been followed in the naming of units. Thus, Formation replaces Stage, and Group replaces Series. Instead of the suggested designation "Super-Group", to replace System, preference has been given to the term Sequence.

(b) A Summary of Previous Work in the Area North of Barberton

The earliest work in the Jamestown Schist Belt was that done by Hall (1918) who regarded the area as the type-locality for his Jamestown Series, a group of rocks consisting predominantly of basic igneous rocks with both massive and schistose habit. In the belt from Noordkaap westwards towards the Transvaal Escarpment he recorded four distinctive rock varieties. In order of abundance these constituted :

(i) soft basic schists

(ii) massive magnesian rocks

(iii) hard siliceous rocks, and

(iv) later intrusions of dykes and exceptionally of sills.

With the group of soft basic schists he included green hornblende schists, chlorite schists, and talc schists, as well as schistose basic rocks containing both talc, carbonate, and chlorite. To Hall (1918) the origin of these rocks was obscure but he considered some of them to be the metamorphosed products of serpentinite.

Serpentinite occupied a major part of Hall's massive magnesian group of rocks. These he found often occurring within a succession of soft basic schists and forming discontinuous, lenticular masses. Together with the group of massive, compact, igneous rocks Hall included many occurrences of talc and amphibolite and he mentioned that "they very closely resemble some of the basic varieties found in the Komati River valley ..." He added that "the occasional development of an amygdaloidal or vesicular structure strongly recalls a larger outcrop of similar rocks, with that structure shown in a more pronounced manner, and found on the south bank of the Komati River".

Within the Jamestown Schist Belt, Hall also remarked on "hard siliceous banded rocks", ---- "banded calico rock" (banded chert), and "hard compact, almost black, fissile, thinly bedded, slaty rocks or siliceous slates". These and "several bands of slaty quartzites and other sedimentary rocks are found conformably alternating with basic schists". Hall (1918) regarded the rocks of the Jamestown Series as being intrusive into his Moodies Series, and occupying a position between the latter, and the granite. The granite, in turn, was regarded as intrusive into the Jamestown Series, resulting in thermal and dynamic metamorphism of the basic rocks.

Van Eeden (1941) described basic rocks, consisting of serpentinite, talc-carbonate schists, talc schists, amphibole schists, and mica-quartz schists, in the area between the Consort Mine and Louw's Creek. He pointed out then, that such rocks cannot easily be distinguished as having been derived from basic lavas or altered basic intrusive rocks. From their field relationships he did, however, tentatively classify them as altered basic and acid lavas of the Onverwacht - a view he did not subscribe to later.

The Geological Survey (Visser, compiler, 1956) also reported the widespread occurrences of serpentinite, amphibolite and basic schist in the Jamestown Belt and areas to the east. They regarded the rocks in the area as forming part of the basic phase of the Jamestown Plutonic Complex, comprising "a group of differentiated basic rocks, diabase and gabbro, which grade into amphibolite, blue serpentinite, green serpentinite and a variety of basic schists". The sedimentary rocks occurring conformably with the basic schists, referred to by Hall (1918), were regarded by the Geological Survey (Visser, compiler, 1956) as part of the Fig Tree Series that had been intruded by the Jamestown basic rocks. In addition to these sedimentary "remnants" of a once more extensively developed Fig Tree Series, small isolated patches of Onverwacht rocks are shown on the Geological Survey map and were regarded as xenoliths preserved in the Jamestown basic rocks. It was stated that "from the position occupied by these rocks it is evident that they have been subjected first to contact metamorphism during the intrusion of the Jamestown Complex and later, during the Barberton orogeny and intrusion of the Nelspruit Granite, to dynamic and pneumatolytic metamorphism".

The Nelspruit Granite to the north of the Jamestown Schist Belt was regarded as intrusive into the schists. It was reported that "this intrusive relationship may be well seen on Lot 140 and Riverside 489 (now Riverside 245 JU), south of the Kaffir Creek Talc mines, where several narrow off-shoots from the Granite project into the basic rocks".

Hall (1918) first described the hornblende granite of the Kaap Valley and distinguished it from the Nelspruit Granite. He considered that the Kaap Valley Granite had attained its more basic character due to assimilation of basic Jamestown rocks, yet he regarded both granites as being of the same age. The Geological Survey (Visser, compiler, 1956) noted that the Kaap Valley Granite was everywhere surrounded by basic rocks and always displayed sharp contacts with the schists. They thus considered that the Kaap Valley Granite, together with the suite of older basic rocks, constituted the Jamestown Igneous Complex and, as mentioned previously, they held the view that this granodiorite was "related to the basic phase of the Jamestown Complex in the same way as the Bushveld Granite is related to the basic rocks of the Bushveld Complex".

The low grade of metamorphism has been commented on by Hall (1918), who compared the metamorphic aureole of the Bushveld Complex with that of the "Older Granite" in contact with the Barberton Mountain Land. He noted that "on the whole, the metamorphism due to the Bushveld Complex is much greater than that due to the Older Granite ...." Hall attempted to explain the low-grade metamorphic phenomena as being due to a buffering effect provided by the intervention of the Jamestown Series rocks, and the generally unsuitable composition of the Barberton rocks. The Geological Survey (Visser, compiler, 1956) recognized the effects of dynamic and thermal metamorphism but considered regional metamorphism to be absent in the area.

Metamorphism due to the Kaap Valley Granite has been noted by most writers to be inexplicably absent, and all are unanimously agreed that the intrusion of the Nelspruit Granite caused by far the greatest, if not all the metamorphism in the area. Metamorphic minerals were noted by Hall (1918), and Visser (compiler, 1956) in the area under discussion, but no attempt was ever made to define metamorphic zones or sub-facies according to the appearance of specific index minerals. The first attempts to systematically examine the metamorphism in the Barberton area were those of Anhaeusser (1964), Viljoen (1964), and Anhaeusser and Viljoen (1965) who investigated the contact belt between the New Consort Gold Mine and Louw's Creek. These authors considered that the rocks in the contact zone had suffered thermal metamorphism caused by the intrusion of a mobilized marginal phase of the Nelspruit Granite and they subdivided the area into three facies of contact metamorphism. Progressively further away from the granite contact the successive facies listed were :

(i) a hornblende - hornfels facies,

(ii) an albite-epidote-hornfels facies, and

(iii) a greenschist facies.

(c) Structure of the Barberton Mountain Land

On the conclusion of the first systematic and comprehensive study of the geology of the Barberton Mountain Land, Hall (1918) concluded that the complex structure of the area could be attributed to the intrusion of the various granites.

Van Eeden (1941), from a detailed structural investigation of the Sheba Hills area, contended that the forces which produced the folds in the Mountain Land were from the south-southeast, and that the region, in general, had been affected by only one period of deformation. The style of the folding in the northwestern part of the Mountain Land was considered to be largely influenced by the Kaap Valley Granite, a granite that van Eeden (1941) considered intrusive into both the Jamestown Complex and the Swaziland System. He further ascribed complications in the fold pattern in the north to the presence of the Kaap Valley pluton, which he maintained was, at the time of deformation, an already crystallized mass. This he added, had acted as a solid buttress against which the less competent and bedded rocks were compressed and deformed by the major deforming stress from the southeast, where a granite, presumably of Nelspruit age, had intruded on the Swaziland side of the Mountain Land.

Hearn (1943) envisaged the folding as having been caused by the compression of the supracrustal rocks between the Nelspruit Granite in the north, and the Swaziland Granite in the south.

The Geological Survey (Visser, compiler, 1956) recognized numerous major fold and fault structures in the Barberton Mountain Land and demonstrated that, in general, the rocks had been folded along axes trending roughly east-northeast, west-southwest. The conclusion was drawn that a relationship existed "between the Barberton orogeny and the intrusion of the Nelspruit Granite". The Geological Survey (Visser, compiler, 1956) discussed the view that prior to the deformation of the Moodies System the Fig Tree Series had, in part, suffered folding. As evidence for this they cited that pebbles of contorted chert and ironstone had been found in the Moodies basal conglomerate.

Hunter (1961) suggested the following sequence of events for the Precambrian of Swaziland :

(i) geosynclinal phase : deposition of Swaziland System.

(ii) initial magmatic phase : Jamestown Complex.

(iii) regional metamorphism.

(iv) main orogenic pulsation : migmatization and granitization.

(v) inter-tectonic sedimentation and volcanism : Insuzi and Mozaan Series.

(vi) second orogenic phase : widespread intrusion of G4 Granite.

(vii) post-orogenic phase : G5 Granite plutons.

Ramsay (1963A), after carrying out a structural investigation in the Barberton belt, maintained that some areas within the Mountain Land had been subjected to several phases of deformation. His mapping in the areas northeast of Barberton led him to conclude that three deformations had occurred in the area, the effects of which he summarized as follows :

Deformation 1

This led to the development of a series of major and minor folds (F1), the traces of which probably trended NE-SW, or NNE-SSW.

Deformation 2

(i) Further compression, with the principal regional compressive strain orientated north-northwest, led to the formation of a slaty cleavage and schistosity which was superimposed across the F1 folds.

(ii) Only locally were new folds (F2) developed.

(iii) Low-grade regional metamorphism was associated with this deformation.

(iv) The Nelspruit Granite was intruded, thermally metamorphosing the adjacent strata.

(v) The main period of gold mineralization was probably late during the deformation.

Deformation 3

(i) This led to the folding of the slaty cleavage and schistosity by large- and small-scale folds (F3) in the north of the region.

(ii) The formation of the great arcuate structure of the first folds and of the slaty cleavage was possibly contemporaneous with the folding of the cleavage seen in the north of the area.

(iii) The development of conjugate folds and faults may have been synchronous with the formation of the arcuate structure (ii), but they may post-date it and be related to a fourth period of deformation.

Many of Ramsay's observations and conclusions were confirmed by later workers in the area north of Barberton (Anhaeusser, 1964;

Viljoen, 1964; van Vuuren, 1964) but these investigators considered it necessary to include the conjugate and crenulation folds into a 4th phase of deformation. Van Vuuren (1964) went a stage further and suggested a later, east-northeast trend of folding in the Ulundi Syncline.

Following Ramsay's work in the northern area, the structure of various other segments of the Barberton belt were examined (Herget, 1963; Poole, 1964; Cooke, 1965; Urie, 1965). The conclusions reached from the synthesis of this information formed the topic of a paper by Roering (1965). In this report, Roering suggested that the main gold-producing area of the Barberton Mountain Land (i.e. the area between Louw's Creek in the east, Barberton in the centre and Montrose in the southwest) had been subjected to six deformation phases. These were listed as :

(i) an Early Trend : possibly a pre-Moodies orogeny.

(ii) a Main Phase Deformation : the main ENE fold trend embracing both the F1 and F2 of Ramsay (1963A).

(iii) the Montrose Trend : N-S to NNW trending structures (possibly part of Ramsay's F3 deformation).

(iv) the Consort Trend : a strong NW trend equivalent to Ramsay's F3 deformation.

(v) a Late Ulundi Trend : a superimposed ENE trend, and

(vi) Flat Folds : a late deformation associated with conjugate and crenulation folds.

(d) Granites on the Northwest Flank of the Barberton Belt

As mentioned previously, Hall (1918) first described and distinguished a massive hornblende granite, which he referred to as the De Kaap Type or De Kaap Valley Type, and a gneissose, biotite granite, which he called the Nelspruit Type. Van Eeden (1941) later recognized three granites in the area :

(i) the Kaap Valley Granite

(ii) the Nelspruit Granite, and

(iii) the M'pageni Granite.

The Kaap Valley Granite was regarded by van Eeden (1941) as the oldest granite in the area, and one which was responsible for the marked change in strike of the various layered rocks surrounding it. He regarded it as having acted as a solid body during the orogeny which deformed the Swaziland System. Contrary to Hall (1918), who regarded the Kaap Valley Granite as a variant of the more widespread Nelspruit Granite, van Eeden (1941) held the view that the latter granite had intruded contemporaneously with the Barberton orogeny and was therefore something quite separate.

The third granite, which van Eeden called the M'pageni Granite, was found to occupy only a small area between Nelspruit and Kaapmuiden. The coarse, pale reddish granite, best developed in the area of the trigonometrical beacon M'pageni (3,894 feet), forms large boulder-like outcrops that are clearly distinguishable from the surrounding finer grained, greyish, gneissose Nelspruit Granite.

Later workers in the area considered the Kaap Valley Granite to be a younger granite than the Nelspruit Granite (Hearn, 1943; Read, 1957; Ramsay, 1963A; Viljoen, 1964; Cooke, 1965; Roering, 1965 and the writer, Anhaeusser, 1966A).

The Geological Survey (Visser, compiler, 1956) regarded the Nelspruit Granite as being "representative of the typical Archean Granite of the Lowveld of the Eastern Transvaal". They considered, furthermore, that "the Nelspruit Granite has not consolidated from a normally, primary granitic magma but represents a product or a series of products of a process or processes generally known as granitization". Intrusive relationships between the Nelspruit Granite and the rocks of the Swaziland System were shown to exist and it was made apparent that various phases of the granite exist, ranging from a "shallow marginal phase (hood-phase), which is gneissose and which contains frequent foreign inclusions close to the contact", ---- "to the deeper phase (core-phase), which is massive, exhibits almost no flow-structures, and bears no trace of the original intruded rock".

Read (1957) suggested that the Nelspruit gneiss had resulted from the migmatization of semipelitic and more siliceous rocks and that the large number of basic inclusions found in the granite terrain represented relics of basic resisters. Read, furthermore, suggested that the negligible degree of metamorphism displayed in the Barberton rocks was due to the belt of basic rocks everywhere surrounding the greenstone belt and which acted as a basic resister, shielding the supracrustal rocks from granitization.

Ramsay (1963A) also noted that both the Kaap Valley Granite and the Nelspruit Granite had intruded the Swaziland successions. He posed the question whether or not all the granitic material surrounding the Barberton belt could be regarded as post-dating the deposition of the sediments. He also queried the composition of the pre-Swaziland basement and suggested that much of the complexity of granites and gneisses surrounding the Barberton belt formed a fundamental basement complex on which the volcanic and sedimentary rocks were deposited. Anhaeusser (1964) and Viljoen (1964) mapping the contact belt between Louw's Creek and Consort Mine found they could distinguish two characteristic types of granite in the Nelspruit terrain of the Krokodilpoort Range. The first consisted of a migmatitic or gneissic type, and the second a homogeneous intrusive granite, confined in its occurrence mainly to the immediate contact zone with the supracrustal rocks. The intrusive granites could further be subdivided into foliated granites, pegmatites, and aplites. These writers also suggested that some of the migmatitic and gneissic Nelspruit terrain might well represent an original floor for the Swaziland System rocks.

(e) Granites from Other Areas of the Barberton Mountain Land

Van Eeden and Marshall (1965) have recently recognized a fourth granite-type near Hectorspruit in the northeastern part of the Barberton greenstone belt, which they have named the Salisbury Kop granite. The rock was described as a fine- to medium-grained, pinkish-coloured granite, containing a high-percentage of quartz, often a milky opalescent variety. The homogeneous, massive granite they stated displays no foliation and is porphyritic in places. No contact of this granite with the Nelspruit Granite to the north is evident because of poor exposure. The Salisbury Kop granite is, nevertheless, intruded into the older sediments and schists of the Swaziland System. There appears to be some confusion in these authors' minds as to the geological history of this granite because, on the one hand, they regard it as being intrusive into Swaziland System rocks, while elsewhere they mention that "this granite may be the oldest granite" ---- "and that the Swaziland System was deposited on it". The intrusive relationships and gradational contacts were explained as being due to mobilization and metamorphism.

In Swaziland, Hunter (1953) first published a new classification of the various granites and gneisses in the territory. The former six-fold division was later changed (Hunter, compiler, 1961), the primary characters of which are set out below :

(i) G1 granite : consisting essentially of two varieties; the first being a migmatitic, coarse-grained, crudely foliated, dark-coloured granite and the second, comprising homogeneous, coarse porphyritic granite, generally pale in colour.

(ii) G3 granite : foliated, dark greenish-black granite with felspar porphyroblasts.

(iii) G4 granite : normally a coarse-grained, grey granite but locally porphyritic or foliated and commonly containing pegmatites.

(iv) G4/5 granite : very coarsely porphyritic granite, grading to coarse-grained, with no pegmatites in the coarser portions.

(v) G5 granite : a coarse porphyritic granite devoid of pegmatites but occurring in clearly defined plutons.

A later, more detailed, study of the various granitic rocks of Swaziland led to Hunter (1965) proposing a new geotectonic approach to the classification of the Swaziland granites. This briefly was modified as follows :

(i) the Ancient Gneiss Complex : the earliest rocks in the area, consisting of (a) basic intrusives and volcanics (?). all altered to amphibolites, and (b) various gneisses with meta-sedimentary relics.

(ii) a Granodiorite Gneiss Cycle : synorogenic granodioritic gneisses and hornblende granodiorite (formerly G3).

(iii) a Synorogenic Granite Cycle : consisting of a differentiated series of granitic rocks ranging from quartz-dioritic to leucocratic granodioritic in composition (formerly G1).

(iv) a Late-orogenic Granite Cycle : constituting (a) medium-grained biotite granodiorite and leucocratic granodiorite (b) grey, medium- to coarse-grained granite (formerly G4) and (c) pegmatites.

(v) an Older Post-orogenic Granite Cycle : constituting cross-cutting plutons of medium-grained and coarse grained porphyritic granite (formerly G4/5), and

(vi) a Younger Post-orogenic Granite Cycle : consisting of sharply cross-cutting plutons of coarse-grained porphyritic granite (formerly G5).

Although Hunter (1965) has advocated the new classification of the Swaziland granites in terms of synorogenic, late-orogenic, and post-orogenic, according to their position in, what he regards as an orogenic cycle, the G series of granite classification has become so entrenched that constant reference is still being made to such granites as the G4 and G5 types.

A less rigorous breakdown of granites in South Africa by Anhaeusser et al, (1967) led to the recognition of a number of distinct granite-types, viz. the Kaap Valley, Nelspruit, Nelshoogte, M'pageni, Salisbury Kop, and Dalmein granites. The basement migmatites and gneisses were regarded as the oldest granitic rocks, followed by a 3,000 m.y. granitic episode superimposed on an already orogenically deformed Swaziland Sequence. Diapiric granite bodies, such as the Kaap Valley Granite, and the Nelshoogte Granite, were held responsible for the structural disturbance of the supracrustal greenstone belt assemblages. The youngest granites, such as M'pageni, Salisbury Kop, Dalmein, and the G5 (or Post Orogenic Granite) of Swaziland were found to cut cleanly across the trends of the supracrustal rocks and were not responsible for much structural disturbance in the invaded areas.

(f) Geochronology

The earliest published data relating to the isotopic ages of rocks in the Barberton and surrounding areas was that of Allsopp et al, (1962) who derived Rb-Sr ages for the G1, G4 and G5 granites of Swaziland. The results obtained conformed with the stratigraphic classification of these granites which was proposed by Hunter (compiler, 1961). Three samples of G5 gave ages of 2,200 ± 50 m.y., 2550 ± 50 m.y., and 2880 ± 340 m.y. respectively, while 4 samples of G4 gave a mean of 3070 ± 60 m.y.

Nicolaysen (1962), working in conjunction with H.R. Roberts, A.J. Burger, and H.L. Allsopp, obtained ages of close to 2600 m.y. "which refer to times of emplacement of post-Moodies migmatitic granites".

Very old lead-model ages, averaging 3460 m.y. are reported from galena samples collected from several gold mines in the Barberton area (Ulrych et al, 1967) while U-Pb ages on Cu-Fe sulphides and zircons from an acid lava horizon in the upper regions of the Onverwacht Group yielded ages of 3360 m.y. (van Niekerk and Burger, 1967). Recently an isochron age of 2980 m.y. was obtained from Fig Tree sediments by means of the Rb-Sr isochron technique applied to 11 shales and greywacke total-rock samples (Allsopp et al, 1968). The same authors obtained values of ~ 2500 m.y. for biotite-tremolite schists and acid lavas of the Onverwacht Group using the same Rb-Sr method.

By far the largest amount of geochronological data is available for the granitic and pegmatitic rocks of the Barberton Area. De Gasparis (1967) reported an age of 2.99 ± 0.07 b.y. for the Nelspruit migmatites and an age of 2.55 ± 0.09 b.y. for the M'pageni Granite, both using the Rb-Sr total-rock method. An age of 3.10 ± 0.10 b.y. is recorded for the Kaap Valley Granite by K/Ar on one biotite and one amphibole, the Rb/Sr method being ineffective owing to unfavourable Rb/Sr ratios. "A definite minimum age for the Swaziland System of 3.00 ± 0.03 b.y. is established by data on the Consort pegmatites and previous work on the Nelspruit granites" (Allsopp et al, 1968). In this paper 11 pegmatite samples consistently yielded ages ranging between 2.86 and 3.40 b.y., again using the Rb/Sr total-rock method. From the results the authors' contended that the "most reliable" age for these rocks was 3.00 ± 0.03 b.y.

Many geochronological results pertaining to the Barberton area are, as yet, unpublished. Van Niekerk (verbal communication 1968) reports a preliminary age of approximately 4,000 m.y. for a granite pebble in the basal conglomerate of the Moodies Group, while U-Th-Pb ages slightly in excess of 3,200 m.y. are reported for the Kaap Valley Granite by Oosthuyzen (verbal communication, 1967). These workers and several others are presently engaged on an extensive geochronological study of the Archean terrain around Barberton.

(g) Mineralization

Once again, it was Hall (1918) who first attempted to describe some of the gold deposits in the Barberton area, and to discuss their distribution. He noted that most of the gold mines occurred within his "Jamestown", or outer margin of his "Moodies Series" rocks, nearly always in close proximity to the granites.

The geology and mineralogy of the Consort and Sheba Mines was studied by Hearn (1943) and a general study of the mineralogy of the gold ores from a few mines in the Barberton area was undertaken by de Villiers (1957). Boardman (1950) compiled a report in which he gave his ideas on the controls of mineralization in the area, illustrating his views with examples from some of the many mineralized occurrences in the belt. He concluded that, apart from the stratigraphic control, the most decisive factor for the establishment of a favourable ore-deposit was the control of structure.

Gribnitz et al, (1961) considered that three main types of ore bodies occurred in the Barberton Goldfield and these were listed as follows :

(i) metasomatic replacement of foot and hanging wall rocks of faults. In this type of ore-body sulphide and non-metallic gangue replacement has occurred in brecciated and mylonitized zones. As examples of this type are cited the Sheba, Consort, Fairview and Agnes Gold Mines.

(ii) gold/quartz vein deposits in which the mineralization is finely distributed in white or black quartz veins in cracks or fractures. Most of the mines in the Barberton area have mineralization of this type, and

(iii) pipe-like deposits formed by mineral stoping.

De Villiers (1957) recognized four main types of sulphide ore, viz : ore containing,

(i) arsenopyrite and pyrrhotite

(ii) pyrite

(iii) lead

(iv) antimony.

He considered that the Barberton gold deposits formed during a single metallogenic epoch and he believed they were genetically related to the Nelspruit Granite. All the early workers in the Barberton area were unanimous in stating that the hydrothermal ore bearing solutions derived originally from the "granites". Some investigators (van Eeden, 1941; Visser, compiler, 1956; and Ramsay, 1963A) considered the arrival of the ore fluids to be broadly synchronous with the intrusion of the Nelspruit Granite, while Hall (1918) suggested that both the Nelspruit and Kaap Valley Granites were the source of the mineralization. Hearn (1943) and Gay (1964) on the other hand, believed that only the Kaap Valley Granite was responsible for the mineralizing solutions.

Gribnitz et al, (1961) provided one of the few discussions as to the relationships between various rock-types, faulting and mineralization. It was recognized that the primary avenues for the hydrothermal solutions, and also frequently the places of deposition, were the regional strike faults, and the secondary fault systems associated with the primary systems. A zonal distribution of auriferous ores was claimed by Gribnitz et al, (1961). It was maintained that arsenopyrite ores had a focal point at the New Consort Mine, decreasing rapidly towards the south and southwest. The arsenopyrite was followed by fine and then coarse-grained pyritic ores.

Up to this stage no really exhaustive studies of the mineralization of the area had been undertaken and most of the information relating to the gold mines was confined to unpublished reports of the mining companies operating in the area. Thereafter, members of the Economic Geology Research Unit began working on aspects of geology relating to the mineralization in the area. A study of trace elements associated with gold was undertaken by Gay (1963, 1964) who found that the fineness values of gold samples collected throughout the Barberton region show a regular distribution, with the highest values around the Consort, Sheba, and Agnes gold mines. He could, however, find no readily apparent zoning of the mineralization.

The geology and mineralogy of the Agnes and Lily gold mines was studied by Poole (1964) and Anhaeusser (1964) respectively. The investigations showed that structural influences were largely responsible for the localization of the mineralization. Anhaeusser (1964, 1966B) considered that some of the gold mineralization in the Lily Mine was of supergene origin and it was suggested, furthermore, that the processes of supergene enrichment in the oxidized zone may have been responsible for many of the small deposits found in the Barberton area.

Further work on the mineralogy of some of the ore-deposits in the Barberton area was undertaken by the National Institute for Metallurgy (Schweigart and Liebenberg, 1965) in an attempt to solve some of the problems associated with the recovery of gold from refractory ores and ores containing abundant graphite. The Institute is also presently concerned with mineralogical studies relating to the presence of nickeliferous minerals in the Barberton ultramafic assemblages.

G. PRESENT INVESTIGATION

The initial work undertaken in the Barberton area by members of the Economic Geology Research Unit required a follow up programme necessitating further detailed structural mapping of the main mineralized area of the greenstone belt. The earlier work of this type by Ramsay (1963A), Anhaeusser (1964), Viljoen (1964), van Vuuren (1964) and Poole (1964) proved to be sufficiently rewarding that it was decided to continue the research in the area for two main purposes. One was to determine the stratigraphic, structural and chemical controls affecting the distribution of gold mineralization in the hope that the data obtained would be of assistance to the local mining companies in their prospecting for further individual reefs and mineralized localities. The other was to gain an insight into the nature of a possible equivalent of the source of the Witwatersrand gold.

During the course of the investigation in the Barberton area the writer considered that it would be useful to have available a bibliography of geological literature pertaining to the area. For this reason a comprehensive bibliography was prepared of publications dealing with all aspects of the geology of the Barberton Mountain Land and immediately adjacent areas, including Swaziland. The bibliography, to be published shortly, has approximately 500 references to geological aspects of the area. These have been arranged both alphabetically and chronologically.

A further undertaking carried out by the writer, was the compilation, from all known sources of information in South Africa, of the gold and silver production figures, for the period 1884 to 1967, of all the gold mines in the Barberton Mountain Land, both in the Transvaal and in Swaziland. An attempt was also made to try and locate in the field, all the mines to which reference was made in old publications. A comprehensive account of this information is also intended for publication shortly but some of the findings have been included in a section of the present thesis.

The mapping programme entailed an investigation of the areas to the north of Barberton, where most of the mining had, and still is, taking place. Thus the Eureka Syncline and the eastern part of the Jamestown Schist Belt were mapped on a scale of approximately 1:6,000 using aerial photographs. Detailed structural investigations involved the recording of many hundreds of measurements of minor structural features such as fold axial traces, plunge directions of folds and lineations, attitudes of fold axial planes, conjugate fold axes and axial planes. Measurements were also taken of cleavage, schistosity, and foliation. From the data a structural synthesis of the northwestern flank of the Barberton Mountain Land has been attempted.

The stratigraphic mapping entailed a comprehensive petrological study of approximately 700 thin sections of a great variety of volcanic, sedimentary, and igneous rock-types. A structural and metamorphic analysis of the northwestern flank of the Barberton belt also form part of this thesis.

Major element chemical analyses on specimens collected by the writer were made possible through the co-operation of the South African Geological Survey, in conjunction with the National Institute for Metallurgy. Partial analyses of Al-rich siliceous schists were carried out by chemists of Anglo Transvaal Consolidated Mines Limited, while the nickel contents of ultramafic and mafic rocks from the area were determined by the National Institute for Metallurgy.

The writer was responsible for the partial analyses (K_2O and Na_2O) of a wide variety of rock-types, particularly the different granites and porphyry bodies found north of Barberton. Apart from modal analyses of rocks, other laboratory work entailed a grain count analysis of granitic rocks stained in order that the relative percentages of soda and potash felspar might be determined.

Reconnaissance mapping was carried out over a wide area to the north of Barberton and included an examination of the granitic rocks surrounding the northern portions of the greenstone belt. In addition, numerous field trips were undertaken into practically all parts of the Mountain Land in order to gain a more comprehensive understanding of the many and varied aspects relating to the geology of the Barberton greenstone belt as a whole.

H. ACKNOWLEDGEMENTS

The writer is especially indebted to Prof. D.A. Pretórius, Director of the Economic Geology Research Unit of the University of the Witwatersrand for having made available the opportunity to undertake this study and for the encouragement and guidance afforded the writer by him at all times. In addition, thanks are extended to Dr. C. Roering who, during the initial stages of the investigation, provided the writer with much helpful advice and constructive discussion on all aspects of the work.

The writer is also particularly indebted to his two colleagues, Messrs. M.J. and R.P. Viljoen with whom he collaborated for the greater part of the duration of the investigations in the Barberton Mountain Land. Although engaged on entirely separate projects the paths of study frequently crossed and all three worked closely together towards building up an understanding of the complete history of the Barberton greenstone belt. Several joint papers were the result of this close collaboration.

The writer is also indebted to many individual persons both in the Economic Geology Research Unit and elsewhere. I would like to thank Dr. K.H. Gribnitz, Chief Geologist of Eastern Transvaal Consolidated Mines Limited, as well as Messrs. S. Voges and E. Winter, geologists with the same company, for their helpful co-operation on all aspects of the study. Likewise, I wish to thank Mr. L. van Rensburg, geologist with Federale Mynbou Beperk, Fairview Gold Mine, and Mr. D.S. Macaulay, geologist with Rand Mines Limited, for their willingness to be of help at all times.

Useful discussions were held with many visitors the writer had occasion to show around the Barberton area. In particular I would like to mention Professor H.S. Yoder and Dr. T.S. Hoering, both of the Geophysical Laboratory of the Carnegie Institute, Washington, Dr. R. Hargraves of Princeton University, New Jersey, Professor J. Sutton and

Dr. J. Watson of the Imperial College of Science and Technology, London, as well as many overseas scientists connected with studies of primitive life-forms and micropalaeontology.

In addition, rewarding exchanges have been made with geologists of the neighbouring territories Botswana, Rhodesia, and Swaziland. Here I would like to mention discussions held in the field with R. Mason of the Botswana Geological Survey, N. Harrison, W. Bliss, K. Viewing, I. Robertson, E. Morrison, F. Tennick, D. Thompson and D. Muirhead of the Rhodesian Geological Survey and Mines Department, and D.R. Hunter, D.H. Jones and J.G. Urie of the Swaziland Geological Survey.

I would also like to thank Mr. P.A. Esselaar of the Economic Geology Research Unit for his advice on certain statistical aspects of the study and Dr. J. Ferguson and Dr. R. Saager for their discussions relating to the chemistry and petrology.

In addition, I would like to thank Mrs. L. Tyler for having typed the manuscript and Miss L. Bell and Mr. M. Hudson for having assisted with the photographic aspects of the thesis.

Finally, I wish to thank my wife for having helped with the typing of drafts and for her patience and encouragement during this study.

* *

CHAPTER 2

GENERAL GEOLOGY OF THE BARBERTON MOUNTAIN LAND

A. GEOTECTONIC SETTING OF THE BARBERTON MOUNTAIN LAND

The Barberton Mountain Land, comprising an exceptionally well-developed and well-preserved remnant of an early Precambrian greenstone belt, is situated on the Kaapvaal Craton, which in turn, forms part of the African sub-continental shield area (Anhaeusser et al, 1969 : see Figure 1, page 36). The cratonic areas of the sub-continent, viz. the Rhodesian Craton and the Kaapvaal Craton are surrounded by younger, linear, high-grade metamorphic mobile belts, such as the Limpopo belt, the Zambezi belt, the Mozambique belt and others.

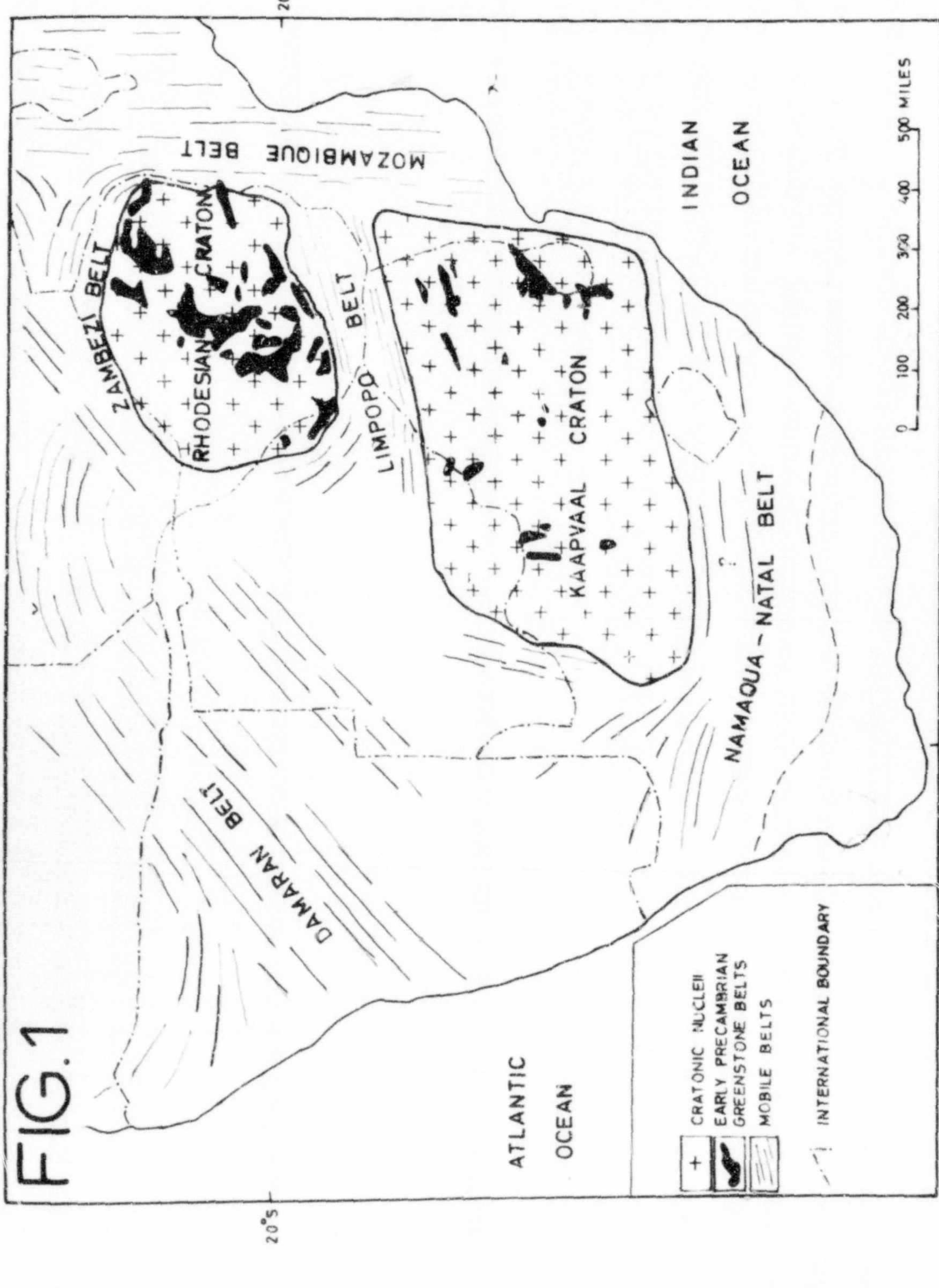

20°S
20°S
20°E
ZAMBEZI BELT
RHODESIAN CRATON
MOZAMBIQUE BELT
LIMPOPO BELT
KAAPVAAL CRATON
NAMAQUA - NATAL BELT
DAMARAN BELT
INDIAN OCEAN
ATLANTIC OCEAN
0 100 200 300 400 500 MILES
CRATONIC NUCLEII
EARLY PRECAMBRIAN GREENSTONE BELTS
MOBILE BELTS
INTERNATIONAL BOUNDARY

FIG.1

In the text, the term "greenstone belt" is used to describe the distinctive meta-volcanic and sedimentary assemblages which occur as scattered remnants on the cratons, forming an essential part of the latter. The most definitive aspect of these belts are the "greenstones" (meta-basalts and andesites), the distinctive, generally complex structure, and the low grade of metamorphism. The greenstone belts are incorporated into the cratons which here are defined as stable nucleii within the shield areas, consisting of complex granitic terrain and which form composite, well-defined entities, that have been unaffected by any major tectono-thermal events for the last 2,400 m.yrs. The term "shield" is used to describe a continental or sub-continental area of crystalline rocks of Precambrian age.

B. DESCRIPTIVE STRATIGRAPHY OF THE BARBERTON MOUNTAIN LAND

(a) Introduction

Geologically the Barberton greenstone belt is underlain by a variety of rock-types collectively grouped as belonging to the Swaziland Sequence. The Onverwacht Group forms the oldest phase, and consists mainly of ultramafic, mafic, and acid rocks, together with a great variety of pyroclasts and siliceous sediments. The assemblage is essentially volcanic in origin, and has suffered considerable alteration in places, producing a variety of mafic and siliceous schists. The rocks in the Group constitute the initial magmatic or volcanic assemblage of the Swaziland Sequence. The Fig Tree Group, which is essentially a sedimentary succession, overlies the Onverwacht rocks, and consists mainly of fine-grained shales, grits, greywackes, banded cherts and banded iron-stones. Some lava horizons may also be developed in places. Finally, the Moodies Group overlies the Fig Tree strata unconformably in places, and is made up of conglomerates, quartzites, shales, and a few bands of magnetic jaspilite and lava.

Anhaeusser et al, (1967) at first considered that the Onverwacht Group constituted the initial magmatic, or ophiolite, assemblage of the "Swaziland geosyncline", with the Fig Tree Group sediments displaying characteristics typical of the flysch sequence of geosynclines and the Moodies Group displaying characteristics of a molasse sequence of geosynclines. Although it was considered that the early Precambrian rocks of the Barberton Mountain Land had many similarities to the classical concept of geosynclines, the many inconsistencies posed several problems and it is intended, later in this thesis, to outline the currently held views on some aspects of early Precambrian shield geology and greenstone belts in particular. Anhaeusser et al, (1968) made known their views when they stated that "Alpine geology has influenced thinking on the Precambrian for many years, and the concepts of geosynclines, orogeny, and all that these imply, in terms of mountain-building, deep burial, regional metamorphism, granitization, and igneous intrusion, have been applied to the Precambrian in an effort to understand Precambrian evolution". They added that "the results have not only been unconvincing, but they have also led to confusion in the many cases in which the facts of Precambrian geology have not fitted theories based essentially on Alpine geology". These authors, furthermore, advocated that "the use of 'geosyncline' in Precambrian geology is considered to be misleading in most cases, especially when applied to mobile belts (the "orogenic belts" of Holmes, 1951), and also in respect of the early Precambrian 'greenstone' belts".

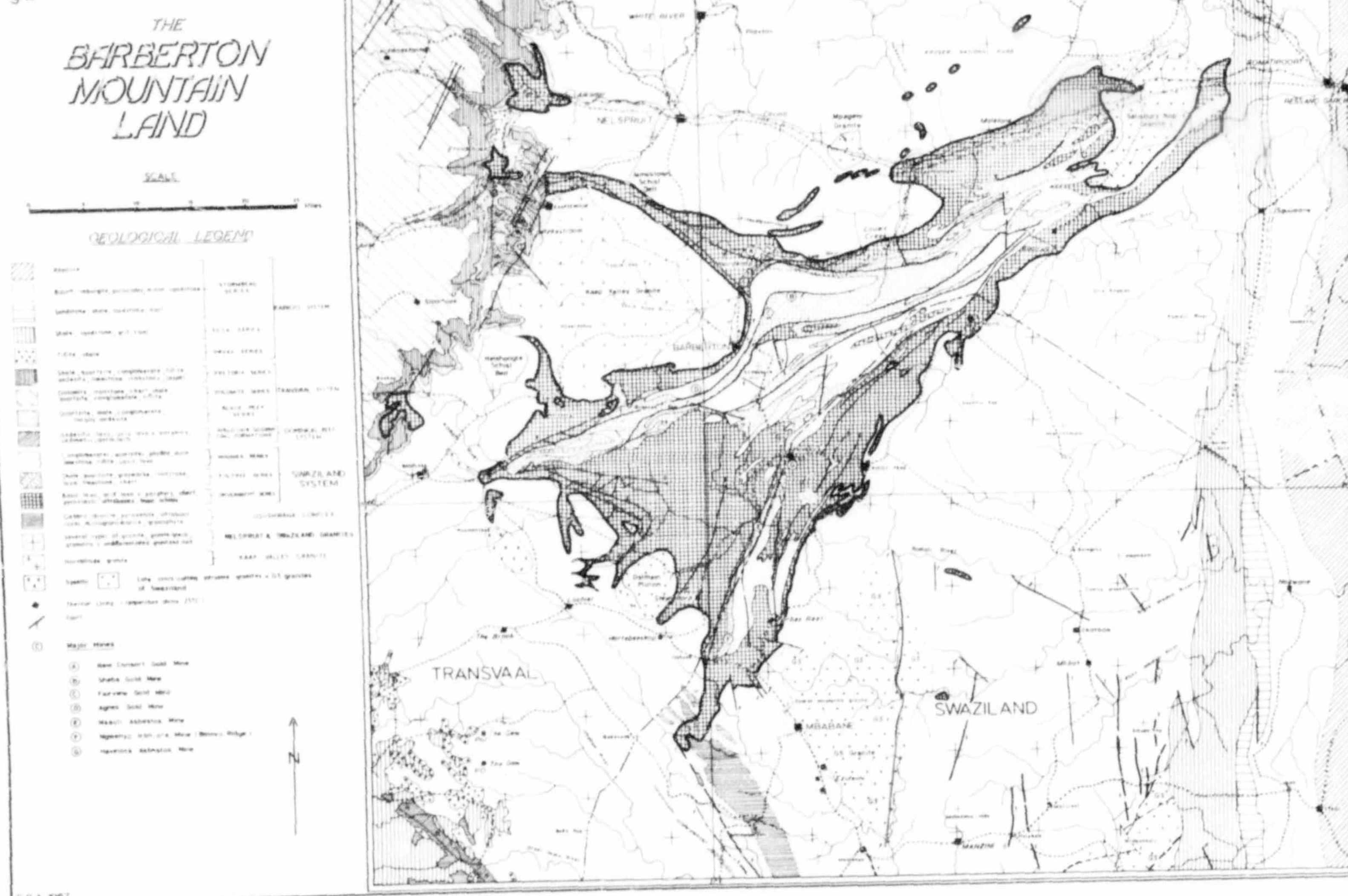
(b) The Onverwacht Group

(i) Introduction

Lying at the base of the Swaziland Sequence is an assemblage of rocks comprising basic pillow lavas, ultramafites, and associated siliceous sediments. These rocks, collectively termed the Onverwacht Group, are best developed and preserved in the southwestern part of the Mountain Land, where they attain a thickness in excess of 50,000 feet (Viljoen and Viljoen, verbal communication, 1968). This essentially volcanic assemblage can be traced right around the Mountain Land, and is everywhere in contact with the various intrusive granites which surround the entire area. Proceeding northwards, from the type-area in the south, the succession thins rapidly, and also becomes more strongly thermally and dynamically metamorphosed. This metamorphism has resulted in the obliteration of many of the diagnostic lava structures, such as pillows and amygdales, which are so well-developed in the south. It has also led to the previous grouping of these metamorphosed basic rocks into the Jamestown Igneous Complex (Visser, compiler, 1956), which was considered to represent a post-Swaziland intrusive sequence of basic and ultrabasic rocks. As pointed out above, however, it has been shown (Anhaeusser and Viljoen, 1965; Anhaeusser et al, 1966; and Viljoen and Viljoen, 1967) that these metamorphosed rocks, consisting essentially of amphibolites, and talc, talc-carbonate, and chlorite schists, are the equivalents of the Onverwacht Group, as defined in the south, and together they constitute the initial magmatic, or volcanic phase of the Swaziland Sequence.

(ii) Stratigraphy

In the type-area, in the southwestern part of the Mountain Land, the Group has been divided into six formation (Viljoen and Viljoen, Fig 2


THE
BARBERTON
MOUNTAIN
LAND
SCALE
GEOLOGICAL LEGEND
SWAZILAND
SYSTEM
NELSPRUIT & SWAZILAND GRANITES
Major Mines
N
WHITE RIVER
NELSPRUIT
BARBERTON
TRANSVAAL
SWAZILAND
MBABANE
C.R.A. 1967

verbal communication, 1968). At the base is the Sandspruit Formation, which attains a thickness of 7,000 feet, and consists predominantly of ultramafic rocks with subordinate mafic horizons and a few minor interlayered sedimentary horizons. The formation is intruded by granites resulting in the widespread occurrence of metamorphic rock-types, particularly antigorite, talc, talc-chlorite, tremolite, and actinolitic hornblende schists.

The Theespruit Formation, which attains a thickness of 9,000 feet, consists of a sequence of metamorphosed mafic lavas with interlayered siliceous sediments and salic tuffs, and occasional, thin, carbonaceous chert horizons and bands and lenses of serpentinized ultramafites. The main distinguishing feature of the sequence is the occurrence of numerous siliceous sedimentary or salic tuffaceous horizons, in the form of white, often friable, fine-grained, quartz-sericite rocks, interlayered with the amphibolitized pillow lavas. Quartz and sericite are the main minerals in these rocks, but smaller amounts of andalusite, staurolite, biotite, muscovite, and sodic felspar are also present. Most of these horizons are capped by thin, black, carbonaceous chert bands. The associated lavas, which frequently contain signs of pillow structures and amygdales, are dark green to black in colour, the main minerals being actinolite, hornblende, grunerite, and cummingtonite, with smaller amounts of quartz and sodic plagioclase. Chlorite and tremolite-actinolite are more common farther away from the granite contact. Numerous, thin, apparently interlayered, serpentinized ultramafic bodies are typical of the lower part of the Formation. These are composed mainly of antigorite and tremolite, with relict olivine crystals, and magnetite being fairly common.

The Komati Formation, attains a thickness of 11,500 feet in the type-area, and comprises an alternating sequence of amphibolitized pillow basalts and ultramafic bands, with the exclusion of any siliceous material. The ultramafics predominate in the lower half of the Formation, and a striking feature is the sympathetic thinning of individual ultramafic and pillow basalt horizons. The ultramafics are remarkably fresh-looking and are usually dark blue to black in colour. They are, however, generally serpentinized to a greater or lesser degree, although in many cases, only partly serpentinized olivine crystals form a mesh, constituting much of the rock. Besides antigorite, which is the main mineral, varying amounts of tremolite, magnatite, clinopyroxene, and talc also occur. These rocks probably represent altered dunites. The main minerals encountered in the altered basalts are tremolite-actinolite, cummingtonite, chlorite, quartz and felspar. Important in the Komati Formation are numerous intrusive bodies of quartz and felspar porphyry, which do not appear to be related to the surrounding intrusive granites, and are thought to represent an integral part of the Onverwacht succession.

The Hooggenoeg Formation reaches a thickness of 15,000 feet in the type-area, and consists of a sequence of pillow basalts with numerous interlayered zones of andesitic to acid lavas, the latter often associated with well-developed chert horizons. The Hooggenoeg succession comprises a number of cycles, each commencing with a broad zone of andesitic to basaltic pillow lavas. The latter are followed by thinner, intermediate to acid lavas, and the cycles are frequently terminated by thin, persistent, well-banded, and often carbonaceous chert horizons. Various calc-silicate and banded carbonate rocks are usually associated with these chert horizons. The predominant mineral in the more mafic lavas is chlorite, accompanied by altered sodic plagioclase and carbonate. In the more acidic lavas, soda plagioclase, quartz, chlorite, sericite, and carbonate are found.

The Kromberg Formation which overlies the Hooggenoeg succession consists of approximately 6,300 feet of mafic and acid massive lava, pillow lava, and chert, in addition to a wide variety of pyroclastic, calc-silicate, and carbonate rocks. The complete succession is best developed in the Kromberg Syncline to the east of the type-area of the lower four formations.

Finally, the rocks of the Zwartkoppie Formation, consisting of approximately 2,800 feet of cherts, intermediate lavas and a variety of talc, talc-chlorite and carbonate schists and greywackes, have been included into the upper portion of the Onverwacht Group by Viljoen and Viljoen (verbal communication, 1968). The Zwartkoppie rocks, as mentioned previously, have in the past always been regarded as part of the lower division of the Fig Tree assemblage.

The lower three Formations of the Onverwacht Group as well as the Zwartkoppie Formation have been recognized in areas right the way around the Barberton Mountain Land, whereas the Hooggenoeg and Kromberg Formations are restricted in their occurrence to the southern portion of the greenstone belt, where they are best developed in the Komati River valley.

The rocks just described comprise mainly the volcanic and sedimentary assemblages of the Onverwacht Group. On the northwestern side of the Barberton Mountain Land, however, there are a number of differentiated mafic and ultramafic bodies that are also considered to belong to the Onverwacht Group. These differentiated ultramafic bodies are best developed in the Kaapmuiden-Malelane area, in the Jamestown Schist Belt, and in the Stolzburg-Sterkspruit area. The ultramafic bodies generally consist of a differentiated assemblage of rock-types comprising dunite, peridotite, pyroxenite, gabbro and anorthosites and are considered to represent intrusive sills emplaced very early on in the history of the

Onverwacht Group. The rocks have been strongly deformed and are altered mainly to serpentinites, amphibolites, and metagabbros.

(c) The Fig Tree Group

(i) Introduction

Immediately and conformably overlying the predominantly volcanic successions of the Onverwacht Group is an assemblage of rocks composed essentially of siliceous chemical precipitates, together with a great accumulation of pelitic sediments. Where best developed in the Ulundi Syncline, north of Barberton, the Fig Tree succession has, up until recently, been subdivided into a lower division, which includes rocks that are at times difficult to distinguish from the metamorphic products of the underlying Onverwacht Group; a middle division, which includes the typical Fig Tree rocks, notably turbidites (shales and greywackes) and banded cherts; and an upper division, characterized by a reworked, unconformable grit horizon, more greywackes, and a volcanic horizon.

A change in classification of the Zwartkoppie rocks from the lower part of the Fig Tree Group into the upper part of the Onverwacht Group would appear to be justifiable in the light of the evidence presently available. The writer thus offers no support to the classification proposals of Steyn (1965) mentioned earlier, in the section on previous work. A note of caution should, however, be introduced at this stage because, all too frequently in the past, have classification changes been made that shortly afterwards require modification, because further mapping has revealed something new.

(ii) Distribution

Rocks belonging to the Fig Tree Group are best developed towards the interior regions of the Mountain Land, where they are sandwiched between the underlying Onverwacht successions and the overlying Moodies strata. The Fig Tree Group attains its fullest development northeast of Barberton, in the Ulundi Syncline, where Ramsay (1963A) estimated a total thickness of at least 10,000 feet for the tectonically flattened strata. Fig Tree rocks are also well-developed in the area south of Malelane, in the area southwest of Barberton, and in the northwestern segment of Swaziland (see Figure 2, page 39). The resistant cherts of the Group build lofty mountain chains while the softer shales occupy deeply incised V-shaped valleys.

(iii) Stratigraphy

The Fig Tree Group comprises a highly varied group of sediments composed essentially of banded cherts, banded ironstones, banded jaspers, shales, greywackes, quartzites, grits, and conglomerates. What was formerly regarded as the lower division of the Fig Tree Group, viz. the Zwartkoppie assemblage, consists of talc-carbonate rocks, quartz-sericite rocks and banded chert. The reclassification of these rocks into the Onverwacht Group is thus based mainly on the associations and assemblages of rock-types encountered.

In the southwestern parts of the Mountain Land, shales and cherts of the Fig Tree Group overlie either acid or mafic volcanic rock-types, and at no place can the typical Zwartkoppie assemblage be identified in direct contact with the Onverwacht Group, the relationship between the two always being complicated by faulting (Viljoen, and Viljoen, verbal communication, 1968). In the Ulundi Syncline, carbonate-chlorite-talc rocks occupy the lowest stratigraphic position, and occur in the cores of anticlinal structures (van Vuuren, 1964). Herget (1963) noted serpentinites occurring as cores in the Zwartkoppie talc-carbonate schists of the Montrose area, southwest of Barberton. Van Vuuren (1964) showed that the Ni and Cr content of these carbonate-bearing rocks is indicative of their being of volcanic origin, and he suggested that they had moved into the anticlinal cores by means of tectonic transport, i.e. the upfolding of the volcanic rocks of the underlying Onverwacht Group.

The 'Zwartkoppie Horizon' occurs as a marker within the Zwartkoppie assemblage in the Ulundi Syncline. In places it is comprised solely of massive and banded chert, but well-bedded cherts and black shales are also developed. In addition, ferruginous shales and banded cherts, referred to as "banded ironstones", occur here, as well as higher in the succession. Koen (1947) concluded that the greenschists in the Zwartkoppie assemblage are markedly similar mineralogically to greywackes, and that they owed their origin to intense mylonitization of greywackes and shales, sandwiched between the competent banded cherts and the underlying carbonate rocks. Van Vuuren (1964) recorded a thin but persistent, sulphide band at the top of the Zwartkoppie succession, the areal extent of which suggested a syngenetic origin with the banded chert. Overlying the 'Zwartkoppie Horizon' is a carbonate-bearing sandy phyllite, followed by an oolite layer.

The Fig Tree Group as envisaged now, consists of a very thick succession of alternating greywackes, shales and grits, with thin chert bands. Higher in the sequence more greywackes, shales, banded ironstones, and gritty greywacke layers are developed. The upper part of the Fig Tree assemblage consists of still more greywackes and shales, banded chert, banded ironstones, and grits. At the top of the succession is a felspathic, tuffaceous greywacke and locally greywacke conglomerates are also developed. The mineralogical composition of the greywackes throughout the Group indicates material clearly derived from ultramafic (Danchin, 1967), mafic, and acid volcanics, as well as from crystalline bodies such as granites, gneisses, or migmatites.

(iv) Evidence of Primitive Life-Forms

The cherts and shales of the Fig Tree Group have yielded evidence of very primitive life-forms dating back more than 3,000 million years. Ramsay (1963A) reported oolitic structures, resembling primitive algae (Calcisphaera) from the Sheba Mine area. Hoering (in : Pretorius, 1965B) reported the presence of straight-chained hydrocarbons with 16 to 24 carbon atoms, in the Fig Tree shales. These, he suggested, were diagnostic of biologically produced petroleums. Other studies by Pflug (1966) and Barghoorn and Schopf (1966) have revealed microfossils preserved mainly in the dark banded chert.

If the new classification of the Zwartkoppie rocks is accepted then many of these micro-organisms will no longer belong to the Fig Tree Group, but will occur in the Onverwacht succession. This applies to most of the findings of the above-mentioned investigators as well as to Oró and Nooner (1967) who reported aliphatic hydrocarbons in Fig Tree rocks and Schopf et al, (1968) who described amino acids from black Fig Tree cherts.

Alga-like forms have, however, already been reported in black, carbon-rich cherts, and siliceous argillites interlayered with sequences of lava belonging indisputably to the Onverwacht Group (Engel et al, 1968).

(d) The Moodies Group

(i) Distribution

The Moodies Group follows, in places conformably, in others unconformably, on the underlying Fig Tree succession. It consists mainly of arenaceous rocks, with minor sandy-shale horizons and a characteristic and persistent basal conglomerate. The rocks of this Group cover large areas, especially in the interior of the Mountain Land (see Figure 2, page 39), where the formations build lofty ranges responsible for much of the scenic beauty of the area. Although having a wide distribution, particularly in the central and eastern portions of the area, the Moodies rocks are generally located in synclines that are separated from each other by large, longitudinal strike faults that trend in a northeast-southwest direction and which divide the Mountain Land into a number of fault-bounded "cells". The Lily, Eureka, Saddleback, and Stolzburg Synclines are but a few examples of major structures in which Moodies rocks are preserved.

(ii) Stratigraphy

The Moodies Group is composed predominantly of psammitic and psephitic sediments. The dominant rock-types are boulder beds, conglomerates, quartzo-felspathic sandstones, sub-greywackes, siltstones, and shales, with local developments of magnetic banded ironstones and jaspilites. Also included in the stratigraphy of the Moodies rocks of the Eureka, Saddleback, and Stolzburg Synclines is a thin amygdaloidal lava horizon, now mainly amphibolitized.

The conglomerates are polymictic, containing well-rounded pebbles and boulders of black and white chert, banded ironstone, jasper, grit, granite, quartzite, micropegmatite, quartz porphyry, shale, and quartz-sericite-schist. In addition, the writer has noted pebbles of conglomeratic material in the basal conglomerate of the Eureka Syncline. The Moodies conglomerate pebbles occur in an arenaceous matrix of felspathic quartzite, greywacke, and sandy shales. The conglomerate is generally followed by a carbonate-rich quartzite.

The most complete succession of Moodies strata is preserved in the Eureka Syncline, where it has been broadly subdivided by Visser, compiler, (1956) as follows :

Upper Shale

Upper Quartzite (Baviaanskop)

Middle Shale

Middle Quartzite (Joe's Luck)

Lower Shale

Lower Quartzite

Basal Conglomerate

The thickness of sediments along the southern limb of this syncline is about 10,300 feet, of which argillaceous rocks represent 46 per cent. Along the northern limb the thickness is approximately 6,500 feet, of which 75 per cent consists of argillaceous material. Magnetic shales and jaspilites occur near the base of the Lower Shale horizon. The Middle Shale also has a magnetic shale and jasper horizon as well as a thin band of amygdaloidal lava. The Upper Shale is capped by a thin, small-pebble conglomerate, with a matrix of coarse, gritty sandstone. The three quartzite horizons have locally developed, conglomeratic bands, but these never approach the dimensions and character of the basal conglomerate. The Moodies rocks of the central portion of the Mountain Land appear to consist of vast thicknesses of quartzitic material, and it does not appear possible to correlate these masses with the Moodies stratigraphy as defined above. In Swaziland, only the basal conglomerate and the Lower Quartzite of the Moodies Group are represented.

(e) Dykes

(i) Introduction

Hypabyssal rocks, mainly dykes, are prolifically distributed over the entire area of the Barberton Mountain Land, but attain their greatest development in the areas underlain by granitic rocks. Practically all the dykes are vertical, and many give rise to striking topographical features. The dykes are of several varieties, each of which tends to prefer a certain well-defined strike direction. The dykes vary widely in age, and in mineralogical, and chemical composition. Sheet- or sill-like intrusions are reported from the area, but are less frequent than the dykes.

(ii) Structural Control of Dykes

The dykes generally conform to definite strike directions. A prominent direction is from 30° to 35° west of north to approximately northwest (Visser, compiler, 1956). A second direction is roughly at right angles to the former, i.e. from 30° east of north to northeast. Some dykes trend north-south, others parallel the strike of the formations, and yet others deviate completely from these directions. Zones of faulting and jointing appear to have had the major controlling influence on the occurrence and trend of the dykes.

(iii) Dykes Varieties

1. Early Dykes in the Migmatites and Gneisses

Highly deformed dykes occur in the Nelspruit Granite, the granites near Badplaas, and in the ancient gneisses of Swaziland. These dykes are often folded, the axial planar structure of the migmatites being identical to the axial plane of the dykes (Roering, 1967). The dykes are locally cross-cut and injected by the granitic matrix into which they at one time intruded and are now amphibolitized.

There are several ages of dykes; some have been folded, others have not, but both types have been involved in the palingenesis of the surrounding migmatitic and gneissic material. The ancient gneisses and associated dykes were possibly reactivated during the G4, or synorogenic, granitic cycle which is dated at 3,070 ± 60 m.y. by Allsopp et al, (1962). The involvement of the early dykes in the migmatite-gneiss palingenesis is used as evidence in support of this terrain being representative of at least part of an ancient, pre-Swaziland Sequence basement.

2. Dykes Later than the Swaziland Sequence

Dykes later than the Swaziland Sequence have been divided into several categories (Visser, compiler, 1956) which reflect the age relationships between the dykes themselves and the various stratigraphic successions of the Mountain Land and the surrounding areas.

The dykes have been grouped as follows :

(i) intrusions older than the Moodies Group

(ii) intrusions older than the Godwan Formation

(iii) intrusions younger than the Transvaal Sequence

(iv) late dykes of Karroo dolerite.

The majority of dykes in the area are diabasic in composition, with some of the larger bodies having differentiated into a wide variety of rock-types. These include peridotite, olivine gabbro, quartz gabbro, quartz diorite, and granophyric end-members with micrographic intergrowths of quartz and felspar. Some diabase dykes are porphyritic and contain large felspar phenocrysts. Pyroxene-amphibole and ultramafic dykes occur less frequently. The last phase of igneous activity in the area is marked by the presence of dolerite dykes of Karroo age.

(f) Granites

(i) General

The supracrustal rocks of the Barberton Mountain Land are surrounded by granites which, in all cases, are clearly intrusive, and which are also responsible for contact metamorphic effects. The granites, of which there are several varieties, have played a considerable role in the geological history and evolution of the greenstone belt as a whole, and no account of the geology of the area would be complete without reference being made to them.

Although no one, apart from D.R. Hunter of the Swaziland Geological Survey, has ever been primarily concerned with a study of the granites, several workers have, nevertheless, taken an interest in the granites of the area. This has been the case particularly where the granites abut against, or surround, parts of the greenstone belt that have come under rigorous examination.

(ii) Granite Varieties and their Regional Distribution

Apart from Hunter's (1961, 1965) breakdown of the various granites in Swaziland those on the South African side of the Mountain Land have been classified according to a scheme proposed by Anhaeusser et al, (1967).

The breakdown of the granites has led to the recognition of a number of distinct types, the localities of which are portrayed in Figure 2 , page 39. These include the Kaap Valley Granite, the Nelspruit, Nelshoogte, M'pageni, Salisbury Kop and Dalmein granites, and many others to which no specific names have yet been given.

The Kaap Valley Granite, near Barberton, forms a huge diapiric pluton surrounded by Swaziland Sequence rocks. It is essentially a hornblende granodiorite or tonalite, often containing biotite. A distinct, foliated fabric is developed close to the contact area with the supracrustal rocks, and the granite is clearly intrusive into the Swaziland Sequence rocks. The Nelspruit Granite is the name given to vast areas of granitic rock that are distinct from the other varieties. It is made up of highly variegated rock-types, ranging from homogenized granites without any visible fabric, through gneisses, to complex migmatites. On the northern side of the Barberton greenstone belt this granite reveals a homogenized phase, several thousand feet wide, which is confined to the contact zone. Pegmatites are clearly related to this homogenized phase. The Nelshoogte Granite, like the Kaap Valley Granite, forms a diapiric pluton north of Badplaas. It is surrounded by Swaziland Sequence rocks in the east, but is covered by younger escarpment formations in the west. Essentially a biotite granite or tonalite, it is intrusive into the Swaziland Sequence rocks and possesses a well-defined, foliated fabric near the contacts.

The M'pageni Granite, situated about 14 miles east of Nelspruit, occurs as a discordant pluton in the Nelspruit Granite terrain. It is characteristically a coarse-grained, homogeneous, non-foliated granite, somewhat similar to the post-orogenic granites of Swaziland described by Hunter (1965). The Salisbury Kop Granite, situated in the far northeastern extremity of the Barberton greenstone belt is somewhat similar in appearance to the M'pageni Granite, and has no visible foliation. It is generally a medium- to coarse-grained granite which intrudes Swaziland rocks, but its exact relationship to the Nelspruit Granite has not yet been established. Van Eeden and Marshall (1965) consider this granite to be a reomorphosed equivalent of the basement on which the supracrustal rocks were deposited. However, Anhaeusser et al, (1967) are of the opinion that this body is a younger granite pluton, similar to the M'pageni and post-orogenic granites (formerly known as the G5 granites), described by Hunter (1961, 1965). The granite is typically homogeneous, and has a narrow chill-phase of aplitic and alaskitic granite around the edges, in contact with the Swaziland Sequence rocks (Viljoen and Viljoen, verbal communication, 1967).

Another, essentially similar, younger granite body, called the Dalmein Pluton, invades the Onverwacht successions in the Komati River Valley and, like the Salisbury Kop Granite just discussed, it truncates the sequence abruptly. The granite is also coarse-grained, porphyritic, and possesses no foliation (Viljoen and Viljoen, verbal communication, 1967).

In Swaziland, Hunter (1965) has recorded the presence of six late plutons of coarse-grained, porphyritic granite, intruded into the older granitic rocks of the area. In Figure 3, page 51, only two of these plutons are indicated, the others being off the map to the south. Apart from the Ancient Gneiss Complex and early tonalitic gneisses which form part of Hunter's (1965) granite classification, a vast area of Homogeneous Granite, consisting of grey, medium- to coarse-grained, biotite-microcline granite and granodiorite, occupies much of the Swaziland area. In Figure 3, page 51, this granite has erroneously been indicated as having a strong foliation along the eastern contact with the Barberton Mountain Land. The foliation in the granites on the South African side of the Mountain Land is, however, very much in evidence, being particularly prominent in the early diapiric granodiorite and tonalitic plutons. The Swaziland homogeneous granite is considered to have a sheet-like form, passing downwards into a migmatite zone.

C. STRUCTURE OF THE BARBERTON MOUNTAIN LAND

(a) General

In broad terms, the Barberton Mountain Land represents a strongly deformed synclinal, boat-shaped remnant of layered, supracrustal rocks, intruded and completely enveloped by a vast and complicated granitic terrain. This synclinorial keel has a length of 80 miles, and a strong east-northeasterly trend. It forms a narrow, elongated triangle, tapering gradually from a maximum base width of 32 miles in the south (between Badplaas and Forbes Reef), to five miles in the extreme northeast, near Hectorspruit, where it disappears under a younger cover of Karroo sediments. The average width of the belt (between Barberton and Pigg's Peak) is 17 miles.

(b) Arcuate Schist Belt Remnants

Strikingly apparent from the structural map (see Figure 3, page 51) are the generally arcuate, narrow, tapering protruberances of layered rocks which trend in all directions away from the main, east-northeast-trending grain of the triangular keel. These protruberances, or schist belts, attain their best development on the northwestern, western, and southwestern sides of the Mountain Land, but are also present as much smaller and generally more conformable features along the other contacts of the Mountain Land. The most spectacular of these is the Jamestown Schist Belt which trends in a northwesterly direction from Noordkaap to Kaapsehoop. It is slightly arcuate, being concave towards the south, i.e. towards the Kaap Valley Granite. The belt, about which a more detailed account will be given later in this report, has a strike length of about 22 miles from Noordkaap to the Transvaal Drakensberg Escarpment, where it disappears under the younger, almost flat-lying Black Reef quartzites and Godwan lavas. Another conspicuous, tapering, triangular belt is the Nelshoogte Schist Belt on the southern side of the Kaap Valley Granite. It also trends in a northwesterly direction, and is slightly arcuate. Several other arcuate schist remnants occur on the south side of the Mountain Land, between Badplaas and Oshoek. Although much smaller than the two above-mentioned belts, numerous coalescing tongues form interfering arcuate structures, as can be seen north of Lochiel (see Figure 3, page 51).

A significant feature of these relatively small, arcuate belts is that almost all of them consist of metamorphosed mafic and ultramafic volcanics of the Onverwacht Group (particularly the three lower formations). This also applies to the outlying, small remnants within the granites near Alkmaar, in the area north of Badplaas, in the area of the Kruger National Park, and in the region extending from Kaapmuiden towards the Consort Mine.

(c) Major Folds

Conspicuous within the main northeast-trending keel, and constituting the main structural features of the Mountain Land, are a