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ARCHAEAN GRANITE-GREENSTONE RELATIONSHIPS ON THE FARM ZANDSPRUIT 191-IQ, NORTH RIDING AREA, JOHANNESBURG DOME

C.R. ANHAEUSSER

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by

C.R. ANHAEUSSER
*(Economic Geology Research Unit, Department of Geology,
University of the Witwatersrand,
Private Bag 3, P.O. WITS 2050,
South Africa)*

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ABSTRACT

An Archaean greenstone remnant, sporadically developed over a distance of approximately 4km on the farm Zandspruit 191-IQ in the North Riding area of the Johannesburg dome, is surrounded and intruded by porphyritic granodiorite. The greenstones, which consist of cyclically repetitive units of harzburgite and pyroxenite, have been altered to serpentinite and amphibolite, respectively, and the intruding granitic rocks have stoped and assimilated xenolithic remnants of the ultramafic rocks.

An account is given of the geological relationships in the Zandspruit-North Riding area, including the nature of the later dyke and sill-like intrusives found in the region. Particular attention is drawn to the manner in which the greenstones have been influenced by the granitic rocks, including descriptions of localities where the ultramafic assemblages are hybridized to dioritic rocks or have been intensely altered as a result of potash metasomatism.

Attention is drawn to the damage caused to the environment by former land misuse resulting from uncontrolled exploitation of the residual soil profile for use as building sand.

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INTRODUCTION

Geological investigations aimed at characterizing the nature of the Archaean basement in the hinterland of the Witwatersrand Basin have led to the discovery of a number of greenstone remnants scattered widely throughout the Johannesburg granite dome. Initial regional mapping of the approximately 700km^2 basement inlier led to the recognition of a number of granite varieties, each displaying distinctive field characteristics and possessing variable textural, geochemical and mineralogical properties (Anhaeusser, 1973). Age determinations carried out on tonalitic gneisses, which on the basis of field relationships were considered to be amongst the oldest granitoids present on the dome, yielded U-Pb isotopic ages of approximately 3200Ma (Anhaeusser and Burger, 1982). The granitic rocks, in general, all appear to post-date the greenstone remnants wherever exposure permits relationships to be observed.

Most of the larger greenstone occurrences associated with the basement inlier are located adjacent to the southern and western rim of the dome (Figure 1) and descriptions of greenstone remnants in the Roodekrans and Muldersdrif areas north of Krugersdorp have been provided by Hendriks (1961) and Anhaeusser (1977, 1978). A smaller remnant, located west of centre in the dome, in the North Riding area, occurs on the farm Zandspruit 191-IQ where it outcops sporadically over a distance of approximately 4km forming a low, northeast-trending ridge (Figure 2).

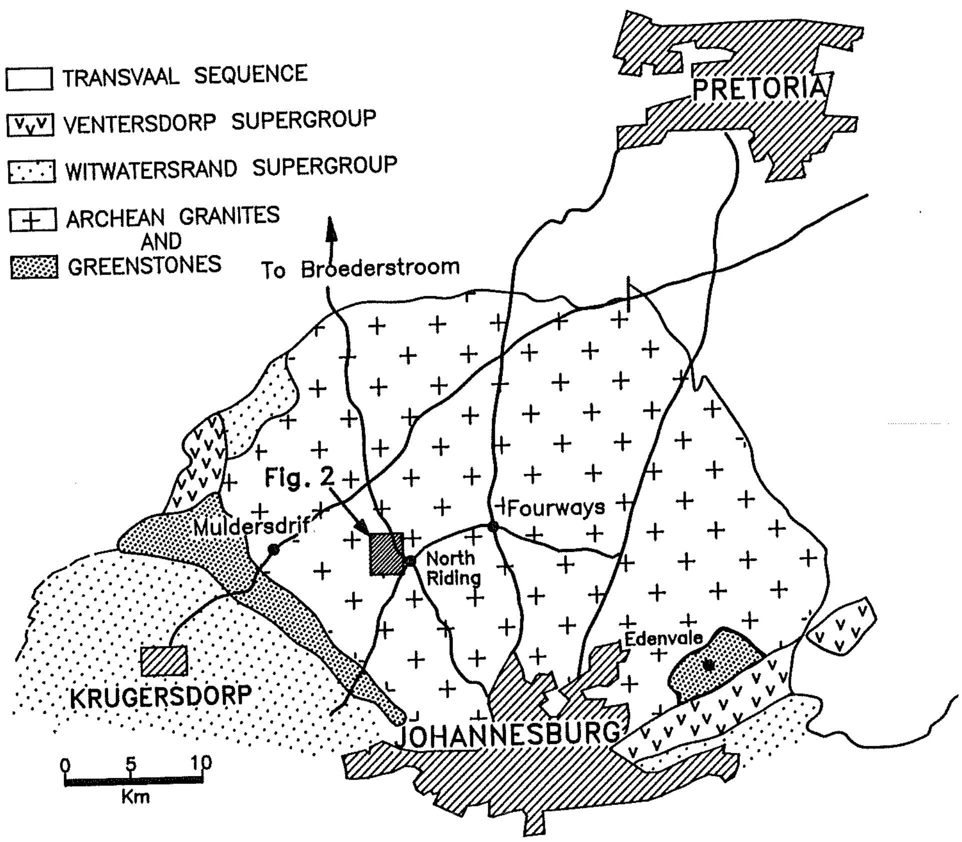
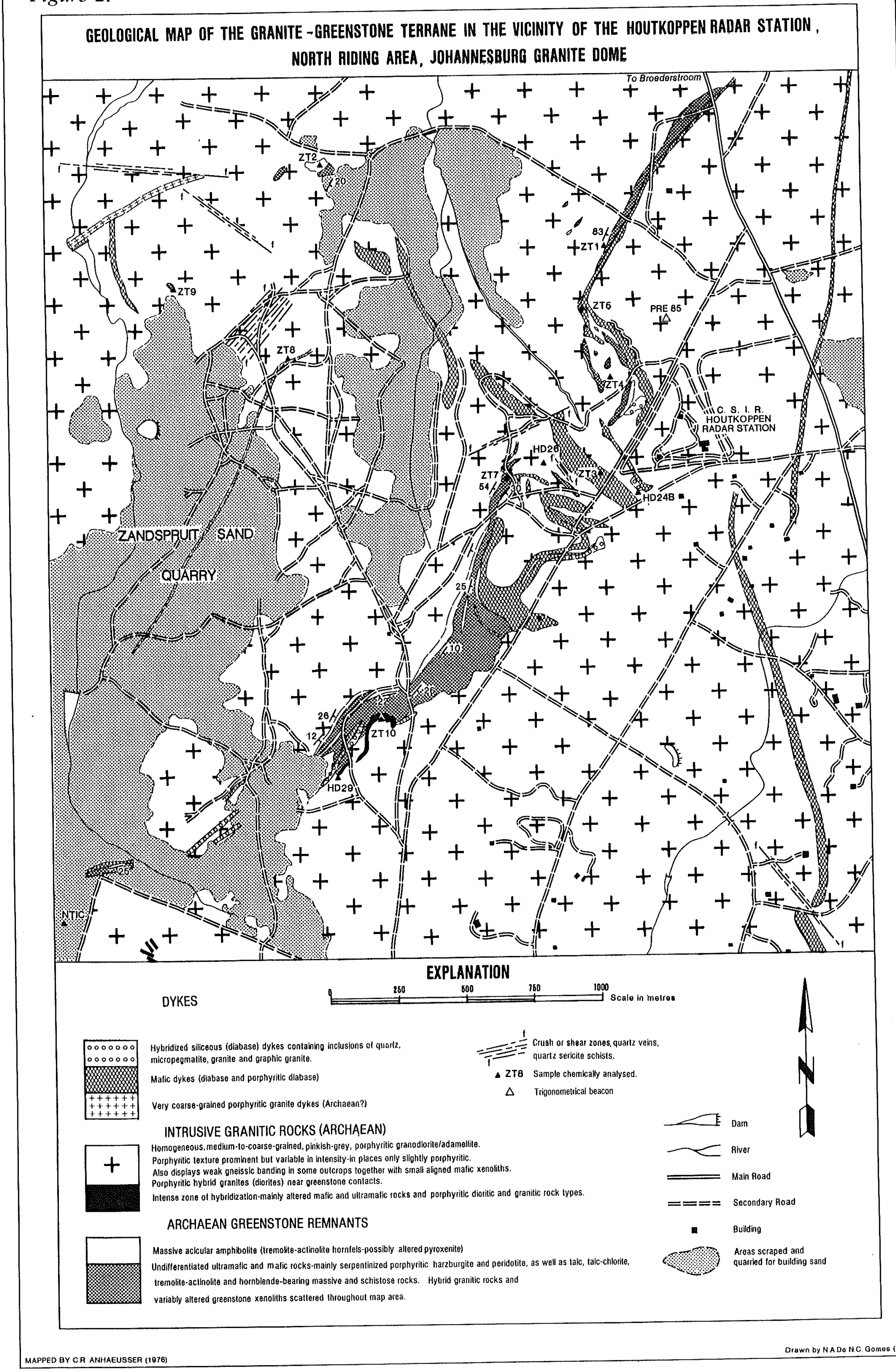


Figure 1: Map of the Johannesburg dome showing the locality of the study area.

Figure 2:


GEOLOGICAL MAP OF THE GRANITE - GREENSTONE TERRANE IN THE VICINITY OF THE HOUTKOPPEN RADAR STATION, NORTH RIDING AREA, JOHANNESBURG GRANITE DOME
To Broederstroom
ZT2
ZT1
ZT9
ZT6
PRE 85
ZT8
ZT4
C. S. I. R. HOUTKOPPEN RADAR STATION
HD26
ZT7
ZT3
HD24B
ZANDSPRUIT SAND QUARRY
ZT10
HD29
NTIC
EXPLANATION
DYKES
0 250 500 750 1000 Scale in metres
Hybridized siliceous (diabase) dykes containing inclusions of quartz, micropegmatite, granite and graphic granite.
Mafic dykes (diabase and porphyritic diabase)
Very coarse-grained porphyritic granite dykes (Archaean?)
Crush or shear zones, quartz veins, quartz sericite schists.
ZT8 Sample chemically analysed.
Trigonometrical beacon
INTRUSIVE GRANITIC ROCKS (ARCHAEAN)
Homogeneous, medium-to-coarse-grained, pinkish-grey, porphyritic granodiorite/adamellite.
Porphyritic texture prominent but variable in intensity-in places only slightly porphyritic.
Also displays weak gneissic banding in some outcrops together with small aligned mafic xenoliths.
Porphyritic hybrid granites (diorites) near greenstone contacts.
Intense zone of hybridization-mainly altered mafic and ultramafic rocks and porphyritic dioritic and granitic rock types.
ARCHAEAN GREENSTONE REMNANTS
Massive acicular amphibolite (tremolite-actinolite hornfels-possibly altered pyroxenite)
Undifferentiated ultramafic and mafic rocks-mainly serpentinized porphyritic harzburgite and peridotite, as well as talc, talc-chlorite, tremolite-actinolite and hornblende-bearing massive and schistose rocks. Hybrid granitic rocks and variably altered greenstone xenoliths scattered throughout map area.
Dam
River
Main Road
Secondary Road
Building
Areas scraped and quarried for building sand
MAPPED BY C.R. ANHAEUSSER (1976)
Drawn by N.A.De N.C. Gomes (1976)

Previous findings have led to direct comparisons being made between the granite-greenstone terrane on the Johannesburg dome with similar rocks in the Barberton Mountain Land of the eastern Transvaal and Swaziland (Anhaeusser, 1977, 1981). Despite the poorer exposure and preservation of the Zandspruit greenstones and granitoids, as well as their metamorphically and metasomatically altered nature, an attempt is made to categorize the rocks and to establish any correspondence with similar rock assemblages elsewhere on the Kaapvaal Craton.

REGIONAL GEOLOGICAL SETTING

The Archaean basement granites and gneisses of the Johannesburg dome were subdivided by Anhaeusser (1973) into a variety of distinct categories on the basis of field relations, textures, mineralogy and geochemical characteristics. The oldest granitic rocks comprise a suite of tonalitic and trondhjemitic gneisses and migmatites, that occupy most of the northern half of the dome (north of Fourways, Figure 1). Tonalitic gneisses and migmatites also occur immediately north of the Witwatersrand successions in the northern suburbs of Johannesburg and neighbouring towns. The south-central portion of the dome consists mainly of a variety of homogeneous, medium-grained, grey granodioritic rocks which, in the west, between North Riding and Muldersdrif, are somewhat coarser grained in places and are commonly porphyritic in texture. Pegmatitic dykes and veins are also common and in places nebulitic remnants of earlier gneisses and migmatitic greenstones may occur.

Numerous small greenstone xenoliths are associated with the trondhjemitic gneisses and migmatites on the northern half of the dome, but outcrop poorly except in some of the river channels. Large greenstone remnants occupy extensive tracts north of the Witwatersrand ridges and extend west and east of Johannesburg to Muldersdrif and Edenvale, respectively (Figure 1).

The Archaean basement is cut by numerous shear zones and a variety of mafic to felsic dykes (Anhaeusser, 1973). Except for the distinctive Pilanesberg dykes, whose age has been established at approximately 1250-1350 Ma (Schreiner and Van Niekerk, 1958; Van Niekerk, 1962), the age of the remaining dykes in the area is not known precisely. Some dykes intruded and metamorphosed by granites are of Archaean age but the majority of the mafic dykes on the dome are thought to be of Proterozoic age associated with Ventersdorp volcanicity and the events leading up to the emplacement of the Bushveld Complex (Antrobus and Whiteside, 1964; McCarthy *et al.*, 1990).

LOCAL GEOLOGY OF THE ZANDSPRUIT-NORTH RIDING AREA

The geology of the Zandspruit granite-greenstone terrane is shown in Figure 2. The northeast-trending Zandspruit greenstone remnant and granitic rocks to the northwest occur on the farm Zandspruit 191-IQ while the granitic terrane to the southeast (south of the CSIR Houtkoppen Radar Station) forms part of the area known as the North Riding Agricultural Holdings.

Mafic and ultramafic rocks

The oldest rocks in the area comprise the greenstones which have been intruded by granitic rocks as well as numerous dykes and sill-like sheets of diabase or porphyritic diabase. The greenstones outcrop intermittently over a strike length of approximately 4km and are best exposed in the central part of the map area where the succession is about 200m wide.

Structurally the greenstones dip at relatively shallow angles of between 10-30° SE in the central areas, steepening to between 50-80° SE in the northern region. The succession is best developed in the area north of sample locality ZT10 (Figure 2) and consists of alternating, cyclically repetitive units of cumulate textured serpentinized harzburgite (Figure 3) and amphibolite (Figure 4).

At least four cyclical units occur in the best preserved area but not all the units can be followed continuously along strike. In the far northern area outcrops consist mainly of serpentinized ultramafics.

The serpentinized harzburgites appear stratified as a result of cumulate igneous layering but pseudostratification, caused by horizontal jointing, may also be responsible for the layered appearance of some outcrops. Where best exposed the rocks have a massive, nodular appearance and are chocolate brown in colour on weathered surfaces. Fresh rocks are dark blueish black with lighter-coloured altered clinopyroxene crystals up to 8mm in length studded throughout the matrix of serpentinized olivine. The pyroxenes are generally steatized or uralitized to talc and amphibole and some fresh olivine occurs sporadically, poikilitically enclosed in the altered pyroxene. Most of the olivine in the harzburgitic rocks has been altered to serpentine (antigorite) and magnetite, with the clinopyroxenes being altered to tremolite. Talc and chlorite also occur in minor amounts.

Chemical analyses of two samples (ZT1 and ZT7) from the northern and central parts of the greenstone remnant are shown in Table 1. The results compare favourably with similar harzburgitic rocks reported from many of the Archaean layered ultramafic complexes in the Barberton greenstone belt (Anhaeusser, 1976; 1985; Wuth, 1980).

Massive, grey-green amphibolites occur as cyclically repetitive layers associated with the harzburgites. These rocks consist almost exclusively of felted needles or blades of tremolite and show only accessory amounts of magnetite. Exposures of this material are generally poor and weathered outcrops have a pinkish-brown colour. Samples from the main greenstone remnant were found to be petrologically identical to sample ZT2 collected from a smaller xenolith located approximately 1,25km to the northwest (Figure 2). A chemical analysis of the tremolite amphibolite is listed in Table 1. Again similarities can be drawn between this rock type and selected pyroxenites from the Barberton layered complexes. The closest analogue is to be found with the clinopyroxenites which, on alteration, yield clino-amphibolites. Numerous clinopyroxenitic units occur in these layered ultramafic complexes where they have been described as websterites (Viljoen and Viljoen, 1970; Anhaeusser, 1985). Precise geochemical correlation is not possible as the Zandspruit rocks have been

TABLE 1: Chemical analyses of selected rock types on the farm Zandspruit 191-IQ, North Riding area

	Ultramafic - mafic rocks				Porphyritic granites			Hybrid granites		Various dykes/sills			
Column	1	2	3	4	5	6	7	8	9	10	11	12	13
Sample No	ZT7	ZT1	ZT2	ZT9	NT1C+	ZT4	HD26+	HD29+	ZT10	ZT5	ZT3	ZT8	HD24B+
SiO_2(wt%)	41.60	45.38	45.65	52.63	72.38	71.82	69.51	59.43	57.00	54.64	55.23	57.47	67.46
TiO_2	0.16	0.13	0.19	0.79	0.24	0.28	0.38	0.32	0.39	0.26	0.40	1.07	0.27
Al_2O_3	4.40	5.70	6.93	5.70	14.38	14.75	14.76	17.67	18.30	10.22	13.66	14.02	13.67
Fe_2O_3*	11.20	9.43	10.44	11.97	0.51	1.87	1.08	0.95	3.95	9.82	9.85	10.76	1.23
FeO	-	-	-	-	1.11	-	1.65	1.65	-	-	-	-	3.28
MnO	0.14	0.14	0.17	0.36	0.04	0.05	0.07	0.08	0.08	0.23	0.17	0.20	0.09
MgO	29.50	28.38	23.30	13.55	0.30	1.02	0.83	3.41	5.50	13.94	6.81	4.52	2.10
CaO	3.50	4.83	7.50	12.93	1.65	1.85	2.69	3.92	2.22	8.34	9.98	6.96	4.54
Na_2O	n.d.	0.47	0.10	1.07	4.39	3.92	4.23	3.17	0.20	1.21	1.70	2.52	3.05
K_2O	0.04	0.21	0.04	0.43	3.97	4.09	3.71	4.49	8.87	0.41	0.63	1.91	2.85
P_2O_5	0.02	0.02	0.03	n.d.	0.07	0.06	0.12	0.13	0.16	n.d.	n.d.	0.15	0.05
H_2O^-	-	-	-	-	0.01	0.73	0.12	0.16	-	n.d.	1.56	n.d.	0.02
H_2O^+	-	-	-	-	0.77	-	0.72	1.66	-	-	-	-	1.12
LOI	8.60	6.11	5.10	-	-	-	-	-	3.56	0.17	-	1.00	-
CO_2	-	-	-	-	0.11	-	-	2.91	-	-	-	-	0.13
Total	99.16	100.79	99.45	100.21	99.93	100.44	99.12	99.95	100.23	99.24	99.98	100.58	99.86
Rb (ppm)	-	16	-	-	328	-	317	260	-	27	-	143	-
Sr	-	19	-	-	302	-	376	154	-	64	-	418	-
Ba	-	14	-	25	-	475	-	-	-	46	129	396	-

Analysts: Bergström & Bakker, Johannesburg
+ Analyses after Anhaeusser (1973)
n.d. Below detection limit
* Total Fe as Fe_2O_3
Columns:
1-2. Serpentinized harzburgites
3. Tremolite amphibolite (altered clinopyroxenite)
4. Hornblende amphibolite (altered komatiitic basalt)
5-7. Porphyritic granodiorites
8-9. Hybridized granite-greenstones (K-metasomatized clinopyroxenite)
10-12. Gabbro-diabase/dolerite dykes
13. Dyke with granitic inclusions

Figure 3: Nodular serpentinized harzburgite from sample locality ZT7 in the central part of the Zandspruit greenstone remnant. The ultramafic rocks display pseudostratification and the nodules consist of uralitized or steatized clinopyroxene, the latter altered to tremolite or talc.

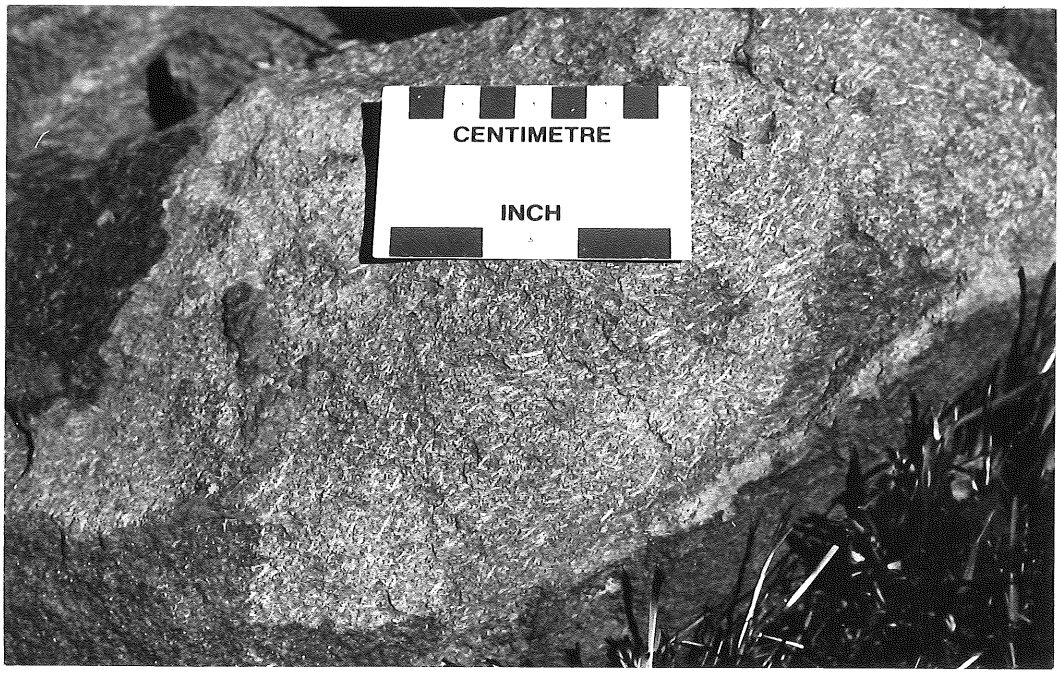


Figure 4: Massive tremolite amphibolite representing metamorphosed clinopyroxenite cyclically interlayered with the serpentinized harzburgites like those shown in Figure 3.

subjected to greater metamorphic alteration and hydration than their counterparts in the Barberton ultramafic complexes. A notable difference can, for example, be seen in the lower CaO content (7.5 percent as opposed to the 12-16 percent CaO recorded from many of the Barberton examples). In addition, the Barberton clinopyroxenites are less hydrated (loss on ignition values ranging from 0,25 - 2,00 percent compared with the 5,10 percent encountered in the Zandspruit sample ZT2).

Most of the greenstones in the study area consist of altered harzburgites or clinopyroxenites like those described above. However, a small xenolith of black amphibolite situated in the northwestern segment of the map area (sample ZT9, Figure 2) appears, on the basis of major element geochemistry (Table 1, Column 4), to correspond with Badplaas type komatiitic basalts as described by Viljoen and Viljoen (1969) from the Onverwacht Group volcanics of the Barberton greenstone belt. The distinctive features of this basalt variety include the high silica (~ 52% SiO_2), magnesium (~ 15% MgO) and calcium contents (~ 13% CaO), and the low aluminium (~ 5,5% $Al_2 0_3$) and alkali contents (~ 1% Na_2O and 0,13% K_2O).

Petrologically the Zandspruit amphibolite consists almost entirely of medium-to coarse-grained, dark, greenish-black hornblende with minor amounts of quartz, sphene, albitic plagioclase and talc, the latter representing steatized orthopyroxene.

Granitic rocks

The Zandspruit greenstone remnant is enveloped by homogeneous, medium-to coarse-grained, pinkish-grey, porphyritic granodioritic rocks (Figure 5) of the type described by Anhaeusser (1973) as occurring in the southwestern quadrant of the Johannesburg dome.

The porphyritic granodiorites are comprised of quartz and plagioclase, the latter generally seriticized and altered such that they appear turbid in thin sections. Some saussuritization of the feldspars is apparent and epidote occurs in places. Biotite and sphene are present in minor amounts and myrmekitic textures were also noted. Large microcline megacrysts (Figure 6) appear late in the mineral paragenesis and occur as poikilitic overgrowths enveloping the earlier-formed quartz and feldspar crystals. The microcline is also largely unaffected by the sericitization event.

Three samples of porphyritic granodiorite were analysed (Table 1, columns 5-7) and show consistent major element abundances from localities widely dispersed throughout the study area. Variations occur, however, where the granodiorites have intruded and assimilated the Zandspruit greenstones. In places numerous small mafic and ultramafic xenoliths occur in the granitic rocks and display various stages of alteration and assimilation as can be seen in Figures 7-10. Locally, alteration and granitization of the greenstones has been of an advanced nature and the granitic rocks are contaminated with ferromagnesian components (mainly amphibole, chlorite and talc, Figure 10). This contamination has resulted in the development of hybrid granite-greenstones like the diorite listed in Table 1, column 8. Tongues of talcose greenstone, occurring as remnants in the granite (Figure 7) are all that remain where assimilation has been intense. Increased calcium, magnesium, iron

Figure 5: Homogeneous, medium-to coarse-grained, massive, porphyritic granodiorite typical of the granitic rocks encountered in the study area and the southwestern quadrant of the Johannesburg dome.

Figure 6: Microcline megacrysts in porphyritic granodiorite near sample site HD26 in the central part of the map area. The intense development of euhedral megacrysts is a localized phenomenon and is probably associated with K-metasomatic fluid activity.

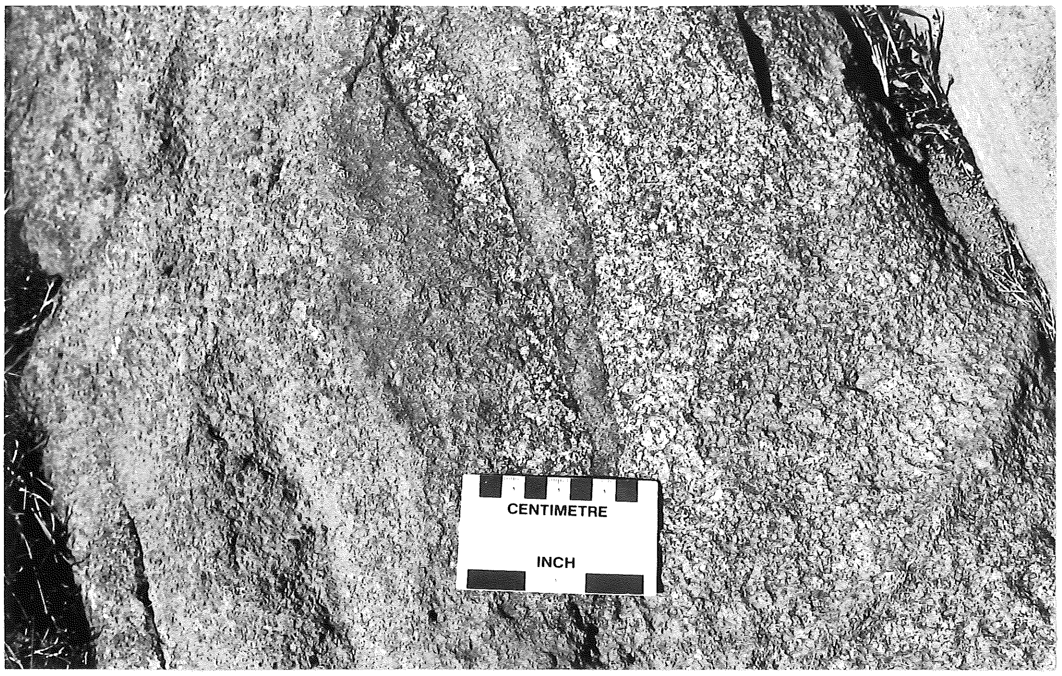


Figure 7: Photograph showing altered, talcose ultramafic rock (left of scale) and a tongue of similar material (centre) intruded by coarse-grained diorite (hybridized granodiorite) from sample locality HD29 in the south-western part of the Zandspruit greenstone remnant.

Figure 8: Xenolith of altered, mainly talcose, ultramafic rock in coarse-grained contaminated porphyritic granodiorite in the vicinity of sample site HD26 west of the Houtkoppen Radar Station (Figure 2).

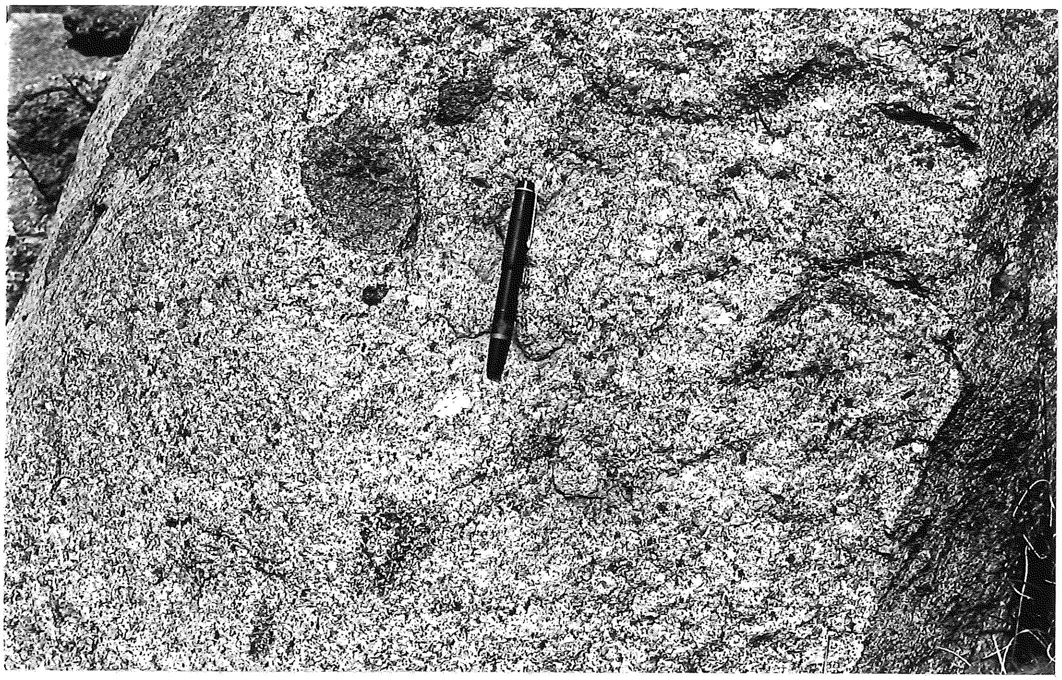


Figure 9: Outcrop of contaminated coarse-grained porphyritic granodiorite showing numerous greenstone xenoliths and mafic clots in various stages of assimilation by the intrusive granitoid. Locality near sample site HD26 (Figure 2).

Figure 10: Homogeneous, contaminated, porphyritic granodiorite showing a partially assimilated (granitized) mafic xenolith from the area near sample site HD26. The examples displayed in Figures 7-10 represent Zandspruit greenstone rocks assimilated by porphyritic granodiorite.

and aluminium and depletion in silica constitute the main chemical changes accompanying the hybridization event.

Potash metasomatic alteration

The late stage development of potash-feldspar megacrusts in the granitic rocks in the Zandspruit-North Riding area was accompanied by localized potash metasomatism of the greenstones. This metasomatism is spectacularly displayed near sample site ZT10 in the southern part of the Zandspruit greenstone remnant (Figure 2). Outcrops of blackish, altered greenstone are extensively replaced by blebs and irregular blotchy patches of potash-rich feldspathic material (Figure 11). Elsewhere in the same area the potash metasomatism has resulted in the growth of large euhedral microcline megacrysts in a dark, fine-grained matrix consisting almost entirely of biotite (Figure 12). In thin section magnetite, ilmenite, and minor leucoxene are also apparent. Carbonate is common in the rocks and appears to post-date the development of the potash-rich feldspar megacrysts.

Field evidence suggests that the metasomatized rocks initially consisted of either harzburgite or clinopyroxenite. Taking into account the mineralogy of the altered rocks, which now contain abundant biotite together with K-feldspar, the choice of parental material appears best resolved in the reaction:

$$\underset{\text{Clinopyroxenite}}{6Ca(Mg,Fe)\,Si_2O_6} + \underset{\text{Anorthite}}{2\,CaAl_2\,Si_2O_8} + \underset{\text{Fluid}}{4K^+ + 12H^+}$$

$$=$$

$$\underset{\text{Biotite}}{2K(Mg,Fe)_3\ Si_3\,AlO_{10}\,(OH)_2} + \underset{\text{K-feldspar}}{2KAlSi_{30}O_8} + \underset{\text{Quartz}}{4SiO_2} + \underset{\text{Fluid}}{8\,Ca^{2+} + 4H_2O}$$

(The albite component in the plagioclase will result in perthitic K-feldspar).

Thus, the K-metasomatized rock (sample ZT10) probably resulted from the transformation of a clinopyroxenite similar in composition to sample ZT2 (Table 1, column 3). If this was, in fact, the case then the chemical alteration seen in sample ZT10 mainly amounts to an increase in silica, aluminium, and potassium and a decrease in the amounts of iron, magnesium, calcium, and fluids (a chemical analysis of the K-metasomatized porphyritic rock illustrated in Figure 12 is listed in Table 1, column 9).

INTRUSIVE DYKES AND SILLS

A variety of dyke or sill-like bodies occur throughout the map area. These intrusives are mainly mafic in composition but a coarse-grained porphyritic granitic dyke was also encountered in the northwestern part of the area studied (Figure 2).

Flat-lying, sill-like sheets of diabase disrupt the Zandspruit greenstone remnant in the area west of the Houtkoppen Radar Station. In some places the diabase sheets interfinger with the greenstones and, in poorly exposed areas, or where partly weathered, can be mistaken

Figure 11: Massive, blackish, biotite-rich rock encasing blotchy patches of potash-rich feldspar and formed as a result of potash metasomatism of a pyroxenitic protolith. Locality near sample site ZT10 (Figure 2).

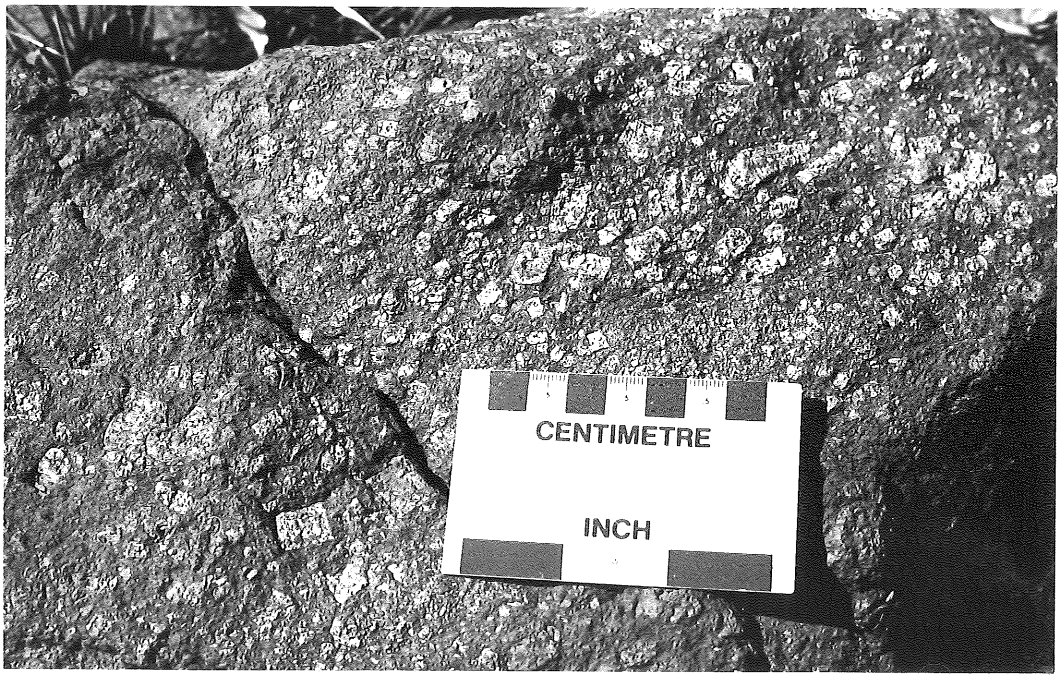


Figure 12: Variably sized, euhedral microcline megacrysts developed in a dark-coloured, biotite-rich, potash-metasomatized pyroxenite from sample locality ZT10. A chemical analysis of this rock is provided in Table 1, column 9.

for part of the mafic-ultramafic succession. Sample ZT3 is representative of a typical diabase sheet or sill comprised of deuterically altered pyroxene and plagioclase. The pyroxene is uralitized to amphibole and the plagioclase (labradorite) is saussuritized to epidote. An analysis of this rock type is listed in Table 1, column 11.

A second dyke variety is represented by sample ZT5 from the northeastern sector of the study area. The rock has a chocolate brown colour on weathered surfaces with small white flecks of plagioclase scattered throughout. In contrast to the diabase described above this rock consists of almost unaltered pyroxene (mainly orthopyroxene crystals up to 1cm in size) and plagioclase (labradorite), together with minor amounts of magnetite and graphic quartz-feldspar intergrowth textures. The rock is enriched in magnesium relative to other mafic intrusives in the area (Table 1, column 10) and may be regarded as a bronzitite gabbro or norite.

Sample ZT8 is typical of the thin dyke-like bodies that intrude the Archaean granitic terrane on the Johannesburg dome. The rock is relatively fine-grained and consists of acicular uralitized pyroxene and plagioclase, the latter partly altered to epidote. A chemical analysis of this rock shows it to be enriched in silica, titanium, aluminium, iron, and alkali elements, relative to the other dykes in the area, and depleted in magnesium and calcium

(Table 1, column 12).

A fourth dyke variety is manifest in a number of localities throughout the study area by intrusive bodies containing numerous inclusions of quartz and granite (Figures 13 and 14), the latter often exhibiting graphic intergrowth textures formed by the partial melting and recrystallization of granitic country rocks stoped and assimilated by the invading dykes. Contamination of the dykes is in places extreme giving rise to highly siliceous rocks like the one listed in Table 1, column 13.

ENVIRONMENTAL GEOLOGY

With the founding and development of the city of Johannesburg and satellite towns a need arose for a steady supply of building materials and, historically, a number of quarries were developed on the Johannesburg granite dome. Some of the quarries were begun in the quest for suitable dimension stone and many of the granite tors located in the central part of the Johannesburg dome were investigated for this purpose (Anhaeusser, 1973). Other quarries were developed to supply crushed aggregate for concrete works and still others were established to provide clays for brick manufacture and building sand.

The granitic terrane north of Johannesburg, being in a relatively humid region of the sub-continent, underwent localized decomposition and the development of residual soils. As outlined by Brink (1979) the quartz remains unaltered in the form of sand grains, often slightly rounded by partial solution, while the micas remain partly unaltered except in the upper zones of the soil profile. The feldspars become thoroughly kaolinized and leached by reaction with water charged with CO_2. The fine-grained colloidal kaolinite is removed in suspension by circulating groundwaters leaving behind a spongy residuum of micaceous silty sand.

Figure 13: Hybridized, siliceous rock (altered and contaminated diabase dyke) from sample locality HD24B near the Houtkoppen Radar Station (Figure 2). The diabase intrusive has stoped and assimilated granitic wall rocks, producing blotchy, graphic-textured inclusions.

Figure 14: Close up view of large, rounded inclusions of graphic-textured quartz and feldspar in a finer-grained matrix of siliceous diabase. The matrix also contains numerous smaller fragments of material derived from the basement granitic rocks stoped by the intrusive dyke. Locality near HD24B shown above.

Several building sand operations were developed in the North Riding area, the largest being situated on the farm Zandspruit 191-IQ. Initially, the sand requirements were met from the northward flowing Sandspruit river tract and several dams were constructed on the farm to wash the sand and gravels. In time, however, the river sand ran out and the operators resorted to scraping the residual sands from extensive areas northwest of the Zandspruit greenstone remnant (Figure 2). This operation led to the virtual destruction of the soil profile on much of the farm and the desecration of the local environment. Exploitation of the area for building sand ceased in the early 1970's and it is only in the past few years that the natural grassland vegetation is again being re-established. However, the environment is fragile following the removal of the residual soil profile and setbacks can be expected in times of drought or if grazing is not carefully controlled.

It would appear that the perpetrators of the environmental damage that was created several decades ago were not held responsible for re-establishing the surface to its former condition once sand recovery operations had ceased. It is to be hoped that legislation currently in place in South Africa will not condone this irresponsible exploitation and destruction of the land.

CONCLUSIONS

1. A greenstone remnant located in the North Riding-Zandspruit area of the North Riding-Zandspruit area of the Johannesburg dome consists of a cyclically layered ultramafic complex similar in character to the Archaean complexes described in the Barberton greenstone belt in the eastern Transvaal and in the Muldersdrif area northwest of Johannesburg (Anhaeusser, 1976, 1978, 1985).

2. The Zandspruit greenstones consist of serpentinized harzburgites repetitively interlayered with tremolite amphibolites, the latter consisting of metamorphosed clinopyroxenites.

3. The greenstone succession is intruded by porphyritic granodiorite and has been dismembered, stoped, and, in places, assimilated by the invading granitoids.

4. A variety of hybrid rock types have been produced as a result of the granite-greenstone interaction and examples of greenstone xenoliths displaying various stages of granitization are evident.

5. Potash metasomatic fluids, the latter believed to be associated with the intrusive porphyritic granodiorites found in the southwestern segment of the Johannesburg dome, were responsible for localized K-metasomatism of the ultramafic rocks in the Zandspruit greenstone remnant.

6. Later, post-Archaean intrusive dykes and sills transgress the Zandspruit-North Riding granite-greenstone terrane and consist of diabase, porphyritic

diabase, bronzitite pyroxenite, and siliceous, inclusion-filled dykes, the latter resulting from the stoping of granitic basement country rocks.

7. Injudicious exploitation, for building sand several decades ago, of the residual soil profile has left much of the farm Zandspruit 191-IQ permanently scarred.

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