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A GEOLOGICAL INVESTIGATION OF THE ARCHAEAN GRANITE-GREENSTONE TERRANE SOUTH OF THE BOESMANSKOP SYENITE PLUTON, BARBERTON MOUNTAIN LAND

by

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ABSTRACT

Numerous greenstone enclaves or xenoliths occur in the trondhjemitic/tonalitic gneiss terrane south of the Barberton greenstone belt. One of these xenoliths outcrops prominently south of the Boesmanskop syenite pluton and has been intruded by diapiric gneiss plutons. These diapiric plutons have caused extensive deformation and metamorphism in the main xenolithic body (the Weergevonden greenstone remnant) and have, in addition, been responsible for the extensive development of migmatites and gneisses in areas flanking the supracrustal sequences as well as the numerous small greenstone rafts found scattered throughout the granitic terrane.

Also intruded into the region are bodies of syenite or quartz syenite approximately 2850 Ma old which were emplaced into a NW-SE striking zone of crustal weakness along which subsequent mafic dyke intrusions took place during the early-to-middle Proterozoic.

Aspects of the geology of the greenstones as well as the granitic rocks are described with the aid of major and trace element geochemistry. Numerous photographs illustrate the complexities encountered in the migmatites exposed in the area. The conclusion is drawn that the greenstones represent scattered remnants of the lowermost formations of the Onverwacht succession (Sandspruit and Theespruit formations of the Tjakastad Subgroup) of the Barberton greenstone belt.

The migmatites are interpreted as having been formed as a result of granite-greenstone interaction, the tonalitic/trondhjemitic magma being responsible for the rafting off of greenstone xenoliths and their subsequent modification by processes involving granitization, metasomatism,resorption (assimilation) and anatectic melting.

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I. INTRODUCTION

The Archaean granite-greenstone terrane south of the Barberton greenstone belt forms part of a study area being investigated as one of South Africa's contributions to the International Geodynamics Programme. Regional as well as detailed field mapping in the drainage system of the Komati River has revealed the presence of numerous greenstone xenoliths which have been traced for upwards of 50 km beyond the southern limits of the Barberton greenstone belt (Anhaeusser, 1977; Anhaeusser and Robb, 1978).

This study documents the field observations made in the area shown in the locality map (Figure 1), and situated immediately south of the Boesmanskop syenite pluton described by Anhaeusser et al. (1979). A detailed geological map of granite-greenstone terrane, mainly straddling the farms Nederland 152 IT and Weergevonden 173 IT, was prepared using aerial photographs enlarged to a scale of 1:10 000. The results of the field investigation are portrayed in the accompanying reduced geological map of the area (Figure 2).

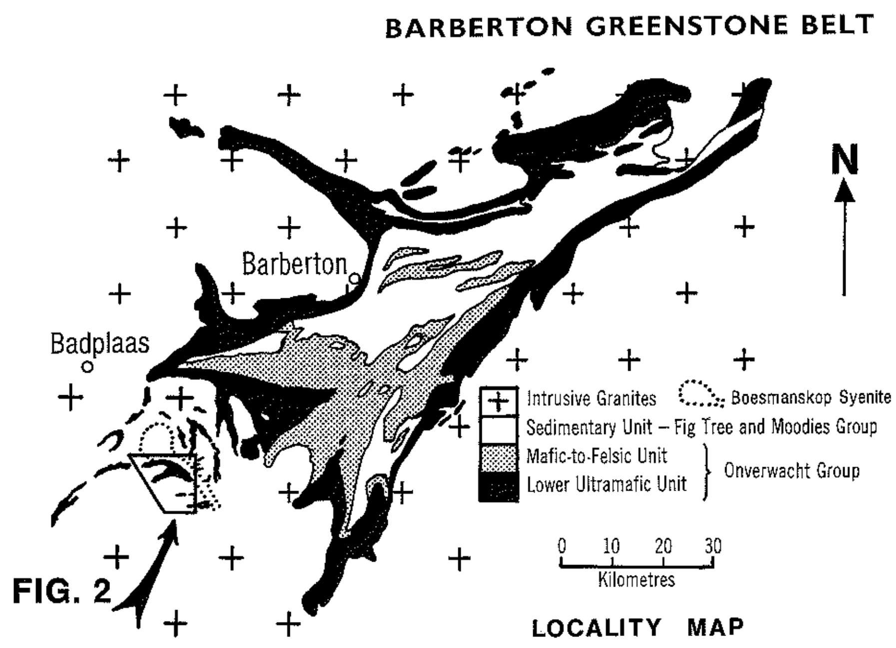

Figure 1 : General geological map of the Barberton Mountain Land showing the locality of the Weergevonden greenstone remnant south of the Boesmanskop syenite pluton.

II. REGIONAL GEOLOGICAL SETTING

Immediately south of the Barberton greenstone belt lies an extensive tract of topographically low-lying country made up predominantly of leuco-biotite trondhjemitic gneisses which occur generally in the form of discrete diapiric plutons, the latter partially or, in some cases, entirely rimmed by remnant greenstone stratigraphy. Studies by Viljoen and Viljoen (1969a, b) and the writer have indicated that the scattered greenstone fragments encountered in the gneisses are comprised entirely of assemblages characteristic of the lower two formations of the Onverwacht Group of the Swaziland succession - namely, the Sandspruit and Theespruit formations. The relationship of the greenstone xenoliths to the lower division of the Onverwacht Group (the Tjakastad Subgroup) is unequivocal as the detailed mapping has shown that not only are the lithologies identical but, furthermore, they can be traced from the gneissic terrane directly into the Barberton greenstone belt in several areas.

Recent geochronological investigations carried out on the Barberton volcanic sequences have yielded a precise Sm-Nd age of 3 540 ± 30 Ma (Hamilton et al., 1979) and all available evidence suggests that these rocks were intruded by trondhjemites ranging in age from ≅ 3 400 - 2 900 Ma (Oosthuyzen, 1970; J.M. Barton, unpublished data). Localized zones of migmatite occur commonly flanking some of the greenstone relics (Anhaeusser and Robb, 1978) and these are interpreted as having been formed as a result of the interaction of the granitic rocks with the greenstone xenoliths.

Also intrusive into the region are potassic granitic rocks (coarse porphyritic granites, adamellites, granodiorites) having batholithic dimensions, but which occupy extensive areas to the south and southeast of Badplaas (Anhaeusser and Robb, 1978). These bodies form topographically elevated areas relative to the flanking trondhjemitic gneisses and range in age from approximately 3 200 - 3 000 Ma (Oosthuyzen, 1970; J. M. Barton, in preparation). They do not occur in the region discussed in this paper (Figure 2) but the southeastern part of the map area has been influenced by pegmatite and other K-rich granitic phases developed along the northern periphery of one of the batholiths (the Mpuluzi batholith, Anhaeusser, in preparation).

A number of syenite bodies intrude the trondhjemitic gneisses and greenstone relics. These form part of a family of undersaturated rock types believed to be linked with the Boesmanskop syenite intrusion that has yielded a Rb-Sr whole rock isochron age of 2 848 ± 31 Ma (2σ) and an initial $^{87}Sr/^{86}Sr$ ratio of 0,7040 ± 0,0004 (2σ) (Anhaeusser et al., 1979). This is significantly younger than the 3 130 Ma model U-Pb concordia intersect ages obtained by Oosthuyzen (1970) and it has been suggested that the 2 850 Ma age represents a time of emplacement of the syenite which may have been derived by partial melting (and subsequent fractionation) of a felsic source rock that was at least 3 130 Ma old.

Magmatic activity in the southern part of the Barberton Mountain Land appears to have culminated with the emplacement of numerous mafic dykes and some sills. These intrusives, which are mainly diabases, have a preferred NW-SE strike direction over most of the region. Less common are NE-SW and N-S orientated dykes, the latter comprising mainly Karoo dolerites. No absolute ages are yet available for the diabase dykes. However, from their relationship with rocks of the Transvaal Drakensberg escarpment west of the Barberton Mountain Land (Visser et al., 1956) they are considered to be mainly early- or middle-Proterozoic in age (circa 1 800 - 2 400 Ma).

III. GEOLOGY OF THE GRANITE-GREENSTONE TERRANE SOUTH OF THE BOESMANSKOP SYENITE PLUTON

A. General Geology

Immediately flanking the southern contact of the Boesmanskop syenite pluton is a large greenstone xenolith, known as the Weergevonden remnant or schist belt. The main greenstone body, which has an ENE to NE strike, is approximately 4,5 km in length and 1,2 km in width where best developed on the farm Weergevonden 172 IT (Figure 2). In the northeast the greenstone remnant is truncated by an approximately 1 km wide dyke-like syenitic body (referred to as the Weergevonden syeno-granite — Anhaeusser et al., 1979) which extends from the Boesmanskop pluton in a southeasterly direction for over 8 km before being buried beneath an extensive diabase sheet in the Lochiel area. In the southwest the Weergevonden greenstone remnant, as well as the intrusive trondhjemitic gneisses, are cut by a prominent fault zone (the Mlingase Fault Zone) along which numerous NW-SE striking diabase dykes and a small porphyritic syenite body (the Welverdiend syenite — Anhaeusser et al., 1979) have been emplaced.

The greenstone remnants in the Nederland-Weergevonden area have been intruded by tonalites and/or trondhjemites that now occur as diapiric gneiss plutons. Zones of complex migmatites are developed in areas flanking the greenstone remnants whereas elsewhere the granitic rocks comprise homogeneous leuco-biotite trondhjemitic gneisses. In the southern part of the map area pegmatite dykes and fine-grained potash-rich granitic veins cut the gneisses and migmatites.

Throughout the area shown in Figure 2 there are numerous diabase dykes, the majority of which trend in a NW-SE direction, parallel to the major regional shear zones and other intrusive bodies (e.g. the various syenite occurrences associated with the Boesmanskop pluton). The dykes are particularly prominent in the vicinity of the Mlingase Fault Zone but are well-developed across the entire map area.

Exposure throughout the region is generally very good, the countryside being dissected by numerous streams that drain into the Theespruit River which, in turn, forms a major tributary of the Komati River. Topographically prominent features include the Boesmanskop syenite pluton, the ultramafic components of the greenstone stratigraphy on the farm Weergevonden 173 IT, and many of the mafic dykes traversing the area. The Mlingase Fault Zone produces a striking negative feature in the form of a narrow V-shaped valley, the latter clearly evident on aerial photographs and satellite images of the region. The dyke-like Weergevonden syeno-granite body also forms a poorly outcropping, negative-weathering zone across the northeastern corner of the map area but further to the southeast rises to form a whale-back ridge that appears to be fault bounded.

B. The Stratigraphy of the Weergevonden Greenstone Remnants

Under this heading are described the rock types comprising the main greenstone remnant shown in Figure 2 as well as the many smaller xenoliths scattered about in the trondhjemitic gneisses to the east, west and southeast of the principal greenstone occurrence.

1. *Mafic and Ultramafic Assemblages*

By far the most common rock types encountered in the greenstone relics are mafic and ultramafic massive and schistose rocks. The mafic rocks include black hornblendites which are developed in the areas immediately flanking the trondhjemitic gneisses, including most of the small xenolithic 'rafts' isolated and enveloped by zones of migmatite. Dark greenish black amphibolites containing mainly actinolite (actinolite ± hornblende ± tremolite ± chlorite) are developed in the ENE striking segment of the Weergevonden remnant on the farm Nederland 152 IT (Figure 2, A2 - A4). In this area which displays a considerable degree of flattening, as is witnessed by the prominent isoclinal folding of the formations, the mafic assemblages are interlayered with banded iron-formations, banded cherts and altered ultramafic layers. The southeastern limb of the greenstone remnant, on the farm Weergevonden 173 IT (Figure 2, B3, B4, A4), differs in that the mafic rocks are tightly infolded with prominent ultramafic layers as well as felsic schists. No banded cherts or banded iron-formations were noted in this segment of the greenstone remnant.

The ultramafic rocks in the map area have all been extensively altered to serpentinite or a variety of ultramafic schists including tremolite schists, talc-chlorite schists, talc-carbonate schists and talc schists. Prominent serpentinite ridges occur in the NE-striking limb of the splayed greenstone fold structure (Figure 2, B3 - B4) as well as in the N-S striking greenstone xenolith northeast of the syeno-granite dyke (Figure 2, A5). As will be discussed later, these ultramafic rocks, as well as an occurrence in map reference area C3 (Figure 2), have attracted attention in the past because of showings of chrysotile asbestos mineralization.

Isolated occurrences of serpentinite and other ultramafic alteration products (mainly talc and talc-chlorite schists) occur in the migmatites and gneisses in the southeastern part of the map area (Figure 2, B5, C3 - C5, D5), and represent resisters to the processes of migmatization and granitization of greenstone lithologies (see later).

2. *Banded Iron-formations and Banded Cherts*

Prominent banded iron-formation and chert units occur interlayered and intricately folded within the mafic schists developed on the farm Nederland 152 IT (Figure 2, A2 - A4, B2). Most of the banded iron-formations comprise oxide facies units, some of which have been prospected unsuccessfully for gold. Banded cherts (Plate 1A) consisting of black (carbonaceous), white, grey and brownish coloured layers are also developed within the amphibolite schists, and are locally prominent where the outcrops have been thickened as a result of duplication by folding (Figure 2, A4, B2). The banded cherts and iron-formations provide useful markers that outline the structural complexity of the isoclinally folded stratigraphy.

3. *Felsic Volcanic and Pyroclastic Rocks*

Felsic schists and pyroclastic rocks occur prominently interlayered and infolded with hornblende-rich amphibolites and serpentinites, particularly in the southern limb of the Weergevonden greenstone remnant. Most of the rocks under this heading comprise quartz-sericite (muscovite) schists, although more rarely, green fuchsitic schists may be encountered. As deformation has been severe primary textures are seldom encountered. A rare exception may be found in a stream section of the northward flowing Siyananabani stream which cuts across the entire greenstone succession where the two arms of the Weergevonden greenstone remnant join (Figure 2, A4, B4). Waterworn pavements in this stream section show what have been interpreted as flattened and sheared felsic agglomerate fragments (Plate 1B) in a matrix of quartz-sericite-biotite schist. Fragments, having dimensions in excess of 30 cm, were recorded at this locality. Felsic schists extending westwards along the southern flank of the northern limb of the greenstone remnant (Figure 2, A3) were once possibly joined to the greenstone remnant located west of the Mlingase Fault Zone (Figure 2, A1, B1). At this locality quartz-sericite schists are developed in a thin band along the southern flank of the xenolith and clearly recognizable lapilli fragments 1-2 cm in size were noted. If the units described above do correlate then it is suggested that the size variations of the fragments in the pyroclastic unit may reflect distance from a volcanic vent, the latter possibly being located near to geochemical sample sites LC14 and LC15 (Figure 2, A4). The prominent thickness, admittedly duplicated by folding, may be an added factor in determining the original site of eruption. Furthermore, and significant from an economic geology viewpoint, signs of sulphide mineralization (mainly pyrite) were detected at the agglomerate exposure.

The felsic units throughout the region have been extensively deformed and are now represented almost entirely by sheared, lineated, schists (Plate 1C). Of particular interest is the distribution of the felsic schists with respect to the intrusive trondhjemitic gneisses. Rare in other parts of the Barberton Mountain Land, but here commonly encountered, are felsic schists in immediate juxtaposition with the gneisses (Plate 1D, Figure 2, B2, B4). Furthermore, numerous felsic xenoliths occur in the granitic gneisses immediately flanking the main greenstone remnant (Plate 2, A, B; Plate 6, E), many of them contributing to the development of the migmatites (Plate 3).

4. *Geochemistry of the Felsic Schists*

Major and selected trace element analyses of three samples of felsic schist (altered felsic tuffs, agglomerates) from the Weergevonden remnant are listed in Table 1. The analyses compare favourably with those of similar rocks found in the Theespruit Formation of the Barberton greenstone belt (Anhaeusser, 1972; Viljoen and Viljoen, 1969a), although they are somewhat depleted in Al_2O_3 and are enriched in alkalis, particularly Na_2O. The felsic schists in the Barberton greenstone belt often contain the Al_2SiO_5 polymorphs sillimanite, andalusite, and pyrophyllite, but the absence of these minerals is also not unusual as quartz and sericite (muscovite, fuchsite) commonly make up the bulk of these rock types.

TABLE 1

CHEMICAL ANALYSES OF FELSIC SCHISTS, FELSIC HETEROGENEOUS GNEISS-MIGMATITES AND MARUNDITES (ALL POSSIBLY ALTERED ACID TUFFACEOUS ROCKS), ASSOCIATED WITH GREENSTONE XENOLITHS SOUTH OF THE BOESMANSKOP SYENITE PLUTON

	1	2	3	4	5	6	7	8
	LC14+	LC15+	LC29+	C3#	C4#	LC25A+	LC25B+	LC26+
SiO_2	76,08	73,14	75,68	74,29	74,80	21,45	20,46	21,53
TiO_2	0,20	0,25	0,15	0,20	0,23	0,31	0,70	0,39
Al_2O_3	12,80	12,95	12,79	12,66	13,10	60,79	59,41	60,56
Fe_2O_3	0,39	0,21	0,32	2,18*	2,22*	0,32	0,87	0,47
FeO	1,08	2,19	1,22			1,01	3,67	2,43
MnO	0,03	0,06	0,04	0,01	0,05	0,03	0,14	0,06
MgO	0,62	0,97	0,62	0,78	0,80	0,60	1,90	0,79
CaO	0,78	2,46	0,54	0,87	1,12	6,34	7,32	7,57
Na_2O	4,38	3,08	3,72	3,77	2,80	0,78	0,86	1,05
K_2O	2,79	2,87	3,93	3,86	3,40	2,39	0,37	0,13
P_2O_5	0,03	0,06	0,03	0,06	0,04	2,42	0,14	0,16
H_2O^+	0,55	1,26	0,83	-	-	3,01	3,83	4,19
H_2O^-	0,10	0,09	0,11	-	-	0,07	0,05	0,09
CO_2	0,16	0,36	0,05	-	-	0,11	0,07	0,05
LOI	-	-	-	0,49	0,74	-	-	-
Totals	99,99	99,95	100,03	99,17	99,30	99,63	99,79	99,47
Rb ppm	89	121	135	88	134	178	44	14
Sr ppm	93	90	101	100	185	871	1514	1650
Zr ppm	225	226	214	-	-	359	454	317
Ba ppm	896	789	1138	845	975	388	155	109

Analysts: + National Institute for Metallurgy # L.J. Robb

* Total Fe as Fe_2O_3

Columns : 1 - 3 Schistose felsic tuffs, agglomeratic in part (quartz-sericite-biotite-microcline-plagioclase). Locality, Figure 2, A4 and B3.

4 - 5 Heterogeneous gneiss-migmatite (possibly altered felsic tuff unit, Anhaeusser and Robb, 1978). Locality, Figure 2, C5

6 - 8 Marundites (corundum, margarite, biotite, epidote, apatite), Anhaeusser (1978). Locality, Figure 2, C5.

Alumina-rich rocks, known as marundites, have been reported in a greenstone xenolith west of the Badplaas-Lochiel road (Figure 2, C4, C5). Here marundites (corundum-margarite rocks) occur interlayered with amphibolites, talc schists, and serpentinites and are considered to represent the metamorphosed or metasomatized products of alumina-rich felsic units like those found in the

Theespruit Formation. Details of the marundite occurrence were provided by Anhaeusser (1978), including chemical analyses of the corundum-rich rocks (see also Table 1, columns 6-8).

Detailed studies of a water-worn river platform east of the marundite occurrence (Figure 2, C5) revealed an outcrop consisting of a heterogeneous gneiss-migmatite and a younger, intrusive, homogeneous tonalitic gneiss (Anhaeusser and Robb, 1978; Robb, in preparation). Evidence was presented suggesting that the hetereogeneous gneiss-migmatite (comprised of a fine-grained equigranular grano-dioritic parent showing differing degrees of deformation and anatectic veining, Plate 3, A-F) very likely represents a migmatized felsic rock that earlier had formed part of a typical greenstone stratigraphy. In support of this contention major and trace element geochemical data was provided which demonstrated the remarkable similarity between the rocks in the migmatite platform and the felsic schists in the Weergevonden greenstone remnant 3,5 km to the northwest (see also Table 1 and compare columns 1-3 with columns 4 and 5)

5. *Lithologic Correlation*

The lithologies described above and which constitute the main rock types encountered in the greenstone xenoliths can, with a high degree of confidence, be correlated with the lowermost stratigraphic members of the Onverwacht volcanic succession in the Barberton greenstone belt situated approximately 16 km to the northeast. Not only are the rock-types and lithological assemblages similar petrologically but, as has already been mentioned, it has been possible to trace, by detailed mapping, the units from one xenolith to the next until they eventually are found to merge with the Sandspruit or Theespruit formations of the Tjakastad Subgroup (the Lower Ultramafic Unit as defined by Viljoen and Viljoen, 1969a).

Geochemical confirmation of the correlations suggested cannot be offered from the study area at this stage as it was considered that the schistose mafic and ultramafic components of the xenoliths were generally unsuitable for analysis. However, numerous samples from xenoliths elsewhere south of the Barberton greenstone belt verify the presence of komatiitic basalts throughout the region (Anhaeusser and Robb, 1978; Anhaeusser, unpublished data).

C. The Granitic Gneisses and Migmatites

Intrusive granitic rocks are responsible for the fragmentation of the southern part of the Barberton greenstone belt and the consequent development of xenolithic remnants and areas of migmatite formation. As described previously the earliest intrusives comprise soda-rich granitic bodies, the latter apparently having been emplaced as diapiric gneiss plutons. Two such diapiric plutons occur in the study area (Figure 2). The smaller of the two, referred to as the Nederland pluton, occupies a roughly oval shaped area 3 km long, by approximately 1,5 km wide, and is responsible for the splaying apart of the Weergevonden greenstone remnant on the farm Nederland 152 IT (Figure 2, B2, B3).

The second and larger diapiric granitic body, known as the Weergevonden pluton, occupies the area southeast of the main greenstone remnant and is flanked in the south and southeast by fragmented xenoliths and an extensive zone of migmatites, gneisses and other hybrid products resulting from the interaction of granitic rocks with greenstones. The eastern sector of the diapiric pluton is obscured, having been truncated by the dyke-like Weergevonden syeno-granite body.

1. *Trondhjemitic and Tonalitic Gneisses*

Regional and detailed studies in the granitic terrane southeast of Badplaas have shown that there are several phases (ages) of trondhjemitic/tonalitic gneiss emplacement in the region (Anhaeusser and Robb, 1978). This observation has been substantiated by geochronological investigations which show a wide range of ages between the various diapiric plutons. Available U-Pb age determinations, undertaken by Oosthuyzen (1970) on zircons, show a spread of ages ranging from $\sim$ 3170 - $\sim$ 3250 Ma. Follow-up Rb-Sr isotopic studies, currently in progress, have confirmed these results and have, in addition, shown a wider range in ages extending from approximately 2900-3400 Ma (J.M. Barton, unpublished data).

The majority of granitic rocks shown in Figure 2 comprise strongly foliated leuco-biotite trondhjemite gneisses. Away from the pluton margins the trondhjemites are frequently, but not always, homogeneous in texture and it is not uncommon to find quartz blebs defining the foliation (Plate 4A). This foliation is invariably most prominently developed near greenstone contacts (Plate 1D) and can intensify to a stage where the gneisses become increasingly banded (Plate 5 A-D). Where xenoliths have been rafted off larger greenstone remnants these are often caught up in the trondhjemitic gneisses and show complex layering and interfingering of granitic and supracrustal components (Plate 2A, B, E; Plate 6A, C, E).

Homogeneous tonalites, believed to be younger than the foliated trondhjemites, occur in the southeastern part of the study area and are well-exposed in the river section east of the Badplaas-Lochiel road (Figure 2, C5). Here the tonalites intrude the heterogeneous gneisses (altered felsic schists) causing anatectic melting and migmatite formation (Plate 3 A-F).

2. *Trondhjemite/Tonalite Geochemistry*

A total of seven major and trace element chemical analyses of trondhjemitic and tonalitic rocks from the study area are listed in Table 2. These include two samples representative of the Nederland pluton (LC35, LC36) and two samples from the Weergevonden pluton (LC2, LC21). In addition, sample LC16 was collected from a small boss intruded into the northern limb of the Weergevonden greenstone remnant (Figure 2, A3), and LC27 originates from an apophysis of tonalite gneiss extending from the Nederland pluton into the greenstones developed on the southern limb (Figure 2, B3).

TABLE 2

CHEMICAL ANALYSES OF LEUCO-BIOTITE TRONDHJEMITIC AND TONALITIC GNEISSES IN THE AREA SOUTH OF THE BOESMANSKOP SYENITE PLUTON

	1	2	3	4	5	6	7
	LC2^{+}	LC16$^{\theta}$	LC21^{+}	LC27^{+}	LC35^{+}	LC36^{+}	C2$^{\#}$
SiO_2	71,26	70,10	70,89	61,88	68,35	66,05	68,77
TiO_2	0,20	0,28	0,19	0,89	0,39	0,64	0,52
Al_2O_3	15,94	15,20	16,19	17,55	16,61	17,18	17,18
Fe_2O_3	0,35	2,10*	0,37	0,81	0,59	0,62	3,22*
FeO	1,13		1,01	4,10	1,65	2,52	
MnO	0,03	0,04	0,04	0,08	0,04	0,04	0,01
MgO	0,62	0,50	0,76	1,64	0,93	1,33	1,14
CaO	2,34	2,05	1,51	4,86	2,64	3,31	3,09
Na_2O	5,45	5,20	5,71	4,12	5,42	5,25	4,45
K_2O	1,68	2,50	2,07	1,77	1,93	1,54	1,51
P_2O_5	0,07	0,09	0,07	0,40	0,13	0,22	0,18
H_2O^+	0,66	0,50	0,79	1,36	0,65	0,93	-
H_2O^-	0,10	0,11	0,13	0,08	0,12	0,11	-
CO_2	0,13	1,00	0,05	0,14	0,05	0,16	-
LOI	-	-	-	-	-	-	0,85
Totals	99,86	99,67	99,78	99,68	99,50	99,90	100,92
Rb ppm	62	75	72	113	81	71	58
Sr ppm	790	820	673	1032	755	868	754
Zr ppm	192	350	136	311	224	300	-
Ba ppm	566	690	758	797	612	562	220

Analysts: + National Institute for Metallurgy, Randburg
θ Bergström and Bakker, Johannesburg
L.J. Robb

* Total Fe as Fe_2O_3

Columns : 1 - 6. Various leuco-biotite tonalitic or trondhjemitic gneisses located on the farms Nederland 152 IT and Weergevonden 173 IT (Figure 2).

7. Younger intrusive tonalite gneiss. Locality in river section east of the Badplaas-Lochiel road (Figure 2, C5). Sample site given in Anhaeusser and Robb (1978).

The younger tonalite gneiss (Table 2, column 7) was obtained from the river platform (Figure 2, C5), the exact sample locality being given in Anhaeusser and Robb (1978).

The analyses provide a measure of the differences that exist in the compositions of the Na-rich granitic rocks taken from diverse geological settings in the study area. Variations are most pronounced in the range of abundances of SiO_2 (61,88% - 71,26%), Al_2O_3 (15,20% - 17,55%)

CaO (1,51% - 4,86%) and combined FeO and Fe_2O_3 (1,37% - 4,91%). Trace element variations are relatively minor with the exception of low Ba in the younger tonalite (Table 1, column 7).

An arbitrary figure of 70% SiO_2 has been selected as the dividing line between rocks referred to as trondhjemites (> 70% SiO_2) and rocks termed tonalites (< 70% SiO_2). The tonalites are furthermore generally more ferromagnesian-rich (mainly due to biotite) and also have higher TiO_2, CaO and P_2O_5 than do the leucocratic trondhjemites. These chemical differences are in accord with the definition of trondhjemite employed by Barker et al. (1976) who viewed these rocks as "tonalites whose plagioclase is oligoclase or albite and whose colour index is 10 or less".

The suggestion has been made that the Sr contents of the trondhjemitic/tonalitic gneisses may provide a basis for distinguishing the relative ages of the granitic rocks in the numerous diapiric gneiss plutons south and southwest of the Barberton greenstone belt. Data has been presented (Anhaeusser and Robb, 1978), and the postulate made, that trondhjemitic gneisses with low Sr concentrations (average 608 ppm Sr) are older than trondhjemitic gneisses yielding high Sr concentrations (average 759 ppm Sr). These observations were backed by the physical relationships exhibited by the two types in the field as well as by a limited amount of geochronology. Further work in progress (Robb, in preparation) may confirm these preliminary findings. Should the concept prove to be correct it might suggest that the trondhjemitic/tonalitic plutons in the study area are of a younger variety (average 813 ppm Sr), and it may eventually be possible to provide absolute age constraints on the plutons in the entire region based on the Sr contents of the rocks.

3. *Migmatites and Banded Gneisses*

Excellent exposures of migmatites and banded gneisses occur throughout the region but are particularly well-displayed in the southeastern part of the map area around the margins of the Weergevonden pluton and in river sections east of the Badplaas-Lochiel road. Good migmatite exposures are also evident along the Theespruit River, west of the Boesmanskop syenite pluton (Figure 2, A1).

As has already been mentioned, the migmatites and some of the well-banded gneisses are not randomly distributed throughout the area but are intimately associated with remnant greenstone xenoliths. This physical interrelationship can be demonstrated throughout the granitic terrane south and southwest of the Barberton greenstone belt (Anhaeusser and Robb, 1978; Anhaeusser, in preparation) and the presence of migmatites is interpreted as being the result of granite-greenstone interaction (anatexis, metasomatism, palingenesis, granitization).

Migmatites, by their very nature, are highly complex rock types possessing variable textures and chemical compositions. Mehnert (1968) defined migmatite as "megascopically composite rock consisting of two or more petrographically different parts, one is the country rock in a more or less metamorphic stage, the other is of pegmatitic, aplitic, granitic, or generally plutonitic appearance". Due to their complex nature a wide range of definitions have emerged describing the many structures commonly encountered in these rocks and a full list is provided by Mehnert (1968). In this contribution some of the features found in the migmatite platforms in the study area are best illustrated in photographs. Detailed studies of selected platforms in the migmatite areas south of the Barberton greenstone belt are currently in progress (Robb, in preparation) — hence, no attempt will be made here to elaborate on the detailed genetical aspects of migmatite formation in the area.

The pattern of migmatite development that emerges appears to follow the sequence of events outlined below :

1. a supracrustal greenstone succession is invaded by an early tonalitic/trondhjemitic magma, the latter probably derived from the partial fusion of basic parental rocks (primitive ensimatic basalts) in a manner similar to that now well-documented by the experimental work of Green and Ringwood (1968) and Lambert and Wyllie (1972).

2. the rising tonalitic magma, emplaced in the form of diapiric plutons, causes structural disturbance of the supracrustal sequences, producing folding and faulting and imparting to the rocks a dynamo-thermal metamorphic fabric (schistosity).

3. at the greenstone margins, particularly, this schistosity is generally more intense and the invading magma takes advantage of the rock anisotropy and forces its way up the fabric planes to produce a lit-par-lit-injection layering. This can take place on a variety of scales and large rafts or xenoliths may result, the latter having been torn or wedged from the parent greenstone body (Plate 2A).

4. continued magmatic activity associated with the emplacement of the granitic diapirs results in the development of additional partial melt products manifest in the migmatite exposures as supplementary veins (concordant as well as crosscutting dykelets genetically linked with the Na-rich intrusive magma).

5. heat effects, stemming from the intrusion of the trondhjemites, cause differential anatectic melting of selected rock types (e.g. felsic schists, Plate 3 A-F; 6C). These anatectic products may also appear as concordant or crosscutting veins and dykelets and become intricately distorted with increasing or superimposed deformation.

6. with advancing diapirism incremental strain additions result in extension and shearing phenomena as well as flattening and folding of the various lithological units. Ductility contrasts between the trondhjemitic gneiss layers and the other granitic and supracrustal units may lead to the development of boudinage structures (Plate 2 A-C; 5F), dismembered layers and lenses (Plate 2D, E), ptygmatic and convolute folds (Plate 3C; 5F), as well as augen structures and zones of mylonite and microbrecciation. Caught up in all this complexity may be additional features such as late stage mafic dykes that are likewise folded, boudinaged, or attenuated (Plate 2F; 6D).

7. in addition to anatectic melting and the tectonic history of the rocks discussed above there is the accompanying metasomatizing or granitizing influence of the invading magma and associated volatiles which, altogether, result in the feldspathization (tonalitization) of the supracrustal and later dyke rocks (Plate 4 B-F; 6D). Successive stages of resorption (metasomatic granitization) may also be witnessed, the process leading to the development of nebulites and, ultimately, to homogeneous granitic rocks devoid of all traces of their involved prehistory.

The majority of migmatites described in the preceding sections are of *arteritic* origin i.e. they were formed by the injection of a trondhjemitic/tonalitic magma into the supracrustal parent rocks. Exceptions include the anatectically banded felsic gneiss-migmatites from the Weergevonden river platform (Figure 2, C5 and also illustrated in Plate 3). These rocks are *venitic* in origin, having been formed by *in situ* mobilization of the veins following differentiation processes that separated the paleosome (parent rock of a migmatite) into lighter and darker bands (leucosome and melanosome respectively).

This process of venitic banded gneiss formation is evident elsewhere in the study region but is particularly prominent west of the corundum-bearing marundite occurrence (Figure 2, C4) where denuded pavement outcrops exhibit stromatic (layered) gneisses (Plate 5 A-D). These exposures occur amidst a fragmented greenstone remnant and the banded gneisses, which consist of light (feldspar and quartz) and dark (mainly biotite) layers, appear as newly formed rocks (the neosome) derived from the modified parent greenstone country rock (the paleosome).

The possibility exists that some of the mafic material seen in these exposures may be dykes but their high degree of conformity with the banded gneisses (Plate 5A) does not permit unequivocal resolution of this suggestion. However, whatever the original nature of these mafic bands may have been they too have contributed to the development of the stromatic layers. Close examination shows how the mafic bands tail out into the more leucocratic banded gneisses, helped along by selective recrystallization caused by metamorphic differentiation (Plate 5 B, C). The rocks at this locality are also strongly tectonized and may have developed in a somewhat deeper metamorphic zone than rocks elsewhere in the area.

D. Hybrid Granitic Rocks

At scattered localities throughout the study area hybrid or contaminated granitic rocks (also supracrustal rocks to a lesser extent) appear as variants to the more commonly developed migmatites. The hybrid rocks probably formed as a result of passive assimilation of the country rocks by the invading granitic rocks. Many of the hornblendite xenoliths show varying degress of feldspathization (Plate 4B, D), and compositional changes range from amphibolites to hornblende diorites.

Assimilated greenstones and hybrid tonalitic and dioritic rocks from an area approximately 2 km west of the corundum occurrence (Figure 2, C3, near asbestos prospects) are illustrated in Plate 4C, E and F. Small altered ultramafic schlieren and skialiths are preserved in places and contribute to the development of the banded foliated rocks seen in some outcrops. The feldspathization process has in places, destroyed or homogenized the parent rock and there is a coarsening of grain-size as is illustrated by the plagioclase blastite shown in Plate 4C.

E. Syenites and Syeno-granites

Syenites and syeno-granitic rocks occur throughout the study region and form part of a family or suite of undersaturated intrusives that are embraced by the term "Boesmanskop syenite" and which have been studied in detail by Anhaeusser et al. (1979).

The Boesmanskop pluton, the largest of four intrusive bodies in the Archaean granite-greenstone terrane of the southwestern part of the Barberton Mountain Land, occupies the area immediately north of the Weergevonden greenstone remnant (Figure 2, A1-A4) and extends over the greater part of the farm Nederland 152 IT.

The Boesmanskop pluton is texturally the most varied of all the syenite bodies, consisting of coarse pinkish-grey porphyritic syenite on the northern flank of the pluton, coarse pink homogeneous syenites in the centre and medium-to-fine-grained pink quartz syenites in the south. Chemical analyses of two samples of quartz syenite from this latter area are listed in Table 3, columns 4 and 5. Sample BK24 originates from one of three prominent bare rock prominences or tors known locally as the "Pramkoppies" (Figure 2, A3, A4 - tors outlined with fine dot pattern). Samples collected in this vicinity yielded a Rb-Sr whole rock isochron age, mentioned earlier, of 2848 ± 31 Ma (R_0 = 0,7040 ± 0,0004).

The syenite pluton does not appear to have influenced thermally, the adjacent Weergevonden greenstones. The contact zone between the two rock units is, however, not well-exposed because of scree covered slopes.

TABLE 3

CHEMICAL ANALYSES OF VARIOUS SYENITIC ROCKS IN THE NEDERLAND-WEERGEVONDEN AREA, EAST OF BADPLAAS

	1	2	3	4	5
	LC12	LC20	LC22	BK24	BK25
SiO_2	63,69	60,06	62,56	64,58	68,54
TiO_2	0,07	0,17	0,16	0,78	0,57
Al_2O_3	17,15	20,76	19,85	15,41	14,76
Fe_2O_3	1,93	1,61	0,75	2,51	1,95
FeO	1,65	0,43	0,79	2,02	1,09
MnO	0,09	0,06	0,05	0,12	0,08
MgO	1,55	0,47	0,87	1,19	0,56
CaO	2,12	4,83	2,10	2,82	1,71
Na_2O	4,84	4,72	4,53	4,36	4,34
K_2O	5,74	5,90	6,68	4,96	4,94
P_2O_5	0,26	0,07	0,07	0,52	0,30
H_2O^+	0,36	0,67	0,96	0,26	0,46
H_2O^-	0,08	0,09	0,13	0,21	0,21
CO_2	0,08	-	-	0,04	0,05
Totals	99,61	99,84	99,50	99,78	99,56
Rb ppm	228	382	405	230	280
Sr ppm	1294	372	234	1530	1120
Zr ppm	704	165	176	260	260
Ba ppm	1506	715	715	1700	1250

Analysts : National Institute for Metallurgy, Randburg

Columns : 1. Foliated, coarse porphyritic, pink syenitic gneiss. Locality, Figure 2, C3.

2-3. Homogeneous, medium-fine-grained, leuco-syenites. Locality, Figure 2, A4.

4-5. Homogeneous, medium-fine-grained, quartz syenites. Locality, Figure 2, A2 and A3.

From the southeastern extremity of the Boesmanskop pluton there extends a dyke-like syenite tail known as the Weergevonden syeno-granite body (Anhaeusser et al., 1979). In the study area rocks forming this 1 km wide zone are poorly exposed except in the tributary valley of the Siyananabani stream (Figure 2, A4) and in other stream exposures to the southeast (Figure 2, B5). At the first mentioned location material suitable for chemical analysis was obtained, the values being listed in Table 3, columns 2 and 3.

The Weergevonden syeno-granite is unlike all the other syenites in the area, being a pale grey, leucocratic rock with a uniform, medium-to-fine-grained texture. The rocks are dominantly composed of microcline, microperthite, orthoclase and plagioclase (oligoclase-albite) with minor quartz. Epidote and sericite are common and accessory quantities of apatite, sphene, chlorite and carbonate were observed (Anhaeusser et al., 1979).

The two analyses listed in Table 3 are enriched in Al_2O_3 and K_2O and depleted in total iron, TiO_2 and P_2O_5 relative to the quartz syenites of the Boesmanskop pluton. Samples from other parts of the dyke-like body yielded SiO_2 values in excess of 73% SiO_2 and lower combined alkalis. Free quartz is also evident in these rocks and the entire suite displays a wide range of compositions extending from syenite to quartz syenite and granite (*sensu stricto*).

The Weergevonden syenite dyke cuts across the main greenstone remnant in the area and has itself caught up a number of greenstone xenoliths. South of the largest of these remnants (Figure 2, B5) river exposures show that the syenite body is extensively sheared, fractured and jointed along the southwestern flank. Evidence outside the map area to the southeast suggests the body may be fault-bounded.

A third syenite occurrence is located immediately north of the Mlingase Fault Zone (Figure 2, C2, C3). Referred to as the Welverdiend syenite (Anhaeusser et al., 1979) this body consists of coarse, porphyritic pinkish syenite, grading into finer-grained quartz syenites and syeno-granites. Exposure is very variable and the syenites display evidence of having been tectonically disturbed by shearing. Sample LC12 consists of pink, porphyritic, quartz syenite with feldspar phenocrysts and ferromagnesian components strongly aligned and displaying an augen texture (Plate 5E). In places feldspar phenocrysts upwards of 4 cm in length were noted and the rocks are strongly foliated in a northeasterly direction, at right angles to the Mlingase shear zone.

The single sample analysed (Table 3, column 1) shows that chemically, the Welverdiend body has affinities with the Boesmanskop quartz syenites and, as is displayed by differences in certain of the major elements (particularly SiO_2, Al_2O_3, total Fe, MgO and TiO_2) and all of the trace elements, is distinct from the Weergevonden syenites listed.

Anhaeusser et al. (1979) concluded that the Boesmanskop syenite suite (i.e. including all the occurrences of syenite in the district) defines a prominently oversaturated trend. Trace and rare-earth element modelling led to the suggestion that the syenitic magma was derived by extensive partial melting of an intermediate-to-felsic source (possibly close in composition to granodiorite). Part of this melt may have intruded along a conduit, possibly at a higher crustal level, to form the distinctive rocks in what is now the Weergevonden syeno-granite tail. The melt remaining in the magma chamber is considered to have undergone fractional crystallization to produce a range of syenites, quartz syenites and granites (*sensu stricto*). Finally, Anhaeusser et al. (1979) maintained that the initial $^{87}Sr/^{86}Sr$ ratio ($\sim$ 0,7040) is not compatible with a primitive basaltic source such as is envisaged for the Archaean Linden syenite in Minnesota (Arth and Hanson, 1975; Hanson et al., 1971; Prince and Hanson, 1972).

F. Intrusive Dykes

A great many dykes were intruded into the granite-greenstone terrane south of the Barberton greenstone belt. The majority of these are mafic in composition and are generally considered to be of Proterozoic age. In addition, however, there are several other dyke varieties, including granitic types, which cut across earlier formations and in some instances are themselves cut by later generation intrusives.

1. *Younger Diabase Dykes*

Most of the dykes displayed in Figure 2 are medium-grained diabase or porphyritic diabase intrusives. In some cases the dykes contain inclusions of granitic country rock showing graphic intergrowth textures. Less common are dykes of gabbro or fine-grained, rapidly chilled intrusives. The dykes vary from narrow veins a few centimetres wide up to substantial bodies several hundred metres across (Figure 2, C4). Most dykes are vertical to subvertical in attitude and trend in a NW-SE direction, parallel to the superimposed regional dyke and fracture directions. A dyke swarm occurs in and adjacent to the Mlingase Fault Zone and it is not uncommon to encounter multiple parallel dykes in places (Figure 2, A4).

No absolute ages are available for these intrusives which show no signs of metamorphism or structural disturbance other than faulting. They do, however, display deuteric alteration, the feldspars in places being saussuritized and the pyroxenes uralitized. As mentioned previously, the relationships displayed by these dykes to rocks of the Transvaal Drakensberg escarpment near Badplaas suggests they may be mainly of early- or middle-Proterozoic age.

2. *Older Mafic Dykes*

Dykes falling under this heading include clearly cross-cutting examples of metamorphosed, often partly resorbed material that appears to have been emplaced into the region prior to the cessation of granitic igneous activity approximately 3 000 Ma ago. These dykes are not extensively developed and are generally only exposed in isolated pavements and river platforms. A good example of a metamorphosed mafic dyke may be seen in the river section east of the corundum occurrence (Figure 2, C5). The dyke, which is only approximately 10 cm wide, is cut by medium-fine grained granodioritic dykes and pegmatite veins. Detailed petrographic as well as geochemical and isotopic studies are currently being undertaken on rocks from this locality and will be reported elsewhere (L.J. Robb and J.M. Barton, in preparation).

Deformed mafic dykes as well as partly granitized dykes were noted in, and adjacent to, the Weergevonden diapiric pluton (Plate 2F; 6D). Other "dyke-like" material is associated with banded gneisses west of the corundum occurrence (Plate 5 A, B, C) but because of reasons already discussed there is no assurance that these rocks may not represent resistant slivers of a once extensive greenstone remnant.

3. *Felsic Dykes*

Numerous felsic dykes occur throughout the area and are manifest in the form of fine-grained aplitic veins, stringers and cross-cutting bands. Also included under this heading are other granitic dykes (including cross-cutting pegmatite and granodiorite veins). Most of the latter rock types occur in the southeastern sector of the map area and are believed to be related to the Mpuluzi batholith and the Lochiel granites (Homogeneous Hood granite described by Viljoen and Viljoen, 1969b).

The felsic dykes are clearly of several ages as they are seen to crosscut one another. Some dykes also display a mineral foliation (Plate 6F) suggesting they may have been injected as late magmatic phases of the trondhjemite gneisses prior to final stage tectonism accompanying diapirism.

IV. STRUCTURE

The structural history of the area south of the Boesmanskop syenite pluton can be divided into two principal episodes; the first associated with the emplacement of the diapiric gneiss plutons and the second being linked with later stages of regional deformation and magmatism. This latter structural episode includes the emplacement of the syenitic bodies, and the late stage injection of the mafic dykes. Linked to both these events are the major regional shear and fault deformations that influenced the magmatic activity.

A. Deformation Associated with Granite Diapirsm

Excluded from this discussion are possible deformational effects that may have been developed in the supracrustal greenstone successions prior to the emplacement of the trondhjemitic gneiss diapirs and which might have included extensive folding and faulting.

Folding there undoubtedly is in the Weergevonden greenstone remnant but whether this was developed solely as a response to diapiric granite emplacement remains uncertain. Throughout the region shown in Figure 2 the attitude of the formations is generally very steep (vertical to subvertical) except in some of the fold closures where flatter dips may be encountered. Because of the generally steep attitude of bedding, schistosity and gneiss foliation it was considered unnecessary, for the purposes of this regional geological account, to include structural data on the geological map of the area. Trend lines of schistosity and foliation are shown and effectively demonstrate the main structural features of the study region.

The Nederland pluton, described earlier, appears to have risen in the axial zone of the Weergevonden greenstone remnant forcing aside the two limbs and initiating (or intensifying) folding in each. These folds, and others in the area north of the Weergevonden pluton, plunge steeply ($\pm$ 75^{o}) to the ENE suggesting that the main greenstone remnant likewise plunges steeply in this direction. Lineations seen in many of the supracrustal rocks (e.g. Plate 1C) and the gneissic granites are also subvertical and are developed in the planes of the schistosity (foliation).

The ENE plunging greenstones curl away to the NW and SE where they abut against the dyke-like Weergevonden syenite body, forming an anvil-shaped structure (Figure 2, A 4). The northern half of the greenstone stratigraphy folds around the southeastern nose of the Boesmanskop pluton whereas the southern half sweeps around the northern arc of the Weergevonden pluton. This dramatic directional change takes place within only a few hundred metres of the contact of the greenstone xenolith and the syenite dyke and it would appear that the telescoping of the formations was produced mainly by the emplacement of the syenite body.

The granite diapirs, as described previously, were responsible for the main disruption of the greenstones and their consequent fragmentation into xenoliths and areas of migmatite formation. The xenoliths, and the structures within the migmatites, are invariably orientated parallel to the foliation of the trondhjemitic gneisses (Plate 1D, 2A).

Involved fold and other structures are evident in many migmatite platforms and these are mainly due to incremental strain brought about by progressive stages of diapiric movement of the gneiss plutons, coupled with the possibility that the diapirs were not necessarily all emplaced synchronously. The migmatite platforms around the northwestern arc of the Weergevonden pluton display folds, sheared and disrupted greenstone lenses and rafts, folded dykes and boudinage structures (Plate 2 A - F). These features, when seen together in single exposures, are generally suggestive of a long and complex history. The complexity is further compounded by the many cross-cutting granitic and other dykes referred to earlier. However, a knowledge of the broader regional geology of the area imposes constraints on the number of geological events that may have influenced the study area structurally. The conclusion is reached that most of the complexity displayed in the migmatites is merely a manifestation of progressive deformation caused by granite diapirsm. Boudinaged lenses of trondhjemitic gneiss together with greenstone relics (Plate 2 A, B, C), are interpreted as having formed in successive stages, involving initial lit-par-lit injection of the granitic components and the subsequent flattening of the sequences as the diapiric plutons matured (see earlier discussion on migmatite development). Spelt out in other words, it is deemed highly unlikely that each structural direction or feature seen in the migmatite pavements reflects a unique deformational episode. Rather they are seen to be the response to a limited number of intrusive events, with each intrusive pluton or diapir being responsible for a continuum of structural responses.

B. Deformations Post-dating the Trondhjemitic Diapirs

The preferred NW-SE orientation of the syenite occurrences associated with the Boesmanskop syenite pluton coincides with a number of other geological features of regional significance. These include the prominent NW-SE dyke swarm, several major fracture or shear zones and the presence of hot springs, the largest of which is located at Badplaas (Figure 1), with a second situated near the confluence of the Theespruit and Mlingase rivers (Figure 2, A1). The prominence of this trend is furter amplified by the development, in the area well to the southeast (≈ 45 km) of the region depicted in Figure 2, of the 2874 ± 30 Ma Usushwana Igneous Complex (Davies et al., 1970). It is therefore evident that the region south and southwest of the Barberton greenstone belt has been involved in a long and complex history of crustal evolution - a process that is still active to this day, as manifest by the thermal spring activity in the region.

The structural effects resulting from the emplacement of the syenite bodies do not appear to have been considerable. Only the Weergevonden syeno-granite dyke, which truncates the main greenstone remnant, appears to have produced an unusual flattened fold structure. Unfortunately, exposure limitations in the greenstone-syenite contact area do not permit a detailed analysis to be made of the mechanics of the structure. It is also not clear whether the syenite alone produced the flattening or whether faulting played any role. It is furthermore possible that the syenite may be obscuring an early trondhjemitic diapiric body, signs of which exist northeast of the dyke (Figure 2, A5).

The Mlingase Fault Zone produces a prominent linear break along the entire southwestern flank of the map area. The river has taken advantage of the fracture system and has cut a deep V-shaped valley which forms a significant topographic feature over a distance of about 15 km. The fault zone comprises numerous parallel fractures, many of which have been filled by quartz veins or diabase dykes. In places the granitic rocks are extensively sheared in the fault area but elsewhere undisturbed granites occur close to quartz filled fractures or mylonitic breaks.

Minor fractures, shears and joints, often associated with quartz veins (Plate 6B) occur throughout the region and vary considerably in age. Some of the youngest faults and fractures cause dyke displacements. The major regional fractures appear to post-date the Proterozoic Transvaal Drakensberg cover sequences as they can be traced, using satellite images, to the escarpment and beyond in the northwest (Anhaeusser, in preparation). They may, however, in so doing, merely reflect reactivation of much earlier, possibly Archaean, faults and shears.

V. ECONOMIC GEOLOGY

In the preceding sections mention has been made of gold and chrysotile asbestos prospects. In addition, corundum as well as sulphides (mainly pyrite) were noted during the regional mapping programme. A hot spring found in the area will also be briefly described in this section.

A. Gold

A limited number of prospect pits occur in the banded iron-formations and ferruginous cherts immediately south of the Boesmanskop syenite pluton (Figure 2, A3). Judging from the scale of these old workings there is little encouragement that gold exists in these rocks.

B. Chrysotile Asbestos

Prospecting for chrysotile asbestos was carried out at three separate localities in the study area. Probably the most extensive prospecting (still only on a small scale) was undertaken near the boundary of the farms Nederland 152 IT and Weergevonden 173 IT, along the southern limb of the Weergevonden greenstone remnant (Figure 2, B3). Prospect pits and shafts also occur in a small serpentinite xenolith approximately 1,5 km south of the abovementioned asbestos showings (Figure 2, C3). Ribbon fibre, like that displayed in Plate 1 E and F, occurs only in limited quantities. A third location where chrysotile fibre has been exposed in trenches and pits occurs in the greenstone xenolith northeast of the Weergevonden syenite dyke (Figure 2, A5) where a large body of folded serpentinite is enveloped by amphibolites. At this and the aforementioned localities insufficient asbestos fibre was found to warrant exploitation.

C. Corundum

Mention has been made of a marundite occurrence in a greenstone xenolith which straddles the Badplaas-Lochiel road on the farm Weergevonden 173 IT (Figure 2, C5). Marundites, a term compounded from the names of the two essential minerals margarite and corundum (Hall, 1920), are comparatively rare rocks, having only been reported in southern Africa in the Pietersburg, Zoutpansberg and Leydsdorp districts of the Transvaal (Hall, 1920, 1922) and the Nkandhla area of Natal (Du Toit, 1931).

Details of the marundite deposit in the study area were described by Anhaeusser (1978) and only a brief account of the occurrence will be given here. Poor exposure limits a clear understanding of the field situation of the marundites which outcrop sporadically over a distance of about 500 m. The "boulder corundum" is marked by the presence of loose blocks that appear to be the eluvial residue of a layer denuded by erosion and which probably lay conformably within the surrounding mafic and ultramafic schists.

In addition to corundum and margarite, the marundites contain a wide range of accessory components including biotite, apatite, tourmaline, magnetite, chlorite, rutile, sericite, epidote, garnet, muscovite and hydromuscovite. Three samples chemically analysed are listed in Table 1, columns 6-8. Although basically similar, the analyses reflect the mineralogical variations encountered (e.g. LC25A contains apatite as a prominent accessory mineral and the rock displays a relatively high P_2O_5 value). In the remaining two samples biotite features prominently and the amounts of Fe, Ti, Mn and Mg show a slight increase over the biotite free sample.

The most significant features of the marundite chemistry are the high Al_2O_3 and CaO and low SiO_2 values, reflecting the principal minerals corundum and the brittle, silvery white or pale pearly pink margarite mica.

The origin of the Weergevonden marundites remains obscure. Other southern African examples have shown that these rocks are often intimately associated with plumasites and that they had been altered pneumatolytically to form intermediate margarite-plumasites and, ultimately, marundites. Anhaeusser (1978) suggested, however, in view of the absence of pegmatites, that the Weergevonden marundites might represent a reconstituted (metamorphosed or metasomatised) Al-rich stratigraphic interlayer, the latter possibly similar to the Al-bearing felsic schists reported in the Theespruit Formation of the Onverwacht Group.

D. Sulphide Mineralization

The felsic agglomerates in the Siyananabani river section (Figure 2, A4) display surface staining resulting from the oxidation of sulphide mineralization (pyrite specks). Grab samples analysed from this locality yielded the following average values : 145 ppm Cu, 13 ppm Pb, 36 ppm Zn and 63 ppm Ni (analyses undertaken by J.C.I. Exploration, Research and Development Division, Randfontein).

E. Thermal Spring

On the north bank of the Theespruit River, on the farm Nederland 152 IT, is a hot spring which bubbles out of the ground approximately 3 m from the mean water level of the main river channel. The spring is situated close to a mafic dyke that occurs in the Mlingase Fault Zone (Figure 2, A1). A smell of H_2S gas is weakly apparent at the site and the temperature of the water was found to be 37°C. The temperature of the adjacent river water was 19,5°C (readings taken in October, 1976, at 17.00 hrs.).

VI. SUMMARY AND CONCLUSIONS

The principal features of the granite-greenstone terrane south of the Boesmanskop pluton may be summarized as follows :

1. A large greenstone remnant (the Weergevonden greenstone occurrence) and numerous smaller xenoliths or enclaves of greenstone represent fragments of the basal stratigraphy of the Barberton greenstone belt, the main body of which is situated approximately 16 km to the northeast (the Sandspruit and Theespruit formations of the lower Onverwacht Group).

2. The greenstone xenoliths resulted from the intrusion, into the areas flanking the Barberton greenstone belt, of numerous trondhjemitic/tonalitic gneiss diapirs which disrupted the supracrustal sequences and, at the same time, reacted with them to produce a complex array of migmatites and gneisses.

3. Granitic diapirism was responsible for most of the deformation and metamorphism exhibited in the greenstone remnants and, in addition, was probably also responsible for the complex structures exhibited in the migmatite platforms. The structural history envisaged is one of granite intrusion (lit-par-lit rafting off of variously-sized greenstone lenses) followed by incremental strain additions accompanying the continuously rising diapiric gneiss plutons.

4. Migmatites occurring in the area are mainly developed in areas flanking greenstone xenoliths, being particularly prominent along strike of the mafic, ultramafic or felsic components of the supracrustal sequences. The migmatites were mainly produced as a result of trondhjemitic magma being emplaced into the region but superimposed K-rich granitic phases have locally enhanced or supplemented the processes of granitization, metasomatism, resorption and anatectic melting in parts of the area.

5. Later magmatic events in the study area included the emplacement of the suite of syenitic rocks associated with the 2 850 Ma Boesmanskop syenite pluton (the Welverdiend and Weergevonden syeno-granites) and the diabase dyke swarm, considered to be mainly early-to-middle Proterozoic in age (1 800 - 2 400 Ma).

6. The late magmatic events described above may have accompanied a period of regional tectonic activity which produced numerous NW-SE orientated faults, fractures and shear zones. These events may have been initiated in the Archaean but probably reached a peak during Proterozoic times.

7. Mineralization in the area appears to be restricted to uneconomical showings of gold, chrysotile asbestos and corundum. Sulphide mineralization present in the felsic agglomerates appears at first sight to be disappointing but offers the most potential as an exploration target for massive sulphide Cu-Zn-type mineralization.

ACKNOWLEDGEMENTS

The writer wishes to acknowledge discussions held with L.J. Robb on aspects of the geology of the region south of the Barberton greenstone belt and with whom collaborative studies are being undertaken as part of the South African Geodynamics Programme. Thanks are also extended to Mr. N.A. de N.C. Gomes who undertook the draughting of the geological map of the area and to Mrs. L. Tyler and Mrs. D. Amaler for typing the final manuscript.

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KEY TO PLATE 1

A. Banded black and white chert from the northern half of the Weergevonden greenstone remnant (Figure 2, A4). The cherts are commonly isoclinally folded and show internal contorted banding (lower left) as well as regular layering.

B. Deformed felsic agglomerate from the Siyananabani river section (Figure 2, A4, B4). The light coloured felsic fragments have been strongly sheared and flattened in a dark matrix of quartz-sericite-biotite schist.

C. Quartz-sericite schists in the Weergevonden greenstone remnant showing a prominent subvertical lineation, the latter plunging to the ENE at approximately 75° (Figure 2, A4).

D. Contact between felsic schist (quartz-sericite schist) and foliated leuco-biotite trondhjemitic gneiss (left). A zone of anatectic quartz occurs along the immediate granite-greenstone contact. Locality, northern rim of the Weergevonden diapiric gneiss pluton (Figure 2, B4).

E. Altered ultramafic rock showing serpentinite "boulders" rimmed by chrysotile asbestos ribbon fibre. Locality, greenstone enclave south of prominent diabase dyke on the farm Weergevonden 173 IT (Figure 2, C3).

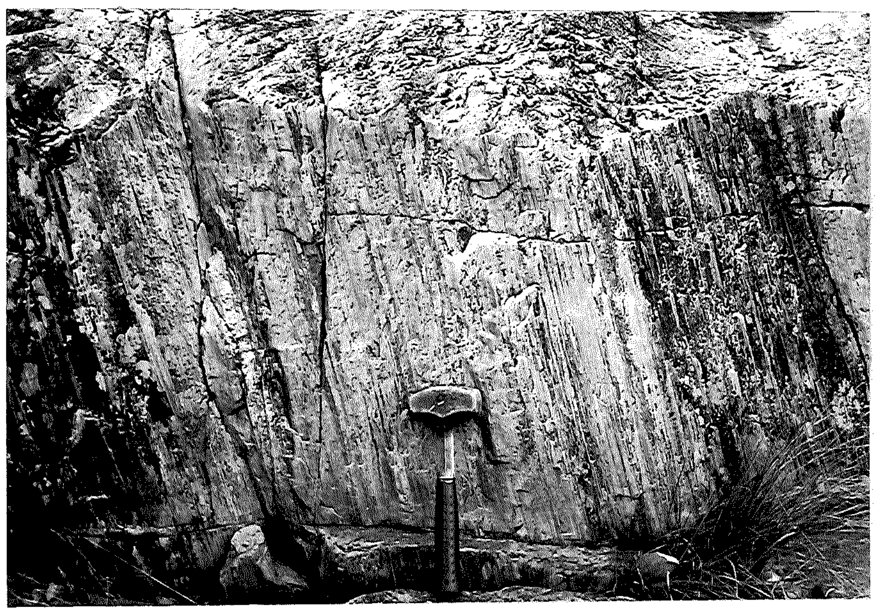
F. Banded chrysotile ribbon fibre in dark blue black serpentinite. Locality, as in E above.

PLATE 1

A

B

C



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KEY TO PLATE 2

A. Migmatite-gneiss pavement on the northwestern rim of the Weergevonden pluton (Figure 2, B4). The trondhjemitic gneisses display lit-par-lit intrusive relationships with the supracrustal greenstones which consist of boudinaged and lensoid rafts of felsic schists. A boudinaged mafic dyke is shown on the left hand edge of the photograph.

B. Foliated felsic schists and boudinaged granitic layer (trondhjemite or early granitic phase related to trondhjemite gneiss pluton) exposed in a migmatite pavement on the northwestern rim of the Weergevonden pluton (Figure 2, B4). Cross-cutting aplitic and anatectic veinlets are also evident.

C. Boudinaged ovoid bodies of foliated trondhjemite gneiss (left) and beneath geological hammer. The material flowing into the necked region between the gneiss boudins comprises banded and foliated felsic schist (altered felsic tuff). Quartz veins and finely developed anatectic stringers occur in the felsic schists and in the voids created between the boudinaged gneisses. Locality, same as B above.

D. Sheared agmatitic lenses of supracrustal rocks intruded by trondhjemitic/tonalitic gneiss. Locality, migmatite platform same as B above.

E. Lenses of granitized supracrustal rocks (mainly felsic schists), intruded by tonalitic gneiss (grey). Both rock types are sheared and foliated parallel to the granite-greenstone contacts. Lighter coloured rocks represent later crosscutting granitic rocks and anatectic veins and stringers. Locality, as with B above.

F. Folded and partially granitized mafic dyke enveloped by foliated trondhjemitic gneiss and granitized felsic schist. Same locality as B above.

PLATE 2

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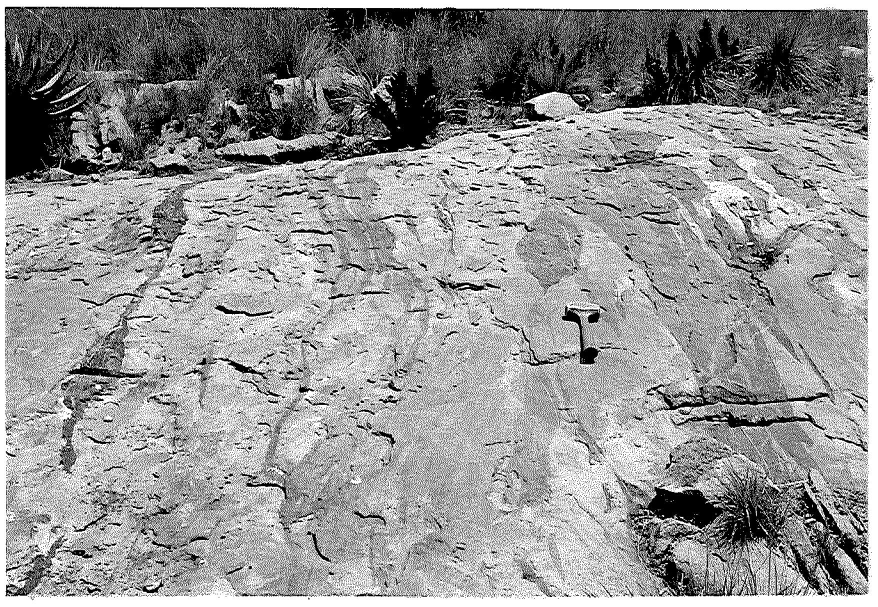

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KEY TO PLATE 3

A. Tonalitic gneiss intruding felsic heterogeneous gneiss in a river platform east of the Badplaas-Lochiel road (Figure 2, C5). The outcrop area which has been described elsewhere (Anhaeusser and Robb, 1978) displays progressive stages of anatexis and migmatization of a hetereogeneous felsic unit, considered to have originally formed part of the greenstone stratigraphy. The photograph shows contorted anatectic veins in the darker felsic host.

B. More advanced stage of anatectic veining and folding of heterogeneous gneiss-migmatite from the same locality as described in A above. Thin pegmatite veins (top) cut across the outcrop.

C. Ptygmatic structures in altered hetereogeneous gneiss from the river exposure described in A above. The disharmonic, extremely tortuous folds ("entrail migmatites") are considered to represent deformed anatectic veins in the altered felsic host rock.

D. Folded heterogeneous gneiss (altered felsic tuff) exposed in the same river platform as described in the examples above. Processes of *in situ* differentiation (venitic migmatization) are responsible for the mineralogical (and colour) banding seen in the exposures.

E. Deformed heterogeneous gneiss, from the same locality as A above, with anatectic veins of various widths showing ptygmatic, crenulation and convolute folds within the hinge zone of a fold structure.

F. Deformed heterogeneous gneiss-migmatite, showing a synoptic view of the same fold as that illustrated in E above. Regular layering, seen on the flanks of the fold, contrasts markedly with the contorted, crenulated layers only centimetres away nearer the fold axis.

PLATE 3

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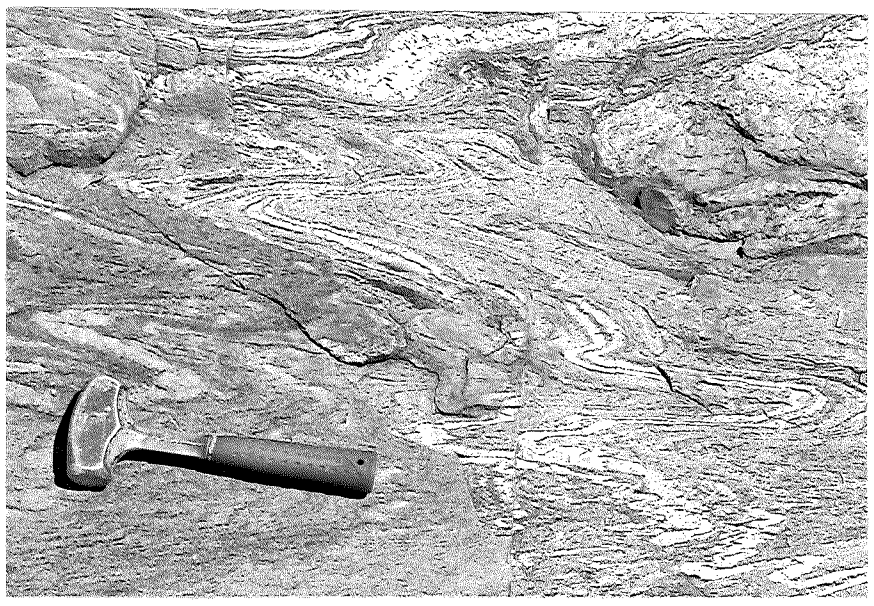

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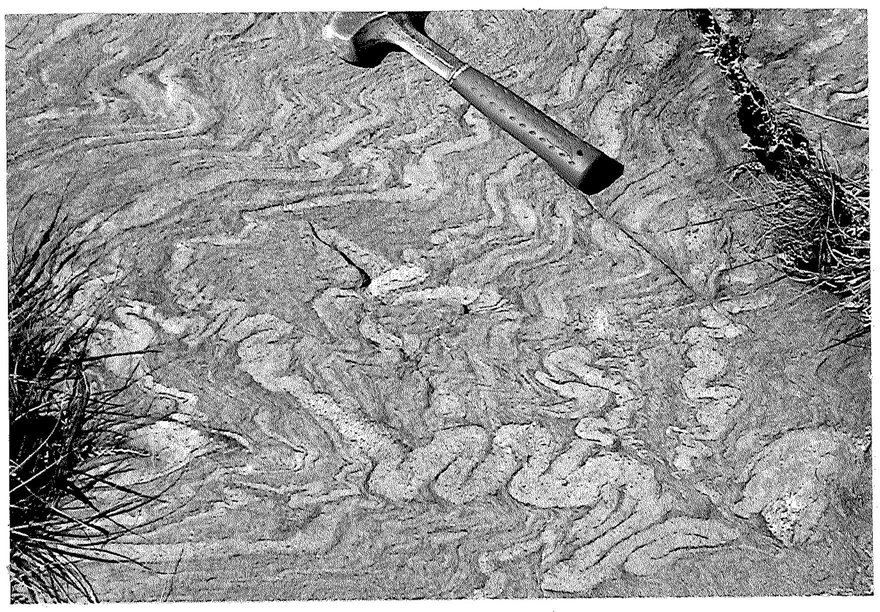

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KEY TO PLATE 4

A. Homogeneous foliated leuco-trondhjemitic gneiss from the central part of the Nederland diapiric pluton (Figure 2, B3). Mineralogically the gneiss contains sodic plagioclase (oligoclase-albite), biotite and quartz, the latter occurring prominently on the etched outcrop surface.

B. Black hornblende-rich amphibolite from a zone of fragmented greenstone enclaves on the southern rim of the Weergevonden pluton (Figure 2, C4). The amphibolite shows incipient feldspathization in an area where a wide range of granitization effects can be seen.

C. Plagioclase blastite exposed in the area 1 km southeast of the Welverdiend syenite body (Figure 2, C3) where mafic and ultramafic greenstone xenoliths have been largely assimilated by intrusive tonalites. The feldspar porphyroblasts consist of albite-oligoclase in a dark matrix of hornblende and biotite.

D. Partially assimilated greenstone xenolith occurring in the southeastern part of the Weergevonden pluton (300 m north of sample locality LC2, Figure 2, C5). The blotchy appearance is caused by irregular patches of hornblende tonalite and hybrid diorite resulting from the assimilation of the amphibolite remnant. A trondhjemitic gneiss vein also cuts across the outcrop (top right).

E. Mafic schlieren (derived from assimilated greenstone) in a melanocratic hornblende tonalite gneiss. Locality, 300 m northwest of asbestos prospects, south of the Weergevonden greenstone remnant (Figure 2, C3).

F. More advanced assimilation and gneissic banding of mafic material rafted of greenstone remnants in the same locality as E above. Na-rich feldspar porphyroblasts are evident in the rocks (cp. C above).

PLATE 4

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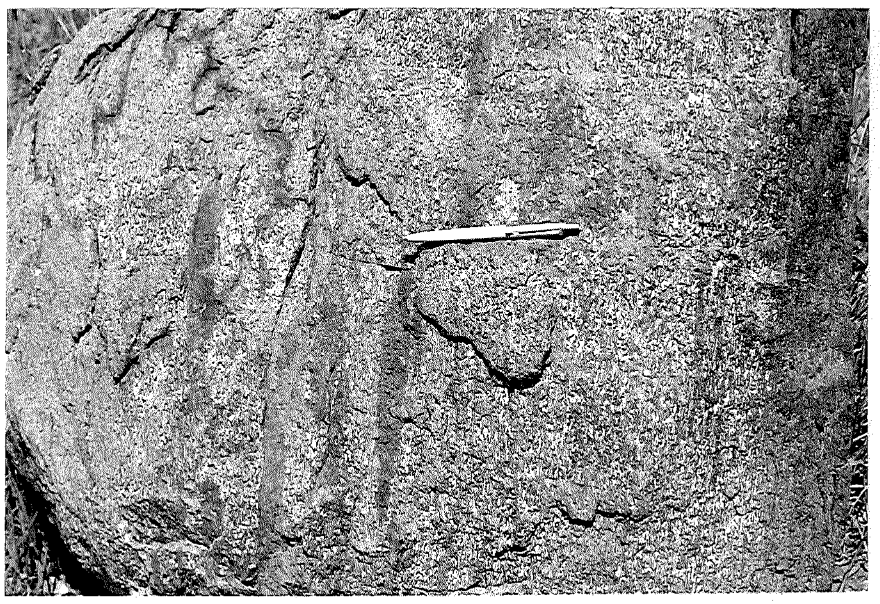

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KEY TO PLATE 5

A. Banded foliated trondhjemitic gneisses exposed on platform 500 m southwest of the corundum occurrence on the farm Weergevonden 173 IT (Figure 2, C4). A number of conformable amphibolite bands occur in the gneisses and could represent early dykes or greenstone resisters.

B. Banded foliated trondhjemitic gneisses (venitic banded gneiss-migmatite) separated into leucosomes and melanosomes (lighter and darker bands respectively). A mafic "dyke" (or greenstone resister band) appears to be contributing to the development of the stromatic layers. Locality same as A above.

C. Close-up view of the mafic band seen in B above. The foliated banded trondhjemitic gneiss probably resulted from selective recrystallization and metamorphic differentiation of early dykes or greenstone xenoliths.

D. Close-up view of folded banded trondhjemite gneiss. The light bands consist of feldspar and quartz (leucosome) and the darker bands contain biotite in addition to quartz and feldspar. Locality same as A above.

E. Coarse porphyritic syenite containing large preferrentially aligned porphyroblasts (orthoclase, orthoclase microperthite). Microcline and lesser quantities of plagioclase occur as matrix material together with quartz and ferromagnesian minerals (mainly biotite). Welverdiend syenite body (Figure 2, C3).

F. Foliated felsic unit (altered felsic tuff) showing boudinaged and ptygmatically folded anatectic veins. Locality, migmatite pavement on northwestern rim of the Weergevonden pluton (Figure 2, B4).

PLATE 5

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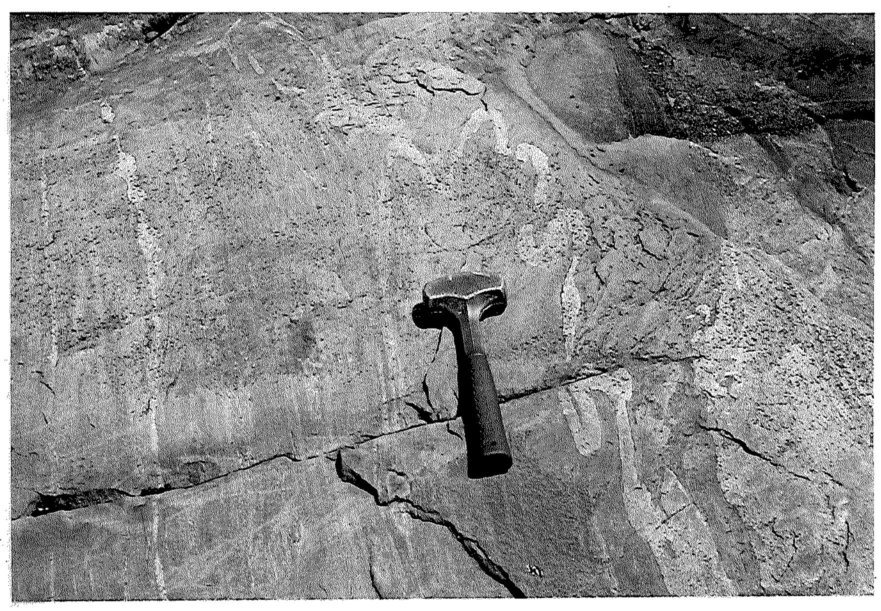

KEY TO PLATE 6

A. Layered or banded gneiss close to the edge of the southern limb of the Weergevonden greenstone remnant (Figure 2, B4). Conformable (lit-par-lit) layers of trondhjemitic gneiss (bands to the right of the hammer) are intruded into felsic greenstones (below hammer) containing anatectic veins.

B. Numerous parallel quartz veins and stringers in a shear zone flanking the Mlingase Fault Zone on the farm Welverdiend 174 IT (Figure 2, B2). The gneisses cut by the quartz-filled shears are altered to quartz and sericite.

C. Well-banded migmatite-gneisses exposed in a river section approximately 600 m east of the corundum occurrence on the farm Weergevonden 173 IT (Figure 2, C5). The dominant rock is a heterogeneous gneiss unit (felsic tuff) that has suffered anatectic melting to produce numerous leucocratic bands, some of which resemble pegmatite veins.

D. Altered (granitized) early mafic dykes cutting foliated tonalitic/trondhjemitic gneisses exposed in the Weergevonden pluton (Figure 2, C4).

E. Banded felsic schists (felsic tuffs, below hammer) intruded by trondhjemitic gneiss. In the Barberton Mountain Land it is comparatively rare to find felsic xenoliths as these rock types are easily assimilated or transformed by the granites. Numerous felsic xenoliths are, however, present along the southern flank of the Weergevonden greenstone remnant as well as in the Nederland pluton (Figure 2, B3, B4).

F. Strongly foliated trondhjemite gneiss intruded by a medium-fine grained felsic dyke (aplite) which is weakly foliated. A xenolith of foliated trondhjemite occurs above the hammer. Locality, immediately south of sample LC2 in the Weergevonden pluton (Figure 2, C5).

PLATE 6

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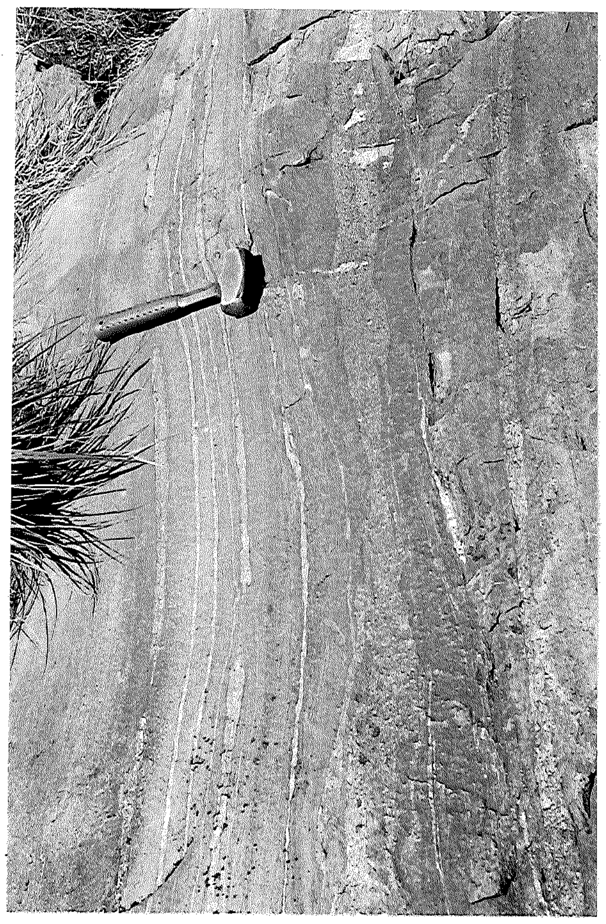

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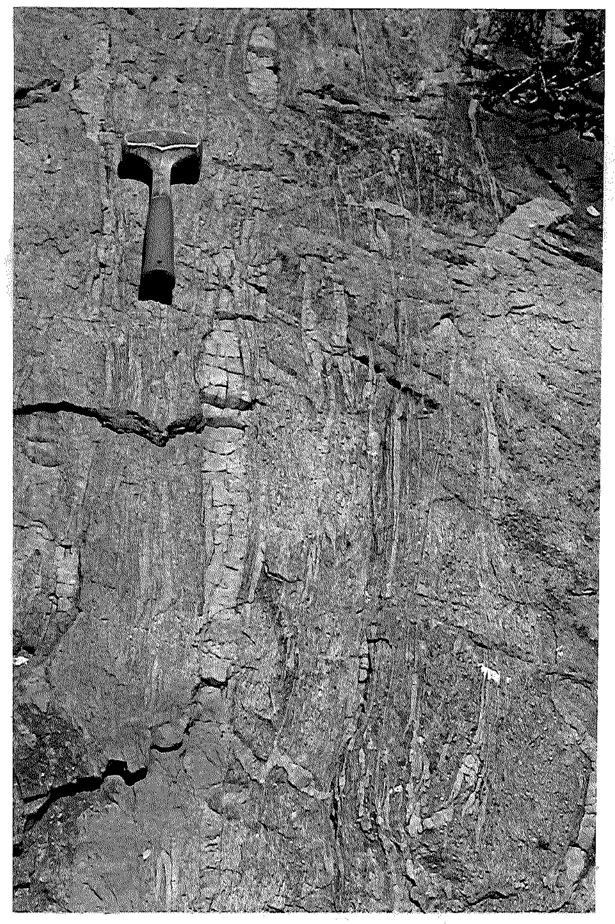

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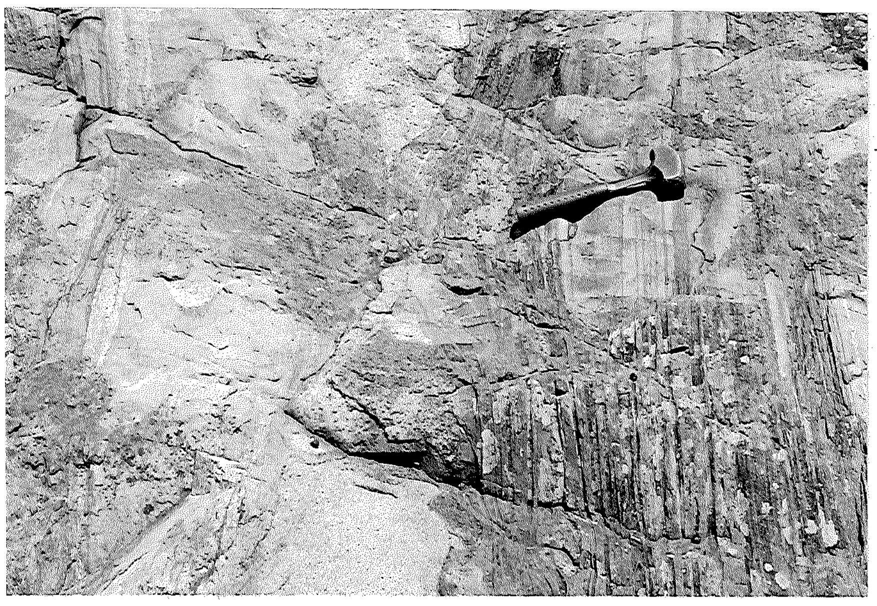

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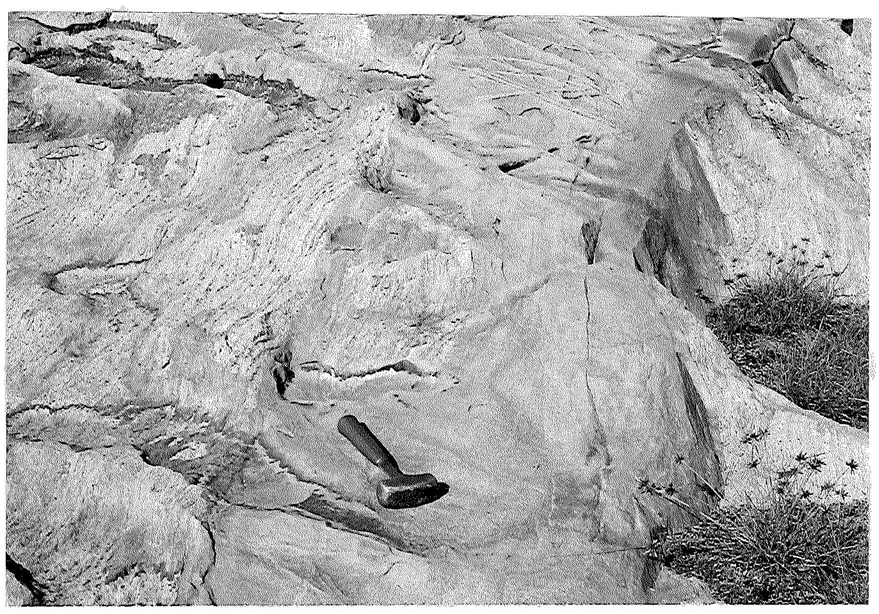
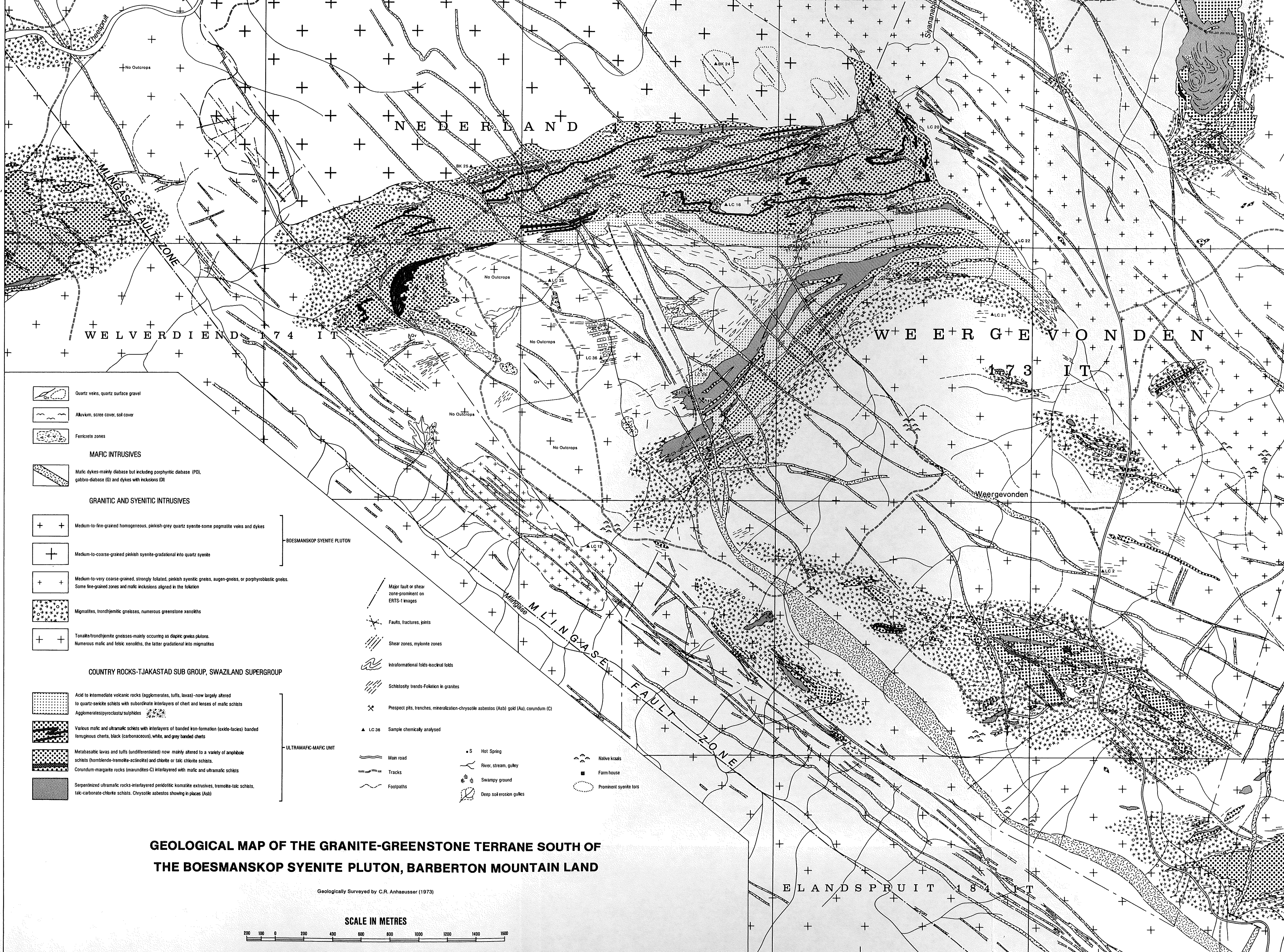
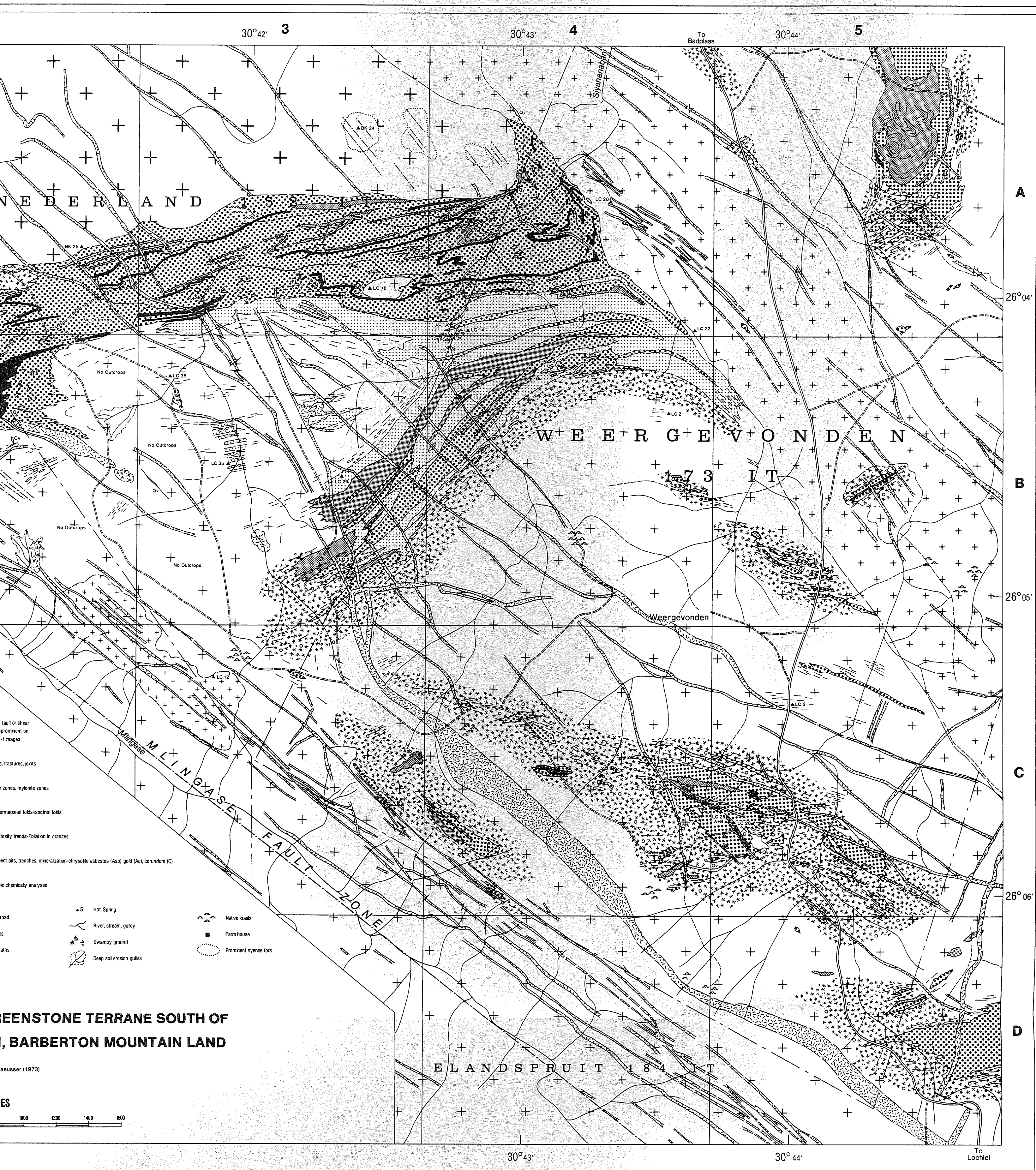




GEOLOGICAL MAP OF THE GRANITE-GREENSTONE TERRANE SOUTH OF THE BOESMANSKOP SYENITE PLUTON, BARBERTON MOUNTAIN LAND



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WEERGEVONDEN 173 IT
ELANDSPRUIT 184 IT
MLINGASE FAULT ZONE
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Siyananabani
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Deep soil erosion gullies
Native kraals
Farm house
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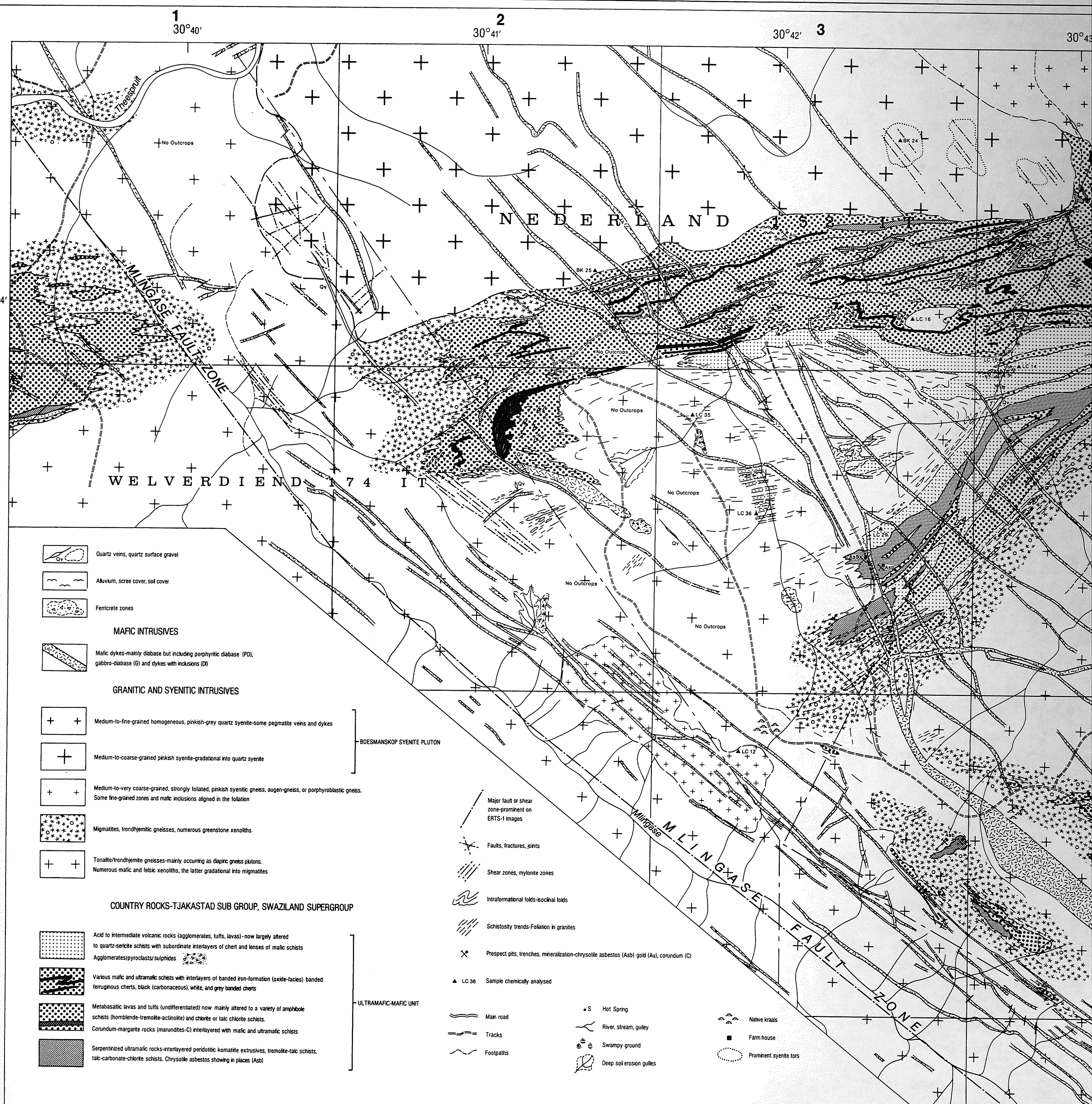

GEOLOGICAL MAP OF THE GRANITE-GREENSTONE TERRANE SOUTH OF THE BOESMANSKOP SYENITE PLUTON, BARBERTON MOUNTAIN LAND

Geologically Surveyed by C.R. Anhaeusser (1973)