti Paragneisses enclose the Luchewe Basin and they also fill the centre of this structure whereas basement gneisses are exposed in paragneisses around the eastern lobes of Bulai Gneiss. Swebebe Hill is also enclosed by paragneisses which are folded into an ENE-trending synform that follows the Etomgwani Valley west of the Nulli quartzites forming Sebetwe Hill.

East of the central belt of Nulli Formation quartzites, which compose the Sebetwe, Shingwanyana, Malezikwe and Nulli hills, is a broad sinuous tract of paragneisses that encloses synformal horizons of Swebebe Ferruginous Member rocks and also reflects the major NW-trending F4 fold structures. In the east this belt extends from the vicinity of the Pande Mine and it is bounded by Nulli Formation quartzites that form Shampali, Mwanandou, Mafungwe and Bodekwa hills. Near the Sinyoni Claims, and along the entire eastern boundary of this belt, rocks of the layered anorthosite suite are prevalent. The centre of the Bodekwa Dome is occupied by Diti Paragneiss which is also wrapped around the outside of the quartzites as thin horizons infolded with anorthositic hornblendites and quartz-hornblende gneisses. Thin bands of paragneiss are commonly infolded within the main belt of quartz-hornblende gneiss south of Mafungwe Hill. Southwards, paragneisses become more complexly infolded with the intrusive anorthositic rocks lying to the east of the Shampali-Mwanandou Ridge and west of the line of Nulli Formation quartzites reflected by Malise, Mabana, Saluwana and Shakwisa hills. Here the sinuous paragneiss horizons reflect the complex structure of this area and also enclose thin bands of ferruginous and calcareous metasediments. East of Shakwisa Hill is the main expression of the Shakwisa Calcareous Member in which paragneisses are intimately interleaved with quartzites and marbles; here too they occupy the core of the dome structure. Southwards near Saluwana Hill and extending across the Shurugwe Fault, paragneisses again form the main outcrop with a few interbanded quartzites, magnetite-quartzite and ultramafic granulites.

For the purpose of description the Diti Paragneisses have been subdivided as follows:

a) Leucocratic paragneiss
b) Garnet-biotite gneiss
c) Granitic biotite gneiss
d) Leucocratic calc-silicate gneiss
e) Garnet granulite
f) Basal biotite-garnet gneiss

The *basal biotite-garnet gneisses* are distinctive in that in places they contain tightly infolded bands of garnet granulite and are locally migmatitic. These gneisses are infrequently exposed as undulose pavements which weather into rough flaggy slabs parallel to the micaceous or, more rarely, hornblendic foliation. The rocks are coarse-grained mesocratic gneisses containing garnet porphyroblasts which may reach 4 cm in diameter. In a sample (25 389) the micaceous layers, defining a strong foliation, wrap around garnet porphyroblasts, adjacent to which quartz-feldspar intergrowths have developed in the low-pressure shadow-zones. The gneisses are commonly tightly folded and quartz-feldspar rods often develop parallel to the fold axes. This rodding is preferentially exposed on weathered surfaces.

A mesocratic garnet-hornblende gneiss (slide 25 390) has small rounded or irregular garnets, 0.4-1.0 mm, which contain numerous tiny quartz droplets and are associated with green hornblende, quartz and irregular ore grains. Hornblende crystals, up to 1 mm long are polygonal adjacent to garnets but are strongly embayed against quartz. Rounded apatites are associated with the ore and tiny zircons occur in the hornblende, whereas, grains surrounding garnets are fractured and these lines are filled with chlorite. Quartz occurs as small rounded or irregular discrete grains or as inclusions in feldspar. It shows undulose extinction and deformation lamellae due to late stress. Plagioclase grains (An 55) show good albite-twinning and are antiperthitic, myrmekitic or sericitic in patches near irregular crystals of perthitic microcline.

The *garnet-granulites* form a heterogeneous group of rocks which occur in a number of associations within the Diti Formation: quartz-rich garnetiferous granulites and gneisses grade into leucocratic gneiss; or they also occur within the Singelele Gneiss; garnet-orthopyroxene-cordierite-plagioclase-granulites are tightly infolded within the basal biotite-garnet-gneisses. Elsewhere in the Diti succession garnet-pyroxene granulites are associated with magnetite-quartzites; garnet (green), diopside, plagioclase, scapolite-granulites occur with sedimentary serpentinite and garnet-plagioclase-granulites grade into anorthositic gneiss. The last three of these associations are described under their appropriate headings.

Although most garnet-granulites in the basal gneiss contain garnet, much of this mineral has been replaced by orthopyroxene and cordierite thereby making the rocks resemble mafic granulite. A complete gradation appears to exist between garnet-sillimanite-cordierite-quartz-granulites in the leucocratic gneisses and the garnet-hypersthene-cordierite-plagioclase rocks found in the basal biotitic gneisses. Garnet-granulites are more frequently found within the basal gneisses where they are strongly infolded. They occur as thin bands in the leucocratic and associated amphibolitic gneisses and at some localities garnet granulites grade into Singelele Gneiss which indicates the sedimentary origin of that rock.

As garnet-granulites exist only as thin horizons in the enclosing gneisses, they do not outcrop significantly but they may give rise to piles of rounded to elongate boulders forming ridges a few metres high. The boulders weather with a rough garnet-studded, reddish, iron-stained skin and the overlying soils are often rich in loose garnets. The granulites themselves are coarse-grained, reddish melanocratic rocks which show little sign of foliation except where they grade into leucocratic gneisses, when they themselves become gneissic. The granulites have been deformed by all the fold phases that have affected the Beitbridge Group and they often define isoclinal folding in the paragneisses. Crenulations are often well-developed parallel to local F2 fold axes which are often defined by quartz-rodding. Garnets are commonly intergrown with quartz, and others are fractured and recemented by quartz. Large-scale boudinage of garnet-granulites within the paragneiss was noted at a number of localities.

Petrography: A garnet-granulite (slide 25 391), from an outcrop in charnockitic Singelele Gneiss north east of Beitbridge Aerodrome, has been chemically analysed (Table 4, Lab. No 75/76). The rock contains porphyroblastic garnets (0.35 - 7.0 mm) in a matrix of quartz, plagioclase, cordierite, sillimanite and biotite. The garnets have smooth to very irregular outlines, are generally rimmed with biotite and have abundant inclusions of biotite, ore, quartz and tiny sillimanite prisms. Quartz crystals (0.35 - 1.0 mm) occur adjacent to or include eyes of cordierite. Cordierite occurs in polygonal aggregates, 0.2 to 1mm across, and individual grains show multilamellar twinning. It occurs with garnet and contains tiny inclusions of sillimanite which also form an assemblage with biotite and quartz in the more granulated cordierite. These minerals wrap around garnet porphyroblasts, showing the irregularly folded foliation of the rock. Foxy-red biotite flakes (0.2 - 1.0 mm) are embayed against cordierite and form irregular trains in the groundmass. Biotite is also associated with and altered to granular ore and light yellow chlorite in places. Biotite flakes form inclusions in garnets and also fill fractures surrounding this mineral. Plagioclase occurs with quartz and cordierite, and larger crystals are fractured and sericitized. The estimated modal composition of the rock is 45 % garnet, 10 % biotite, 8 % sillimanite, 16 % cordierite, 15 % quartz, 5 % plagioclase and 1 % ore.

Two samples of garnet-hypersthene granulite were collected (slides 25 392 and 25 393). In the first of these (25 392) symplectic intergrowths of hypersthene and cordierite are well-developed whereas the adjacent garnet-cordierite assemblage does not show signs of an intergrowth. Hypersthene forms idioblastic or irregular poikiloblastic crystals (up to 10 mm) and also occurs symplectically with cordierite as small pleochroic, optically orientated laths (up to 0.35 mm) together with quartz and rods of rutile. Cordierite locally contains irregular garnets associated with rutile needles as well as green spinel and ore granules. Garnets have straight borders with cordierite, and in places form against elongated quartz crystals. They are sometimes poikiloblastic and contain inclusions of rutile and quartz. The second rock (slide 25 393) is of similar appearance and texture, but the symplectic intergrowths are between ore and hypersthene, and hypersthene and plagioclase. Quartz may be intergrown with garnet which is replaced in part by hypersthene-plagioclase symplectite. Diopside occurs in association with ore and hypersthenes are part-altered to hornblende. The composition of this rock is estimated as 25 % garnet, 25 % quartz, 20 % plagioclase, 15 % hypersthene, 2 % diopside, 3 % hornblende and 10 % ore.

An intermediate granulite (slide 25394) has hypersthene-cordierite symplectites coexisting with garnet and quartz. The rock has a granoblastic-elongate texture in which garnets form irregular crystals (0.35 - 3.50 mm). They contain inclusions of sillimanite and rutile, and when forming in poikiloblastic quartz crystals, they contain hypersthene. Biotite flakes are also associated with the garnets. Cordierite aggregates are rimmed by hypersthene and these two minerals are intergrown in places.

A garnet-sillimanite-quartz-granulite (slide 25 395) grades into leucocratic gneiss near Shakwisa Hill. Red sieve-textured porphyroblastic garnets (2 - 6 mm) form about 60 % of the rock and occur in a matrix of quartz and fibrous sillimanite. Quartz droplets and inclusions may make up 25 % of any one garnet, but quartz mostly occurs as equant to elongate crystals (0.9 - 3.5 mm) comprising 30 % of the rock matrix.

Leucocratic calc-silicate gneisses have the greasy feldspathic appearance of anorthositic gneiss but they are conformable with and grade into leucocratic gneiss. These rocks are most commonly found in bands a few metres to 30 m wide within the gneisses surrounding the Bulai and Singelele gneisses in the west of the area. They are fairly common west of Beitbridge where they are described by Watkeys (1979). These rocks grade into darker calc-silicate gneisses with an increase in the amount of mafics, which include diopside, sphene, allanite and garnet. The garnets are commonly porphyroblastic and they may be rimmed by an intergrowth of clinopyroxene, plagioclase and quartz. They are commonly speckled owing to the presence of dark minerals; garnet trains in places define a nebulous foliation or isoclinal folding within the rock. Quartz tends to be rodded and, on weathering, it is preferentially exposed on a smooth yellow-brown skin. When broken, the gneisses are usually found to be fresh, which is a common feature of calc-silicate rocks. Consequently the gneisses are hard and are exposed as pavements or flaggy boulders, commonly cross-cut by quartz veins and patches of secretion pegmatite.

A number of samples of leucocratic calc-silicate gneiss were collected. They vary from very fine to coarse-grained nebulitic, feldspar-rich granoblastic rocks to gneisses with a well-developed mineral foliation. The foliation is usually defined by bands of plagioclase, up to 3 mm wide, separated by trains of yellowish-red grossular garnet and sphene. In one sample (slide 25 396) bands of garnet and augite occur and in another (25 397) crystals of diopside and sphene define a faint foliation.

Quartz forms blocky or elongated irregular crystals 2 - 5 mm which constitute 8-70 % of the leucocratic calc-silicate gneisses. In one sample (slide 25 398) quartz contains smooth inclusions of plagioclase, apatite, allanite and sphene and in another (slide 25 399) the quartz grains are strongly aligned parallel to the foliation. In places the quartz has interlobate or interpenetrating borders against plagioclase and it often forms tiny droplets along the borders of plagioclase crystals. Quartz usually shows undulose extinction as well as the development of deformation lamellae, both parallel and perpendicular to the foliation. Plagioclase forms smaller crystals (0.3 - 3.5 mm) which have interlobate, curved or sutured borders against quartz. Plagioclase comprises 50 - 75 % of these rocks and it generally shows well-developed albite and pericline twinning. Its composition is estimated as An_{46-84}. A few larger crystals (in 25399) show patches of antiperthite and contain inclusions of sphene, apatite, allanite, diopside and zircon. In another rock (slide 25 398) the plagioclase shows signs of sericitization around the crystal edges and along cleavage planes.

Clinopyroxene forms 4-12 % of these rocks. Diopside occurs as irregular equant to elongate crystals which are aligned within the foliation (slide 25 400). These crystals have interlobate borders against plagioclase and quartz, and they contain rounded inclusions of plagioclase, sphene, ore and metamict allanite, which is usually surrounded by radiating fractures. Verdant green augite forms crystals up to 1 mm long; these are usually intergrown with epidote. In slide 25 396, augite forms aggregates of small irregular crystals with garnet and plagioclase. The pyroxenes may be rimmed by hornblende but in slide 25 400 diopside is part-altered to a deep green chlorite. Hornblende generally occurs as irregular intergranular crystals associated with diopside and garnet. Garnet, also, is usually intergranular to the plagioclase. Individual calc-silicate gneisses may have 1- 40 % of this mineral. The garnets contain numerous inclusions of metamict allanite, sphene, apatite and plagioclase (slide 25 397) and they occur as irregular aggregates in slide 25 401, where they are rimmed by hornblende, itself altering to a brown chlorite. Another rock (slide 25 397) shows a rim of augite crystals symplectically intergrown with plagioclase and sphene which may have been the result of a reaction during the time of retrograde granulite-metamorphic conditions. Allanite, apart from forming inclusions in garnet, diopside and plagioclase, occurs as zoned crystals in slide 25 396 where the core is yellow and the rim colourless and highly birefringent. Ore is often graphically intergrown with plagioclase and it is also associated with allanite and sphene which is partly rimmed by deep green chlorite.

Granitic-biotite gneisses are limited in their exposure and they are not easily distinguishable from the enclosing paragneiss except for their granular, often decomposed, granitic appearance. They form rough, weathered exposures in the Diti River where the road from Diti Store crosses this stream near Lukange School. They have also been found in the gneisses north of Lutumba Store and north-east of the old Main Drift across the Limpopo River.

The granitic biotite-gneiss forms medium-grained, friable, leucocratic to mesocratic grey-brown rocks which have been stained by iron oxide. The gneisses are homogeneous with a grain size of 1 to 2 mm, in which a dissemination of small biotite flakes may define a poorly or well-developed foliation. A rough crenulation and quartz rodding is developed in some rocks and the quartz is preferentially exposed on weathered surfaces. On weathering the feldspars turn to clay and the rock becomes friable due to the granular quartz and associated biotite flakes. Both garnetiferous and non-garnetiferous granitic biotite-gneisses occur and these grade into one another.

These rocks vary from massive, inequigranular granitic gneiss (slide 25 402) to well-foliated rocks (25 403). The foliation is defined by the orientation of platy and prismatic minerals and their segregation within the quartzofeldspathic groundmass (25404). Some granulation has taken place resulting in fine-grained polygonal aggregates of quartz and feldspar. Green and brown biotite form irregularly laminated intergranular flakes and aggregates, 0.2 - 2 mm across (25 402). Biotite may constitute up to 40 % of the rocks, and in one instance (slide 25 404) it is associated with a little allanite. Biotite flakes tend to wrap around and rim quartz and feldspar crystals, and in some cases it is symplectically intergrown with quartz. The biotite shows various stages of alteration to green chlorite, ore and epidote; some flakes are strongly stained by limonite. Green hornblende forms polygonal, interlobate crystals up to 2 mm long which are embayed against, and intergranular to, the feldspars. It is intergrown with ore and garnet granules and includes tiny allanite crystals (25403). Hypersthene forms a few intergranular crystals 1 - 2 mm long, which contain rounded inclusions of garnet and biotite. It is fractured in slide 25404 where it is veined with limonite, rimmed by ore granules, and also occurs as inclusions in plagioclase. Garnets occur as small rounded but irregular crystals (up to 0.35 mm), and as larger aggregates in some rocks.

Quartz which may form 50 % of these rocks, occurs as irregularly shaped grains 0.3 - 3.5 mm across. It is intergranular to the plagioclase, but interlobate with crystals of high-temperature microcline. In some places, quartz forms inclusions in the feldspar, and in slide 25 403 it shows undulose extinction and deformation banding perpendicular to the foliation. Microcline occurs as irregular crystals up to 3.5 mm across which show strongly developed undulose extinction (slide 25 404) and, more rarely, the presence of cross-hatch twinning. Plagioclase granules, 0.35 - 2.00 mm, contain quartz droplets which grade into myrmekitic intergrowths adjacent to the potash feldspars. The feldspar shows good carlsbad and albite twinning and has an estimated composition of An_{35} - An_{45}. Some grains show marginal irregular sericitization. As an accessory a few large, irregular patches of yellow metamict allanite commonly occurs in association with tiny, rounded zircons and biotite flakes (slides 25 403 and 25 404).

Garnet-biotite-gneisses are common within the Diti Paragneiss succession, but they are easily weathered and therefore do not outcrop well except in the more dissected country along the Limpopo River where they occur as pavements and low dwalas. The better exposures often show exfoliation which produces flat to rounded boulders, depending on the degree of foliation in the gneiss. Northwards, weathered outcrops appear to be restricted to stream bed exposures.

The garnet-biotite-gneisses vary from intermediate, leucocratic to mesocratic micaceous grey-coloured rocks. The oxidation of garnet may impart a yellow stain to the gneisses. They are generally homogeneous, medium-grained rocks although the grain size varies from 0.25 - 5.00 mm in places. The biotite-rich gneisses are the most strongly foliated although trains of garnet and some secretion pegmatites are also aligned in these rocks. This banding often highlights both open and isoclinal folding which produces complex interference patterns in the rock (Plate 1 B and C). Boudinaged leucocratic bands enclosed within biotite gneiss show another structural feature of these rocks (Plate 1 D). Well-developed lineations caused by crenulations of quartz-feldspar rodding are also common and garnet, hornblende or biotite may also be developed parallel to this lineation. Quartz-feldspar secretion-veinlets commonly show tight folding or ptygmatic folding. Plate 3 D shows three sets of cross-cutting, ptygmatically folded veinlets. The relative intensity of folding of the veins in any one direction indicates that the maximum shortening of the rock was from the north, possibly a cause of Bulai Gneiss injection.

Secretion-pegmatite veinlets commonly enclose biotite flakes or garnets as well as potash feldspar porphyroblasts, up to 10 cm in length; these are, however, usually restricted to the biotite-gneisses adjacent to the Bulai Gneiss or charnockitic aureole. Late hydrothermal activity has also modified the biotite-gneisses along fractured lines where evidence of epidotization and albitization and the replacement of biotite and garnet by green chlorite is seen.

Petrography: Two samples of biotite-gneiss have been chemically analysed (Table 3, Lab.No's 75/57 and 76/37). The sample represented by slide 25 405 is a grey-intermediate biotite gneiss, whereas slide 25 406 represents a biotite-rich variety. Both samples are corundum-normative, which, together with the presence of biotite and garnet, indicates that the rocks are paragneisses.

A leucocratic rock (slide 25 405) streaked with biotite and dotted with garnets, is intermediate between a leucocratic gneiss and a garnet-biotite-rich gneiss. A foliation is defined by quartz rodding and by the alignment of micas and sweat-out veinlets. A few microcline porphyroblasts and large quartz lenses rimmed by granular microcline, have crystallized across this foliation. Quartz occurs as elongated crystals and lenses, up to 2 mm long, which tend to be smooth and rounded. Garnets occur as trains of rounded or irregular aggregates (up to 4mm), whereas biotite forms aggregates of tiny flakes which are associated with ore granules and may wrap around quartz crystals. Fine-grained granular high-temperature microcline and microperthite forms most of the groundmass, whereas plagioclase is subordinate.

Where the latter occurs, microcline and quartz-myrmetitic patches are formed and patch-perthite is more in evidence. The composition of this rock is estimated as 30 % quartz, 59 % microcline and perthite, 4 % plagioclase, 5 % garnet and 2 % biotite. Another sample (slide 25 407) contains 61 % plagioclase and only 1 % microcline.

A fine-grained, grey garnet-rich biotite-gneiss (slide 25 406) shows a foliation caused by the flattening and alignment of garnet, quartz, feldspar and mica. The rock has a granular appearance; quartz crystals (0.2 - 1 mm) are elongated, rounded or irregular. Quartz forms 35 % of the rock and may be intergrown with biotite around its crystal boundaries. Granular garnets form 20 % of the rock and they occur as rounded to irregular crystals (0.3 - 2.0 mm). They enclose numerous tiny quartz droplets and some ore granules, whereas biotite flakes have crystallized along the fracture lines in the garnet. Biotite, which is associated with garnet, forms about 10 % of the rock and it is aligned with the garnet in trains parallel to the foliation. It commonly occurs as ragged flakes (0.1 - 1 mm) which are intergranular to quartz and feldspar, and may be intergrown with these minerals. This indicates that the quartz continued to crystallize, after the biotite was enclosed within it. In places biotite is part-altered to epidote which has crystallized parallel to the cleavage planes. Plagioclase forms equant to elongate crystals (0.35 - 2.00 mm) which have embayed borders against quartz, biotite and garnet. It shows good albite and pericline twinning, from which a composition of An_{44} was estimated. Many of the crystals, however, show no twinning at all and sericitization along cleavage traces is common. This andesine makes up about 35 % of the rock.

The *leucocratic paragneisses* are more resistant to weathering than the other gneisses and therefore they are the most common variety seen in outcrop. It is these garnetiferous quartzofeldspathic rocks, more than any other lithology, that are distinctive of the Diti Paragneiss succession throughout the Central Zone in Zimbabwe, and, as the Maryland Leucocratic Gneiss Formation, in South Africa. In the south, where they are better exposed, leucocratic paragneisses and granulite may form low boulder-strewn koppies and ridges up to 15 m high. Elsewhere the gneisses are best exposed in rivers but in the north they may occur only as flat pavements near pans or as piles of boulders along the main roads, where they have been redistributed during construction. The leucocratic gneisses tend to outcrop as elongated, tabular boulders the shapes of which are controlled by jointing, fracture-cleavage and a well-developed mineral lineation. The massive leucocratic granulites, however, form rougher and more irregularly shaped boulders.

The leucocratic gneisses are hard, white to sparsely biotitic light grey rocks, which may be spotted with orange patches caused by alteration of garnet. These rocks develop a smooth brown weathered skin, commonly studded with garnets up to 3 mm in diameter. When there are numerous, haphazardly distributed garnets the rock has a mottled appearance, but often there are no garnets and a weak foliation is defined by ribbons of quartz and feldspar. Trains of granular garnets and tiny biotite flakes emphasize this foliation and may define early isoclinal folds and complex interference patterns, whereas quartz rodding tends to be aligned to the F3 fold direction. Differential weathering tends to accentuate the quartz rodding. Ptygmatic folding of some secretion veinlets indicates the former plastic

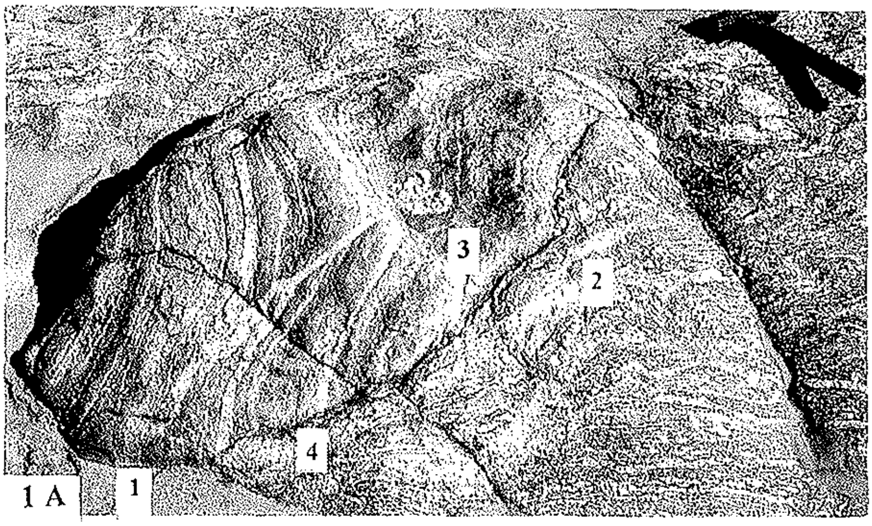
Explanation to Plate 1

1 A : A boulder of enderbitic basement gneiss (1) is enclosed within tightly folded biotite paragneiss (2). The foliation of the basement gneiss is displaced by an open folded, quartz filled fault line (3), and the boulder itself is orientated oblique to the enclosing paragneiss (4).
Grid Ref. TL 131 330.

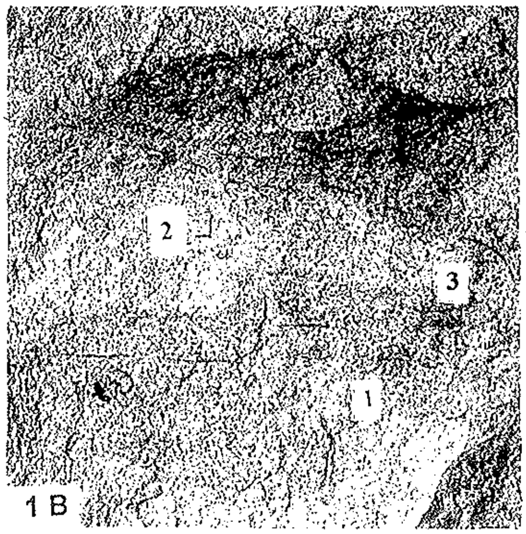
1 B : Biotite paragneiss (1) within the charnockitic aureole containing infolded leucocratic paragneiss (2).
Grid Ref. SL 982 501

1 C : Tight F2–similar folds within biotite paragneiss of the Diti Formation.
Grid Ref. TL 210 274

1 D : Boudinage of leucocratic gneiss layers (1) within biotite paragneiss (2).
Boudins are rimmed by secretion veinlets (3) which are ptygmatically folded elsewhere.
Grid Ref. TL 011 375



1 A



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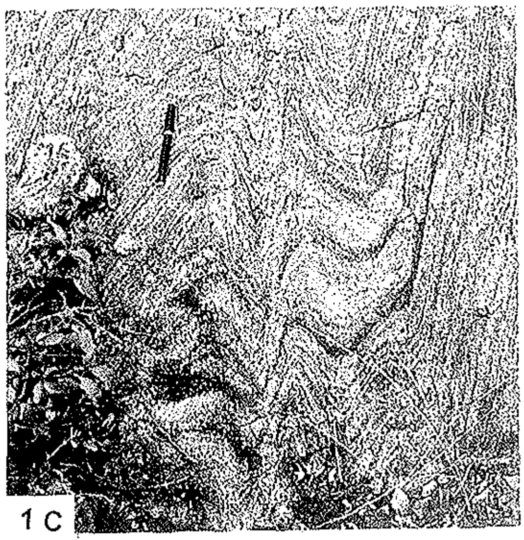
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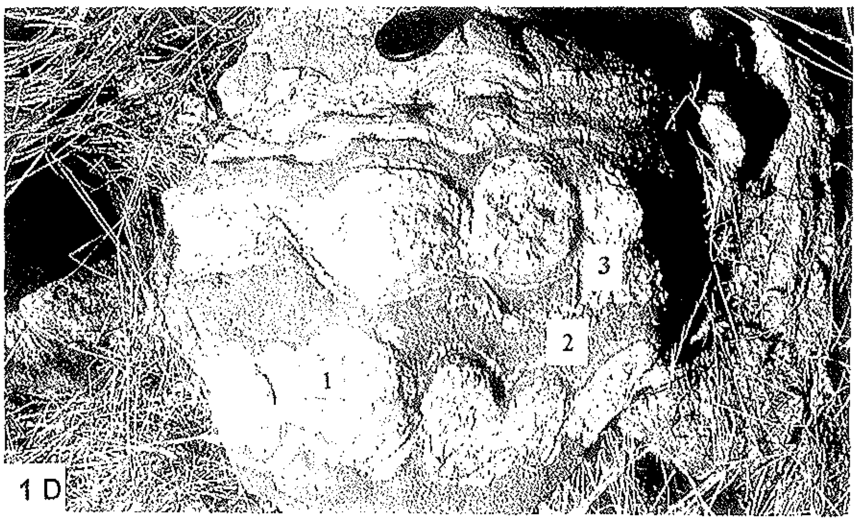


1 D

state of the paragneisses, in which the more competent leucocratic bands may show kink-banding and boudinage.The leucocratic gneisses are usually medium-grained, although they do vary in grain size. The anatectic granulites, however, tend to be pegmatitic, showing a graphic intergrowth of quartz and feldspar.

Garnets form irregular crystals and augen 0.5 - 10.0 mm in diameter, in the leucocratic gneisses; but in the anatectic granulites they may be 20 mm across. Orientated or haphazardly distributed potash feldspar porphyroblasts are locally developed, especially in the aureole surrounding the Bulai Gneiss. They may either be euhedral or lens-shaped and are 0.5 - 7.0 cm across. Various ages of secretion-pegmatite veining are also common adjacent to the Bulai Gneiss, where the leucocratic gneisses may develop a migmatitic appearance and show signs of anatexis.

Late hydrothermal activity has modified the gneisses especially adjacent to fracture-lines and dolerite dykes. Plagioclase becomes sericitized or epidotized and it may develop a pink coloration owing to fine dissemination of hematite. Hematite and kaolin develop parallel to cleavage planes in plagioclase (slide 25 411), but generally potash feldspar shows the strongest hematite staining. In another sample (25 412) epidote granules and veinlets occur in plagioclase, and iron ore granules occur along the same fracture line in an adjacent potash-feldspar crystal. Biotite has been replaced by chlorite and magnetite, and garnets are replaced by hematite and rimmed by chlorite. Ore granules may be fractured and recemented by epidote, and veinlets of drusy quartz and calcite fill fractures in the hydrothermally altered rocks.

Petrography: Two samples of leucocratic paragneisses from the Beitbridge area were chemically analysed (Table 3, Lab. No's 75/60 and 76/34). Both samples contain normative corundum, which indicates that the rocks could have had a sedimentary origin.

A fine-grained, well-banded leucocratic gneiss (slide 25 413), has gneissic foliation defined by layers of orientated garnet and biotite in a mass of elongated quartz and feldspar granules. The garnets form sub-rounded and elongated, irregular crystals (up to 3.5 mm), which appear to have been rotated within the plane of foliation. Brown biotite flakes are orientated parallel to the foliation in which they may occur as aggregates. Biotite tends to enclose the garnets and may be embayed against quartz. It is in places altered to chlorite. Quartz forms irregular, elongated crystals up to 2 mm long. Smaller crystals, however, are rounded and form inclusions within the feldspars. Quartz shows undulose extinction due to deformation. Plagioclase, which comprises some 48% of the rock forms equant rectangular crystals, up to 2 mm long. They show good albite twinning, some patches of antiperthite, and signs of myrmekitic intergrowth adjacent to microcline grains. The plagioclase is partially sericitized and it has an estimated composition of An_{35}. High-temperature microcline forms about 22 % of the rock and is mostly intergranular in relation to the quartz and plagioclase. A garnetiferous leucocratic gneiss (slide 25 414) has hornblende as the major associated mafic mineral.

A medium-grained leucocratic granulite (slide 25 415) is white and largely feldspathic with only irregular garnets and tiny biotite flakes. The rock has a granoblastic-elongate texture in which the quartz is intergranular to the feldspars. The granular plagioclase is antiperthitic in places and also shows alteration to clay. Albite twinning indicates a composition of An_{24}. Some intergranular microcline occurs, locally associated with crystals of cordierite which contain tiny quartz droplets. Intergranular mica flakes have been replaced by epidote and are associated with iron oxide granules. Only one granule of metamict allanite was noted.

A microcline-rich leucocratic gneiss (slide 25 416) has the foliation emphasized by quartz rodding, by tiny flakes of muscovite and by a few altered garnets. Microcline shows clear cross-hatched twinning, the development of some patch-perthite and alteration in places to kaolin.

Shakwisa Calcareous Member

Rocks of the Shakwisa Calcareous Member form a distinctive assemblage of metasedimentary rocks midway in the Diti Formation. The assemblage indicates a shallow water sedimentary environment and consists of marbles, ophicalcites, calc-silicate rocks and quartzites interbanded with leucocratic gneiss, garnet-granulite, rare corundum-bearing spinel-granulite and enstatite-cordierite-granulite. Often interlayered with these rocks are two-pyroxene mafic granulites or amphibolitic gneisses that may be of igneous origin, and which are similar to those found associated with quartzites of the Nulli Formation. The Shakwisa rocks are equivalent to the Alldays Marble Formation in South Africa which in the Messina area is developed across the linear zone south of the Dowe Tokwe Fault and north of Tshipise. In Zimbabwe this assemblage continues north of the Shurugwe Fault and to the east of the main surface expression of the layered anorthosite suite. Calcareous rocks are also encountered north-east of

Beitbridge where Diriza Hill is the most prominent feature.

The Shakwisa assemblage is represented as follows:

1) Forsterite-serpentine and diopside-bearing granulitic marbles of variable purity
2) Cross-cutting late secretion dolomite veins
3) Metasedimentary serpentines (ophicalcites)
4) Diopside-hornblende-tremolite-plagioclase-microcline and garnet-bearing calc-silicate rocks
5) Massive and sillimanite-bearing quartzites
6) Corundum-bearing spinel-granulites
7) Enstatite-cordierite-granulite
8) Leucocratic paragneisses with garnet-granulites
9) Amphibolitic gneisses and granulites

The close association of limestones and quartzites indicates a shallow water origin for these rocks. The relationship of graphite and magnetite with the limestones may indicate a lagoonal environment in which organic carbon and iron have been biogenetically precipitated. Dolomite is characteristic of back-reef areas and apparently results from the reaction of lime-carbonate sediments with magnesium-bearing sea water (Pettijohn 1957, p. 421). Dolomite was probably fairly abundantly developed as indicated by the ubiquitous formation of forsterite in these rocks. The sedimentary origin of the serpentinites associated with the marbles is indicated by the complete gradation from serpentinite into forsterite-free marble. Spectrographic analyses of these rocks by I.H. Green show that the nickel, chromium and copper contents, all less than 200 ppm, are low in comparison with the proportions of these elements in serpentinites of known igneous origin. Diopsidic calc-silicate rocks are also closely related to the marbles and quartzites and they grade into both of these rock types.

Distribution and Field Relations

Rocks of the Shakwisa Calcareous Member are exposed in two major areas on either side of a major NNE-trending synclinorium which includes the Nulli Range, the main development of the Swebebe Ferruginous Member as well as the Layered Anorthosite Suite. On the west side of the synclinorium the calcareous rocks form the Diriza Range, occur 5 to 6 km south-east of the main Beitbridge to Masvingo road and trend parallel to it. In the south-east of the map-area, the Shakwisa Calcareous Member occurs in the Shakwisa Dome just east of Shakwisa Hill. These rocks extend beyond the map-area and are known to continue through the Chipise Communal Land to Bubani Ranch north-east of Marungudzi (Broderick 1979).

Within the Shakwisa Dome the calcareous assemblage consists of a series of complexly infolded layers of forsteritic or serpentine-bearing marbles, calc-silicate rocks, garnet-granulites, leucocratic paragneiss and amphibolitic gneiss. These bands occupy the low ground between parallel but isoclinally folded ridges of massive quartzite, where generally the calcareous bands are only 1 - 8 m wide. These rocks extend to the south-east where they dip steeply S and SW, and have been injected by secretion-veins of high-grade crystalline dolomite. A thin horizon of corundum-bearing enstatite-cordierite-granulite, in which sillimanite has been formed, occurs 15 km east of Shakwisa Hill. Near here, sedimentary serpentinites are especially noticeable; one zone, about 1 km long, is bounded by two oblique NW-trending faults 300 metres apart. Dips along the western side of the dome are to the W, but in the north the beds are overturned and dip south at moderate angles. In the east calcareous metasediments, paragneisses and serpentinites dip eastwards at moderate angles and a southern lobe is comprised largely of calc-silicate rocks, some of which are tremolitic.

The calcareous rocks forming the Diriza Ridge are terminated to the south-west by an anticlinal closure. The same lithological assemblage is seen as in the Shakwisa Dome, but corundum-bearing spinel-granulites are more in evidence especially at the Diti Dip claims. Forsteritic marbles form the core of the anticline in the south where they flank low quartzite ridges that dip steeply SE. The limbs of the antiform continue discontinuously as a series of elongate, isoclinally folded quartzites with sporadic marbles developed along their length. The two limbs are about 3 km apart by the time they pass north-eastwards beyond the map-area.

Elsewhere, thin horizons of calc-silicate rock occur west of Ngwani Hill and 4 km further south-west, where granular and massive quartzites cap a low hill composed of interbanded calc-silicate rocks and marbles. Other thin bands of diopside-bearing calc-silicate granulite are exposed north-west of Saluwana Hill and west of Malise Hill. Similar horizons occur west of the Pande Mine serpentinite and south of the Pande Mine road near the Samtete River.

Marbles are usually associated with quartzite ridges between which they occupy the low- lying ground. They may outcrop as flat, scree-covered pavements, although more commonly they are exposed in river beds or at pans. The more massive granular marbles weather into rough rounded boulders, but those with a better developed mineral foliation form slabs. These boulders usually show a classic grey elephant-hide weathered surface but they may also show a rough pitted skin owing to the preferential weathering out of mafic minerals. Other boulders may be rough and granular if the minerals are resistant and stand out on the surface. The soils tend to be grey or reddish and the surface commonly contains marble chips or graphite flakes.

The marbles are coloured in various shades of grey; they differ from mesocratic granular rocks and fine-grained melanocratic rocks rich in forsterite or serpentine. The latter may be greenish-grey whereas magnetite-dusted marbles, in places intergrown with graphite, may have a dirty grey or black, coal-like lustre. Lenses of coarse-grained crystalline dolomite are white, and these cut across the foliation of the surrounding grey marbles. The enclosing marbles are homogeneous medium- to coarse-grained dolomitic limestones or limestones which are generally granular in texture. Preferential orientation, sometimes in trains, of rounded to elongate crystals of calcite, forsterite, diopside, mica, magnetite, spinel, garnet or hornblende, may define a diffuse undulose foliation. Although folding occurs in the marbles, it is rarely seen, but an exposure in the Lukawe River west of Diriza Hill shows the contact between biotite-paragneiss and an overlying calcareous layer (Plate 2 A). This indicates that the marbles have been disharmonically folded and, owing to their incompetence, they have cut across the foliation of the paragneiss.

A partial analysis of a *secretion-dolomite vein* (slide 25 417, Barclays Bank analysis of 18/9/73) shows 20.74 % magnesia and 30.53 % lime. This represents an almost pure crystalline dolomite (compare analyses of dolomitic limestone marbles, Table 5, Lab. No's 70/380 and 76/94). The coarse grain size and the cross-cutting character of the secretion dolomite indicates that it represents a late event, and was formed probably at the expense of calcite and forsterite following the introduction of water and carbon dioxide into the limestones:

$$4\ Fo + 5\ Ca + 5\ CO_2 + H_2O \rightarrow 5\ Dolo + 1\ Talc$$
(Winkler 1974)

Petrography: The first of four samples of marble (slide 25 420) is a coarse granular grey biotite-diopside marble; the second (25 421) is a medium-grained spinel-bearing marble; the third (25 422) is a coarsely crystalline black coal-like marble and the fourth (25 423) a dark lustrous magnetite-graphite-marble. Forsterite- and serpentine-rich marbles are described as ophicalcites with the sedimentary serpentinites.

Calcite, which makes up 60 – 95 % of a marble, occurs as euhedral or irregularly-shaped crystals that may be skeletal or, as in slides 25 420 and 25 421, strongly sutured. This indicates a period of post-tectonic annealing. The crystals (0.35 - 7.10 mm) may be elongated parallel to a vague foliation. Some large calcite crystals are dusted with iron ore or stained by irregular patches of limonite.

Diopside in slide 25 420 occurs as subhedral intergranular crystals 0.5 - 6.0 mm long. Tiny irregular inclusions of plagioclase, biotite and calcite occur in the diopside which is part-altered to a dark green iron-rich chlorite which fills branching 2-mm veinlets. Green hornblende forms small euhedral or irregular crystals (up to 1 mm) which may be rimmed by iron ore. These crystals contain inclusions of ore, calcite and zoisite. Slide 25 420 contains rounded crystals and irregular aggregates of a colourless garnet with inclusions of biotite and magnetite. Garnet also occurs as inclusions in diopside, plagioclase and calcite crystals. Brown biotite flakes occur in two samples (25 420 and 25 422), where they are associated with magnetite. Biotite shows crenulated cleavages due to stress, and is sometimes altered to green chlorite and stained by limonite.

Polygonal crystals of spinel, up to 1 mm (slide 25 421), are apparently replaced by corundum which occurs as radiating laths. The spinel remnants are rimmed by iron oxide. Corundum also forms irregular fractured crystals, up to 2 mm, which show patchy blue coloration and which are associated with magnetite. Sphene crystals in this rock have a corona of randomly orientated zoisite prisms surrounded by an outer layer of ore granules. Magnetite (in slide 25 423) forms euhedral or irregular intergranular crystals up to 2 mm. Magnetite also forms sheafs of rodded crystals in the foliation, and these are intergrown with fine-grained carbonate material. Finely disseminated graphite occurs in layers parallel to the cleavage in magnetite crystals, but this is not discernable in thin section. In slide 25 422 the calcite is dusted and intergrown with skeletal crystals of magnetite that are orientated in the cleavage planes. Much of the magnetite has altered to hematite and this gives the rock a red speckled appearance.

Sedimentary serpentinites and ophicalcites are common within the Shakwisa Calcareous Member. Ophicalcites are defined as a variety of marble in which forsterite has been altered to serpentine. The serpentinites outcrop on low rounded calcrete-covered rises or ridges that are covered by light grey or brown coloured soils. They grade into serpentine-bearing marbles which weather into rough elongate flaggy

Table 5 : Chemical analyses of Beitbridge Group Metasediments and related Igneous Rocks (in %)

Slide No.	**25 418**	**25 419**	**25 430**	**25 439**	**25 465**	**25 487**	**25 496**	**25 498**
Lab.No.	**70/380**	**76/94**	**70/377**	**75/65**	**76/43**	**76/36**	**75/70**	**76/45**
SiO_2	9.85	11.18	47.92	16.15	56.66	90.12	87.95	57.66
Al_2O_3	2.01	tr	10.99	52.68	23.37	7.04	0.67	4.92
Fe_2O_3	2.13	0.54	0.49	2.07	1.89	0.16	tr	1.34
FeO	0.72	1.43	6.91	7.40	5.93	0.32	2.00	7.70
MgO	17.01	17.69	9.63	11.52	4.29	0.31	3.65	15.66
CaO	31.67	34.18	19.61	5.78	0.66	0.28	5.00	8.78
Na_2O	0.33	0.46	0.61	0.15	0.89	0.29	0.10	0.93
K_2O	0.02	0.10	0.67	1.42	3.66	0.50	0.04	0.40
H_2O^+	4.11	1.35	1.99	1.03	1.36	0.87	0.12	1.34
H_2O^-	0.18	0.11	0.04	0.15	0.17	0.18	0.09	0.10
CO_2	30.59	31.66	0.68	0.34	0.32	0.13	0.11	0.25
TiO_2	0.05	0.16	0.45	1.51	0.79	0.55	0.03	0.44
P_2O_5	0.03	0.03	0.13	0.19	0.42	0.17	0.02	0.32
MnO	1.22	0.73	0.41	0.22	0.07	0.01	0.14	0.23
Totals	99.92	99.62	100.53	100.59	100.48	100.93	99.92	100.07
Specific gravity	2.75	2.82	3.12	3.18	2.85	2.65	2.78	3.08

Analysts: B.J. Radclyffe, ZGS : 70/377, 70/380, 75/75 and 75/70
A.D. Powell, " : 76/36, 76/43, 76/45 and 76/94
Rock types and localities: See Appendix

boulders that owe their form to better defined mineral alignment. The serpentine-rich marbles are soft and may develop a pitted surface on weathering, whereas the serpentinites have a rough brown earthy skin about 1 cm thick.The serpentine-rich marbles usually contain about 30 % of serpentine and a little diopside, although these minerals can occur in varying proportions. Some marbles contain up to 10 % talc.The marbles are even-grained rocks with individual calcite grains up to 4 mm across. They may contain large rounded patches of serpentine or conformable layers of bluish serpentine which are resistant to weathering. Fine-grained, deep-green serpentinites locally contain thin, discontinuous and anastomosing veinlets of chrysotile which seems to fill fracture lines. Other fractures are indicated by trains of ore granules in forsteritic marbles, and isoclinal folding is sometimes seen. Folded bands of marble in the serpentinite may also show boudinage which indicates the relative incompetence of the latter. The development of surface magnesite and magnesite veining is common within the sedimentary serpentinites.

Petrography: All sedimentary serpentinites and ophicalcites are very similar, and their mineralogical and textural differences are illustrated by the samples 25 424 - 25 429. These rocks vary from fine- to coarse-grained, and two distinctive textures are represented. Calcite-rich serpentinous marbles (slide 25 425) have a poikiloblastic granoblastic texture, in which calcite, forsterite and serpentine form well-shaped or rounded interlobate crystals which in places show irregular or sutured margins. Serpentine, which has replaced the forsterite, forms granular ribbons defining the foliation in these rocks. Bands of diopside (slide 25 427) form aggregates of polygonal crystals up to 0.5 mm across.

Serpentine-rich marbles contain up to 75 % serpentine (slide 25 424) and have an irregular granoblastic texture caused by a jumble of interfingering and hair-like intergrowths of calcite, antigorite, chlorite, magnesite and talc. Calcite is usually embayed against the serpentine and is fractured and twinned parallel to the cleavage traces. It appears to be of two ages, as early irregular crystals up to 7 mm, are cemented by secondary intergranular calcite. In slide 25 429, calcite forms skeletal crystals containing inclusions of secondary carbonate which has partly replaced magnetite, serpentine and chlorite, around the grains thereby forming coronas. The calcite is usually clear but is sometimes cut by veinlets of iron oxide that tend to follow the cleavage directions. Some grains are stained by irregular patches of iron oxide.

Forsterite forms rounded euhedral to subhedral crystals (0.2 - 7.0 mm), which are strongly fractured and cross-cut by a network of branching veinlets. These fractures are filled with granules of iron ore, serpentine and a pale yellow clinochlore derived from the serpentine. Forsterite contains inclusions of magnetite and is commonly rimmed by iron oxide. It may survive only as aggregates in the cores of interfracture zones in the serpentines (slide 25 426), and in these areas remnants of an hourglass structure is preserved, in which antigorite fibres grow outwards from the rhombic fragments of forsterite that they enclose. In other rocks (slide 25 424) antigorite forms fibrolamellar aggregates which fill parallel veinlets in calcite, or which occur as patches throughout the rock. Some forsterite is replaced by concentric radiating antigorite fibres. The serpentine is partly or completely rimmed by magnetite or hematite granules, and these minerals are cut by clinochlore-filled veinlets. In ore rock (slide 25 424), long filaments of serpentine have grown at the expense of calcite whereas in another (25 427) serpentine has been replaced by chlorite which also rims the ragged edges of calcite crystals. Generally the serpentine alters to a light coloured clinochlore and this appears to have resorbed iron during its formation. Sometimes a colourless penninite forms tiny flakes which replace serpentine adjacent to calcite crystals. This chlorite is commonly intergrown with magnetite, and radiating chlorite aggregates rim some serpentine and calcite crystals or else cut across them.

Cross-fibre chrysotile fills anastomosing fracture-lines that form sub-parallel to the foliation (slide 25 424). Granular iron ore trains fill the core of the chrysotile veins and may also crystallize parallel to the fibre direction. Rounded patches of serpentine contain inclusions of magnetite and they may be largely altered to massive decussate crystals of talc (slide 25 425).

Fractures may also be filled by talc veinlets in which a talc-magnetite intergrowth may rim microgranular magnesite. The serpentines are commonly cut by a network of limonite-stained magnesite veinlets and some serpentines are largely replaced by magnesite (slide 25 426). Veins of dark brown-stained cryptocrystalline quartz (slide 25 425) have apparently formed during serpentinization, as they are an earlier product than the clinochlore.

In some samples garnet occurs as granules up to 3 mm across, and these are rimmed by nearly isotropic serpentine. In slide 25 428 phlogopite forms ragged flakes associated with forsterite. It is vaguely orientated in the foliation and is partly altered to chlorite, with associated iron ore. In this rock, green pleonaste spinel and magnetite crystals occur in association with forsterite. In slide 25 429 some green spinels are rimmed by limonite and magnetite, whereas others have a corona of epidote surrounded by radiating chlorite and iron ore. Many of the spinels are partly or wholly replaced by iron ore filaments.

Several foliation directions can be recognised in the serpentinites. An early, strongly developed foliation is indicated by segregation layers of granular calcite, forsterite and iron ore, which were probably aligned during the F1 fold phase. A later F2/F3 foliation is indicated by the orientation of calcite and olivine crystals almost at right angles to the F1 direction (slide 25 424). Oblique granular calcite bands in the chrysotile veins are terminated at the edges of such veins and they may represent a period of fracturing prior to serpentinization. Fracturing of these rocks during the F4 phase was apparently followed by crystallization of cross-fibre chrysotile within foliation planes. Some chrysotile veinlets show very open fold-structures which may be related to the F4 fold phase. Late in this fold phase, the development of a fracture cleavage, both perpendicular and oblique to the foliation defined by chrysotile veins, is indicated by the orientation of some diopside, calcite, plagioclase, antigorite and magnetite grains, and also by the trend of the chrysotile fibres themselves.

Calc-silicate rocks are more resistant to weathering than the marbles and they tend to outcrop along low calcrete-covered rises. They weather to rough rounded or elongate boulders and are usually overlain by grey soils with a fine surface scree of garnet, mica, diopside and amphibole fragments. The deeper soils have a red coloration. These calc-silicate rocks vary greatly in colour from pale grey, pink or brown to dark green. The light-coloured rocks tend to be composed of microcline, plagioclase, zoisite and scapolite, whereas the darker rocks contain diopside, hornblende, garnet, quartz and iron ore. Diopsidic calc-silicates are the most common, however. These rocks develop a reddish weathered skin, whereas the paler calc-silicate rocks have a powdery white cover of sericite and clay.

The leucocratic, feldspathic calc-silicate rocks are fine-grained and homogeneous, sometimes containing thin laminations of mafic minerals. These rocks grade into non-foliated granulites, whereas the mesocratic calc-silicate rocks tend to be more coarse-grained and granulitic. Indistinct folding is emphasized by the numerous secretion-quartz veins which are themselves isoclinally folded. On the rough, pitted surface of these rocks the layering is accentuated by differential weathering. Crenulations are often developed along foliation planes parallel to an early mineral rodding. Fold noses may be thickened and boudinage is common owing to the incompetence of calc-silicate rocks in relation to adjacent lithologies. A fracture cleavage has developed at right angles to the foliation, probably during the F4 fold phase. Quartz and diopside crystals are in places orientated in this cleavage.

Secretion veinlets of quartz, plagioclase, diopside or pink thulite are up to 30 cm thick and these are usually intergrown with the calc-silicate groundmass. The veinlets locally grade into large graphically intergrown crystals of diopside, quartz and plagioclase. The calc-silicate rocks are also cut by numerous pegmatites which is probably a function of their tendency to fracture.

Petrography: A sample of diopsidic calc-silicate rock from a horizon near the Limpopo River, west of the Pande Mine, has been chemically analysed (Table V, Lab. No. 70/377). This is a quartz-free, olivine-normative calc-silicate rock in which most of the lime is tied up in anorthite and diopside.

The Shakwisa calc-silicate rocks are generally fine- to medium-grained and equigranular, with granoblastic, porphyroblastic or poikiloblastic textures. Poikiloblasts of diopside, plagioclase, garnet and hornblende contain inclusions of these same minerals, as well as iron ore and sphene. In places, the orientation of poikiloblastic diopside and plagioclase crystals defines a foliation (slide 25 431). With the granoblastic rocks the foliation is indistinct where the crystals are equant and polygonal, but it is well defined where crystals of diopside are elongated and aligned in ribbons of quartz, feldspar, garnet, hornblende and sphene. In one sample (25 432) thin segregation layers contain diopside, garnet, quartz, feldspar, scapolite, calcite and zoisite in a feldspathic groundmass.

Diopside forms aggregates of euhedral to subhedral crystals in the granoblastic rocks and it may comprise between 10 % and 90 % of them. The crystals, usually 1 - 2 mm, have smooth curved or undulose borders against one another. Diopside is usually embayed or sutured against quartz and plagioclase, and is commonly intergrown with these minerals (slide 25 432). Diopside may also occur as irregular poikiloblasts, up to 20 mm, which contain inclusions of plagioclase, garnet, quartz, zoisite, hornblende and calcite (slide 25 433). Other diopsides may also contain inclusions of sphene, ore and foxy-red biotite. In another rock (slide 25 434) diopside shows irregular alteration to hornblende in patches, up to 0.4 mm across. Hornblende forms the bulk of this rock and is a pale apple-green to olive-green variety. It occurs as polygonal or irregular crystals, up to 1 mm long, which show simple twinning. Hornblende (slide 25 435) fills cross-cutting fractures in plagioclase, and in other samples tremolite is apparently derived from diopside. In slide 25 436 a little pleochroic hypersthene is associated with magnetite.

Quartz may or may not be present in the calc-silicate rocks; where it exists it usually occurs as rounded to irregular crystals averaging 1 mm across. The quartz may contain inclusions of iron ore and sphene, and itself occurs as droplets in poikiloblastic diopsides. Quartz usually has embayed boundaries against plagioclase and is smooth to lobate against diopside, hornblende and microcline. It is commonly intergrown with garnet. Undulose extinction and deformation-lamellae are developed in the quartz. Some secretion veinlets, however, are composed of large sutured quartz crystals, up to 14 mm across (slide 25 434), which enclose plagioclase and other materials derived from the vein walls. Microcline-rich calc-silicate rocks occur occasionally (25 437); in these rocks the mineral poikiloblastically encloses or is embayed against diopside. It shows good cross-hatched twinning, rare perthitic intergrowth and some alteration to sericite along fractures. Plagioclase comprises 0 - 39 % of calc-silicate rocks examined and usually occurs as crystals or aggregates of crystals, 1.0 - 3.5 mm across. In some samples large grains, up to 10 mm across, are seen and in one example (slide 25 438) such crystals contain optically orientated inclusions of pyroxene, irregular hornblende, garnet, calcite and quartz grains. Good albite, carlsbad and pericline twinning is developed; some crystals show zoning, but the composition of plagioclase estimated from a number of rocks varied from An_{54} to An_{87}. The most common values, however, lay between An_{64} and An_{71}. Plagioclase shows abundant sericitization and kaolinization in patches, up to 2 mm across, and it is often iron stained. Some fractures are filled with chlorite or zoisite, and saussurite has been observed (slide 25 433). Irregular patches of plagioclase (25 438) are filled with randomly arranged epidote prisms surrounded by sericite.

Pink garnets form rounded skeletal poikiloblastic crystals in some calc-silicate rocks. These garnets contain irregular inclusions of plagioclase, epidote, sphene and iron ore and they are often intergrown with quartz. Some samples also contain ragged intergranular flakes of foxy-red biotite in association with iron ore. Calcite, scapolite, sphene, apatite, zircon and green spinel are common accessories. The last mineral is usually associated with exsolved magnetite, as in slide 25 434.

Corundum-bearing spinel-granulites from the Diti Dip Claims near Diriza Hill are hard, black fine- to coarse-grained granular rocks. They are normally massive but in places they show a segregation layering between spinel and corundum. These rocks grade into well-foliated micaceous spinel-granulites and laterally they merge into the adjacent marbles. Coarse-grained amphibole-bearing secretion-pegmatites occur within the spinel-granulites at this locality. Related *enstatite-cordierite granulites* were noted 1.5 km east of Shakwisa Hill where they occur as coarse-grained, hard, grey to reddish-grey rocks, with a nebulous foliation defined by the segregation of orthopyroxene and cordierite. Quartz lenses occur within this rock, orientated parallel to the foliation. A rock of similar composition has been described by Chinner & Sweatman (1968) from a point 3 km north of Beitbridge on the main Bulawayo road. They suggest that corundum was formed from sillimanite, producing excess silica which reacted with kyanite and enstatite to form cordierite. These granulites may originally have been derived from magnesian, alumina-rich clays.

Petrography: A sample of spinel granulite from the Diti Dip (Beverly's Corundum) Claims has been chemically analysed (Table 5, Lab. No 75/65). Textures in these granulites are porphyroblastic or granoblastic, whereas biotite-rich varieties show a stronger foliation. The green spinel, which is pleonaste approaching hercynite in composition (Phaup 1951), forms rounded or roughly shaped porphyroblasts up to 7 mm across. Generally these crystals have irregular cuspate boundaries and they are intergranular in relation to plagioclase (slide 25 440). They contain inclusions of corundum and are partly schillerized, owing to the orientation of tiny exsolved plates of magnetite. Corundum may form in layers up to 10 mm thick, where it occurs as intergranular intergrowths with spinel in the biotite-rich rocks (slide 25 439). The corundum is colourless to sapphire-blue and it contains tiny flakes of biotite; elsewhere it appears to have recrystallized into radiating aggregates of corundum and muscovite. Plagioclase forms irregular polygonal aggregates and is often porphyroblastic, with the crystal faces being lobate or undulose against spinel. The crystals show good albite and carlsbad twinning, and a composition of An_{80} was estimated. Red-brown biotite flakes define a foliation in some granulites where they may comprise up to 10 % of the rock. Biotite flakes also fill fractures in the plagioclase-rich spinel-granulites where they appear to have altered to a colourless mica. Sieve-textured sphenes in the biotite-rich granulites contain inclusions of rutile and biotite. In the plagioclase-rich varieties sphene crystals form aggregates up to 2 mm across, in which rutile crystals are associated. Square brown allanite inclusions in plagioclase are surrounded by radiating fractures; opaque ore is apparently derived from the breakdown of spinel.

An enstatite-cordierite-granulite (slide 25 441) has a poikiloblastic to granoblastic-elongate texture, in which subhedral prisms of enstatite and cordierite enclose fragments of quartz, orthopyroxene, biotite and ore. Enstatite crystals are elongated along a foliation which is paralleled by trains of biotite flakes and rutile grains. Cordierite forms polygonal crystals up to 1.5 mm long, in aggregates. These crystals usually have lobate borders against enstatite; rounded droplets of enstatite in the cordierite are commonly optically continuous, suggesting that the cordierite has replaced a pre-existing enstatite crystal. Enstatite normally occurs as subhedral to euhedral prisms up to 6 mm long, but it also forms intergranular aggregates. Two stages of crystallization are indicated by a euhedral crystal which is irregularly rimmed by enstatite with a different orientation. Serpentine may partly pseudomorph enstatite containing rounded quartz inclusions. It may also fill veins, rimmed by pinite, which run along the foliation and join individual pseudomorphs. Biotite flakes, up to 1.5 mm across, are associated with ore and rutile in the foliation. These flakes penetrate both cordierite and enstatite crystals, and ore grains are rimmed by a white alteration product, probably leucoxene after ilmenite. A few small aggregates of corundum have pseudomorphed sillimanite prisms which form inclusions in cordierite and enstatite. The composition of this rock is estimated as being 50 % enstatite, 45 % cordierite, 3 % biotite and 2 % ore and rutile.

Garnet-granulites, associated with leucocratic paragneisses and sedimentary serpentinites in the Shakwisa Calcareous Member, are characterized by a mineral assemblage of green garnet, diopside and scapolite. They are distinctive apple-green, medium- to coarse-grained banded rocks. The banding is defined by the segregation of minerals into garnet-rich and quartz-rich layers.

A sample (slide 25 442) from near the Pande River, west of the mine, is a well-foliated green garnet-diopside-scapolite-quartz rock, in which the layering is emphasized by the segregation of poikiloblastic garnets and clinopyroxenes from quartz-rich layers. Aggregates of poikiloblastic garnets have interlobate borders with pyroxene crystals which occur as intergranular masses and as inclusions in the garnet. Scapolite is intergrown with the diopside and forms lobate borders with garnet. Garnet-rich bands may grade into diopside-rich layers in which euhedral diopsides reach 3 mm in length. A few zircons and some sphene are associated with scapolite in the diopside-rich bands. Quartz forms wide ribbons, up to 4 mm across, which are composed of large sutured crystals intergrown with or embayed against green garnet. The composition of this rock is estimated as 34 % quartz, 33 % green garnet, 22 % diopside and 11 % scapolite.

At a locality west of Lukange School, green garnet-granulites are seen to grade into quartzite (slide 25 443). Wide quartz bands give this rock a strong foliation, as they separate green garnet, diopside and scapolite-rich layers. Individual crystals are elongated and their orientations apparently define two foliations. Near boundaries of quartz layers, garnets and scapolite are included. A few patches of clouded plagioclase show partial or complete alteration to scapolite and associated zoisite crystals. This plagioclase is intergrown with, or embayed against quartz, and it has an estimated composition of An_{57}. Scapolite forms fine-grained intergranular aggregates and ribbons associated with garnet and diopside. Green garnets form tiny individuals or masses of crystals, 0.5 mm across, which are associated with diopside prisms. The rock is composed of 59 % quartz, 20 % garnet, 6 % diopside and 15 % scapolite.

Swebebe Ferruginous Member

The Swebebe Ferruginous Member comprises a variety of iron-rich quartzites and granulites as well as aluminous gneisses and a few calc-silicate rocks. These rocks are directly correlated with the Artonvilla Cordierite Gneiss Formation in South Africa. In Zimbabwe the assemblage can be traced north-eastwards to Triangle and Chiredzi. An interesting feature is the very definite tendency for intrusive serpentinites and mafic granulites of the Ultramafic Suite to be preferentially emplaced within strata of the Swebebe Member. Rock types included within the Swebebe Ferruginous Member, which vary greatly in respect of their iron content, are as follows:

1) Magnetitites
2) Magnetite-quartzites and magnetite-grunerite / cummingtonite- quartzites
3) Massive quartzites
4) Garnet-hypersthene-magnetite-quartzites and the corresponding granulites
5) Garnet-quartz-granulites and garnet-quartz-magnetite-granulite
6) Biotite-garnet-sillimanite-quartz-schists and the corresponding gneisses
7) Biotite-garnet-sillimanite-cordierite gneisses and granulites
8) Calc-silicate rocks

Lithology

The ferruginous quartzites are usually brown, reddish or steel grey and are covered by dark red soils, with a surface scree of quartz and magnetite. The magnetitites have a metallic black colour, whereas the pyroxene granulites are dark green. The finer- grained cordierite-bearing gneisses have various shades of grey, whereas the coarse-grained gneisses have a distinct dark and light colour banding. Iron oxide may give a pink colour to adjacent massive quartzites. The ferruginous quartzites are resistant to weathering and they form low ridges and steep-sided hills, which are subdued in the flat gneissic country to the north. The outcrops of quartzites are slabby owing to jointing control, fracture-cleavage and strong mineral alignment. Cordierite gneisses are not usually exposed north of the zone of active erosion adjoining the Limpopo River. Near the river, however, they form small rises, a few metres high, or else they outcrop as exfoliation pavements and low dwalas. Elongated boulders form as a consequence of the strong mineral alignment in these rocks. Although the ferruginous soils only support a sparse, stunted growth of mopani and thorn bush, they show up as a dark, almost black tone on aerial photographs and are therefore easily located.

Where cummingtonite/grunerite crystals are present they are preferentially weathered and replaced by goethite or limonite. This gives the rock a pitted, yellow, earthy appearance. The weathering of iron minerals may also give the rock a pitted surface, whereas garnets tend to stand out. Yellow-green nontronite clay commonly forms as an alteration product of the ferruginous rocks. Although the grain size varies, individual cummingtonite/grunerite blades, magnetite octahedra and garnets may reach 15 - 30 mm across. Quartz and the other constituent minerals are usually strongly aligned along a foliation and also with oblique crenulation lineations. Randomly orientated cummingtonite/grunerite crystals may also lie within the foliation plane and locally they fill cross-cutting fractures. Alternating laminae, in which the constituent minerals are concentrated, usually have sharp contacts with adjacent layers and these may show tight folding (Plate 2 B). Similarly, the contacts between magnetite-quartzites and massive quartzites are sharp. Gash veins in the magnetite-quartzites may be filled with white quartz, and coarse-grained, folded secretion-pegmatites of magnetite and quartz may also occur in various shapes. A purple mineral, apparently stichtite, and colourless to mauve opaline silica fill fractures in some magnetite-quartzites adjacent to serpentinite bodies.

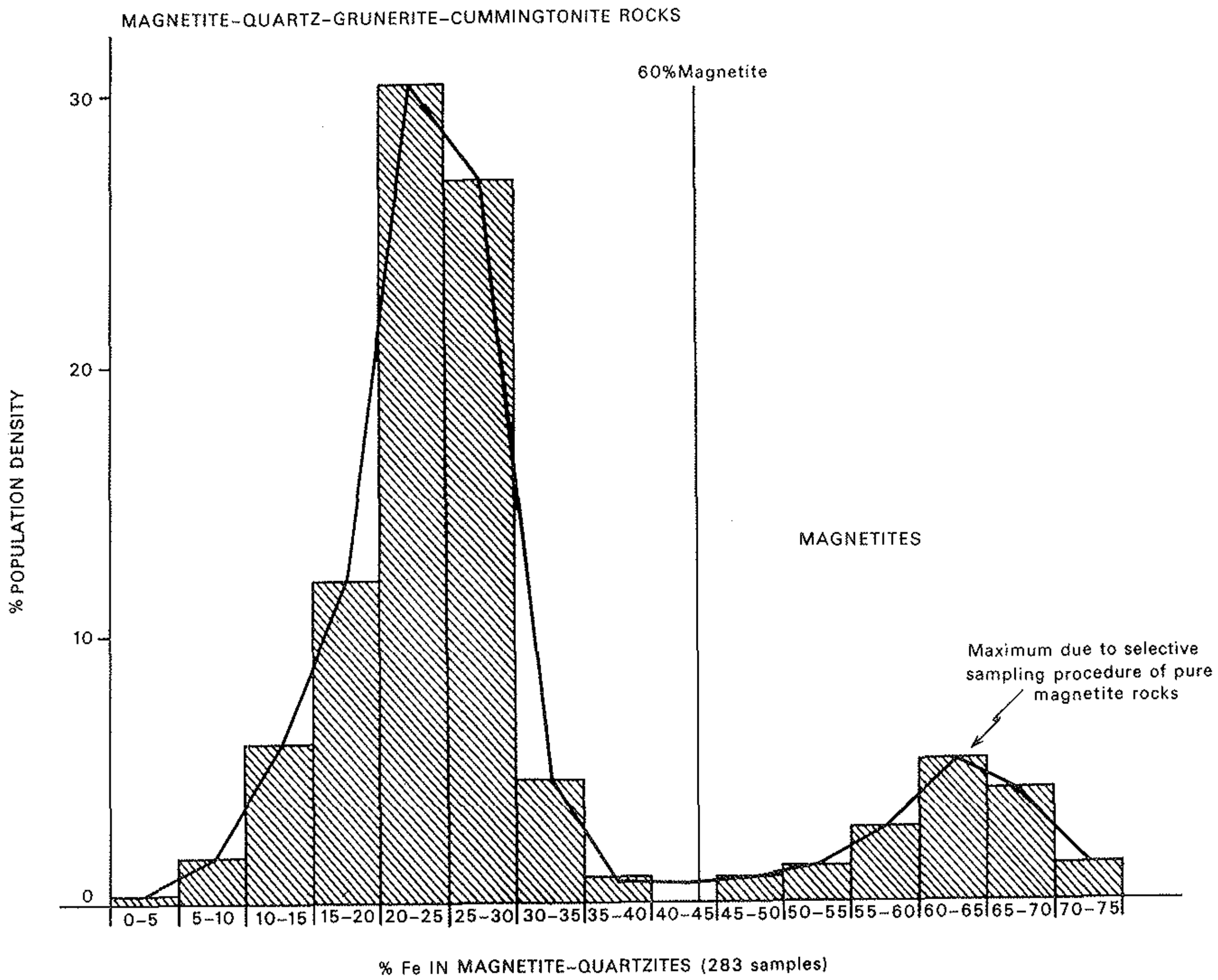


Figure 2: Analysis of the Iron content for 283 samples of Swebebe Ferruginous Quartzites

Where magnetite-cummingtonite / grunerite-quartzites contain more than 20 % of the diagnostic minerals, they are also generally free of garnet and hypersthene. A total of 283 samples were gravimetrically analysed for their iron content. For this purpose cummingtonite-grunerite was considered to represent a mixture of quartz and magnetite. The results are represented in Figure 2, which indicates a mean iron content for the ferruginous quartzites of 22.5 %, that for the rare magnetites being 62.5 %. Of the samples analysed, 67 % have an iron content of 15 – 30 %.

In sillimanite-cordierite-gneisses, the quartzo-feldspathic bands are commonly boudinaged and enclosed by mesocratic layers of biotite, cordierite, sillimanite, potash feldspar and porphyroblastic garnet. These layers are usually strongly plicated and the garnets show evidence of rotation.

Distribution and Field Relations

Rocks of the Swebebe Ferruginous Member are exposed along the flanks of the Nulli Formation quartzite ridges and basins, but their main expression is in a broad NNE- trending belt which passes through the centre of the map-area. Tight basin structures or fold-interference patterns, of which Swebebe Hill is an example, occur alternatively west and east of the central belt. This central belt is 4 km wide where it crosses the Limpopo River west of Pande Mine. It extends north-eastwards west of Dombadema Hill on a major NW-trending antiformal axis and then swings eastwards north of Mwanandou Hill on a complementary synformal axis. The belt continues northwards parallel to the east side of the Nulli Range and thins to 1 km where it leaves the map-area. It consists of thin bands of isoclinally folded ferruginous rocks within the Diti Paragneiss. Magnetite-quartzites and massive quartzites occur throughout the belt but magnetite-grunerite-quartzites appear to be confined to the north and cordierite gneisses to the south and centre. Interbanded pyroxene, garnet-magnetite-granulites and magnetite-quartzites occur near the headwaters of the Samtete River west of Mwanandou Hill. Thin calc-silicate horizons occur east of the southern extremity of the Nulli Range and also west of Dombadema Hill. Serpentinite bodies occur sporadically throughout the main outcrop, either enclosed in or adjacent to ferruginous quartzites. They often occupy F3 or F4 fold noses in rounded, oval, lens-shaped or irregular forms which may distort the quartzites or cut across them. The greatest concentration of serpentinite bodies is to the east of the Nulli Range where other mafic granulites are also associated. In the south-western part of the belt the rocks dip steeply south-east, but elsewhere the inclination is to the north or west.

East of the Pande Mine, Swebebe magnetite-quartzites form a ridge around a northerly elongated dome; they also discontinuously flank the eastern side of the Shampali quartzite range. Iron-poor quartzites occur on the Limpopo River west of the Pande 2 quarries. Tightly folded but discontinuous magnetite-quartzites and cordierite-gneisses are exposed at the Cull Claims, and between Mabana Hill and Saluwana Hill. Thin horizons continue northwards on the eastern side of the Shakwisa Ridge. Ferruginous rocks rim the shallow Nulli Formation basin which is marked by flat-lying magnetite-cummingtonite /grunerite quartzites underlain by nontronite clays on Dombadema Hill. The attenuated nose of this structure extends north-westwards into the central Swebebe belt. Northwards, ferruginous rocks are exposed beyond Mafungwe Hill and to the east of Bodekwa Dome. The centre of the Bodekwa Dome is also rimmed by ridges of magnetite-quartzite, and beyond the dome Swebebe rocks flank north-trending Nulli quartzites and are interbanded with them on Marambo Hill.

To the west ferruginous and massive quartzites, mafic granulites and serpentinites surround the Luchewe Basin and they compose Luchewe Hill. Tightly folded magnetite-quartzites are also interbanded with anorthosites and mafic granulites in the centre of the basin, where an occurrence of garnet-pyroxene-magnetite-granulite was also noted. The best exposures of the Swebebe Ferruginous Member are on Swebebe Hill itself, where they occur in a one-kilometre wide, tear-drop shaped isoclinal basin. A south-trending band of ferruginous quartzites on the east side of the Swebebe structure extends to the Limpopo River. The Swebebe Member in its type locality consists of interleaved magnetite-quartzites, magnetite-cummingtonite/grunerite-quartzites, massive quartzites, sillimanite-cordierite-gneisses; garnet-sillimanite-quartz-schists, garnet-granulites and nontronite clay beds. An adit on the south side of the hill penetrates decomposed cordierite gneisses between ferruginous quartzites.

Cordierite-gneisses flank the north-western side of the Nulli quartzites making up Sebetwe Hill and they appear to be interbanded with magnetite quartzites west of Malezikwe Hill, where these rocks are enclosed in anorthositic gneisses. Cordierite-gneisses also appear discontinuously along the south-eastern side of this quartzite ridge and they occur west of the Shingwanyana Hills. In the Sinyoni Claims area, north-east of the old Main Drift, Swebebe rocks form thin horizons over a broad zone which culminates in a complex structure on the hills covered by the Fort Claims.

Ferruginous rocks east of Malezikwe Hill merge into the central zone and also widen out in a fold closure covered by the Nulli Claims and crossed by the Tshiturapadsi road. Discontinuous magnetite-quartzites extend up both the east and west sides of the Nulli Range.

In the extreme NW-corner of the map-area serpentinites are intrusive within folded-magnetite quartzite associated with mafic granulites. Garnet-pyroxene-granulites south of Beitbridge aerodrome and cordierite-gneisses to the east are considered to be part of the Swebebe Member.

Rocks of the Swebebe Member are everywhere conformable with the enclosing paragneisses and mafic granulites, with which they have sharp contacts and are closely intercalated. Magnetite-quartzites form tight interference-patterns and individual bands are often duplicated or become stretched out and detached. Thin horizons, however, can be traced over great distances along which they retain approximately the same thickness. Although the ferruginous rocks commonly occur adjacent to quartzites of the Nulli Formation, they are usually separated from this formation by paragneiss. In some localities the ferruginous rocks appear to grade into the quartzites, Elsewhere, magnetite-quartzites grade into magnetites or, with a decrease in the proportion of iron, into massive quartzites containing blebs of magnetite. They become closely intercalated with white quartzite bands, some of which may be repeated by folding. Garnet-quartz-granulites and hypersthene-bearing quartzites are also seen to grade between magnetite-quartzite and the enclosing leucocratic gneiss. Cordierite-gneisses are commonly tightly interbanded with the ferruginous quartzites and granulites, although a gradation from these rocks into the gneiss has not been observed. The biotite-garnet-sillimanite-quartz schists and gneisses appear to represent a rock intermediate between cordierite-gneiss and the ferruginous granulites.

The association of the iron-rich rocks with aluminous sillimanite-cordierite-gneisses and calc-silicate rocks, together with some evidence of relict graded bedding, suggests that these rocks are of sedimentary origin. The low manganese content (0.25 %), determined spectrographically of garnets from associated granulites, is also indicative of a sedimentary rather than a volcanogenic origin.

Petrography

In general, the pyroxene- and garnet-bearing rocks have granulitic textures, whereas the magnetite-quartzites and the grunerite and cordierite-bearing rocks are more gneissic.

In the *ferruginous quartzites* quartz is the main textural element. It usually forms elongated interpenetrating grains, up to 2 mm across, but, more rarely, individual grains are much larger. Small polygonal crystals occur in ribbons and are commonly associated with elongated crystals of magnetite or grunerite (slides 25 444 and 25 445). Quartz may show two elongation orientations in the foliation (slide 25 445) and generally shows undulose extinction and tends to be lobate against magnetite and intergranular to cummingtonite/grunerite crystals. Well-rounded or polygonal magnetite crystals tend to be confined to quartz crystal boundaries, or are enclosed within cummingtonite/grunerite. Goethite fibres, apparently after pyroxene and cummingtonite/grunerite, and goethite needles (slide 25 447) occur extensively in bands of cryptocrystalline quartz.

The magnetite content of quartzites ranges between 3 – 100 %, high magnetite-content varieties being heavy, black, crystalline rocks (slides 25 448 and 25 449). Magnetite occurs as euhedral or elongate crystals, 0.2 - 4.0 mm across. The larger grains tend to be irregular and to contain quartz inclusions, whereas the smaller crystals are intergranular in relation to quartz and are included in it. The magnetite crystals sometimes occur in orientated trains or fill later fractures (slide 25 450); they are largely altered to hematite and goethite, or limonite, especially around crystal rims and along fractures. The goethite-limonite replacement of magnetite is quite distinct from the goethite-quartz intergrowths after hypersthene, cummingtonite or grunerite.

X-ray diffraction work has shown that, for a number of samples, the amphibole associated with magnetite-quartzites is cummingtonite and not grunerite. Data from two samples (25 451 and 25 445) gives 31.2 and 33.5 mole percent $Fe_7Si_8O_{22}(OH)_2$, lower than the 50-100 mole percent required for grunerite as defined in the cummingtonite/grunerite series (Klein & Waldbaum 1967). Cummingtonite or grunerite may form up to 70 % of a quartzite, as well-shaped brown, yellow or fresh-pink bladed crystals, 2 - 8 mm long, occurring as large aggregates or in swarms of fibrous needles aligned with the foliation. The amphibole contains rounded inclusions of quartz and iron oxide (slide 25 452) and occasionally forms a pure, coarse-grained magnetite-cummingtonite/grunerite rock (25 451). In one sample (slide 25 453) cummingtonite/grunerite bands separate hypersthene from anthophyllite bands. Crystal boundaries parallel to the foliation are straight, but the crystal ends are ragged. Individual crystals commonly show fine multilamellar twinning. In another rock (slide 25 454), swarms of cummingtonite/grunerite needles form wavy bands, 2 mm across, or occur adjacent to and intergrown with quartz crystals. Fibrous manganoan anthophyllite needles fill cross-cutting fractures and occur as radiating spheroidal aggregates after cummingtonite/grunerite. This indicates three periods of amphibole crystallization with the spheroidal aggregates probably forming during a period of no stress. Cummingtonite/grunerite is commonly replaced by goethite and a colourless clay, but the amphibole has been observed to be altered to a radiating intergrowth of chlorite and epidote (slide 25 455).

Quartz is prominent in some garnet- and pyroxene-bearing *granulites,* which contain a number of other minerals in varying proportions. Pleochroic hypersthene occurs in many of these rocks as euhedral prisms, as large poikiloblastic crystals or as intergranular aggregates (slides 25 456, 25 457 and 25 458). The sieve-textured hypersthenes contain quartz and magnetite inclusions with hematite rods which have formed parallel to the cleavage. The hypersthene is schillerized in places and it may be partly serpentinized or chloritized. Grey to yellow bastite-serpentine (slide 25 460) pseudomorphs hypersthene crystals, the boundaries of which are marked by fine botryoidal hematite-granules. Hypersthene, like grunerite, alters to an intergrowth of platy hematite and quartz and, with the addition of water, hematite alters to goethite.

Hornblende has been observed as well-shaped crystals (slide 25 457) where associated with aggregates of garnet and allanite. Garnet may form up to 50 % of an individual granulite and one sample (slide 25 461) is a coarse-grained garnet-quartz-magnetite-granulite. The garnets may occur as large poikiloblasts or as smaller subhedral trains parallel to the foliation. They may contain inclusions of quartz, plagioclase, hypersthene, magnetite, biotite, sillimanite, rutile or zircon, and in one sample (25 462) garnet augen have cores filled with magnetite inclusions, an inner zone with quartz, biotite, rutile and zircon, and an outer zone with sillimanite inclusions. Cross-cutting fractures in these garnets may be filled with biotite flakes and an intergrowth of quartz, biotite and sillimanite may form in pressure shadows associated with the garnets. Foxy-red biotite flakes, up to 1.5 mm across in the same rock, are associated with quartz, sericite and sillimanite which enclose individual garnet augen. Quartz seems to have reacted with sillimanite to produce sericite. Zircons occurring in the biotite flakes have dark pleochroic haloes.

Green to nearly opaque hercynite spinels are present in the hypersthene-granulites where they occur as small crystals commonly associated with garnet. In one rock (slide 25 457) individual spinels or trains of crystals occur in the one and in another sample (25 461) magnetite has been exsolved parallel to three cleavage directions in the spinel. In the same rock, reddish-brown allanite forms crystals, up to 1.5 mm long and rimmed by green spinel. The allanite contains rounded inclusions of hypersthene, and chlorite also rims these crystals, as does green or colourless corundum.

Yellow-green pleochroic nontronite clay has replaced the iron-bearing silicates at a few localities (slides 25 462, 25 464). These rocks are either quartzites with clay bands containing remnant goethite and limonite, or they are formed almost entirely of large, soft, earthy nontronite flakes. Later nontronite flakes lie obliquely to the foliation in the banded rocks, and lattice expansion has fractured the iron oxide granules.

A sample of cordierite-gneiss has been chemically analysed (Table 5, Lab. No. 76/43). The aluminous nature of this rock is emphasized by the high percentage of normative corundum present. The rocks are generally medium- to coarse-grained with an inequigranular granoblastic, porphyroblastic or poikiloblastic texture. The gneisses tend to be poikiloblastic in biotite-garnet-sillimanite- and cordierite-rich zones; and granoblastic, in the quartz-feldspar layers. Garnet and some plagioclase, quartz and cordierite crystals, form augen in the foliation which is emphasized by the strong alignment of biotite and sillimanite.

Garnet forms 5 – 25 % of the gneisses, in which two distinct ages of crystallization are indicated. The older garnets form lens-shaped, rounded or irregular augen and aggregates, 3 - 7 mm in diameter. These are commonly elongated oblique to the foliation. This foliation is strongly emphasized by the orientation of biotite, sillimanite, cordierite and younger garnet crystals which tend to envelope the older garnet augen. The older augen are usually free of inclusions which, if they do occur, are quite distinct from those of the younger garnets. The older garnets may contain quartz, biotite, needles of sillimanite, hematite or plagioclase in random orientation except near crystal boundaries. In the schistose gneisses the distribution of quartz inclusions indicates that these garnets have been rotated, and in some cases an outer zone contains orientated laths of sillimanite (Plate 6, in pocket). In unrotated garnets the quartz is randomly arranged near the centre of these crystals. In one sample (slide 25 466) a garnet partly encloses a cordierite-gneiss fragment with an early oblique fabric emphasized by inclusions of quartz, biotite, garnet and microcline (Plate 6). The garnet appears to replace the cordierite, and rounded quartz inclusions in the garnet decrease in size and density concentrically outwards from the gneissic inclusion. The garnet is rimmed by cordierite and a younger foliation, defined by elongated cordierite, microcline and sillimanite, encloses and is sheared against the garnet poikiloblast. Late crystallizing biotite flakes penetrate the garnets and also wrap around them (slide 25 467). The younger garnets, with abundant inclusions of biotite, cordierite and sillimanite, are elongated parallel to the F3 fold-direction. These garnets have very irregular interlobate boundaries with quartz, cordierite and microcline and they contain large prisms of sillimanite unlike the older garnet augen.

Foxy-red biotite flakes form up to 25 % of the cordierite-rich gneisses, in which they enclose sillimanite in cordierite crystals, and are often intergrown with magnetite. The flakes usually lie parallel to the foliation, although their orientation may vary and follow oblique cleavages (slide 25 468). Cordierite with sillimanite makes up 10 – 30 % of the gneisses. The cordierite forms elongated poikiloblastic intergranular crystals, up to 3 mm long. They form ribbons rimmed by biotite and quartz, and may occur in finer-grained aggregates. There are apparently two ages of crystallization, as those crystals containing garnets have a distinct gradational border against cordierite full of sillimanite and biotite. Cordierite augen without sillimanite but containing biotite and quartz are apparently older than the foliation containing biotite and cordierite which encloses them. Cordierites (slide 25 469) show simple and multilamellar twinning. Sillimanite occurs in swarms of subparallel needles and as individual prisms, up to 0.75 mm long. They are closely associated with and included in cordierite crystals, and in places they form fibrous knots. Tiny sillimanite needles are included around the rims of some garnet augen but generally they are strongly orientated in the foliation plane parallel to the F3 direction.

Quartz makes up 15 – 70 % of these gneisses and may form rounded, lens-shaped or irregular grains, 0.5 - 7 mm in length. The quartz is finer-grained near biotite, and it commonly occurs as discontinuous ribbons between layers of biotite and sillimanite. Biotite flakes may rim quartz which forms interlobate boundaries against cordierite. Deformation lamellae and strong evidence of annealing in the quartz is present.

Myrmekitic intergrowth is developed in plagioclase and some cordierite grains where these are adjacent to perthitic microcline. The microcline forms poikiloblastic intergranular crystals intergrown with quartz and cordierite in the biotite-rich layers. It shows indistinct twinning, undulose extinction and the development of patch or rod-perthites, typical of microclines formed at high temperature. The crystal-boundary relationships suggest that the microcline crystallized after the cordierite. Plagioclase makes up to 40 % of the cordierite-bearing gneisses as well-formed crystals occurring individually or in aggregates. Clear albite-pericline- and carlsbad-twinning indicates a composition of calcic andesine. In one rock (slide 25 470) some plagioclase is antiperthitic. It is commonly poikiloblastic (slide 25 471), and kaolinization and sericitization is common.

The massive and pitted *quartzites* found in the Swebebe Member of the Diti Formation are identical, both lithologically and petrographically, to those found in the Nulli Formation, and the calc-silicate rocks of the Swebebe Member are very similar to those of the Shakwisa Member. They are therefore described more fully under these headings. However, a sample (25 472) from the Shakwisa River, 4 km north of Mwanandou Hill, is an unusual medium-grained, grey calc-silicate rock associated with ferruginous quartzites. This rock has a poikiloblastic to granoblastic texture in which diopside and microcline form trains that mark out a vague foliation. Individual diopsides are up to 3.5 mm long, and plagioclase crystals, up to 2 mm across, contain inclusions of sphene and diopside. The plagioclase is part-altered in irregular patches to dark clay and sericite.

NULLI FORMATION

The Nulli Formation is the uppermost division of the Beitbridge Group in Zimbabwe. The constituent rocks are correlated directly across the Limpopo River with the Mount Dowe Metaquartzite Formation, which falls within the Messina Sub-group of South Africa. The Nulli Formation comprises a variety of quartzites, amphibolitic gneisses and granulites, some calc-silicate rocks and a discontinuous basal development of biotite-gneiss. In a few places these rocks are cut by conformable sills of olivine-spinel-granulite and plugs of serpentinite of the ultramafic suite. This assemblage has been traced northwards through the Bubye ranching area and then north-eastwards across Mwenezi Ranch towards Triangle. It is characterized by the following rock types.

1) Massive quartzites
2) Granular sillimanite-bearing quartzites
3) Diopside-bearing quartzites
4) Sheared and mylonitic quartzites
5) Diopside calc-silicate rocks
6) Amphibolitic gneisses and granulites
7) Basal biotite gneiss

Quartzites associated with the Diti Paragneisses, the Shakwisa Calcareous Member and the Swebebe Ferruginous Member are lithologically very similar to those described from the Nulli Formation. The Nulli quartzites, however, form the major topographic features in the Beitbridge area, the Nulli Range being the most prominent. Dip and scarp slopes characterize these hills which clearly show the complex major structures of the region. The quartzite ridges have a thinly developed soil cover which supports a thick undergrowth of *Combretum, Commiphora and Cassia* species.

Distribution

In the area east of Beitbridge the Nulli Formation has its best expression in a broad centrally placed belt of NE-trending and north-trending hills. An eastern belt of similar orientation is separated from quartzites exposed near the Pande Mine which make up the Shampali and Mwanandou ridges and also form those which enclose the Bodekwa Dome.

The central belt crosses the Limpopo River as a broad zone of massive and granular quartzites associated with amphibolite gneisses immediately north of the old Main Drift. These rocks form an F3 antiformal closure near Artonvilla Mine and continue north-eastwards into Zimbabwe for 3 km, before they break into two isoclinal synformal limbs separated by an antiformal belt of Diti Formation rocks. The northern limb is 18 km long, passing north-eastwards through Sebetwe Hill before becoming attenuated into a narrow closure, 2 km south of Malezikwe Hill. The southern limb can be traced for 32 km to a closure just west of the southern extremity of the Nulli Range. Cross-folding of the north-west trend causes this limb to swing east to form the Shingwanyana Hills and then turn north to Malezikwe Hill, both these features being located on a fold axis. Beyond Malezikwe Hill the rocks trend east and then north again to a termination that straddles the Tshiturapadsi road between Nulli School and the Nulli iron claims. The north-striking Nulli Range extends for 16 km, and the constituent quartzites can be traced far beyond the limits of the map-area. Although the range dominates the surrounding country in the south, with Malezikwe peak rising 300m above the plain, the topography farther north is much more subdued. The hills represent a classic dip and scarp range; there is an extensive exposure of massive quartzite on the western side.

The eastern belt, a much thinner and more sinuous zone of massive and granular quartzites, occupies a cross-folded isoclinal synform 100 - 500 m wide. Quartzites occur north of the Shurugwe Fault on Malise Hill and can be traced north-eastwards to Mabana Hill where they are cross-folded on a NW-trending axis. The belt swings east and dips southwards near Saluwana Hill, where there is further cross-folding and a reversal of dip to the north-west. The quartzites run northwards for 9 km, where they widen considerably to form Shakwisa Hill. From here a thin east-trending quartzite defines the outer margin of the Shakwisa Dome and joins the north-trending Lukumbwe Range along the eastern border of the map-area, where the rocks are inclined moderately westwards.

The Bodekwa Dome, a ring of quartzite hills between the Nulli and Lukumbwe ranges, is crossed by the Tshiturapadsi road. The dome measures 6 km from north-west to south-east and is 4.5 km wide at its short axis. The quartzite occurs in a synformal structure, that completely encloses a core of Diti Paragneiss and magnetite-quartzite. The Nulli Formation rocks consist of massive and granular quartzites interbanded with amphibolitic and ultramafic granulite and a marker horizon of grey diopsidic calc-silicate rock. Quartzites with low dips are preserved north of the Bodekwa Dome, and a continuation of these rocks can be traced beyond the bounds of the map-area into the Bubye ranching area. A west-trending arm of quartzite extends around Marambo Hill, at the southern corner of Lesanth Ranch.

Thin quartzites infolded with rocks of the Swebebe Ferruginous Member rim the Pande structure west of the mine. The Pande Mine serpentinites cut across these quartzites, which are folded to the east near the Limpopo River and then trend northwards to form Shampali Hill. A line of low quartzite hills trend north and north-east as far as Mwanandou Hill, which represents an F2 synformal fold enclosure. West of Cemberere Hill, quartzites form a large flat-dipping basin which is dominated by Dombadema Hill on its southern flank.

Outliers of Nulli Formation quartzite are preserved on Mafungwe Hill, south of the Bodekwa Dome, and on Ngwani Hill, 13 km east of Pande Mine. Quartzites flank the southern margin of the Luchewe Basin along the Limpopo River and they form irregular bands around the southern lobe of Bulai Gneiss, just west of the Lipani River.

Lithology and Field Relations

The massive quartzites are resistant and form sharp-crested, steep-sided ridges with blocky outcrops that are controlled by jointing and an F4 fracture-cleavage, the combination of which is illustrated by Plate 2 D and E. The quartzites vary in colour from a glassy translucent white to green or reddish brown, depending on the presence of fuchsite or iron ore. These minerals, together with sillimanite needles and rare garnet, pyroxene, amphibole or biotite, are usually orientated along an apparent bedding plane that is now a foliation, but they may also lie along oblique crenulations, parallel to which quartz crystals are rodded. Weathering removes the accessory minerals and gives the rock a pitted appearance which is particularly noticeable where magnetite has been leached out and brown oxide-lined cavities remain, or where actinolite which has replaced diopside weathers to a yellow-green earthy material.

The granular quartzites are more friable and less resistant as they contain more sillimanite and fuchsite mica, the presence of which appears to control the degree of granulation. Lenses of massive quartzite enclosed in granular quartzite have a low sillimanite content, whereas quartz rocks with up to 20 % sillimanite become almost schistose. The granular rocks do not have the same depth of colour as the massive quartzites, but usually have an off-white, speckled appearance. Layering is enhanced by a colour banding produced by orientated fuchsite or sillimanite, and thin layers of massive and granular quartzite alternate to emphasize this. Contacts

Explanation to Plate 2

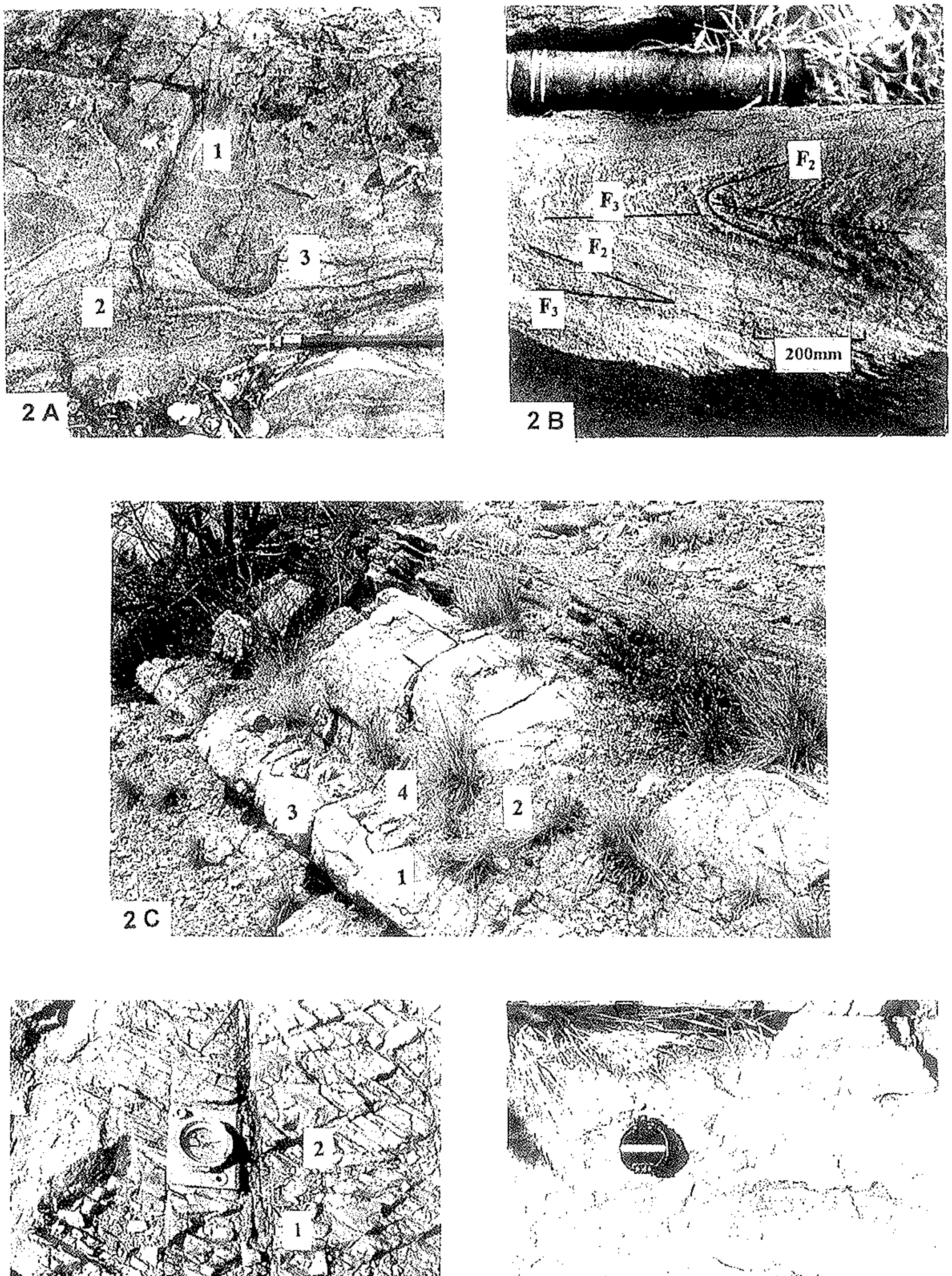
2 A : A marble layer (1) overlying biotite paragneiss (2) with a disharmonic contact (3), due to its incompetence during folding.
Grid Ref. TL 023 481

2 B : Coaxial F_2 /F_3 cross fold interference pattern in magnetite quartzite.
Grid Ref. TL 276 571

2 C : Massive (1) and granular sillimanite-bearing quartzites (2) showing apparent graded bedding with a sharp basal contact (3) to the massive quartzites, and a gradational upper contact (4).
Grid Ref. TL 235 393

2 D : F_4 fracture cleavage (1) and conjugate jointing (2) in massive quartzite of the Nulli Formation.
Grid Ref. SL 983 350

2 E : An F_4 open fold with axial planar F_4 fracture cleavage in massive quartzite of the Nulli Formation.
Grid Ref. TL 274 415


1
3
2
2 A
F_2
F_3
F_2
F_3
200mm
2 B
4
3
2
1
2 C
2
1
2
2 D
2 E

between the bands are sharp and differential weathering accentuates the various components.

The sheared quartzites are stained brick red and are strongly foliated, whereas fine-grained mylonitic quartzites are white with ribbons of finely foliated quartz, muscovite and magnetite. These rocks appear to have formed in flexural slip folds, where shearing has taken place along the foliation planes.

The quartzites can be traced over great distances, along which their thickness is approximately constant, even around isoclinal fold-noses.They are everywhere conformable with the leucocratic and amphibolitic gneisses with which they are closely interlayered. Although the massive quartzites commonly have the appearance of vein quartz, their uniform continuity indicates that they are of sedimentary origin.

Rocks which constitute a complete gradational series from pure quartzite through feldspathic quartzite to leucocratic gneiss have been recognised. White massive quartzites have also been seen to grade into diopsidic calc-silicate rock, and diopside-bearing quartzites appear to be intermediate between these two types. Massive quartzites containing magnetite grade both into ferruginous quartzites and into pure quartzites. Apparent small-scale graded-bedding has been observed in the quartzites of the Bodekwa Dome, and large-scale graded-bedding between interbanded layers of massive and granular sillimanite-quartzites occurs in the Dombadema Basin. Here granular quartzites grade upwards into massive quartzites, the top of which is succeeded abruptly by the next granulated layer (Plate 2 C). The interbedded nature and gradational relationships of massive and granular quartzites, diopside-quartzites, grey diopsidic calc-silicate rocks, magnetite-pitted quartzites and paragneisses, together with the presence of apparent graded-bedding, are taken as evidence of a sedimentary origin for all of these rocks. Lenses and veins of massive sillimanite-bearing quartz, which locally cross-cut the foliation on Lukumbwe Hill, show sheared-out apophyses and are thought to represent locally remobilized quartzite.

Petrography

Two samples (25 473 and 25 474) are typical of the *massive fuchsite-bearing quartzites* of the Nulli Range. In general the massive quartzites contain over 90 % quartz with small amounts of sillimanite, fuchsite mica, garnet, feldspar, diopside or hornblende. These rocks are usually coarsely crystalline and white in colour, although fuchsite may impart a green tinge and iron oxides may stain the quartzites red or pink. A variety of textures and appearances are exhibited by the massive quartzites and can be illustrated by a number of samples. Slide 25 475 is a massive, glassy quartz rock; slide 25 476 is a massive, white feldspar-bearing quartzite; slide 25 473 shows a massive, white fuchsite-flecked quartzite; slide 25 477 is a massive, green-tinged fuchsite-quartzite; slide 25 478 is a green fuchsite-garnet quartzite; slide 25 479 is a massive, pitted iron-stained quartzite; slide 25 480 is a blue-tinged, hornblende-bearing quartz rock, and slide 25 481 shows an intermediate granular fuchsite-bearing quartzite.

The massive quartzites usually have an annealed granoblastic-elongate texture. Quartz may vary considerably in grain size within a single specimen; a range of 0.5 - 28.0 mm has been recorded. Quartz grains, however, are on average 5 mm long and 1 mm in width. Where continuous layers of mica or sillimanite occur along the boundaries of quartz ribbons, individual quartz grains have rectangular crystal-faces developed. Most interquartz grain boundaries are irregular and interlobate, but some are stepped subparallel or perpendicular to the foliation. Much of the quartz shows undulose extinction owing to thin deformation lamellae and wide deformation bands. The deformation bands may be distorted by the presence of fuchsite flakes. Irregular crystals of unstrained, optically orientated quartz are apparently growing at the expense of the strained quartz, and sutured boundaries between the two types are produced (slide 25 482).

Sillimanite forms sheaves of needles, up to 0.25 mm in length, along quartz boundaries, but it may also occur in randomly orientated groups in the centre of these crystals. Where sillimanite is fairly abundant, the quartz is finer grained, apparently due to crushing. The prismatic shape of many of the sillimanite aggregates suggests that this mineral has pseudomorphed another mineral. Sillimanite itself is pseudomorphed by fine sericite which forms in elongate patches and bands.

Fuchsite and muscovite micas form discrete flakes, up to 3 mm in length, or else they occur in linear intergranular aggregates along crystal boundaries. The micas are usually orientated parallel to the foliation, but in places they fill cross-cutting fractures (slide 25 483), or they occur along mica-rich parting planes where they have apparently replaced sillimanite. When abundant finely disseminated fuchsite is present, the rock becomes an attractive green aventurine quartzite (slide 25 484). The mica flakes are straight with ragged ends and they are embayed against the quartz. Fuchsite is hydrothermally altered to sericite and hydromuscovite or, if combined with magnetite, hematite and a colourless chlorite are formed.

Feldspars form rare individual crystals or aggregates which are all sericitized, kaolinized or replaced by chlorite. The potash feldspar tend to be embayed and intergranular and they are partly perthitic. Plagioclase, as in slide 25 485, generally has straighter boundaries and is oligoclase in composition.

Garnets containing quartz inclusions form intergranular concentrations or interlobate crystals, 3 - 10 mm across (slide 25 486). They are often flattened in the foliation, and fractured and stained by brown iron oxides. The fractures are filled with ore granules and sericite. Accessory minerals occur as tiny discrete crystals that often cross-cut quartz boundaries. They include zoned rutile, which sometimes encloses sphene, together with zircon, apatite and magnetite largely altered to hematite and limonite.

A sample of *granular sillimanite quartzite* has been chemically analysed (Table 5, Lab. No. 76/36). These quartzites differ in texture from the massive quartzites due to their higher sillimanite or mica content. The sillimanites and micas, or the sericite replacing them, form in layers or intergranular sheaves which have apparently controlled the granulation of quartz crystals. These rocks grade from intermediate, partly granulated massive quartzites (slide 25 488) to white, fine-grained, well-foliated granular quartzites (slide 25 489). Granular sillimanite-bearing quartzites are illustrated by slides 25 490 and 25 491, and a pale green, foliated fuchsite-quartzite is represented by slide 25 492. Granulation results in angular or deformed quartz grains, 0.02 - 4 mm across. Later post-tectonic recrystallization of the quartz has produced polygonal textures in places. A sample (slide 25 493) is a biotite, sillimanite-flecked quartzite intermediate in composition between quartzite and paragneiss.

The *sheared quartzites* (slide 25 494) have a granoblastic-elongate texture in which laminar layers of deformed quartz crystals are separated by a continuous layer of fine muscovite which makes up to 10 % of the rock. These rocks are stained red by iron oxides parallel to the shear planes. A mylonite quartzite (slide 25 495) has foliation planes, up to 1 mm apart, which give it a ribbon texture. The quartz is finely recrystallized, and rounded feldspars have been partly rotated by shearing along the foliation. Annealing of the quartz after granulation has partly destroyed the mylonitic texture.

A sample of *diopside-bearing quartzite* has been chemically analysed (Table 5, Lab. No. 75/70). The sample (slide 25 496) has a granoblastic-elongate texture due to the orientation of quartz and diopside crystals in a foliation which is emphasized by the alignment of pits on the weathered surface of the rock. Individual quartz crystals with irregular boundaries are 0.3 - 7 mm in length. Some crystals enclose polygonal to oval-shaped diopside prisms. Diopside may make up to 30 % of these rocks, and in slide 25 497 it is intergranular to the quartz. Its presence gives these rocks a dark green glassy lustre. Diopside is often partly altered to hornblende or to the pale green actinolite and irregular patches of calcite. In slide 25 497 it has altered to penninite in places. The infrequent feldspars appear to be andesine and these grains are embayed against quartz and are altering to sericite or kaolin.

Amphibolitic gneisses and granulites form a distinctive association with the Nulli Formation quartzites. They are common in the Messina area, and similar amphibolites within the Swebebe Ferruginous Member may have originated in the same way. These gneisses occur in the hollows between quartzite ridges, and their exposure is often masked by quartz scree, the only indication being the presence of amphibole in the red soil. The amphibolitic gneisses weather easily to crumbly rocks in which resistant garnets and quartz-feldspar intergrowths are preferentially exposed.

Fresh, conformably, closely interbanded quartzites and amphibolites are sometimes seen in stream sections. Repetition of these bands which vary between 10 cm and 5 metres in thickness may, in part, be due to folding. Isoclinal and open fold structures are seen in outcrop and massive quartz, possibly of secretion origin, is boudinaged in many places. Crenulation lineations are developed in the foliation planes of the layered amphibolitic gneisses which show segregation banding between hornblende and plagioclase.These two minerals display a salt and pepper texture typical of amphibolites elsewhere. Some varieties contain large garnet porphyroblasts and adjacent quartzite bands may also contain orientated garnet and hornblende augens up - 2 cm across. At a locality in the Nulli Range, garnet intergrowths form lenses, 1.5 cm wide and 7 cm long, and patches of quartz and feldspar also occur in this amphibolite. In the Luchewe Basin a conformable hornblende, garnet, pyroxene-bearing quartzite was found to grade laterally into an amphibolite.

South of Pande Mine a massive quartzite contains a rounded fragment of amphibolitic gneiss rimmed by feldspar. This inclusion apparently has been derived by penecontemporaneous erosion of the interbedded mafic rocks during the deposition of the quartzites.This, together with their conformable nature, would suggest that the mafic rocks represent water-laid tuffs or reworked volcanic ashes. The consistent tholeiitic composition of these rocks is indicated by a chemical analysis (Table 5, Lab.No.76/45) and this would also suggest that the amphibolites have an igneous origin.

The *amphibolitic gneisses* are identical mineralogically and often texturally with the fine-to medium-grained garnetiferous anorthositic gneisses. Examples of a salt and pepper texture and segregation layering between hornblende and plagioclase, typical of many amphibolites, are given by three samples (slides 25 499, 25 500 and 25 501). An unusual variety (slide 25 502) is a plagioclase augen amphibolite. The white plagioclase augens are 2 - 15 mm wide and 6 - 20 mm long. They are enclosed in a medium-grained mafic groundmass with a granoblastic-elongate texture. The plagioclase augens may be composed of aggregates of crystals which often cut across hornblende crystal boundaries. The hornblende occurs as irregular well-orientated prisms 1 to 3.5 mm in length and a little free quartz is present. The amphibolitic gneisses consist of about 50 % hornblende and 50 % plagioclase which classifies these rocks as hornblende gabbros (Fig. 3).

The *basal biotite gneisses* were only found at a few localities one of which marks the base of the Nulli Formation on Shakwisa Hill. The gneisses are well-foliated, medium-grained mesocratic rocks with a reddish-brown colouration. The distinctive banding is represented by segregated layers of biotite sandwiched between bands of quartz and feldspar. In places these rocks have been granulated, probably due to tectonic movement along the plane separating the quartzites from the underlying, less competent paragneisses.

A sample (slide 25 503) of a well-banded biotite gneiss shows micaceous layers, up to 6 mm wide, interleaved by quartz and feldspar-rich bands. The foxy-red biotite flakes, up to 1.5 mm across, are embayed against the quartz and they enclose tiny zircons which produce dark pleochroic haloes. Quartz crystals are up to 1 mm across, with irregular boundaries. They form rounded inclusions in the feldspars and show deformation banding and undulose extinction. Plagioclase crystals are 0.3 - 6 mm across and often enclose droplets of quartz or are intergrown with it. The plagioclase has a composition of An_{24} and forms finer-grained crystal aggregates. Some of the larger plagioclase grains are antiperthitic whereas a few irregular microcline crystals are perthitic.

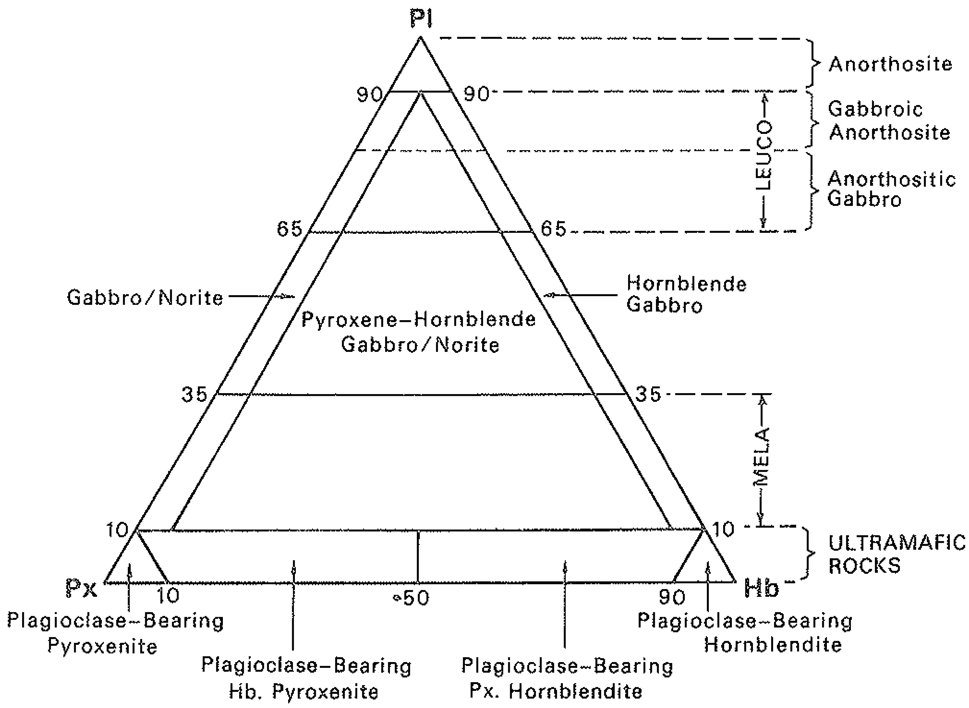


Figure 3: Classification of Gabbroic Rocks containing Hornblende (modified after Streckeisen, 1976 and Windley, 1973)

SYNTECTONIC INTRUSIVE ROCKS

LAYERED ANORTHOSITE SUITE

The Layered Anorthosite Suite comprises a variety of related, metamorphosed intrusive rocks, which were first described from the Messina area (Söhnge 1945). The wide distribution of these rocks within the Central Zone of the Limpopo Mobile Belt indicates their importance in the history of the belt (Hor *et al* 1975, Barton *et al.* 1977 b). In Zimbabwe, concordant sheet-like anorthositic bodies have been traced NNE from the Limpopo River, to where they pass beneath the Karoo basalts of the Nuanetsi Syncline. Reconnaissance north of the Karoo cover has shown that related hornblendic gneisses occur near Mbizi Siding (Broderick 1979). The spatial distribution of the anorthositic rocks emphasizes the vastness of a plutonic igneous event which resulted in the intrusion of these rocks into the Beitbridge Group, c. 3 350 Ma ago (Barton, personal communication).

Anorthosite has been defined as a plagioclase rock having a maximum mafic mineral content of 10 % (Streckeisen 1976). The percentage of mafic minerals may rise to 10-20 % or 20-35 %, in which case the rocks are termed gabbroic anorthosites and anorthositic gabbros respectively (Windley 1973, see Fig. 3). Subsequent metamorphism of the anorthositic rocks, although resulting in recrystallization and foliation, has remained isochemical.

The subdivision of the Layered Anorthosite Suite east of Beitbridge is as follows:

Upper Group:

f) Pegmatitic anorthositic granulite
e) Banded and massive leucocratic to mesocratic anorthositic gneiss
d) Hornblende-rich anorthositic gneiss and leucocratic gabbroic anorthositic granulite
c) Hornblendites and anorthositic gabbroic granulite

Lower Group:

b) Pegmatitic quartz-hornblende-gneiss
a) Quartz-hornblende-gneiss

Leucocratic, anorthositic calc-silicate gneisses are distinguishable from rocks in the anorthosite suite and they are described separately with the Diti Formation paragneisses.

Distribution and Field Relations

The rocks of the layered anorthosite suite appear to form as large concordant sill-like bodies that have been intruded into and below the Swebebe and Shakwisa members of the Diti Formation. The Upper and Lower groups apparently are separate bodies, although the various rock-types are interlayered in places. Taken as a unit, the anorthositic rocks form a distinctive and widely distributed group east of Beitbridge.

Quartz-hornblende-gneisses of the Lower Group are exposed mainly east of the Pande Mine where they occupy a broad belt, 10 km wide, of flat-lying country which separates Malise, Mabana, Shakwisa and Lukumbwe hills in the east from Shampali, Mwanandou, Mafungwe and Bodekwa hills to the west. From the Limpopo River these rocks can be traced for 70 km across the Central Zone in Zimbabwe to where they pass beneath the Karoo cover NNE of the Marungudzi Complex which itself is intrusive into hornblendic gneisses.

Along the western boundary of this body, adjacent to Shampali Hill and the Pande Mine Ridge, two major NNE-trending belts of leucocratic anorthositic gneiss are exposed. They dip steeply to the SE. South of Ngwani Hill complexly infolded hornblende-rich anorthosites dip steeply westwards, whereas to the east and north-east quartz-hornblende-gneisses and infolded paragneisses are bounded by ultramafic granulites which have moderate dips to the south and south-west. Four kilometres north of Mabana Hill, near the Diti River, tightly folded pegmatitic quartz-hornblende-gneiss forms a low ridge, whereas north-east of Ngwani Hill a large triangular raft of tonalitic basement gneiss occurs. Northwards from Ngwani Hill the whole belt swings north past Shakwisa and Mwanandou Hill, and north-west of Mwanandou Hill a triangular northwesterly-folded outlier of quartz-hornblende-gneiss and hornblende-rich gneiss is infolded with paragneiss. The belt swings east between Mafungwe Hill and the northern ridge of the Shakwisa Dome and is again folded northwards between Lukumbwe Hill and the Bodekwa Dome where it runs along the eastern map boundary. The quartz-hornblende-gneisses are mostly bounded to the east and west by hornblende-rich anorthositic gneisses, and the sudden changes in strike are largely controlled by late NE-trending F4 folds. In places the anorthositic rocks have been cut by rounded plugs of serpentinite. Hornblende-rich anorthositic gneisses are also wrapped around and enclosed in the Bodekwa Dome where they occur below rocks of the Swebebe Ferruginous Member and are associated with rocks of the Ultramafic Suite.

The Messina Layered Intrusion (Barton, *et al.* 1977 b) passes NNW-wards into Zimbabwe across the Limpopo River where it includes the Sinyoni Claims, 9 km west of the Pande Mine. The anorthosites continue across the Pande Mine road for 11 km where they bifurcate and give way to paragneisses east of the Shingwanyana Hills. The belt is 2 to 5 km wide and consists of hornblendite, leucocratic and hornblende-rich anorthosite-gneisses with interlayered paragneiss and quartzites of the Swebebe Ferruginous Member. At the Sinyoni Claims corundum-kornerupine-sapphirine and gedrite-bearing granulites occur within the anorthosites, and quartz-epidote breccias are mineralized with copper. The main anorthosite body is synclinally folded and the north-western limb re-enters South Africa along the Limpopo River near the Sand River junction. Hornblende-rich anorthositic gneisses are also folded with the Singelele Gneisses near the Old Main Drift across the Limpopo River, and from here they continue north-eastwards for 10 km to the Fort iron claims in a zone of infolded quartzites of the Swebebe Member. Most of the anorthositic rocks in this belt dip moderately or steeply to the southeast. Within an anticlinal core, between NE-trending quartzites of the Nulli Formation, anorthositic gneisses are exposed 2 km east of Sebetwe Hill.

East of Beitbridge hornblende-rich anorthositic gneisses are wrapped around the Luchewe Basin whereas complexly folded leucocratic and hornblende-rich anorthosites occupy the centre of the structure with infolded ferruginous rocks and paragneiss. These rocks dip moderately towards the centre of the basin whereas the leucocratic anorthosites continue south-eastwards to enclose the northern half of the Swebebe Basin where they dip steeply westwards. South-east of Swebebe Hill the leucocratic anorthosites are intricately folded into a major NE-trending belt that can be traced for some 24 km along the Etomgwani Valley past Malezikwe Hill to the Nulli Dip on the Tshiturapadzi road. The belt, which is up to 5 km wide, has a core of paragneiss interleaved with hornblendites, and a zone of Singelele Gneiss occurs close to the south-eastern contact of the belt. The rocks along this contact dip steeply to the NW whereas, further north, SE-dips are recorded. West of Malezikwe Hill ferruginous rocks are interfolded with leucocratic anorthosites and north of this the belt breaks into two, the northern portion of which terminates near the Nulli Dip.The margins of this belt are bounded by hornblende-rich anorthositic gneisses and the southern continuation of these is folded parallel to the western margin of the Nulli Range.The Nulli quartzites themselves are enclosed in hornblende-rich gneisses.

Hornblende-rich anorthosites, infolded with paragneiss, are folded around the Bulai Gneiss north of the Mat serpentinite basin.They can be traced along the northern contact of the Bulai Gneiss into the Diriza Hills, the quartzites of which they parallel to the NE as a number of discontinuous bodies.Leucocratic and hornblendic anorthositic gneisses occur as inclusions in the Bulai Gneiss, and also as isolated horizons in the paragneisses west and north-west of Lutumba Township and south of the Nulli Range.

A number of features indicate the intrusive origin of the anorthositic rocks. Cumulate layering, represented by hornblende-rich banding, is the most common indication, although concentrations of ilmenite and magnetite are also seen. Chromite layering, as seen in some of the anorthosite bodies in South Africa (van Eeden, *et al.* 1955), was not observed east of Beitbridge. The more mafic varieties of the anorthosite suite, however, have high nickel and chrome contents, up to 2000 p.p.m., whereas the magnetite- and ilmenite-bearing anorthosites have much lower nickel and chrome contents. A banded anorthositic gneiss (Plate 3A), from NW of Marabini Dip, shows isoclinally folded layers of hornblende, in places having a primary cumulate texture. A sample (slide 25 504), from just west of Lunkange School, is from a dark calc-silicate rock containing concordant bands of anorthositic gneiss with hornblende crystals showing cumulate settling textures. The contacts with the calc-silicate bands are irregular and gradational. The anorthositic gneiss cross-cuts the calc-silicate bands in places and it also contains small inclusions of the country rock.

The rocks of the anorthositic suite are tightly infolded with paragneisses or other rocks of the Beitbridge Group, and tightly folded intercalations of paragneiss may form as much as 50 % of an anorthosite horizon. The contact between anorthosites and the country rock are, however, generally sharp, although some calc-silicate gneisses show gradational boundaries. Rocks of the younger Ultramafic Suite have sharp contacts against the anorthosites and are often interbanded with or intrusive into them.

The concordance of the anorthositic rocks and the parallelism of cumulate layers to the foliation suggests that the intrusion of the sill-like bodies took place before the F1 folding. In a few places, however, the foliation of the anorthosites lies obliquely to the paragneisses and some ironstone horizons are cut off by anorthosites. These oblique relationships may, however, be a result of later deformation as the anorthositic gneisses appear to have behaved incompetently in relation to the paragneisses. The anorthosites contain some large garnet porphyroblasts which were apparently developed during the period of no stress between the F1 and F2 fold periods. The anorthosites definitely predate the intrusion of the Bulai Gneiss, which contains bands and inclusions of anorthositic gneiss, which it is believed, was intruded at the end of the F1 fold phase just prior to the period of no stress. The quartz-hornblende-gneisses, however, show cross-folded interference patterns caused by the intersection of F1 and F2 fold trends. This indicates that the Lower Group was intruded during or prior to the F1 fold phase.

The Lower Group

The *quartz-hornblende-gneisses* weather easily and are poorly exposed across the flat terrain in the eastern third of the map-area. Along the Shakwisa and Diti rivers, however, hornblendic gneisses form low ridges and bouldery koppies, up to 5 m high. They are also exposed as large flat pavements littered with exfoliated sheets of rock. North of the Tshiturapadsi road the hornblende-gneisses are covered by deep, monotonous red soils and are only exposed at pans or in wells. The shallower soils are grey to greyish-brown in colour and are covered with a hornblende-magnetite sand which contains fragments of hornblendic gneiss. The gneisses in places weather to subrounded, angular or flaggy boulders, with a coarse, rough surface. Pitting occurs where hornblende clots have been preferentially weathered out.

The quartz-hornblende-gneisses are composed essentially of plagioclase and hornblende, with a little biotite and intergranular quartz. They are medium- to coarse-grained, mottled or banded mesocratic grey rocks which have a gabbroic appearance. They contain 40 – 60 % of plagioclase and up to 40 % of hornblende which gives them the composition of hornblende-gabbro. The pegmatitic varieties are more feldspathic and leucocratic.

The foliation in these rocks is defined by segregation-layering of mafic and felsic minerals and by the alignment of platy minerals. Many of the foliated quartz-hornblende-gneisses contain layers, lenses and fragments of quartz, and these may be separated by dark bands of stumpy prismatic hornblende crystals. Owing to pronounced foliation and crystal alignment these rocks tend to break into flaggy slabs. The gneisses show complex isoclinal fold-patterns overprinted by similar folds on both small and large scale. The long axes lie within the foliation plane. Secretion-veins of quartz-hornblende-pegmatite are developed, and these contain plagioclase, quartz and large clots of hornblende crystals, up to 2 cm across. Many of these veins show ptygmatic folding, and are partly migmatized and displaced by later quartz and pegmatite veinlets.

Pegmatitic quartz-hornblende-gneisses form an ENE-trending isoclinally folded structure near the Diti River north of Mabana Hill. The pegmatite defines a low ridge and is closely associated with quartz-hornblende-gneiss and paragneiss. These coarse-grained mottled feldspathic rocks are reddish-brown and show an indistinct foliation. The feldspars are 2 to 4 mm long and they enclose subrounded aggregates of pyroxene, up to 4 mm across. The pegmatites weather with a hard rough skin on which quartz is preferentially exposed.

Petrography

A sample of quartz-hornblende-gneiss (slide 25 505), collected west of Diti School near the Shakwisa River, has been chemically analysed (Table 6, Lab. No. 014). The quartz-hornblende-gneisses contain more silica, magnesia and iron than the anorthositic gneisses, which are relatively rich in lime and soda.

Other coarse-grained rock samples collected (slides 25 506, 25 507 and 25 508) have a granoblastic-elongate gneissic texture in which the foliation is defined by the elongation of both mafic and felsic minerals and also by the formation of segregation layers, 1 to 2 mm thick. Hornblende and other mafic minerals may form discontinuous bands, ribbons and aggregates, up to 20 mm long, and plagioclase may also form elongate granular aggregates in the foliation. Quite commonly biotite is also present. Green hornblende forms equant to elongate prismatic or irregular intergranular crystals, 0,35 - 3.00 mm long. Larger crystals tend to have embayed borders, whereas the smaller crystals form polygonal, intergranular aggregates around large plagioclase grains. Clinopyroxene, in the form of diopside, occurs in slide 25 508 as augen, up to 7 mm long, which have an outer zone partly altered to green hornblende containing iron ore granules along the cleavage planes. The hornblende alteration zone contains inclusions of quartz, 0.2 mm in diameter, intergrown with pyroxene and hornblende. Zones of patchy hornblende replacement grade into large idioblastic hornblende crystals indicating that hornblende formation occurred simultaneously with the alteration of diopside. Biotite flakes (slide 25 506) appear to have crystallized as a primary mineral.

Plagioclase forms equant to elongate crystals, 0.6 - 3.5 mm long. The larger crystals have irregular interlobate borders, but smaller grains usually occur adjacent to hornblende laths. The plagioclase usually shows good albite- and pericline-twinning with normal zoning. However, untwinned plagioclase showing undulose extinction is also common.

Hornblende commonly forms tiny euhedral inclusions in the plagioclase. Sericitization occurs preferentially along twin planes and adjacent to cross-cutting fractures. In one rock (slide 25 507) the plagioclase is altered to a dark clay and is replaced by epidote. In another (25 508) some perthitic microcline is embayed against plagioclase and quartz. Quartz in this rock forms equant or elongate grains, up to 3,5 mm long, which occur preferentially in the mafic zones. Apatite is a common accessory.

A granular quartz-hornblende-gneiss (slide 25 509), from east of Lukange School, has been hydrothermally altered. Epidotization and pink albitization are concentrated along and adjacent to a fracture line. Plagioclase elsewhere is kaolinized and stained faintly pink by hematite. Hematite and chlorite patches occur in the plagioclase which is partly replaced preferentially by epidote. Hornblende, too, is partly replaced by calcite, epidote and chlorite.

A garnet-hornblende augen-gneiss (slide 25 510), collected NW of Mwanandou Hill, contains large irregular garnets, up to 20 mm in diameter, in a dark hornblendic groundmass. The garnets are poikiloblastic and contain rounded inclusions of ore, quartz and plagioclase. Quartz and plagioclase crystals, 1 to 2 mm long, have crystallized in the pressure-shadow zones around the augen. The groundmass in which the garnets have crystallized is finer-grained and is composed largely of hornblende; plagioclase and a little quartz.

A sample of pegmatitic quartz-hornblende-gneiss (slide 25 511), from the Diti River north of Mabana Hill, is a coarse-grained, pink-stained, granular rock composed largely of polygonal plagioclase grains, up to 8 mm in diameter. The plagioclase shows good carlsbad-albite- and pericline twinning. A composition of An_{33-43} andesine was estimated. A diffuse zoning indicated by undulose extinction is visible in some crystals, whereas others show bent cleavage planes. Tiny round sphenes occur as inclusions in the plagioclase which is partly sericitized against thin concentrations of microcline. Some plagioclase crystals also contain antiperthitic patches of microcline which show undulose extinction and carlsbad twinning. Verdant green augite forms intergranular, embayed crystals, 0.4 mm across, which form irregular aggregates with sphene and opaque ore granules. Tiny crystals of zoisite rim some augites. Apatite crystals are associated with the augite and also form rounded inclusions in the plagioclase.

The Upper Group

Hornblendites and *gabbroic hornblende-rich anorthositic gneisses* in places form low, elongate rises in the gneiss terrain which are covered with rounded or flaggy boulders. The hornblende-rich gneisses, however, tend to form valleys between outcrops of hornblendite. Generally these rocks are easily weathered and they rarely outcrop. They are covered by expanses of red to dark-brown soil but, where there is an underlying layer of calcrete the soils become dark-grey or black. A scree of fine- and coarse-grained hornblende gneisses often covers the surface of these soils together with the occasional garnet. Mica, quartz and dolerite fragments also occur where the rocks are highly fractured. The hornblende rocks are normally covered by a stunted growth of mopani, *Comiphora* and *Combretum* scrub which gives a darker tone to the air photographs when compared with areas underlain by paragneiss or quartz-hornblende gneiss.

The hornblendites and hornblende-rich anorthositic gneisses vary from hard, shiny black granulites to well-banded, greenish-grey rocks composed essentially of dark-brown hornblende with veins and layers of plagioclase. Some hornblendites are garnetiferous and others contain remnants of pyroxene. The rocks differ in grain-size but are generally coarse-grained and equigranular. Locally they develop augen of hornblende, plagioclase or garnet, up to 10 mm across. Other hornblende-rich anorthosites have a granoblastic-elongate texture with individual hornblende crystals, up to 1 mm long.

Granulitic hornblendites have a weakly developed foliation, but they grade into well laminated hornblendic gneisses which show conspicuous segregation layers, 2 - 10 mm wide, of hornblende and plagioclase. Where the hornblendes do not lie with random orientation in the plane of this layering, their long axes are commonly aligned so that they define a lineation parallel to F2 or F3 fold axes. The hornblendic anorthosites commonly form bands, 10 cm - 30 metres wide, which are tightly folded with horizons of paragneiss, diopsidic quartzite or calc-silicate gneiss.

Garnet augen may be rimmed by quartz, with an outer layer of hornblende, but they are usually irregular and intergrown with quartz. The augen form layers which have been isoclinally folded, sometimes in association with feldspar porphyroblasts. Some of the plagioclase megacrysts are twinned on the Baveno twin law. These augen are commonly orientated and elongated parallel to F2 and F3 fold axes.

Secretion-veinlets are fairly common in the mafic anorthositic rocks. Lenses and bands of intergrown garnet and hornblende, or quartz, plagioclase and garnet, may form in patches, up to 20 cm across. The bands have been isoclinally folded, apparently during the F3 fold phase, and the quartz, feldspar, hornblende and garnet lenses appear to have originated by secretion. Hornblende, quartz and plagioclase are commonly rodded parallel to fold axes. In places, isoclinally folded hornblendic gneisses have been brecciated and are recemented by quartz/feldspar secretion-veinlets. In addition, late stage pegmatites often cut the anorthositic rocks in which they form outcrops as low ridges of short strike-length.

Petrography: The hornblendites associated with the upper group of the Layered Anorthosite Complex are ultramafic rocks that are more correctly defined as being plagioclase-bearing pyroxene-hornblendites or hornblende-pyroxenites (Fig. 3), whereas the hornblende-rich anorthositic gneisses would be classified as pyroxene-hornblende-gabbros or norites. A sample of hornblende-rich anorthositic gneiss has been analysed (Table 6, Lab. No. 70/378).

The plagioclase-pyroxene hornblendites vary in colour from greenish-black to shiny black, crystalline rocks that are medium- to coarse-grained. Grain-size varies from 0.5 - 4 mm and the rocks generally have a granoblastic-elongate texture, although a faint layering is locally discernable when plagioclase is present. A number of samples (slides 25 513, 25 514, 25 515, 25 516, 25 517 and 25 518) were examined petrographically.

Diopsidic clinopyroxenes form equant to elongate polygonal or slightly irregular crystals, 0.35 to 3.5 mm long. Generally the crystal boundaries are straight or slightly embayed against hornblende crystals, but in one rock (slide 25 517) clinopyroxene shows interlobate borders against hornblende with which it is intergrown. Smaller pyroxene crystals tend to be rounded, irregular and interlobate against hornblende, but larger crystals are partly poikiloblastic and contain inclusions of plagioclase. Hypersthene occurs as polygonal crystals, up to 1 mm long, and interpenetrating borders are seen against clinopyroxene (slide 25 517). In slide 25 519 hypersthene occurs as equant but irregular crystals that contain abundant inclusions of hornblende. In many rocks the clinopyroxenes are seen to be partly-altered to hornblende around the periphery of grains and along cleavage traces.

Laths of pleochroic olive-green hornblende (slide 25 514) are rimmed with pyroxene, which is oxidized along irregular fractures, cleavage traces and at the interface between the pyroxene and hornblende. Generally, however, hornblende laths are pleochroic from olive-green or green to yellow. They are equant to elongate, and from 0.02 - 4.00 mm long. The hornblende locally forms as aggregates composed of small rounded or euhedral grains. Some crystals form as straight prisms with ragged terminations and the mineral tends to show straight borders against other hornblende crystals but have irregular contacts with quartz if this occurs. Tiny inclusions of quartz and rods of clinopyroxene are commonly enclosed parallel to the cleavage traces of hornblende, whereas specks of iron-ore may occur in the 100^{o} cleavage-direction. In slide 25 514, a zoned colourless amphibole with a green pleochroic core occurs as tiny prismatic crystals, 0.35 mm long. It appears to be edenite. Small flakes of biotite, 0.3 mm across, are orientated in the foliation plane and are associated with the hornblende. Ore granules, deep-green spinels and tiny zircons are accessory minerals.

Plagioclase, varying in composition between An_{30} and An_{72}, makes up a small percentage of the hornblendites and occurs as intergranular bands of equant, polygonal crystals, up to 0.9 mm across. The plagioclase forms irregular interlobate borders against hornblende, with which it is intergrown in fine granular aggregates. Some plagioclase crystals are large poikiloblasts, up to 7 mm across, which have commonly been granulated by later deformation. Some plagioclase grains show irregular zoning and good albite-twinning.

The composition of the hornblendites varies considerably, especially in the relative amounts of pyroxene and hornblende. One sample (slide 25 518), a pyroxene hornblendite is estimated to have a content of 60 % hornblende, 30 % clinopyroxene, 9 % plagioclase and 1 % quartz. Other samples have more pyroxene than hornblende, and in some, hypersthene is more abundant than clinopyroxene.

The hornblende-rich anorthositic gneisses contain a greater percentage of plagioclase than the hornblendites, and they are more akin to hornblendic gabbros or norites. Two rocks (slides 25 520 and 25 521) have a coarse-grained granoblastic-elongate texture with a poorly developed foliation defined by aggregates of plagioclase interleaved in bands of mafic minerals. Another rock (slide 25 522) has an inequigranular, granoblastic texture where subrounded aggregates of hornblende, up to 15 mm across, enclose intergranular patches of plagioclase. Plagioclase comprises 28 – 53 % of these rocks and occurs as equant to elongated crystals, 0.3 - 5 mm across. The crystal boundaries are commonly interpenetrating or interlobate against hornblende, but intergranular to this mineral where it is abundant. In slide 25 521 the plagioclase is diffusely zoned and albite-twinning shows the composition to vary between An_{40} and An_{95}. The plagioclase appears to be more sodic in rocks richer in hornblende. It is preferentially sericitized along cleavage traces and in the core zones which may be replaced by epidote.

Hypersthene and diopside together (slide 25 520) constitute 10 % of ore rock. Hypersthene is intergrown with and is partly replaced by hornblende, whereas diopside is rimmed by hornblende, quartz and ore. Green or brown hornblende forms 35 – 70 % of these rocks where it forms prismatic crystals, 0.35 - 3.5 mm long. Large, simply twinned hornblende crystals in one rock (slide 25 522) have irregular borders and are sutured against intergranular plagioclase grains. The smaller hornblendes are polygonal and usually contain tiny droplets of plagioclase and apatite.

Quartz may form up to 2 % of these rocks, largely in the form of rounded to elongated droplets in the hornblende. Quartz is also intergranular to the hornblende and appears to result from the reaction:

$$Cpx + Opx + Plag + H_20 \rightarrow Hb + Qtz$$

Garnets form as tiny rounded crystals in slide 25 520, whereas apatite, ore and epidote occur as accessory minerals.

The *anorthositic gneisses* tend to outcrop as flat pavements or along low rises that are covered by flaggy feldspathic boulders. They are also exposed on hill-sides, such as the western slope of the Malezikwe Hill, and along rivers where they may form low cliffs. In the flatter country to the north the anorthosites are poorly exposed and they are only seen in pans, wells, ant-bear holes or where bedrock has been lifted up by baobab tree roots. The anorthosites produce different coloured soils depending on depth of burial. In the more dissected southern area near the Limpopo River the soils are thin and light-grey. They are similar to those covering the Bulai Gneiss, but are associated with scree of hornblende and anorthositic gneiss. In the north the soils are deep and red, making it very difficult to separate the various rock types.

The anorthosites have various shades of grey owing to dominance of plagioclase which on a freshly broken surface is itself a greasy-grey colour. The hornblende-bearing anorthosites are light-grey and banded whereas the biotite-bearing rocks are nebulitic. Coarser-grained, massive anorthositic pegmatites are white or pinkish in colour and they locally contain augite. Where the anorthosites are hydrothermally altered, the feldspars develop a pale-green, greasy appearance caused by the presence of iron-stained hornblende.

The medium-grained felsic anorthosites are commonly closely interlayered with bands of mafic anorthositic gneiss or metasedimentary rocks of the Beitbridge Group. These bands may be between 20 cm and 20 m wide, and west of Lukange School a thin horizon in calc-silicate gneiss shows cumulate settling textures. The layering in the anorthosites appears to be a primary segregation feature that has been accentuated by metamorphic differentiation. Cumulate settling-textures were found at a number of localities where a hornblende-rich band, 1 - 6 mm thick, grades upwards into a hornblende-poor layer, 10 - 14 mm thick. The feldspathic layer then gives way abruptly to the next hornblendic horizon. Elsewhere the feldspathic layer may give way to a leucocratic micropegmatite layer composed of an intergrowth of quartz and feldspar. This layering is seen in a sample (25 523), from north of the Shakwisa Dome, in which the size and proportion of ilmenite and magnetite granules helps to emphasize the cumulate texture.

Foliation in the anorthositic gneisses is defined and emphasized by the segregation layering between the mafic minerals (hornblende, diopside, biotite, garnet and ore) and the felsic minerals (plagioclase and quartz). The platy and prismatic minerals are usually aligned within this foliation. The leucocratic anorthosites usually show a stronger foliation than the mafic varieties which are more granular. Concordant anorthositic pegmatite bands are often tightly infolded with the gneisses, usually in layers up to 10 mm thick. The anorthosites commonly show complex crossfold patterns caused by the interference of F2, F3 and F4 folds. Lineations are formed by the rodding of feldspar or hornblende parallel to the various fold axes. The anorthosites appear to have behaved incompetently relative to the enclosing paragneisses and this may be the reason for foliations that lie oblique to those of the paragneiss. Alternatively, it could indicate the intrusive nature of the anorthosites. Boudinage of the more competent materials in the anorthositic gneiss is a common feature. The boudins, usually feldspar-rich, are themselves elongated parallel to the various fold axes and, where the rocks are tightly folded, the boudins have been deformed by the F4 folding. Secretion-pegmatites have commonly crystallized in the low-pressure neck-regions of the boudins, and feldspar augen are rimmed by a discontinuous layer of hornblende or an intergrowth of hornblende, garnet, feldspar and quartz. The anorthositic gneisses are cut by numerous irregular garnet-quartz-feldspar-pegmatites which may be tightly or ptygmatically folded. In places these pegmatites appear to have been derived from the adjacent leucocratic gneisses or from the Bulai Gneiss.

Petrography: Two chemical analyses of anorthositic gneiss are presented in Table 6, Lab. Nos.

Table 6 : Chemical analyses of rocks in the Layered Anorthosite and Ultrmafic Suites (in %)

Slide No.	25 505	25 512	25 524	25 525	25 542	25 543	25 561	25 588
Lab. No.	014	70/378	016	70/381	76/38	76/39	70/379	76/42
SiO_2	59.44	49.03	49.44	49.44	52.66	49.77	39.27	52.53
Al_2O_3	16.54	15.60	24.68	29.34	tr	11.64	5.10	12.56
Fe_2O_3	1.48	1.32	1.03	0.81	3.73	3.19	6.07	1.48
FeO	4.92	9.04	3.45	1.61	6.16	9.51	3.19	8.52
MgO	3.81	8.65	1.85	1.16	17.70	7.80	32.42	8.64
CaO	7.49	11.47	13.43	13.24	15.05	10.86	2.44	11.06
Na_2O	4.30	2.33	2.60	2.67	1.76	2.70	0.10	1.56
K_2O	0.27	0.20	0.92	0.38	0.66	1.00	0.03	0.60
H_2O^+	0.83	1.07	1.63	0.57	0.66	1.99	8.50	1.54
H_2O^-	0.12	0.05	0.12	0.03	0.12	0.12	0.46	0.12
CO_2	0.03	0.09	0.28	0.12	0.44	0.05	0.13	0.58
TiO_2	0.52	0.62	0.48	0.63	0.33	1.00	0.80	0.57
P_2O_5	0.26	0.08	0.07	0.02	0.03	0.38	0.06	0.28
MnO	0.12	0.16	0.08	0.02	0.24	0.21	0.14	0.22
Cr_2O_3	-	-	-	-	-	-	0.99	-
NiO	-	-	-	-	-	-	0.23	-
Totals	100.13	99.71	100.06	100.04	99.54	100.22	99.93	100.26
Specific Gravity	2.82	3.03	2.76	2.79	3.14	3.03	2.80	2.96

Analysts: B.J. Radclyffe, ZGS : 70/381, 70/378 and 70/379
Dept. Metallurgy : 014 and 016
A.D. Powell, ZGS : 76/38, 76/39 and 76/42

Rock types and localities: See Appendix

016 and 70/381.The anorthositic gneisses are a variable group of rocks, although they are all composed of similar minerals and all have similar textures. They can be classed as banded leucocratic to mesocratic anorthositic gneiss, mesocratic, biotite-bearing anorthositic gneiss, homogeneous anorthositic gneiss, garnetiferous anorthositic gneiss, anorthositic granulite and anorthositic pegmatite.

Most of the anorthositic gneisses are medium-grained, banded rocks with an equigranular, granoblastic-polygonal or elongate or granoblastic-elongate texture. In many of the leucocratic anorthosites the plagioclase develops as porphyroblasts or granular aggregates, 2 to 20 mm across, which are enveloped in mafic minerals. Inequigranular, granoblastic-polygonal textures are also developed and appear to result from the recrystallization of granular zones produced by crushing during periods of intense deformation (slide 25 526). Less definite layering is seen in the mesocratic biotite-bearing anorthositic gneisses (slides 25 527 and 25 528). The homogeneous anorthositic gneisses (25 529) show a faint foliation indicated by mineral orientation.

Plagioclase forms up to 80 % of the anorthositic gneisses and occurs as equant to elongated polygonal crystals, 0.1 - 7.0 mm across. The crystal faces are curved or irregular and where porphyroblasts are developed the crystal faces commonly meet in a triple point. Plagioclase has lobate or sutured borders against hornblende (slide 25 530) and is embayed against quartz crystals. Commonly plagioclase and hornblende are graphically intergrown. Albite, pericline and, more rarely, carlsbad twins are developed in the plagioclase, but commonly no twinning is present. The plagioclase may develop patches of antiperthite, and undulose extinction reveals a diffuse zoning in many grains. The plagioclase varies in composition between An_{40} and An_{90} but is most commonly recorded as An_{70} which is labradorite or bytownite. Plagioclase is preferentially sericitized along grain boundaries. In slide 25 531 tiny radiating patches of sericite are developed in the plagioclase, whereas in slide 25 532 plagioclase is altered to epidote and zoisite with tiny crystals of vesuvianite replacing the feldspar along cleavage traces.

Clinopyroxene occurs as apple-green augite (slide 25 531) where it is associated with hornblende and ore. It forms stumpy crystals, 0.7 to 2 mm long, which are embayed against plagioclase and locally show a schiller-structure caused by the inclusion of tiny rounded quartz and feldspar droplets. Diopside forms irregular crystals, up to 2 mm long, but in two rocks (slides 25 529 and 25 533), it occurs as larger lens-shaped crystals containing inclusions of hornblende. The clinopyroxenes are altered to hornblende and chlorite.

Greenish-yellow to dark-brown hornblende occurs as subhedral to irregular crystals, up to 2.5 mm in length. The hornblende forms straight borders against other crystals of the same mineral, but is embayed against and intergranular to plagioclase. Hornblende locally contains inclusions of plagioclase and quartz, up to 0.1 mm across, and small allanite inclusions are rimmed by brown pleochroic haloes (slide 25 527). Hornblende is commonly replaced by iron-stained chlorite, epidote or zoisite and is associated with biotite containing tiny rods of hornblende as inclusions. A sample (25 527) contains trains of biotite flakes, 0.25 to 2.50 mm across, which are wrapped around feldspar aggregates. Hornblende appears to have replaced biotite in erratic patches, but other biotite is of late origin, as it has crystallized in cross-cutting fractures. The biotite flakes contain rounded inclusions of apatite, zircon and myrmekitic quartz.

The garnetiferous anorthositic gneisses (slides 25 534 and 25 532) are mesocratic rocks containing a high proportion of pinkish-brown garnet, apparently with a high content of grossularite. The garnets form rounded to polygonal skeletal intergranular crystals, 0.1 - 1.0 mm in diameter. Skeletal crystals contain symplectic intergrowths of plagioclase, but they grade into solid garnet. In one sample (25 532) a very irregular garnet porphyroblast, 10 mm in diameter, contains an idioblastic augite crystal in its core. This garnet is fractured and veined by symplectic intergrowths of augite and plagioclase. Ore granules fill the centre of these veinlets which radiate out from the augite core. Plagioclase is partly scapolitized in these vein fillings.

Quartz forms a few polygonal intergranular crystals, up to 1 mm across. It may be intergrown with plagioclase, and trails of rounded crystals often mark out the foliation (slide 25 536). The quartz usually shows undulose extinction. Ore granules form as polygonal or skeletal crystals usually associated with pyroxene, hornblende or biotite. Much of the ore is pyrite, although both magnetite and ilmenite are common. Apatite, sphene, metamict allanite and, more rarely, vesuvianite occur as accessories, commonly with garnet or ore granules.

One sample (25 535) is a hydrothermally altered anorthositic gneiss. The rock appears to be hornblende and the feldspars are stained in a distinctive pale-green colour. This is caused by the almost complete replacement of hornblende by calcite/epidote or zoisite. The plagioclase has been sericitized and is itself epidotized. In other hydrothermally altered anorthosites the release of hematite stains the feldspars pink.

Gabbroic anorthositic granulites are represented by three samples (25 536, 25 537 and 25 538). These rocks are mesocratic and vary from inequigranular to equigranular granulites which locally show a gneissic texture or the development of garnet aggregates. In slide 25 538 quartz defines the foliation as it occurs in ribbons, up to 3.5 mm wide. The plagioclase forms in fine-grained bands with intergranular augite, rounded sphenes and garnets which have embayed boundaries against the quartz. In slide 25 537, plagioclase forms as irregular crystals, up to 5 mm long. It shows good albite- and pericline-twins which give an estimated composition for the feldspar of An_{38} - An_{46}. In slide 25 536, some twin lamellae have been bent by later deformation. Rounded and elongate crystals of yellowish allanite, up to 0.35 mm across, are surrounded by radiating fractures in the plagioclase with which they have an intergranular relationship. The plagioclase is partly sericitized and contains tiny rods of goethite. Some microperthitic microcline crystals are intergranular to the plagioclase in places.

Irregular crystals of verdant-green augite, up to 1 mm in length, are embayed against the plagioclase and are associated with rhombic crystals of sphene. In slide 25 537 intergranular hornblendes contain pyroxene and ore inclusions. Ore forms rounded granules, up to 0,6 mm across, and these are sometimes partly rimmed by sphene. Hematite sometimes forms skeletal "fir tree" structures in the plagioclase. Apatite and zircon occur as accessories.

The *anorthositic pegmatites* are coarser-grained feldspathic rocks with a granoblastic polygonal to elongate texture. Individual aggregates of plagioclase grains are 2 - 30 mm across and the intergranular mafic minerals, usually hornblende and biotite, form less than 10 % of the rocks. The plagioclase grains are up to 7 mm long and they are interlobate against the mafic minerals. In one sample (25 539) plagioclase forms in aggregate polygonal crystals, in which albite twins are developed in some grains, but not in others. Another sample (25 540) is white and much coarser-grained. Pseudo cross-hatching and widely-spaced albite-twinning is developed in the plagioclase which contains patches of antiperthite. The composition of the plagioclase is An_{40} - An_{64}. The plagioclase is sericitized along cleavage traces and is locally replaced by epidote and calcite.

Hornblende (slide 25539) forms rounded crystalline aggregates, up to 20 mm long. The hornblende crystals are partly replaced by epidote, chlorite and ore. In slide 25 540 the intergranular hornblende crystals are larger, and they are associated with flakes of biotite containing tiny epidote granules along the cleavage. A few garnets and some diopside also occur.

Another sample (25 541) is a poikiloblastic pyroxene-granulite which is cut by a quartz-rich anorthositic pegmatite vein. The quartz grains are rodded parallel to the foliation giving the pegmatite a granoblastic-elongate texture.

THE ULTRAMAFIC SUITE

The ultramafic suite consists of a group of dark coloured, coarse-grained syntectonic intrusive rocks, which vary from pyroxene-amphibole-spinel granulites to hornblende- and olivine-rich granulites, now largely serpentinized. These rocks were first described from the Messina area by Söhnge (1945) as perknites, peridotites and serpentinites. The pyroxene- and hornblende-rich granulites tend to occur as concordant horizons within the Beitbridge stratigraphic sequence, but the dunitic granulites usually occur as oval, plug-like bodies. The concordant ultramafic granulites reflect the regional structure, but in outcrop they are usually granular and coarse-grained.
The ultramafic rocks have been subdivided as follows:

1) Ultramafic Granulites and Gneisses
    a) Pyroxene-amphibole-spinel-granulite
    b) Layered peridotitic gneiss
2) Hornblendite
3) Tremolitic Ultramafic Rock
4) Serpentinite (Dunitic Granulite)

Rocks of the Ultramafic Suite show a complete gradation from dunitic granulite into peridotitic, hornblendic and pyroxenitic granulites which are clearly related in origin, as is seen in zoned serpentinite bodies such as that covered by the Mat Claims. All rocks of the Ultramafic Suite have a high content of nickel and chrome, usually 1000 - 4000 ppm which indicates their certain igneous origin. Although many of the ultramafic rocks may form concordant bands within the paragneisses and anorthositic rocks, the two mafic igneous suites appear to have intruded at separate times, the former preferentially into rocks of the Swebebe Ferruginous Member and the latter below them. Chemically the differentiation trend of the Ultramafic Suite appears to follow a tholeiite trend, whereas the anorthositic rocks follow a calc-alkaline trend. However, the two rock suites were probably derived from differentiation within a single magma chamber. The concordant ultramafic rocks are granulites and were therefore intruded as sills or extruded as lavas before the end of high grade metamorphism. They have undergone at least two phases of isoclinal folding which indicates that they were intruded in the period of no stress prior to the F2 folding. Later deformations have resulted in the remobilization of some metapyroxenites and serpentinites, and allowed for their migration into the low pressure zones of F1, F2, F3 and F4 synformal fold noses and some F4 antiformal closures, where they commonly cross-cut the enclosing country rock.

The layered sequence of hornblendite, pyroxenite and serpentinite in the zoned ultramafic bodies indicates that cumulate settling was operative during their genesis. Some cross-cutting relationships between these rock-types in the Pande SW orebody may be a result of deformation. The texture and mineralogy of the ultramafic rocks indicates that they crystallized under granulite-grade conditions. Pargasitic hornblende which is abundant in the pyroxene granulites, is mostly of primary origin, although some is of retrogressive metamorphic origin. The spinels also have a dual origin, both primary and secondary where they are intergranular. This mineralogy suggests the following reaction (Deer, Howie and Zussman 1972, p.173):

olivine + labradorite + $H_2O \rightarrow$ orthopyroxene + endenite (Fe-free pargasite) + spinel

Accordingly, the primary intrusive rocks could have been gabbroic or plagioclase-bearing ultramafic rocks which have been transformed by the above reaction. The medium-grained, layered, serpentine-bearing hornblendites appear to have been derived from the retrogression of layered peridotitic gneisses, and the coarse-grained garnetiferous hornblendites could represent retrograded pyroxenites.

The decussate texture shown by the tremolitic ultramafic rocks appears to have formed during a period of retrograde amphibolite-grade metamorphism under little directed stress. This could have been at the close of the main period of deformation. Tremolite was probably formed by the reaction of diopside, enstatite and quartz, which may represent the original mineral composition of the intrusive mafic rock (Deer, Howie and Zussman 1972, p. 163):

diopside + enstatite + quartz + $H_2O \rightarrow$ tremolite

Ultramafic granulites, gneisses and hornblendites

The ultramafic rocks occur mainly as concordant layers, 1 - 30 m thick, within the central belt of the

Swebebe Ferruginous Member. The abundance of ultramafics within the ferruginous horizons may result from the competence of these rocks which, during deformation, were fractured parallel to the foliation thus providing routes for the intrusion of mafic magma. The possibility of these rocks originating as ultramafic lavas cannot be discounted, as the association of such lavas with banded iron-formation in the Zimbabwean greenstone-belts is a known phenomenon. Rocks of the Ultramafic Suite also occur as concordant layers in quartzites of the Nulli Formation, in paragneisses of the Diti Formation and in the meta-anorthosites. Ultramafic granulites form the outer rims of zoned bodies, such as the Mat and Pande SW serpentinites. Hornblendites which are commonly garnetiferous usually form the outer rim of these bodies, whereas partly serpentinized pyroxene-granulites are perfectly inlayed with serpentinites and commonly grade into them. Ultramafic granulites occur as discontinuous rafts within the Bulai Gneiss.

Distribution

Ultramafic granulites associated with the central belt of the Swebebe Member extend north-east from the old Main Drift across the Limpopo River, around the southern lobe of Singelele Gneiss towards the Fort Iron Claims. North-west and south of Dombadema Hill ultramafic granulites form thin concordant bands in the paragneiss, whereas 4 km south of Nulli School a tightly folded belt, up to 250 m wide, consists mostly of hornblendites, with some pyroxene-granulites in association with magnetite-quartzites. Between the southern end of the Nulli Range and the Bodekwa Dome, a complexly infolded belt of hornblendic rocks, 2 km wide, lies within the central belt of the Swebebe Member. These rocks extend 12 km to the north as a large lobe, where they are interbedded with hornblende-rich anorthosites, and they continue ESE to Mafungwe Hill where they dip steeply SW. East of Mabezikwe Hill, below the Nulli Range, a 200 m-wide belt of hornblendites parallels the strike within paragneisses of the Diti Formation. This belt crosses the road to Tshiturapadsi and is folded back on itself near the eastern Nulli Dip.

Ultramafic granulites and hornblendites form concordant horizons within the maon belt of quartz-hornblende-gneisses in the east. NE of Malise Hill ultramafic granulites are infolded with quartzites and calc-silicate rocks of the Shakwisa Calcareous Member, and thin bands of hornblendic granulite occur south of Mabana and Saluwana hills. North of Mabana Hill and west of Shakwisa Hill ultramafic granulites are complexly infolded with paragneiss, quartz-hornblende-gneiss and calc-silicate rocks. They contain numerous serpentinite swells and dip steeply southwards in the south and have a moderate dip to the west near Shakwisa Hill. Ultramafic rocks are infolded within the Shakwisa Ridge. In the north-eastern corner of the map-area a NNW-trending belt of ultramafics are interlayered with quartz-hornblende-gneisses and are cut by pods of serpentinite.

Complexly infolded ultramafic rocks occur within the Pande Basin west of Shampali Hill. The Pande SW magnesite orebody is a zoned serpentinite within the synform and has an outer rim of pyroxene-granulite, up to 400 m wide, with peripheral hornblendites. East of the Pande Mine, near the Cullinan Claims, complexly infolded ultramafics are associated with serpentinite pods in the Pande Antiform. East of the Samtete River, along the western boundary of the Pande Basin, a belt of hornblendic ultramafic rocks extends NE across the Pande Mine road; other granulites are infolded with quartzites, magnetite-quartzites and calc-silicate rocks in the vicinity of the Fiat magnesite claims.

Ultramafic rocks occur as concordant horizons within quartzites of the Nulli Formation, west of the Shingwanyana Hills and northwards to Malezikwe Hill. Thin horizons of ultramafic rock occur south and north-west of Swebebe Hill, where they are interleaved with anorthosite, quartzites and paragneiss. West and south-east of Luchewe Hill, hornblendites and pyroxene-granulites form part of the northern rim of the Luchewe Basin. Hornblendites cover the southern slopes of Diriza Hill, whereas the Mat Serpentinite is rimmed by garnetiferous hornblendite and banded with hornblendite and pyroxene-granulite. Just north of Lutumba Township the main Masvingo road crosses a large triangular patch of ultramafic rocks, mainly pyroxene-granulites. In the north-western corner of the map-area, hornblendites and pyroxene granulites enclose large serpentinite bodies in a synformal structure. These rocks are interbedded with ferruginous quartzites and are cut by ENE- and NW-trending dolerite dykes.

Field Relations and Lithology

The pyroxene-granulites do not form any particular topographic features except when they occur as small hills surrounding serpentinite bodies. The layered peridotitic gneisses outcrop as rough, jagged elongate boulders. The ultramafic granulites are generally covered by deep red to dark brown soils which usually contain fragments of pyroxene and hornblende. The coarse-grained hornblendites are not well exposed owing to their susceptibility to weathering, and they usually occur in valleys as rough, rounded boulders. Finer-grained hornblendites, however, form irregularly shaped koppies and ridges covered by rounded to elongated boulders. The soils overlying these rocks contain more hornblende than pyroxene fragments. The tremolitic ultramafics are rare and they are not reflected topographically. They develop rough or smooth elongate boulders. The rocks themselves are green to greenish black in colour, medium-grained, and are composed of radiating or partly orientated prisms of tremolite, 0.3 - 3.5 mm in length.

The ultramafic granulites are very hard rocks which are black to greenish-black on a freshly broken surface, but which weather with a reddish skin. The rocks are medium- to coarse-grained with individual grains varying from 0.25 to 3.5 mm across. The texture varies from being even-grained and granoblastic to granoblastic-elongate, porphyroblastic or augen-textured. Some granulites contain hypersthene poikiloblasts, up to 45 mm long, which contain inclusions of amphibole and spinel. A foliation is usually developed in these rocks owing to alignment of amphiboles and pyroxenes, and segregation-layering of these minerals may also occur.

The hornblendites are fine- to coarse-grained hornblende- and plagioclase-bearing granular rocks that are black to shiny black in colour. They are usually homogeneous, but may contain red garnets or quartz-feldspar intergrowths. Fine- to medium-grained hornblendites are commonly banded, but the coarse-grained rocks are equigranular containing hornblende crystals over 10 mm in length. The finer-grained rocks vary from granulitic to well-foliated gneisses which may contain augen of garnet or hornblende, and which show segregation-banding between hornblende and plagioclase. The granulitic hornblendites do not show the clear fold-structures which are well represented in the gneissic varieties, especially adjacent to more competent quartz bands.
The ternary diagram (see Fig. 4) includes the variety of ultramafic rocks that contain hornblende. The composition of rocks in the Ultramafic Suite of Beitbridge suggests that a large proportion of these variants are represented in the map-area, including dunites, now largely serpentinized, various peridotites, pyroxenites and hornblendites.

The common amphibole appears to be pargasite, whereas spinels are represented by dark-green hercynite, picotite, chromite and magnetite. Hypersthene is the most common pyroxene and clinopyroxene, mostly diopside, was found only at two localities.

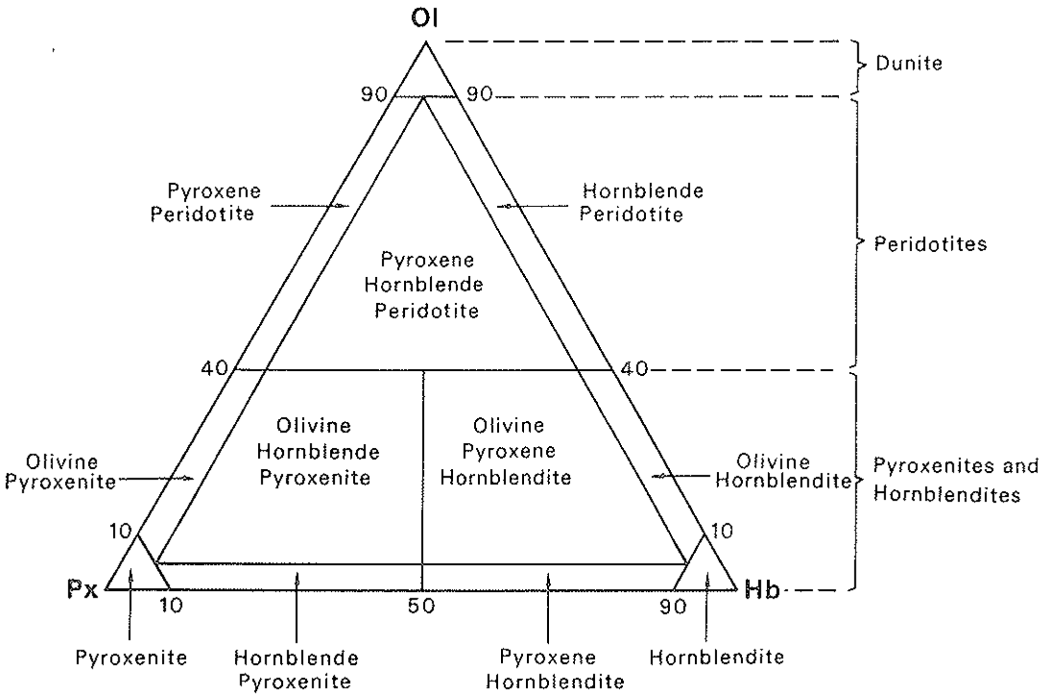


Figure 4: Classification of Ultramafic Rocks containing Hornblende (after Streckeisen, 1976)

Petrography

The ultramafic affinities of a pyroxene-granulite and an interbanded amphibolitic mafic granulite from the Fiat Claims west of Pande Mine are demonstrated by their chemical analyses (Table 6, Lab. Nos. 76/38 and 76/39). The pyroxene- and peridotitic granulites vary from even-grained, fine to coarse granular rocks with granoblastic or elongate granular textures. Other coarse-grained granulites are inequigranular, and porphyroblastic or poikiloblastic, with some large sieve-textured hypersthene crystals that reach 45 mm in length. The layered peridotites have a gneissic texture marked by discontinuous segregation-layers of polygonal amphibole, hypersthene spinels and irregular streaks of serpentine after olivine. Generally these rocks consist of varying amounts of serpentine or olivine, hypersthene, diopside, green spinel, ore and a little mica.

The orthopyroxenes, usually hypersthene, form irregular or rounded sieve-textured poikiloblasts. They are a faint pink colour and may be pleochroic from pink to green. In one sample (slide 25 544), the foliation wraps around the hypersthenes indicating that they crystallized earlier, and may represent relict sieve-textured poikiloblasts from the primary intrusive magma, a common texture of many pyroxenites. The orthopyroxenes are lens-shaped or ovoid with interlobate borders. Individual crystals have straight contacts with other hypersthenes and are embayed against amphiboles and olivine. Poikiloblasts contain numerous elongate and rounded inclusions of spinel and amphibole, which are commonly strongly orientated parallel to cleavage direction (slide 25 545). In ore rock (25 546) lobate orthopyroxenes contain up to 40 % of irregular pargasite inclusions, about 0.75 mm across, which in places are optically continuous with adjacent crystals. This suggests that the two minerals crystallized simultaneously. In another sample (25 547) clinopyroxenes are dominant, mostly as diopside, but also occurring as augite. The clinopyroxenes contain tiny inclusions of spinel, 0.1 mm across, whereas the hypersthene forms smaller polygonal crystals. Hydrothermal and low-temperature alteration of the pyroxenes has resulted in their replacement along fractures by yellow serpentine (slides 25 544 and 25 548). In slide 25 548 hypersthene is also altered to a colourless clinochlore and in places to clinozoisite.

Most of the amphibole in the ultramafic granulites is pargasite which is pleochroic from apple-green to colourless, is biaxial positive with a maximum extinction angle, $\underline{x}$ to $\underline{c}$, of 22 - 25°. In some rocks (e.g. slide 25 547 which contains abundant clinopyroxene), the pargasite is more deeply coloured and iron-rich. Some pargasite crystals show simple twinning on their basal section. They form equant to elongate polygonal crystals, 0.35 - 7.00 mm long, which in places crystallize around the ends of hypersthene poikiloblasts (slide 25 549). The amphiboles have straight borders when in contact with other crystals of the same mineral, and may be rounded or irregular, showing embayed or interpenetrating borders. Straight contacts may also occur where the cleavages of amphibole and hypersthene crystals are parallel. Amphiboles are also generally embayed or interlobate against olivines with which they tend to be intergranular. Pargasite locally contains tiny rounded or polygonal inclusions of olivine or hypersthene. In one rock (slide 25 550), amphibole crystals have been replaced by serpentine along the cleavage traces. Often amphiboles are fractured and schillerized owing to the inclusion of iron oxide granules and they may be replaced by chlorite. Olivine forms equant, idioblastic, polygonal or irregular crystalloblasts which are 1 - 7 mm long and are generally of medium-grain. The olivines commonly occur in thin layers (25 544), but they also occur as augen-shaped aggregates. In one sample (25 544) the olivines are aligned in the foliation, but some are elongate across the trend indicating that olivine crystallized before the deformation. Olivine has lobate or embayed borders against hypersthene and may be intergranular in relation to it, but in olivine aggregates borders are straight and the crystals polygonal. Both biaxial positive and negative olivines were identified, indicating that the mineral is forsteritic in composition. The olivines are cut by a set of fracture lines parallel to or sub-perpendicular to the foliation. These fractures are filled by fibrous clinochlore after chrysotile, and have a central core of iron ore (slides 25 551 and 25 552). Anastomosing veinlets of secondary hematite occur along olivine grain-boundaries, and in some completely serpentinized rocks this ore is the only indication of the original polygonal olivines. The olivines, which are largely serpentinized, commonly show a classic mesh or hour-glass structure indicating that they were derived from peridotitic and dunitic granulites. The fibrous antigorite which replaces the olivine (slide 25 551) is usually dark-yellow or mostly brown in colour and it may be rimmed by quartz. Crystals of hypersthene and amphibole containing inclusions of serpentine are commonly cut by radiating fractures owing to expansion during serpentinization. Grey to brown iron-stained clay (sepiolite) has apparently replaced the serpentine, as has clinochlore in some rocks.

The spinels appear to be recrystallized primary ore grains which occur as opaque black, brown, yellow, olive-green or verdant-green granules of chromite, picotite or hercynite. They tend to form layers or trains commonly within olivines, but cross-cutting pyroxenes and amphiboles. This indicates that they crystallized early, although some trains wrap around olivines and orthopyroxene poikiloblasts, suggesting later crystallization. The spinels form square or rhombic, rounded to irregularly-shaped crystals, up to1 mm long. They may be elongated parallel to the foliation and they often occur as tiny inclusions in hypersthene. Trains of primary, square to rhombic spinels appear to have formed by cumulate settling, as they are not always parallel to the later foliation. The intergranular spinels are embayed against pyroxenes, amphiboles and olivines, and they appear to have a secondary origin. Many spinels are cut by fracture lines filled with opaque hematite which commonly rims the granules and may replace them. Green spinels are commonly stained brown or black, or they are altered to iron-stained chlorite, biotite and magnetite. In one rock (25 548) spinel granules have an inner corona of serpentine which has altered to clinochlore. Clinozoisite also appears to have partly replaced spinel in this rock, and intergrowths of magnetite and chlorite may have replaced primary phlogopite. Magnetite granules occur in irregular belts and aggregates as well as along fracture lines and crystal boundaries, especially in association with serpentinized olivines. Magnetite is largely replaced by hematite or limonite and is commonly intergrown with chlorite.

The fine- to medium-grained hornblendites are granular rocks with a granoblastic-elongate texture (25 553). One sample (25 554) is a coarse-grained rock consisting of irregular to subhedral crystals of hornblende, up to 8 mm long, with intergranular plagioclase, quartz and garnet. Quartz, garnet and hornblende also form inclusions in poikiloblastic diopside crystals. Hornblende locally shows simple twinning and contains elongate blebs of quartz, up to 0.2 mm long. There are straight or curved contacts between hornblende crystals, but the mineral is sutured against plagioclase and embayed with garnets. Another sample (25 555) from Pande Mine contains simply twinned hornblende laths rimmed in places by a colourless amphibole. The hornblende in this rock is oxidized along fractures where it has been replaced by an intergrowth of chlorite and limonite. The hornblendites are composed of 50 – 90 % of hornblende.

Hypersthene forms a few irregular, sutured, poikiloblastic crystals which enclose granules of plagioclase, diopside and ore. Hypersthene locally rims diopside crystals, up to 3 mm long. Diopside contains ore granules along its cleavage traces and shows straight contacts against plagioclase, but it is sutured with intergranular quartz. Garnets form rounded, irregular crystals, up to 2 mm in diameter (in 25 554). They are sutured against plagioclase and contain tiny rounded inclusions of hornblende, quartz, plagioclase, pyroxene and apatite. Rounded garnets (slide 25 555) are confined to the centres of cordierite crystals, where they are rimmed by ore. The cordierite forms rounded intergranular crystals with smooth lobate contacts against hornblende. The crystals show some multilamellar twinning and they also contain tiny inclusions of sphene. Cordierite partly altered to an intergrowth of quartz, hematite and chlorite.

Plagioclase fills the intergranular spaces between hornblende laths, against which it has irregular, lobate boundaries. It has good albite-twinning and the plagioclase composition is An_{64} to An_{84}. The plagioclase locally contains inclusions of quartz and itself occurs as inclusions, 0.3 mm across, in hornblende. Ore granules, 0.35 mm across, are associated with some rutile (slide 25 555), and accessory apatite is present. Fractures in the rocks are filled with chlorite, fine silica and iron oxide.

One sample (25 556) from north of Ngwani Hill, is a poikiloblastic plagioclase-rich hornblendite. The hornblende may have been derived by complete replacement of pyroxene, and the plagioclase occurs as rounded poikiloblasts, 2 - 20 mm across. The plagioclase contains rounded inclusions of quartz and droplets of green hornblende, 0.35 mm across. The plagioclase shows good albite- and pericline twinning and a composition of An_{74} - An_{78} bytownite was estimated. Green pleochroic hornblende laths occur largely as intergranular aggregates, and in bands where it is embayed against the plagioclase. The coarse-grained, green tremolitic ultramafics (slides 25 557, 25 558, 25 559 and 25 560) have a polygonal to decussate texture of radiating crystals, 3 - 4 mm in length. A faint foliation (25 557) is defined by the orientation of crystals in alternating layers of segregated poikiloblastic hypersthenes and tremolite prisms. Sample 25 558 has a granoblastic-polygonal texture and it appears that these rocks were derived by retrograde metamorphism of pyroxene granulites during a period of no stress. The rock consists of up to 65 % tremolite, replacing the orthopyroxenes. Hypersthene occurs as irregular, elongated poikiloblasts in a rock (slide 25 557) which contains about 50 % of polygonal tremolite that commonly rims the poikiloblasts as granular aggregates. Tremolite is also intergrown in optical continuity with hypersthene crystals. In slide 25 559 tremolite forms radiating and randomly orientated idioblastic crystal boundaries, indicating later crystallization. In certain rocks (25 559 and 25 560) patches of intergranular talc after tremolite are common as an alteration product.

Serpentinites

Serpentinites owe their origin to both intrusive and metasedimentary mechanisms within the map-area. The metasedimentary serpentinites have been derived from forsteritic marbles or ophicalcites within the Shakwisa Calcareous Member of the Diti Formation and they are described under those headings. The rocks of intrusive origin have arisen from the serpentinization of dunitic, peridotitic and pyroxenitic granulites.

The largest serpentinites include the Pande, Mat, Nulli and Mafungwe bodies, which occur in rounded, elongated or horseshoe-shaped synforms or basins, 1 - 2 km across. These bodies tend to be located adjacent to or just below the Nulli Formation quartzites which they locally penetrate. They are also located preferentially within fold-noses of F1, F2, F3 and F4 synforms, where they may be zoned with an outer rim of hornblendite, garnetiferous hornblendite and pyroxenite and a central core of dunitic serpentinite. The last is commonly veined with magnesite. Most of these serpentinites do not reflect the regional structure, although the Pande, Mat and Mafungwe bodies form major cross-fold interference patterns owing to intersection of F1, F2, F3, and F4 fold-axes.

Serpentinite also forms small rounded or irregular pods, lenses and blows, up to 0.5 km across. These serpentinites are usually associated with rocks of the Swebebe Ferruginous Member which they often distort or cross-cut. They may show some zoning with magnetite cumulative layering. Conformable serpentinites also occur, usually within the Swebebe Member, and they can be attributed to the serpentinization of layered peridotites, pyroxene granulites and hornblendites. The conformability of these serpentinites may indicate that they originated as ultramafic lavas, but chemically they plot on the same magnesium tholeiite variation line as serpentinites elsewhere in the stratigraphy. This indicates that all the serpentinites were derived from the same magma chamber and not from separate sources, as would be required for a pre-metamorphic volcanic origin.The conformable serpentinites have been distorted by at least two isoclinal fold phases.

Lithology

Lithologically and petrographically the serpentinites can be classed as follows:

a) Unaltered green serpentinites derived from dunitic, peridotitic and pyroxene granulites
b) Banded magnetite-serpentinites
c) Altered serpentinites, including talcose serpentinite, slip-picrolite-serpentinite, silicified or birbiritic serpentinite and carbonated serpentinite with nodular magnesite veins.

The serpentinites vary considerably in colour depending largely on their degree of alteration. The unaltered serpentinites are various shades of green, dark-brown or grey. They may be mottled or spotted, and they commonly show a fine black lamination. The banded magnetite-serpentinites are dark-red, green or yellowish-grey adjacent to magnetite bands, whereas talcose serpentinites are soft pale grey-green or bluish rocks with a soapy feel. Slip-picrolite serpentine has a columnar structure with a smooth, vitreous light-green appearance. The silicified or birbiritic serpentinites are hard, vitreous or earthy banded rocks that are dark-red to orange-brown in colour. The carbonated serpentinites are partly altered to and are cross-cut by numerous magnesite veinlets. They have a variety of light tobacco-brown colours and are earthy in texture.

The serpentinites are usually homogenous and equigranular, the common grain-size being about 1 mm, although large pseudomorphs after pyroxene may show hour-glass structure. Some large poikiloblastic pyroxenes, up to 12 mm long, are also replaced by serpentine, and anthophyllite prisms and veins of fibrous antigorite may also be present. Banded magnetite-serpentinites contain up to 30 % of granular magnetite in layers, up to 50 mm thick. The talcose rocks may contain clear green steatite flakes, up to 8 mm across.

The serpentinites are generally structureless, but may show an indistinct or strong foliation depending on whether they were derived from dunite or layered peridotite. A lamination caused by metamorphic segregation has ribbons of spinel, pyroxene, amphibole and olivine, which are separated by bands of serpentine locally containing strongly orientated magnetite grains, and having a flat base and an irregular top which is suggestive of a relict igneous lamination. Closely spaced layers of nodular magnesite may also emphasize the foliation. Isoclinal folding is quite common in the layered serpentinites but this is commonly indicated only by folded bands of primary magnetite granules.

The green serpentinites with a yellow coating, up to 5 mm thick, may be carbonated. The surface may be pitted and studded with tremolite, magnetite and bastite (after hypersthene). Birbiritic serpentinites weather to rough, black, granular, grooved or pitted rocks in which the hollows are filled with limonite and quartz. The carbonated serpentinites may be ribbed or grooved along the foliation and develop a rough, reddish, limonite-stained coating which is usually soft and decomposed. Quartz veining may form boxworks and these serpentinites are commonly coated in calcrete and veined by magnesite.

Sets of straight or irregular fractures are developed parallel, perpendicular or oblique to the foliation in the serpentinites, which are rendered blocky and veined. Irregular fractures are commonly filled with fine-grained, granular or colloform translucent silica veinlets and, more rarely, with short, cross-fibre chrysotile asbestos. Magnesite veins are generally related to a later event affecting many serpentinites, especially the larger bodies, and are commonly cut by silica veinlets. These irregular, undulose, nodular or lined magnesite are best exposed in the Pande serpentinite where they fill horizontal release-joints as well as steeply inclined fracture lines which commonly cut across the flat-lying veins. Veins are 0.3 - 20 cm wide and may form a stockwork of tiny veinlets filled with porcelain-like nodular magnesite with a conchoidal fracture.

Distribution and Field Relations

Serpentinites form distinctive calcrete-covered, sparsely vegetated rises and ridges, particularly in the flat pan country in the north. Some serpentinites are covered with a scree of magnesite recemented by calcrete, and more rarely the silicified serpentinites are associated with ferricrete. Elsewhere these serpentinites are usually bounded by ferruginous quartzites where they form low, smooth rises or rough ridges covered by pitted, irregular boulders. The overlying soils are yellow or brownish, becoming grey when calcrete is abundant. They change rapidly as from the serpentinite on to gneiss terrain and they are usually covered by a surface scree of serpentine, magnesite, pegmatite and coarse hornblende. Where serpentinites cut hornblendic rocks, the soils are redder and have scattered hornblende fragments.

A large outlier of ultramafic and ferruginous rocks occurs in the north-western corner of the map-area, where three rounded serpentinite bodies are rimmed by associated magnetite-quartzites, green garnet-granulites and fuchsite-bearing quartzites. The Mat zoned-serpentinite, north-west of Beitbridge airfield, occurs in an ENE-orientated symmetrical oval basin, 1 km wide and 2 km long. There is a repetition of early F1 and F2 interference patterns within the north and south border zone, owing to folding during F3 along the long axis of the basin (Plate 5, in pocket). The serpentinite is rimmed by hornblendites, is veined with magnesite and encloses patches of hornblendite. It is cut by fracture lines and is downthrown to the north along a dolerite-filled ENE-trending line which is parallel to the F3 fold axis. A south-trending serpentinite body occurs on the south-east side of the basin. It is 900 m long and appears to cut across the structure as a later intrusion. A few small serpentinite blows occur west and south-east of Luchewe Hill where they are associated with ultramafic granulites, anorthosite gneiss and ferruginous quartzite.

The main development of serpentinite is in the central belt of rocks of the Swebebe Member, east of the Nulli Range. In this zone, rounded pod-like serpentinite bodies have been intruded adjacent to or into magnetite-quartzites, massive quartzites and ultramafic granulites, which they often dilate or distort. A large serpentinite, 1.5 km south-east of Nulli Dip, is veined with magnesite, and a smaller body, 2 km north-east of the Dip, is birbiritic. Some silicified serpentinites have been brecciated and recemented by magnesite. An elongate body containing some large anthophyllite crystals, south-east of Nulli Hill, has dilated the magnetite quartzites. Some layered peridotitic serpentinites and pyroxene-granulites are also interbedded with the ferruginous quartzites in this area. Other oval bodies have been intruded into ultramafic and anorthositic gneisses enclosing the Bodekwa Dome. One of these, a large pod north of Nulli Hill, has been displaced by a NE-trending fault. Southwards, still within the central Swebebe Member belt, irregular and rounded serpentinites occupy fold noses north-west and west of Dombadema Hill. Some of these bodies are restricted to the paragneiss.

In the environs of the Pande Mine many rounded, elongated and irregular serpentinites occupy the core zone of F3 and F4 fold closures. The main Pande serpentinites fill a northern horseshoe-shaped basin and also a south-trending synform, 1.5 km long, nearer the Limpopo River. The ultramafics have been intruded just below the Nulli Formation, and the northern Pande body appears to occur in an F1, F2 synformal fold structure. The southern extremity of the Pande SW- orebody has been refolded around an F3 antiformal axis. A number of smaller pods have been intruded between the Pande Mine and Shampali Hill. Zoning is apparent in the main Pande bodies, with hornblendites partly enclosing and partly occurring within the serpentinite. The hornblendites locally contain garnet and cordierite, and magnesite veining is largely confined to horizontal release joints in a central zone of tobacco-brown serpentinite which is overlain by a hard serpentine capping. Talc and silicification occur locally and slip-picrolite is developed in fracture lines adjacent to dolerite dykes where it shows smooth, slickensided and striated surfaces. The Pande serpentinites have been cut by pegmatites and by silica veinlets.

Smaller serpentinites, are abundant in the flat-lying area of quartz-hornblende-gneisses enclosed between Mwanandou, Bodekwa, Shakwisa and Lukumbwe hills. They also occur farther south in this zone, between Shampali and Ngwani hills and north of Saluwana Hill where their positions are controlled by folding. Concordant serpentinized hornblendite and pyroxene-granulite occur along the crest of Lukumbwe Hill, and some large serpentinite pods are intrusive into ultramafic and quartz-hornblende horizons in the north-eastern corner of the mapped area.

Genesis

The Beitbridge serpentinites have a high nickel and chrome content (Table 6, Lab. No. 70/379) and they are seen to grade into hornblendites and pyroxenites. Chemically, their composition lies on the same magnesium variation trend as other ultramafic and anorthositic rocks, which indicates that they were derived from the same magma chamber and were therefore intruded at a similar time. From their texture it is apparent that the ultramafic rocks were intruded when granulite-grade conditions were operative. This is further suggested by their close association with green, chrome-bearing garnet-granulites and green-stained fuchsite-quartzites.

Large serpentinite bodies appear to fill synformal interference configurations produced by F1 and F2 folding, or they are folded around F3 axes. Other bodies preferentially occupy F1, F2, F3 and F4 fold-closures. The Pande North serpentinite cuts across the nose of an F2 fold, indicating that the rocks were molten during the time of redistribution. Layered serpentinites show interference patterns produced during F2 and F3 folding and they must have been intruded prior to these, probably during a period of no stress following the F1 fold period. West of Pande Mine serpentinite was seen to cut across hornblendite and pyroxenite and this suggests that the serpentinite was the last ultramafic material to be intruded, although this could have taken place when some of the ultramafics were remobilized.

The timing of serpentinization appears to have coincided with the intrusion of mica-pegmatites about 2 000 Ma ago. Pegmatites studied in the Pande Mine quarries are bounded by an aureole of unserpentinized pyroxene-granulite which grades laterally into unaltered green serpentinite (slide 25 562). Serpentinization must have taken place at a temperature below 500° C (Turner and Verhoogen 1960, p. 318), but at the time of pegmatite intrusion the granulite aureole remained above 500° C and was therefore not altered with the remainder of the ultramafic body. This serpentinization may be related to the unroofing of ultramafic granulites during Waterberg times. A general reaction in which olivine and enstatite are replaced by serpentine is given by Turner and Verhoogen (1960):

1. Olivine + H_2O + CO_2 $\rightarrow$ serpentine + magnesite

2. Enstatite + H_2O $\rightarrow$ serpentine + SiO_2

The release of silica and magnesite produced early vein-fillings, and steatitization, as a result of carbon dioxide metasomatism, is considered to be a local after-effect of serpentinization. Alteration zones in the serpentinite occupy and run sub-parallel to steeply dipping fracture-lines and early, cross-cutting horizontal release-joints. Silica veinlets are of three ages and are confined to alteration zones adjacent to dolerites, which they penetrate. The veinlets fade into the serpentinites, suggesting that they had their origin there, possibly due to the following reaction (Turner and Verhoogen 1960):

Serpentine + CO_2 $\rightarrow$ magnesite + SiO_2 + H_2O

More widely spaced horizontal release-joints displace the alteration zones especially in the central, carbonated, tobacco-brown serpentinites. This jointing appears to be a surface phenomenon as it is confined to the upper 40 m of the larger bodies. Below this level the serpentinite is unaltered and the central zone appears to have been saturated by meteoric waters rich in carbon dioxide, so facilitating the formation and deposition of nodular and lined magnesite. During post-Karoo times the central serpentinite zones appear to have been largely replaced by magnesite and limonite. This replacement appears to have occurred over an extended period, as some of the lined veins at Pande Mine show more that 22 layers of deposition. An unaltered and unfractured serpentinite capping over the Pande orebodies may have been above a former water table, and the production of magnesite may have caused vertical expansion due to an increase in volume resulting from its formation. Cross-cutting, silicified, calcium-rich magnesite veins appear to be a late event, probably related to post-Karoo hydrothermal activity.

Talcose serpentinites (slides 25 563, 25 571 and 25 572) have a decussate or foliated texture defined by partly radiating flakes of orientated talc and phlogopite mica, up to 7 mm across. Iron oxides have crystallized along the cleavage-traces of these minerals. Talc has straight or ragged outlines and may be interlayered with phlogopite, partly altered to penninite. Some mica flakes are tightly folded and talc flakes show kink-banding. Magnesite and finely crystalline, iron-stained quartz veinlets cut across the folding, as do fractures filled by granular talc.

A sample of slip-picrolite serpentinite (25 573), from the Pande Mine quarries, has largely been replaced by clinochlore. A few remnants of olivine with magnesite inclusions are preserved in the centre of the strongly stained greenish-yellow groundmass of fibrous antigorite, which commonly shows an hourglass structure. Remnants of hornblende and pargasite are also fragmented and partly serpentinized. Flakes of talc and chlorite occur in places and magnesite has partly replaced the serpentine. Cross-cutting veinlets of chrysotile and fine-grained quartz have several orientations and the surface has a smooth slickensided appearance.

The silicified or birbiritic serpentinites (slides 25 574 and 25 575) have 10 – 50 % silica. Fine-grained crystalline quartz, 0.02 - 0.20 mm across, occurs as radiating aggregates, bands or irregular patches which cut across earlier clinochlore veinlets. The structure of the original serpentine is often lost as a result of this replacement, although relict polygonal crystal boundaries may be marked by iron-ore granules. Fine-grained quartz may almost fill the spaces between fractures, where it is commonly rimmed with limonite, or may be stained green. In one sample (25 575) remnants of amphibole are stained by iron oxide and appear to be partly altered to phlogopite and chlorite parallel to their cleavage directions. In another sample (25 574) biotite rims magnesite and patches of cryptocrystalline quartz, whereas in other rocks it defines a foliation or occurs along fracture lines. In some places the silica has been largely replaced by magnesite crystals, and lined magnesite veinlets cut across earlier magnesite crystals and veins of fine, crystalline quartz and hematite.

Carbonated serpentinites (slides 25 576, 25 577 and 25 578) have been replaced by 15 – 70 % magnesite. Antigorite forms fibrolamellar aggregates and is commonly replaced by irregular magnesite patches with a centre zone of dark-brown nemalite in a boxwork of clinochlore veinlets. In slide 25 577 mottled-green veinlets of chlorite, after serpentine have become opaque when altered to clay, and bastite is commonly altered to chlorite or sepiolite. Fine-grained polygonal crystals of magnesite, 0.02 - 0.35 mm across, form irregular and interlobate aggregates (25 577), and they may be rimmed by limonite, hematite or radiating green chlorite (25 576). Aggregates of amphibole, pyroxene and flakes of prochlorite remain unaltered. Phlogopite forms flakes, up to 0.2 mm wide and 14.0 mm long, which are broken into tiny fragments (slide 25 578), and mats of talc flakes are also orientated parallel to the cleavage of the serpentines. Closely spaced, branching magnesite veins (slide 25 579) occur mainly parallel to the foliation and they form radiating rims around partly resorbed fragments of silica veinlets.

In general the colloform magnesite vein-fillings are composed of well-shaped, locally rhombic, granules and aggregates, up to 0.7 mm across. The spherical colloform structures are defined by an iron-stained rim (slide 25 580). Coarser-grained magnesite tends to rim the finer material which shows less iron staining (25 581), and the magnesite may enclose irregular patches of altered serpentinite with inclusions of chlorite and quartz (25 582). Thin quartz veinlets occur adjacent to the nodules in slide 25 583, and magnesite has recrystallized along fracture lines.

THE MAFIC GRANULITES

Mafic granulites, locally difficult to distinguish from dolerite, are common throughout the Beitbridge Group. They represent part of the syntectonic group of intrusive rocks and can be described as a) concordant two-pyroxene granulites, and b) folded metabasic dykes. Their dating has proved to be a very useful tool in unravelling the early history of the Central Belt in the Beitbridge and Messina areas (Barton & Ryan 1977).

Two-pyroxene Granulites

These rocks are massive and homogenous, usually forming concordant horizons within the gneisses and intrusive suites of the Beitbridge Group. It is believed that they represent metamorphosed dolerite sills, probably related in time of intrusion to some of the tholeiitic metabasic dykes which have a very similar mineralogy. The two-pyroxene granulites are common within the dolomites of the Diriza Hills, east of the Beitbridge to Masvingo road, and they also occur east and north of Mapai Dam. Some two-pyroxene granulites appear to have been intruded close to the interface between magmatitic basement gneisses and the overlying garnetiferous paragneiss.

The two-pyroxene granulites are usually hard, fresh, dark-green rocks with a greasy appearance. They outcrop as slabs or rounded boulders, but reflect no distinctive topography and are covered with a red to brown soil. They are fine- to medium-grained rocks with a grain-size of 2 - 3 mm, with some rather coarser plagioclase aggregates. The greasy appearance of the feldspars is indicative of a high grade of metamorphism, and the rocks have a granoblastic to gneissic texture. Segregation layering is defined by plagioclase feldspars, biotite and pyroxene, whilst quartz-rich bands may also be present.

Petrography

The normal two-pyroxene granulite (slide 25 584) has a fine, equigranular, poikiloblastic granular texture. Other rocks (25 585 and 25 586) are coarser-grained, with a more irregular, faintly layered texture involving segregation of plagioclase and pyroxene. A specimen (25 587) with poikiloblastic-elongate texture contains large sieve-textured hypersthene crystals which enclose flakes of foxy-red biotite and partly orientated clinopyroxene granules.

Plagioclase forms as irregular aggregates composed of crystals, 0.2 - 1 mm across, with rounded, irregular or idioblastic borders. Plagioclase (slide 25 584) tends to be embayed against the pyroxene with which it is intergrown. Albite-pericline and carlsbad-twinning is present and a composition of An_{70} is estimated. The feldspars may be antiperthitic and in one sample (25 584) they contain tiny rounded inclusions of brown hornblende, pyroxene and apatite. The larger feldspar aggregates appear to partly replace earlier feldspar laths (25 586), suggesting that the rocks were derived from dolerites with an intergranular or sub-ophitic texture.

Colourless to pink pleochroic hypersthene forms large, irregular, elongated poikiloblastic crystals, up to 2 mm long. These contain inclusions of brown hornblende, plagioclase, quartz and magnetite, 0.2 - 0.9 mm across. Hypersthene (slide 25 585) also forms smaller aggregates of polygonal crystals with straight or curved borders. Much of the hypersthene has altered to hornblende along cleavages and in irregular patches rimmed by radiating fractures. Hypersthene shows schiller-structure, and crystals are stained by iron oxide along the cleavage.

Diopside forms polygonal or elongate crystals, up to 0.5 mm long, which are associated with and included in orthopyroxenes. Brown hornblende forms small rounded or polygonal intergranular crystals. Large prisms of colourless amphibole, apparently edenite, in slide 25 585, contain cores of green hornblende and show multilamellar twinning. Foxy-red biotite occurs as irregular flakes associated with orthopyroxene, and ore granules, up to 0.5 mm across, occur with biotites and hypersthene aggregates. The two-pyroxene granulites contain 40 – 60 % of plagioclase, 10 – 15 % hornblende and up to 25 % of pyroxene. Many hornblendites may have been derived by retrograde metamorphism in which the pyroxenes have been replaced by hornblende.

Metabasic Dykes

Deformed tholeiitic mafic granulites occur as layers within the basement gneisses, in rocks of the Beitbridge Group and in related intrusive suites. These horizons may be 0.1 -1 m wide, and in places they are clearly discordant with respect to the gneissic foliation and the mineral fabric. They are therefore interpreted as original mafic dykes. In the Sand River exposures of basement gneiss, south of Messina, at least two suites of strongly deformed tholeiitic dykes have been recognized (Barton *et al.* 1977a). Rb/Sr whole-rock isotopic analyses yielded isochrons of 3 643 ± 102 Ma for the older suite and 3 128 ± 81 Ma for the younger suite using an initial 87Sr / 86Sr ratio of 0.7014 ± 0.0003. Similar dykes occur west of Beitbridge where those of different age can be distinguished by structural means (Watkeys 1975).

East of Beitbridge four ages of metabasic dykes are recognized. They are:

a) The folded dykes, found only in the basement gneisses, do not penetrate the Beitbridge cover sequence. They are probably represented in the map-area by folded and attenuated mafic inclusions in the Bulai and charnockitic aureole gneisses, derived by partial assimilation of the basement during anatexis. They are probably equivalent to the 3 643 Ma suite in South Africa.

b) Folded dykes which cross-cut tight folds in quartz hornblende gneiss, 2 km south of Diti Store. They are discordant to the foliation of the enclosing gneiss and have themselves been tightly folded during the D2 deformation period elsewhere. Mineralogically these dykes are similar to the two-pyroxene granulites and they probably represent the 3 128 Ma group of dykes in South Africa which were intruded after the anorthosite suite, dated at c 3 350 Ma.

c) A set of tightly folded metabasic dykes cut across the Bulai Gneiss and are therefore younger than the emplacement of the gneiss 2 690 ± 60 Ma ago. They are deformed by F3 folding and show a retrograde granulite texture, indicating that they were intruded prior to the decline in metamorphic grade.

d) Unfolded amphibolitic dykes are intrusive into ENE-trending fractures. There is a strong foliation parallel to the length of these dykes. Similar dykes have been dated in South Africa at 2 265 ± 65 Ma (Barton & Ryan 1977). All the younger mafic dykes are described in the section on dolerites.

The mafic granulites associated with metabasic dykes are dark-green or black, fine-grained, homogeneous or foliated rocks. They form narrow deformed mafic bands within the enclosing gneisses, and the wider dykes may produce rounded boulders and dark-red soils. A tightly folded mafic dyke which cross-cuts the foliation of a biotite gneiss, 3.75 km south of Shampali Hill near the Limpopo River, is illustrated in Plate 4 C. This dyke has been deformed by F2 and F3 folds and secretion-pegmatites have crystallized along the axial planes of these folds. Another folded mafic dyke, which cross-cuts a tight F1 fold structure in quartz-hornblende-gneiss, 1.75 km SE of Diti Store, is illustrated in Plate 4 B. A tholeiitic mafic dyke, intrusive into leucocratic paragneiss, 1.5 km NNE of the Pande Mine, has been chemically analyzed (Table 6, Lab. No. 76/42). Other metabasic dykes form rafts and deformed horizons within the Bulai Gneiss.

The metabasic dykes may either be clinopyroxene-bearing or clinopyroxene-free granulites. The older dykes are usually fine-grained diopside-hornblende-plagioclase-granulites, in which the estimated plagioclase composition is An_{37} to An_{48}. A dyke which cuts across paragneisses near Mabana Hill is a clinopyroxene-free granulite with a plagioclase composition of An_{40}, whereas the analysed rock (25 588) contains plagioclase with a composition of An_{62}. Watkeys (1979) reports an olivine-bearing mafic dyke which may be a feeder to rocks of the ultramafic suite.

Petrography

Clinopyroxene-bearing mafic granulites, the most common variety, have a granoblastic-elongate texture emphasized by the orientation of green hornblende, pyroxene and plagioclase crystals. Hornblende forms elongate crystals, 1 - 2 mm long, which are intergranular to and embayed against plagioclase. The crystal boundaries of grains lying in the foliation of a sample (25 589) are commonly straight, whereas in slide 25 590 hornblende forms aggregates of polygonal crystals. Diopside occurs as small, rounded equant to elongated, locally irregular crystals from 0.2 - 0.35 mm across. It forms aggregates with hornblende and in one example (slide 25 589) hornblende partly or wholly rims diopside grains or else occurs as patches within it. Diopside is usually intergranular to quartz, but tiny quartz droplets may be enclosed in pyroxene granules (25 590).

Plagioclase forms equant to elongated polygonal laths, 0.2 - 0.7 mm in length. It has straight, curved or lobate boundaries against hornblende and in some rocks (25 589 and 25 590) plagioclase forms aggregates of polygonal grains with quartz, about 1 mm across. These aggregates appear to have partly replaced primary plagioclase laths (slide 25 589), suggesting that the original rock was probably a dolerite. Rounded, polygonal or irregular granules of opaque ore, 0.26 - 1.00 mm across, occur within hornblende crystals or are associated with diopside and plagioclase. Fine granular ore fills cross-cutting fractures in some diopside grains. These mafic granulites have a composition of 50 - 60 % plagioclase, 25 – 34 % hornblende and 7 – 25 % clinopyroxene. Quartz and iron ores make up 3 – 5 % of the rocks.

A sample (25 591), representative of the clinopyroxene-free metabasic dykes, contains sieve-textured poikiloblastic garnets, up to 3.5 mm in diameter, within a fine-grained matrix ribbed by quartz and hornblende which defines a foliation. Quartz shows two sets of indistinct deformation lamellae at 45 to the length of the ribbons, and in the matrix it forms irregular intergranular crystals, 0.5 - 0.7 mm across. Hornblende forms deep-green pleochroic square crystals (up to 3 mm), which are layered within the foliation. Crystal boundaries are straight, but may be embayed against quartz which locally occurs as tiny inclusions in the hornblende. Plagioclase forms rounded crystals, 0.1 - 1.5 mm long. Many of these show carlsbad, and pericline-twinning and borders are straight or lobate. The plagioclase is commonly sericitized in irregular patches or parallel to twin interfaces. Brown biotite flakes form aggregates, up to 3 mm across, where they are intergrown with hornblende or are associated with ore, quartz and tiny zircons. Individual flakes may measure up to 1.5 mm across, and sometimes cut across the foliation or penetrate hornblende crystals. Poikiloblastic garnets are intergrown with biotite and plagioclase and they contain rounded quartz inclusions and fragments of ore. The foliation wraps around the garnets indicating that they had already crystallized when the penetrative foliation was formed. Apatite crystals are a common accessory. The composition of this granulite was estimated as being 50 % hornblende, 25 % plagioclase, 15 % quartz, 5 % garnet, 3 % biotite and 2 % iron-ore.

THE BULAI GNEISS SUITE

Singelele and Charnockitic Aureole Gneisses

The "Singelele Gneissic Granite" was first defined by Söhnge (1945) from its type area on Singelele Ridge, immediately east of the town of Messina in South Africa, and was said to be "recognized by its reddish colour, medium- to fine-grain and characteristic habit of weathering into piles of monolithic boulders that tower above the flat of granitoid gneiss". Söhnge *et al.*(1948) believed "the Singelele granite to have been formed by partial metasomatic replacement of the varied gneisses and metasediments and more local syntexis, with forcible intrusion into the wall rocks". Owing to its presence as xenoliths in the Bulai Gneiss east of Beitbridge, the formation of the Singelele Gneiss was considered to predate the intrusion of that body. Further detailed work by Bahnemann (1973) led to the conclusion that the Singelele Gneiss originated from a granitic basement of tonalitic composition which suffered partial anatexis in anticlinal areas, resulting in rocks which tend towards the composition of hornblende-syenite and alaskite. However, more recent mapping east of Messina (Lilly 1975) indicates that the Singelele Gneiss there occurs in a synformal and not an antiformal structure. It was postulated that the gneiss represents a metamorphosed greywacke, felsic tuff or marl, with the first option being preferred.

Regionally the development of red to pinkish-red Singelele Gneiss is very patchy and in Zimbabwe, both east and west of Beitbridge, these gneisses are closely associated with the charnockitic aureole gneiss surrounding the Bulai Gneiss. The charnockites and Singelele Gneiss *sensu stricto* grade directly into gneisses of the Diti Formation, which suggests that they originated as part of the cover sequence rather than from the basement. A second locality, more akin to the type area, occurs in a rugged area of low, bouldery koppies SE of Beitbridge, near the Old Main Drift on the Limpopo River. A lens-shaped antiformal body here occupies a position immediately below quartzites of the Swebebe Ferruginous Member, and appears to be partly intrusive into gneisses of the Diti Formation from which it has probably been derived. Enderbitic basement gneisses and charnockitic gneisses are clearly related to the Singelele Gneiss, and the introduction of feldspar megacrysts into these rocks adjacent to the Bulai Gneiss suggests that their formation pre-dated the 'wet' intrusion of this gneiss. These factors suggest that a 'dry' metamorphism and mobilization of basement and cover took place at granulite grade, resulting in the partial melting and subsequent intrusive relationships of the Singelele Gneiss. Orange gneisses of Singelele aspect developed along the borders of the charnockitic gneiss, and appear to owe their origin partly to shearing which allowed the preferential introduction of water and the subsequent development of hornblende from orthopyroxene in the original charnockites. Subsequently, a large-scale introduction of water into the basement resulted in the intrusion of the Bulai Gneiss within the area that had suffered the most intense granulite-grade metamorphism, with related formation of charnockite. The charnockitic gneiss, therefore, would not be a true metamorphic aureole surrounding the Bulai Gneiss, but a consequence of anatexis operative in the zones of highest-grade metamorphism. In support of this is a date of 2 690 Ma suggested for the origin of both Singelele and Bulai gneisses by Van Breemen (1968), although a Rb/Sr whole-rock isochron of 2 509 ± 260 Ma for the Singelele Gneiss has recently been recorded (Barton & Ryan 1977).

Lithology

Lithologically the Singelele Gneiss has been divided into three main groups:

a) Mesocratic to mafic charnockitic gneisses
b) Orange Singelele Gneiss
c) Intermediate gneisses which resemble the Singelele Gneiss, but also have characteristics of paragneisses in the Diti Formation.

All of these varieties may become porphyroblastic-augen-, or flaser gneisses within the aureole of the Bulai Gneiss.

The *mesocratic to mafic charnockitic gneisses* vary in colour from grey to a dark orange-brown or grey-brown, and the amber to honey-brown feldspars give the rocks a greasy lustre. The gneisses weather easily owing to the presence of biotite and hornblende and locally they have a white bleached skin. The charnockitic gneisses are medium- to coarse-grained rocks that are massive or well-foliated. The foliation is emphasized by discontinuous segregation layers, spaced 1 - 8 mm apart, and composed of biotite, hornblende, orthopyroxene, clinopyroxene, magnetite, quartz and feldspar. The more mafic varieties contain diopside, whereas garnet is present in variable amounts in other rocks that range from garnet-bearing paragneisses to garnet-free tonalitic gneisses resembling those in the basement. Augen and porphyroblasts of microcline, up to 25 mm long, together with intergrowths of quartz and feldspar, occur in the charnockitic gneisses. In places a strong banding is formed by quartz layers and orientated lensoid feldspar porphyroblasts. Blastesis usually occurs adjacent to intrusive dykes of Bulai Gneiss, suggesting that its origin is related to these dykes. Irregular, lens-shaped leucocratic and hornblendic inclusions appear identical to those found in the Bulai Gneiss.

The *Orange Singelele Gneiss* weathers to form blocky boulders, up to a metre across, which are elongated parallel to a prominent mineral lineation. As the name suggests, they weather to a distinctive orange colour, but grey and brown forms also occur. Darker coloured varieties are found adjacent to mafic bands. Differential weathering removes the softer, dark minerals giving the rock a pitted, quartz-ribbed surface.

Ultimately weathering gives rise to a soft, crumbly, orange oxide-stained rock. The rocks are fairly homogeneous, medium-grained gneisses that contain wavy bands of biotite, 1 - 3 cm wide, separated by coarser quartzofeldspathic material. A foliation is emphasized by layers of aligned hornblende, biotite, quartz and feldspar. Hornblende, however, defines a lineation which cuts across the foliation plane. An augen or flaser texture locally develops parallel to the foliation, with the mafic minerals being wrapped around the 20 - 30 mm feldspar augen. Tightly folded inclusions of paragneiss are seen in places as are discontinuous mafic bands. Ancient, deformed mafic dykes cut across the gneiss and are themselves cut by secretion-pegmatites formed during remobilization of the Singelele Gneiss.

The *intermediate gneisses* closely resemble leucocratic paragneiss of the Diti Formation into which they commonly grade. However, these rocks also show the faint colouring and homogeneous nature of the orange Singelele Gneiss, and a poorly developed foliation is visible through the alignment of the sparse mafic minerals. Other gneisses which have formed in this way are leucocratic calc-silicate gneisses of the Diti Formation which occur close to the charnockitic rocks. Related red-coloured gneisses grade from massive to well-foliated, granular, quartzofeldspathic rocks. The red colouration is apparently due to staining after the break-down of iron-bearing minerals.

Distribution and Field Relations

Singelele rocks occur in two distinct environments east and north-east of Beitbridge. Orange Singelele Gneisses are closely related to the distribution of charnockitic aureole gneiss which encloses the Bulai Gneiss discontinuously, and continues for 22 km north-eastwards along the main road to Masvingo and lies mainly between the road and the Diriza Hills. Orange Singelele Gneisses also occupy F2 antiformal fold-closures adjacent to and immediately below rocks of the Swebebe Ferruginous Member, north-east of the Old Main Drift across the Limpopo River. Intermediate Singelele Gneisses, occupying the same stratigraphical position, form thin, concordant horizons along the Etomgwani Valley, north-east of the Old Main Drift exposures.

The best exposures of aureole rocks occur in the broad, 5 km-wide, NE-trending belt which extends from Beitbridge airfield towards the northern boundary of the map-area. That part of the belt north of the Bulai Gneiss outcrop appears to occupy a major F3 antiformal structure, as the rocks in the west dip shallowly west, whereas directly north of the airfield they dip steeply south. SE of Lutumba Store the belt is inclined shallowly to the NW along the northern border, and very steeply NW on the southern boundary. North of the Tshiturapadsi road the gneisses are divided into two lobes, a short one to the south-east which dips steeply NW, and a longer one which stretches along the main road as an antiform inclined steeply SE. East of Beitbridge airfield similar charnockitic gneisses enclose the northern lobe of Bulai Gneiss. Orange Singelele Gneisses and charnockites also partly enclose the southern lobe of Bulai Gneiss and are exposed in the antiformal area separating the two lobes.

Orange Singelele Gneiss outcropping as rugged bouldery koppies, is exposed in an irregular lens-shaped, partly overturned antiformal structure which is orientated on an ENE-axis and measures 4 km in length by 2 km in width. The south-westward closure of this structure is near the Old Main Drift on the Limpopo River. The northern side, which is partly bounded by the continuation of the Messina Fault, dips steeply to the SE, whereas the south-eastern contact shows a moderate SE dip. A roughly triangular basin of mafic granulite, anorthositic gneiss and a little leucocratic and biotite gneiss is exposed in the centre of the Singelele outcrop. Some gneisses intermediate between Singelele Gneiss and gneisses of the Diti Formation into which they grade, are also found. North-east of the main outcrop and just west of the Sinyoni Copper Claims, a narrow, 2 km-long, east-trending belt of Orange Singelele Gneiss dips steeply to the south.

About 1 km west of Swebebe Hill, gneisses, intermediate in composition between Orange Singelele Gneiss and leucocratic gneisses of the Diti Formation, are exposed as lenses adjacent to anorthositic gneiss. South of Swebebe Hill similar concordant gneisses, within anorthosites occurring near the base of the Swebebe Ferruginous Member, are folded into a broad antiform near the junction of the Lipani River with the Limpopo River. They dip NW at moderate angles and continue as a broad 300 m- wide band which forms a NE-trending line of low koppies along the Etomgwani Valley.

The porphyroblastic and charnockitic aureole gneisses, because of their coarser grain, weather easily and form a flat plain with rare low dwala outcrops. The more homogeneous orange Singelele Gneiss and some of the flaser gneisses form more resistant horizons in the aureole and give rise to low bouldery ridges or steep-sided dwalas elongated parallel to the foliation. Elsewhere, especially in the Old Main Drift area, the orange Singelele Gneiss forms bouldery ridges and castle-koppies. Reddish soils overlie the Singelele Gneiss and are indistinguishable from those covering the paragneisses although they commonly contain fine particles of hornblende.

In the charnockitic aureole the Orange Singelele Gneisses, which form the only topographic features, are confined to thin bands, 50 - 300 m wide, which generally lie parallel to the boundary with the Bulai Gneiss. Together with some of the charnockitic rocks they often exhibit a flaser or augen-texture and they are considered to have formed along old shear zones initiated during the intrusion of the Bulai Gneiss. Close to the Bulai Gneiss the charnockitic and orange gneisses commonly contain microcline porphyroblasts which indicate that they are older than the Bulai Gneiss. However, the Singelele rocks, which are closely interbedded with rocks of the Diti Formation, show characteristics of being both sedimentary and intrusive in origin.

The Orange Singelele Gneiss is commonly garnetiferous and it grades directly into biotite paragneisses or leucocratic gneiss which occurs as tightly infolded inclusions. The intermediate Singelele Gneisses along the Etomgwani Valley have apparently been produced by irregular charnockitization of leucocratic calc-silicate gneisses which lie in and are flanked by leucocratic gneisses and anorthosites in the Diti Formation. Hornblendic Singelele Gneisses grade into amphibolitic garnet-granulites and in a few places interbedded gneisses, resembling those of the basement, occur within the Singelele and adjacent gneisses. The varying composition of the Singelele Gneiss is apparently directly related to the adjacent rocks from which it has been derived.

The charnockitic gneisses commonly contain irregular mafic inclusions, and they appear to have been remobilized, possibly during the time of intrusion of the Bulai Gneiss. In places adjacent to the Bulai Gneiss, the aureole rocks contain abundant randomly-arranged microcline porphyroblasts which also occur in the leucocratic gneisses into which they grade. Later folding has resulted in the preferred orientation of many of the feldspar porphyroblasts. The Orange Singelele Gneisses also appear to have become plastic and partly remobilized at this time. Although no definite intrusive relationships were seen, the gneiss near the Old Main Drift appears to be partly intrusive into rocks of the Diti Formation below the Swebebe Ferruginous Member.

Petrography

A porphyroblastic *charnockite gneiss* (slide 25 592), from south of the Masvingo road at the Chantalikiti River crossing, contains large rounded and lensoid porphyroblasts of perthitic microcline, up to 20 mm long. These occur in a coarse-grained feldspathic matrix in which individual feldspars, showing a greasy lustre, are wrapped in ribbons of quartz and associated mafic minerals. The porphyroblasts, with coarsely sutured borders, are surrounded by finer-grained myrmekitic oligoclase and microcline. Microcline in the groundmass forms irregular to elongate crystals, 2 mm long, which are partially rimmed with myrmekite. Oligoclase, associated with granular microcline, forms as equant polygonal or irregular crystals, up to 3 mm, which show diffuse zoning, good albite twinning and some antiperthitic exsolution lamellae. Quartz forms discontinuous ribbons, up to 10 mm long, composed of irregular grains with interlobate borders and 1.0 - 3.5 mm long. Quartz also forms droplet inclusions in the potash feldspar, and it shows the development of deformation lamellae in two sets at right angles. Hypersthene crystals form rounded to elongate granules or aggregates up to 1 mm long. The crystals are cut by irregular veinlets of limonite which apparently give the rock its orange-brown colour. Biotite which is sometimes intergrown with quartz, forms as flakes and aggregates, up to 2 mm, that are orientated within the vague foliation. Biotite also rims granular aggregates of opaque ore and some microcline crystals. The rock has suffered granulation along fractures lying both parallel and perpendicular to the foliation. An estimated modal composition is 50 % quartz, 40 % microcline, 5 % oligoclase, 2 % biotite, 1 % hypersthene and 2 % ore.

A similar charnockitic gneiss (slide 25 593), from just north of Beitbridge airfield close to the Bulai Gneiss contact, contains microcline porphyroblasts which are only about 3.5 mm long and are not as widely developed as in the previous sample. Antiperthitic andesine is prominent as small augen which are poikiloblastically enclosed in aggregates and ribbons of quartz, prismatic hypersthene, biotite, ore and apatite. Green-brown hornblende forms irregular crystals, up to 3 mm long, which contain inclusions of rounded apatite, ore, myrmekitic plagioclase and large biotite flakes. Another sample (25 594) is a coarse-grained, melanocratic enderbitic gneiss with a greenish, greasy appearance. A vague foliation is defined by coarse-grained andesine and quartz associated with prismatic hypersthene crystals, up to 6 mm long, and flakes of biotite. The hypersthene is partly altered to either a strongly pleochroic blue-green hornblende or to a fibrous, faintly pleochroic amphibole.

Two samples of *Orange Singelele Gneiss* which have been chemically analyzed (25 595 and 25 596, Table 7, Lab. Nos. 75/56 and 013), were collected from 2 km NE of Beitbridge airfield, along the Masvingo road, and from 1 km NE of the Old Main Drift, respectively. The 25 595 sample is an orangey-pink, quartzo-feldspathic gneiss with a faint foliation defined by the elongation of feldspars and quartz ribbons with associated discontinuous bands of ore, some small yellow-brown crystals of allanite, a few irregular flakes of biotite and tiny zircons. Quartz forms equant to elongate crystals with interlobate boundaries in ribbons, up to 7 mm long. The quartz encloses rounded droplets and aggregates of high-temperature microcline and it shows deformation banding. Perthitic microcline occurs in irregular, granular bands of equant to elongate crystals, up to 1 mm across. These bands are commonly rimmed by a thin vestige of oligoclase which may be myrmekitic or else forms crystals, up to 2 mm long. The microcline, however, is largely altered to a brown, iron-dusted clay. The estimated composition of this rock is 50 % quartz, 34 % microcline, 15 % oligoclase and 1 % ore and biotite.

Similar textures are seen in the second rock (25 596), which is a flesh-coloured, finer-grained and better foliated rock owing to the orientation of quartz ribbons and the higher proportion of mafic minerals, i.e. biotite flakes, green hornblende, ore, garnet fragments, zircon and yellow-brown metamict allanite. Some of the garnets contain quartz inclusions, are penetrated by biotite flakes and are rimmed by oligoclase. This suggests that quartz and garnet have reacted to produce biotite and plagioclase.

A sample of leucocratic, *calc-silicate gneiss* (slide 25 597), *intermediate* between the orange Singelele Gneiss and gneisses in the Diti Formation, was also chemically analyzed (Table 7, Lab No. 76/46). The feldspars have become green and greasy in appearance, and although there is no hypersthene,

Table 7 : Chemical analyses of Bulai and Singelele Gneiss rocks (in %)

Slide No.	**25 595**	**25 596**	**25 597**	**25 599**	**25 600**	**25 601**
Lab. No.	**75/56**	**013**	**76/46**	**75/61**	**75/64**	**76/47**
SiO_2	74.59	75.96	76.66	63.11	62.86	63.72
Al_2O_3	12.92	12.76	11.44	16.58	16.23	14.60
Fe_2O_3	1.41	0.92	1.71	2.22	1.89	1.49
FeO	0.90	1.76	1.21	2.88	3.05	2.95
MgO	0.08	0.34	0.54	1.93	1.78	2.01
CaO	0.86	2.30	3.93	4.16	3.24	3.91
Na_2O	2.73	2.70	3.33	3.33	3.38	4.30
K_2O	5.59	3.15	0.55	3.08	3.88	4.55
H_2O^+	0.43	0.43	0.30	0.90	0.70	1.02
H_2O^-	0.14	0.08	0.10	0.19	0.14	0.10
CO_2	0.01	0.08	0.34	0.03	0.13	0.45
TiO_2	0.21	0.13	0.31	0.84	0.84	1.05
P_2O_5	0.04	0.11	0.31	0.38	0.37	0.43
MnO	0.03	0.05	0.13	0.06	0.06	0.07
Totals	99.94	100.77	100.86	99.69	99.55	100.65
Specific Gravity	2.65	2.67	2.66	2.77	2.78	2.68

Analysts: B.J. Radclyffe, ZGS: 75/61, 75/64 and 75/56
Dept.Metallurgy: 013
A.D. Powell, ZGS: 76/47 and 76/46

Rock types and localities: See Appendix

augite, sphene and ore granules define a foliation in the coarse-grained groundmass of granular quartz and plagioclase. The plagioclase is andesine, and is irregular and embayed against equant to elongate crystals of quartz, up to 3.5 mm long, which have irregular, interlobate boundaries with adjacent mineral grains.

The groundmass also contains aggregates of ore with associated purple zircons and small yellow allanites rimmed by radiating fractures. Some of the intermediate Singelele gneisses, especially the hornblendic varieties, contain so much magnetite and ilmenite that they become magnetic. One such sample was that collected from near the Lipani River south-east of Swebebe Hill (25 598).

The Bulai Gneiss

First described by Söhnge (1945) the "Bulai Gneissic Granite" from a type-area west of Messina in South Africa, was said to be "the only batholithic intrusion about the mode of emplacement of which there is little doubt". It occupies an area of some 260 km^2 NW of Messina, and the gneiss extends northwards beyond the Limpopo River, and has been described to the west of Beitbridge by Watkeys (1979). A further 50 km^2 of country is occupied by porphyritic Bulai Gneiss both north and east of Beitbridge.

The intrusion of this late, syntectonic biotite-rich granite took place during the second period of high-grade metamorphism to affect the Archean rocks around Beitbridge. It resulted from anatexis, largely of the basement gneiss, but which also involved parts of the Diti Formation. The Bulai Gneiss displays structural features of the F3 and later phases of deformation, especially around the edges of the body, and it varies in composition from a biotite-rich tonalite to an adamellite. More rarely, garnetiferous potash-granites formed as a result of assimilation of the cover rocks. Bahnemann (1972) regarded the Bulai Gneiss and other surrounding gneisses as being a basement to the Messina Formation. Enderbitic Bulai Gneiss and a charnockitic aureole gneiss are described by Watkeys (1979) as being related in origin to the intrusion of the tonalitic and granodioritic Bulai Gneiss. It would appear, however, that the charnockitic aureole represents an earlier 'dry' remobilization of the gneisses which was followed by anatexis and the intrusion of a 'wet' Bulai melt. However, being a wet intrusion, the Bulai Gneiss was probably incapable of moving very far from its source (Cann, 1970).

Recent Rb/Sr whole-rock isochrons give dates of 2 690 – 2 772 Ma (Van Breemen, 1968; Barton & Ryan 1977) for the Bulai Gneiss. These ages show that the Bulai Gneiss is younger than the Beitbridge Group and they probably represent the time of its emplacement into this cover sequence. Chronologically, chemically, petrographically and structurally the Bulai Gneiss is analagous to the Porphyritic Granites of the Northern Marginal Zone of the Limpopo Belt (Robertson 1973a) and to the Matok Granite in the Southern Marginal Zone (Du Toit and Van Reenan 1977).

Lithology

The Bulai Gneiss is most commonly represented by coarse-grained, biotite-rich tonalitic or granodioritic gneiss which, by the development of large porphyroblasts of alkali feldspar, tends towards adamellitic gneiss. The Bulai Gneiss is usually a leucocratic to mesocratic mottled-grey rock which contains many feldspar phenocrysts. It often shows incipient or complete hydrothermal alteration, in which the feldspars are stained pink or red and the mafic minerals are replaced by epidote. This forms the bright red and green ornamental stone (unakite).

The Bulai Gneiss varies from a dark fine- to medium-grained rock, usually represented as dykes within the country rock, to a coarse-grained rock with mineral grains, up to 4 mm across, which occupies the centre of the intrusion. Simply twinned potash-feldspar and plagioclase megacrysts, from 1 - 6 mm long and 0.5 - 2.5 cm wide, are ubiquitous. These crystals vary in shape from rectangular to rounded, although in foliated gneisses ellipsoidal, lensoid or augen-shaped megacrysts appear to have been affected by the folding. The rounded megacrysts appear to have been absorbed during the intrusion of the Bulai Gneiss, whereas others show a vague to strong preferred orientation, and rectangular phenocrysts may even cut across the foliation, suggesting that their introduction was later. The strong foliation which is developed in the contact zone of the Bulai Gneiss is due to biotite mica and hornblende forming a schlieren which wrap around the perfectly orientated feldspar megacrysts. This appears to have resulted from a flow-lamination that has a metamorphic foliation superimposed on it. Some dykes and many of the foliated contact rocks contain garnets and numerous fragments or xenoliths of recognisable basement- and cover-gneiss. Thin amphibolitic gneiss inclusions appear to represent dismembered crosscutting mafic dykes. Secretion-pegmatites form bands and lenses, up to 10 cm wide, in the Bulai Gneiss. Their contacts are gradational and they are orientated parallel to the foliation. Later developed quartz-, feldspar- and mica-bearing pegmatites may have been related to the further introduction of potash feldspar megacrysts into the Bulai Gneiss and the surrounding cover rocks.

Distribution and Field Relations

Bulai Gneiss occupies a large area both north and east of Beitbridge, where it represents part of a northward continuation of the far more extensive mass in South Africa. The gneiss is traversed by the main road to Masvingo and also by the Beitbridge to Rutenga railway-line. The central or western portion is exposed in an antiform which separates the Luchewe Basin to the south from the Mat serpentinite basin north-west of Beitbridge airfield. Eastwards two lobes develop; the northern one extends for 10 km from Beitbridge airfield to a position 3.5 km south of Diriza Hill, and the southern lobe extends for 5 km south-eastwards from the railway-line to a point 3 km east of Luchewe trigonometrical beacon. The northern lobe is a synform and it is separated from the southern lobe by an F3 antiform (see cross section), in which enderbitic basement gneiss and various paragneisses are exposed. Conformable dykes of Bulai Gneiss are intrusive into the gneisses surrounding the main intrusion. From the general shape of the Bulai Gneiss outcrop, which reflects a distorted F2 / F3 interference pattern, it would appear that the Bulai Gneiss has been intruded into low-pressure zones within F2 fold noses. Garnetiferous gneiss similar to the Bulai Gneiss was found at only one other locality, 5 km ESE of Shakwisa Hill, where it is exposed as a narrow NW-trending band overlain by quartzites that dip steeply SW. This exposure is in a similar stratigraphic position in relation to the Shakwisa dolomites, as is the north boundary of the northern lobe in relation to the Diriza Hill limestones. The Bulai Gneiss has therefore been intruded into the base of the Diti Formation and has not penetrated the quartzites of the Shakwisa Calcareous Member.

Directly east of Beitbridge a narrow north-trending belt of Bulai Gneiss extends across the Limpopo River and dips steeply westwards. It contains abundant rafts and inclusions of paragneiss and mafic granulite and displays sharp intrusive contacts with the adjacent rocks. The gneisses here are folded around the Luchewe Basin where they are cross-cut by a dense swarm of ENE-trending dolerite dykes and NW-trending pegmatites and quartz reefs. In the central portion of the Bulai Gneiss outcrop partly covered by Byerley's Uranium Claims, abundant tightly folded remnants of paragneiss, ferruginous quartzite and mafic granulite occur with moderate SE dips. Northwards these remnants become steeply inclined to the NE and SW. Fractures trending ENE and NW are filled by the above mentioned pegmatites and quartz reefs which may form low koppies. Thin horizons of anorthositic gneiss and garnet-granulite are also enclosed in the central portion of the Bulai Gneiss.

The southern lobe of Bulai Gneiss is folded around the Luchewe Basin and plunges SW beneath it. The nose of this lobe is synformal and it is marked by moderately dipping dykes of porphyritic gneiss which enclose a large belt of paragneiss. The SW dips along the northern margin of this lobe steepen westwards where the Bulai Gneiss appears to cut across a narrow horizon of mafic granulite in the charnockitic aureole. In the southern portion of the lobe, rafts of dioritic and enderbitic basement-gneiss are enclosed within a lens of Bulai Gneiss. These inclusions show patches of incipient anatexis and the development of potash-feldspar phenocrysts. The nose of the antiform which separates the northern and southern lobes of Bulai Gneiss is not well exposed, but it appears to be terminated by ENE-trending faults west of Beitbridge airfield.

The northern lobe has a fairly straight northern boundary, but the southern border has a number of large parasitic folds developed along it. This lobe contains abundant inclusions and rafts of a variety of basement and cover rocks which are generally oriented from east to west. The lobe is also cut by numerous east-trending dolerites and breccia lines. South of Mapai Dam the contacy between the Bulai Gneiss and the Charnockitic Aureole Gneiss is gradational and feldspar blastesis in the enclosing gneisses can be seen, as the development of migmatites. Dips along the northern margin are largely steep and to the south, although towards the east northerly dips are also recorded, whereas in the nose of the lobe they become easterly. The westward extension of the northern lobe beecomes folded around the Mat serpentinite basin and the north-trending western arm of this body contains rafts of ferruginous quartzite.

Across the area north and east of Beitbridge the Bulai Gneiss forms a flat plain which is covered by soils varying in colour from greyish to light-brown and red. It is, however, commonly grey due to the preferential formation of calcrete in the soil, which is covered by a surface scree of feldspar crystals, quartz and ironstone fragments. The Bulai Gneiss, because of its coarse grain-size and biotite content, weathers easily and, mainly in the centre of the body, it is exposed as flat low-lying pavements which show typical granite exfoliation. Nearer the boundaries of the body steep-sided dwalas or elongated boulder-

Explanation to Plate 3

3 A : Banded anorthositic gneiss (1) with isoclinally folded layers of hornblendite, in places having a cumulative texture (2).
Grid Ref. TL 312 474

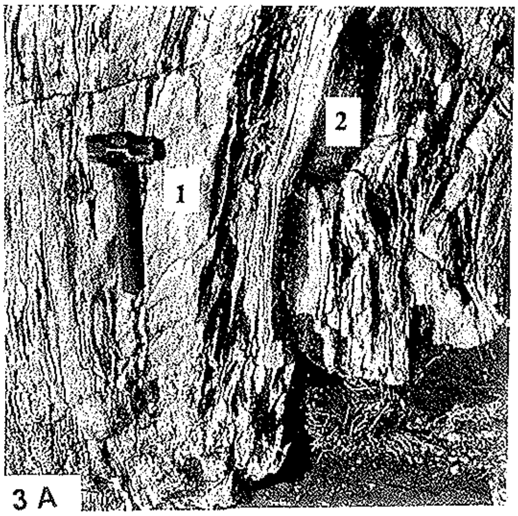
3 B : A folded mafic dyke (1) cutting across tight F_1 folding, in quartz hornblende gneiss (2).
Grid Ref. TL 316 384

3 C : A tightly folded mafic dyke (1) cross-cutting the foliation of biotite paragneiss. Secretion pegmatites have crystallized along the axial planes of the F_3 folds (2).
Grid Ref. TL 210 274

3 D : Three sets of ptygmatically folded veinlets (1) cross-cut an earlier set of folded veinlets (2), in biotite gneiss.
Grid Ref. SL 973 406

3 E : A displaced fracture line in leucocratic paragneiss (1) which has been injected by an apophyse of Bulai Gneiss (2).
Grid Ref. SL 907 400

3 F : Strongly foliated and sheared Bulai Gneiss, close to its contact with leucocratic paragneiss.
Grid Ref. SL 936 431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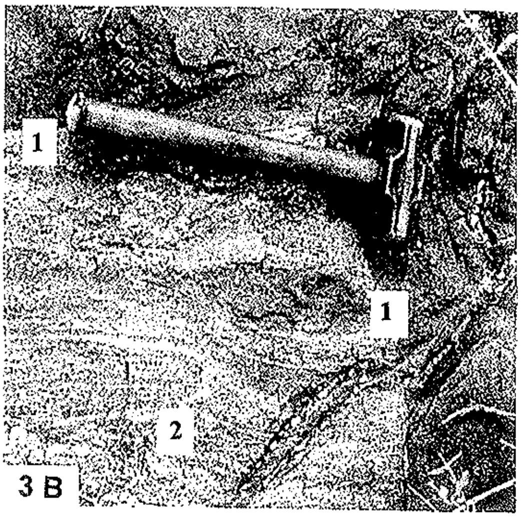
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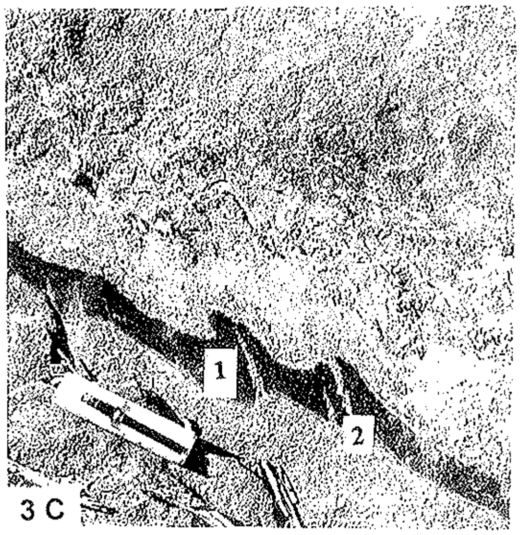
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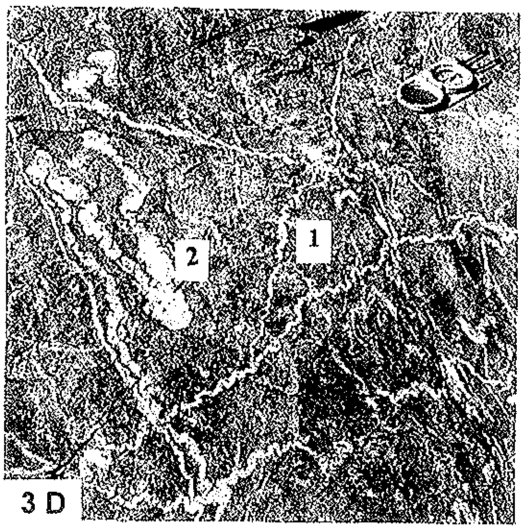
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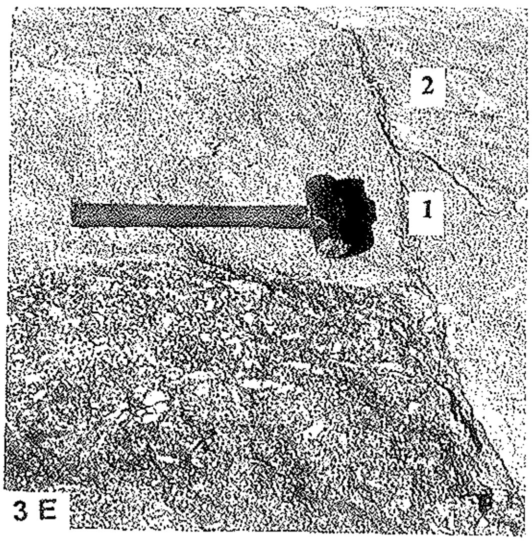
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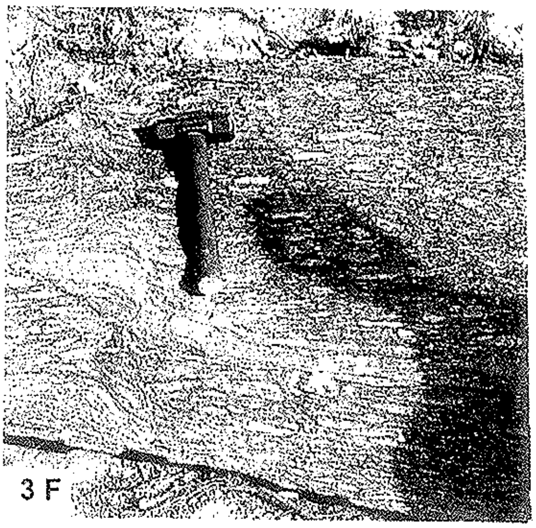

3 F

strewn koppies have formed parallel to the steeply dipping or vertical foliation, and the boulders themselves are usually elongated parallel to this foliation.

The Bulai Gneiss is generally concordant with the paragneisses of the Diti Formation, although it shows local crosscutting relationships (Plate 3 E) and contains many gneissic xenoliths. The contact between the Bulai and the cover gneisses is not everywhere simple, however, and it is often represented by a zone, 100 – 400 m wide, in which dykes of Bulai Gneiss are interleaved with the paragneiss in *lit par lit* fashion. The frequency of these dykes decreases away from the main intrusion, and at great distance only rare dark-coloured contaminated dykes are found. The gneissic rafts and 'ghosts' in the Bulai Gneiss are tightly folded, showing earlier fold patterns than those reflected in the Bulai Gneiss itself. These inclusions are commonly indistinct and are partly resorbed in the gneiss. Assimilation of the paragneiss results in many places in the Bulai Gneiss in garnet formation. More intense deformation around the borders of the Bulai Gneiss has produced well-banded to schistose gneisses with perfectly orientated microcline megacrysts lying parallel to the margins (Plate 3 F). Local shearing has produced augen- and flaser-gneisses along the contact zone. Towards the centre of the intrusion, potash-feldspar megacrysts are either randomly arranged or they are orientated in bands which mark out zones of sinuous flow. Similarly, large microclines in the Bulai dykes are usually perfectly orientated near the walls, but they may be random in the centre.

Petrography

Three samples of Bulai Gneiss have been chemically analyzed (Table 7, Lab. Nos. 75/61, 75/64 and 76/47). They may be compared with analyses of three samples of Singelele Gneiss (Lab. Nos. 75/56, 013 and 76/46).

A leucocratic adamellitic gneiss (slide 25 602) has a glomero-porphyroblastic texture in which aggregates of feldspar and quartz, 2 - 10 mm across, are wrapped in trains of orientated biotite flakes and polygonal to elongate crystals of quartz and feldspar. The quartz, which shows deformation-lamellae, forms irregular embayed porphyroblasts, up to 7 mm long, which contain lenticular inclusions of plagioclase. The plagioclase is calcic oligoclase and commonly occurs as myrmekitic intergrowths. Perthitic, high-temperature microcline forms well-shaped or irregular crystals, up to 5mm across, which contain rounded inclusions of quartz. Coarse, flaky biotite aggregates are embayed against the feldspars and quartz, whereas randomly orientated biotite flakes have also crystallized in the pressure shadows at the ends of quartz ribbons. Biotite is also associated with skeletal crystals of ore and with small garnets which have been derived by assimilation of the paragneiss. Chlorite derived from biotite, rims some of the plagioclase, and with ore granules it fills fractures parallel to the cleavage. An estimated modal composition of the rock is 20 % quartz, 35 % oligoclase, 38 % microcline, 4 % biotite and 3 % garnet and ore.

An adamellitic augen-gneiss (slide 25 603), from a dyke marking the synformal closure of the southern Bulai lobe 3 km east of Luchewe Hill, was collected adjacent to the charnockitic aureole gneiss. Large high-temperature microcline augen, 6 - 10 mm wide and 18 - 35 mm long, are simply twinned and show the development of patch-perthite. They contain irregular inclusions of optically continuous myrmekitic plagioclase which appears to represent the remnants of an original porphyroblast. Quartz-feldspar aggregates, up to 10 mm long, occur with the augen in an even-grained groundmass in which biotite flakes define a foliation and envelope the augen. Quartz, containing biotite inclusions, forms irregular crystals and sutured ribbons which commonly enclose microcline crystals in the groundmass. Larger quartz crystals are surrounded by granulated and recrystallized quartz and plagioclase. The plagioclase, which contains quartz droplets in crystals up to 1 mm across, shows well-developed pericline-twinning and has the composition of andesine. Biotite flakes form aggregates, up to 7 mm across, in the granular quartzo-feldspathic groundmass. Some biotites are kinked due to post-crystallization stress. Irregular intergranular green hornblende is associated with iron-ore granules and accessory apatite and zircon. The modal composition of the rock is estimated at 15 % quartz, 33.5 % plagioclase, 35 % microcline, 10 % biotite, 5 % iron-ore, 1 % hornblende and 0.5 % apatite and zircon.

A tonalitic gneiss (slide 25 604), from a dyke in the Lukawe River north of the northern Bulai lobe, contains perfectly orientated microcline and plagioclase megacrysts, up to 3 mm long. They are set in a fine-grained, granulated and recrystallized groundmass of quartz, feldspar and biotite. The high-temperature microcline which forms some of the megacrysts contains patch-perthite and rounded inclusions of myrmekitic plagioclase, quartz and biotite. Irregular myrmekitic intergrowths have also been developed in pressure-shadow zones at either end of microcline megacrysts. Simply twinned antiperthitic plagioclase forms blocky porphyroblasts, up to 3.5 mm long, which contain patches of microcline and rounded quartz droplets. Some of these phenocrysts are partly replaced by microcline-microperthite. Plagioclase in the groundmass shows good albite- and pericline- twinning and grains show deformation-lamellae, undulose extinction or bent twin-planes. It is sometimes myrmekitic adjacent to quartz, and is sericitized along fractures or in irregular patches. Tiny round zircons form pleochroic haloes in biotite flakes and aggregates, up to 3 mm across, which also enclose apatite and opaque ore. The estimated composition of this rock is 15 % quartz, 55 % plagioclase, 10 % microcline, 15 % biotite and 5 % ore.

Samples 25 605 and 25 609 collected near the junction of the main Bulawayo and Masvingo roads show a complete gradation, due to hydrothermal alteration, from megacrystic Bulai Gneiss to unakite. A relatively unaltered rock (25 608) is a well-foliated, biotite-rich augen-gneiss in which the biotite flakes are partly altered to chlorite and colourless tremolite. The feldspar augen, although remaining white, have become intensely sericitized and partly kaolinized. A second sample (25 609) shows that the micas have altered to chlorite and epidote and that the iron released from the biotite has stained the kaolinized potash feldspars pale pink. Later epidote and calcite veins cut the rock. Further release of iron turns the feldspar megacrysts red and alters them to albite (25 607). Biotite and hornblende in this sample are altered to chlorite, calcite and epidote, and in places they are replaced by epidote. Complete epidotization and albitization forms bright-red and green, coarse-grained unakite, which consists of iron-stained feldspar, epidote, quartz and patches of hematite (slides 25 605 and 25 606).

SYNTECTONIC ROSE QUARTZ REEFS

Glassy rose-quartz horizons occur concordantly within granular and massive quartzites of the Nulli Formation. They are best exposed as resistant ridges along the spine of Mwanandou Hill where the northern fold closure has been pegged as the Nimbus Claims. Similar quartz reefs have also been noted on Lukumbwe Hill, south of Ngwani Hill, and in the vicinity of Shampali Hill. The reefs on Mwanandou Hill are 1 - 10 m thick, and they show pinch-and-swell structures and some apophyses which cut across the enclosing quartzites. The contact between rose quartz and quartzite is usually sharp and straight. A foliation is defined in the reef quartz by bands of tourmaline prisms or, more rarely, fuchsite flakes which indicate some small-scale folds and a lineation.

The rose quartz is pink, massive and tourmaline-bearing, but it commonly grades into bluish or grey quartz containing patches of rose quartz or tourmaline. Rose quartz may also grade into green, massive quartz containing fuchsite. The quartz is hard, glassy and brittle, and it fractures into numerous granular shards when struck. The rose quartz itself varies in colour from a faint pink hue to a deep-pink and it has been shown that anisotropic colour centres develop in the quartz space-lattice owing to replacement of quartz by aluminium and titanium (Cohen *et al.* 1958). Minute rutile needles aligned within the space-lattice are seen in the quartz (slide 25 610) and these appear to be an exsolution product.

The rose quartz reefs have been intruded into and folded with the quartzites. Tourmaline crystals, although defining a foliation, are randomly orientated and form close to the reef boundary. In places on Mwanandou Hill the enclosing quartzites are also stained pink and this suggests a later boron metasomatism. These facts suggest that the rose quartz reefs were intruded during the later stages of deformation and metamorphism, which may have resulted in a mobilization of the quartzites, probably during the time of intrusion of the Bulai Gneiss.

In a sample (25 610) from Mwanandou Hill, interlobate and sutured quartz grains are up to 20 mm across. Rounded to euhedral tourmaline crystals are 0.3 - 1.5 mm long and occur with random orientation as aggregates and bands within the quartz. The tourmaline is black in hand specimen, but pleochroic from light to dark-yellow in thin section. It appears to be dravite, with refractive indices varying between 1.6280 and 1.6470. The quartz is pitted and parallel needles of rutile, up to 0.25 mm long, appear to be an exsolution product. A few flakes of phlogopite, grains of iron-stained potash-feldspar and a fragment of sphene also occur.

APLITIC RIEBECKITE-GNEISS

At a few localities, isolated examples of metamorphosed adamellitic and tonalitic aplite-gneiss are found grading into one another and often banded with concentrations of blue riebeckite granules. They occur to the east, south and west of Bodekwa Dome and also north of the Mat Magnesite Claims. The adamellitic aplite-gneisses are medium- to coarse-grained, well-laminated leucocratic rocks. The quartz and feldspars appear to be graphically intergrown suggesting that this is a primary igneous texture. The tonalitic aplites are finer-grained, mesocratic to leucocratic rocks which commonly contain clots of mafic minerals, up to 3 mm across.

The aplitic gneisses have a well-developed foliation which indicates that they have undergone severe deformation. The potash- and plagioclase feldspars are invariably kaolinized as a result of hydrothermal alteration, and riebeckite may have formed during the release of sodium in this reaction. However, the graphic appearance of the aplites suggests that they are intrusive and it is known that riebeckite may be of primary igneous origin. The riebeckite-gneiss may, therefore, be a late stage differentiate of the Bulai Gneiss.

Petrography

An adamellitic aplite gneiss (slide 25 611), from west of the Bodekwa Dome near the Tshiturapadsi road, has a good foliation defined by interlayered bands of blue amphibole and a coarse-grained intergrown mesh of iron-stained potash feldspar and oligoclase which is largely altered to brown kaolin. The feldspar grains are up to 3.5 mm across and myrmekitic intergrowth commonly occurs around the edges. Quartz forms rounded and irregular crystals, up to 2mm across, and also occurs as rounded inclusions within potash feldspar which appears to be microperthitic. The quartz grains show undulose extinction and larger crystals have irregular, interlobate contacts with other minerals. Blue-green hornblende forms irregular to well-formed intergranular crystals, up to 0.35 mm long. The hornblende is stained dark-grey around crystal boundaries, and there is a discontinuous rim of riebeckite which is stained dark-brown by iron oxide. Riebeckite also occurs around some altered plagioclase grains, and in an intergrowth of epidote and iron-ore with quartz. Riebeckite is associated with thin quartz veinlets, and these relationships suggest a secondary origin for the amphibole. In another sample (25 612) most of the feldspars are kaolinized and the plagioclase is estimated to be An_{40}. Here also, radiating masses of fibrous riebeckite appear to be of hydrothermal origin. The laths are pleochroic from dark-blue to almost colourless, they have an extinction angle of 20^{o} and a refractive index of about 1.66.

A tonalitic aplite gneiss (slide 25 613), from south of Bodekwa Dome, is a darker, speckled rock in which quartz and plagioclase grains, 0.1 - 2 mm across, form a granular texture. The plagioclase is sericitized and scapolite veins occur. Green hornblende forms as intergranular crystals, 0.2 - 1 mm long, together with diopside, iron ore and a few zircons. These rocks are seen to grade into riebeckite-bearing aplites.

FLASER GNEISS AND MYLONITE

One of the last periods of deformation to affect the Beitbridge Group rocks in early Proterozoic times appears to have been the formation of flaser gneisses and accompanying mylonites in flat-lying and steeply-dipping cataclastic zones. These rocks are best seen in isolated occurrences across the northern half of the mapped area. The flaser gneisses are dark brown to reddish-brown, well-foliated, medium- to coarse-grained rocks. They contain elongate lenses of pink feldspar and quartz, 1 - 10 mm long and 2 - 3 mm wide, which define a preferred orientation in the dark mylonitic matrix. A primary gneissic banding can be seen in the flaser gneisses and the glassy mylonites, and the shearing, which has resulted in mylonitization, is often at right angles to this foliation. This has resulted in the granulation of early epidote and quartz which are stable in the kyanite-almandine-muscovite subfacies of the amphibolite facies of metamorphism. After the mylonite formation late crystallization of staurolite took place suggesting that the grade of metamorphism had fallen to the staurolite-almandine subfacies. Later post-Karoo hydrothermal activity has resulted in the introduction of drusy quartz, calcite and chlorite veining together with attendant sericitization and pink iron staining of the feldspars.

Petrography

A sample of flaser gneiss (slide 25 614), collected about 1 km east of Lutumba Store along the Tshiturapadsi road, is a dark fine-grained rock in which a strong fabric is indicated by quartz ribbons made up of interpenetrating, sutured grains. Some straight quartz ribbons are rimmed with granules of feldspar, chlorite and magnetite and they are separated from one another in a dark, iron-stained feldspathic matrix. The quartz and feldspar grains show a strong preferred orientation, the latter being sericitized andesine (An_{43}). Irregular garnets occur in the granular quartz - plagioclase matrix and they are often rimmed with limonite. Ragged biotite flakes are associated with ore granules as intergranular brown hornblende laths. Skeletal ore grains are frequently intergrown with sphene, flakes of pennine chlorite and greenish diopside granules. Later fractures cut the fabric at right angles and are filled with calcite, hematite and limonite.

Another sample (slide 25 615), from 9.25 km north-east of Lutumba Store along the main Masvingo road, is a dark leucocratic gneiss that has been sheared into a flaser rock. Ribbons of sutured quartz grains flow around pink, iron-stained feldspar augens and rounded sieve garnets, 0.35 mm in diameter. Iron ore granules and irregular patches of intergranular chlorite occur in a granular groundmass of quartz and partially sericitized andesine (An_{45}).

Mylonites (slide 25 616) were found along the track between Mwanandou Hill and Diti School. They are brown to black-coloured, fine-grained glassy rocks which contain elongate, angular lithic fragments, 0.5 - 15 mm long. Angular quartz fragments occur in the partly devitrified, dark, iron-stained matrix which contains fine, granular quartz and epidote shards, 0.01 mm in diameter. A possible primary foliation is defined by ribbons of elongate quartz crystals, which are cut by parallel bands of granulated quartz, epidote and mica, 0.9 mm across. This mylonite fabric is approximately perpendicular to the primary foliation, and a later displacement has occurred where oblique fracture lines are filled with drusy quartx, calcite and chlorite. Plagioclase crystals within the lithic fragments are partly replaced by calcite and intergranular patches of calcite also occur. Banded intergrowths of sphene, magnetite and quartz appear to be replacing crystals of ore, probably ilmenite. A few tiny zoned zircons also occur in this rock. Aggregates of staurolite crystals, up to 0.2 mm long, cut across the mylonite fabric. They include granular epidote and are associated with previously granulated quartz crystals.

Another sample (slide 25 617), from north-east of Bodekwa Dome, is a recrystallized mylonite which has weathered to a smooth, chalky yellow-brown rock. The rock is very fine-grained and vughs, up to 8 mm in diameter, are filled with powdery ochre. Three different foliation or fracture directions are seen in the very fine-grained granular quartz matrix. These foliations are indicated by discontinuous quartz ribbons. The rock is finely pitted due to differential weathering, and original magnetite is largely replaced by hematite and limonite which forms around grain boundaries.

PEGMATITES

Simple quartz-feldspar-mica pegmatites are fairly common throughout the Beitbridge area, but in no way has widespread pegmatite injection been operative as it has in other metamorphic terrains such as the Zambezi Metamorphic Belt. Most pegmatites appear to be associated with the Bulai Gneiss, but away from it they are intrusive into the paragneisses, hornblende gneisses and, quite commonly, into the serpentinites of the Beitbridge Group. There may be more than one age of pegmatite injection, the first being a late stage production of secretion pegmatites related to intrusion of the Bulai Gneiss. However, most pegmatites post-date the regional metamorphism and deformation in the Beitbridge area and have been seen to cut across old coarse-grained dolerites, south-east of Swebebe Hill (Figure 5 and Plate 4 A). Consistent ages of $\pm$ 2 000 Ma have been recorded for pegmatites in the Beitbridge area (Holmes and Cahen (1957) and Van Breemen 1968)). These facts suggest that the pegmatites themselves were an expression of the 2 000 Ma thermal event that has been widely recorded in the Limpopo Mobile Belt. A late injection of micropegmatite veins was noted in fractured platy feldspar in the Limpopo Gorge, where they are cut off abruptly by post-Karoo mafic porphyry dykes.

In the Bulai Gneiss pegmatites form steep-sided north-west-trending ridges that appear white and are distinctive on aerial photographs. In the leucocratic gneisses, however, they form low rises covered by coarse pegmatite rubble. The pegmatites occupy old fracture lines and river courses are controlled by them. They are sometimes exposed in the pan country to the north but their presence is usually suggested by overlying red soil and pegmatite scree. The pegmatites vary considerably in their appearance and mineral composition, and this seems to be related to the various rock-types they intrude.

The most common pegmatites are composed of microcline and quartz or microcline, quartz and biotite. Biotite-bearing pegmatites occur in the cordierite gneisses and a graphic hornblende-quartz pegmatite was seen to intrude amphibolites in the Shakwisa Dome. In some shear zones two types of pegmatite are seen adjacent to each other. These may be of different ages and are mica-bearing massive or graphic pegmatites and quartz or quartz-mica pegmatites.

Pegmatites are commonly fractured and brecciated and they are very susceptible to albitization and epidotization by hydrothermal fluids. They have often been recemented with drusy quartz (slide 25 618).

A trend analysis of the pegmatites showed that there are three major orientations, although dykes can be found in the field with almost any orientation. 16.1 % of pegmatites are orientated along a south-easterly trend of 125 – 135°, whereas 14.5 % fall into the east-north-easterly Limpopo trend on 75 – 85° and 11.3 % of the pegmatites have a north-north-westerly trend of 345 – 355°. Most of the brecciated pegmatites occur in east-northeast fractures indicating that they were

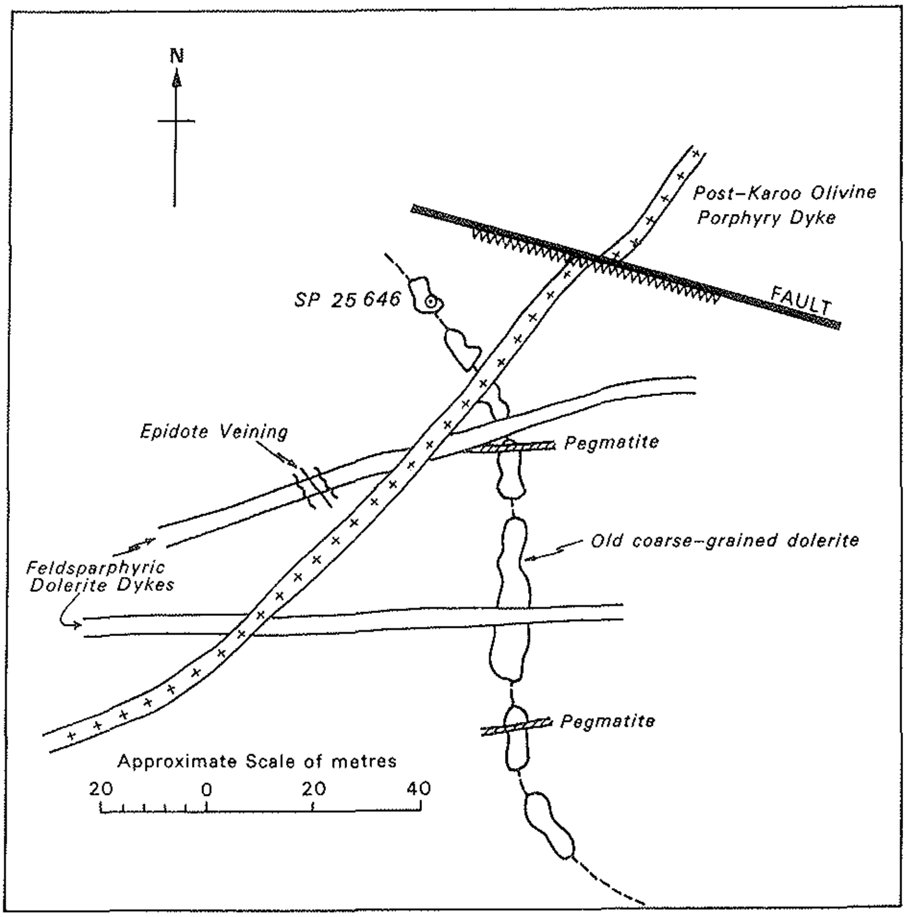


Figure 5: Sketch showing dyke relationships 1.5 km south-east of Swebebe Hill

initiated prior to pegmatite injection but were later reactivated to allow dolerite intrusion and the passage of hot hydrothermal fluids.

Petrography

Slide 25 619 shows a graphic pegmatite of albite intergrown with vermiform quartz. The albite encloses the quartz poikilitically and is optically continuous across individual crystals. It is largely kaolinized especially along a penetrative set of irregular fractures. Some oligoclase occurs along these fractures and also rims the albite adjacent to quartz inclusions. It is probable that the feldspar was originally perthitic microcline that has altered to kaolin, albite and oligoclase. The vermiform quartz intergrowths are made up of individual quartz grains, 0.9 - 3.5 mm across. The crystals have sutured margins and they show undulose extinction, deformation lamellae as well as some granulation and recrystallization.

A muscovite, quartz, feldspar pegmatite (slide 25 620), injected into the Pande Mine serpentinite, has a coarse-grained, foliated, hypidiomorphic-granular texture. Flaky books of muscovite, 10 - 20 mm across and up to 4 mm thick, give the rock its foliation. A few flakes of phlogopite and greenish-brown biotite with interleaved chlorite and magnetite, derived after hydrothermal alteration, seem to penetrate the earlier-formed muscovite. The biotite also includes patches of potash feldspar and muscovite parallel to the cleavage. In the coarse-grained groundmass quartz is intergrown with potash feldspar which shows good grid iron twinning. Grain contacts are interlobate between quartz and feldspar but straight and unsutured between individual quartz crystals. Granulated patches of quartz and feldspar rim the ends of mica books. The fractured grains show undulose extinction and are about 1 mm in diameter.

Another sample (slide 25 621) is from a micropegmatite dyke intrusive into the Bulai Gneiss north-east of Beitbridge. The rock has an allotriomorphic-granular texture formed by an intergrowth of quartz, perthitic microcline and plagioclase crystals, up to 3.5 mm across. The potash feldspars are perthitic in the centre but well-twinned around their rims, where they show embayed contacts with adjacent quartz crystals. The plagioclase (An_{39}) occurs in groups of equant to elongate crystals which show irregular lobate borders and are preferentially sericitized along cleavage traces. Flakes of biotite have altered to chlorite containing epidote granules within the cleavage. Irregular, rounded aggregates of yellow, partly metamict allanite and crystals of apatite are accessory minerals.

The action of hot hydrothermal fluids through the pegmatites has resulted in pink hematite staining of perthitic potash feldspars (slide 25 622), often parallel to exsolution lamellae. In slide 25 623 antiperthitic plagioclase is completely sericitized, whereas biotite has altered to epidote, magnetite and chlorite.

METASOMATIZED BRECCIAS AND APLITES

Metasomatized breccias and harrisitic aplite dykes are largely confined to the charnockitic gneiss terrain around Lutumba Township where they are best exposed in the Lukawe and Chantalikiti rivers. Similar breccias have been found east of Luchewe Hill and along the Samtete River. Where the main Masvingo road crosses the Chantalikiti River, 3.5 km south-west of Lutumba Township, a 30 cm wide contaminated, harrisitic aplite dyke occurs. The forceful intrusion of the dyke has distorted the gneissic foliation, but the aplite itself is undeformed. It was probably injected during the period of waning metamorphism, synchronous with the pegmatite intrusion. The dyke shows a vague zoning with a homogeneous, medium-grained, biotite-rich core zone, a poorly defined intermediate zone and a border zone represented by concentrations of potash feldspar crystals, 2 - 3 cm long, which have grown perpendicular to the wall, apparently as a result of a reaction between the potash-rich paragneiss and the aplite during its time of intrusion (Plate 4 B).

The metasomatic breccias are usually dark grey, recrystallized, granophyric cataclastic rocks that are cross-cut by later dolerite dykes and appear to occupy early north-east- trending fracture lines. Further brecciation resulted in the formation of granoblastic augens of quartz, plagioclase and microcline surrounded by granulated country rock. The plagioclase crystals themselves developed a polygonal network of fractures which gave them a snake skin appearance. Potash-bearing hydrothermal solutions, apparently derived from the surrounding charnockitic paragneiss, were introduced and reacted with quartz and plagioclase to produce orthoclase. Myrmekitic intergrowths of quartz and perthitic orthoclase have filled the polygonal fractures in the plagioclase crystals and have also formed harrisitic growths around the edges of crystals. Sericitization of the orthoclase, pink iron-staining of the plagioclase and alteration of biotite to chlorite and epidote is apparently a result of later, post-Karoo hydrothermal activity.

Petrography

Samples collected from the harrisitic aplite dyke (slides 25 624 – 25 628) were examined. The core zone of the dyke has an equigranular gneissic texture due to a weakly preferred orientation of biotite flakes which are intergranular to aggregates of plagioclase, potash feldspar and quartz. The biotite forms irregularly- shaped flakes, whereas quartz forms equant, rounded or partly polygonal crystals, up to 10 mm across, which are intergrown with smaller irregular crystals of plagioclase and perthitic microcline partly sericitized. The plagioclase shows good albite and pericline twinning and a composition of An_{30} was determined. Irregular round poikiloblastic garnets, 0.4 mm in diameter, are full of tiny inclusions of iron ore and biotite altering to chlorite. A few tiny zircons, usually enclosed in biotite flakes, are accessory.

The border zone is composed of simply twinned high-temperature microcline occurring as elongate crystals, up to 20 mm in length, in a fine-grained mass of quartz, microcline and mica. The microcline crystals, which make up some 60 percent of the border zone, have undulose extinction and a microperthitic structure. The crystal boundaries are straight except against skeletal biotite flakes where they are irregular and embayed. The biotite flakes have ragged edges, contain inclusions of quartz and microcline and are largely altered to patches of green chlorite filled with granular iron ore and clinozoisite.

A sample of light grey, granophyric breccia (slide 25 629) was collected from a north-east- trending fracture line along the Lukawe River. Rounded and platy augen of quartz, plagioclase and microcline occur in a myrmekitic groundmass of orthoclase and micropegmatite. Quartz forms about 20 % of the breccia and occurs as blocky or elongate crystals, 0.3 to 3.5 mm across, which show undulose extinction and embayed boundaries, an indication that quartz has been resorbed by the groundmass. Discontinuous, partly-resorbed quartz mullions, up to 15 mm long, are seen in slide 25 630, whereas quartz is sometimes granulated in slide 25 629, the individual grains measuring 0.06 mm in diameter. Plagioclase, in the oligoclase - andesine range, forms some 30 % of the breccia, and it occurs as rounded augen-shaped aggregates, up to 8 mm across. The plagioclase is cut by a net-like set of fractures filled by wormlike veinlets of potash feldspar associated with metasomatic orthoclase which has crystallized at right angles to the borders of plagioclase aggregates. Plagioclase is sericitized in patches, and some square orthoclase crystals show picture frame zoning and are microperthitic in the centre. Orthoclase also occurs as myrmekitic intergrowths with vermiform and radiating quartz crystals in the groundmass. Biotite flakes altering to yellow chlorite and epidote occur in slide 25 631, as do tiny iron ore rods and a few rounded zircons. Calcite patches occur in slide 25 629.

QUARTZ REEFS

Late intrusive quartz reefs are associated with the Bulai Gneiss north of Beitbridge and have also been found intrusive into ferruginous quartzites north of Bodekwa Hill where one specimen (slide 25 632) shows a coarse-grained crystalline aggregate of white vughy quartz. Individual subhedral to euhedral crystals are up to 20 mm long and are dusted with hematite. Secondary crystallization of the quartz has continued in optical continuity but is not iron stained. Later fracturing of the quartz has resulted in granulation and fracture lines are filled with hematite and secondary quartz crystals.

STRUCTURE OF THE BEITBRIDGE GROUP

The structural and metamorphic history of the Beitbridge Group, of its basement and of the related intrusive rocks within the Central Zone of the Limpopo Mobile Belt, effectively ended some 2 000 Ma ago. Faulting, flexural warping, erosion, sedimentary deposition and igneous intrusion, however, have been active in post-Karoo to recent times, all these events owing their loci to the favourable crustal environment, which the Limpopo terrane provides. A long and complex series of Archaean and early Proterozoic structural and metamorphic events have been distinguished in the Beitbridge area and are summarized in Table 8, modified after Light and Watkeys (1977). During the time span from 3 858 ± 116 Ma to c. 2 000 Ma, five deformational periods comprising six phases of folding and two of shearing have been recognized.

The *first deformation* (D_0) appears to have affected only the basement gneisses which, at the Sand River exposures south of Messina, are dated at 3 858 ± 116 Ma (Barton *et al.* 1977a). These rocks underwent an isoclinal plastic deformation (F_0) and developed a gneissic foliation (S_0) prior to intrusion of the earliest metamorphosed mafic dykes 3 643 ± 102 Ma ago. The foliation, however, is offset by small ductile shear-zones that seem to have developed into normal faults as the load pressure decreased. The intrusion of mafic and quartzo-feldspathic dykes and veins appears to be diagnostic of the basement gneisses, as they have not been observed in the Beitbridge Group.

The *second deformation* (D_1) followed the deposition of the Beitbridge Group in which the original sedimentary bedding was enhanced by metamorphic differentiation and strain. The first fold-phase to affect both the basement and cover rocks was F_1 which involved recumbent, isoclinal, similar folding on an ESE to SE subhorizontal axis before or during intrusion of the layered anorthosite suite c. 3 350 Ma ago (J.M. Barton, pers. comm.). Attenuation of F_1 fold limbs resulted in horizontal, ductile shears and an apparent duplication of the stratigraphic pile. The formation of the F_1 gneissic foliation (S_1) has largely destroyed the sedimentary bedding and a regional lineation (L_1) formed from the alignment of elongated minerals, seems to have undergone the same number of deformations as S_1. Ptygmatically folded quartzo-feldspathic veins and quartz-feldspar-garnet secretion pegmatites were injected syntectonically. Quartz-hornblende-gneisses forming the lower group of the Layered Anorthosite Suite appear to have been intruded along a major, conformable suture line during the F_1 period. Anorthositic gneisses of the Upper group still have primary cumulate textures preserved, but are considered to have been involved in this fold phase. Serpentinites of the Ultramafic Suite preferentially occupy fold closures into which they may have migrated. Some remobilized serpentinites cut across F_2 axial zones which suggests that they were intruded before F_2. From differentiation trends, it is likely that the Layered Anorthosite and Ultramafic suites were derived from the same tholeiitic magma chamber.

The *third deformation* (D_2) involves two periods of folding spanning the time of intrusion of the Bulai Gneiss 2 690 ± 60 Ma ago (Van Breemen 1970). The main F_2 folding appears to have preceded the Bulai Gneiss but was after the metamorphic event at 2 900 ± 100 Ma suggested by Barton & Ryan (1977), to which no deformation can be tied. The F_2 folding was isoclinal, upright and similar on a subhorizontal NE-trending axis. During the early stages (F_{2a}) some zoned garnet porphyroblasts were rotated and shattered, whereas during the more intense stage (F_{2b}) a foliation (S_2) was formed by the crystallization of enstatite, clinopyroxene, kornerupine, cordierite, potash feldspar, sillimanite, spinel and elongated garnet. In some pelitic metasediments, sillimanite, cordierite and feldspar create a nematoblastic fabric. A mineral lineation (L_2) is defined by the alignment of magnetite, biotite and quartz. In the final stages of this fold phase (F_{2c}), anatexis of the basement gneisses caused the intrusion of the Bulai Gneiss, which forcibly modified the structures in its immediate vicinity. The Bulai Gneiss appears to have been intruded into low-pressure zones within F_2 fold noses and its outcrop reflects distorted F_2/F_3 interference patterns.

Early in the subsequent F_3 folding, kornerupine was stable with a symplectic intergrowth of sapphirine, cordierite and gedrite. Soda-metasomatism of the kornerupine produced this intergrowth (Schreyer and Abraham 1976) which cuts across the earlier S_2 foliation and also intersects early corundum-cordierite-symplektites. With a decline in the grade of metamorphism, an intense phase of tight, inclined, similar folding (F_{3b}) ensued with an approximately NNE-subhorizontal axis. This folding imposed its trend throughout the region and a cross-cutting gneissic foliation (S_3) resulted. A lineation (L_3) was defined by the alignment of quartz rods, muscovite, sillimanite, cummingtonite, hornblende and gneissic boudins, while various porphyroblasts were rotated and elongated parallel to this preferred orientation.

At a late stage (F_{3c}) secretion-pegmatites were injected into the F_3 axial zones of folded mafic dykes (Plate 3 C), and between quartz-rimmed augen or boudins (Plate 1 D), the latter being accompanied by ptygmatic folding. D_2 appears to be the equivalent of the first deformation recognized at Selebi-Pikwe in Botswana (Wakefield 1974). This indicates a widespread tectonic event across much of the Limpopo terrain at this time.

The *fourth deformation* (D_3) followed on from the previous period and involved open, upright, concentric folding with gentle to moderate NW-plunging axes. This was a brittle deformation which resulted in shearing parallel to the foliation planes as well as the development of an accompanying axial planar cleavage (S_4) best seen in the quartzites (Plate 2 D and E). Concomitant with the folding was the development in the magnetite-quartzites of *en échelon* gashes, now filled with quartz. L_3 lineations were rotated around an axis, centred on the F_4 fold axis whereas muscovite and cummingtonite aligned parallel to an L_4 lineation. This deformation was terminated by the tightening of F_4 folds to produce upright, conical folds (F_5) with NE to ENE subvertical axes. The effects of the F_5 folding is most evident south of the Nulli Range in the area covered by the Samtete iron claims.

Prior to the *fifth deformation* (D_4) the metamorphic conditions stabilized to medium grade. A period of flat-lying, brittle, cataclastic deformation (D_{4a}) produced flaser gneisses and mylonites which defined an S_5 fabric. Later ENE- trending steep mylonite zones (D_{4b}) created a second generation of flaser gneisses with an S_6 fabric. The latter mylonite zones were the forerunners of the extensive ENE-fracture-system that defines the Limpopo Trend (Cox *et al.* 1965). Some mafic dykes were intruded along these fractures 2 265 ± 64 Ma ago (Holmes & Cahen 1957). Reactivation of steep cataclastic zones developed vertical fractures which controlled the sedimentation of the Waterberg Group in the Soutspansberg district (Barker 1977). Subsequent reactivations of these fracture trends have controlled the injection of numerous swarms of dolerite and felsic dykes up to and including post-Karoo times.

The superimposition of these various fold-trends has resulted in the formation of complex interference-patterns both on a regional and a small scale. Some of the prominent large scale patterns are presented on Plate 5 (in pocket) which shows the surface expression of a variety of dome, basin, mushroom and arcuate structures reminiscent of the type 2 and type 3 patterns described by Ramsay (1962).

Plate 6 (in pocket) illustrates the growth and rotation of individual garnets in relation to the various phases of folding and to intervening periods, during which there was little or no directional stress.

METAMORPHISM OF THE BEITBRIDGE GROUP

Winkler's (1974) concept of metamorphic grade is preferred to the concept of metamorphic facies. The Archaean rocks of the Limpopo Belt reflect a gradual decrease in the effects of metamorphism, from high-, to very low-grade over a time span of some 2 000 Ma. This may represent the continued de-roofing of the Limpopo terrane, as it became a source region contributing to adjacent sedimentary depositories (Watkeys 1979). In the Beitbridge Group mineral assemblages and symplektic intergrowths indicate prevailing temperature and pressure conditions, thus allowing for the subdivision of regional metamorphism into two high-grade events, a medium-grade event and a low- to very low-grade

Table 8 : Summary of the Archaean and Early Proterozoic Geological Events of the Central Zone of the Limpopo Mobile Belt around Beitbridge

Radiometric Ages	Sedimentary & Igneous Events	Structural Events	Grade	Metamorphic Events	P/T Regimes
		No stress	LOW AND VERY LOW GRADE	M_{4b} : Formation of nontronite rocks.	Below 330°C
2 000 Ma	Intrusion of mica pegmatites.	D_4 — D_{4b} : ENE trending, steep mylonite zones. Formation of flaser gneisses with S_6 fabric.		M_{4a} : Serpentinization of ultramafic rocks and dolomites.	Below 500°C
2 100 Ma		D_4 — No stress		M_{3e} : Grunerite stable. Cross-cutting staurolite crystallizes in mylonites.	Above 530°C
		D_4 — D_{4a} : Flat-lying cataclastic zones. Formation of mylonites with flaser gneisses with S_6 fabric.	MEDIUM GRADE	M_{3d} : Epidote granulated. Random gedrite and grunerite infill cross-cutting shears.	
		No stress.		M_{3c} : Crystallization of tremolite actinolite, anthophyllite and cummingtonite.	
		D_3 — F_5 : Upright conical folds with NE to ENE subvertical axes.			
		D_3 — F_4 : Open, upright, concentric folds with gently to moderately plunging NW axes, with accompanying axial planar cleavage (S_4). Formation of L_4 lineation defined by muscovite and grunerite.		M_{3b} : Crystallization of biotite, diopside, calcite and antigorite.	Above 500°C
		D_2 — F_{3c} : Ptygmatic folding of secretion pegmatites.			
	Secretion pegmatites injected into F_3 axial planes and between boudins.				
	Partial melting of the Singelele Gneiss	D_2 — F_{3b} : Tight, inclined, similar folds with NNE subhorizontal axes. Formation of L_3 lineation defined by quartz rods, muscovite, grunerite, hornblende and boudins. Formation of cross-cutting S_3 foliation.		M_{3a} : Hypersthene retrogrades to hornblende. Muscovite stable.	640°-675°C
		D_2 — F_{3a} : Early stage.	HIGH GRADE — Sillimanite	M_{2c} : Rotation and simultaneous crystallization of garnets with sillimanite-bearing cordierite rims. Kornerupine, corundum, cordierite, sapphirine and gedrite stable. Hypersthene, clinopyroxene, plagioclase, garnet and quartz stable as symplektites.	765° - 860°C 4,2 kb - 7,8 kb
2 690 ± 60 Ma	Anatexis of basement gneisses and intrusion of the Bulai Gneiss. Intrusion of riebeckite aplites and rose quartz. Migmatization of garnetiferous paragneisses and formation of charnockitic gneisses.	D_2 — F_{2c} : Late stage.	HIGH GRADE — Sillimanite	M_{2b} : Kornerupine, sillimanite stable; gedrite unstable forming cross-cutting symplektites.	765° - 860°C 4,2 kb - 7,8 kb
	Remobilization of some meta-pyroxenite-serpentinite suites into F_2 fold noses.	D_2 — F_{2b} : Isoclinical, upright, similar folds with subhorizontal NE axes. Formation of S_2 foliation. Formation of lineation L_2 defined by quartz, magnetite and biotite.	HIGH GRADE — Sillimanite	M_{2a} : Orthopyroxene, cordierite, and sillimanite stable. Clinopyroxene stable.	
		D_2 — F_{2a} : Early stage.	HIGH GRADE — Kyanite and sillimanite	M_{1c} : Garnet porphyroblasts rotated and shattered. Rimmed by inclusions of orientated sillimanite and kyanite. Sillimanite aggregates replace kyanite prisms.	
3 128 ± 81 Ma	Intrusion of mafic dykes.				
3 221 ± 48 Ma	Intrusion of meta-anorthosite suite and metapyroxenite-serpentinite suite. Later intrusions of meta-anorthosite pegmatites into former.				
		No stress	HIGH GRADE — Kyanite and sillimanite	M_{1b} : Development of garnet porphyroblasts with rim of random kyanite and sillimanite inclusions. Outer halo of cordierite.	Circ. 860°C Above 10,2 kb
	Intrusion of quartzo-feldspathic veins and quartz-feldspar-garnet secretion pegmatites.	D_1 — F_1 : Isoclinical, recumbent, similar folds with ESE to SE subhorizontal axes. Attenuation of fold limbs to form horizontal shears. Formation of gneissic foliation S_1. Formation of regional lineation L_1 by alignment of platy minerals.	HIGH GRADE — Kyanite	M_{1a} : Enstatite, kyanite and quartz stable. Cordierite and sillimanite unstable. Gedrite unstable, forming cross-cutting symplektites.	Above 860°C Above 11 kb
	Deposition of the Diti and Nulli Formations.				
	UNCONFORMITY				
3 643 ± 102 Ma	Intrusion of mafic dykes.	D_0 — Faulting of the basement gneisses.			
		D_0 — Development of small ductile shear zones.			
	Intrusion of quartzo-feldspathic dykes and veins.	D_0 — F_0 : Folding of the basement gneisses. Formation of a gneissic foliation S_0.		M_0 : Early orthopyroxene?	
3 858 ± 116 Ma	Formation of the Macuville Group.				

event. The metamorphism is summarized in Table 10 and is related to structure, igneous intrusion and geochronology.

The *first metamorphism* (M_0) probably affected the basement gneisses prior to the deposition of the Beitbridge Group. This is indicated by the fact that the oldest deformed mafic dykes at Sand River were intruded into already banded and migmatitic gneiss. Assuming that the basement rocks were originally granitic, the grade of this metamorphism may have been of low to medium grade. However, if the rocks were formerly sediments, it could have been a high-grade event and so would help to explain the association of enderbitic gneisses in the basement.

The *second metamorphism* (M_1) was the first to affect the Beitbridge Group and this event took place during F_1 times after intrusion of the Layered Anorthosite Suite, c. 3 350 Ma ago. This was a high-grade (kyanite granulite) event (M_{1a}) in which the assemblage enstatite-kyanite-quartz was stable. At this time the pressure exceeded 11 kb (Chinner & Sweatman 1968) and the temperature was in excess of 840° C. The P-T stability fields of the mineral assemblages encountered are indicated in Figure 6. In a subsequent episode of no stress (M_{1b}) the temperature remained at 840 – 870°C, while the load pressure fell (10.2 - 11.0 kb). Garnet porphyroblasts developed, with a core of random magnetite, quartz, plagioclase or biotite. The garnet rims included tiny disorientated laths of sillimanite (Plate 6, in pocket). Various arrangements of inclusions within zoned garnets from different localities suggests that the conditions of garnet growth were partly diachronous with the F_2 fold phase. Some garnets developed an outer halo of cordierite or micropegmatite, the former mineral being partly formed by the following reaction (Chinner & Sweatman 1968):

Enstatite+ Al_2SiO_4 + Quartz + Vapour → Cordierite

At this time early diopside, augite, feldspar and micropegmatite porphyroblasts also crystallized (Plate 6), whereas gedrite remained unstable in these parageneses.

Following the intrusion of the Anorthosite Suite and during the early stage of F_2, metamorphic conditions remained much the same (M_{1c}). However, zoned garnet porphyroblasts were rotated and shattered, and sillimanite and kyanite inclusions became orientated parallel to the direction of rotation (Plate 6). The kyanite prisms were subsequently replaced by bundles to form cordierite and corundum (Chinner & Sweatman 1968).

The *third metamorphism* (M_2), as indicated by the above mineral changes, shows a decline in metamorphic grade, in which stable mineral assemblages suggest a range of temperature from 840 to 910° C and load pressure from 8.7 to 10.2 kb. Mineral assemblages at this time (M_{2a}) include kornerupine-corundum-cordierite-sillimanite; spinel-enstatite-cordierite and garnet-quartz-clinopyroxene-spinel. Under these high-grade conditions, and concomitant with the F_2 fold phase, basement and charnockitic aureole gneisses as well as some ultramafic rocks were remobilized into F_2 fold noses. Metamorphic grade remained high (M_{2b}) during anatexis of the basement and the subsequent intrusion of the Bulai Gneiss. This was associated with migmatization and potash-metasomatism in the adjacent gneisses. Kornerupine and sillimanite reacted to form early cordierite-corundum symplektites, whereas spinel-cordierite symplektites developed in garnet cores, probably by the following reaction:

garnet + 2 sillimanite → spinel + cordierite

Early in the subsequent F_3 fold phase, kornerupine was stable with a symplektic intergrowth of sapphirine, cordierite and gedrite, irregularly replacing it. Soda metasomatism of the kornerupine produced this intergrowth (Schreyer & Abraham 1976) which cross-cuts an earlier foliation and the early cordierite-corundum symplektites. This retrogressive reaction appears related to the intrusion of soda-metasomatized riebeckite-aplites, and, although taking place under high-grade conditions (M_{2c}), temperatures now ranged at 740 - 840° C and pressures of 4.9 - 8.7 kb. A second generation of hypersthene also developed during this metamorphic phase, forming symplektic intergrowths with garnet, quartz, clinopyroxene, plagioclase or cordierite in pelitic rocks. Augite-plagioclase symplektites filled fractures in garnets within the anorthositic gneisses.

The temperature and pressure conditions deduced for the early, high-grade metamorphism of the southern marginal zone are consistent with those from Beitbridge (Van Reenen & Du Toit 1978). Here the commonly observed stable assemblage is cordierite-garnet-hypersthene, ascribed to the reaction:

garnet + quartz = cordierite + hypersthene

Cordierite-sapphirine symplektites also occur in the northern marginal zone (Robertson 1977) suggesting that similar metamorphic conditions obtained there.

Samples collected at the Sinyoni Claims include an enstatite-sapphirine-gedrite symplektite after kornerupine (slide 25 633). Another sample (25 634) is a primary sillimanite-cordierite-biotite granulite,

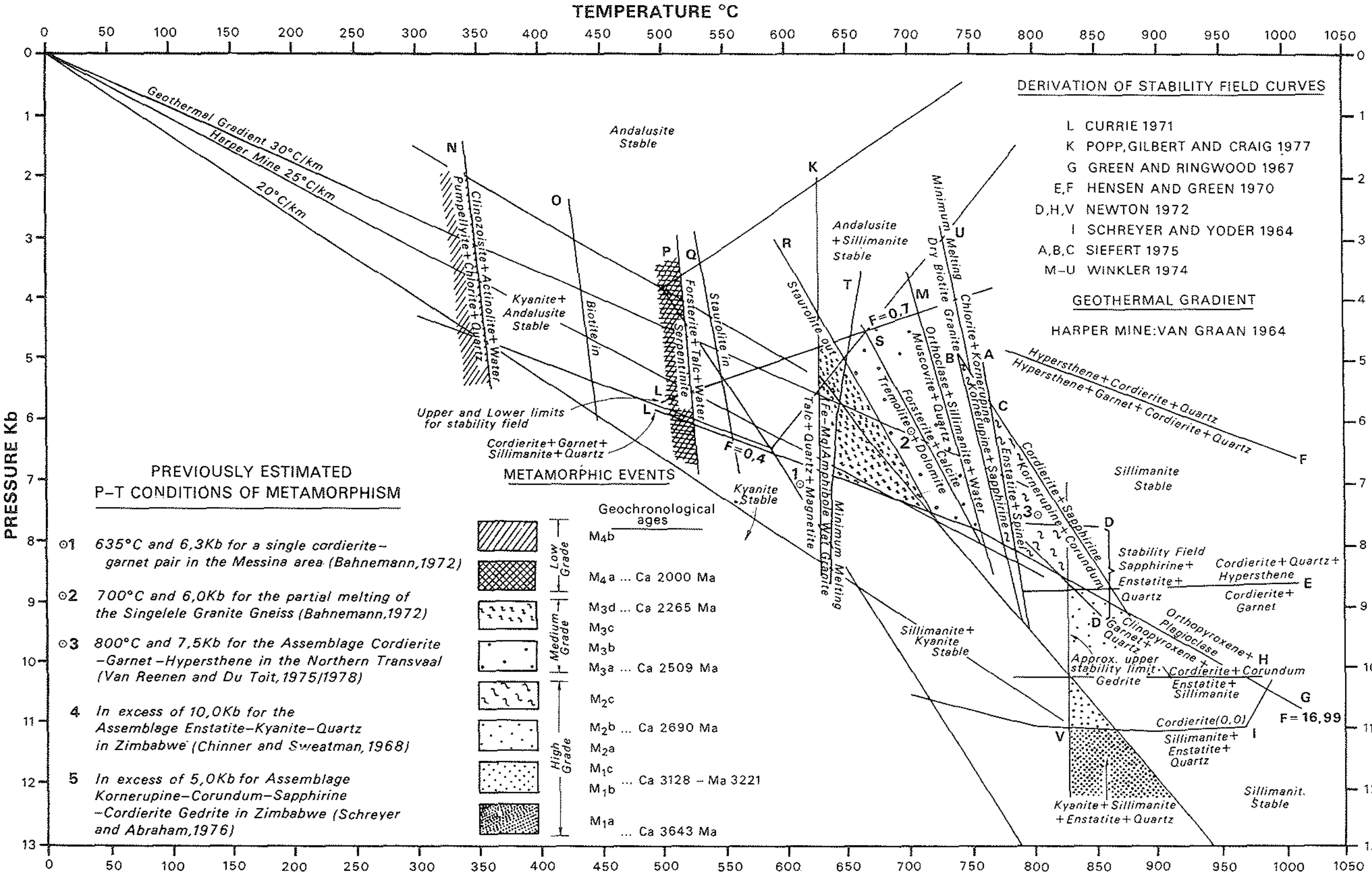


Figure 6: P - T conditions prevailing during metamorphism of the Beitbridge Group (Light, 1979)

which is cross-cut by an intergrowth of corundum and cordierite as well as by large euhedral crystals of sapphirine and cordierite. Other samples include a complex intergrowth of sillimanite, sapphirine, cordierite and biotite (slide 25 635), a sapphirine-cordierite-corundum intergrowth (25 636) and a sillimanite-cordierite symplektite (25 637).

The *fourth metamorphism* (M_3) commenced after intrusion of the Bulai Gneiss, when medium-grade conditions prevailed. During the F_3 fold phase, hypersthene became rimmed or wholly replaced by hornblende, whereas cummingtonite-grunerite and muscovite became stable minerals. Coexisting cordierite-garnet- and other stable parageneses indicate a temperature range of 680 – 750° C and pressures of 5.9 - 7.7 kb for the M_{3a} episode. The effects of such a retrogression on any particular rock type depends largely on its composition and on the prevailing water pressure. The assemblage hypersthene - clinopyroxene-plagioclase may retrogress to hornblende and quartz, but if no clinopyroxene is present the assemblage downgrades to hornblende, quartz and almandine garnet. Paragneisses containing hypersthene, garnet and microcline break down to biotite and quartz, whereas hypersthene and cordierite in aluminous paragneisses retrogress to garnet and biotite.

During the F_4 fold phase temperatures and pressures remained much the same, as muscovite and cummingtonite crystallized along an L_4 lineation (M_{3b}). With the D_4 cataclastic deformation, epidote crystallized and was granulated (M_{3c}) prior to staurolite crystallizing and cutting across the epidote (M_{3d}). This was a period of no stress, in which spherulitic and random growth of tremolite, anthophyllite, corundum and muscovite crystals took place. Randomly orientated anthophyllite needles infilled crosscutting F_4 shears in magnetite-quartzites, while quartz filled F_4 gash veins *en échelon*. The temperature and pressure conditions estimated from these coexisting parageneses suggests a temperature range of 620 - 750° C and load pressure of 6.0 - 6.75 kb (Fig. 5).

The *fifth metamorphism* (M_4) was a low- to very low-grade episode, following on from M_{3d} in which a rapid decline in temperature is indicated. Potash metasomatism along some breccia lines is associated with pegmatite injection, whereas continued retrogression is shown by alteration of diopside to chlorite and hornblende to actinolite. Serpentinization of the ultramafic rocks and the formation of ophicalcites suggests a decrease in temperature to 500 – 525° C (M_{4a}), whereas decussate nontronite rocks formed under no stress in ferruginous quartzites show a decrease in temperature below 350° C (M_{4b}).

THE KAROO SYSTEM

South of Mabona Hill sediments of the Karoo System occupy an area of 2 km^2 between the Limpopo River and the Shurugwi Fault. The fault represents the ENE- extension of the Dowe-Tokwe Fault in the Messina area of Transvaal, and the Karoo outlier here is the most westerly occurrence of Karoo sediments known along this fault in Zimbabwe. There are basal fossiliferous shales with overlying grits and sandstones. The rocks appear to be equivalent to the carbonaceous shales and arkosic grits of the Upper Chipise Shale Formation in the Bubye Coalfield (Bruce 1975). Elsewhere isolated fragments of Karoo sediments occur as float and rubble, indicating wider distribution in the past.

Distribution and Field Relations

The sediments form low undulating country with ridges developed along the north-eastern and northern edges of the block. Along the bank of the Limpopo River they are obscured by alluvium, and the shales are best exposed along the beds of rivers flowing SSE off Mabana Hill. West of the fault block and south of the Shurugwi Fault the gneissic basement is covered by residual yellow-brown soils and Karoo boulder-scree. Abundant rounded pebbles and boulders of ironstone, granulite and gneiss across the flat tops of hills in the Luchewe Basin are suggestive of a former covering of Karoo rocks here too. Fragments of creamy-white, massive, well-sorted and fine-grained Forest Sandstone (slide 25 638-25 639) were located NE of the old Main Drift on the Limpopo River and along the main Masvingo road SW of Lutumba Store. A fine-grained, well-laminated red sandstone (slide 25 640) from just east of Cemberere Hill appears to belong to the Red Beds unit.

Within the fault block the shales only exposed in stream beds are conformably overlain by pale pebbly grits that grade upwards into massive sandstones. The unconformable relationship between Karoo grits and the underlying gneisses is demonstrated along the northern margin of the fault block. Here all the rocks dip steeply to the SW, due to drag along the faulted contact. Westwards the sediment cover becomes very thin and the underlying gneisses are exposed as inliers along water courses. Generally the sediments are flat-lying, but they dip gently southwards at 15° near the centre of the fault block. Adjacent to the Shurugwi Fault the dip is 55° SSE, and on the eastern side of the block the dip is locally as much as 45° decreasing inwards. The underlying gneisses are also noticeably affected by fault drag. Short NW-trending fractures and breccias lying parallel to the Shurugwi Fault cut the sediments as do a few altered dolerite dykes. The more resistant sandstones form low scarp slopes which are covered by pale, yellowish sandy soil and scree, quite distinct from the red soils which overlie the shales. The vegetation is stunted and sparse.

Lithology

The basal shales which weather to piles of angular shards in the stream beds, are black in the lower part of the succession and grey to cream-coloured higher towards the grits. The shales are well laminated and locally show a colour banding, with siliceous and carbonaceous layers, 2 - 10 mm thick. The cream-coloured shales are fossiliferous, but are too shattered for the plant remains to be positively identified. The fossils appear to represent plant stems and carbonaceous material apparently derived from leaves. One stem is possibly *Vertebraria* of Lower Karoo age. Similar species occupy the same stratigraphic position in the Bubye Coalfield and range from Lower Ecca to Lower Beaufort in age (Bruce 1975).

The grits are soft, pale granular buff-coloured rocks that are stained dark-grey in places. They grade upwards into hard, white, massive gritty sandstones. Both types are medium-grained and are interbedded in layers, 10 - 30 cm thick. They contain finer-grained light- and dark-coloured laminations and in places have well-developed cross-bedding, some convolute, in sets beds up to 3 m thick. The grits commonly contain rounded pebbles forming discontinuous lenses of pebbly conglomerate, up to 15 cm thick. The pebbles of up to 30 mm in diameter, consist mainly of glassy quartzite. The bedding of the rocks is emphasized by preferential weathering of the softer layers. Breaking into flaggy slabs along the bedding, the rocks develop a smooth, reddish iron-stained patina on weathered surfaces. A finely laminated sandy grit exposed along a stream on the fault block, contains weathered circular impressions, about 10 mm in diameter, that lie in the bedding plane. These could be of concretionary origin and resemble ill-defined molluscan remains, but are most probably rain prints.

Petrography

A shale (slide 25 641) from a river section in the centre of the fault block is very fine-grained, well laminated, creamy-brown in colour and contains abundant plant fragments. The slide consists almost entirely of brown-stained clay, the individual flakes of which are too fine for resolution, but which in aggregate exhibit positive elongation. Silt-size quartz fragments are scattered throughout and there are ragged flakes, mainly of detrital biotite, but some muscovite, up to 0.2 mm long. These are generally elongated parallel to the bedding and deformed by compaction. Rods, filaments and whorls, apparently of plant remains now completely replaced by red iron oxide, lie within the bedding or are slightly oblique to it.

Sandstones from the low ridges in the north-eastern part of the fault block are moderately hard and vary from yellowish to grey-white. Bedding is perceptible in hand specimen, but is well defined only locally, as in a specimen (25 642) which has a layer with very well-rounded, vitreous quartz pebbles ranging between 3 - 10 mm in diameter. The groundmass composed of subangular to subrounded quartz averages 0.3 mm in diameter, and shows little variation in size. The grains are tightly packed, but there are small scattered intergranular cavities occupied by iron-stained kaolinite, distorted sericitized feldspar, and rare detrital epidote, chlorite and muscovite. A rock similar in hand specimen, is completely different in thin section (slide 25 643). Angular, equant quartz grains, averaging 0.5 mm in diameter, but ranging between 0.2 - 2 mm are patchily coated with a very thin film of iron oxide. Colourless, cryptocrystalline kaolinite accounts for the remaining 25 % of the rock volume. It occurs interstitially, encircling the quartz grains, and also as patches and streaks. It has not formed *in situ* from breakdown of feldspar, of which there is none in this slide. There are a few grains of detrital epidote, but no other minerals, and the slide is particularly clean looking. Another specimen (25 644) consists of subangular to subrounded quartz (0.5 mm) and rare sericitized feldspar grains, fairly tightly packed. Small intergranular cavities are occupied by iron-stained kaolinite and rare detrital epidote, chlorite and muscovite. The quartz grains have a greater development of iron oxide coating than in the other specimens, but like them are unstrained, seldom exhibiting undulose extinction. And there is no clear evidence of any authigenic regrowth.

DOLERITES

In addition to the deformed and metamorphosed mafic dykes described earlier, innumerable dolerite intrusions of different types and ages occur throughout the map-area and indeed across the entire

Limpopo Mobile Belt in Zimbabwe. They are almost always in the form of dykes occupying the intense fracture-systems which traverse the metamorphic belt. At only one locality, west of Lutumba Township, is dolerite seen as a sheet, and this occupies an area of less than 1 km^2.

The dolerites range in age from pre-Waterberg to post-Karoo. In the Messina area, K/Ar data place the age of the Golf Links Dykes at 1 800 – 1 500 Ma, the Messina Dyke at 1 850 Ma and the Artonvilla Dyke at 185 Ma (Jacobsen *et al.* 1975). Younger ages that have been determined for the older dykes are attributed to hydrothermal influence. From south of Messina, ages of 2 265 ± 64 Ma and 1963 ± 89 Ma are recorded (Barton & Ryan 1977).

Although most of the dykes in the Beitbridge-East area are of Karoo age, representatives of older suites, probably equivalent to those dated in the Messina area, are recognized and there are two types of post-Karoo intrusions as well. In fact, field relationships permit seven ages of dolerites to be distinguished:

1. Early coarse-grained dolerite
2. Fine- to medium-grained dolerites
3. Glomerophyric dolerite
4. Platy feldspar dolerite
5. Mafic porphyry dykes
6. Porphyritic picrite
7. Late fine-grained dolerite

The last three categories are described in the chapter dealing with post-Karoo igneous activity.

The strike distribution is illustrated by Figure 7. The orientations are resolved into a very weak northerly trend and a strong ENE-trend. The 55° alignment corresponds to the Messina Trend and the 75° direction to the Dowe-Tokwe Trend in South Africa. In Zimbabwe the dominant ENE-fracture orientation is the Limpopo Trend and the SSE-fractures, parallel to the Nuanetsi synclinal axis, are denoted the Nuanetsi Trend. Dykes intruded along all of these directions may bifurcate to present the complex interwoven pattern shown on the map.

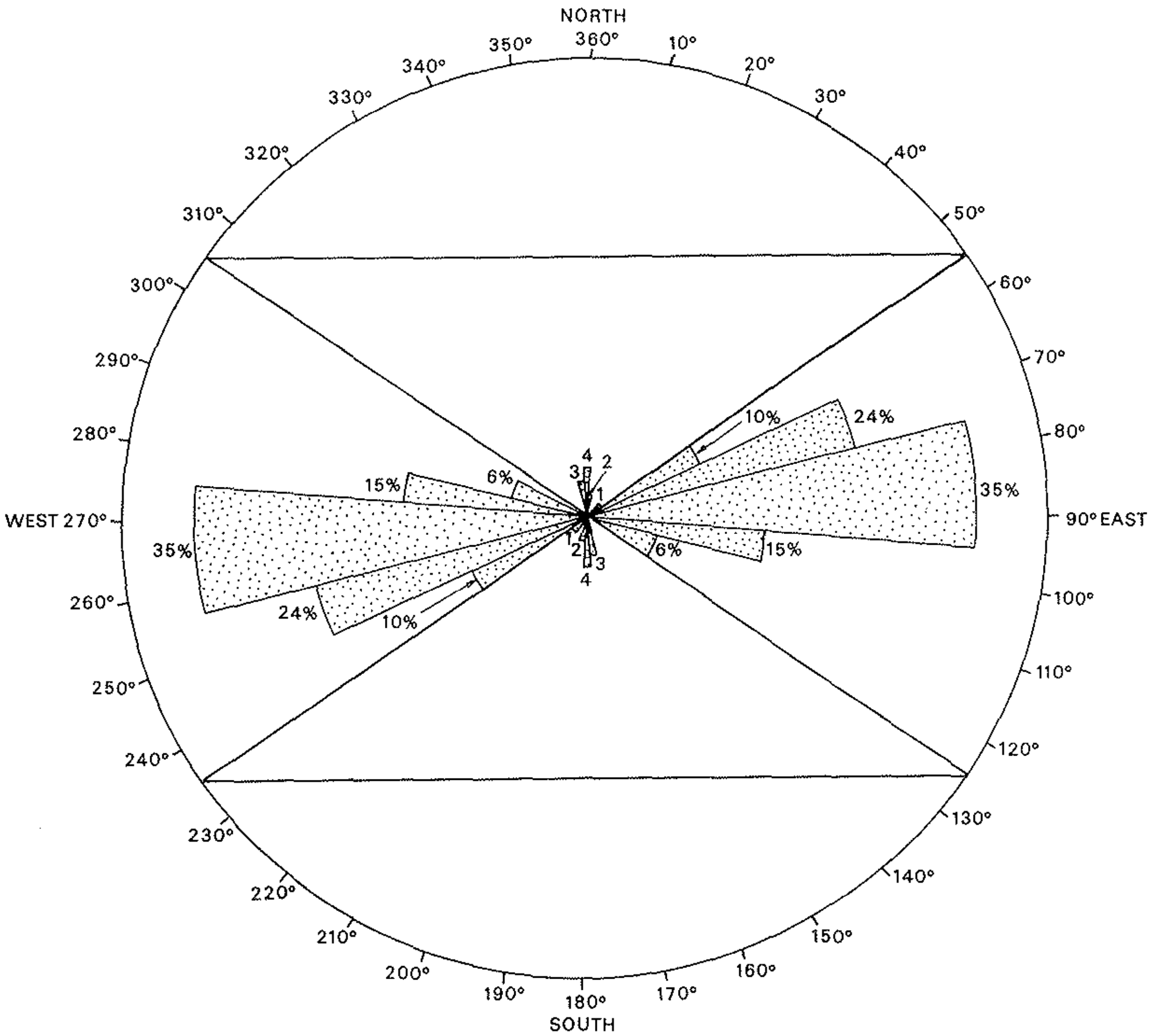


Figure 7: Strike distribution of Dolerite dykes East of Beitbridge

The east- to ENE-trending dolerites are concentrated in dense swarms particularly noticeable across the northern half of the area. A dense dolerite swarm also occurs east of Beitbridge and cuts the Luchewe structure, and a third concentration occurs in the vicinity of the Pande Mine. The fractures which were followed were initiated after the last deformation, as the dykes are undeviated by earlier structures. Individual dykes are 0.2 and 50 m wide, but are mainly 2 - 3 m wide. Fracture zones, up to 200 m across, may be filled with irregular anastomosing dykes which envelop islands of brecciated and recemented country rock. Other fracture lines have acted as routes for several pulses of mafic magma, and chilled margins characterize composite dykes such as those in the Limpopo Gorge and at the Mapai Dam spillway. In these intrusions, irregular gneissic inclusions are hydrothermally altered and are cut by doleritic apophyses.

COARSE-GRAINED DOLERITES

The earliest dolerites recognized are generally coarse-grained and were intruded prior to the emplacement of the mica-bearing pegmatites. They also precede the major episode of ENE-trending fracturing and brecciation, and appear to be equivalent to the pre-Waterberg and Waterberg-age dykes of the Messina area. Furthermore, the coarser-grained varieties are of a granular recrystallized appearance, like some of the Great Dyke satellites which penetrate the Northern Marginal Zone of the Limpopo Mobile Belt, and are believed to have been converted in like manner during the waning phase of the c. 2 000 Ma metamorphic episode which is reflected consistently throughout the Limpopo Belt. Correlation with the well-developed Mashonaland and Umkondo dolerite suites of Zimbabwe is unjustified, other than to note that these rocks are of similar Proterozoic age. Of importance is the recognition that there are dolerites of considerable age in the area, and that not all fresh dolerites are of Karoo age, as has been tacitly but erroneously assumed by many earlier workers in the field.

Coarse-grained dolerite commonly forms plug-like bodies which build significant koppie features along fractures trending NE or NW. Elsewhere the dolerites form normal dykes which may be distorted by later shearing. The age and field relationships are illustrated on a sketch map of an exposure near the Lipani River, just SE of Swebebe Hill (Fig. 5).

Most of the pre-Karoo dolerites recognized tend to be the coarser-grained varieties and they are apparently more common in the southern half of the map-area. This may be attributed partly to being more poorly exposed in the north and also to the fact that any finer-grained modifications of this age would be indistinguishable from Karoo-age dolerites in the field, although spectrographic analysis has shown that the older intrusions consistently contain less titanium than the Karoo rocks.

A single undeformed east-trending dyke of massive tremolite-rock traversing Shakwisa Dome, has no apparent affinity with any other dykes in the area. It is about 4 km long and attains a maximum width of 30 metres. The dark associated soil contains fragments of pale greenish-grey rock that has a few scattered, cuboid and broken crystals of ilmenite, the largest measuring 8 mm across.

Petrography

The tremolite dyke (slide 25 645) consists almost entirely of randomly disposed tremolite prisms with ragged terminations and averaging 0.3 mm in length. Throughout are opaque-black grains, presumably of ilmenite, almost square in section and measuring 0.1 mm. Associated with them is grey to cloudy leucoxene. There are several large ilmenite phenocrysts replaced by leucoxene, and other diffusions, replaced by tremolite which merges into the matrix. A possible amygdale, measuring 6 mm across and outlined by red iron oxide comprises an extremely fine-grained reticulated mass of talc.

A specimen from an older coarse-grained dolerite dyke (Fig. 5 and slide 25 646) has an unusual texture. It is granulated and partly recrystallized which is consistent with emplacement during the closing stages of regional metamorphism. Stumpy prisms of orthopyroxene, up to 2 mm long, are marginally and locally internally replaced by pigeonite. The internal replacement, in optical continuity with the marginal pigeonite, imparts a vague schiller structure. The two pyroxenes are present in approximately equal proportions, together forming about half of the rock. The pigeonite in part has a granular recrystallized appearance and is patchily replaced by pale-brown hornblende and red-brown biotite. Andesine (An_{42}) also forms stumpy subhedral laths, 1 to 3 mm long. It is clear, unaltered and well twinned. Apart from a few specks associated with the hornblende and biotite the rock is devoid of iron-ore.

A second coarse-grained dolerite (slide 25 647) from SE of Shakwisa Hill, is speckled with irregular and partly skeletal 2 mm magnetites which constitute about 7 % of the rock. Poorly formed prisms and granular aggregates of pigeonite, up to 2 mm across, comprise 25 % of the rock. The pyroxene is in part replaced by brown hornblende, itself changed to green chlorite. These minerals, and 10 % or more of graphic micro-pegmatite occur interstitially in relation to the slender laths of labradorite (An_{60}) which make up more of the rock. The texture is subophitic or, more correctly, intersertal. The feldspars are usually quite clear and well twinned, but there are patches of saussuritization and also replacement by the micropegmatitic intergrowth. There is an appreciable amount of early-formed apatite, some accessory sphene and a little red-brown biotite.

FINE- TO MEDIUM-GRAINED DOLERITES

Dolerites of this description are widely distributed throughout the Beitbridge District. They were injected simultaneously along NE- and ENE-trending fractures, and in places members of the suite are against another, or else form composite dykes. This indicates that there was more than one mafic magma pulse, probably during Karoo times.

At a number of localities fine-grained glassy dolerites, which tend to occupy NNE- fractures, are cut and dextrally displaced by medium-grained dolerites which trend ENE. West of Lutumba Store, there is evidence of sill formation parallel to foliation planes in the gneiss.

The dolerites resist weathering to a varying degree. In places, especially at dyke intersections, they may form low rises and ridges or, more usually, they weather with negative relief. Where east-trending dykes cross the north-striking Nulli Range they have negative relief and occupy saddle features along the range. Stream courses preferentially follow dykes and fractures and consequently dolerite is commonly exposed in river beds. In the north it locally outcrops in pans. Generally the coarser-grained varieties tend to weather more readily than the fine-grained ones. Spheroidal weathering is common, and decomposed boulders show the development of concentric black and yellow-stained oxidized zones. Commonly, however, the only surface expression of a dyke is the presence of small fragments of dolerite in yellow-brown soils. Only the deeply weathered dolerites are overlain by red soils. An increase in the density of stunted vegetation on dolerite in the flat para-gneiss terrain is distinctive on aerial photographs; on the colour photographs, dykes show up well as brown traces across the plain.

Fresh surfaces of the coarser dolerites are deep olive-green in colour. They have a khaki-brown weathered skin, whereas the fine-grained, black chilled marginal varieties weather to a lighter-grey colour. Dolerites that have intruded Karoo sediments are black, altered and heavily decomposed. Those cut along breccia zones may themselves be brecciated and such dykes are commonly cut by epidote veins and cemented by drusy quartz mineralized with copper.

Petrography

An aphanitic dark-grey fine-grained dolerite (slide 25 653) from a north-trending dyke near the Cull Claims has clear labradorite laths, up to 0. 3 mm in length, and ophitic relation to subhedral pigeonite of similar size. These minerals constitute more than 90 % of the rock. Irregular blebs of iron-ore, averaging 0.05 mm in diameter, are evenly distributed throughout, with 3 % of clear unserpentinized olivine cracked and rimmed by iron oxide. A specimen from the black and chilled almost glassy selvage of a dyke in the Nulli Range (25 654) has a weathered surface, curiously etched by differential weathering, resembling a fine scale version modification of the elephant-hide weathering of limestones. The groundmass seems to consist entirely of feldspar microlites (20 - 40 microns) and iron-ore granules. No glass or other mineral can be detected. Microphenocrysts, the form of slender 0.15 mm-laths of plagioclase, are evenly distributed, with fewer pigeonite and olivine phenocrysts, the latter largely replaced by talc, serpentine and calcite. A fine-grained fresh dolerite (25 655) has 1 mm laths of plagioclase (An_{40}) constituting 60 % or more of the rock. Pigeonite (25 %) and olivine (7 %), are anhedral and occur intergranularly. Blebs of iron-ore, 1 mm across, occur throughout. The olivine has fractures and rims coated with iron-ore, but is not serpentinized. There are well-formed prisms of accessory apatite and some secondary biotite. A medium-grained dolerite (slide 25 656), from east of the Cull Claims, has irregular plates and aggregates of pigeonite, 1 mm or more across, ophitically enclosing plagioclase laths. Clotted iron-ore is prominent and regularly distributed. Minor development of uralite and biotite in association with iron-ore occurs at the margins of some pyroxene crystals. This rock is almost identical to an older dolerite (25 647) from SE of Shakwisa Hill, but contains no micropegmatite.

GLOMEROPHYRIC DOLERITES

This is a most interesting suite characterized by the presence of clusters of plagioclase crystals set in a generally fine-grained matrix. Three, four or more interpenetrating plagioclase laths, each 2 - 7 mm long, form the clusters which generally lie 2 - 3 cm apart. The rock is easy to identify in the field, although there are examples in which the feldspar crystals are as much as 2 cm long and not so characteristically clustered (slide 25 660). These last could be confused with rocks of the platy dolerite suite in hand specimen, although the latter generally have a coarse matrix in which the flat feldspar plates have a tendency towards parallel arrangement.

Petrography

Under the microscope the rocks are unmistakable (slides 25 648, 25 650-52, 25 659-60). All have iron-ore largely in the form of thin rods, 0.3 - 0.5 mm long, and arranged in a triangular geometric pattern. Additionally all contain brown basaltic glass, ranging from 50 % in slide 25 648 to 5 % in slide 25 560. The pyroxene is pink pigeonite, hardly distinguishable from the glass in plane polarized light; it forms only about 10 % of the more glassy rocks, but comprises about 30 % of the more crystalline members. There are three generations of plagioclase. The large phenocrysts range between An_{65} and An_{80} in composition. The second generation plagioclase is the most prominent mineral in all the slides, and it occurs as randomly orientated 0.5 mm-laths, between which the glass, pyroxene and olivine occur interstitially. Olivine accounts for 2-3 % of the rocks. It is hardly discernible in fresh specimens, but stands out well in the more altered ones owing to replacement by green serpentine and reddish-yellow iddingsite. A third generation of feldspar as indistinct microlites, and minute granules of iron-ore, are the only distinguishable phases in the glassy mesostasis.

PLATY FELDSPAR DOLERITES

From chilled margin relationships in composite dykes it can be deduced that the distinctive platy-feldspar dolerites were the youngest dolerite intrussions of Karoo age. They are relatively common in the Limpopo Mobile Belt and occur as part of the ENE-trending swarms. They usually produce negative relief and weather to rough spheroidal boulders, with reddish-brown surfaces on which the feldspar plates stand out. These crystals are 2 - 3 mm thick and measure 20 - 50 mm across. Different dykes may contain different proportions of phenocrysts; in some the phenocrysts comprise as much as 80 % of the rock. The feldspar plates commonly show a strong orientation parallel to the walls of the dyke, but in the centre they usually have a random orientation. These features may be due to flowage.

Two possible ages of intrusion are indicated in the Limpopo Gorge exposures. At one locality a pale-coloured inclusion of phenocryst-rich platy feldspar dolerite was found in a dark-coloured feldsparphyric dolerite. At another locality an early, fine-grained dolerite cuts across a breccia zone and is itself cut off by a younger, hydrothermally altered dolerite. The platy feldspar dolerite is chilled against the other end of the early dyke and is brecciated and cut by pink, hydrothermally altered micropegmatite veinlets which abut against a post-Karoo mafic porphyry dyke, itself chilled against the platy feldspar dyke. Inclusions of gneiss and breccia often occur along these chilled contacts and hydrothermal activity appears to have been related to the intrusion of mafic porphyries. A chemical analysis of the platy feldspar dolerite is presented in Table 9 (Lab.No. 015).

Petrography

A typical specimen (25 658) from a dyke intruded east of the Luchewe Basin contains platy feldspar phenocrysts, up to 20 mm long, which comprise at least 80 % of the rock. Although generally clear, the large feldspar laths are somewhat strained and patchily sericitized. The average composition is An_{65}. Second generation feldspar laths in the matrix are about 1 mm long and are slightly more sodic. The other main mineral in the matrix is pigeonite, with a positive optic axial angle of about 20^{o}. It is marginally altered to green-brown hornblende. There are patches of micropegmatite and a little biotite altered to chlorite. Blebs of iron-ore measuring 0.5 mm across are preferentially associated with the pyroxene. Slender prisms of accessory apatite, up to 0.5 mm long, are a feature of parts of the rock. There is no olivine.

POST-KAROO IGNEOUS ROCKS

The extended period of igneous activity within the Nuanetsi Igneous Province (Cox *et al.* 1965) is only peripherally represented in the Beitbridge area. There are various hypabyssal rocks which occupy fractures, commonly with a radial disposition, but perhaps a more important expression is the widespread hydrothermal activity which was operative in post-Karoo times. It is believed that the origin of copper mineralization, as at Messina, is associated with this activity, the emplacement age of which is given as 185 ±7 Ma (Jacobsen *et al.* 1975).

Following the outpourings of Karoo basalts and rhyolites, plutonic igneous activity continued far to the north-east of Beitbridge. Gabbros, granophyres, granites and syenites were intruded as plugs, sheets and ring-dyke complexes. Their hypabyssal equivalents have a widespread distribution, in many cases as radial dykes which focus on the main plutonic centres, some of which may not have been exposed. In the Beitbridge area there are coarse-grained tonalites and fine-grained aplites, representative of the acid phase of intrusion. Nepheline-syenite dykes are related to the alkali-syenite phase of the Marungudzi Complex east of the map-area, and mafic porphyry, porphyritic picrite and fine-grained dolerites represent the last mafic intrusive phase.

TONALITES AND APLITES

Most of the few tonalite and aplite outcrops occur in the environs of the Shakwisa Dome. Others are associated with the Bulai Gneiss nearer to Beitbridge. Both tonalites and aplites are undeformed and they occur as short dykes. The tonalites are coarse, granular quartzo-feldspathic rocks that are white or reddish in colour. They contain small proportions of mafic minerals and in one specimen (25 662), there is a vague linear arrangement of the hornblende. Some of the aplites occupy NNE-trending fractures and they show strong evidence of hydrothermal alteration. They are veined by epidote, and the feldspars are stained pink by iron oxide indicating that the rocks were intruded prior to or during the main hydrothermal event. In hand specimen the fine-grained aplites are flesh-coloured, vaguely porphyritic rocks and they also are of tonalitic composition. They have scattered 2 - 5 cm cavities with drusy linings.

Petrography

Two tonalites (slides 25 663-64) from north of Shakwisa Hill are coarse-grained allotriomorphic-granular rocks, composed largely of oligoclase and quartz. The feldspar has the composition An_{30} and comprises up to 70 % of the rock. It is usually clear and well twinned, but there are patches of sericitization and saussuritization. The irregular grains of both feldspar and quartz commonly exceed 5 mm in diameter, and there is an unusual textural relationship between them. Lobes of quartz penetrate feldspar as if replacing it, and the reverse, with round blebs of feldspar apparently completely enclosed in quartz, may be seen. This gives the appearance of myrmekite intergrowth on a coarse scale, but remnant microcline in the rock constitutes less than 1 % and there is no evidence to suggest that it was formerly a more important constituent. Both rocks are practically devoid of other minerals, but slide 25 662 contains about 5 % of ragged patches of green hornblende, enclosing rather large and rounded apatite prisms and associated with a little epidote and iron-ore. A few small ragged flakes of biotite are present.

Two specimens of fine-grained porphyritic aplite (25 665-66), from SE and SW of Shakwisa Hill, respectively, consist of blocky feldspar phenocrysts, up to 0.6 mm long, set in an allotriomorphic groundmass of 0.1mm grains of quartz and plagioclase. The feldspar laths have ragged terminations and are locally marginally fretted. Both phenocrysts and groundmass feldspars are pinkish-brown and virtually opaque owing to alteration, so that only vestiges of twinning remain. On the evidence of a refractive index lower than that of quartz they appear more sodic than the plagioclase of the tonalite. There are a few poorly formed, partly chloritized phenocrysts of hornblende and a little iron-ore and epidote occur in the groundmass. The quartz content is about 35 %.

MAFIC PORPHYRY DYKES

Mafic porphyry dykes, like those forming the intense swarm east of the Marungudzi Complex, are less common in the Beitbridge area, where they occur within the main east-north-east dolerite swarms. They also occupy north-easterly radial fractures parallel to the porphyritic picrite dykes. These fractures intersect in an area 15 km west of the Marungudzi Alkali Centre and this may indicate the site of an unexposed pluton.

The mafic porphyries are distinctive as all have a dark green, fine-grained matrix containing oval feldspar phenocrysts, up to 1 cm long. They weather into smooth, spheroidal boulders, a metre across, but they do not commonly outcrop. In the Limpopo Gorge west of Beitbridge, two parallel porphyry dykes have formed a resistant wall to the south, whereas adjacent dolerites have been eroded. Dykes, one or two metres wide, are the common expression, although a fresh, 40 m-wide intrusion traverses the Nulli range. Chilled margins show that the mafic porphyry dykes are younger than most other dolerites. They are chilled against platy feldspar dolerites in the Limpopo Gorge and at the Mapai Dam spillway. At the latter locality the porphyry appears to have more than the usual number of feldspar phenocrysts within the contact zone. It is possible that there have been two periods of intrusion of mafic porphyry, because in the Limpopo Gorge and elsewhere there are younger dykes with abundant feldspar phenocrysts which are chilled against an older one containing fewer phenocrysts.

Hydrothermal activity has affected the mafic porphyry dykes to varying degrees. This has resulted in kaolinization and the pink coloration of feldspars, as well as in the introduction of chlorite and epidote. A fresh mafic porphyry and a metasomatized variety have been chemically analysed (Table 9, Lab. No. 75/69 and 76/40). The altered porphyry has gained silica, soda and potash and has lost magnesia, lime, iron oxide and alumina, so that it tends towards the composition of the tonalitic aplites. Therefore the main period of hydrothermal activity may have been a later phase of the acid igneous cycle in the Nuanetsi Igneous Province.

It is perhaps significant that these late porphyry dykes are almost always sparsely mineralized with iron and copper sulphides. Their relationship with the hydrothermal activity may suggest a genetic link with copper mineralization in the Limpopo Mobile Belt.

Petrography

The mafic porphyries have a matrix that varies from dark to pale grey, altered rocks being tinged brown or reddish-brown. The matrix is fine-grained and is composed essentially of plagioclase and pigeonite. Laths of the former average 0.3 mm, and the pyroxene crystals, locally euhedral but more often of granulated appearance, measure 0.1 - 0.2 mm in diameter. An ultra fine-grained rock (slide 25 670), aphanitic and almost black, is an exception; it contains a little glass and minute pyroxene granules and the feldspars are less than 0.1 mm long. Most rocks are characterized by the presence of oval-shaped plagioclase phenocrysts, up to and locally exceeding 205 mm in diameter. These comprise from 5 % by volume (25 668) to about 50 % (25 671). Composition is An_{54} - An_{73}. There are also a few small phenocrysts of pyroxene. In some of the rocks the plagioclase phenocrysts are fresh and clearly twinned, but in other places they are completely saussuritized. The oval shape in some instances is apparently due to resorption, but others have sharp margins between phenocryst and matrix, and the shape has been determined by strain which has resulted in the stepping of twin lamellae.

Table 9 : Chemical analyses of Dolerite and Post-Karoo Intrusives (in %)

Slide No.	**25 657**	**25 667**	**25 668**	**25 674**	**25 678**
Lab. No.	**015**	**75/69**	**76/40**	**75/72**	**75/68**
SiO2	52.38	47.17	61.90	46.41	47.92
Al2O3	15.14	17.30	13.46	12.12	20.00
Fe2O3	1.39	4.11	2.34	1.79	2.27
FeO	9.02	6.09	5.33	7.37	3.10
MgO	5.16	4.98	1.54	14.14	3.25
CaO	9.37	11.46	3.76	13.32	6.03
Na2O	2.90	3.22	3.86	1.44	5.91
K2O	0.96	1.85	4.66	1.35	5.68
H2O+	1.40	1.51	1.86	1.05	1.15
H2O-	0.12	0.41	0.25	0.19	0.15
CO2	0.07	0.05	0.44	tr	tr
TiO2	1.99	0.92	0.66	0.55	1.40
P2O5	0.46	0.34	0.03	0.19	0.74
MnO	0.15	0.17	0.17	0.17	0.13
Totals	100.51	99.58	100.26	100.09	97.73
Specific Gravity	2.92	2.85	2.62	3.05	2.77

Analysts: B.J. Radclyffe, ZGS: 75/68, 75/69 and 75/72
Dept. Metallurgy: 015
A.D. Powell, ZGS: 76/40
Rock types and localities: See Appendix

In a relatively fresh specimen (25 669) the plagioclase phenocrysts, although usually clear and well twinned, are severely cracked and distorted. They are sericitized in part and are indistinctly zoned. Several of the few pigeonite phenocrysts remain unaltered, others however, are replaced by sieve-textured green-brown biotite. Similarly partial biotite replacement affects the groundmass pyroxene. Groundmass chlorite may have replaced a very small percentage of original olivine. The blebs of iron-ore (0.1 mm) are regularly distributed. Hydrothermal alteration of the mafic porphyries results in almost complete conversion of groundmass feldspar to pink-brown saussurite (slide 25 673). Pyroxene is converted into amphibole, and interstitial quartz has been introduced. The iron-ore, in the form of hematite, retains its regular distribution. Calcite is associated with the biotite in some of the rocks.

PORPHYRITIC PICRITE DYKES

These dykes have not been affected by the hydrothermal event and they probably represent a late-stage, ultramafic phase of the Nuanetsi Igneous Province, possibly related to the undersaturated Madawula Centre of Marungudzi. The dykes occupy the set of radial fractures which focuses at a point some 15 km west of Marungudzi. Unless affected by particularly deep weathering, the dykes are composed of fresh dark-grey rock which has phenocrysts, generally 1 - 5 mm, in a very fine-grained matrix. These may be prominent on the reddish-brown weathered skin, but are less clearly defined on freshly broken surfaces. The olivine phenocrysts are glassy and almost emerald-green or yellow-brown. The pyroxenes are less readily distinguished.

Generally the dykes are well exposed, especially in the gneissic terrain, where they stand out as low ridges littered with rounded or blocky boulders up to a metre across. Weathering results in a rough, pitted surface caused by weathering-out of phenocrysts. In places there is a gnarled linear appearance of the boulder surfaces suggesting flow banding. In deeply weathered outcrops the rocks become greenish-brown and develop a smooth brown skin.

At many localities the dykes cut dolerites, and east of Swebebe Hill one of them contains inclusions of dolerite. At a point 4 km east of Pande Mine a prominent NE-trending dyke is intruded along the contact between anorthosite and enclosing gneisses. The course of this dyke swings northwards as it passes through two ENE-trending breccia zones but it is not itself brecciated. The presence of another picrite dyke cutting albitized and epidotized Bulai Gneiss near Beitbridge airfield indicates that intrusion post-dated both the ENE-fracturing and the main hydrothermal event. Late ESE-brecciation and right lateral movement has, however, affected a picrite dyke east of Swebebe Hill.

A sample (25 674) of porphyritic picrite collected SW of Lutumba Township was chemically analyzed (Table 9, Lab. No. 75/72). The high magnesia and low silica content and the high percentage of olivine and the presence of nepheline in the norm illustrate the undersaturated nature of the rock.

Petrography

Three specimens (25 674-76) were collected from locations along the Nulli Range and SW of Lutumba Township. They differ only very slightly in grain-size and in mineral proportions. Approximately 50 % of the first rock is composed of phenocrysts. Of these the bulk are olivine and pyroxene in almost equal proportions, but there are also a few small clusters of 1 mm plagioclase crystals.

All phenocrysts vary in shape from perfect idiomorphs to subhedral form, and are mainly 1 - 5 mm in diameter, with the pyroxenes tending to be a little larger than the others. The other rocks (25 675-76) do not contain plagioclase phenocrysts and in the second of these the phenocryst content is only 15 %. The pyroxene insets are augite with a moderately large optic axial angle. This mineral has a neutral grey-brown colour and is not perceptibly pleochroic. Several crystals poikilitically enclose feldspar laths. The larger olivines may be perfectly clear and colourless or may have been subjected to a low but variable degree of serpentinization. The green colour seen in hand specimen is due to vividly green serpentine and the yellow-brown colour results from alteration to phlogopitic mica. The composition of the olivine is Fo_{85}.

The groundmass consists mainly of subhedral to granular pyroxene, 0.2 mm across, disposed between plagioclase laths of much the same length. There are small and variable proportions of greyish glass, olivine and accessory iron-ore, as minute granules. Only in the second rock (24 676) is the groundmass olivine prominent. It occurs as clear and unserpentinised grains of 0.1mm, partly coated with reddish-brown proportions of greyish glass. In the other slides it has been altered to a mixture of serpentine and mica.

Apart from their greater olivine content, the porphyritic picrites differ from most other dyke rocks in the area in containing augite rather than pigeonitic pyroxene.

NEPHELINE-SYENITE DYKES

Soda-rich dykes are especially noticeable where they are crossed by the main road from Beitbridge to Masvingo, between 5 and 8 km NE of Lutumba Township. They are poorly exposed elsewhere and generally have no marked topographic expression. One dyke, 5 km from Lutumba, however, forms a series of low, disjointed koppies to the west of the road. It does not occupy a single east-trending fracture, but is offset *en èchelon*. Other dykes in the vicinity occur in fractures trending 35^o and 85^o, respectively. The dykes, which are 4 – 10 m in width, do not occur within the main dolerite swarms, so they may be filling newly formed fractures associated with post-Karoo intrusion. Some are displaced by north-trending faults, as are those north of the map-area in the country south of Mwenezi.

The nepheline-syenite is dark grey and fine- to medium-grained. On wetted freshly broken surfaces, black flecks of ferromagnesian minerals (1-2 mm) are seen in a grey-white groundmass. This description applies to most of the rock, but there are also irregular streaks of much coarser-grained material, of pale-grey colour, in which the individual grains measure up to 5 mm across. It has been suggested that they represent partly digested inclusions of invaded wall rock, but a more probable explanation is that they are due to pegmatitic segregation.

Weathering produces rounded blocky boulders with a rough off-white to yellow-brown skin. Preferential removal of the ferromagnesian minerals results in a pitted and speckled appearance. There is no evidence of hydrothermal alteration, which indicates a late alkali phase of intrusion towards the close of the igneous cycle.

Petrography

A sample of fine-grained nepheline-syenite from a 4 m dyke, 5.3 km NE of Lutumba Township, has been analyzed (Table 9, Lab. No. 75/68). A slide (25 678) shows both fine and coarse portions and the sharp contact between them.

The identity of the felsic material which constitutes 70 % of the rock is uncertain. Most of it is of low birefringence and much is clouded by alteration. There are laths and aggregates of laths, up to 1 mm long, with a semblance of carlsbad-twinning, partly enclosed in almost isotropic patches, and there are very small areas in which microcline cross-hatching is discernable. No consistent differences in refractive index between these can be made out and all interference figures are negative and either uniaxial or biaxial with small angle. The proportions of nepheline and alkali feldspar, presumably sanidine, are therefore not known. Interstitial patches and streaks of a clear, colourless and isotropic mineral are believed to be composed of sodalite or analcite.

The mafic minerals, mainly pyroxene, tend to be clustered. It forms euhedral crystals, up to 1 mm long and with the pink hue of titanaugite, but the optic axial angle is consistently less than 40^o. It is centrally clear and unaltered, although the margins of the crystals are practically always replaced by deep-brown hornblende. In a few instances there is replacement by green uralitic amphibole which spreads out into the felsic minerals as trains of minute granules. Prominent, due to its deep colour, is the biotite which is preferentially associated with grains of iron-ore. It does not mantle the pyroxenes, and although in some orientations is similar in appearance to the brown hornblende, it is more foxy-red in colour and displays the characteristic mottling of extinction. Rare crystals of olivine (Fo_{90}) are colourless and are not serpentinized, but may be encircled by iron-ore and uralite flakes and grains. Slender prisms of accessory apatite are well developed in parts of the rock.

The pegmatite phase (or inclusion) differs in being coarser-grained, the pyroxenes measuring up to 5 mm. The felsic minerals are more clouded and there is virtually no marginal replacement of pyroxene by brown hornblende. The contact between the two phases is quite sharp and without gradation.

LATE FINE-GRAINED DOLERITES

There are dykes of fine-grained dolerite in the map-area which show evidence of hydrothermal alteration, but in the metamorphic terrain they are difficult to distinguish from the earlier fine-grained dolerites. It is believed that they are equivalent in age to intrusions described by Broderick (1979) as cutting the pulaskite ring-dyke of the Marungudzi Complex and also to those seen cutting red granophyres at Chitove Falls near the Save-Runde confluence. West of Pande Mine near the Samtete River a fine-grained dolerite which trends ENE cuts through and contains inclusions of a NE-trending porphyritic picrite dyke thereby suggesting a late post-Karoo origin.

Petrography

A specimen (25 679), from the Chitove Falls Dyke, is a dense smooth black rock. It contains a few small perfectly idiomorphic laths of calcic plagioclase, partly replaced by a green serpentine mineral, and one crystal of pigeonite. These are set in a matrix rendered almost black and opaque by myriads of minute iron-ore grains. There is vague suggestion of the growth of microlites, and there are light patches throughout which consist of a central core of quartz, measuring up to 0.04 mm, surrounded by very small flakes of green mica. These are probably minute amygdales.

FAULTING AND BRECCIATION

The final phase of intense regional metamorphism and deformation which affected the Limpopo Mobile Belt has been dated at c. 2 000 Ma (Van Breemen 1969) and was followed by penetrative fracturing throughout the area. Faults and fractures follow distinct trends, and it is clear that there has been a re-activation on several occasions between their initiation and late-Karoo times. The most common fracture filling is dolerite, although many fractures are occupied by pegmatites, quartz veins and aplites.

An analysis of the strike of 88 breccia-zones (see Fig. 8) shows that, to varying degree, the breccias occupy all trends in the area other than the north trend followed by some dolerites. The easterly trend (80°) is the strongest; other trends of lesser or similar intensity bear SE (110°) and NE (60°), the latter parallel to the Messina Fault.

Fractures striking between N and NW appear to be the earliest. They displace secretion-pegmatites in the Bulai Gneiss, but are themselves displaced by NE- and SE-trending fractures which are commonly brecciated. The earliest fractures are occupied by the older coarse-grained dolerite dykes believed to have been intruded more than 1 850 Ma ago, this being the age attributed to the Messina Dyke (Jacobsen *et al.* 1975).

Outcrops of breccia are not usually distinctive except along river beds and across the resistant quartzites which form the Nulli Range. In the south, as along the Shurugwe Fault, they form low ridges. Brecciated dolerites are susceptible to weathering and consequently tend to occupy shallow hollows or valleys. Such breccias usually have a red soil cover containing quartz-epidote scree, and the adjacent country rocks may provide evidence of hydrothermal alteration.

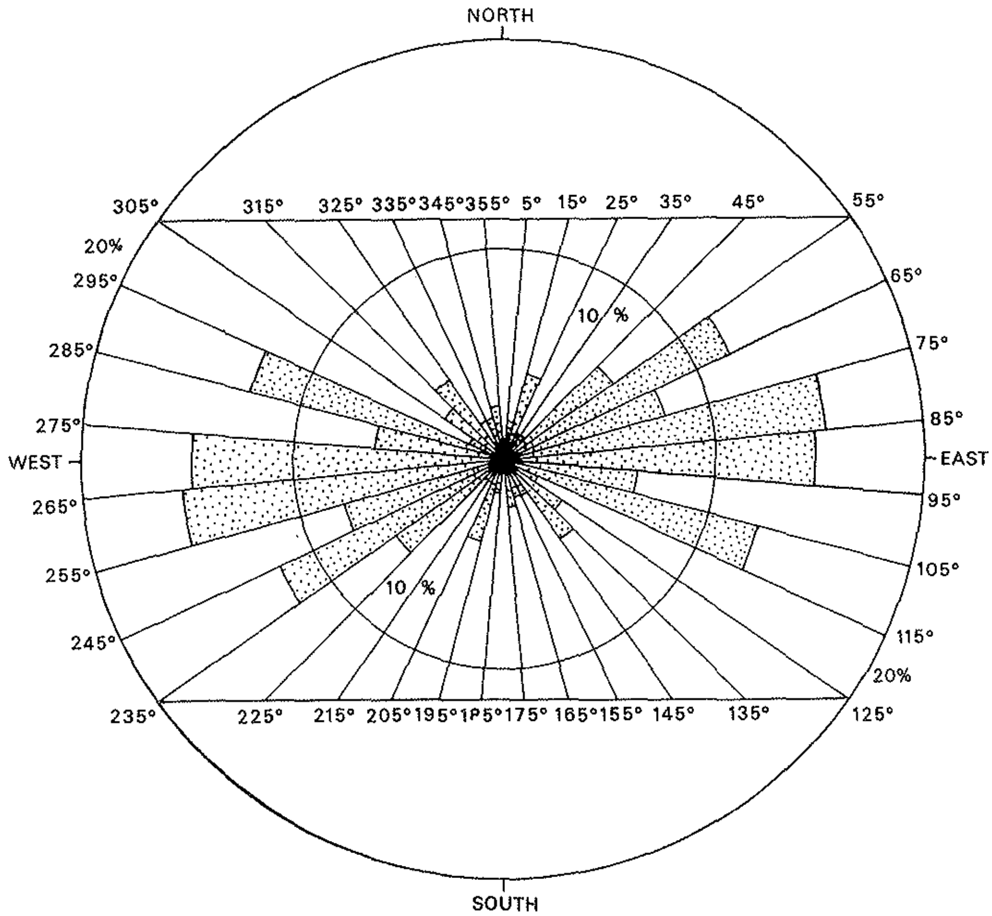


Figure 8: Strike distribution of 88 Breccia Zones East of Beitbridge

HYDROTHERMAL ACTIVITY

Post-Karoo hydrothermal activity is widespread over much of the southern portion of Zimbabwe and is most obviously evidenced by epidotization and the reddish alteration of feldspars. Rocks that are easily fractured and brecciated, contact zones between rock types, faulting and other lines of weakness are loci for hydrothermal alteration. Commonly affected rocks are feldspathic varieties, such as the leucocratic gneisses of the Diti Formation, the Bulai Gneiss and mica-pegmatites. Albitization of the feldspars is preceded by sericitization and kaolinization; ferromagnesian minerals are commonly altered to chlorite.

At the junction of the Bulawayo and Masvingo main roads, unaltered Bulai Gneiss becomes progressively epidotized and grades into red and green unakite. Epidotization of anorthosite and quartz-hornblende-gneiss make them resemble calc-silicate rocks, and is accompanied by the formation of chlorite. Some of the early coarse-grained dolerites are completely epidotized and are locally accompanied by secondary copper deposits. East-trending dolerites are commonly veined with epidote, and epidosite dykes are present near Beitbridge Airfield and east of Lutumba Township.

The steatization, silicification and formation of magnesite in the serpentinites at Pande Mine and elsewhere is probably a result of hydrothermal alteration along fracture lines.

A study of copper mineralization in hydrothermally altered breccia zones shows epidote veins cutting dolerites of Karoo-age, with accompanying albitization of the country rock. The epidotized breccias were again fractured and re-cemented by calcite and by lined- and drusy-quartz veining. Quartz and calcite-filled vughs in these breccias commonly have a core of secondary chrysocolla and malachite, indicating that the redistribution of copper took place during the late stages of hydrothermal activity and after epidotization. Jacobsen *et al.* (1975) consider that the hydrothermal activity at the Messina Mines took place before 185 Ma. In Zimbabwe, hydrothermal activity could be related to the late stages of the acid phase in the Nuanetsi Igneous Province. The age of the hydrothermal fluid would thus be later than the intrusion of the gabbros at Marungudzi, dated at 192 ±10 Ma (Gough *et al.* 1964).

Copper mineralization is associated with quartz-epidote breccias at Sinyoni Claims and Zwebebe epidote claims. The copper mineralization on Swebebe Hill is mainly confined to biotite-garnet-cordierite-sillimanite-gneisses, but dykes and dyke intersections are also commonly mineralized.

SUPERFICIAL DEPOSITS

Soils are mainly red, medium-grained loamy sands or sandy loams of colluvial origin where they overlie Archaean rocks, but of residual origin over much of the southern half of the map-area. Variations in appearance and characteristics of soils overlying individual rock types have been described in the relevant sections.

North of the line passing east through Lutumba Business Centre and along the Tshiturapadsi road, the red soils become monotonous in colour and do not reflect the underlying geology. The country becomes flat pan terrain with an altitude of 550 - 620 m, and is regarded as part of the Pliocene erosion surface (Lister 1987). The soil, although appearing to be residual, is usually underlain by a continuous layer of calcrete which, in areas close to pans where wells have been sunk, is up to 10 m thick. There is thus no direct contact between the underlying bedrock and the soil. Generally the red soil becomes grey to black and very powdery, as the calcrete layer is exposed in vlei areas. The soils are covered by fine granular ironstone, quartz and feldspar fragments, as well as fragments of float from recently eroded Karoo cover.

Alluvium, in the form of light-coloured fine sands and humus-rich sandy soils, has been deposited discontinuously along the length of the Limpopo River, especially on the inside of broad bends in the stream. The alluvial sands are 400 - 500 m wide in the SW of Swebebe Hill and south of the Pande Mine. They reach a thickness of 15 - 20 m and commonly form steep banks along the river where the underlying rocks are exposed only near water level. No sedimentary structures are evident within the unconsolidated sands and the Limpopo River itself is largely sand-filled.

Elsewhere small patches of alluvium overlie the red soils and reach a maximum thickness of 8 m in places along the Lipani and Etomgwani rivers. These deposits show a layering that indicates several periods of deposition.

The alluvial soils, especially along the Limpopo River, sustain large trees, mostly *Acacia spp.*, adjacent to the water course. However, away from the river line a thin veneer of unconsolidated sand supports scrub vegetation only.

Calcrete or surface limestone is widespread throughout the Beitbridge area and may be an economic source of agricultural lime. Similar widespread calcrete development has taken place in eastern Botswana where it is considered to have formed between 34 000 - 10 000 yrs.B.P. (Key 1977).

Calcrete is mainly confined to drainage channels in the southern half of the map-area, where it forms discontinuous belts, up to 500 m wide on either side of these. It is particularly evident where it overlies the Bulai Gneiss and rocks of the anorthosite suite, especially where the drainage is controlled by fault lines.

North of the E- W line through Lutumba Township, the calcrete appears to form an almost continuous horizon underlying the flat pan and vlei terrain. It is exposed only across irregular low-lying areas and on low rises formed by ultramafic bodies. The contrast between the monotonous red-soil-covered pan country and the more dissected area to the south is clearly seen on LANDSAT photographs.

The calcretes are pale, cream-coloured, soft to hard calcareous rocks that may be granular or conglomeratic. The angular and immature nature of the debris cemented in the calcretes indicates that the deposits are closely related to the drainage. Many calcretes are composed of recemented conglomerate and breccias material, which indicate that carbonate deposition has been intermittent over a long period and that intervening erosion has broken up precemented rubble. The perfect lamination of some calcrete suggests that deposition probably occurred in still pools with alternating periods of evaporation and rapid run-off. Calcretes also fill vertical and oblique fractures and joints in which they incorporate cement material derived from the overlying rocks.

Calcium carbonate is at present being precipitated by the evaporation of hard water. This was observed in isolated shallow pools downstream of the Mapai Dam on the Lipani River, where calcareous material is cementing the heterogeneous river debris to produce a rock indistinguishable from calcrete. Similar conditions may have prevailed in earlier times.

In the north, calcretes have formed indifferently across paragneisses, ultramafic rocks and marbles. They also occur away from the water courses and may have had a source beyond the rocks they now cement. This source could have been a former covering of Karoo or Cretaceous rocks, the carbonates from which may have percolated downwards into the existing surface rocks. Decomposed lime-rich feldspars in the country rocks may be the source of lime salts in the percolating water.

Petrography

In typical specimens (25 698, 25 699, 25 700 and 25 701), the carbonate cement is fine-grained (0.01 - 0.05 mm), colourless and translucent. It is stained by brown iron oxides in irregular but widely spaced patches, up to 0.3 mm across. Pure calcite forms radiating and spherical aggregates, and rims, often in several layers, up to 0.8 mm thick, around mineral and rock fragments. Calcite also fills fractures and vughs in the calcrete, the latter locally rimmed with black dendritic manganese oxide.

The fragments cemented in the calcretes are very variable in shape and size. Quartz fragments are the most abundant, but sericitized plagioclase, potash feldspar, hornblende and iron-ore granules are also common. The calcrete is commonly iron-stained around the last-named. Rounded and irregular clasts of magnesite, up to 40 mm in diameter, have been observed within an iron-stained calcrete (slide 25 701).

Structural features in the calcretes indicate several periods of formation. Sample 25 699 consists of brecciated calcrete fragments cemented in larger, rounded iron-stained calcrete blocks which have been recemented in fine-grained calcrete. Similar relationships are seen in slide 25 698. In slide 25 700 fine undulose bands of calcite are enclosed within a coarse aggregate of calcrete and country rock. This probably represents a washout which allowed the precipitation of calcium carbonate in very still conditions. The washout is filled with finely layered calcite, quartz, epidote and iron-ore, and the curvature of the layering decreases as the hollow was filled up.

A sample of calcrete from near the Diti Store on the Shakwisa River was collected for chemical analysis (Table 11, Lab. No. 76/41).

Ferricrete and ferricrete conglomerates occur at a few restricted localities, generally overlying or close to ferruginous quartzites and granulites or near dolerite dykes.

The soils in the ferricrete areas are reddish-orange in colour and are often covered by ferricrete, magnetite quartzite and quartzite scree. The ferricrete conglomerates are composed of rounded pebbles and cobbles of country rock, mostly quartzite, cemented in a red to ochre-coloured matrix of hydrated iron oxide. Ferruginous calcretes are formed locally.

PART II - ECONOMIC GEOLOGY

All measurements have been converted to metric units and all outputs and mining information, unless published elsewhere, are up to 31st December, 1965, only.

The area described in this bulletin falls entirely within the Masvingo Mining District and has been a target for active prospecting since the early part of the century. Much of this has centred on the possibility that the "Messina Line" of copper mineralization enters Zimbabwe across the Limpopo River. Although copper showings are common in the Beitbridge area, this intense activity which has included exploration under twelve Exclusive Prospecting Orders has failed to reveal any economic mineralization similar to that at Messina or Artonvilla.

Since 1965 the only significant mineral production has been that of magnesite from the Pande Mine which has had an important bearing on the recent economic development of the Beitbridge District. The only other mineral production has been that of a little crystal corundum. Potential does, however, exist for the future exploitation of copper, iron ore, magnesite and semi-precious stones such as garnet, unakite, rose quartz and aventurine. Interest has also been shown in the occurrence of uranium mineralization.

Beitbridge has recently acquired well-equipped marshalling yards which can handle traffic both into South Africa and northwards, through Rutenga, into the midlands of Zimbabwe. Should the Bubye Coalfield, to the east, be developed, it is probable that a rail link will be constructed to help in this development. The Pande Mine drew its labour force from the surrounding tribal areas and there would be no shortage of semi-skilled workers, should other mineral deposits be established. A plentiful water supply is obtainable from the Limpopo River, but away from it there are no known major sources of water. A 33-kV transmission line was constructed from Beitbridge to Pande Mine, and the availability of electricity in the future should not be a problem.

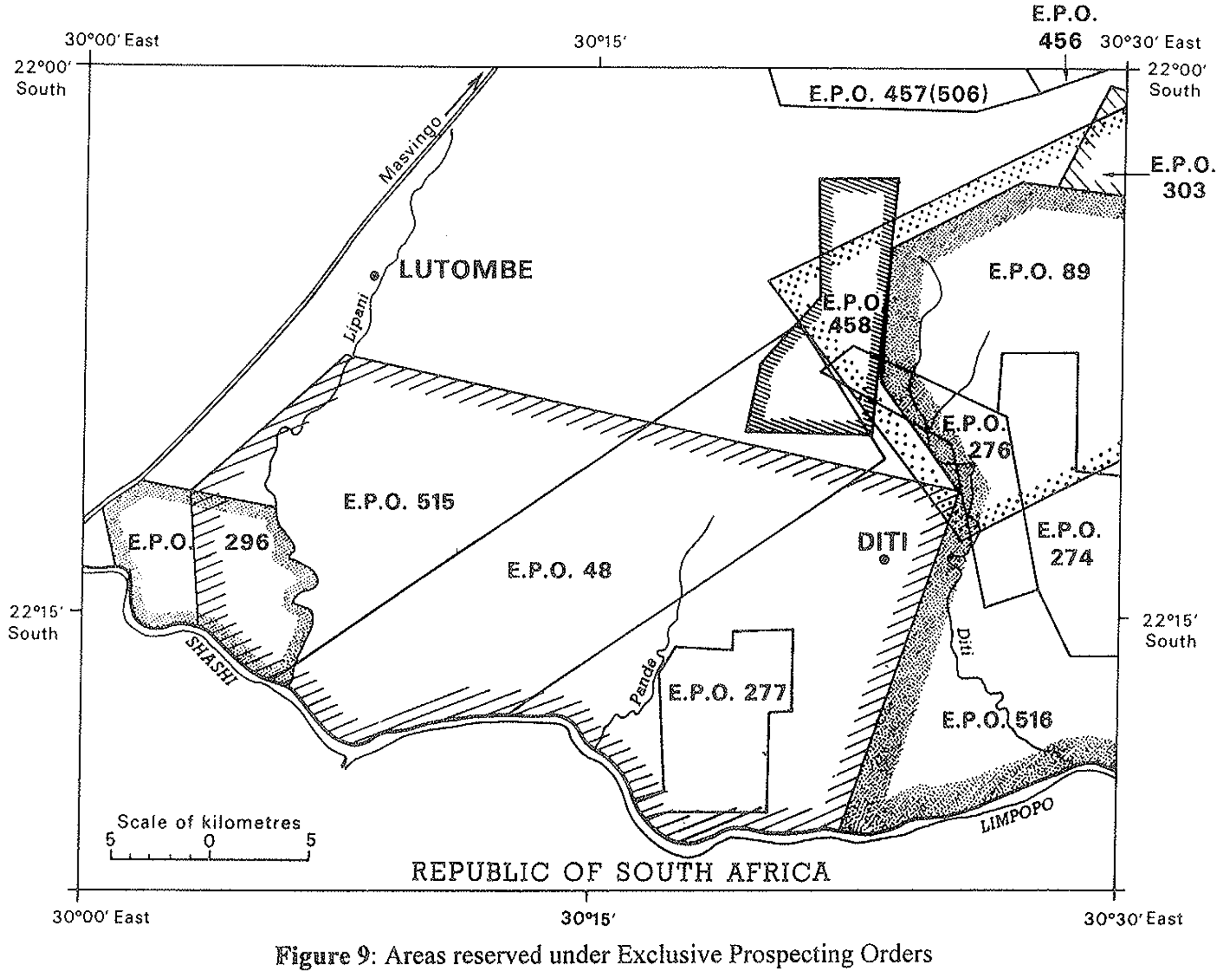


Figure 9: Areas reserved under Exclusive Prospecting Orders

Exclusive Prospecting Orders

All twelve of the Exclusive Prospecting Orders granted within the mapped area have primarily been concerned with the exploration for base minerals, especially copper and nickel. This exploration has been concentrated along the Limpopo Valley itself and north-east of Beitbridge along a line between Messina and the Mateke Hills. Exclusive Prospecting Orders 515 and 516 remain current, but final reports on the remainder have been summarized by Morrison (1974, 1975 and 1978). These reports are available in the technical files of the Geological Survey Library. The location and extent of the reservations are shown in Figure 9 and details of the individual orders are summarized in Table 10.

E.P.O. 48 granted to African Metals Corporation Limited, was centred some 25 km east of Beitbridge. It extended north-eastwards for 30 km from the old Main Drift on the Limpopo River and was thought to cover the strike extension of the Messina Fault, a possible locus of significant copper mineralization.

Prior to the granting of the order the company had obtained an option on the Baboon copper claims which extended 8 km north-eastwards from the Limpopo River. This area had previously been prospected by the Messina (Transvaal) Development Company Ltd. which had sunk a number of prospect shafts. A self-potential survey was made in 1953 and defined a few consistent, but low-order anomalies.

Exploration was concentrated on the south-western portion of the reservation. The claims blocks and adjacent country were mapped at a scale of 1:10 000. Interest focused on a strike of about 100 metres of quartz-veined, hydrothermally altered breccia impregnated with malachite. Grab samples collected from dumps of three pre-existing excavations assayed 0.96, 2.15 and 1.93 percent copper. Two diamond drillholes were sited to test the zone. A total of 280 m was drilled, but no copper was visible in the cores, and the best assay obtained was 0.18 % Cu over 2 m in a dolerite dyke. Concurrent with the drilling a trenching programme was completed on an adjacent claims block.

Additionally two areas overlying the supposed extension of the Messina Fault were soil sampled. A total of 3 500 samples was analysed for copper, and three anomalies were defined and trenched. All three were found to be ancient smelting sites.

No claims were pegged during the tenure of the order and the option on the Baboon Claims was not exercised. Total expenditure by the company amounted to R$ 64 000.

Table 10 : The Exclusive Prospecting Orders (EPOs) of the Beitbridge area

EPO No.	Company	Minerals	Period	Area (km^2)
48	African Metals Corp. Ltd.	All Base Metals	1.1.57 – 31.12.59	233.1
89	Messina (Rhod.) Dev.Co. Ltd.	All Precious and Base Metals	1.1.60 – 2.11.62	1 191.4
274	Blanket Mines (Pvt.) Ltd.	Cu, Ni, Au	31.5.69 – 30.5.71	82.9
276	"	Cu, Ni, Au	5.7.69 – 30.4.71	44.0
277	"	Cu, Ni, Au	21.6.69 – 20.6.71	46.6
296	Messina (Rhod.) Dev. Co. Ltd.	Cu, Ni	11.10.69 -10.10.71	69.9
303	Blanket Mines (Pvt.) Ltd.	Cu, Ni, Au	11.10.69-10.10.70	41.4
456	Prospects of Rhodesia Ltd.	Fe, Cu, Zn, Pb, Precious Metals	8.2.74 – 20.8.76	284.9
457	"	"	8.2.74 – 27.2.76	134.7
458	"	"	8.2.74 – 2.8.74	58.0
506 (457)	"	"	5.7.75 – 27.2.76	134.7
515	"	Ni, Cu, Pb, Zn, Precious Metals	7.11.75 – 7.11.79	602.5
516	"	"	7.11.75 – 7.11.79	414.5

E.P.O. 89 extended north-eastwards from the Diti River to the Mateke Hills. During the three years of tenure by Messina (Rhodesia) Development Company Limited an expenditure of R$61 316 was incurred. The area to the south-west of the order had been prospected previously under E.P.O. 48 and only the south-western third of the reservation occurred within the mapped area.

The order was sought on the theoretical grounds that the copper mineralization at Messina is genetically related to the post-Karoo intrusives of the Mateke Hills. The Messina Fault, which lies close to all the copper ore bodies in that area, strikes north-eastwards towards Marungudzi and the Mateke Hills and it was hoped that a continuation of this fault would be located within the reservation. Consequently the geological mapping concentrated on finding faults and associated breccia or wall-rock alteration similar to that at Messina.

The reservation was geologically mapped at a scale of 1: 40 000, but no evidence of the Messina Fault was found, although other faulting was investigated. Eighteen areas totalling about 300 km^2 were selected for soil sampling and 21 515 samples were spectrographically analysed for Cu, Ni, Co, Zn, Pb, Mo and As. The arsenic was considered to be a possible indicator of gold mineralization. Only two of these target areas occurred within the mapped area, near the Bodekwa Dome and between it and Lukumbwe Hill. Cu, Ni and Co were the only metals to give anomalous results and the values, together with more detailed geological mapping were plotted on plans at a scale of 1:10 000. In addition, a number of regional traverses were completed and terraced gravels along the main water courses were panned. It should be noted that at this time African Selection Trust carried out a regional stream-sediment sampling programme between Beitbridge and the Mateke Hills, but outside of the bounds of E.P.O. 89.

E.P.Os. 274, 276, 277 and **303**, all situated east of Beitbridge, were investigated concurrently as the Flame Project by Blanket Mines (Private) Limited. The application for the orders followed a photogeological investigation, carried out on behalf of the company by Aircraft Operating Company Technical Services (Pty.) Ltd.. The survey was designed to select prospecting areas, mainly on structural grounds, with characteristics similar to those of the Pikwe-Selebi copper-nickel deposits in Botswana, 160 km to the west. E.P.O. 275 covered the Lemco Halt structure north-west of Beitbridge and is not discussed here. The four remaining orders covered a total area of 215 km^2 and R$ 46 190 was spent on their exploration.

The prospecting methods used were the same in all the reservations, although the extent to which detailed work was undertaken depended upon positive results in the preceding stages. Preliminary work consisted of the compilation of photogeological maps at a scale of 1:25 000 and 2 250 line-kilometres of combined magnetic and Barringer Input electromagnetic surveys were flown at 0.2 km intervals.

First-stage ground prospecting included geological mapping at a scale of 1:10 000 and systematic soil sampling of the "A I" soil horizon on 300 x 150 m grids. The - 80 mesh sample fractions were analysed for copper, cobalt and nickel, and in some instances for zinc, by atomic absorption spectrometry. Frequency distribution diagrams were prepared and background, threshold and anomalous values were determined for each element in each reservation, and subsequently in each detailed area investigated. At the same time "first-priority" Input anomalies where present were investigated by detailed geological mapping, closely spaced soil sampling, trenching or pitting and by geophysical surveys.

Second-stage exploration consisted of the progressive assessment of second- and third-priority Input anomalies and of the geochemical soil anomalies found during the initial programme. No economic copper-nickel mineralization was found in any of the reservations and no claims were pegged prior to the expiry or revocation of the orders.

E.P.O. 274 was centred 50 km east of Beitbridge where it covered the Shakwisa Dome structure comprised largely of metasediments belonging to the Shakwisa Calcareous Member. One first-priority Input anomaly occurred on two adjacent flight lines and ground-geophysical and soil sampling surveys were completed across it. Geological mapping and trenching indicated that graphite in the metamorphosed limestones was the likely cause of the conductivity and that the soil anomalies were related to Karoo-age dolerite dykes. The airborne magnetic survey also showed a pronounced linear anomaly which was found to be due to a poorly exposed dolerite dyke.

Following on from the regional soil sampling programme, six small target areas were investigated in detail. Nickel anomalies were found to overlie serpentinites, but in the absence of associated copper values they were not regarded as significant. Minor copper anomalies were found to overlie both dolerite dykes and quartzites. One copper-cobalt anomaly with maximum values of 160 ppm Cu and 50 ppm Co was investigated by nine pits. This was found to be due to 20 cm-wide veinlets of ferruginous gossan in quartzite. They were too small to be of economic interest.

E.P.O. 276 adjoined the western boundary of Order 274 and included Shakwisa Hill, an outlier of Nulli Formation quartzites. The remainder of the area was poorly exposed and is largely underlain by quartz-hornblende gneiss related to the Layered Anorthosite Complex. Only the eastern half of the reservation was covered by the airborne geophysical survey, but no significant magnetic or Input anomalies were detected.

Following systematic regional soil sampling of the entire area, three anomalous blocks were selected for additional work. The blocks were geologically mapped and 615 soil samples collected on 150 x 60 m grids, were tested for copper, nickel, cobalt and zinc. In two of the blocks, broad nickel anomalies were found. At one locality values of up to 580 ppm Ni overlie quartzite and enstatite-garnet granulite, but were not investigated because of the absence of associated anomalous copper values.The second broad nickel anomaly is also devoid of high copper values, and was attributed to silicate nickel in ultramafic rocks. In the third block a partly coincident copper-nickel anomaly with maximum values of 142 ppm Cu, 257 ppm Ni, 48 ppm Co and 120 ppm Zn overlies quartzite in a 450 x 60 m area. No additional work was done, although it is stated that the copper values appear to be due to sulphide mineralization.

E.P.O. 277 was situated in the vicinity of the Pande magnesite mine which is 32 km east-south-east of Beitbridge. It was obtained to cover the area surrounding the Calabash Claims which were under option to the company. The reservation covers Nulli Formation quartzites on Shampali Hill as well as various gneisses and ferruginous quartzites of the Diti Formation. Lenticular serpentinite bodies are common in the area.

At the Calabash Claims soil samples were collected at 15 m intervals. Nickel values greater than 2 000 ppm, and sympathetic cobalt values up to 80 ppm, are confined to the serpentinites. Copper values are antipathetic and anomalous values up to 80 ppm are confined to the surrounding quartzites and leucocratic gneisses. A jaspery ferruginous gossan on the claims is attributed not to the weathering of sulphides, but to the removal of magnesium from the serpentinite and the consequent formation of veins of magnesite in the adjacent serpentinite. The option on the claims was not exercised.

No first-priority Input anomalies were recorded. Two second-priority anomalies were investigated by detailed geological mapping and soil sampling. Weak copper anomalies were attributed to dolerite dykes and nickel values to serpentinite. No coincidental copper-nickel anomalies were found and the Input anomalies are attributed to abnormally conductive overburden.

Reconnaissance soil sampling indicated two areas of potential interest which were mapped and again soil sampled in detail. Non-coincident copper and nickel anomalies were related to dolerite dykes and serpentinites. Weakly anomalous coincident copper-nickel-cobalt and copper-cobalt-zinc values appeared to overlie quartzites, but were thought to be too weak and isolated to warrant additional work.

E.P.O. 303 was located west of the Marungudzi Complex, about 55 km north-east of Beitbridge. The area is largely underlain by very poorly exposed quartz - hornblende gneisses and hornblendites of the Layered Anorthosite Suite. These rocks are intruded by three oval serpentinite bodies, which were the reason for acquiring the reservation, and by numerous mafic and alkali dykes, some of which are related to the Marungudzi Complex.

No Input anomalies of any significance were recorded and the complex magnetic pattern is reported to be related to the tightly folded, predominantly anorthositic rocks.

Regional soil sampling indicated three areas of interest which were mapped and soil sampled in detail. Broad nickel anomalies devoid of coincident high copper values overlie ultramafic rocks and were considered to be of silicate origin. Other anomalies, for example a 300 m long linear zone of 160 ppm zinc against background values of about 40 ppm, were not investigated. A small occurrence of malachite and azurite staining exposed in a shear zone and a minor asbestos occurrence are mentioned.

E.P.O. 296 covered the Luchewe and Swebebe structures immediately east of Beitbridge and was bounded in the east by the Lipani River and in the south by the Limpopo River. Messina (Rhodesia) Development Company Ltd. expended a total of R$ 4 211 on exploration for copper and nickel in the area.

An airborne geophysical survey on lines 400 m apart was flown at an elevation of 120 m above ground and magnetic, electromagnetic and radiometric plans were produced. A geological map at a scale of 1:25 000 was also prepared and the reservation was covered by reconnaissance stream-sediment sampling. The - 80 mesh fractions of these samples were tested for copper and nickel by atomic absorption spectrometry.

The airborne geophysics was said to indicate fracturing not discernible on the ground, along a direction parallel to the Messina Fault. Where the fractures cut the main Luchewe fold structure electromagnetic responses were present. Ground electromagnetic, magnetic and self-potential surveys were done in two areas, over the nose and along the north-eastern flanks of this fold. The stream-sediment sampling showed an anomalous zone of copper values from 135 - 160 .pm Cu against a background of 30 - 40 ppm. The zone trends north-east across the Luchewe structure and is, in part, coincident with the electromagnetic anomalies. Inspection disclosed hydrothermal alteration, which is locally intense, along the zone. Malachite-stained outcrops are also present. Two special blocks, the Luchewe and Luchewe 2 claims, were registered by the company, when the reservation expired on 10th October 1971.

E.P.Os. 456, 457 (506) and 458, all to the north-east of Beitbridge, were investigated concurrently by Prospects of Rhodesia (Private) Limited. They covered a total area of 478 km^2, although Order 458 was the only reservation lying completely within the mapped area. A total expenditure of R$ 440 580 was incurred by the company during the tenure of these three orders.

Exploration in the reservations followed a similar pattern. Regional soil geochemistry and aeromagnetics were used to select target areas of greater potential and these were subsequently examined in more detail using close-grid soil sampling and ground geophysics. Pitting and trenching were subsequently undertaken, in some instances to ascertain the source of the anomaly or to define targets for diamond drilling.

E.P.O. 456 lies mostly to the north of the mapped area on Lesanth Ranch. The reservation was geologically mapped and subjected to fairly intense geophysical and geochemical investigation. One block of claims was registered by the company prior to the expiry date of the order.

E.P.O. 457 (subsequently replaced by Order 506) is also situated north of the map boundary and is centred on Matamve trigonometrical beacon. A total of 23 898 soil samples was collected during a regional soil-sampling and geological - mapping exercise. The samples were analysed for copper, nickel, lead and zinc. Together with an airborne magnetometer survey, fourteen areas were defined for further investigation. Of these areas two were protected under special claims blocks and one, the Murie Claims, occurs partly within the mapped area. Here magnetite quartzites, quartzites and sulphide-derived gossans are associated with a zone of sillimanite-rich rocks.

E.P.O. 458 was situated east of the Nulli Range and was centred on the Nulli Store. The order had been investigated previously under E.P.Os. 48, 89 and 276 and is largely underlain by magnetite quartzites of the Swebebe Ferruginous Member. These quartzites have been intruded by a number of small serpentinite pods. The reservation was geologically mapped and soil sampled on a regional basis prior to its early abandonment.

E.P.Os. 515 and **516** remain current and are being investigated by Prospects of Rhodesia (Private) Ltd. for copper, nickel, lead, zinc and Precious Metals. The orders are situated due east of Beitbridge where they cover an area of 1 017 km^2 which is bounded in the south by the Limpopo River. A reconnaissance photogeological map covering the reservations and most of the mapped area has been prepared by the Exploration Research Unit of Johannesburg Consolidated Investment Company Ltd. (Parsons 1976).

ASBESTOS

Asbestos sometimes occurs in shear zones within serpentinite of the Ultramafic Suite. Very little was seen during the regional mapping of the area, although a specimen of short staple asbestos was found on the Pande Mine dumps. A minor occurrence was reported from E.P.O. 303 and the Dawn Claims lie west of Marungudzi. The only claims reported to have been within the mapped area are the Waterlily Claims which were east of the Pande Mine and south-west of Ngwani Hill, apparently where the Cull magnesite claims are now located. The Waterlily Claims were registered by Charles Blumberg and J.H. Moore in 1926 and 1929 and were transferred to the Limpopo Asbestos Company (Pvt.) Ltd. on 31st August, 1929. The claims were forfeited in 1931 and 1935. The Malala Claims were apparently east of the map boundary near the Limpopo River.

None of these properties appears to have produced any asbestos fibre or to have warranted further exploration.

COPPER AND NICKEL

Copper prospecting has been pursued actively in the Beitbridge area since the turn of the present century, and a number of claims are reported to have been registered along the Limpopo River, in the vicinity of Main Drift, between 1901 and 1910. The Rhodesia Investment Company Ltd. are reported to have pegged the Matthew, Mark, Luke, John, Peter, Paul, Simon, Caesar, Mark Anthony and Cleopatra claims in this vicinity. A.J.C. Molyneux registered the Hal's Luck, Refugee, Lone Hill and Coronet claims. Consolidated Exploration and Development (Rhodesia) Co. Ltd. pegged the Limpopo Claims and repegged the Lone Hill property. Other claims were registered by Messrs. J.M. Macaulay, Coulson and Weider. More recently base metal exploration has been undertaken under the Exclusive Prospecting Order scheme, with the belief that copper mineralization similar to that at Messina is likely to be present.

Numerous copper showings were observed during the survey, most of which are within 6 km of the Limpopo River. The copper mineralization occurs in breccias, preferentially within the anorthositic gneisses and often adjacent to them in epidote-cemented magnetite-quartzite breccias. However, the breccias themselves often trend at right angles to the anorthosites. This suggests that they and the magnetite-quartzites are easily fractured and were thus permeable to copper-bearing solutions. Where the Messina Fault crosses the Limpopo River, it is within quartzites of the Nulli Formation which appear to have resisted mineralization. It is only in the gneissic rocks that this fault line becomes mineralized in Zimbabwe.

Apie Claims : The Apie Claims are, as indicated on the claims plan, 4 km north-east of the old Main Drift across the Limpopo River. The copper mineralization would therefore apparently be related to an extension of the Messina Fault and occur within hornblendic gneisses of the Anorthosite Suite. The only mineralization in the form of malachite noted anywhere near here, however, is about 1 km to the south along a brecciated dolerite dyke which has the same trend as the Messina Fault. This mineralization is apparently that formerly reserved as the Y block of the Baboon Claims. Fragments of slag occur in the soils at this point, indicating that it is an ancient copper smelting site.

The Apie Claims were pegged for copper by Messina (Rhodesia) Development Company Ltd. in November, 1963, but have since been forfeited.

Baboon Claims : The Baboon Claims were held by Baboon Asbestos (Pty.) Ltd. of Pietersburg, South Africa. The X block covered an 8-km extension of the Messina Fault from its entry into Zimbabwe across the Limpopo River. The Y claims followed a parallel fracture zone to the south-east and the Z claims were pegged nearer the Sinyoni Claims. African Metals Corporation Ltd. secured an option over these claims which were prospected under E.P.O. 48. Prior to this Messina (Transvaal) Development Company Ltd. had prospected the area by means of trenches and shallow prospecting shafts. A self-potential survey was carried out during 1953 and a few low-order but consistent anomalies were defined.

South-east of the Messina Fault line is a rugged stretch of country underlain by Singelele granitic gneiss. The brecciated fault line which contains epidote and reddish crystals of piedmontite runs subparallel to massive quartzites and hornblendic gneisses of the Nulli Formation. The most extensive and promising malachite encrustations occur just north-east of the Limpopo River where there is a conspicuous outcrop of quartz-veined and hydrothermally altered breccia derived from the quartzites and hornblende gneiss. This breccia attains a width of about 80 metres. A broad, intensely sheared dolerite dyke lies in immediate contact with the fault plane and has been extensively impregnated with malachite. Dump samples from three old shafts along this dyke were assayed and found to contain 0.96, 2.15 and 1.93 % Cu. The dyke and the breccia are, however, cut off by the curvature of the fault beyond the workings. Two inclined diamond drillholes were sited to test the main mineralized zone at depth. They reached depths of 143 and 137 m respectively, but no copper was visible in the cores and the best assay obtained was 0.18 % Cu over 2 m in a dolerite dyke. Further trenching was also carried out over the Baboon Claims during the tenancy of E.P.O. 48.

Calabash Claims : The Calabash Claims were situated 2.5 km east of the Pande Mine. They were registered for nickel by Claridges Real Estate (Private) Ltd. in February, 1969 and were forfeited in March, 1972. During the tenure of E.P.O. 277, between 1969 and 1971, the claims were held under option and investigated by Blanket Mines (Private) Limited.

The geology of the claims was mapped by the company in the detailed scale of 1 : 500. A small, oval serpentinite body is partly capped by a reddish-brown, slightly ferruginous and siliceous gossan. The body is intrusive into leucocratic and amphibolitic gneisses, just west of a ridge of north-trending quartzites of the Nulli Formation. The serpentinite is itself cut by two east-trending dolerite dykes. Soft, yellowish serpentinite in places contains abundant narrow veinlets of magnesite. No other mineralization was observed and nickel and cobalt values in the soil are only weakly anomalous over the serpentinite. The copper values do not coincide and it is thought that the gossanous capping was developed not as a result of the oxidation of sulphides, but by a leaching of the serpentinite during the formation of magnesite.

Evertry Claims : See **Sinyoni Claims**

Luchewe Claims : The Luchewe Claims are situated a few kilometres east of Beitbridge where they cover part of the Luchewe basin structure. They were registered for copper by Messina (Rhodesia) Development Company Ltd. in October 1971, just prior to the expiry of E.P.O. 296.

Airborne geophysics indicated fracturing across the Luchewe structure parallel to the Messina Fault. Electromagnetic anomalies also occurred along these fractures and copper mineralization, with attendant hydrothermal alteration, was found near the Limpopo River just north of the Driftwood corundum claims. These showings were protected by the Luchewe 2 Claims, the Luchewe 1 Claims covering an area to the north-east where similar structural and geochemical data suggested that copper mineralization may be present.

On the Luchewe 2 copper showings, trenching and pitting was undertaken on the western side of a magnetite-quartzite horizon which trends on 355° and dips to the east at 30°. The magnetite quartzite has been brecciated, and it is here that the malachite mineralization is present.

Madre d'Ore Claims : These claims are reported to have been near the Limpopo River, south-west on strike from the Sinyoni copper claims. Copper showings are known to occur in this vicinity. The claims were registered by Messrs. L.W. Moorcroft - Taylor and H.C. Shears in May, 1929, but they were all forfeited in January, 1930.

Murie Claims : The Murie Claims are mostly north of the map boundary and are situated in poorly exposed country, 9 km north of Bodekwa Hill. Here magnetite quartzite, quartzite and sulphide-derived gossans are associated with a zone of sillimanite - rich rocks. The claims are held by Prospects of Rhodesia (Private.) Ltd.

Sinyoni Claims : They are situated just north of the Limpopo River, midway between its Lipani and Samtete tributaries. They lie within an area of anorthosites which represent the northward extension of the Messina Layered Intrusion (Barton *et al.* 1977 b). The numerous copper showings related to hydrothermally altered breccia zones were, in part, covered by the Evertry Claims. The Sinyoni Claims were registered by G. Black in September, 1968 and the Evertry Claims were registered by him in August, 1969.

The Sinyoni copper claims are immediately adjacent to the Sinyoni sillimanite claims and they were visited by R.J. Linnell in May, 1969. Quite extensive trenching had been carried out, but no primary copper ore body was located. Several depressions and pieces of copper-stained slag indicate the site of an ancient working. In the vicinity of the Evertry Claims, however, numerous mineralized quartz-epidote breccias occur and three shallow shafts have been sunk. The breccias occur largely in anorthosite and contain drusy quartz with later calcite, malachite and azurite encrustations. Some vughs in the drusy quartz are filled with chrysocolla and the adjacent anorthosites have been epidotized. Elsewhere the breccia itself is cemented by epidote and is cross cut by veins of drusy quartz with a calcite core. The iron-stained calcite may be cut by malachite veins.

Swebebe Mine : See **Zwebebe Claims**

Zwebebe Claims : The Zwebebe Claims are south of Swebebe Hill and include the old Swebebe adit. They were registered for copper by N.J.P. Swart on 8th November, 1974. The old adit occurs within garnet-sillimanite-quartz schists lying between north-trending magnetite-quartzite bands. Quartz breccias associated with dolerites and anorthosites have been observed at a number of localities on either side of the Lipani River just to the east of the claims.

A copper showing of interest occurs where the Dowe-Tokwe fault-breccia zone enters Zimbabwe across the Limpopo River. Here chalcopyrite and malachite make up less than two percent of the breccia on the northern side of the zone.

CORUNDUM

The Beitbridge area has a history of sporadic crystal-corundum production dating back to 1939. The main zone of production was 10 - 25 km north-north-west of the town and partly straddled the main road from Beitbridge to Bulawayo (Watkeys 1979). Only three corundum claims blocks are recorded east of Beitbridge and most of the information on these is given by Morrison (1972).

Byerley's Claims : The Byerley's Claims, also known as the Diti Dip Claims, are 1.6 km east of

Diriza Hill on the old Gilchrist road, 17.7 km north-east of Beitbridge. The claims, which cover one of the most easterly known occurrences of corundum in the district, were pegged by L.C. Byerley in 1951, but were forfeited without producing.

According to Phaup (1951) the corundum occurs in a hard, black, massive rock composed of 55 % spinel, 30 % corundum, 10 % calcite and 5 % combined sphene and magnetite. The spinel is pleonaste approaching hercynite in composition, and it occurs as grains 0.1 - 3.0 mm across which form groups of crystals measuring up to 10 mm. The corundum forms 0.1 - 2.0 mm crystals. The sphene is present as scattered crystals, less than 0.1 mm long, in the corundum patches and there are a few specks of black iron ore. Calcite is scattered throughout as 10 - 15 mm patches of small white crystals.

The poorly-exposed rock apparently constitutes a sedimentary bed, 6 - 30 m wide, which strikes east and dips near vertically. The surrounding rocks are paragneisses , quartzites, limestones and calc-silicate rocks of the Shakwisa Calcareous Member. The quartzites are of two types, dark grey rocks composed of sheared quartz, biotite and red garnet, and pale green rocks composed largely of sugary quartz. The limestone is a massive crystalline rock consisting predominantly of calcite with accessory euhedral olivine and specks of pleonaste. A thin feldspathic pegmatite containing pale green amphibole was recorded at this deposit but mafic rocks were not observed.

Diti Dip Claims : See **Byerley's**

Driftwood Claims : The Driftwood Claims have been worked intermittently by J. Epstein since 1939, under various names. They have also been known as the Limpopo, Milan and Saph 2 claims, and as the Van der Westhuizen Mine. In March, 1939, 9.98 tonnes of corundum valued at $ 148.55 were produced and in 1948, when the claims were known as the Van der Westhuizen Mine, 115.45 tonnes valued at $
1 162.30 were recovered. The claims are situated 4.8 km southeast of the Beitbridge Bridge, on the east bank of the Limpopo River.

Several pits and trenches have been excavated along a strike of 350 metres, in a body of ultramafic rock which occurs conformably interlayered in metasediments of the Nulli Formation. The ultramafic rock is composed of equal amounts of hypersthene and actinolite. The two minerals exhibit an hypidiormorphic-granular texture, the hypersthene occurring as euhedral grains and the actinolite as laths. The rock is generally fresh in appearance and contains small amounts of talc, mica and calcite and is possibly of metamorphic origin. The body strikes at 140° and dips steeply to the north-east.

The foot-wall rocks are leucocratic gneisses composed of quartz, pinkish altered plagioclase, fresh microcline and sericite. They are locally garnetiferous and, close to the contact with the ultramafic body, the gneisses are composed dominantly of quartz with biotite, feldspar and amphibole. Hornblende is developed in the ultramafic body along the foot-wall contact with the gneisses and the rock is locally an amphibolite. The hanging-wall rock is quartzite.

The corundum occurs close to the foot-wall contact in a vertical shear zone which is parallel to the regional strike. The shear zone is about 1.2 m wide and is filled with coarse-grained black biotite, corundum, garnet and sillimanite. The garnet has a composition of 60 % pyrope, 25 % almandine and 15 % andradite as determined from Troger graphs. Epidote occurs along shear planes and disseminated specks of malachite are present. Fibrous grains of sillimanite occur as rims to some of the corundum particles. The corundum crystals, which are of pale grey-green colour, average 15 mm in length and 4 - 5 mm in width. Many are enclosed poikilitically in crystals of garnet which are 40 - 50 mm in diameter. The sillimanite occurs as needles.

The claims are on a dissected terrace, about 50 metres above the present bed of the Limpopo River. The surface of the terrace is covered by a bed of gravel, up to 1.8 metres thick which is partly cemented by calcrete. The bulk of the corundum was obtained by screening and washing this gravel and very little was recovered from the bedrock described above.

Limpopo Claims : See **Driftwood**

Luchewe 3 Claims : They are situated on the banks of the Limpopo River adjacent to and north-west of the Driftwood Claims. They were registered for corundum by M.R. Rhodes on 6th August, 1973. However, in that year he declared 1 000 kg of garnet valued at $ 40, and between 1973 and 1977 34.01 kg of aventurine were sold for $ 290.

Milan Claims : See **Driftwood**
Saph 2 Claims : See **Driftwood**

Sinyoni Claims : The Sinyoni Claims were registered for sillimanite by G. Black in 1967, and are situated 4.8 km north-east of the old Main Drift across the Limpopo River. There has been no production.

Sillimanite-cordierite-corundum rocks occur within a zone of anorthosite which strikes north-east and is infolded into the gneisses and metasediments of the Nulli Formation. The anorthosite exhibits boudinage structure on a large scale. It is composed of 80 % labradorite, 10 % hornblende which is in part altered to biotite, and 10 % hypersthene. The plagioclase is generally unaltered, though some grains are partly sericitized and zoisite is associated with the alteration. At the eastern workings, sillimanite and cordierite occur both separately and as intergrowths in layers, up to 90 cm wide, in a quartz-bearing hornblende anorthosite which strikes parallel to the regional structure. The layers are separated by narrow zones of biotite mica. Cordierite is the principal mineral and it contains an intergrowth of kornerupine, sillimanite needles with a little biotite and rutile.

The western workings are similar to the eastern workings. Quartz is absent except in a cross-cutting cordierite vein and corundum occurs with sillimanite and cordierite in an amphibolitic anorthosite. An unusual cordierite - sapphirine-gedrite symplectic intergrowth is the most abundant rock here and apparently this has replaced the kornerupine (Schreyer and Abraham 1976). This symplektite lies within a foliated cordierite-bearing, enstatite-blue spinel granulite.

Van der Westhuizen Mine : See **Driftwood**

Alluvial corundum: Pebbles of alluvial crystal corundum, 5 - 25 mm in diameter, are quite common in high-level gravels on the south bank of the Limpopo River in South Africa, but there has been no record of production from similar gravels on the Zimbabwean bank of the river.

IRON

The production of low-grade iron ore from the Beitbridge area could well become of considerable importance in the future, especially if an iron and steel industry can be established using coking coal from the Bubye Field and suitable limestone from the Shakwisa area. Magnetite grunerite-bearing quartzites are very common within the Swebebe Ferruginous Member of the Diti Formation, and in places they have undergone secondary enrichment and alteration to hematite. The ores would therefore contain a fairly high proportion of coarse-grained magnetite and hematite, with coarse, granular quartz and subordinate grunerite. There are rare occurrences of high quality crystalline magnetitites. From a total of 283 magnetite-quartzite samples collected, about 75 percent have an iron content of 15 - 35 % (see Fig. 2). Only rarely are the ores enriched to contain more than 60 % Fe. A number of claims have been registered for iron in the past, but only on the Jute Claims, has any attempt been made for development.

Dombadema Claims and **Dombadema East Claims** : They were registered for iron by Prospects of Rhodesia (Private) Ltd. on 30th October, 1973. They cover a large flat-lying to northerly dipping expanse of magnetite quartzite which caps Dombadema Hill as well as bands of north-trending quartzite and magnetite quartzite to the east.

Fort Claims : The Fort Claims cover hills formed by a broad horseshoe-shaped occurrence of magnetite quartzite, 3 km south-west of Shingwanyana Hill and 6 km north of the Limpopo River. The claims were pegged by Prospects of Rhodesia (Private) Ltd. on 18th October, 1973.

Jute Claims : The Jute Claims are indicated as being situated 3 km north of old Main Drift beyond the Messina Fault extension. They were registered for iron by Adam Allers on 22nd October, 1960 and were, for a time during 1961, on tribute to Tandi Iron Ore (Proprietary) Ltd., of Johannesburg. At this time the claims were prospected and developed under the name of the Lucky Scott Mine by H. Muller. The claims have been visited by members of the Geological Survey on two occasions. The mine may have been located within what became the Swebebe North Claims.

Initial prospecting was along two zones in which concentrated magnetite with hematite were located on surface in a 3-4.5 m wide band of ferruginous quartzite. Trenching on the western exposure proved a strike length of 570 m of iron-ore, some 2.2 m wide and dipping at 50° west. An indicated ore reserve of 188 000 tonnes was calculated having an apparent composition of 66.2 % Fe, 2.36 % SiO_2 , 0.15 % TiO_2, 0.12 % P and 0.032 % S. Plans were made to produce an initial 2 000 tonnes of ore per month from stoping operations, with a further 500 tonnes coming from underground development.

An adit has been driven into the nose of a south-west-plunging isoclinal syncline in which a concentration of massive iron ore, mainly magnetite, occurs. The limbs of the fold strike northwards and dip west at about 55°. The amount of iron present decreases noticeably away from the fold nose and occurs mainly as layers of coarse-grained black hematite, up to a few centimetres wide, in a 3 - 4.5 m wide bed of ferruginous quartzite. There is an inclined shaft on the northern slope of the hill which is

probably connected to the adit. The economic potential of these claims appears to be negligible.
Luchewe North Claims : They cover complexly folded magnetite quartzites surrounding Luchewe trigonometrical beacon and those striking north-westwards away from it. The claims were registered for iron by Prospects of Rhodesia (Private) Ltd. on 30th October, 1973.

Lucky Scott Mine : See **Jute**

Malezikwe Claims : They were also reserved for iron by Prospects of Rhodesia (Private) Ltd. during October, 1973. The claims cover complex infolds of magnetite quartzite adjacent to quartzites of the Nulli Formation on Malezikwe Hill.

Nulli Claims and **Nulli S.E. Claims** : They straddle the main Tshiturapadsi road 3 km south-west of Mabezikwe peak. They cover a broad area of westerly dipping magnetite quartzites and were registered by J.H. Lardner-Burke on 19th April, 1972.

Samtete Claims : They cover conically folded magnetite quartzites, 7 km north of Dombadema Hill. They too were registered for iron by Prospects of Rhodesia (Private) Ltd in October, 1973.

Terra Ferrum Claims : They cover the northern lobe of Swebebe Hill and were registered for iron by Arnhold, Wilhelmi and Company (Proprietary) Ltd. on 27th April, 1973.

Zwebebe 2 Claims : They straddle the Lipani River and are south-south-east of Swebebe Hill. They were registered for iron by N.J.P. Swart on 8th November, 1974, but do not appear to cover any outcrops of magnetite quartzite. However, there are copper showings on the reservation.

Zwebebe North Claims : They cover part of Swebebe Hill and are adjacent to the Terra Ferrum Claims. They were pegged by Arnhold, Wilhelmi and Company (Proprietary) Ltd. on 28th March, 1973.

LIMESTONE

Limestones of possible economic potential occur in two forms within the Beitbridge District. Beds of forsterite-bearing marbles and late, cross-cutting secretion dolomites occur within the Shakwisa Calcareous Member of the Diti Formation. These rocks are best developed in the Shakwisa Dome structure and are known to continue north-eastwards towards the Bubye River. Similar dolomitic limestones occur on Diriza Hill, east of the main road from Beitbridge to Masvingo and extend north-eastwards along strike. The Shakwisa deposits are remote but they do offer a large tonnage of calcareous material which may be of use for agricultural purposes.

The second potential source of lime, especially for agricultural purposes, is represented by the widespread occurrence of calcrete. The calcrete occurs as surface layers, several metres thick in places, and is restricted mainly to vleis, drainage channels and the flat pan country north of the Tshiturapadsi road. A chemical analysis of calcrete is given in Table 11 (Lab. No. 76/41). This particular sample is very impure, but if deposits containing considerably less silica and magnesia can be found, particularly close to the new Rutenga railway link, they will be of value.

Diti Dolomite Claims : The claims were pegged by the Tribal Trust Land Development Corporation Ltd on 20th March, 1975, and although there has been no production, the claims remain current. Initially pure white dolomite, forming secretion veins in a fine-grained, grey marble, was pegged 3.5 km south-east of Shakwisa Hill. A 3 km extension of the broad south-east-trending dolomitic limestone horizon, which reaches 0.75 km in width, has also been protected by these claims. A sample for chemical analysis (Table 11, Lab. No. 70/380) was collected from the claims area. It too, proves to be highly siliceous and impure.

Scapolite Claims : They are situated on the north-western slope of Diriza Hill and were reserved for limestone by Mrs. Eberneza Moyo on 29th October, 1974. A chemical analysis of a sample collected near the Diti Dip corundum claims is given in Table 11 (Lab. No. 76/94).

Table 11 : Chemical analyses of Magnesite and Calcrete, Beitbridge area (in %)

Slide No.			**25 702**		
Lab. No.	**74/62**	**GM 1166**	**76/41**	**70/380**	**76/94**
Insoluble Residue	0.7	0.24	12.51	12.22	14.09
R_2O_3 Group	0.7	0.08	1.24	4.14	0.54
CaO	0.6	0.70	30.25	31.67	34.18
MgO	46.8	46.98	14.90	17.01	17.69
Loss on Ignition	51.4	52.00	40.51	34.88	33.12
Totals	100.2	99.80	99.41	99.92	99.62
$CaCO_3$- equivalent	1.10	1.25	54.00	56.52	61.00
$MgCO_3$- "	98.28	98.30	31.25	35.72	37.15

Analysts: B.J. Radclyffe, ZGS: 70/380, 74/62
P.I. Brewer : GM 1166
A.D. Powell, ZGS : 76/41, 76/94

Rock types and localities:
74/62 : Magnesite from stockpile, Pande Mine
GM 1166 : Magnesite from the Mat Claims
76/41 : Calcrete from east of stream, near Diti Store
70/380 : Dolomitic limestone from the Diti Dolomite Claims
76/94 : Dolomitic limestone from the Scapolite Claims

MAGNESITE

Cull Claims : See **Pande Mine**

Cullinan Claims : See **Pande Mine**

Cullinan South Claims : See **Pande Mine**

Fiat Claims : See **Pande Mine**

Fract Claims : See **Mat Claims**

Mat Claims : They are located in the Mtetengwe Communal Land, 10 km north- northeast of Beitbridge between the main roads to Bulawayo and Masvingo. They are 4 km north-west of the Beitbridge aerodrome on undulating ground which covers an oval serpentinite body about 1.5 km^2 in area. The serpentinite was first pegged for magnesite by C.H. Page in 1949 and was reported on by A.E. Phaup the same year. The blocks were forfeited in 1950 and 1954.

Interest in the magnesite potential was taken by Gypsum Industries of Johannesburg and Thermal Syndicate Ltd. of Wallsend, Northumberland / England, and encouraged a visit and report on the deposit written by Goldberg and Short (1964). The serpentinite was repegged by Cullinan Refractories Ltd. during 1967, and the claims are currently held by Pande Magnesite Company (Private) Ltd. as the Fract and Fract A claims and five blocks of Mat Claims.

Prior to exploratory work by Cullinan Refractories Ltd. only shallow trenching had been carried out over the eastern and western lobes of the serpentinite. This company initiated an auger drilling programme, during which 80 holes were drilled at 6 m intervals to depths of 8.5 metres. The 4 ha ore body, so defined, was crossed with a series of trenches in order further to determine the extent of the deposit as well as the concentration of magnesite (Fig. 10). The depth of the ore body was not determined, but assuming that it extends to 30 m and that a recovery of 6 % can be obtained, there would be reserves of the order of 150 000 tonnes of magnesite. The deposit was due to come into production with the closing of Pande Mine during 1977, but this has been postponed.

The bulk of the ultramafic mass is composed of deeply weathered light brown to green serpentinite which encloses and is entirely rimmed by coarsely crystalline hornblendite, defining a basin structure. The ultramafic body is intruded by dolerite dykes and is surrounded by leucocratic gneisses and charnockitic gneisses of the Diti Formation. It occurs just north of the main body of the Bulai Gneiss.

Trenching has indicated that the magnesite occurs largely as narrow layers or veinlets lying almost horizontally. The magnesite is more platy and irregular than the nodular material from the Pande Mine. Its lime content is marginally higher than the Pande product, but the silica content compares favourably (Table 11, Lab. No.74/62 and GM 1166). Magnesite also encrusts serpentinite float and outcrop, although in the eastern half of the body the coating is more commonly calcareous. Surface magnesite or magnesi-crete occurs over a wide area, but it is rarely more than a few centimetres thick. The magnesite makes up about 6 percent of the exposed rock in the trenches, and taken overall, the material does not measure up to the first-grade magnesite of Pande Mine.

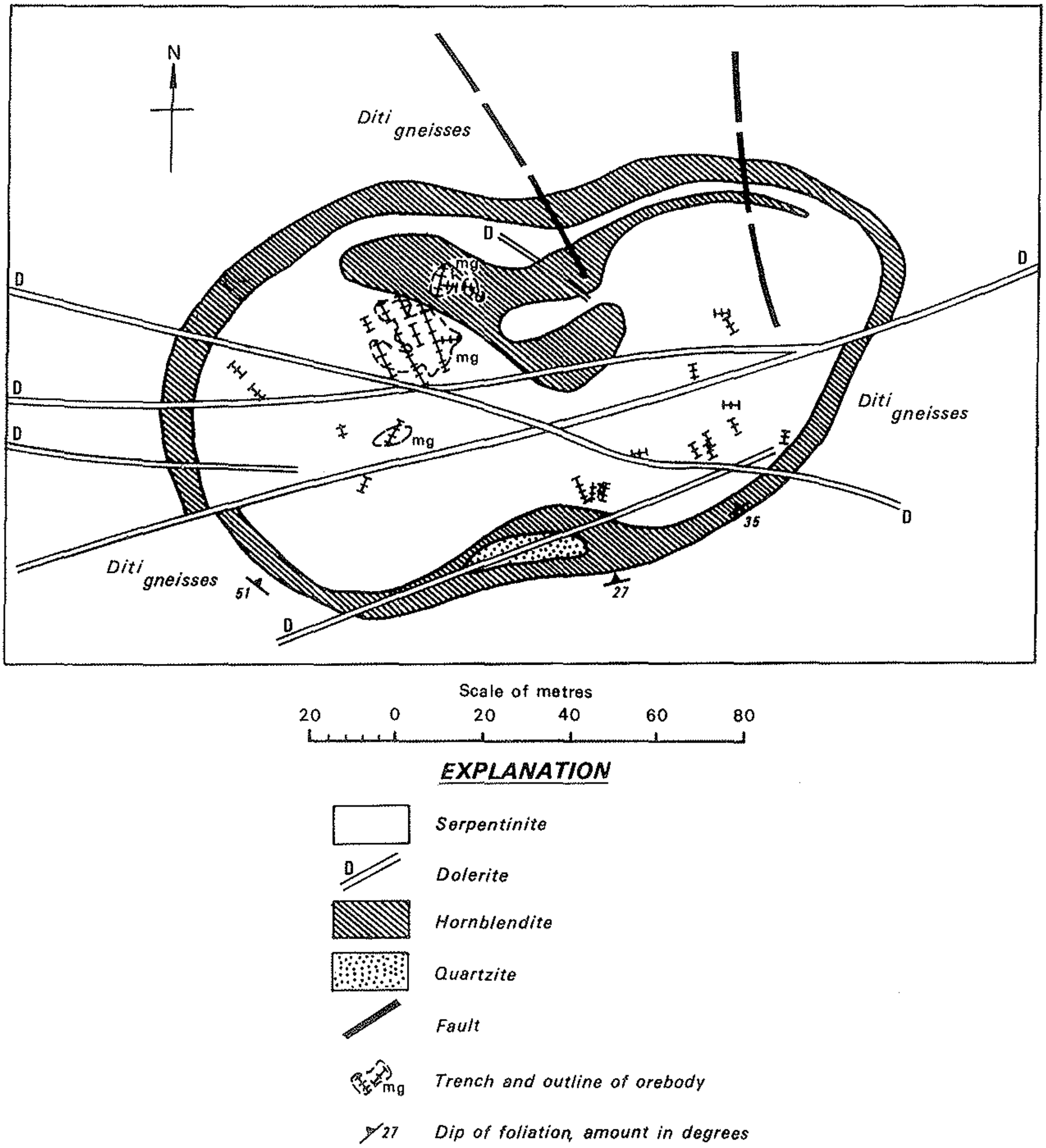


Figure 10: Surface plan of the Mat Magnesite Deposit

Pande Mine : The Pande Mine is situated in the Diti Communal Land, 32 km east-south-east of Beitbridge and 3 km north-east of the Limpopo River. The mine was served by a well maintained gravel road from Beitbridge prior to its closure on 30th April, 1977. The claims, 23 in all, are mostly east of the Pande River and the Pande 2 Claims, on which the largest open cast quarries are situated, lie between and north of two quartzite ridges trending slightly west of north. The claims cover rugged, hilly mopane-wooded country.

The Pande magnesite deposit was brought to the notice of Cullinan Refractories Ltd. by an African prospector. The deposit at first appeared unimpressive, but chemical analyses of the magnesite changed these impressions and claims were pegged during 1964 and 1965. Consequent production from these claims has made a major contribution to the economic development of the Beitbridge District. They were later placed under the assets of Culver Proprietary Ltd., a company registered as a joint venture between Cullinan Refractories Ltd. and Vereeniging Refractories Ltd., each holding a 50 percent share interest in the mine. The claims were pegged as shown in Table 12.

Magnesite was extracted by the Culver Company between 1965 and 1st June, 1967 when the Pande Magnesite Company (Private) Ltd. was formed to manage production from the mine. The mine was visited by I. Goldberg (1965) and further information has been gained from the Mine Manager, Mr J.W. Graham and a Cullinan Minerals Ltd. geologist, Mr C.P. La Grange.

The extent of the magnesite ore bodies was first determined by a programme of pitting and wagon drilling. The northern serpentinite body was the first to be explored, and major quarrying had started on both the Pande 2 and Pande S.W. claims by 1968. The development of the mine up until 1974, by which time the bulk of the high-grade ore had been extracted, is indicated on Figure 11. Excavations within the northern serpentinite are termed the East Pande, West Pande and South Pande quarries. Those within the southern serpentinite body are the Pande 2 quarries. The Cullinan Claims, between the Pande Mine and Shampali Hill, have also been quarried.

Table 12 : List of registered claims, Pande Mine

Name	Registered No.	Date of Registration
Pande	8 112 B.M.	April 1964
Pande S.W.	8 113 B.M.	" "
Pande S.W.2	8 114 B.M.	" "
Pande S.E.	8 115 B.M.	" "
Pande 2	8 116 B.M.	" "
Pande 3	8 177 B.M.	June 1964
Pande 4	8 226 B.M.	Oct. 1964
Pande 5	8 229 B.M.	" "
Cullinan	8 227 B.M.	" "
Cull	8 232 B.M.	" "
Pande S.W.3	8 249 B.M.	Nov. 1964
Fiat	8 252 B.M.	" "
Pande 6	8 372 B.M.	June 1965
Pande 7	8 498 B.M.	May 1966
Pande 8	8 499 B.M.	" "
Pande 9	8 500 B.M.	" "
Pande S.W.4	8 600 B.M.	Febr. 1967
Pande S.W.5	8 601 B.M.	" "
Pande S.W.6	8 602 B.M.	" "
Pande S.W.7	8 603 B.M.	" "
Cullinan South	8 674 B.M.	October 1967

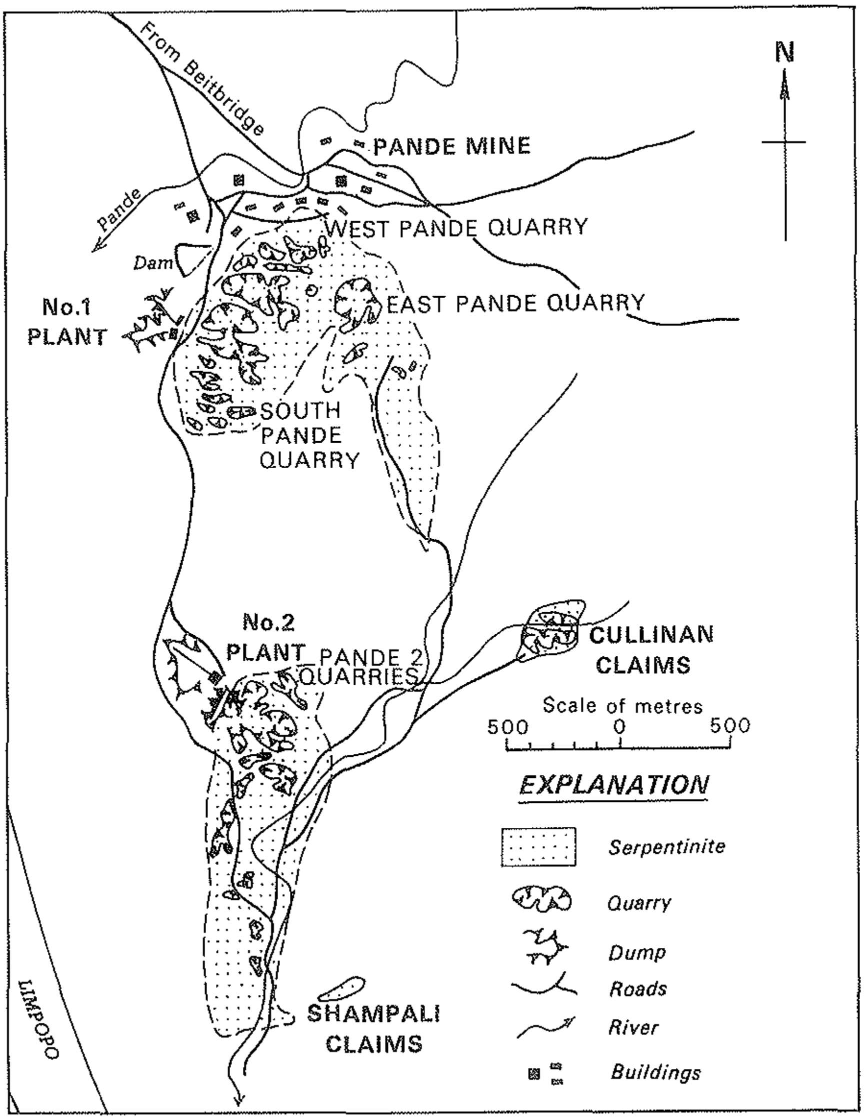


Figure 11: Surface plan of the Pande Mine (1974)

A number of smaller serpentinite bodies have also been investigated for magnesite by Cullinan Refractories Ltd. These include the Cullinan South claims, to the south-west of Shampali Hill and adjoining the Pande S.W. orebody, the Pande S.E. Claims, situated 3 km east-north-east of Pande Mine, the Cull Claims, some 8 km south-east of Pande Mine near the Limpopo River, and the Fiat Claims, 2.5 km west of Pande Mine between the Samtete and Pande rivers. Serpentinites that have also been pitted, but which are not protected by claims are a) between the Cull Claims and Ngwani Hill, b) just north of the main Pande Mine road, north-east of the Sinyoni Copper Claims and c) 4.5 km north-west of Dombadema Hill.

The Pande Mine is situated on two large serpentinite bodies which fill synformal closures in Diti paragneiss. However, they occur below Nulli Formation quartzites which have been cross-cut in places. The northern Pande serpentinite is a large horseshoe-shaped body, about 1.5 km^2 in area. The body is folded on a north-trending axis and is broadest on the western limb which has a rounded southern lobe, about 0.5 km in diameter. The eastern limb is narrower and pinches out southwards. The southern Pande serpentinite is about 1.5 km long and up to 0.5 km wide. It is folded at its southern extremity. A number of small oval-shaped serpentinites occur both east and west of the main Pande bodies, and those covered by the Shampali and Cullinan South claims appear to represent boudinaged pods or the southern Pande serpentinite.

Layers and patches of hornblendite and pyroxene granulite associated with the Ultramafic Suite, lie within the Pande serpentinites and occur around its boundaries. One such hornblendite is a cordierite, garnet-bearing granulite from the East Pande Quarry which trends 20^o and dips 80^o towards the west.

Many quartz-rich mica pegmatites cut across the serpentinites, often with an orientation of 335º. Swarms of east-north-east-trending dolerite dykes, 0.2 - 1 m in width, also cut the serpentinite. They sometimes show liesegang banding parallel to their contacts which is apparently due to hydrothermal alteration. In addition, alteration in the form of steatization and silicification occurs in steeply dipping zones related to faulting and fracturing in the serpentinites. The detailed geology of the environs of Pande Mine is shown in Figure 12.

The best quality magnesite occurs in horizontal veins and layers towards the centre of the serpentine bodies. The serpentinite is usually tobacco-brown in colour, is carbonated and often completely replaced by a mesh of limonite containing cores of magnesite with cross-cutting veinlets of magnesian clinochlore. Towards the outer limit of the serpentinites, however, the rock becomes darker green, harder and is almost barren of magnesite. Here the magnesite occurs as discrete particles randomly distributed throughout the rock which appears to have resisted the horizontal fracturing. The tobacco-brown, magnesite-bearing serpentinites extend downwards for upwards of 30 m, but are usually only 20 - 25 m deep, before they grade into dark green serpentinite.

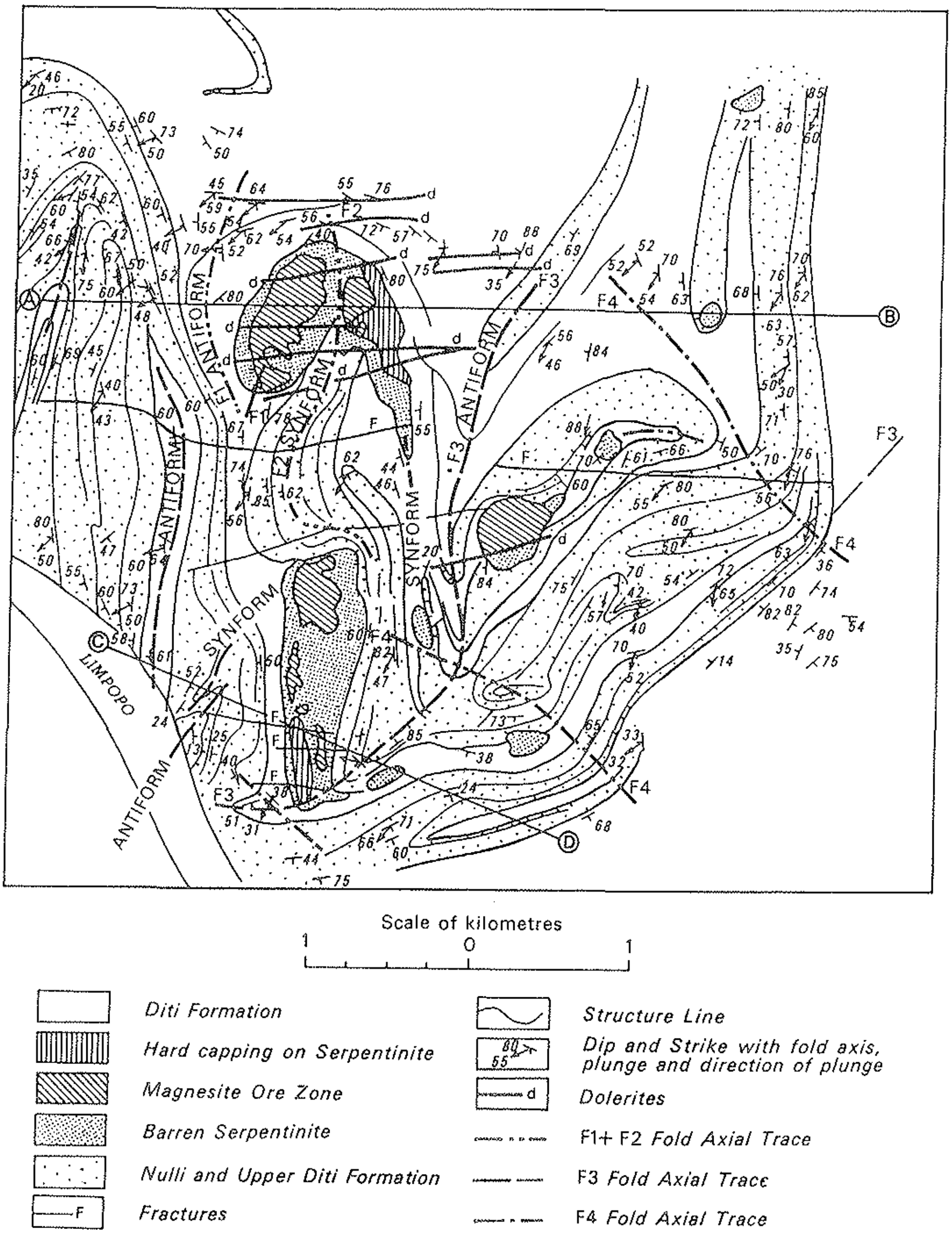


Figure 12: Relationship of Serpentinite position to the regional structure (Pande Mine)

A capping of fracture-free serpentine, 3 - 6 m thick, overlies the magnesite-bearing serpentine in the East Pande Quarry and dips eastwards at 7°. Early mining was started at the edge of this capping and stepped in at a normal open cast pit angle. This resulted in a collar of magnesite-bearing serpentine being left behind beneath the capping, but this has since been recovered. The southern Pande serpentinite has a ridge of hard, impervious serpentine which forms a spine down its centre. This probably represents the remnants of a former capping.

The subhorizontal fractures in the Pande serpentinite are filled with nodular magnesite and are 0.5 - 6 cm wide. They occur 5 - 20 cm apart and appear to represent a set of release sheet joints formed in the softer tobacco-brown serpentine, as pressure was reduced during erosion of the overlying rocks. The opening of these fractures may have been assisted by the increased volume of the rock resulting from the formation of magnesite. The relative concentration of the magnesite possibly reflects the original composition of the peridotitic magma, with the magnesite being restricted to the magnesia-rich dunitic central portion. In addition, the serpentine appears to have been saturated with water during the time that the nodular magnesite veins were formed. The barren capping may represent serpentine which lay above the water table and was not subjected to magnesite replacement.

Magnesite nodules, up to 30 cm in diameter, have been seen, but generally are 1 - 5 cm across. The good-quality, hard, dense magnesite nodules, which ring when struck, have a superficial coating with a high silica and lime content consisting of low density magnesite. Poorly formed nodules are also composed of this low grade material. Goldberg (1965) reported that the magnesite concentration in the upper 3 m of the southern Pande deposit was about 15 %, but that it fell to 10 % at a depth of 21 m, and to 5 % at the maximum depths drilled. The nodules here are nearly always coated with a thin film of serpentinous dust, but when cracked open the snow -white, cryptocrystalline and hard nature of the material becomes apparent (samples 25 703 and 25 704). The nodules break cleanly and readily from the country rock, which is a great advantage in its beneficiation.

Within the West Pande Quarry subhorizontal, nodulose fractures dip eastwards from 35 - 50 degrees near fractures. Two sets of subhorizontal layers and some irregular, vertical magnesite veins were noted here. Similarly, in the East Pande Quarry, two sets of nodulose fractures dip at 10° E and 15° W respectively. Nodules in the Pande 2 quarries are also arranged in near horizontal, closely-spaced layers, although no actual seams as such exist. Here, magnesite layers also strike 60° and are inclined south-eastwards at 40 – 65°. Many of these nodules have a limonite-stained core.

The horizontal release fractures appear to dip more steeply near zones of alteration which they often parallel. This is due to the serpentine fracturing preferentially along old lines of weakness. In the West Pande Quarry a zone of irregular magnesite veining passes abruptly into one of shallowly dipping veins which are terminated adjacent to a zone of alteration. Here too, horizontal fractures are seen to be refracted, when they pass through vertical dolerite dykes (see Plate 4 C).

Zones of alteration in the Pande serpentinites are marked by a darker apple-green to black colouration (slide 25 578), with an apparent coarsening of the texture. The most common form of alteration is silicification, and in a sample 25 705 quartz has partly replaced clinochlore veinlets. Elsewhere, the rock may be completely silicified and subparallel silica veinlets may contain dendritic manganous oxide. These zones of alteration measure a few centimetres to 25 cm in width, when they occur on either side of a fracture line. Other steeply inclined tabular zones of alteration may be 15 m wide, but these do not appear to be related to fractures, dolerites or pegmatites. In one of these bodies in the West Pande Quarry silica veinlets were found to dip east at 24°, whereas the alteration dips at 55° to the west. The rock in these zones is composed of partly altered granoblastic to poikiloblastic enstatite, tremolite granulite (slide 25 706). In the Pande 2 quarries matted, fibrous talc often occurs in these rocks which are themselves sometimes cut by nodular magnesite layers.

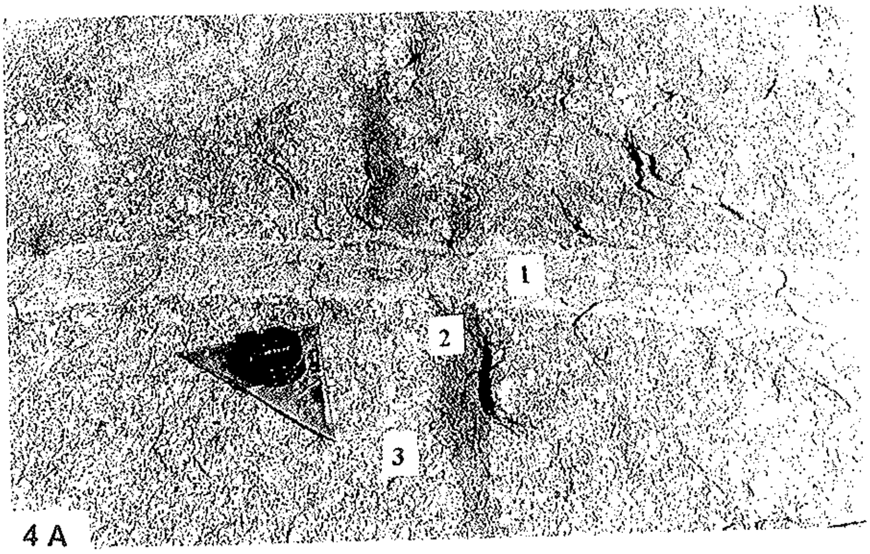
Alteration of the serpentinite has also taken place adjacent to pegmatites and dolerites. Brown silicified or berberitic serpentine (sample 25 707) occurs adjacent to a pegmatite in the West Pande Quarry, as do siliceous veinlets in an altered serpentine. Similar silicified veins with associated magnesite occupy the fractures in a columnar jointed dolerite (sample 25 708). Apple-green picrolite has formed against some dolerites, whereas blue-grey steatite rocks in the East Pande Quarry contain intergrown flakes of talc and pennine chlorite. The relationship of this alteration with dolerite dykes indicates that it probably occurred in post-Karoo time during the ring complex period of hydrothermal activity. Silicification has resulted in these rocks resisting carbonatization and horizontal fracturing.

Explanation to Plate 4

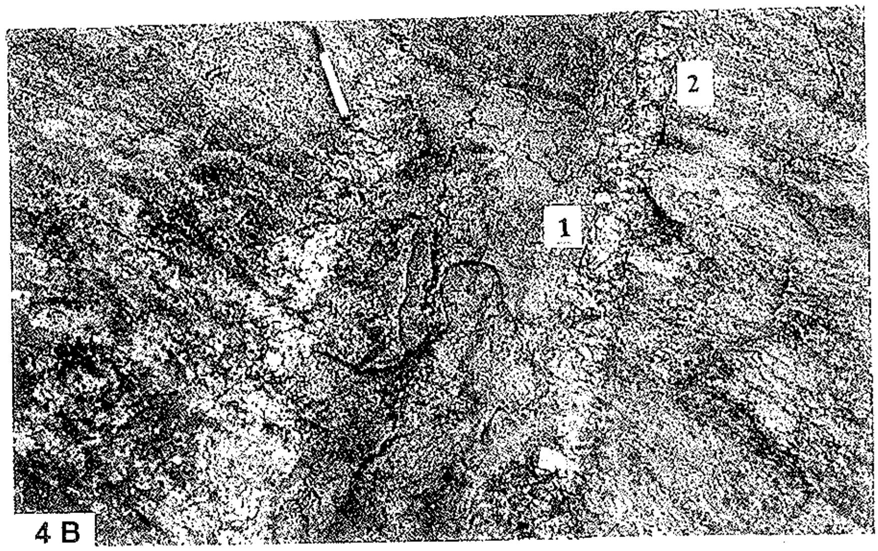
4 A : A north orientated zoned pegmatite (1) which left-laterally displaced a mafic inclusion (2), orientated parallel to the foliation of porphyroblastic Bulai Gneiss (3).
Grid Ref. SL 937 453

4 B : A zoned harrisitic aplite dyke with biotite-rich core (1) displacing the foliation of biotite paragneiss (2)
Grid Ref. TL 004 524

4 C : Horizontal nodulose magnesite veinlets (1) refracted through vertical dolerite dykes (2), in the Pande Mine serpentinite.
Grid Ref. TL 184 317



4 A



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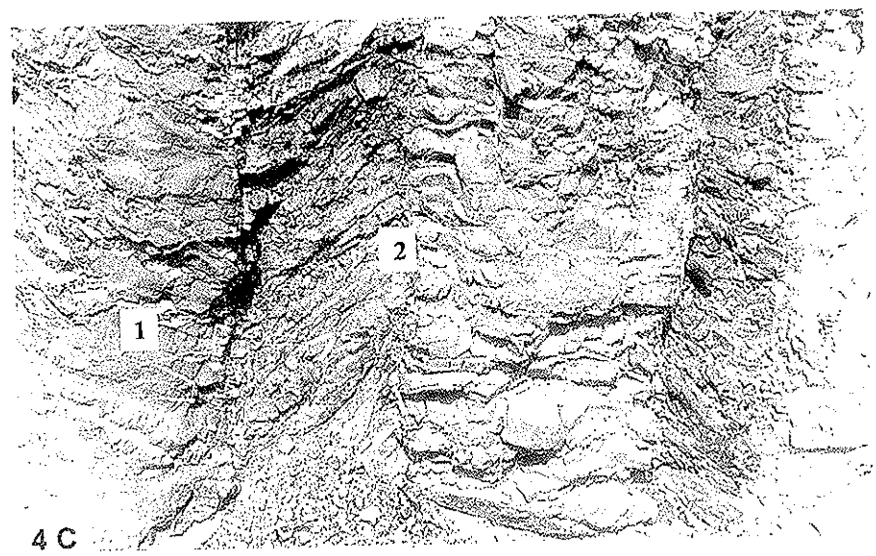

4 C

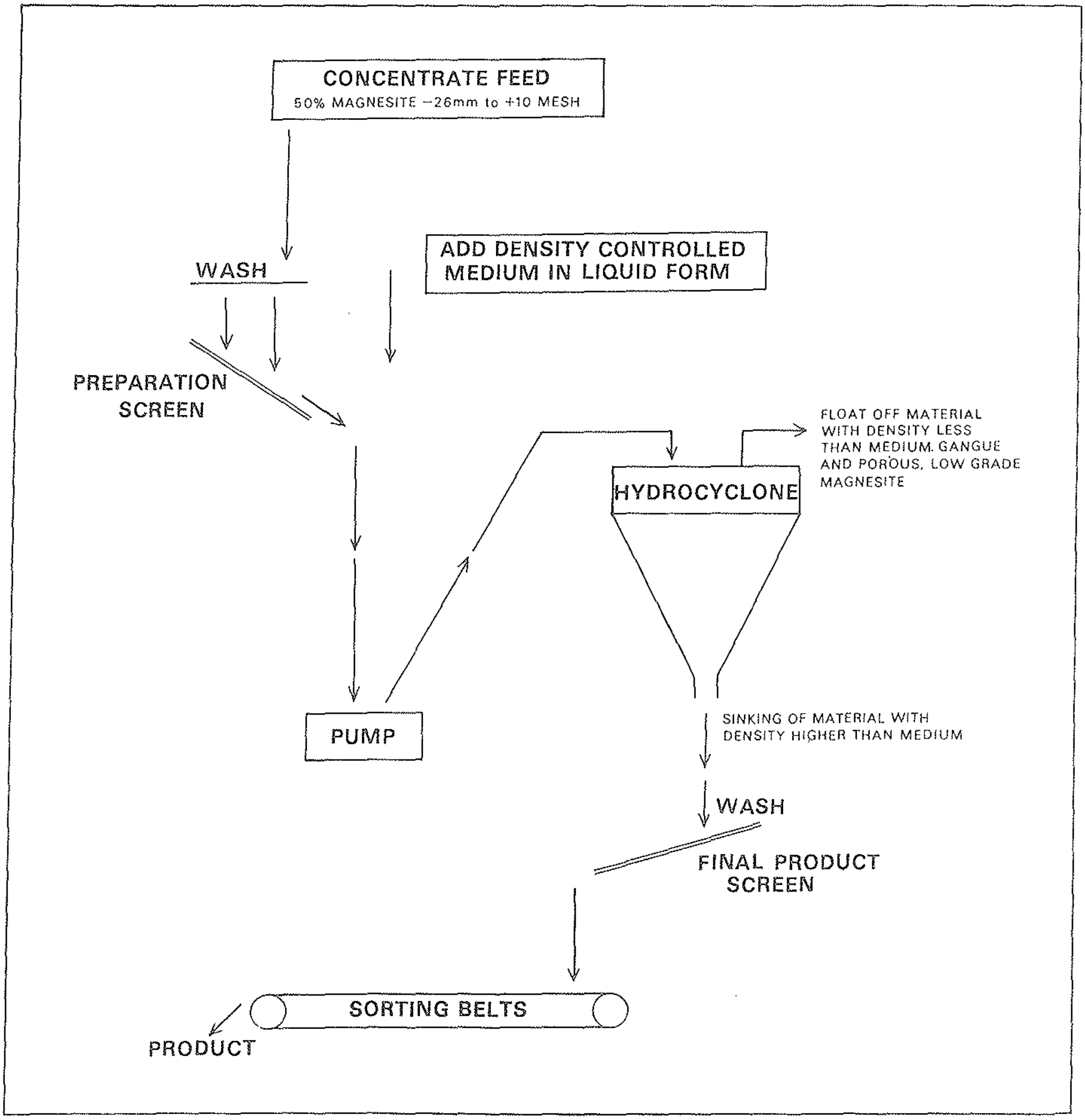

Figure 13: Pande Mine, No.3 Plant, Heavy Separation Beneficiation Flow Sheet

Massive collophorm magnesite veins have intruded along steeply dipping striated fractures trending on 030° and 130° in the East Pande pit, where they cut across nodulose magnesite layers. These siliceous magnesite veins are 0.3 - 1 m wide, and in the early stages of mining they were not removed. However, later beneficiation processes have enabled the use of this silica-rich material.

The soft, easily-won ore, which averaged 12 - 13 % magnesite, was mined in open cast quarries using mechanical shovels and bulldozers. The ore was then transported by truck to one of the two beneficiation plants on the mine.

The good-quality magnesites grade through to porous, platy, granular magnesite with a high silica and lime content. In the crushing process most of the granular material is lost and the overall grade of ore is improved. Originally the mine worked only the larger nodules, greater than 4 mm in diameter, which contained relatively little silica. However, as the size of nodules in the poorer grade ore decreased, there was a need to recover these, and by 1975 the average size of nodules recovered was less than 2 mm in diameter.

A pilot plant was built in 1965 to upgrade ore by trommelling and magnetic separation. The magnesite was finally hand-sorted and the process was capable of handling 25 tons of ore per hour so upgrading it to 85 % magnesite.

The No.1 Plant was transferred from Cullinan at Kaapmuiden in South Africa and reinstalled adjacent to the West Pande Quarry by 30th June, 1965. It was capable of treating 120 - 150 tons of ore per hour to produce up to 12 000 tons of concentrate averaging 94 % magnesite per month. The No. 2 Plant was installed adjacent to the Pande 2 quarries between July and December, 1966 and could process 220 tons of ore per hour. The No.1 Plant treated quarried ore until December, 1975 and the No. 2 Plant until January, 1975.

The beneficiation process was modified and improved over the years. But in 1963 the upgrading of ore on No. 1 Plant was as follows: Ore was first passed over a grizzly to remove the 5 mm material and was then conveyed to a large trommel which sized the ore into five grades. The finest material, dust, was removed to a fines dump. Three of the remaining grades were passed over magnetic separators whereas the material greater than 2.5 mm was hand sorted. Large bins were erected to collect the magnesite and waste.

During 1967, screening plants with a higher throughput and better selectivity were installed. Manual sorters were employed and the classification of the magnesite to first and third grade was done visually. In 1968 the screening plants were combined with wet trommels which sorted to 1.5 mesh. The tumbling effect removed the outer skins of the nodules which resulted in upgrading of the ore and improved visual classification. From 1968 to 1970 further magnets were installed to deal with the smaller-sized material.

Between 1970 and 1973 No. 3 Plant, a heavy media separator, was established. Prior to this all zones of siliceous alteration were removed from an area intended for quarrying. This resulted in a loss of ore as the heavy, non-magnetic materials could not be removed. With the introduction of the hydrocyclone equipment the smaller sizes yielded either first or second grade magnesite according to the analysis of the product. The coarse material was washed and hand sorted to first grade, prior to this process. After 1974, by strict control on the density of liquid in the heavy media separator, it was possible to extract quartz with a density of 2.74 g/cm^3 from the magnesite with densities around 2.8 g/cm^3

After January, 1973, No 2 Plant was rebuilt and the trommels were replaced by Mogeson sizer screens. The feed was reversed in order to reprocess the dump material. Intensive grinding was then required to promote second grade to first grade material, and this produced smaller sized nodules. This plant was fed with blended quarry and dump material until December, 1975 and after this date No. 1 Plant was fed only with dump material for retreatment. At this time only limited amounts of first grade ore were available and most of the production was of third grade.

The final system of beneficiation operative from 1975, is indicated on the flow sheets (Fig. 14). At No.1 Plant the ore underwent screening, sorting and later magnetic separation. At No.2 Plant ore with a size greater than ¼ mesh was screened and sorted and that less than ¼ mesh was magnetically separated. At the heavy media separation plant (No.3 Plant) hydrocyclones were used with a ferro silicone, magnetite fluid medium of intermediate density between the magnesite and gangue thereby achieving further separation.

At No. 4 Plant concentrates and low grade retreated dump material were received, wet and ground to reduce the soft gangue to a slurry less than 10 mesh in diameter. This process also ground off the siliceous coating of the low grade magnesite nodules. A battery of ball mills, 3.6 m long and 1.1 m in diameter, were charged with steel balls and magnesite concentrate in proportion to the size of the nodules and the amount of grinding required.

Generally the feed concentrate to these mills was from 30 - 70 % $MgCO_3$. The concentrate obtained after milling contained 50 - 75 % of hard, dense good quality magnesite which had lost its superficial coating. The poor grade, low density magnesite was mostly worn to slime and removed, whereas the heavy minerals and quartz were normally not worn down in the mills.

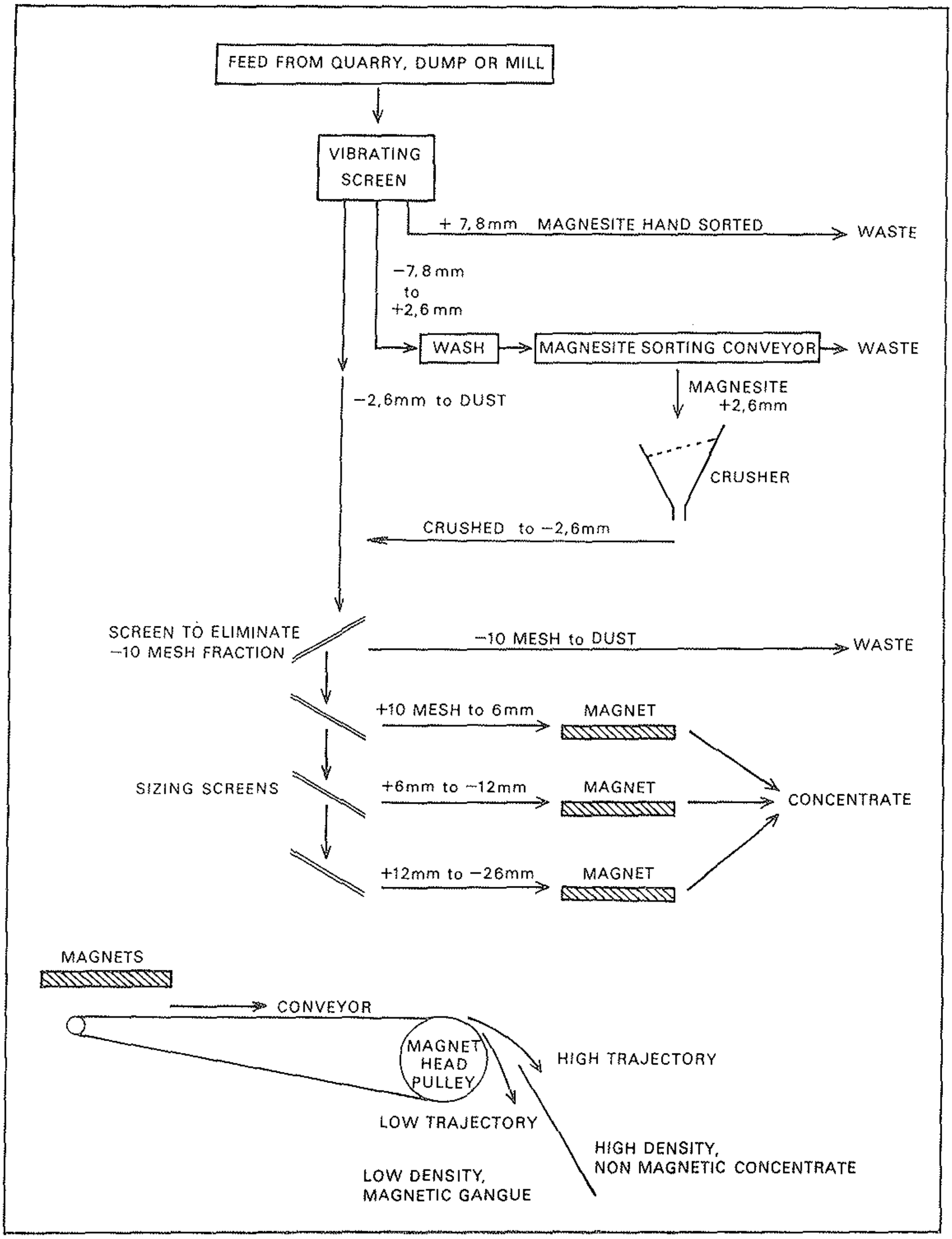

Figure 14: Pande Mine, No. 1 and No. 2 Plants Magnetic and Screening Plant Flow Sheet

The magnesite produced at Pande Mine was graded depending on the maximum amount of silica and lime allowed.

SiO_2 %		CaO %
First Grade	0.80	1.0 (nil after 1975)
Second Grade	2.00	1.2 (nil after 1975)
Third Grade	3.00	1.5
More than 4 % SiO_2, no commercial value		

The magnesite product from Pande Mine was transported by road to the railhead at Beitbridge by large trucks. It was then railed to the Cullinan Refractories Ltd. works at Olifantsfontein, near Germiston and to the Vereeniging Brick and Tile Company's works at Vereeniging.

Pande Mine was closed on 30th April, 1977, after the magnesite quarries had been completely worked out and the dumps retreated. A total of 26 697 tonnes of magnesite valued at R$ 80 101 was produced from the Pande Mine during 1964 and 1965.

Shampali Claims : The Shampali Claims cover a small, oval serpentinite body south-west of Shampali hill and they adjoin the Pande S.W. ore body. The claims were pegged for magnesite by D.A. Barnard on 4th March, 1968 and were transfered to African Mining and Trust Company Ltd. on 14th August, 1968.

SEMI-PRECIOUS STONES

A variety of semi-precious stones are found within the Beitbridge District and potential exists for the production of aventurine, epidote, garnet, rose quartz and unakite. Only one occurrence of aventurine (green fuchsite-quartzite) was found to be of deep enough colour for potential exploitation. A sample (slide 25 709) was collected from the outcrop on Mabana Hill, where a shallow pit has been excavated on the crest. Rose quartz reefs form the crest of Mwanandou Hill, and F.D. Shacklock has reserved the northern lobe of this feature under the Nimbus Claims. An unusual and attractive pegmatite with graphically intergrown quartz and hornblende was found along the northern boundary of the Shakwisa Dome, at grid reference TL 402 441. This material could make attractive stones with tumbling (slide 25 710).

Unakite is common in the Beitbridge area and the best material is found near the junction of the main Bulawayo and Masvingo roads, where it represents hydrothermally altered Bulai Gneiss. The Swar and Zwebebe 3 Claims situated just west of Swebebe Hill have recently been reserved for epidote by N.J.P. Swart. The epidote is associated with hydrothermally altered fracture zones.

SILLIMANITE AND CORDIERITE

Sinyoni Claims : The Sinyoni Claims were registered for sillimanite on 5th December, 1967, by G. Black. Here sillimanite, cordierite and corundum occur as symplectites within a zone of anorthosites (see under Corundum). Elsewhere sillimanite occurs in granular quartzites of the Nulli-Formation, but there is little potential for its economic exploitation. Cordierite-hypersthene granulite may be an economic source of cordierite. A possible locality for its production occurs 1.5 km east of Shakwisa Hill at grid reference TL 377 415.

URANIUM

Byerley's Uranium Claims : They are situated north- and north-east of the Beitbridge township reserve, between the old strip road to Masvingo and the main Bulawayo road. They were first registered by the Great Wizard Company Ltd. in April, 1951, and a second block straddling the Bulawayo road, was registered by Mrs. D.E. Byerley in June, 1953. All of these claims were forfeited during 1956, but two blocks covering the 'Banjo' pit were repegged by the Sable Mining Company (Private) Ltd., in August, 1957. These too were forfeited in September, 1958, but most of the claims were again repegged by N.J.P. Swart in April, 1973.

Quite intensive interest and correspondence has been generated by these claims in the past. Samples have been analysed by the Atomic Energy Division of the Geological Survey of Great Britain, and the area has been visited on a number of occasions by geologists of the Geological Survey Department and Gold Fields Rhodesian Development Company Ltd.

North-west -striking pegmatite dykes are very common in the claims area, where they are associated with the Bulai Gneiss. The dykes are from 1 - 4 m wide and as a rule are more than 100 m long. They contain little mica and consist chiefly of coarse, massive milky white quartz containing irregular pink microcline crystals that are often graphically intergrown with grey quartz. Accessory minerals form less than 1 % of the rock and appear to be chiefly black iron ore, garnet, sphene, zircon and rare beryl. The claims are traversed by fine-grained dolerite dykes and fractures with a general north-easterly trend.

The entire claims area is anomalously radioactive and the source has been attributed to feldspars in the pegmatites. Airborne scintillometer traverses undertaken by Messina (Rhodesia) Development Company Ltd. during the tenancy of E.P.O. 296 showed the gneisses to have higher count values and that the area adjacent to Byerley's Claims is weakly anomalous.

Samples collected by A.E. Phaup in April, 1951, were found to contain 0.04 % U_3O_8 and less than 0.1 % ThO_2. Idiomorphic to hypidiomorphic crystals of altered thorite were identified in a thin section from one of the quartz-rich pegmatite veins.

Allanite, thorite, euxenite, zircon, monazite and romeite were reported to be present in samples from Byerley's Claims examined by the Atomic Energy Division of the Geological Survey of Great Britain. The concentrate from a 90 kg bulk sample of gneiss collected at the claims returned a radiometric analysis of 0.45 % equivalent U_3O_8 or 1.75 % equivalent ThO_2. Rate-meter readings on a Geiger-Mueller counter and ultraviolet light fluorescence indicated that the Banjo pit near the old strip road was of greatest interest. Here readings were highest on the floor of the circular pit, where the uraniferous minerals are disseminated in the gneiss. There are abundant pegmatite stringers, but they do not show any concentration of radioactive material, although they probably represent the primary source of the minerals. By 1953 the Banjo pit was 9 metres deep and many other trenches had been excavated across pegmatites and other anomalous areas within the claim boundaries.

This occurrence appears to be of no economic value at present. The minerals present cannot be economically treated, as they are of very low grade and are too refractory.

REFERENCES

BAHNEMANN, K.P.,1972. A review of the structure, stratigraphy and the metamorphism of the basement rocks in the Messina District, Northern Transvaal. Unpublished D.Sc. thesis, Univ. Pretoria.

BAHNEMANN, K.P.,1973. The origin of the Singelelele Granite Gneiss near Messina, Northern Transvaal. *Geol. Soc. S. Afr., Spec. Publ.*, **3**, 235-244.

BARKER, O.B.,1977. The Soutspansberg Group - a proposed subdivision of an elongated fault basin of early Waterberg age. *17th Congr. geol. Soc. S. Afr., Abstr.*, 8-11.

BARTON, J.M., FRIPP, R.E.P. & RYAN, B., 1977 a. Rb/Sr ages and geological setting of ancient dykes in the Sand River area, Limpopo Mobile Belt, South Africa. *Nature,* **267**, 487-490.

BARTON, J.M., FRIPP, R.E.P., HORROCKS, P. & McLEAN, N., 1977 b. The geology, age and tectonic setting of the Messina Layered Intrusion, Limpopo Mobile Belt. *Botswana geol. Surv.* , Bull. **12,** 75-81.

BARTON, J.M. & RYAN, B., 1977. A review of the geochronologic framework of the Limpopo Mobile Belt. *Botswana geol. Surv.* Bull., **12,** 183-200.

BARTON, J.M., RYAN, B. & FRIPP, R.E.P., 1978. The relationship between Rb-Sr and U-Th-Pb whole-rock and zircon systems in the > 3 790 M.Y. old Sand River gneisses, Limpopo Mobile Belt, southern Africa. Unpublished. *U.S. geol. Surv.*, open file report 78/701.

BRODERICK, T.J., 1979. Explanation of the geological map of the country south of Nuanetsi, Nuanetsi and Beitbridge districts. *Rhod. geol. Surv,* Short Report No. 46.

BRUCE, J.T. 1975. A re-examination of the Karoo rocks of the central portion of the Bubye Coalfield. Unpublished. B.Sc. (Special Hons.) project, Univ. Rhodesia.

BURKE, E.E. (ed.), 1969. The journals of Carl Mauch. His travels in the Transvaal, 1869-1872. National Archives of Rhodesia, Salisbury.

CANN, J.R. 1970. Upward movement of granitic magma. *Geol. Mag.,* **107,** 335-340.

CHINNER, G.A. & SWEATMAN, T.R., 1968. A former association of enstatite and kyanite. *Mineralog. Mag.,* **36,** 1052-1060.

COHEN, A.J. & GARDNER SUMNER, G., 1958. Relationships among impurity contents, colour centres and lattice constants in quartz. *Amer Min.*, **43,** 58-68.

COMPSTON, W. & McELHINNY, M.W., 1975. The Rb-Sr age of the Mashonaland Dolerites of Rhodesia and its significance for palaeomagnetic correlation in Southern Africa. *Precam. Res.,* **2,** 305-315.

COX, K.G., JOHNSON, R.L., MONKMAN, L.J., STILLMAN, C.J., VAIL, J.R. & WOOD, D.N., 1965. The geology of the Nuanetsi Igneous Province. *Phil. Trans. Roy. Soc. Lond.,* **A 257**, 71 - 218.

CURRIE, K.L., 1971. The reaction 3 Cordierite = 2 Garnet + 4 Sillimanite + 5 Quartz as a geological thermometer in the Opicnicon Lake region, Ontario. *Contr. Miner. Petrol.,* **33,** 215-226.

DEER, W.A., HOWIE, R.A. & ZUSSMAN, J., 1972. An introduction to the rock forming minerals. Longman, London.

DU TOIT, M.C. & VAN REENEN, D.D., 1977. The southern margin of the Limpopo Mobile Belt, Northern Transvaal, with special reference to metamorphism and structure. *Botswana geol. Surv.,* **12,** 83-97.

ELTON, F.J., 1872. Journal of an exploration of the Limpopo River. *J. Roy. Geog. Soc.,* London, **42,** 1-49.

ERMANOVICS, I.F., KEY, R.M. & McEWEN, G. (Eds), 1977. The proceedings of a seminar pertaining to the Limpopo Mobile Belt. *Botswana geol. Surv.*, **12.**

GOLDBERG, I., 1965. Notes on the Pande Magnesite Mine, Diti Tribal Trust Land, Beitbridge District. Unpublished. *Rhod. Geol. Surv.,* Technical Files.

GOLDBERG, I. & SHORT, T., 1964. Geological report on the Mat magnesite deposit, Crown Land, Beitbridge area, Gwanda District. *Rhod. Geol. Surv.,* Technical Files.

GOUGH, D.I., BROCK, A., JONES, D.L. & OPDYKE, N.D., 1964. The palaeomagnetism of the ring complexes at Marangudzi and the Mateke Hills. *J. Geophys. Res.,* **69,** 2499-2507.

GREEN, D.H. & RINGWOOD, A.E., 1967. An experimental investigation of the gabbro to eclogite transformation and its petrological implications. *Geochim. et. Cosmochim. Acta.,* **31,** 767-833.

HENSEN, B.J. & GREEN, D.H., 1970. Experimental data on coexisting cordierite and garnet under high-grade metamorphic conditions. *Phys. Earth Planet. Interiors.,* **3,** 431-440.

HOLMES, A. & CAHEN, L., 1957. Geochronologie africaine 1956. Resultats aquis au 1 er juillet 1956. *Mem. Acad. Royale Sci. Colon. Belg.,* 1-169.

HOR, A.K., HUTT, D.K., SMITH, J.V., WAKEFIELD, J. & WINDLEY, B.F., 1975. Petrochemistry and mineralogy of early Precambrian anorthositic rocks of the Limpopo Mobile Belt, southern Africa. *Lithos*, **8**, 297-310.

JACOBSEN, J.B.E., REX, D.C. & SEVENSTER, W.J., 1975. K-Ar ages of some mafic dykes from the Messina District, Transvaal, and their bearing on the age of copper mineralization. *Trans. geol. Soc. S. Afr.*, **78**, 359-360.

KEY, R.M., 1977a. The geochronology of Botswana. *Trans. geol. Soc. S. Afr.*, **80**, 31-42.

KEY, R.M., 1977 b. The geological history of the Limpopo Mobile Belt based on the field mapping of the *Botswana Geol. Surv. Botswana geol. Surv.*,**12**, 41-59.

KLEIN, C. & WALDBAUM, D.R., 1967. X-Ray crystallographic properties of the cummingtonite-grunerite series. *J. Geol.*, **75**, 379-392.

LIGHT, M.P.R. (in press). The Archaean and early Proterozoic geological history of the region around Beitbridge, Zimbabwe-Rhodesia. Contribution to *Geol. Soc. S. Afr.*, Geokongres 79, Univ. Port Elizabeth.

LIGHT, M.P.R. & WATKEYS, M.K., 1977. An outline of the Archaean and early Proterozoic geological history of the region around Beitbridge. *Ann. Rhod. geol. Surv.*, **3**, 35-40.

LIGHTFOOT, B., 1938. Notes on the south-eastern part of Southern Rhodesia. *Trans. geol. Soc. S. Afr.*, **41**, 193-198.

LILLY, P.A., 1975. The geology of the Singelele Hills, Messina. Unpublished. Hons. Proj., Univ. Witwatersrand.

LINNEL, R.J., 1970. Unpublished map. *Rhod. geol. Surv.*

LISTER, L.A., 1987. The erosion surfaces of Zimbabwe. *Zim. geol. Surv.*, **90**.

MANTON, W.I., 1968. The origin of associated basic and acid rocks in the Lebombo-Nuanetsi Igneous Province, southern Africa, as implied by strontium ratios. *J. Petr.*, **9**, 23-39.

MASON, R., 1973. The Limpopo Mobile Belt, southern Africa. *Phil. Trans. Roy. Soc. Lond.*, **A 273**, 463-485.

MOLYNEUX, A.J.C., 1899. Report to the shareholders of the Tuli Consolidated Coalfields Co. Ltd. Unpublished. *Zim. geol. Surv.*, Technical Files.

MORRISON, E.R., 1968. Rough notes on a visit to the Beitbridge area. Unpublished. *Rhod. geol. Surv.*, Technical Files.

MORRISON, E.R., 1972. Corundum in Rhodesia. *Rhod. geol. Surv.*, Mineral Resources Series, **16**.

MORRISON, E.R., 1974. Exclusive Prospecting Orders No. 1-250. *Rhod. geol. Surv.*, **72**.

MORRISON, E.R., 1975. Exclusive Prospecting Orders No. 251-400. *Rhod. geol. Surv.*, **74**.

MORRISON, E.R., 1978. Exclusive Prospecting Orders No. 401-500. *Rhod. Geol. Surv.*, **82**.

NEWTON, R.C., 1972. An experimental determination of the high-pressure stability limits of magnesian cordierite under wet and dry conditions. *J. Geol.*, **80**, 398-420.

PARSONS, C.F., 1976. Geological report on the Tengwe and Diti E.P.O's, Rhodesia. Unpublished. JCI Exploration Research Unit, **15**.

PETTIJOHN, F.J., 1957. Sedimentary rocks. Harper and Row, New York.

PHAUP, A.E., 1949. Geological report on the Mat Magnesite Claims, Crown Land, Beitbridge, Gwanda District. Unpublished. *Rhod. geol. Surv.*, Technical Files.

PHAUP, A.E., 1951. Report on Byerley's corundum claims. Unpublished. *Rhod. geol. Surv.*, Technical Files.

POPP, R.K., GILBERT, M.C. & CRAIG, J.R., 1977. Stability of Fe-Mg amphiboles with respect to oxygen fugacity. *Amer. Min.*, **62**, 1-12.

RAMSAY, J.G., 1962. Interference patterns produced by superposition of folds of similar type. *J. Geol.*, **70**, 466-481.

ROBERTSON, I.D.M., 1967. Geological report - Maramani. *Rhod. Schools Explor. Soc*, 17th Expedition, 34-39.

ROBERTSON, I.D.M., 1968. Geological report – Siyanje. *Rhod. Schools Explor. Soc.*, 18th Expedition, 44-49.

ROBERTSON, I.D.M., 1973 a. Potash granites of the southern edge of the Rhodesian craton and the northern margin of the Limpopo Mobile Belt. *Geol. Soc. S. Afr.*, Spec. Publ., **3**, 265-275.

ROBERTSON, I.D.M., 1973 b. The Geology of the country around Mount Towla, Gwanda. *Rhod. geol. Surv.*, **68**.

ROBERTSON, I.D.M., 1977. Some granulite facies metasediments of the Rhodesian part of the North Marginal Zone the Limpopo Mobile Belt. *Botswana geol. Surv.*,**12**, 157-176.

ROBERTSON, I.D.M. & DU TOIT, M.C. (in press). The Limpopo Belt. In: Precambrian geology of the Southern Hemisphere. Elsevier, Amsterdam.

SCHREYER, W. & ABRAHAM, K.,1976. Natural boron-free kornerupine and its breakdown product in a sapphirine rock of the Limpopo Belt, southern Africa. *Contrib. to Min. and Petr.*, 54, 109-126.

SCHREYER, W. and YODER, H.S., 1964. The system Mg cordierite - H_20 and related rocks. ***Neues. Jahrb. Min. Abh.,*** Vol. 101, pp. 271-342.

SEIFERT, F., 1975. Boron-free kornerupine: a high-pressure phase. *Am. J. Sci.,* **275**, 57-87.

SÖHNGE, P.G.,1945. The geology of the Messina Copper Mines and surrounding country. *S. Afr. geol. Surv.,* Mem., **40.**

SÖHNGE, P.G., le ROEX, H.D. & NEL, H.J., 1948. The geology of the country around Messina. An explanation of sheet No. 46 (Messina). *S. Afr. geol. Surv.*

STOCKLMAYER, V.R., 1977. A note on the chemistry of Precambrian dolerites of eastern Rhodesia. *Ann. Rhod. geo Surv.,* 3, 58-62.

STRECKEISEN, A., 1976. To each plutonic rock its proper name. *Earth Sc. Rev.,* **12,** 1-34.

TURNER, F.J. & VERHOOGEN, J., 1960. Igneous and metamorphic petrology. McGraw-Hill Book Company, New York.

TYNDALE-BISCOE, R., 1949. Notes on a geological reconnaissance of the country east of Beitbridge, Southern Rhodesia. *Trans. geol. Soc. S. Afr.,* **52,** 403-411.

VAIL, J.R. & DODSON, M.H., 1969. Geochronology of Rhodesia. *Trans. geol. Soc. S. Afr.,* **72,** 79-114.

VAN BREEMEN, O., 1970. Geochronology of the Limpopo orogenic belt, southern Africa. *J. Earth Sci. Leeds,* **8,** 57-61.

VAN EEDEN, O.R., VISSER, H.N., VAN ZYL, J.S., COERTSE, F.J. & WESSELS, J.T., 1955. The geology of the eastern Soutspansberg and the lowveld to the north. Explanation of sheet 42 (Soutspansberg). *S. Afr. Geol. Surv.*

VAN GRAAN, S.J., 1964. Geology of the Messina copper deposits. In: The geology of some ore deposits in southern Africa, II, 303-314.

VAN REENEN, D.D. & DU TOIT, M.C., 1978. The reaction Garnet + Quartz = Cordierite + Hypersthene in granulites of the Limpopo Metamorphic Complex in Northern Transvaal. *Geol Soc. S. Afr.,* Spec. Publ., **4,** 149-177.

WAKEFIELD, J., 1974. The geology of the Pikwe Ni-Cu province, eastern Botswana. Unpubl. Ph.D. thesis, Univ. Leeds.

WATKEYS, M.K., 1979. Explanation of the geological map of the country west of Beitbridge. *Rhod. geol. Surv.,* Short Report, **45.**

WINDLEY, B.F., 1973. Archaean anorthosites: a review with the Fiskenaesset Complex, west Greenland as a model for interpretation. *Geol. Soc. S. Afr.,* Spec. Publ., **3,** 319-332.

WINKLER, H.G.F., 1974. Petrogenesis of metamorphic rocks. Third Ed., Springer Verlag, New York.

APPENDIX

List of reference slides in the collection of the Geological Survey, Harare

Collection No	Sample No.	Formation	Rock Type	UTM Grid Ref.
25 377	18 / 75	Basement	Enderbitic gneiss	SL 999 429
25 378	19/75	"	Dioritic gneiss	SL 965 413
25 379	MPL 3797	"	Biotitic enderbite gneiss	TL 065 458
25 380	MPL 4237	"	Biotitic	TL 003 435
25 381	MPL 4245	"	Basement gneiss	TL 001 431
25 382	MPL 5354A	"	Basement inclusion in Bulai gneiss	SL 966 414
25 383	MPL 9978	"	Coarse hypersthene / hornbl. gneiss	TL 126 367
25 384	MPL 10152	"	Hornblendic diorite gneiss	TL 153 381
25 385	MPL 4525	"	Basement gneiss	TL 055 450
25 386	MPL Aug	"	Diorite augen gneiss	SL / TL
25 387	MPL 5473	"	Fine-grained enderbitic gneiss	TL 132 328
25 388	MPL 4250	"	Glomeroporphyr. enderbite gneiss	TL 000 428
25 391	MPL 2121A	"	Garnet granulite	SL 964 482
25 392	MPL 867	"	Garnet hypersthene granulite	TL 390 449
25 393	MPL 5910	"	"	TL 067 339
25 394	MPL 10122	"	Hyp.cord.garn. qtz. sympl. granulite	TL 132 392
25 395	MPL 957	"	Garnet sillim. quartz granulite	TL 363 415
25 396	MPL 2644	"	Garn. leucocrat.calc-silicate gneiss	SL 942 532
25 397	MPL 2709	"	Diops.sphene calc-silicate gneiss	SL 920 607
25 398	MPL 2107	"	Leucocratic calc-silicate gneiss	SL 955 476
25 399	MPL 5368	"	Leucocratic calc-silicate gneiss	SL 965 407
25 400	MPL 5369	"	Diopsidic calc-silicate gneiss	SL 965 407
25 401	MPL 9111	"	Calc-ilicate gneiss	TL 048 390
25 402	MPL 5501	"	Granitic biotite gneiss	TL 105 370
25 403	MPL 3495	"	Granitic biotite gneiss	TL 073 613
25 404	MPL 5719	"	"	TL076 347
25 405	MPL 2525A	"	Imtermediate biotite gneiss	TL 073 608
25 406	75/5	"	Biotite garnet gneiss	TL 179 324
25 407	MPL 301	"	Imtermediate biotite gneiss	-
25 408	MPL 5395	"	Fine-gr. biotite garnet gneiss	TL 155 341
25 409	MPL 2976	"	Leucocratic paragneiss	SL 912 393
25 410	MPL 75/1	"	"	TL 059 318
25 411	MPL 263	"	Hydrothermally altered paragneiss	-
25 412	MPL 305	"	Epidotized leucocratic gneiss	-
25 413	MPL 544	"	Leucocratic gneiss	TL 420 645
25 414	MPL 5388	"	Garnetiferous leucocr. paragneiss	TL 071 343
25 415	MPL 3507	"	Leucocratic granulite	TL 095 607
25 416	MPL 303	"	Microcline-rich leucocratic gneiss	TL 024 550
25 417	MPL 2019	Beitbridge Group	Secretion dolomite vein	TL 39- 39-
25 418	MPL CH 6	Shakwisa Calc. Member	Dolomitic marble	TL 394 391
25 419	MPL 3648A	"	"	TL 053 491
25 420	MPL 863	"	Coarse biotite diopside marble	TL 363 423
25 421	MPL 912	"	Spinel-bearing marble	TL 397 434
25 422	MPL 1057	"	Coarse black marble	TL 396 834
25 423	MPL 889	Beitbridge Group	Magnetite graphite-bear. marble	TL 37- 43-
25 424	MPL 861	Shakwisa Calc. Member	Ophicalcite-serpentin. marble	TL 365 425
25 425	MPL 866	"	Calcite-rich serpentin. marble	TL 368 425
25 426	MPL 902	"	Ophicalcite-serpentin. marble	TL 402 442
25 427	MPL 902A	"	Ophicalcite	TL 402 442
25 428	MPL 3083	"	"	TL 023 482
25 429	MPL 7965	"	Ophicalcite-serpentin. marble	SL 996 365

Collection No	Sample No.	Formation	Rock Type	UTM Grid Ref.
25 430	MPL CH3	"	Diopsidic calc-silicate rock	TL 176 299
25 431	MPL 868	"	"	TL 370 425
25 432	MPL 462B	"	Calc-silicate granulite	TL 292 635
25 433	MPL 909	"	Diopsidic calc-silicate rock	TL 400 435
25 434	MPL 5503	"	Diop. Hb. calc-silicate rock	TL 104 370
25 435	MPL 978	"	Hornblendic calc-silicate rock	TL 387 416
25 436	MPL 530	"	Calc-silicate granulite	TL 417 628
25 437	MPL 806	"	Microcline-rich calc-silicate rock	TL 410 464
25 438	MPL 863B	"	Calc-silicate rock	TL 363 423
25 439	MPL 3648B	"	Spinel granulite	TL 053 491
25 440	MPL 3648	"	"	TL 053 491
25 441	MPL 969	"	Enstatite cordierite granulite	TL 376 416
25 442	MPL 6085	"	Green garnet granulite	TL 172 326
25 443	MPL 129B	"	"	TL 331 448
25 444	MPL 5117	Swebebe Ferruginous M.	Magnetite quartzite	TL187 488
25 445	MPL 477	"	Cummington. grunerite quartzite	TL 333 649
25 446	MPL 5198	"	Magnetite quartzite	TL 217 524
25 447	MPL 325	"	Goethite cryptocryst. quartz rock	TL 292 551
25 448	MPL 7173	"	Magnetitite	TL 293 280
25 449	MPL 7613	".	"	TL 190 330
25 450	MPL 322	"	Ferruginous quartzite	TL 298 555
25 451	MPL 2828	"	Coarse magnetite granulite rock	SL 925 646
25 452	MPL 248	"	Cummingtonite grunerite quartzite	TL 289 570
25 453	MPL 7940	"	Cummingt. hypersth. quartz gneiss	SL 994 360
25 454	MPL 4756	"	Cummingt.gruner. magnetite rock	SL 996 370
25 455	MPL 1929	"	Weathered ferruginous quartzite	SL 933 415
25 456	MPL 1414	"	Qtz garn. hypersth.spinel granulite	TL 300 497
25 457	MPL 3832	"	"	TL 127 478
25 458	MPL 6014	"	"	TL 084 322
25 459	MPL 1516	"	Qtz hypersth. magnetite granulite	TL 335 457
25 460	MPL 6624	"	Serpentinized qtz. hyp. granulite	TL 184 294
25 461	MPL 5659	"	Garnet qtz. magnetite granulite	TL 104 327
25 462	MPL 4923C	"	Garnet augen granulite	SL 988 370
25 463	MPL 7555	"	Nontronite clay rock	TL 211 371
25 464	MPL 4929B	"	"	SL 990 370
25 465	MPL 75/14	"	Codierite gneiss	TL 089 392
25 466	MPL 7125	"	Garnet cordierite gneiss	TL 211 292
25 467	MPL 2323	"	"	SL 991 538
25 468	MPL 4665	"	Garnet cordier. Sillim. gneiss	SL 999 405
25 469	MPL 5403	"	Cordier. Sillim. gneiss	TL 149 344
25 470	MPL 1221	"	Codierite gneiss	TL 333 385
25 471	MPL 1517	"	"	TL 335 487
25 472	MPL 1334	Swebebe Ferrugin. M.	Calc-silicate rock	TL 280 449
25 473	MPL 5095	Nulli Formation	Massive fuchsite bearing quartzite	TL 219 647
25 474	MPL 5096	"	"	TL 217 641
25 475	MPL 3015	"	Massive glassy quartz rock	SL 993 477
25 476	MPL 5126	"	Massive feldspar bearing quartzite	TL 188508
25 477	MPL 495A	"	Fuchsite quartzite	TL 351 650
25 478	MPL 4847	"	Fuchsite garnet quartzite	SL 939 370
25 479	MPL 38	"	Massive, iron-stained quartzite	TL 239 558
25 480	MPL 280	"	Hornblende-bearing quartz rock	TL 188 285
25 481	MPL 314A	"	Granular fuchsite quartzite	TL 317 566
25 482	MPL 518	"	Massive quartz rock	TL 359 625
25 483	MPL 5118	"	Fuchsite quartzite	TL 185 501
25 484	MPL 4806	"	"	SL 931 382
25 485	MPL 5068	"	Feldspathic quartzite	TL 223 643

Collection No	Sample No.	Formation	Rock Type	UTM Grid Ref.
25 486	MPL 53	"	Garnet-bearing quartzite	TL 245 551
25 487	MPL 75/4	"	Granular sillimanite quartzite	TL 067 325
25 488	MPL565	"	Granulated massive quartzite	TL 318 578
25 489	MPL 227A	"	Well-foliated granular quartzite	TL 233 646
25 490	MPL 475	"	Granular sillimanite quartzite	TL 339 651
25 491	MPL 815	"	"	TL 418 463
25 492	MPL 4846	"	Granular fuchsite quartzite	SL 963 372
25 493	MPL 6697	"	Biotite sillimanite quartzite	TL 208 453
25 494	MPL 814	"	Sheared quartzite	TL 416 463
25 495	MPL 5088	"	Mylonitic quartzite	TL 175 637
25 496	MPL 5097	"	Diopside-bearing quartzite	TL 217 641
25 497	MPL 5034	"	"	TL 230 572
25 498	MPL 75/6	"	Amphibolitic gneiss	TL 078 392
25 499	MPL 516	"	"	TL 415 609
25 500	MPL 7162	"	"	TL 276 277
25 501	MPL 115	"	"	TL 243 576
25 502	MPL 22	"	Plagioclase augen amphibolite	TL 245 565
25 503	MPL 960	"	Basal biotite gneiss	TL 367 411
25 504	MPL 1298	Layered Anorthos. Suite	Anorthos. Gneiss with cumul. text.	TL 331 448
25 505	MPL 75/9	"	Quartz hornblende gneiss	TL 303 408
25 506	MPL 267C	"	"	TL 185 283
25 507	MPL 1306	"	"	TL 324 461
25 508	MPL 2087A	"	"	TL 922 478
25 509	MPL 847	"	"	TL 373 448
25 510	MPL 5344	"	Garnet hornblende augen gneiss	TL 252 440
25 511	MPL 10816	"	Pegmatitic qtz hornbl. Gneiss	TL 354 344
25 512	MPL CH4	"	Hornblende anorthosite	SL 975 370
25 513	MPL 1462	"	Plagioclase pyroxene hornblendite	TL 332 565
25 514	MPL 1472	"	"	TL 347 442
25 515	MPL 5495	"	"	TL 118 364
25 516	MPL 5569	"	"	TL 108 332
25 517	MPL 5569B	"	"	TL 108 332
25 518	MPL 9218	"	"	TL 080 366
25 519	MPL 4734	"	Hypersthene hornblendite	TL 005 385
25 520	MPL 5062	Layered Anorthos. Suite	Hbl.-rich anorthositic gneiss	TL 235 616
25 521	MPL 7028	"	"	TL 273 324
25 522	MPL 122 B	"	"	TL 237 584
25 523	MPL 804	"	Layered anorthositic gneiss	TL 366 458
25 524	MPL75/13	"	Anorthosite	TL 133 346
25 525	MPL	"	"	SL 978 374
25 526	MPL 804A	"	Anorthositic gneiss	TL 366 458
25 527	MPL259	"	Biotite-bearing anorthositic gneiss	TL 190 280
25 528	MPL2459	"	"	RF
25 529	MPL 1184	"	Anorthositic gneiss	TL 320 400
25 530	MPL 7132	"	"	TL 207 286
25 531	MPL 7901	"	"	TL 008 336
25 532	MPL 4489	"	Anorthositic garnetif. gneiss	TL 025 443
25 533	MPL 803	"	Anorthositic gneiss	TL 368 454
25 534	MPL 2720	"	Garnetiferous anorthosite gneiss	SL 981 633
25 535	MPL 3470	"	Hydroth. altered anorthosite gneiss	TL 056 517
25 536	MPL 2211	"	Gabbroic anorthosite granulite	RF / SL
25 537	MPL 2085	"	"	SL 920 481
25 538	MPL 2689	"	"	SL 590 595
25 539	MPL 1306A	"	Anorthositic pegmatite	TL 327 477
25 540	MPL 5486	"	"	TL 130 351
25 541	MPL 5321	"	Poikiloblastic pyroxene granulite	TL 207 425

Collection No	Sample No.	Formation	Rock Type	UTM Grid Ref.
25 542	MPL 75/6	Ultramafic Suite	Pyroxene granulite	TL 166 315
25 543	MPL 75/7	"	Amphibolitic mafic granulite	TL 166 315
25 544	MPL 1375	"	Pyroxene granulite	TL 279 480
25 545	MPL 1092	"	"	TL 344 404
25 546	MPL 2781	"	"	RF
25 547	MPL 6637	"	Clinopyroxene granulite	TL 166 315
25 548	MPL 762	"	Pyroxene granulite	TL 417 501
25 549	MPL 1443	"	"	TL 348 527
25 550	MPL 6071	"	Pargasitic pyroxene granulite	TL 040 313
25 551	MPL 7137	"	Peridotitic granulite	TL 208 277
25 552	MPL 2151	"	"	SL 930 503
25 553	MPL 294	"	Hornblendite	TL 185 285
25 554	MPL 945	"	"	TL 408 435
25 555	PG 32	"	"	TL 189 321
25 556	MPL10905	"	Poikiloblastic hornblendite	TL 301 369
25 557	MPL 2832	"	Tremolite ultramafic	SL 925 641
25 558	MPL 1081	"	"	TL 352 397
25 559	MPL 877	"	"	TL 388 426
25 560	MPL 848	"	"	TL 377 448
25 561	MPL CH5	"	Serpentinite	TL 218 321
25 562	PG 10D	"	Unaltered green serpentinite	TL 184 317
25 563	MPL 5280	"	Peridotitic serpentinite	TL 173 420
25 564	MPL 6062	"	Pyroxene serpentinite	TL 047 314
25 565	MPL 1132	"	Serpentinite	TL 375 380
25 56 6	MPL 1135	"	"	TL 379 381
25 567	MPL 2079	"	"	SL 927 498
25 568	MPL 5486	"	"	TL 130 351
25 569	PG 14D	"	Veined serpentinite	TL 184 317
25 570	MPL 393A	"	Banded magnetite serpentinite	TL 287 535
25 571	MPL 5612	"	Talcose serpentinite	TL 105 341
25 572	PG 20	"	"	TL 184 317
25 573	MPL 6777	"	Slip-picrolite serpentinite	TL 187 319
25 574	MPL 425	"	Birbiritic serpentinite	TL 280 580
25 575	MPL 6810	Ultramafic Suite	Birbiritic serpentinite	TL 213 320
25 576	MPL 331A	"	Carbonated serpentinite	TL 284 544
25 577	MPL 393	"	"	TL 287 535
25 578	PG 2	"	"	TL 184 317
25 579	MPL 557	"	Magnesite-vein serpentinite	TL 294 657
25 580	PG 35	"	Colloph. magnesite	TL 189 321
25 581	MPL 392	"	Magnesite	TL 287 535
25 582	PG 12	"	"	TL 184 317
25 583	MPL 393B	"	"	TL 287 535
25 584	MPL 10185	Mafic Granulites	Two pyroxene granulite	TL 183 418
25 585	MPL 5321	"	"	TL 207 425
25 586	MPL 7893	"	"	TL 000 370
25 587	MPL 2126A	"	"	SL 962 487
25 588	75/12	"	Tholeitic dyke rock	TL 176 333
25 589	MPL 1218	"	Mafic granulite	TL 316 384
25 590	MPL 1834	"	"	SL 910 407
25 591	MPL 7340	"	Clinopyr.-free metabasic dyke rock	TL 329 284
25 592	MPL 2302B	Singelele Gneiss	Porphyroblastic charnockitic gneiss	TL 005 524
25 593	MPL 2105	"	Charnockitic gneiss	SL 950 476
25 594	MPL 2651	"	Melanocratic enderbitic gneiss	TL 013 538
25 595	MPL 2118	"	Gneiss	SL 973 486
25 596	75/2	"	"	TL 041 320
25 597	75/17	"	Transitional gneiss	TL 064 396

Collection No	Sample No.	Formation	Rock Type	UTM Grid Ref.
25 598	MPL 7898	"	Magnetite-rich transit. gneiss	TL 001 341
25 599	MPL 2977	Bulai Gneiss	Gneiss	SL 910 393
25 600	MPL 5371	"	"	SL 928 435
25 601	75/20	"	Schistose gneiss	SL 936 430
25 602	MPL 2368	"	Leucocratic adamellitic gneiss	SL 970 400
25 603	MPL 5361	"	Adamellitic augen gneiss	SL 971 416
25 604	MPL 2916	"	Tonalitic gneiss	TL 014 467
25 605	MPL 283	"	Unakite	RF
25 606	MPL 289	"	"	"
25 607	MPL 289A	"	Epidotized augen gneiss	"
25 608	MPL 289B	"	Biotite-rich augen gneiss	"
25 609	MPL289C	"	Hydroth. altered augen gneiss	"
25 610	MPL 1236	Syntectonic rose quartz	Rose quartz	TL 274 415
25 611	MPL 320	Aplite riebeckite gneiss	Adamellitic aplite gneiss	TL 300 555
25 612	MPL 7639	"	Riebeckite bearing aplitic gneiss	TL 013 366
25 613	MPL 1525	"	Tonalitic aplite gneiss	TL 345 495
25 614	MPL 306B	Flaser gneiss & mylonite	Flaser gneiss	TL 038 550
25 615	MPL 2544	"	"	TL 085 625
25 616	MPL 1152A	"	Mylonite	TL 298 407
25 617	MPL 538	"	Recrystallized mylonite	TL 372 638
25 618	MPL 1959A	Pegmatites	Fractured pegmatite	SL 916 440
25 619	MPL AP	"	Graphic prgmatite	
25 620	MPLPG15A	"	Musc. qtz. feldspar pegmatite	TL 184 317
25 621	MPL 2001	"	Micropegmatite dyke	SL 937 450
25 622	MPL 287A	"	Hydrothermally altered pegmatite	RF
25 623	MPL 762	"	Altered pegmatite	TL 417 500
25 624	MPL 2302	Metasom. brecc. & apl.	Harrisitic aplite dyke	TL 004 524
25 625	MPL 2302A	"	"	TL 004 524
25 626	MPL 2302B	"	"	TL 004 524
25 627	MPL 2302C	Metasom. Brecc. & apl.	Harrisitic aplite dyke	TL 004 524
25 628	MPL 2302D	"	"	TL 004 524
25 629	MPL 3261	"	Granophyric breccia	TL 063 564
25 630	MPL 3533	"	"	TL 044 544
25 631	MPL 2363	"	"	TL 009 515
25 632	MPL 517A	Late Quartz Reef	White vughy quartz	TL 354 624
25 633	MPL 4P	Symplektites	Enstatite gedrite symplektite	TL 098 341
25 634	MPL 8P	"	Sillim.cord. biot. granulite	TL 098 341
25 635	MPL 6P	"	Sill. sapph.cord. biot. symplektite	TL 098 341
25 636	MPL 10P	"	Sapph. cord. corund. symplektite	TL 098 341
25 637	MPL 2C	"	Sillim. cord. symplektite	TL 098 341
25 638	MPL 5907	Karoo System	Fine-grained sandstone	TL 064 342
25 639	MPL 2654A	"	"	TL 010 532
25 640	MPL 1234	"	Fine-gr. red sandstone	TL 272 395
25 641	MPL 7445	"	Fossiliferous shale	TL 367 295
25 642	MPL 11173	"	Crossbedded grit	TL 379 297
25 643	MPL11173D	"	Grit	TL 379 297
25 644	MPL 11174	"	"	TL 378 297
25 645	MPL 920	Dolerites	Tremolitic dyke rock	TL 391 425
25 646	MPL 7641	"	Old coarse-grained dolerite	TL 010 364
25 647	MPL 1031	"	"	TL 373 397
25 648	MPL 6833	"	Feldsparphyric dolerite	TL 240 324
25 649	MPL 11083	"	"	TL 357 365
25 650	MPL 5070	"	Variolitic feldsparphyric dolerite	TL 231 582
25 651	MPL 198	"	"	TL 235 637
25 652	MPL 6947	"	"	TL 261 288
25 653	MPL 6949E	"	Fine-grained dolerite	TL 264 291

Collection No	Sample No.	Formation	Rock Type	UTM Grid Ref.
25 654	MPL 189	"	Chill. margin fine –gr. dolerite	TL 229 620
25 655	MPL 6949F	"	Medium-grained dolerite	TL 264 291
25 656	MPL 7181	"	Gabbroic dolerite	TL 302 277
25 657	75/10	"	Platy feldspar dolerite	TL 170 361
25 658	MPL 4907A	"	"	SL 964 395
25 659	MPL 127	"	"	TL 224 589
25 660	MPL 5160	"	"	RF
25 661	MPL 517C	"	"	RF
25 662	MPL 1120	Post Karoo Rocks	Tonalite	TL 354 376
25 663	MPL 841	"	"	TL 363 446
25 664	MPL 842B	"	"	TL 366 445
25 665	MPL1034	"	Fine-gr. porphyritic aplite	TL 381 397
25 666	MPL 1184	"	"	TL 318 400
25 667	MPL 2525B	"	Mafic porphyry	TL 073 608
25 668	75/8	"	Metasomatized mafic porphyry	TL 167 402
25 669	MPL 177	"	Mafic porphyry	TL 234 613
25 670	MPL 114	"	"	TL 243 577
25 671	MPL 5172A	"	"	RF
25 672	MPL 5172B	"	"	RF
25 673	MPL 635	"	Hydroth. altered mafic porphyry	TL 380 565
25 674	MPL 5372	"	Olivine porphyry	SL 961 528
25 675	MPL 96	"	"	TL 243 562
25 676	MPL 109	"	"	TL 238 568
25 677	MPL 2278	"	"	SL 955 525
25 678	MPL 2512	"	Nepheline vogesite	TL 058 592
25 679	MPL GRZ	Post Karoo Rocks	Late fine-grained dolerite	
25 680	MPL 7651A	Breccias	Quartz-epidote breccia	TL 008 359
25 681	MPL 9062	"	Mottly breccia	TL 040 380
25 682	MPL 9001	"	Recemented quartz breccia	TL 044 361
25 683	MPL 7650	"	Carbonated breccia	TL 006 359
25 684	MPL 845B	"	Quartz breccia	TL 372 447
25 685	MPL 6694	"	Brecciated paragneiss	TL 191 280
25 686	MPL 122	"	Epidotized breccia	TL 237 584
25 687	MPL 1048	"	"	TL 425 394
25 688	MPL 5689	"	Recrystallized epidote breccia	TL 091 329
25 689	MPL EP2	"	Epidote from breccia zone	SL 985 365
25 690	MPL 5694	"	Chloritic breccia	TL 089 339
25 691	MPL 7891	"	Actin. qtz epidote breccia	TL 000 366
25 692	MPL 7968	"	Calcite quartz breccia	TL 002 358
25 693	MPL 5695	"	Malachite-bear. epid. qtz breccia	TL 091 337
25 694	MPL 2219	Hydrothermally Activity	Epidosite	SL 953 461
25 695	MPL 2953	"	"	TL 048 547
25 696	MPL 5695	"	Cu. Quartz epidote breccia	TL 100 340
25 697	MPL EP 1	"	Crystalline vughy quartz & epidote	SL 980 370
25 698	MPL 267B	Superficial Deposits	Calcrete	TL 039 500
25 699	MPL 319	"	"	TL 303 558
25 700	MPL 452	"	"	TL 291 605
25 701	MPL 1235	"	"	TL 285 390
25 702	75/11	"	"	TL 307 400
25 703	PG 6A	Economic Geology	Magnesite	TL 184 317
25 704	PG 9	"	"	TL 184 317
25 705	PG14B	"	Silicified serpentinite	TL 184 317
25 706	PG14C	"	Enstatite tremolite granulite	TL 184 317
25 707	PG 15	"	Silicified serpentinite	TL 184 317
25 708	PG 11	"	Magnesite veined dolerite	TL 184 317
25 709	MPL Q	"	Aventurine	TL 358 307
25 710	MPL DP	"	Graphic qtz. hbl. pegmatite	TL 402 441