

**ECONOMIC GEOLOGY
RESEARCH UNIT**

University of the Witwatersrand
Johannesburg



THE GEOLOGY AND GEOCHEMISTRY OF THE
MULDERSDRIF ULTRAMAFIC COMPLEX,
KRUGERSDORP DISTRICT

C. R. ANHAEUSSER

— • INFORMATION CIRCULAR No. 117

UNIVERSITY OF THE WITWATERSRAND
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by

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ABSTRACT

The Muldersdrif Ultramafic Complex is located in an Archaean greenstone remnant situated on the western edge of the Johannesburg granite dome. The layered igneous body, which consists of cyclically repetitive units of serpentized dunites, harzburgites and pyroxenites, together with meta-gabbroic rocks, is similar to many of the apparently unique layered ultramafic complexes found in the Lower Ultramafic Unit in the Barberton Mountain Land.

The Muldersdrif Complex has been intensely deformed by several stages of cross-folding and is made up of an involved series of interfering synclines and anticlines, the fold axes of which plunge differentially either to the east or to the west. The interfering folds produce a complex outcrop pattern and the deformation was mainly responsible for the development of chrysotile asbestos mineralization in the serpentized dunites found throughout the region.

The paper provides an account of the geology of the Muldersdrif Ultramafic Complex as well as some of the surrounding areas and includes petrological and geochemical descriptions of some of the principal rock types encountered in the region.

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I. INTRODUCTION AND PREVIOUS WORK

The Archaean greenstone belts of southern Africa contain a number of apparently unique layered ultramafic complexes, the latter containing important deposits of chrysotile asbestos which place the region third in the world, after Canada and the U.S.S.R., as a supplier of chrysotile asbestos fibre (Anhaeusser, 1976). Whereas the Canadian and Soviet Russian asbestos production is derived almost entirely from Palaeozoic or late Precambrian "alpine-type" masses of peridotite and pyroxenite, associated with deformed sediments of the Appalachian and Urals orogenic belts, the southern African asbestos production is derived almost exclusively from Archaean differentiated bodies showing magmatic segregation into layered, often cyclically repetitive, differentiation sequences (Anhaeusser, 1969, 1972, 1976, 1978; Viljoen and Viljoen, 1969a, b).

The presence of chrysotile asbestos occurrences is not the sole criteria for regarding these layered complexes as unique. What does make them distinctive is the fact that they were derived, as far as can be ascertained, from magma of ultramafic composition (Anhaeusser, 1976; Viljoen and Viljoen, 1969a). This magma, or starting liquid, is believed to have contained approximately 25 per cent MgO (suggested average peridotitic komatiite liquid, Cawthorn and McIver, 1978, in preparation) and underwent olivine, orthopyroxene, and clinopyroxene fractionation to produce a wide range of cumulus-enriched liquids and melt composites ranging from dunites, orthopyroxenites, websterites, and gabbroic igneous rocks, to peridotitic and basaltic komatiites, high-Mg basalts and oceanic tholeiites (Anhaeusser, 1977).

In South Africa most of the Archaean layered ultramafic bodies are located in the Barberton greenstone belt in the eastern Transvaal Lowveld (Anhaeusser, 1975, 1976). One exception to this distribution is the Muldersdrif Ultramafic Complex which occurs as a greenstone remnant located on the western half of the Johannesburg granite dome and situated approximately 10 km north of Krugersdorp (Figure 1).

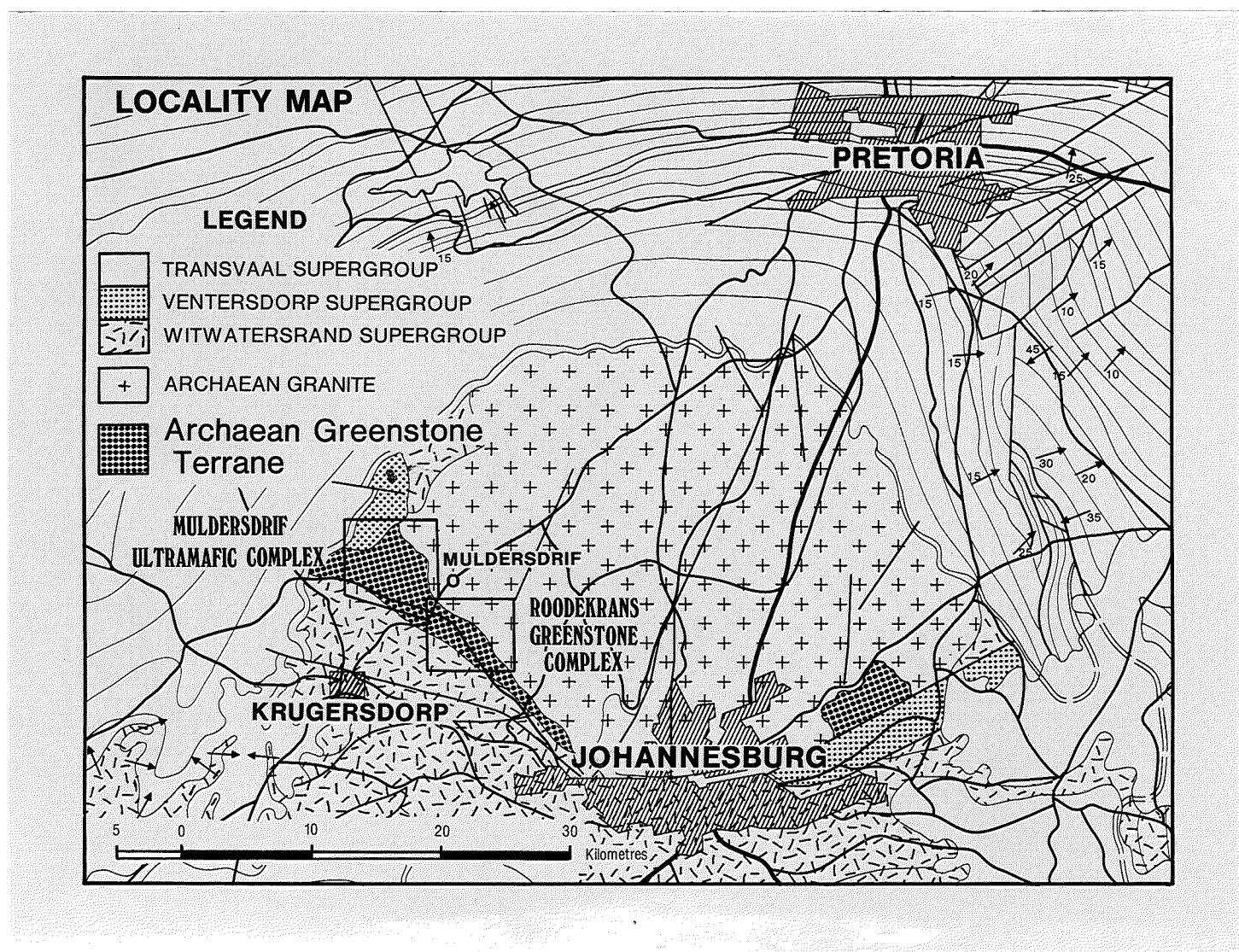


Figure 1 : Locality map showing the Johannesburg granite dome and the Archaean greenstone remnants in the Muldersdrif area north of Krugersdorp (after Anhaeusser, 1977).

Rocks older than the Witwatersrand succession north of Krugersdorp were first noted by Hall (1906), Hall and Humphrey (1906), and Kynaston (1907a, b), who reported the presence of a variety of ultrabasic, basic and acid schists which they correlated with the Swaziland System (now Supergroup). No detailed maps of the area were produced but later Mellor (1917, 1921) outlined the generalized extent of the Swaziland successions on his geological maps of the Witwatersrand and country surrounding Johannesburg. In 1933 Willemse studied aspects of the Johannesburg-Pretoria granite and referred briefly to the ancient greenstones which occurred from place to place across the dome. He subdivided these greenstones, which were considered to be pre-granite in age, into two groups, the first of which were referred to as the basic schists and the second, which he called the acid schists. Willemse (1933) further distinguished, on petrological grounds, three main classes of rocks in the basic schist group. These he called the serpentinous variety, the amphibolite variety, and the hornblende variety.

The serpentinous varieties were found to contain relic crystals of olivine as well as enstatite, monoclinic pyroxene, and a little feldspar, and appeared to represent the altered products of original dunitic or harzburgitic rocks. Massive serpentinites, together with their sheared, often talcose, equivalents were also noted.

The amphibolite and hornblende varieties both contained hornblende but differed mainly in the fact that the former had a talcose-serpentinous matrix, whereas the latter variety was reported to have small amounts of microcline, plagioclase, orthoclase and quartz which were thought to have been introduced into a rock originally of pyroxenitic composition.

The acid schists Willemse (1933) referred to consist mainly of quartz sericite schist and occur in only a limited area on the northwestern and northern margins of the dome, well removed from the Muldersdrif greenstone locality. These acid schist were subsequently found to be unrelated to the Archaean greenstone remnants being, instead, the products of intense structural alteration of a pre-Transvaal felsic volcanic unit conformably underlying the Black Reef quartzites (Anhaeusser, 1973b).

The first attempt at mapping some of the greenstone terrane was that undertaken by Hendriks (1961), who produced a 1:50 000 scale compilation of the area between Krugersdorp and the most northerly outlier of the Witwatersrand successions on the farm Zwartkop 525 JQ, the latter located approximately six kilometres north-northwest of Muldersdrif (Figure 1).

The investigations by Hendriks (1961) revealed an abundance of talc schists and blue and green serpentinites, the latter he considered to have been derived from the alteration of pyroxenites and harzburgites, respectively. Signs suggestive of magmatic layering were noted and the rocks in the area were correlated with the ultrabasic sequences of the now defunct Jamestown Igneous Complex, the latter having been originally defined in the Barberton area by Visser et al. (1956).

Following a re-investigation of the Archaean granitic rocks of the Johannesburg dome (Anhaeusser, 1973b) the writer began a systematic study involving the detailed mapping of selected greenstone remnants north of Johannesburg. Preliminary accounts of the geology of the Muldersdrif Ultramafic Complex and the neighbouring Roodekrans greenstone remnant were presented (Anhaeusser, 1973a, 1974) and later, aspects relating to the chrysotile asbestos mineralization of the area were briefly outlined (Anhaeusser, 1976).

More recently the detailed geological and geochemical findings of the Roodekrans Greenstone Complex, situated immediately to the southeast of the Muldersdrif Ultramafic Complex (Figure 1), were published (Anhaeusser, 1977). The successions in this area were divided into two principal components - rocks belonging to a layered ultramafic sequence (the Roodekrans Ultramafic Complex) and rocks forming part of a succession of Mg-rich pillow basalts and subordinate peridotitic interlayers. The rocks of the layered ultramafic sequence have been serpentinized and deformed whereas the metabasalts show signs of contact metamorphism resulting from the intrusion of a porphyritic granodioritic phase of the Johannesburg granite dome. It was concluded that the rocks in the layered ultramafic sequence did not constitute part of a differentiated complex but were, most probably, representative of an eruptive succession of ultramafic flow units like those described by Pyke et al. (1973) from the Munro Township in the Abitibi greenstone belt of north-eastern Ontario, or those described from the Komati Formation in the Barberton area by Viljoen and Viljoen (1969c).

The only other previous work carried out in the Muldersdrif area involved prospecting, by various mining companies and individuals, for chrysotile asbestos, gold, and serpentine. According to Coetze et al. (1976) some production of chrysotile asbestos was recorded from the farm Driefontein 179 IQ (Figure 2) before 1930.

Auriferous quartz lodes interbedded in Black Reef quartzites were mined at the Kromdraai Mine, northwest of the Muldersdrif Ultramafic Complex. These quartz lodes extended over a strike of approximately 3,5 km on Kromdraai 520 JQ and Tweefontein 523 JQ in the Krugersdorp District (Hammerbeck, 1976). According to Dörffel (1903), highly argentiferous galena and, as a mineralogical curiosity, galena rich in gold, were present in a portion of the mine. Near the surface exceptionally rich secondary enrichment zones were found but the average grade in the quartz lode was of the order of 20 to 25 g/t (Hammerbeck, 1976). The Kromdraai deposit, which was discovered in 1881, was one of the very first gold finds in the Witwatersrand area (Pieterse, 1943).

The account which follows deals primarily with the geology of the Muldersdrif Ultramafic Complex and surrounding terrane. In addition, aspects relating to the mineralization of the region will be briefly discussed.

II. GENERAL GEOLOGY

The area west of Muldersdrif was mapped 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).

A. Archaean Greenstone Assemblages

The Archaean greenstone successions west of Muldersdrif fall into two categories. The first of these comprises the Muldersdrif Ultramafic Complex, the latter occupying the north-central part of the region shown in Figure 2. This layered complex, which will be discussed in more detail later in this paper, consists mainly of a variety of serpentinized ultramafic rocks, together with subordinate, but important, marker units of amphibolite (meta-gabbroic rocks terminating cyclical units within the layered complex).

The second category of greenstones includes the extensive, yet poorly exposed, development of altered mafic and ultramafic lavas that occupy the southern portion of the map area, and which extend in a southeasterly direction into the adjoining Roodekrans area, described by Anhaeusser (1977). Most of the southern portions of the farms Honingklip, 178 IQ, Vlachfontein 181 IQ, and Rietvlei 180 IQ, are underlain by deep red soils and outcrops are relatively rare. The original farms listed above have, over the years, been subdivided into numerous small agricultural holdings and the rich soils support intensively cultivated fruit orchards and flower farms. At the time of writing only one small area remains where the original nature of the rocks can still be investigated in the field. At this locality, which is on the farm Rietvlei 180 IQ (Figure 2, C3, D3), mafic spherulitic pillow lavas (Plate 1A) alternate in rapid succession with poorly developed talc schists and serpentinized peridotites, both of which probably represent the altered equivalents of peridotitic komatiite flow units. Where exposed the altered basalts consist mainly of dark coloured amphibolites (hornblende- or actinolite-rich rocks) but, in places, fine, alternating, bands of amphibolite and chlorite occur suggesting that some of the rocks may represent altered mafic tuffs.

In two localities thin layers of banded ferruginous chert were encountered, the latter associated with black carbonaceous shaly lenses, together with various amphibole and chlorite schists. The first of these localities is in a road cutting approximately 1 km west of the intersection of the Krugersdorp-Johannesburg highways (Figure 2, D3). Outcrops are poor and are largely concealed beneath the tarred surface of the old road which passes just north of the present highway. The second, better exposed, banded ferruginous chert occurrence (Plate 1B), is located on the farm Van Wyks Restant 182 IQ, in a narrow sliver of altered amphibolites wedged between the Muldersdrif Ultramafic Complex and the Archaean granites (Figure 2, B2). As far as the writer is aware these banded cherty units represent the only examples of chemical sedimentary rocks yet recorded in the ancient greenstone remnants on the Johannesburg dome.

The lithological assemblages in the Muldersdrif greenstone remnants, consisting, as they do, almost exclusively of various mafic and ultramafic volcanic and plutonic rocks, suggest that they may be equivalents of part of the Lower Ultramafic Unit as defined by Viljoen and Viljoen (1969d) for the basal division of the Swaziland Supergroup in the Barberton Mountain Land.

B. Granites

The Muldersdrif greenstones are intruded by Archaean granites which occupy large areas of the eastern half of the map area (Figure 2). A wide tongue of sheared granite, on the farm Van Wyks Restant 182 IQ, effectively separates the Muldersdrif Ultramafic Complex from the basaltic and peridotitic lavas that extend from Roodekrans 183 IQ, in the southeast, to Honingklip 178 IQ in the west.

The granitic rocks in the region are generally poorly exposed and have been subjected to extensive alteration, the latter caused mainly by shearing, which is prolific around the western and northwestern periphery of the Johannesburg dome (Anhaeusser, 1973b).

Where the granites are still preserved, as for example north of Roodekrans 183 IQ (Figure 2, D3 - sample locality MD4) they consist of homogeneous, medium- to coarse-grained porphyritic granodiorites. Rocks of this type were shown by Anhaeusser (1973b) to occupy extensive areas of the southwestern quadrant of the Johannesburg dome. The porphyritic granodiorites, chemical analyses of which are provided in Table 1, columns 9 and 10, are considered to represent one of the latest granite events on the Johannesburg dome, a fact also being borne out by the preliminary U-Pb isotopic age determination studies (A.J. Burger, personal communication, 1976).

TABLE I

Chemical Analyses of Various Rock Types Intrusive
into the Area Surrounding the Muldersdrif Ultramafic Complex

	Pilanesberg Composite Dykes										Felsite Dykes			Granodiorites			
	Mafic Portion			Felsic Portion													
	1	2	3	4	5	6	7A	MD 22	MD 16B	MD 4	SK 1	9	10				
	VW 29B+	G 33	A1	VW 29A+	640	7A											
SiO ₂	48,60	47,94	48,00	62,02	62,84	58,09	75,87	75,96	72,26								
TiO ₂	2,07	2,23	2,14	1,01	1,05	1,27	0,03	0,03	0,23								
Al ₂ O ₃	14,22	15,69	14,41	15,16	16,19	17,35	13,56	13,48	14,42								
Fe ₂ O ₃	3,56	3,40	3,16	2,33	1,64	1,93	0,14	0,16	0,49								
FeO	9,21	9,45	9,72	4,47	3,96	4,18	0,26	0,29	1,11								
MnO	0,20	0,21	0,21	0,08	0,13	0,11	0,03	0,03	0,04								
MgO	6,41	6,15	6,39	1,37	1,86	1,71	0,12	0,12	0,33								
CaO	9,77	8,72	10,13	3,22	2,84	3,57	0,07	0,23	1,62								
Na ₂ O	2,21	2,45	2,26	3,17	3,80	5,40	3,43	3,52	4,34								
K ₂ O	0,79	0,94	0,64	3,59	3,72	4,02	5,86	5,53	4,02								
P ₂ O ₅	0,23	0,22	0,24	0,45	0,28	0,17	0,01	0,01	0,06								
H ₂ O ⁺	2,14	1,62	2,19	2,08	1,28	1,14	0,52	0,55	0,80								
H ₂ O ⁻	0,11	0,22	0,16	0,16	0,27	0,22	0,06	0,02	0,01								
CO ₂	0,34	0,55	0,65	0,27	0,18	0,49	0,02	0,08	0,15								
TOTALS	99,38	99,79	100,30	99,86	100,04	99,65	99,98	99,98	99,88								

Analysts : + National Institute for Metallurgy, Johannesburg.

Columns : 1. Mafic portion of Pilanesburg composite dyke (dyke margin - tholeiitic basalt)

2. Mafic portion of Pilanesburg composite dyke (dolerite, Simmer and Jack Gold Mine - van Niekerk, 1959).

3. Average tholeiitic basalt (Group 1A, Pilanesberg magma - Ferguson, 1973).

4. Felsic central portion of Pilanesberg dyke VW 29B (granodiorite).

5. Felsic centre of Pilanesberg composite dyke (granodiorite, Simmer and Jack Gold Mine - van Niekerk, 1959).

6. Average Tristanite (Group 7A, Pilanesberg magma - Ferguson, 1973)

7 - 8. Felsite dykes, Muldersdrif area (Anhaeusser, 1973).

9 - 10. Homogeneous, medium-coarse porphyritic granodiorites (Anhaeusser, 1973).

In the field, the granite-greenstone contacts are rarely seen due to poor exposure. The areas flanking the Muldersdrif Complex are intensely sheared and the various mafic and ultramafic rocks have been converted into a wide variety of schists (mainly talc, chlorite, and amphibole schists). The granites near the contacts are likewise extensively sheared and in places consist of very coarse-textured rocks comprised of quartz (some being blue opalescent) and pale yellowish-green sericite. In some localities, for example south of the poultry farm on Van Wyks Restant 182 IQ (Figure 2, C3), coarse-grained hybridized granites were encountered, the latter formed as a result of the interaction (assimilation) of the granodiorite and the greenstones.

Numerous small white quartz veins occur throughout the granites and in the east, extending for over 6 km is a topographically prominent, north-south striking, shear zone, the latter marked in the field by abundant vein quartz scree.

Intensely sheared granites, extending westwards in the granitic tongue on Van Wyks Restant 182 IQ, appear to merge with equally severely sheared intermediate-to-felsic rocks on the eastern boundary of the farm Honingklip 178 IQ, and which the writer suspects may be of Ventersdorp age. Proof for this contention is lacking in the area shown in Figure 2 but elsewhere around the western and northwestern rim of the Johannesburg granite dome the writer (Anhaeusser, 1973b) found numerous occurrences of sheared felsic (in places porphyritic) volcanic rocks lying conformably beneath the Black Reef quartzites and resting mainly on the granites or on Witwatersrand strata (west of the farm Zwartkops 525 JQ).

In the Honingklip area the sheared acid rocks abut against serpentinites of the Muldersdrif Complex and are laced with quartz veins that build a topographically elevated ridge in the central part of the map area (Figure 2, B2). An additional feature leading to the conclusion outlined above lies in the fact that the sheared granites commonly contain coarse quartz grains whereas the suspected felsic lavas generally appear as fine-grained, white- to buff-coloured, quartz sericite schists.

C. Ventersdorp and Transvaal Cover Sequences

As has already been mentioned the possibility exists that intermediate-to-felsic volcanic rocks of Ventersdorp age are present in the map area. These may once have extended over much of the district but are only preserved in a few localities around the periphery of the Johannesburg dome. Other rocks of possible Ventersdorp equivalence occur to the west and northwest of the Muldersdrif layered body. On the farm Honingklip 178 IQ a roughly oval shaped area of mafic volcanic rocks exists south of the old Geden Asbestos Mine. Outcrops are again generally poor but at sample locality VW 25 (Figure 2, B1) the basalts are well-exposed and consist of greenish-grey amygdaloidal basalts with little or no foliation. They are, however, dissected by a network of veinlets consisting mainly of quartz and sericite. From place to place across the outcrops the appearance and colour of the rocks varies, some areas being apparently more siliceous than others. In general the rocks do not look unlike some of the mafic Ventersdorp lavas encountered in the Klipriviersberg hills south of Johannesburg, described by Wyatt (1976), and it is largely on these field characteristics that the Muldersdrif occurrences are correlated with the Ventersdorp successions. This correlation is tentative, however, as the exposures are too limited to make an unequivocal assessment. Coupled with this also, is the fact that the chemistry of the basalt (Table 2, column 7) is not unlike that of the high-Mg basalts reported from the neighbouring Roodekrans greenstones (Anhaeusser, 1977) or the spherulitic pillow lavas on the farm Rietvlei 180 IQ (sample VW 39, Figure 2, C3 and Table 2, column 6). As stated earlier, the author's preference is that these rocks be grouped with the Ventersdorp although the possibility cannot be ruled out that they may form part of the Archaean greenstone sequence in the area.

Northwest of the Muldersdrif Complex, on the farm Kromdraai 520 JQ (Figure 2, A1), there occurs an extensive development of westerly dipping sediments, the latter lying unconformably over the ultramafic schists. Scree slopes obscure much of the geology but the area is underlain mainly by shaly sandstones containing scattered pebbles, as well as conglomerates, grits, and quartzites. North of the area boulder conglomerates occur in places. Most of the rocks show signs of having been extensively sheared, and deformed conglomerates are evident in road cuttings west of the map area.

The successions outlined above are grouped within the Ventersdorp Supergroup and are overlain by shales, quartzites, and conglomerates (Black Reef Quartzite) and dolomites and shales (Malmmani Dolomite) of the Transvaal Supergroup.

D. Dykes

A variety of dykes of differing composition and age occur throughout the area. Five distinct types were noted. These include :

1. Diabase dykes
2. Porphyritic diabase dykes
3. Hybrid dykes with inclusions

4. Felsite and porphyritic felsite dykes
5. Pilanesberg composite dykes.

1. Diabase Dykes

Dark, fine- to medium-grained, diabase dykes are the most commonly encountered variety on the Johannesburg granite dome (Anhaeusser, 1973b) and a few of these were noted in the area west of Muldersdrif. They are considered to represent a phase of activity probably associated with the emplacement of the Bushveld Complex approximately 2 000 m.y. ago.

2. Porphyritic Diabase Dykes

These dykes are very similar to the diabase variety but are conspicuously porphyritic, often containing large, sometimes zoned, feldspar phenocrysts. In most cases the feldspars are saussuritized and epidote is prominent in the rocks. The porphyritic dykes are probably closely related to the non-porphyritic diabases, but presumably underwent different cooling histories. One example of this nature is present in the area west of the Scott asbestos workings (Figure 2, B2).

3. Hybrid Dykes with Inclusions

A single example of a hybrid dyke containing large graphic granite inclusions occurs near the Muldersdrif School on the farm Van Wyks Restant 182 IQ (Figure 2, B3 and C3). Similar inclusion-filled dykes were reported from localities elsewhere on the Johannesburg dome (Anhaeusser, 1973b) and are not uncommon in the Archaean granitic terrane of the eastern Transvaal Lowveld. Dykes of this type are considered to have developed as the result of the excessive assimilation of the granitic wall rocks through which the dyke magma was injected.

4. Felsite and Porphyritic Felsite Dykes

Numerous felsitic dykes were noted by Anhaeusser (1973b) in various parts of the Johannesburg dome. However, the greatest concentration of these was recorded in the far western part of the region near Muldersdrif, and areas to the north. In the map area, a felsite dyke swarm, striking northeast, cuts across the main Krugersdorp-Pretoria highway (Figure 2, C3) and smaller dykes, of a similar nature, occur south of the Muldersdrif Complex in the westerly protruding granite tongue, as well as in the layered body itself (Figure 2, B3).

The dykes which have been described by Anhaeusser (1973b), Hendriks (1961), Kynaston (1907a), Mellor (1917), Wagner (1907) and Willemse (1933) are recognized in the field by their generally pale pinkish-grey colour, their exceptionally fine-grained texture, and the intense nature of their jointing. Under the microscope the rocks consist of a fine-grained mosaic of quartz and feldspar, the latter generally altered to sericite. In places feldspar phenocrysts give the rock a porphyritic texture.

Two chemical analyses of felsite dykes found near Muldersdrif (Figure 2, C3) are listed in Table 1, columns 7 and 8. Anhaeusser (1973b) suggested that the composition of the dykes appeared to be influenced by the host rocks into which they had intruded - those in the Muldersdrif area reflecting a relatively high K_2O content, possibly because the porphyritic granodiorites in the area reflect the highest potash/soda ratios of all the granitic rocks on the Johannesburg dome.

Willemse (1933) concluded that the felsite dykes represented possible feeders to felsic volcanism associated with the Ventersdorp period of igneous activity. This view was supported by Anhaeusser (1973b) although he also speculated that the felsite dykes could, in places, represent rapidly chilled, filter-pressed, products of remobilized phases of the pre-existing granitic rocks in the area - an explanation extended by Scholtz (1946) for quartz felsite dykes transgressing the younger Precambrian granite plutons of the southwestern Cape Province. However, in view of the presence of felsic rocks of probable Ventersdorp age in the vicinity of Muldersdrif, the early suggestion by Willemse (1933) now seems to be the most plausible.

A further alternative was introduced by Fumerton (1975) who examined what he believed to be similar rocks in underground exposures at the E.R.P.M. Gold Mine east of Johannesburg. He concluded, from isotopic studies, that the felsites and aplites were possibly derived from the melting or partial melting of basement granitic rocks about 2 100 m.y. ago. He suggested that their origins were probably related to the thermal activity associated with the emplacement of the Bushveld Igneous Complex.

5. Pilanesberg Composite Dykes

Dykes associated with the Pilanesberg alkaline igneous event transgress the Johannesburg granite dome mainly from northwest to southeast (Anhaeusser, 1973b). These dykes, according to Ferguson (1973), are generally subalkaline and femic in character but some of the larger dykes frequently display a composite nature, with femic margins and salic centres.

Two Pilanesberg dykes have been dated by Schreiner and Van Niekerk (1958) and Van Niekerk (1962) and range in age between $1\ 290 \pm 180$ m.y. and $1\ 330 \pm 80$ m.y. From available dates of a variety of other rocks connected with the Pilanesberg alkaline province it would appear that the dominant period of igneous activity associated with the Pilanesberg event covers the span 1 115 to 1 420 m.y. (Ferguson, 1973).

In the Muldersdrif area a northwest striking composite Pilanesberg dyke 3,5 km long cuts across the farms Rietylei 180 IQ, Vlachfontein 181 IQ, and Van Wyks Restant 182 IQ. The composite nature of the dyke is best observed at sample locality VW 29A/VW 29B (Figure 2, D2) where the mafic and felsic portions outcrop near the main road.

As has been demonstrated by Ferguson (1973), the range in composition of rocks associated with the Pilanesberg igneous activity is extensive. However, by employing the technique of statistical cluster analysis Ferguson established a chemical classification which sorted the available data into groups for comparative purposes. Two chemical analyses, one from the mafic portion of the Muldersdrif dyke and the other from the felsic portion, are listed in Table 1, columns 1 and 4, respectively. Also listed is the chemistry of the mafic and felsic portions of a composite Pilanesberg dyke which was intersected underground in the old Simmer and Jack Gold Mine, located east of Johannesburg. The mafic portion of both the Muldersdrif and Simmer and Jack dykes fall into Ferguson's Group 1A Pilanesberg magma, the latter corresponding to average tholeiitic basalt in composition. The felsic portions of these dykes fall into Group 7A which coincides with average low potassic tristanite.

Petrologically, the mafic portion of the dyke consists of fresh clinopyroxene (augite) and twinned plagioclase (andesine) both minerals occurring in euhedral- to sub-hedral crystal form. Magnetite and iron sulphides (pyrite) commonly occur as accessory constituents, and small aggregates of chlorite occupy spaces between the larger pyroxene and plagioclase crystals. The felsic portion of the dyke is made up of prominent euhedral blades of plagioclase, the latter displaying well-developed twinning. Quartz, amphibole, carbonate, chlorite, and orthoclase, makes up the remainder of the rock which has a pale pinkish-red colouration due to staining by iron oxides.

III. THE MULDERSDRIF ULTRAMAFIC COMPLEX

A. Introduction

Rocks forming part of the Muldersdrif Ultramafic Complex occupy an area approximately 10 km² in extent on the farms Driefontein 179 IQ, Honingklip 178 IQ, and Van Wyks Restant 182 IQ, west of Muldersdrif. Topographically, the southern portion of the complex is relatively flat-lying, except for a few low hills and ridges of serpentinite that provide some relief in the area. The central and, to a lesser extent, northern parts of the complex consists of a series of bush-clad ridges and intervening grassy valleys all of which trend in an approximately WNW direction across the area (Plate 1, C and D).

As mentioned previously the complex is enveloped, in all but the western and southwestern regions, by intrusive Archaean granites, the latter probably being mainly responsible for the structural disturbances so prominent, not only around the greenstone remnant margins, but also within the main body itself (Figure 2).

B. Geology of the Muldersdrif Complex

Ultramafic rocks, all of which have been extensively altered to serpentinites and various amphibole, chlorite, and talc schists, make up the bulk of the layered body. The remaining rock types, which are volumetrically subordinate but which nevertheless provide important marker beds, comprise mainly thin meta-gabbroic layers, many of which are less than one metre wide. Because of their importance as marker beds their true thickness has generally been exaggerated on the accompanying geological map of the region (Figure 2). In places the mafic interlayers are up to five metres wide whereas, at the other extreme, they can occur as units only centimetres wide.

The differentiated ultramafic complex displays characteristics similar to those found in many of the layered bodies that occur in the Barberton area, including the presence of cyclically repetitive sequences of dunitic, harzburgitic, pyroxenitic, and gabbroic rocks (Anhaeusser, 1976, 1978; Viljoen and Viljoen, 1969b). Whereas it has been possible to establish the details of the geology of some of the Barberton layered bodies (due mainly to the fact that they are better preserved and more clearly exposed) the Muldersdrif occurrence, by virtue of its high degree of alteration, does not provide an environment sufficiently favourable to resolve all the problems linked with this type of complex.

An unknown number of cycles, each commencing with a variety of ultramafic rocks, and terminating with a medium- to fine-grained meta-gabbroic member, occur in the area. The ultramafic rocks are almost everywhere altered to serpentinites but the original cumulate textures are frequently preserved. In many places mottled, serpentinized, dunites either outcrop, or are

available for examination on many of the mine dumps and prospect heaps scattered throughout the region. The mottled dark and light coloured altered olivine cumulates led to the coining of the field term "guinea fowl textured dunites" (Plate 1E). Generally the olivine crystals are totally pseudomorphed by antigorite and average approximately 5 mm in diameter. However, the mottled dunites may contain olivine crystals and aggregate olivine clusters measuring the size of a golf ball (Plate 1F).

In thin sections the dunites show no relic olivine whatsoever. Instead the rocks mainly contain antigorite, talc, tremolite, and chlorite. Brucite and magnetite occur as accessory minerals, the latter forming small dust-like particles and aggregates that are generally found around the outer periphery of the altered olivine grains. In some specimens chrysotile fibre is evident as well as the olivine alteration products serpophite and iddingsite. Surface alteration is also responsible for the development of some opal and cryptocrystalline, minutely fibrous or radiating, chalcedony, the latter filling small cavities in the deformed, differentially weathered dunites, like those shown in Plate 2A.

The serpentized dunites display very little that is chemically diagnostic. As can be seen in Table 2, they contain in excess of 11 per cent H_2O^+ - values found by Viljoen and Viljoen (1969e) to be indicative of ultramafic rocks that have largely lost their distinctive chemical and mineralogical characteristics. Judging from the findings of these authors the Muldersdrif serpentized ultramafic rocks have probably suffered a loss of CaO , Al_2O_3 , SiO_2 , Na_2O and K_2O , as well as total iron. Only MgO appears as if it may have increased as a result of the serpentization process.

Other ultramafic rocks encountered in the basal portions of the cyclic units include altered harzburgites and pyroxenites. Both these rock types are also almost entirely altered to serpentinites but may be distinguished from the dunites, both in the field and under the microscope, by changes in colour, mineralogy and texture. The harzburgitic rocks (there are probably altered wehrellites and lherzolites included under this category) consist of antigorite, the latter pseudomorphous after olivine, and bastite and talc, both of which are pseudomorphous after large cumulate pyroxene crystals. The pyroxenes are almost totally altered, but appear to have been mainly orthopyroxenes (enstatite, bronzite) although relic clinopyroxene was seen in places as well.

In the field the serpentized harzburgitic rocks are generally bluish-black in colour where they are free of severe alteration and shearing. This is in contrast with the dunites which are greyish-green to olive-green on surface, but which may also show dark-green to bluish-green colours in samples from some of the underground workings in the area.

Only one sample of harzburgitic rock was analysed, and this is listed in Table 2, column 3, for comparison with the serpentized dunites and pyroxenites from the area. Again a high water content has probably "de-natured" the rock but it is evident that the presence of the pyroxene in the harzburgite has caused the increases seen in the SiO_2 and CaO values as well as the reduced MgO content, relative to the dunites.

Serpentized pyroxenites are mainly responsible for the prominent bush-clad ridges that trend in a WNW direction across the central and northern parts of the Muldersdrif Complex (Plate 1, C and D). As is the case in many of the Barberton layered bodies, the pyroxenites are the most resistant units in the stratigraphy, and form jagged boulder-strewn outcrops. It is possible that the preferential development of bush and trees on the pyroxenites may be linked with the chemistry of the rocks. It is considered more likely, however, that the "rough texture" of the outcropping ridges provides a more suitable environment for this type of vegetation to gain a foothold than does the surrounding smooth, open, unprotected tracts.

The pyroxenites vary considerably in colour from grey-green to blue-black. In places the surface exposures have a reddish brown weathered crust whereas elsewhere the rocks may display various shades of grey or green.

In thin section the pyroxenites can be distinguished from the other serpentized ultramafics in the region by the presence of large cumulate pyroxenes, the latter almost invariably totally pseudomorphed by bastite or talc. Antigorite occurs interstitial to the altered pyroxenes, and accessory amounts of magnetite may also be present. The serpentized ridges appear to have originally been orthopyroxenite layers (enstatolites or bronzitites) but elsewhere in the complex some altered clinopyroxene-bearing pyroxenites were noted.

A single chemical analysis of a serpentized orthopyroxenite from the northern part of the Muldersdrif Complex (sample VW 37, Figure 2, A2) reveals little difference when compared with the neighbouring serpentized dunite from sample locality VW 38 (Table 2, columns 1 and 2). This is in direct contrast with the chemical characteristics of similar, but less water-affected pyroxenites in the Barberton greenstone belt. Here, with H_2O^+ contents of between one and five per cent, the pyroxenites have SiO_2 values generally exceeding 50 per cent (Anhaeusser, 1976; Viljoen and Viljoen, 1969a). As with the serpentized dunites, the Muldersdrif pyroxenites have "lost their chemical identity" and reflect prominent decreases in the amounts of SiO_2 , total iron, MnO , and CaO , compared with their Barberton counterparts. MgO , on the other hand, shows a considerable increase.

TABLE II
Chemical Analyses, CIPW Norms and Colour Indices of Various Rock Types
Occurring in the Muldersdrif Ultramafic Complex and Surrounding Volcanic Sequences

	1	2	3	4	5	6	7	8	9	10	11	12
	VW 38 ^ø	VW 37 ^ø	VW 26 ^ø	VW 30 ^ø	VW 27 ^ø	VW 39 [†]	VW 25 ^ψ	HK 1 [▽]	HK 2 [▽]	HK 3 [▽]	HK 4 [▽]	HK 5 [▽]
SiO ₂	40,06	40,00	48,10	45,84	48,71	48,95	51,20	37,71	37,77	39,09	37,73	38,35
TiO ₂	0,07	0,06	0,05	1,00	0,75	0,58	0,34					
Al ₂ O ₃	2,70	2,84	1,05	13,50	15,36	12,14	14,80					
Fe ₂ O ₃	4,05	5,45	1,21	2,36	1,83	1,32	1,88					
FeO	1,74	1,15	3,81	10,52	9,14	9,14	5,60					
MnO	0,10	0,09	0,26	0,24	0,19	0,20	0,13					
MgO	38,15	37,52	31,59	7,60	8,18	11,19	9,10	39,25	39,65	37,58	38,59	39,88
CaO	0,25	0,26	4,48	15,56	10,10	10,47	13,10					
Na ₂ O	0,0	0,26	0,04	0,61	0,35	1,78	1,10					
K ₂ O	0,10	0,10	0,10	0,20	1,72	0,19	0,16					
P ₂ O ₅	0,05	0,05	0,06	0,08	0,10	0,09	0,04					
H ₂ O ⁺	11,45	12,02	8,43	2,39	3,16	3,05	1,70					
H ₂ O ⁻	0,15	0,19	0,13	0,08	0,08	0,12	0,06					
CO ₂	0,25	0,11	0,14	0,07	0,16	<0,05	0,0					
R ₂ O ₃ ^Σ							9,26	7,40	9,19	9,76	7,45	
L.O.I.							13,11	14,62	13,23	12,41	12,82	
Cr ppm *	2190	2230	4200	225	152							
Sr ppm *	<5	<5	13	285	236	101						
Rb ppm *	19	16	19	18	110	22						
Cu ppm *	29	23	<15	38	138							
Ni ppm *	2760	2860	820	340	245							
Co ppm *	126	113	102	57	61							
S ppm *	630	390	420	210	220							
TOTALS	99,43	100,21	100,01	100,10	99,87	99,32	99,21	99,33	99,44	99,09	98,49	98,50
No. of Analyses	1	1	1	1	1	1	1	14	10	10	9	13

CIPW weight norms

Cc	0,70	0,32	0,75	0,24	-							
Ap	0,15	0,18	0,24	0,22	0,10							
Il	0,10	1,88	1,46	1,14	0,66							
Or	0,65	1,17	10,41	1,16	0,97							
Ab	0,37	5,11	3,03	15,57	9,52							
An	2,61	41,26	36,09	25,40	35,77							
Mt	1,92	3,39	2,72	1,98	2,79							
Di	14,88	16,12	6,83	15,07	18,47							
He	1,06	12,01	4,21	7,13	5,98							
Q	-	-	3,34	-	5,38							
Fo	18,21	3,70	-	3,46	-							
Fa	1,63	3,48	-	2,07	-							
Fs	4,58	5,42	13,25	9,70	5,75							
En	53,15	5,98	17,68	16,88	14,61							
C	-	-	-	-	-							

Colour Index (Normative)

95,42	94,86	95,57	50,27	44,92	56,49	47,70
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Analysts : + General Superintendence Company Limited.
 ø National Institute for Metallurgy, Johannesburg.
 * C.S. Bergström.
 ψ Bergström and Bakker.
 ▽ S.A. Manganese AMCOR Ltd.
 Σ R₂O₃ - Total Fe+Al₂O₃+Cr₂O₃

Columns : 1 Serpentinite (dunite)
 2 Serpentinite (orthopyroxenite)
 3 Serpentinite (harzburgite)
 4- 5 Metagabbroic rocks
 6- 7 High Mg-basalts (metatholeites, metakomatiites).
 VW39 - Archaean spherulitic pillow lava.
 VW25 - Ventersdorp (Archaean ?) massive lava.
 8-12 Average partial analyses of serpentinites sampled from borehole cores.

Although it is possible to distinguish, in the field, the original character of some of the ultramafic rocks in the Muldersdrif Complex, it was considered impracticable to differentiate the various types on the accompanying map of the region. Any such attempt at refining the field mapping would require a vastly expanded petrological examination of rocks in the area - a task deemed unwarranted for the elucidation of the broader aspects of the geology of the complex. An expanded petrological approach to mapping would also encounter considerable difficulties, particularly where the rocks have been excessively tectonized and appear as schists containing one or more of the following components : talc, chlorite, tremolite-actinolite, antigorite, carbonate.

Meta-gabbroic rocks terminate the cyclical units in the Muldersdrif body - a relationship that was first recognized in the Handcup-Mundt's Concession and Stolzburg layered complexes in the Barberton Mountain Land (Anhaeusser, 1969, 1976, 1978). The meta-gabbros, when traced in detail, outline a complex series of interference folds (Figure 2) indicating that the layered body has been subjected to several superimposed fold deformations. In the field the gabbroic rocks are generally fine-grained, dark brown to black or dark greyish-green coloured rocks when seen on fresh surfaces but display a distinctive reddish brown colour on weathered surfaces. Exposures of the meta-gabbroic rocks are generally rather poor and it is often difficult to trace the units as they commonly occur only as ankle-high outcrops. However, the mapping of the meta-gabbros was facilitated by virtue of the fact that the early asbestos prospectors recognized a sympathetic relationship between the development of chrysotile asbestos fibre and the massive, compact gabbroic rocks. They thus set about trenching the area and many of the prospect pits, and other old workings, outline their presence in many parts of the region (Plate 2B).

In thin sections, the meta-gabbroic rocks display decussate textures and consist mainly of amphibole (mainly actinolite), together with varying amounts of epidote (saussuritized plagioclase), sphene and opaque oxides (magnetite, ilmenite, leucoxene). Even the freshest exposures show signs of uralitization and saussuritization of the original pyroxene-plagioclase components. This alteration has probably influenced the major element geochemistry of the rocks but these changes do not appear to be as marked as those influencing the ultramafic rocks in the area. The analyses of two samples from widely separated areas within the Complex are listed in Table 2, columns 4 and 5, together with their norms and colour indices. Compared with better-preserved equivalent meta-gabbros from most of the layered complexes in the Barberton area (Anhaeusser, 1976) the Muldersdrif rocks display lower amounts of SiO₂, MgO, and Na₂O, and greater amounts of TiO₂, Al₂O₃, total iron, MnO, CaO, and K₂O. Whereas the Barberton meta-gabbros show affinities with the komatiite-type basalts, as defined by Viljoen and Viljoen (1969d), those in the Muldersdrif body are tholeiitic. Whether this difference is real or imposed remains uncertain at this stage. There is, however, in the writer's opinion, a close genetic link between the various examples compared above and it appears likely that the differences may well reflect the degree of alteration suffered by the Muldersdrif assemblages.

C. Economic Geology

1. Chrysotile Asbestos

Chrysotile asbestos mineralization attracted the attention of early prospectors and led to the establishment in the area of three pre-World War II asbestos mines, the locations of which are shown on the accompanying geological map (Figure 2, B1 and B3). However, judging from the size of the respective workings the operations could not have produced much fibre.

Asbestos showings occurred throughout the region and, as a consequence, prospect pits testing the quality and availability of the fibre are prolific. The present study showed that the development of chrysotile asbestos appears to have been largely dependent on the style of deformation and on the composition of the deformed host rocks. Almost invariably the asbestos fibre of significance is located in the basal portion of the dunite or harzburgite zones where these rocks immediately overlie the massive, fine-grained, meta-gabbroic terminal phases of a preceding differentiated cycle. Competency contrasts and differential movement at these contacts are clearly responsible for fibre growth.

In some localities the ultramafic rocks overlying the meta-gabbros display what appear to be narrow chill contacts. These zones, which vary from a few centimetres upwards to about 20 cm wide, contrast sharply with the dark brown or black meta-gabbros, and generally show up as pale grey to pinkish-grey or pale bluish-grey, talcose serpentinites (Plate 2, C and D). In thin section some of the layers display densely interlocking radiating fans of chlorite, the latter exhibiting anomalous greyish interference colours. Scattered grains of magnetite also occur in these rocks together with accessory amounts of brucite, bastite, and a cinnamon-coloured isotropic mineral (possibly grossular garnet).

At this point it might be appropriate to introduce an argument that has been raised in the field concerning the so-called meta-gabbroic rocks. It has been suggested, because of the unusual outcrop pattern of interlocking and apparently crosscutting gabbro layers, that these rocks could represent intrusive dykes. Attention is directed at the chill-zone contact rocks, described above, which are called upon to support the intrusive mafic dyke argument. While conceding that this would normally be an acceptable interpretation, a more complete understanding of the Muldersdrif occurrences makes this view untenable. Selected traverses from south to north across the Complex, particularly in

the central area (Figure 2, segment B2), demonstrates the involved nature of the folding of the successions (Anhaeusser, 1976) and it can be seen that the meta-gabbroic rocks occur as conformably interlayered units deformed into a series of predominantly east-west-trending synclines and anticlines. A less prominent north-south fold trend is responsible for the development of the differential fold plunges located throughout the region. The involved and closely spaced folds found in the region renders it inappropriate to add dip and strike information to the existing map of the area. Selected areas could be chosen for a more detailed structural appraisal as this did not fall within the scope of the present investigation.

It might still be argued that the meta-gabbroic rocks could represent sill-like layers intruded into the Complex prior to deformation. This view is more difficult to reject and it is necessary to direct the readers attention to the classic examples of Archaean layered ultramafic complexes in the Barberton area which provide unequivocal evidence of similar meta-gabbroic interlayers terminating cyclically differentiated units (Anhaeusser, 1969, 1976, 1978). In the writer's opinion the Muldersdrif meta-gabbros are of this nature and probably represent the residual liquid fraction remaining after the crystallization of the earlier cumulus phases of the layered body.

Where the chill serpentinites are absent there are generally indications of chrysotile asbestos. The fibre development appears to be restricted to a zone immediately in contact with the meta-gabbros. This zone can extend up to a metre in width but more commonly the fibre seams, which are orientated parallel to the meta-gabbro-serpentinite contacts, are seldom more than 20 cm wide. In most places the fibre is poorly developed but elsewhere ribbon seams, like those shown in Plate 2 (E and F), are present. The fibre seams closest to the gabbro contacts are often the widest and generally become narrower and more closely spaced before disappearing altogether in the overlying serpentinites.

Chrysotile asbestos, which is a stress-controlled mineral, develops as cross-fibre asbestos where tensional conditions prevail. It thus appears that the competency contrasts between the massive, brittle, footwall gabbroic rocks and the overlying serpentinites provided an ideal structural setting, particularly where folding caused the rocks to yield differentially. Faulting and shearing in the Muldersdrif Complex also undoubtedly played a role in fibre development but no significant tonnages could be located.

In some prospect trenches the asbestos fibre can be seen occurring not only at the upper contact of the gabbro with the serpentinite but also at the lower contact as well. In quarries forming part of the Gelden Asbestos Mine it is not unusual to find a central pillar of meta-gabbro still preserved and having fibre seams mined out on either side. The attitude of the fibre zones is dictated by the attitude of the gabbroic interlayers. In the areas where mining has occurred the asbestos has generally been stoped from vertical to subvertically orientated zones of fibre development (Plate 3A).

At the old Gelden Mine access to some of the underground workings was by way of a vertical shaft, the headframe of which is still partly preserved (Plate 3B). The shaft is presently flooded and inaccessible. The remaining mines in the area have access to the underground workings by way of adits driven into the side of the hills. These occur mainly with respect to the Scott and West Rand asbestos mines (Figure 2, B3 and Plate 1D).

2. Serpentine

Asbestos mining ceased in the early 1940's and today the only mining operations in the area centre around the quarrying of serpentine. The Samancor (formerly Amcor) serpentine quarry is situated on the farm Honingklip 178 IQ (Figure 2, B1 and Plate 3C) in altered, deformed dunites, the latter also having narrow interlayers of meta-gabbro.

Chemical data from several borehole samples in the quarry area shows that the serpentinites are enriched in MgO and have relatively low SiO₂ contents (Table 2, columns 8 to 12). The open cast mine produces approximately 4 500 tonnes per month and has been in operation since early 1970. According to a report in Coal Gold and Base Minerals (1976) the serpentine is used by Palmiet Chrome of Krugersdorp and Transalloys of Witbank as a flux in their ferroalloy producing operations. In addition, Chemfos uses the material for the manufacture of calcium magnesium phosphate fertilizers.

IV. SUMMARY AND CONCLUSIONS

The Muldersdrif Ultramafic Complex comprises a layered differentiated body, the latter consisting of an unknown number of cycles, each cycle commencing with a variety of ultramafic rocks and terminating with a medium- to fine-grained meta-gabbroic member. The ultramafic rocks are everywhere altered to serpentinites, but petrological evidence is available suggesting that these rocks were formerly mainly of dunitic, harzburgitic, and pyroxenitic composition, in which cumulus olivines and pyroxenes (ortho- and clino-pyroxenes) were prominent. The meta-gabbroic rocks terminating the cycles were possibly crystallized from residual liquids trapped in the cooling igneous body. A striking degree of similarity exists between these differentiated igneous rocks and the layered

ultramafic complexes reported from the Barberton Mountain Land (e.g. Stolzburg, Noordkaap-Kaapschehoop, Kaapmuiden-Malelane).

In addition to the marked similarity of rock types, a further feature of significance is the occurrence, common to all these layered ultramafic bodies, of chrysotile asbestos mineralization. The chrysotile asbestos fibre development appears to have been largely dependent on the style of deformation and the composition of the deformed host-rocks. Almost invariably the asbestos fibre of significance is located in the basal dunite zones that immediately overlie the massive, fine-grained meta-gabbroic terminal phase of a preceding differentiated cycle. As in the case of the chrysotile asbestos deposits found in the ultramafic complexes in the Barberton area the combined factors of rock composition (usually serpentinized high-Mg dunites), and suitable structural disposition, seem to be a pre-requisite for the development of exploitable asbestos fibre. The Archaean layered ultramafic complexes that appear to have developed as penecontemporaneous concordant sills within the greenstone volcanic piles therefore represent some of the most favourable target areas in which to search for chrysotile asbestos.

In conclusion, it is interesting to note that many of the layered ultramafic complexes that are associated with the lowermost stratigraphy of greenstone belts are often situated in, or adjacent to, peridotite-poor extrusive successions. This is particularly evident with regard to some of the Kaapmuiden-Malelane complexes described by Viljoen and Viljoen (1969a) as well as the Stolzburg Complex situated near the Nelshoogte Schist Belt in the Barberton area (Anhaeusser, 1976, 1978). The Muldersdrif Complex provides a further example with the adjacent volcanic sequences extending across the area from Honingklip in the west, to the Roodekrans area in the east, being notably lacking in peridotite flow units and having instead great volumes of basalts (either high-Mg basalts or basaltic komatiites). By contrast, layered ultramafic complexes of the type described in this paper are entirely lacking from areas well-endowed with peridotite extrusives, such as the Komati Formation type-location in the Barberton greenstone belt, described by Viljoen and Viljoen (1969d).

The inference to be drawn from these observations suggests that where peridotite flows are either absent or only sparsely developed the ultramafic magma that, given other conditions, would have erupted as flows, has instead built up in massive, sill-like, chambers and has undergone olivine, orthopyroxene and, in some cases, clinopyroxene fractionation (Anhaeusser, 1977), the latter process leading eventually to the generation of a wide range of cumulus-enriched liquids ranging from dunites, orthopyroxenites, websterites, and gabbroic igneous rocks.

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KEY TO PLATE 1

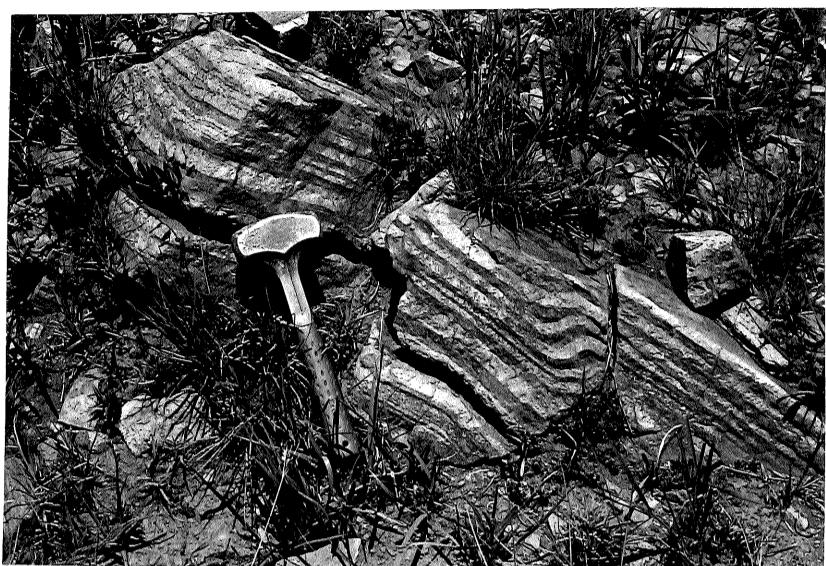
- A. Undeformed, high-Mg pillow basalts showing spherulites concentrated mainly around the outer margins of the pillow structures. Locality near sample VW 39 (Figure 2, D3).
- B. Banded ferruginous cherts, the latter partly recrystallized to a fine-textured quartzitic rock, and occurring interlayered with amphibolites located on the western half of the farm Van Wyks Restant 182 IQ (Figure 2, B2). The banded cherts represent the first reported sedimentary rocks present in any of the Archaean greenstone remnants found on the Johannesburg granite dome.
- C. Aerial view of the central part of the Muldersdrif Ultramafic Complex showing the east-west-trending bush-clad ridges made up predominantly of serpentinized pyroxenite and subordinate dunite layers.
- D. Aerial view again showing the bush-clad ridges forming part of the Muldersdrif Ultramafic Complex. In the centre foreground are some of the asbestos workings of the Scott Asbestos Mine. Several prospect pits and trenches are also evident in the smooth grassy tracts made up of serpentinized dunite on the left of the photograph.
- E. Cumulate textured serpentinized dunite ("guinea fowl textured dunite"), found on old rock dumps at the Gelden Asbestos Mine (Figure 2, B1). The rock consists almost entirely of antigorite, with minor bastite. The latter minerals pseudomorphically replace cumulus olivine and orthopyroxene crystals.
- F. Serpentinized dunites showing large olivine crystals, or crystal aggregates of olivine, the latter totally altered to antigorite. The dark matrix also consists of serpentinized olivine (antigorite and lizardite pseudomorphous after cumulus olivine crystals). These rocks occur on an old dump at a prospect winze located west of the main workings of the West Rand Asbestos Mine (Figure 2, B3).

PLATE 1

A



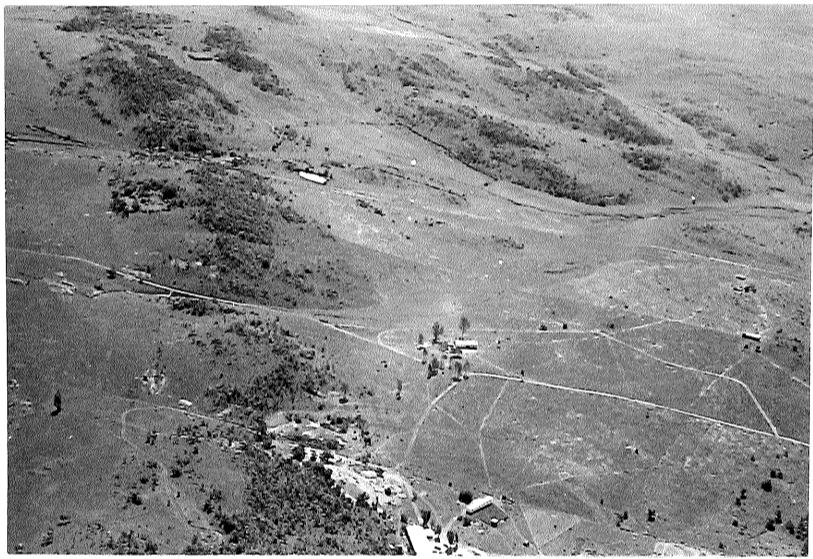
B



C



D



E



F



KEY TO PLATE 2

- A. Deformed serpentinized dunite typical of many of the exposed cumulate textured ultramafic rocks in the Muldersdrif layered complex. Despite the shearing and flattening of these rocks the cumulate textures are generally still evident. The rocks in the area are intensely folded and dip at all angles. Without selective detailed structural mapping it would be extremely difficult to portray the attitude of the formations as they change so frequently. Vugs and cavities caused by differential weathering sometimes contain opaline silica and chalcedony, the latter minerals derived from the breakdown and release of SiO₂ during serpentinization.
- B. View, looking east towards the Johannesburg granite dome (background), showing portion of the central part of the Muldersdrif Ultramafic Complex. In the foreground are outcrops of serpentinized pyroxenites forming a scree slope while in the middle distance can be seen many of the prospect pits and trenches that were excavated in the search for chrysotile asbestos mineralization. The trenches also expose many of the thin meta-gabbroic units that generally occur in contact with dunites of an overlying differentiated cycle. Chrysotile asbestos mineralization is commonly encountered in the dunites adjacent to these contacts.
- C. Meta-gabbroic rocks commonly terminate individual cyclical units making up the Muldersdrif Ultramafic Complex. In this photograph the dark-weathering meta-gabbros are capped by a chill-zone dunite layer from the overlying cyclical unit. The chill-zone consists mainly of talcose serpentinite, the latter also frequently containing abundant chlorite that displays anomalous grey interference colours. This chlorite may be structurally more closely related to the kandites or serpentines. The name septechlorite has been proposed for them as they are structurally characterized by serpentine-like layers (Deer et al., 1971).
- D. Meta-gabbroic layer capped by a thin chill-zone talcose (chloritic) serpentinite layer a few centimetres wide. Differential weathering has removed the overlying serpentinized dunite which should have occurred on the right of the photograph above the chill contact. Exposures like these are common throughout the area but are best developed in the central part of the Muldersdrif Complex (Figure 2, segment B2).
- E. Serpentinized dunite showing parallel ribbon fibre seams of chrysotile asbestos. The longest fibres are generally developed nearest to the contacts of the serpentinites with the meta-gabbroic rocks. The fibre zones are seldom wider than one metre and generally average less than 20 cm. In the specimen shown, the meta-gabbroic contact originally occurred above the head of the hammer.
- F. Serpentinized dunite (left) grading into a zone approximately 20 cm wide in which poor quality chrysotile asbestos is developed. To the right of the hammer is the contact zone of the serpentinized dunite with a fine-grained meta-gabbroic layer. The poor quality asbestos is known as picrolite. This mineral has a columnar fibrous appearance, but the fibres or columns are not easily flexible and are not easily separable. The fibre seams are generally greenish-grey in colour and commonly have a splintery fracture.

PLATE 2

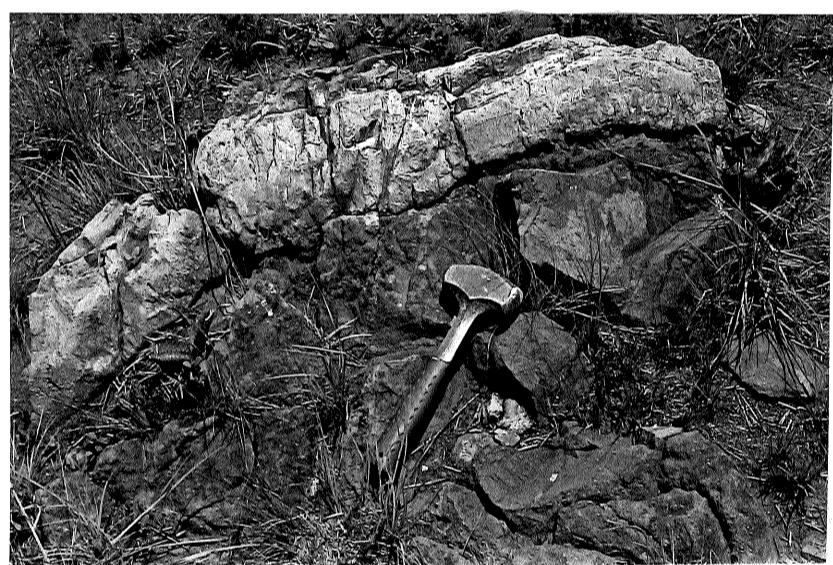
A



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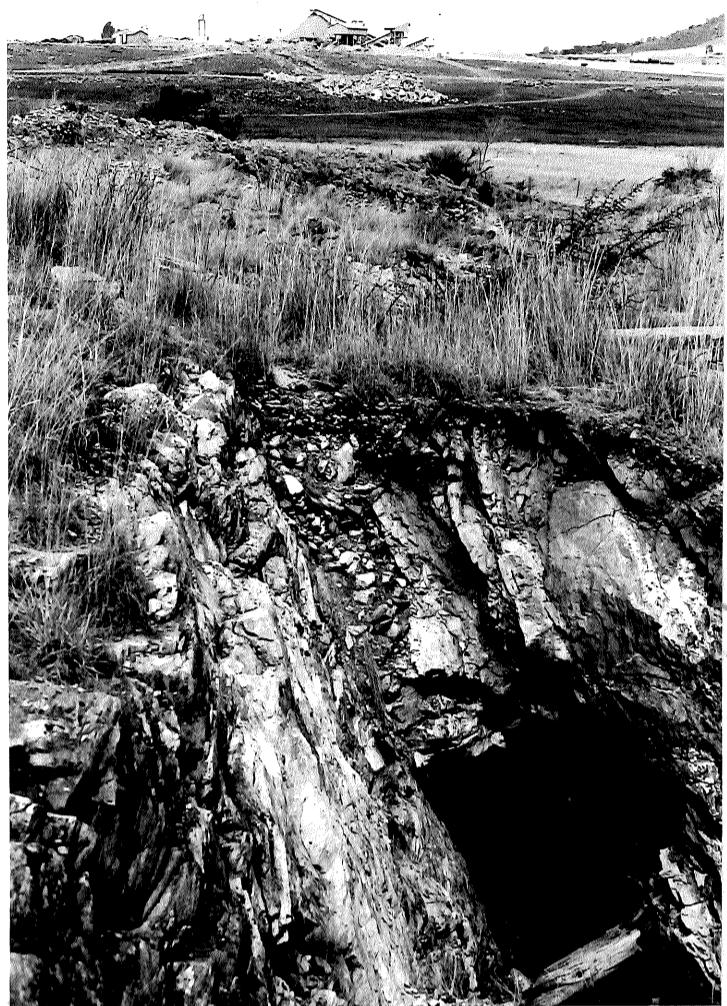
KEY TO PLATE 3

- A. View, looking east, of the serpentine crushing plant (far background) at the Samancor serpentine quarry on the farm Honingklip 178 IQ. In the foreground is an old stope forming part of the chrysotile asbestos workings of the Gelden Asbestos Mine.
- B. View, looking west, of all that remains of the headframe of the old Gelden Asbestos Mine on the farm Honingklip 178 IQ. The shaft at the mine is presently under water.
- C. View, looking south, of the Honingklip serpentine quarry. Approximately 4 500 tonnes of serpentinite are mined each month for use as a flux in the ferro alloy and fertilizer industries.

Figure 2 positioned on the inside back cover

PLATE 3

A



B



C

