

Extremely deformed conglomerate pebbles in the Lily Syncline are indicative of the intense folding and flattening that occurred regionally along the contact belt as a whole. The rocks possess a strong foliation and become mylonitic and chert-like at times. The most marked feature as a whole is the considerable reduction in grain size of the rock constituents.

Pebbles of chert, flattened in the bedding plane are drawn out into boudinaged structures. In the Honeybird Creek road cutting a few distorted pebbles can be seen but generally in this area, the rocks are so altered that they almost resemble a banded chert in places. Crenulation folds occur in the brittle cherts but are not common.

Jointing is conspicuous and occurs at right angles to the regional trend of the Syncline. The possibility has been discussed, in the section on Structural Geology, that a longitudinal thrust fault occurs along the southern edge of the quartzites and conglomerate horizon of the Lily Syncline. Evidence in support of the fault, called the Main Southern Fault, is strongest between Joe's Luck Siding and Noordkap where the fault trace is filled with vein quartz. There is also a complete repetition of the normal stratigraphic successions indicating the presence of a longitudinal high angle thrust fault (M. Viljoen verbal communication); see also Fig. 7.

(d) Metamorphism

The alteration of the Moodies rocks has been largely due to dynamic metamorphism resulting from the intense shortening and flattening of the successions coupled with heat effects of the intrusive granites. The entire sequence has been mylonitized and the original grain size has undergone considerable reduction.

The impure quartzites and shales have become massive and siliceous probably resulting from the metasomatic introduction of silica into the country rocks. Mica, sericite, garnets and chloritic materials are present but never in any great amount. Original carbonate matter has been altered to zoisite and clinozoisite. Ramberg (1952) has shown that zoisite forms at the expense of calcite and chlorite when the temperature exceeds that of the greenschist facies. The Moodies rocks are bounded on the northern side by green amphibole schists probably falling into the albite-epidote-hornfels facies. The Lily quartzite-conglomerate succession, therefore, may be regarded as belonging to the lower portions of the albite-epidote-hornfels facies corresponding to the low temperatures and pressures of the outer margin of a zoned metamorphic aureole. (See Fig. 27).

The Basal Conglomerate of the Eureka Syncline shows little or no evidence of metamorphic alteration although at Sheba Siding the underlying "lava or tuffaceous graywacke" has been slightly metamorphosed and recrystallized.

F. INTRUSIVE ROCKS

(a) Green Serpentinites

(1) Introduction

Some of the basic rocks in the area are thought to be of igneous origin and probably belong to the Jamestown Igneous Complex. Included within this group are:

1. massive green serpentinites.
2. isolated ultrabasic zones with magnesite occurrences.
3. nickeliferous magnetic serpentinites.
4. talc zones in massive serpentinites.

The association of basic and ultrabasic rocks may be classified as being of the "alpine type" occurring in folded geosynclinal sediments of an orogenic belt (Turner and Verhoogen, 1960).

(11) Field Occurrence and Description

The serpentinitic bodies are confined primarily to two areas. The one occurrence is near Sugden Siding in the central portion of the area, while the other main body occurs in the western portion of the area i.e. northwest of Sheba Siding. In addition a few minor occurrences are to be found to the south of the Lily range on the farm Crystal Stream.

Included in these serpentinite masses are zones of magnetite, talc and nickel-bearing tremolite.

The massive body to the north and northwest of the Scotia Talc Mine appears to have intruded into the sedimentary sequences of the Lily Syncline causing the formation to split into three distinct bands that appear first to the east of Eureka Siding. They continue towards the west where the divergence reaches its maximum. Long narrow quartzite formations are severed by the basic intrusives. Intercalations of serpentinite and the numerous alteration products of serpentinites occur within the Moodies rocks.

In the field the rock has a pale greenish colour or where weathered it has a dirty brown colour. It is usually massive and generally exhibits a mesh structure. Zones of magnesite occur in the narrow valley to the northwest of the Scotia Talc Mine. Numerous lenticular talc bodies occur in this area as well and trenches and old workings mark their locality.

In thin section the serpentinite contains relict olivine crystals but is essentially composed of a felted or fibrous mass of antigorite. Magnetite is generally abundant and it together with a few chromite grains, form the principal accessory minerals in the rock. Occasionally these euhedral grains form in parallel bands suggestive of magmatic differentiation. Talc is developed in aggregates and in cracks. At times a little carbonate is present.

The serpentinites obtained from the magnesite-bearing zone near Syden Siding also display altered olivine crystals. The transformation of the rocks to chlorite and serpentine was seen. Carbonates (magnesite) are common. Antigorite fibres replace the olivine in cracks and pseudomorphs of serpentine after olivine were noted. Again magnetite is ubiquitous and a little talc altering from the antigorite is present. The serpentinites occurring between Avoca and Crystal Stream are slightly different in that they are a more massive finely crystalline blue-green variety. In thin section the rock is composed almost entirely of antigorite laths. There is a little carbonate and talc present while magnetite occurs in fine crystals that often lie in uninterrupted parallel stringers.

North of the Scotia Talc Mine and near the Bar 5 trigonometrical station the serpentinites are locally magnetic due to the presence, in certain shear zones, of the nickel-magnetite mineral trevorite. Partridge (1943) also noted a nickel silicate mineral nepouite, but all thin sections examined by the writer consisted only of magnetite, trevorite, antigorite and a little talc.

The talc occurrences are centred around the Scotia Talc Mine which is described at a later stage in the section on the Economic Geology of the area. It can be mentioned however, that tourmaline occurs abundantly in the talc. Less pure zones contain talc and carbonates. Trevorite has also been noted in the talc mine.

(iii) Structure

Invariably the serpentinites are massive structure-less bodies, but in some cases the strong regional foliation is evident especially in

the small narrow bodies. These bodies appear to be steeply inclined lenses or sheets lying concordantly with the surrounding quartzites of the Lily Syncline. The dip of the foliation is difficult to measure but generally conforms to the regional structure probably indicating that it underwent deformational events similar to or synchronous with those of the adjacent rock types.

(iv) Metamorphism

A difficulty arises in trying to establish whether or not the serpentinite bodies were intruded at high temperature or whether they were emplaced as "cold intrusions". This difficulty is due to the fact that the intrusive serpentinites all occur in close proximity to the Hespript Granite contact. The grade of metamorphism along this contact is sometimes extremely high as is seen by the occurrence of sillimanite and pyroxene-bearing hornfelses. The fact that a high grade aureole occurs on the granite side of the serpentinite mass near Bar 5 beacon and not on the south side suggests that metamorphism was primarily due to the intrusion of the igneous granitic rocks.

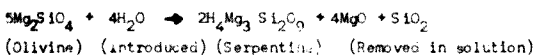
The metamorphic influences of the ultrabasic bodies are slight and the successions adjacent to them have altered assemblages that may be classified as belonging to the greenschist facies or to the lower grade members of the albite-epidote-amphibolite facies. Bowen and Tuttle have found experimentally that there is no likelihood of a serpentine magma existing below 1000°C (Turner and Verhoogen, 1960). On this experimental data, however, Hess's (1938) idea that an ultrabasic magma could be intruded at low temperature with 5 to 15 per cent H₂O present, must be rejected.

Bowen proposed a theory of mechanism of ultrabasic intrusion whereupon he stated that the "magma" at the time of intrusion consisted largely of olivine crystals kept mobile by small quantities of intergranular magmatic liquid or even water vapour. Gravitational settling of the olivine would be a mechanism capable of producing "magmas" of this type. It was argued that these basaltic magmas should be expected to be accompanied by other and more siliceous rocks representing the complementary liquid differentiate (Turner and Verhoogen, 1960).

Bearing this last mentioned fact in mind and the apparent high degree of silification and chertification of practically all the successions in the area the writer suggests that might this not be some expression of the processes outlined above?

The ultrabasic bodies have been serpentinized and only in rare instances were olivine remnants observed. The serpentinization is more or less evenly distributed throughout the ultrabasic masses. Hess (1933) noted that the ultrabasic bodies he examined showed a lack of volume change when altered to serpentinite. He also stated that the serpentinization resulted during the last stages of the same cycle of igneous activity as the intrusion of the ultrabasic. Bowen and Tuttle have shown, however, that serpentinization approximates to an equal-volume replacement and occurs at temperatures of 200° to 400°C. Water, silica and carbon dioxide necessary for the alteration could have been derived from the hydrothermal solutions emanating from nearby granite intrusives, or from magmatic waters or water charged geosynclinal sediments (Turner and Verhoogen, 1960).

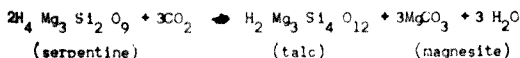
These writers also give a reaction in which olivine is replaced by the same volume of serpentine. The excess MgO and SiO₂ being removed in solution.



The metamorphic mineral assemblage of the serpentinite occurrences in the report area generally show a lack of minerals other than serpentine (antigorite), magnetite, magnesite, quartz and rarely olivine and chromite.

The serpentinites near Sudden Siding show signs of actinolite and chlorite indicating that a high temperature was present to cause the alteration of the ultrabasic rocks. There is abundant magnesite developed due probably to the introduction of CO₂ to the serpentinite.

Turner and Verhoogen (1960) show this reaction as follows:



Talcification of the serpentinite-bearing rocks probably was the last process to have taken place. Hess (1933) stated emphatically that serpentinization preceded steatitization and Turner and Verhoogen (1960) although not as adamant as Hess nevertheless appear to support this view. The alteration of the serpentinites to talc may be due to the effect of hot aqueous hydrothermal solutions probably derived from the nearby intrusive Nelspruit Granites. The fact that black needles of tourmaline are found together with the talc would tend to support this contention.

Other examples of talc deposits of the steatitized type consisting of concordant lenticular bodies of altered ultrabasics are described by Hess (1933).

(v) Origin

The presence of olivine, magnetite, chromite and nickel together with magnesite and talc occurrences suggest that the rocks originally were derived from a magnesian rich parent rock of ultrabasic composition - possibly a peridotite or dunite. Barth (1952) stated "the home of the dunite is, generally speaking, the folded mountain chains". These are frequently accompanied by serpentinites but as was stated earlier the problem as to how the ultrabasic bodies intrude still remains although Bowen and Tuttle (1949) think that there is no escape from the conclusion that dunites can be intruded only in the solid state.

(b) Nelspruit Granite

(i) Introduction

The term "Nelspruit Granite" was used by Hall (1918) to describe the Archaean granite-gneiss that constitutes a large area of the Eastern Transvaal Lowveld. Unlike the dark hornblende-bearing Kaap Valley Granite, the Nelspruit Granite is essentially a leucocratic variety but does have numerous dark zones rich in biotite.

(ii) Field Occurrence, Description and Structure

The Nelspruit Granite occurs along the entire northern fringe of the Barberton Mountain Land where it builds well-rounded hills that form part of the Krokodilpoort Range. This range forms the watershed between the Crocodile River in the north and the Kaap River in the south.

On the whole outcrops are poor except where the Kaap River has cut into the granites. Large areas consist of flat-lying extensively decomposed rock and near Louw's Creek Station the granites are overlain by vast stretches of arable farmland.

The granites exposed in the area may roughly be divided into three categories:-

1. Intrusive contact granites.
2. homogenous granites.
3. massive gneissic granite.

1. Intrusive Contact Granites

The granite along the Contact Belt is an intrusive granite that has been injected into the dark contact amphibolites. The intrusive nature of these rocks appears limited to the fringe of the granite massif and extends northwards for only a few hundred yards before gradationally changing into a more compact finer-grained homogeneous granite.

Typically, the granite seen in the area is medium- to coarse-grained and light in colour. Hand specimens consist of quartz, feldspar and mica. In thin section the rock is principally composed of quartz, microcline, twinned and untwinned plagioclase feldspar (usually oligoclase or albite), muscovite, biotite and magnetite. In addition minor amounts of green hornblende and epidote were noted.

The contact zone is characterized by numerous intrusive pegmatite bodies and veins as well as granitic and aplitic occurrences. Xenoliths of amphibolite are largely restricted to this zone and are folded together with the granites. The folding has deformed the intrusive veins and in the Kaap River cutting near Honeybird Siding a well exposed outcrop shows contemporaneous folding of granite veins and amphibolite. Budinaged structures occur on the flanks of the folds while in the hinge zones minute parasitic folding has taken place (see Plates 16 and 17). All along the contact the granites appear deformed and have obviously undergone extensive folding. Lineations considered to be associated with the folding are well developed, especially in the Kaap River cutting and in the area to the north of the Beacon, Bar 5. The relationship of the lineations to the folding is explained more fully under Structural Geology later in this report.

The granites are well foliated along the immediate contact and mica flakes (essentially muscovite) show a parallel orientation. In thin section the lineated granites display buckled and twisted crystals of mica (see Plates 18 and 19). The quartz in the deformed granite shows strain extinction and the plagioclase feldspar (oligoclase, albite) is frequently seen undergoing incipient alteration to sericite.

Numerous pegmatite and aplite veins penetrate the earlier granites and xenoliths and therefore post-date them. The pegmatite veins anastomize throughout the contact area and pygmaic veins are frequently seen in the contact amphibolites and xenoliths. No distinction is made in the mapping of the granites and the pegmatites due to their obscure gradational nature in poorly exposed areas.



Plate 16. Similar folds of granite and gneiss in contact with amphibole schist. The granite veins are boudinaged in the plane of the folds. Soap River exposure looking east.



Plate 17. Small granite vein in the plane of gneiss, looking east. The granite is of medium to fine grained texture. The gneiss is composed of quartz, feldspar, and mica.

Characteristically the pegmatites possess large feldspar crystals consisting of albite, oligoclase and microcline. The larger veins often show zoning with a chill phase around the outside and coarse feldspar and quartz crystals towards the centre. In most cases the feldspar is partly altered to sericite. The microcline has well developed polysynthetic twinning and occasionally small muscovite 'books' are developed.

2. Homogeneous Granites.

Gradational boundaries exist between the granites along the contact and those to the north. The homogeneous granites seldom occur in large bodies. The gradual change from a sheared lineated rock to a compact, almost undisturbed variety can be seen in the Kaap River cutting which provides an excellent section for about three miles into the massif. There is a notable colour change from a light coloured granite to a more pinkish variety. Dark zones are due to an increase in the biotite content of the rock.

In some instances there is a complete absence of foliation. Apart from the Kaap River exposure the nature of the outcrops does not permit any detailed study but aplitic and pegmatitic veins were seen to intrude into the homogeneous granites.

3. Massive Gneissic Granites

Further north the granite becomes gneissic with foliation planes defined by the parallelism of mica flakes. The gneissic granite is often intensely folded and intruded by veins of pegmatitic and aplitic material. There is a notable absence of xenoliths in this zone. Much of the granite is weathered and the soils derived from them are light gray in colour and are very sandy. Jointing is often very prominent where exposures are good. On the farm Lovedale shear zones in the granites have been filled by hydrothermal quartz veins and the granites adjacent to the shears have undergone recrystallization to a fine-grained aplitic rock. Trenching was carried out many years ago due to minor indications of gold in the vein quartz.

A porphyritic diabase dyke that cuts through the granites on the farm Lovedale has altered the foliation direction of the gneisses immediately adjacent to the dyke. The normal or regional foliation trends roughly east-west but in the neighbourhood of the dyke it lies parallel to the contact and is probably the result of a combination of shearing and heat associated with the dyke's emplacement.



Plate 18. Photomicrograph of thin section, lead in contact granite. The dark mineral is magnetite and the light gray mineral is quartz. (of Bowenite 100x)

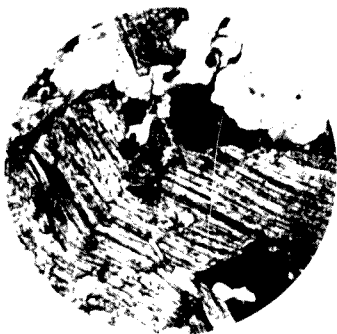


Plate 19. Photomicrograph of thin section, iron flakes in the leaded contact granite west of Bowen 111000. (Special of this x70)

North of Eureka Siding and on the farm Peri, migmatites, consisting of intimately mixed granitic and amphibolitic country rock, are exposed. Flow folding and irregular banding was also noted (see Plate 20).

A few marshy areas occur at the foot of the slopes leading up to the granite hills and springs are to be found in some of the shear zones.

(iii) Metamorphism Produced by the Granite Intrusion

Heat from the intrusive body spreading into the surrounding sediments resulted in a mineralogical and textural reconstruction of the rock fabrics and produced a thermal aureole of contact metamorphism. By examining the mineral assemblages in successive stages away from the granites it was possible in this area to define and identify three facies of metamorphism. These are, starting at the contact and progressively moving away from it:

1. the hornblende-hornfels facies
2. albite-epidote-amphibolite facies
3. greenschist facies. (See Fig. 27)

Heat has been dealt with more fully earlier in this report. It is sufficient here to mention the wide variety of metamorphic minerals ranging from sillimanite and garnets near the intrusive granite contacts through a progressive decrease in metamorphic grade to the south where calc and actinolite finally give way to entirely unaltered sediments.

The deficiency of metamorphic phenomena in the sediments of the Barberton Mountain Land has been noted and commented upon by numerous investigators in the past. One of the most plausible explanations to date is that advanced by Read (1951) who considered that the basic rocks surrounding the Mountain Land acted as buffers that dissipated the heat associated with the granitic intrusions.

The relative absence of regional metamorphic effects would also tend to suggest that the successions revealed today could not have been buried beneath any great stratigraphic cover in the past.

(iv) Origin

The relationship of the granites to the rocks of the Barberton Mountain Land has posed numerous problems for which many viewpoints have



Fig. 20 Flow folding making isoclinal axis.
planar development in the middle of the granite
north of Snake Hill.

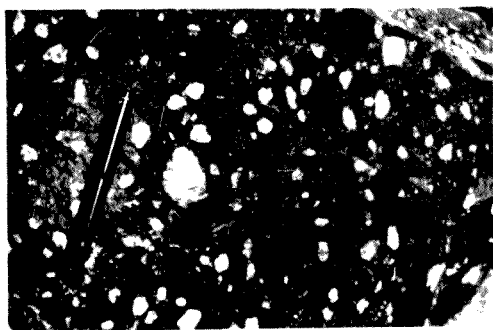


Fig. 21 Isoclinal folding, low. The rock
preserves a planar development of the
isoclinal axis.

been extended in an attempt to clarify or explain certain phenomena. One of the foremost difficulties has been to account for the origin of the Kaap Valley Granite, the Nelspruit Granite and the corresponding 'G' Series granites in Swaziland and their relationships in time and place. Briefly summed up below are several of the suggestions, findings and theories presented in the past.

Age determinations done on biotites from the area between Nelspruit and Kampmuiden have given an age of 2,600 million years (Nicolaysen, 1962). The nearby Kaap Valley Granite has been dated as being $3,200 \pm 100$ m.y., (Sample from the farm Somerset in the Barberton Valley. Nicolaysen, verbal communication). On the Barberton-Agnes Mine road the intrusive relationships between the Kaap Valley Granite and the Swaziland System can be seen. On the other side of the Barberton Mountain Land in Swaziland, the G4 granites have been given a mean age of $3,070 \pm 60$ m.y., obtained by 'total-rock' analysis (Allsopp, Roberts and Schreiner, 1962). Near Forbes Reef in Swaziland the G4 granite is intrusive into the Swaziland System and apl'itic-granite dykelets invade the Jamestown schists (Hunter, 1961). van Eeden (1941) reported that the Nelspruit Granite was intrusive into both the Swaziland and Moodies Systems in addition to the Jamestown Igneous Complex. In the report area the granites are only intrusive into the acid and basic rocks of the Conweracht Series on the northern limb of the Lily Syncline (formerly regarded as the Jamestown Complex).

The Geological Survey (Visser, 1956) has shown that several phases of the Nelspruit Granite were exposed in the District and they suggest that the granite represents a series of products derived from the processes of granitization.

Read (1951) interpreted the granites as being the products of the migmatization of semi-pelitic and more siliceous rocks. He classifies them as autochthonous granites i.e. granites produced by granitization that are surrounded by great aureoles of migmatites and metamorphic rocks. Autochthonous granites, Read explained, formed in place at the base of the migmatite complex.

The granitized material, rendered mobile by soaking, will tend to move as a whole upwards into a lower pressure environment. Mobilized material, usually only a fraction of the original granitized mass may differ in composition and character from the parent material as it moves into a different environment.

The granites and gneisses in the report area are dominantly soda rich with abundant oligoclase and albite feldspar. The 'intrusive

later granites and pegmatites have an increased potash content and microcline becomes abundant. Read (1957) quotes several examples of autochthonous granites with similar characteristics to those found in the area.

Ramsay (1963) was of the opinion that the granites represent the original basement on which the sediments were later deposited. He considers the whole to have been deformed and intruded by later granites.

The age of 2,600 m.y. given for the Nelspruit Granite is not entirely in keeping with the idea that these granites represent the original basement. The difficulty might be explained by the fact that the age was determined using biotite only and not the 'total-rock' method. The age obtained might represent a superimposed period of metamorphism coincident with the last intrusive phase of granites. (Nicolayson, verbal communication).

Another problem of prime importance is the juxtaposition of high level and low level rock types and the associated metamorphic phenomena encountered throughout the District. By high level rock types is meant the stratigraphic successions comprising the rocks of the Barberton Mountain Land that were deposited on the low level rocks made up of granites, migmatites and gneisses of varying compositions. With such a vast development of granites entirely surrounding the Mountain Land it has generally been regarded as extraordinary that the metamorphic effects observed in the area are practically negligible and are largely confined to the marginal or contact zones. In some places less than a mile from and seldom exceeding 3 miles from the granites the formations are entirely unaltered. It would appear that the Precambrian rocks in the area were never covered by any great thickness of younger formations. The metamorphism, therefore, is principally of the contact metamorphic type with a contact aureole of varying grades and extent. Dynamic effects, no doubt, have locally influenced the rocks especially along faults and in strongly deformed areas but wide scale regional metamorphism is poorly developed.

It was mentioned earlier that the granite is followed by a very regular succession of strata dipping outward from the massif. Both the granites and the adjacent sedimentary and volcanic rock sequences are well foliated. Contemporaneous with the mobility and injection of the granites the possibility exists that transport of certain constituents (biotite, muscovite and hornblende) along paths of differential shear could have occurred, thereby producing the conformable foliations.

Perhaps the most efficient explanation applicable to the area may be found in Wegmann's infra and superstructural concept. Read (1957) quoting Wegmann shows how he distinguished between the non-migmatitic superstructure and migmatite infrastructure. The latter conditions advancing from below involve the basement rocks and the geosynclinal fill material while the transitional zone between the migmatites and the sedimentary cover is the sphere of activity of regional metamorphism.

Within the mobile belt the infrastructure penetrates the superstructure. The injection is accompanied by intense metamorphism and metasomatism and tongues of magmatic granite ultimately appear at higher levels.

Finally, and purely a suggestion not based on any extensive investigation is an idea proposed by D. A. Pretorius (verbal communication) who considers the possibility that the oldest granites encountered in Southern Africa viz. the Kaap Valley Granite, the G1 granites of Swaziland and the Old Granite north of Johannesburg among others, might represent the "cores" of the granite massifs that have been elevated to their present day positions. The granites encircling these generally dome shaped bodies are younger and may represent some expression of a "crust of granite" that has locally been made mobile, especially in areas fringing the uplifted masses.

(c) Dykes

(i) Introduction

Several varieties of hypabyssal dyke rocks occur in the area. They are seldom seen in outcrop, save where they are exposed in river beds. In the granites the dykes are more conspicuous due to their darker colouration. Good exposures are also afforded by the road and rail cuttings between Eureka and Honeybird Sidings.

Often a close visual similarity exists between the dykes and the basic rocks of the Onverwacht Series especially where they are weathered.

Four varieties of dyke were distinguished in the field. These are:

1. dolerite dykes.
2. diabase dykes.
3. porphyritic diabase dykes.
4. amphibolitic dykes.

(ii) Field Occurrence and Structure

The dykes occur intruded into all the formations throughout the area. A few occur as low mounds rising out above the surrounding formations, while others in the granite for example, form notable depressions. In most cases outcrops are poor and continuity is brief.

The dykes to the south of the granites strike roughly at right angles to the trend of the sedimentary formations into which they intrude. Jointing was noted in well exposed outcrops of amphibolite and quartzite. These joints are also roughly oriented at right angles to the regional trends. The intrusion of the dykes therefore, may have been partly controlled by the regional joint pattern. A few dykes do deviate from the general trend; these occur mostly in the granites where they strike, in addition to a north-south direction, roughly northeast.

A very persistent porphyritic diabase dyke also strikes northeast and can be traced for several miles before it disappears into the granites.

The dykes with few exceptions are narrow, sometimes only a few feet in width. The principal exception is the dyke that occurs in the Honeybird Creek area. This dyke is in places, up to 100 feet wide but pinches and swells irregularly and in addition possesses off-shoots that give the impression that the dyke is still wider. Most of the dykes are obscured in the 3rd dimension but appear to be vertical. The porphyritic dyke exposed in the rail-cutting north of Eureka Siding dips steeply to the west.

(iii) Detailed Description of the Dykes

1. Dolerite Dykes

Only a few dolerite dykes were noted and these passed at times into diabase dykes. In the granite a dolerite dyke occurs northeast of Honeybird Siding while near Louw's Creek on the farms Lilydale and Surprise the dyke trending north is frequently of coarse-grained dolerite composition. A porphyritic dolerite dyke occurs on the farm Klipbokrant.

In this section the rocks are fine-grained, holocrystalline with fresh feldspar and pyroxene. Ophitic intergrowths of plagioclase and pyroxene are common. Alteration of the constituents usually produces variable amounts of chlorite. The feldspar is generally labradorite-bytownite while the pyroxenes are augite and pigeonite. A little magnetite and biotite was also noted.

2. Diabase Dykes

Most of the dykes fall into this category and show considerable variation in texture and composition. The rocks are generally medium-grained and dark in colour. In thin section the feldspar is seen to be labradorite. Two pyroxenes were frequently noted viz. augite and enstatite. Magnetite and green hornblende as well as apatite occur fairly regularly. Calcite with good rhombohedral cleavage is also not uncommon. The pyroxenes are very often completely encased in amphibole crystals and the feldspars are saussuritized and altered to sericite.

On the farm Lovedale, small dykes north of the quartz vein consist of feldspar and green amphibole with alteration products of epidote and sericite. Microcrystalline quartz is present together with green chlorite, carbonate, magnetite, ilmenite and its alteration product leucoxene.

In the Kaap River north of Honeybird Siding a dyke intruded into the granite possesses a narrow chill contact. This chill zone was between 9 and 12 inches wide and consisted of a dark fine-grained porphyritic rock with euhedral 'ghost' relics preserved in the vitreous matrix. Augite phenocrysts were observed that displayed herringbone structure and polysynthetic twinning. Quartz occurs both in the matrix and as phenocrysts.

The granites in contact with the dyke were not affected at all.

3. Porphyr-itic Diabase Dykes

There were three occurrences of this rock type, the most prominent being that on the farms Peri and Lovedale. This dyke although seldom more than 10 feet wide could be traced almost uninterruptedly for about 2 miles before it disappeared into the granites on the farm Lovedale. Two further occurrences were found near Eureka Siding. The one occurs in a gulley north of the tarred road while the second, possibly a continuation or off-shoot of the former, occurs to the north-west of Eureka Siding.

The rock is diabasic in composition with numerous large feldspar phenocrysts (see Plate 21). They are commonly euhedral crystals that sometimes reach a diameter of 2 to 3 inches and are arranged in zones within the dyke. Nearest the contact the rock is typically diabasic with few inclusions. The phenocrysts increase in

number and size towards the centre of the dyke and are clearly related to the cooling history of the intrusion.

In thin section the feldspars (labradorite) are both fresh and altered. Saussuritization has altered them partly to sericite and epidote. Magnetite and ilmenite with leucoxene is ubiquitous throughout while the fine-grained groundmass consists essentially of sericite, chlorite and feldspar.

4. Amphibole Dykes

The large well developed dyke in Honeybird Creek consists of green amphibole. The amphibole is usually euhedral consisting of jagged laths and acicular needles. Fine quartz is fairly abundant while magnetite occurs in small amounts. The amphibole is actinolite and this mineral usually encases the few clinopyroxene crystals of augite that may occur in the specimen.

5. QUARTZ VEINS

One exceptionally long and well developed quartz vein and several smaller veins occur in the area. North of Euraka Siding, starting on the farm Perl, is a ridge of vein quartz marking the beginning of a strong shear zone that continues in an ENE direction for about 4 miles before it finally disappears into the granites north of Honeybird Siding. The maximum development of this white quartz vein occurs in the central and eastern portion where it exceeds 50 feet in width and builds a prominent ridge. Evidence of intense shearing adjacent to the vein can be seen in the granites quarried for road metal on the farm Lovedale.

Within the broad zone of contact amphibolites there are developed numerous smaller white quartz veins, some containing tourmaline. Fairly well developed veins occur on the farms Surprise, Lower's Creek and Lillydale.

Whereas most of the veins in the formations north of the Fig-tree series are white quartz veins, those that occur to the south are more usually blue-gray in colour. These veins are generally narrower and lie predominantly in the bedding planes. In the Lily Mine both the white and blue-gray quartz varieties occur.

As has been mentioned elsewhere some rock types reveal an extensive development of tourmaline. In the Lily Mine black tourmaline needles occur frequently in quartz veins while in the Scotia Talc Mine tourmaline needles occur with the talc.

Thin section study showed that practically every stratigraphic succession contained tourmaline to a greater or lesser extent and that it was most frequently seen in rocks adjacent to quartz veins. In the Lily Mine tourmaline was found developed both parallel to the foliation and at right angles to it. The latter examples probably indicate that the tourmaline was not a primary constituent of the sediments but was introduced at a later stage.

Evidence concerning the tourmalinization in the area is scant but its relationship to hydrothermal quartz veins probably suggests a process of metasomatism: introduction of boron dependent on hydrothermal activity associated with the intrusion of the nearby Melspruit Granite. Other examples of boron metasomatism connected with granite intrusions are noted by Turner and Verhoogen (1960).

4. SURFICIAL DEPOSITS

(a) Calcrete or Oaklin Terraces

Terraces of carbonate of lime in the form of small lumps, pebbles and irregular masses occur cemented together along the banks of the Keap River between Eureka and Honeybird Sidings. In places pebbles and small fragments of rock, sand and grit are cemented together to form a rock resembling concrete. On the farm Lovedale a few stone implements or mollusks made of chert were found. The deposits are probably fairly recent as Stone Age cultures are "sono fossili" of the Quaternary (Hamilton and Cooke, 1960).

(b) Alluvium

In the flatter areas of the Keap River Valley there are numerous tracts of fertile land suitable for agricultural purposes. In addition there are several flat lands on the farms Avoca, Crystal Stream and Lilydale and in the area surrounding Louw's Creek Station. Most of the soils in the Keap River Valley are deep and generally boulder free but on the farm Avoca alternating soil and boulder beds are exposed in a gully (see Plate 23).

(c) Rubble and Scree

The steep nature of the rock formations has been conducive to the production of abundant rubble on the hillslopes. These deposits



(Plate 22) Flatly dipping
magnetite veins "Zebra Ore"
in quarry near Supton
Siding.

(Plate 23) Gully on the
farm Avoca showing three
layers of boulders and
pebbles separated by soil.
(see Recent Deposits)



obscure large tracts of the area immediately south of the Lily ridge. Several recent rock falls have taken place on the sheer cliffs on the farm Crystal Stream.

I. POSSIBLE PRE-DEFORMATION HISTORY OF THE AREA

Earlier in this report several reasons were given contesting the prevalence of the assemblage of rocks formerly classified by the Geological Survey as belonging to the Jamestown Complex. The evidence was presented in stages and the full impetus of the idea, that many of the rocks belonging to this succession do not appear to be altered basic igneous rocks, may not have been made sufficiently tenable.

The remarks that follow in this section are based not on one particular facet of evidence but were formulated from the considerable amount of information obtained from structural and metamorphic phenomena in the area.

An almost identical arrangement of rock types to those found in the report area, exist in the Amphibole-Schist Series of Pahang, Malaya, and their origin has, during the past, been considered from several viewpoints. (Richardson, 1947). Generally it was conceded by all the investigators that the original rocks must have been rich in iron, magnesia and lime or that alternatively quantities of these radicles, together with alkalis, were introduced during metamorphism.

Reverting to the rocks found in this report area, a precisely similar origin must be envisaged. The parent rocks might possibly have been one of the following:-

1. dolomitic limestones, calcareous and magnesian shales and tuffs.
2. basic igneous rocks (possibly both intrusive and extrusive)
3. sedimentary rocks influenced by iron, magnesian and lime-rich effluents derived from ultrabasic igneous rocks.

With these alternatives in view, an attempt was made to reconstruct the possible stratigraphic column of the original or pre-deformational successions. This task, although virtually impossible to accomplish successfully without considerably more detailed study being undertaken, (e.g. on trace element analysis of the basic suites), nevertheless, could be attempted using other information.

The method undertaken was to work backwards relying essentially on a knowledge of structure, sedimentology and metamorphism together with the changes this last mentioned phenomena invokes in rocks of various chemical compositions.

The rocks in the area, and for that matter in the whole district, are tremendously variable in type, texture and composition, but many of them may often be grouped in the same genetic category. It is also the writer's opinion that there are no really complex structures in the Barberton Mountain Land comparable, for example, with those occurring in the European Alps. Admittedly some areas are locally far from simple structurally or otherwise but the broader aspects of the Mountain Land are seen to comprise a system of fairly regular synclinal basins separated by narrower anticlinal divides. The pattern presented in the field, although badly defaced by the passage of time, orogeny and igneous activity should not be made more complex than it really is by invoking on numerous theories to describe local variations.

It was seen earlier how, in the stratigraphical column, the rocks were grouped.

- (i) a, those occurring on the northern limb of the Lily Syncline
- (ii) those occurring on the anticlinal divide south of the Main Southern Fault, and
- (iii) those occurring on the northern limb of the Eureka Syncline respectively.

The supposition was made, therefore, that the rocks from the granite contact to the Lily Fault at the base of the Fig-tree Series formed part of one depositional "cell", and that the rocks from the fault southwards and incorporating the Eureka Syncline, formed part or the whole of a second "cell".

The Lily Syncline, comprised of conglomerates, quartzites and a variety of basic schists, lies overfolded to the north. A section drawn through the central portion of the area would show the occurrence of several acid or siliceous horizons on both the north and the south side of the main quartzite-conglomerate ridge. Two explanations could be advanced to explain the recurrence of these horizons.

- (1) The horizons on the northern limb of the syncline may fold around at depth to reappear on the southern side. This would at the same time probably mean that the basic rocks were similarly folded around in sympathy with the siliceous horizons.

(2) Taking into account the presence of the Main Southern Fault that truncates the quartzite block of the Lily Syncline in the Noordkaap-Joe'-Luck Siding area it may be possible to extend the fault eastwards, also along the southern portion of the Lily ridge past Durka Siding to Louw's Creek. This high angle thrust fault can then be called upon to explain the repetition of basic rocks and the acid horizons immediately south of the quartzite ridge. Figure 7 shows diagrammatic sections of both possibilities.

The problem immediately involved hinges around the dissimilarity of the rock types on either side of the Lily conglomerate-quartzite ridge. A solution to this problem might possibly be found in the facies principal of diorseral in a geosynclinal trough. The rocks may have had a common source thus belonging to the same province, but they could differ in character from place to place (Pettijohn, 1957). Putting this into other words, the rocks might have a markedly different lithological appearance but chronologically they may have been of one and the same age.

At this stage a brief generalized palaeohistory of the Barberton Mountain Land as a whole might be considered before discussing the more localized history of the Lily Syncline (see Fig. 8).

Briefly it is assumed that the Onverwacht rocks, consisting of dolomitic limestones, lavas, etc. were initially laid down on a basement of granite and gneisses. Following the Onverwacht period of deposition there was subsidence in the centre of the basin together with uplift in places around the edges.

Erosion took place involving rocks from surrounding formations together with some granite and Onverwacht material. Deposition took place in the newly formed deeper portions of the geosyncline and the Fig-tree Series was culminated by the outpourings of lava and the deposition of tuffaceous graywackes.

It must be mentioned here that contorted pebbles of banded chert have been found in the Basal Conglomerate of the Moodies System (Geological Survey, Visser 1956), which seems to indicate that the rocks of the Swaziland System had been folded to some extent before Moodies times.

The final stages involved the deposition of the Moodies suite of rocks in the central section of the basin and in other localized areas of transgression. Subsequently the Jamestown intrusive rocks were injected into the various successions producing localized structural variations.

Finally the Nelspruit Granite intrusion occurred in a series of pulses continuous on one another. These pulses are reflected in the deformation history of the sedimentary sequences of the geosyncline.

The Lily Syncline "cell" is pictured as having been a miogeosyncline on the fringe of the greater basin or basins to the south. This shallow water depositional environment would be conducive to the development of dolomites, limestones and orthoquartzites. The acid or siliceous horizons might also have been represented by extrusive acid lava outpourings, followed by further deposition of dolomite formations.

There was no development of Fig-tree rocks in the miogeosyncline except in the west between Bar 5 beacon and the New Consort Mine where a narrow zone of argillaceous sediments and cherts were deposited. This lack of Fig-tree deposition was possibly due to elevation of the area by gradual updoming from below (see Fig. 8). Towards the south and away from the margins of the basin the deep water flysch or argillaceous facies attained its greatest development. This zone is almost entirely clastic and the deposition must have been nearly continuous with only a few interruptions during which time bedded cherts were deposited. As the basin filled with thousands of feet of shales and graywackes, subsidence must have taken place probably causing turbidity flows of material around the margins of the area thus causing considerable variations in the composition.

Subsequently the entire sequence was transgressed by a group of rocks that may be designated molasse. This group consisted of thick clastic layers comprised mainly of sandstones and shales much coarser than the flysch and containing notable conglomerates. Continued subsidence probably took place and the geosyncline was deformed and in places intruded by basic and ultra-basic magma.

Subsequent to the major deformations the intrusion of the Nelspruit Granites took place into the margins of the deformed area. The metamorphic effects from the intrusions produced a contact metamorphic aureole that decreased in intensity away from the granites.

It is therefore possible, that the great variations of basic and siliceous rocks on either side of the Lily Syncline can be explained as having been due to:

- (i) original facies variation of deposition coupled with
- (ii) differential metamorphism of the contact metamorphic type.

No great facies variations need be called for to explain the different rock types encountered across the Lilly Syncline. Investigators such as Richardson (1947), Tilley (1948) and Turner and Verhoogen (1950) have shown that rocks ranging in composition from hornblende amphibolites, tremolite-actinolite amphibolites and talcose schists may be derived by different grades of contact metamorphism from either dolomitic limestones or basic igneous rocks.

In terms of stratigraphic classification therefore, the earliest rocks to be laid down on the basement of Archaean granite-gneisses, as sediments or lava flows were those belonging to the Onverwacht Series. In the basin there were facies variations away from the shoreline and only in the deeper portions were Fig-tree Series rocks deposited. The entire sequence was then transgressed by Moodies System conglomerates and quartzites and subsequently folded. At the same time as the folding longitudinal strike faults were developed and basic and ultrabasic rocks were intruded.

J. STRUCTURAL GEOLOGY

(a) Introduction

Structural features found in the various rock types have been mentioned earlier in this report and it is intended here to discuss the overall structure of the area mapped. An attempt will be made to analyse the tectonic history of the area and to place it into the regional structural pattern. The structural terminology used in the report is that defined by de Sitter (1956), Weiss (1958), Ramsay (1958, 1962 a and b, 1963) and Cloos (1947).

(b) Bedding and Foliation

Bedding and foliation attitudes in the area are very regular. The regional strike is approximately east-west and deviations from this direction are entirely due to the forceful injection of basic intrusives and localized folding. Foliation in the granites is best developed in the contact zone where the alignment of mica flakes in the plane of foliation is most evident. Northwards away from the contact the granite becomes more homogeneous and loses its foliated character.

The foliation invariably dips south away from the granite massif and is followed by an apparently conformable sedimentary rock succession. The granite has possibly undergone an upward doming resulting in realignment of the constituents along paths of differential shear.

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The sedimentary successions following on the granites dip steeply to the south or are almost vertical at times. The Fig-tree sequence provides the greatest variations in the dip directions of bedding due to the innumerable tight isoclinal folds that occur in these incompetent banded argillaceous strata. Measurements taken in the fold hinges have a variable spread (see Fig. 1C).

There is in the area, a marked coincidence of schistosity with primary structures such as bedding and the vertical attitude of metamorphic rocks over a considerable area. The over-all symmetry of the fabric and the parallel alignment of biotite and quartz lensoid aggregates suggests that the schistosity has been achieved by compression normal to the foliation. Alternatively, the fine-grained laminated sediments may have been folded with the development of a slaty cleavage parallel to the axial planes of the folds. The axial plane cleavage or schistosity produced is due to planar flow of material normal to compression.

(c) Folds

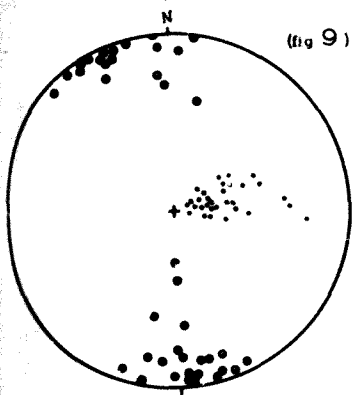
(i) General Folding of the Rocks in the Area

Along the granite contact belt folding can be seen both in the granites themselves and in the adjacent contact amphibolite zone. The late phase granitic, aplitic and pegmatite intrusives were injected into the amphibolites and at the same time they were folded together producing similar folds and attendant lineations.

The disturbance along the contact belt has resulted in folding, the axial planes of which dip at angles varying between 15 and 35 degrees to the south while the fold axes trend roughly east-west. Exposures of these folds are seldom clearly seen and in addition to the excellent Keap River exposure there are a few folds displayed in an irrigation furrow cutting on the farm Lovedale.

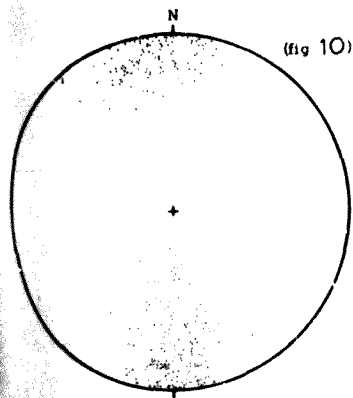
The basic rock successions are comparatively free of folded structures and the major readjustment in these rocks has taken the form of metamorphism and realignment of mineral constituents in the plane of least stress.

The Moodies System rocks have acted as a more rigid competent unit. The occurrence within the succession of flattened, boudinaged pebbles indicates that plastic flow distortion, due principally to increase in temperature and a high confining pressure, was probably



(fig 9)

- Poles to axial planes of isoclinal folds
- Plunges of isoclinal folds



(fig 10)

- Poles to bedding planes of the banded Fig-tree succession in the Lily Mine

operative in the area. Only locally do less competent bands occur but these weaker rocks have not been appreciably affected due to the protection afforded them by their sturdier neighbours.

The Fig-tree Series, consisting of alternating narrow argillaceous bedded units has behaved entirely as an incompetent mass. Strong compression has resulted in considerable shortening and flattening of the succession and the formation of tight isoclinal folds. These folds plunge steeply to the east in the Lily Mine area and plots (Fig. 9) show a distinct spread along a great circle. This feature either indicates differential compression and a corresponding variation of movement in the 'a' direction, or it could probably represent a super-imposed folding on an originally uneven surface.

The Onverwacht Series of brittle quartz-sericite schists has recorded the most numerous minor structural features. These include conjugate folds, crenulation folds and accordion folds and will be dealt with shortly.

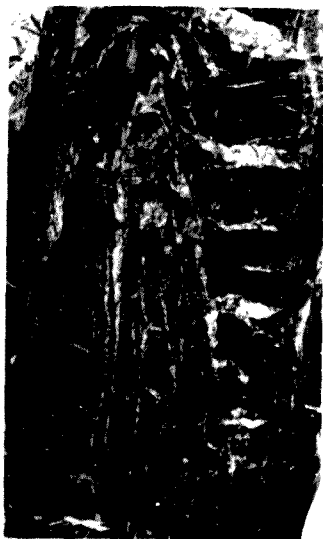
The Lily Syncline is the major structural feature of the area and consists of a massive isoclinally folded syncline the southern limb of which is overfolded to the north. The syncline is best seen near Louw's Creek (see Plate 1) while in the central portion of the area the structure is that of a closed fold. To the west the structure is most disturbed by the intrusion of serpentinites and the quartzites near the Bar 5 beacon dip at shallow angles to the southeast forming a gently warped or basin-shaped structure with an axial trace direction roughly parallel to the fold axial plane of the great Eureka Synclinal inflection.

The approximately east-west trending Lily Syncline bends to the northwest near Eureka Siding and then only reverts back to the regular trend of the formation in the Joe's Luck Siding area.

(11) Minor Folds

1. Conjugate Folds

Typical conjugate folds occur in the brittle laminated rocks of the Onverwacht Series. In addition to these, several were noted in some of the silicified shale horizons of the Lily Syncline north of Eureka Siding and in the contact amphibolite schists near Honeybird Siding. Plate 25 indicates the approximate size of a conjugate fold in brittle banded ferruginous cherts of the Fig-tree Series found to the west of the Lily Mine. The competent layers of chert have broken



(Plate 24) Tight isoclinal fold showing parasitic folding in the hinge zone and quartz filled tension cracks.

Moodies shales
Lily Syncline --Eureka.



(Plate 25) Conjugate fold in banded ferruginous cherts of the Fig-tree Series west of the Lily Mine. The cherty competent units break angularly while the incompetent shale is moulded between the harder layers.
(slightly less than actual size).

angularly in the hinges of the folds and the rock is partially brecciated. The incompetent intercalated shale has suffered flow folding and is roughly conformable with the competent units. The conjugate fold systems are useful in determining the maximum compression direction in addition the other forces involved in the deformation of the region (Ramsay, 1962a). Plots of data derived from several of these folds throughout the area indicated that the maximum compressive forces were vertical or nearly vertical (see Fig. 13) during the final phase of deformation.

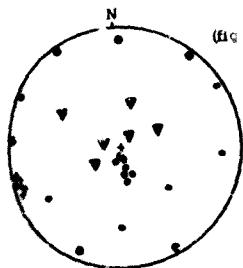
2. Crenulation Folds

These folds are also developed principally in the brittle rocks of the Moodies and Onverwacht successions. Invariably the folds display only one shear direction (see Plate 11) but folds with horizontal or near horizontal axial planes do occur. Frequently the closely parallel axial planes of the crenulation folds produce a lineation. The folds may have their axial planes parallel to one of the conjugate shear directions or they may have axial planes perpendicular to the P maximum stress that produces conjugate folds. Plots (see Fig. 13) of the axial plane attitude coincide approximately with the P maximum stress field indicated by the conjugate folds in the same diagram. The crenulation folds are especially well developed in the exposures in the road cutting on the farm Crystal Stream and in the rocks to the north of the Lily Mine (see Plate 10). They are essentially small scale structures generally measurable in millimeters or centimeters.

3. Similar Folds

Almost all the remaining folds found in the area are similar or cleavage folds and these are mostly of an isoclinal nature (see Plate 24). They are essentially confined to the laminated Fig-tree rocks but are locally developed in some of the Moodies rocks of the Lily Syncline. The folding has produced a combined shortening and flattening of 62.5 per cent in the successions of the Lily Mine (see Structure of the Mine).

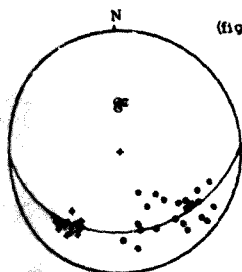
Commonly the isoclinal folds show tension jointing in the hinges and shear joints on the flanks. Parasitic folding in the crests of folds from the Moodies System were seen near Eureka Siding. Tension cracks in the fold layers have been partly or wholly replaced by quartz and appear to be boudinaged (see Plate 24).



(fig 13)

Diagram showing the approximate maximum stress field as indicated by plots of conjugate folds and minor folds in Orverwacht Rocks (only).

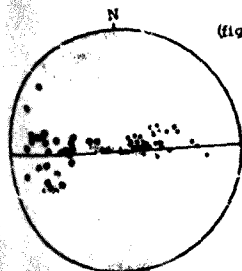
- (i) Maximum pressure (▼) associated with
- (ii) Intermediate pressure (●) conjugate folds
- (iii) Minimum pressure (●)
- (iv) Poles to axial planes of minor folds (+)
- (v) direction and plunge of minor folds (+)



(fig 14)

Plots of lineation direction and plunge from:-

- (i) ▼ Contact Belt northwest of Scotia Talc Mine and the Bar 5 beacon
- (ii) + Keap River granite exposures (Honeybird)
- (iii) ● Poles to axial plane of post granite intrusion folds



(fig 15)

Diagram showing:-

- (i) ▼ lineations in quartz sericite schists northeast of Eureka
- (ii) + pebble elongation near Sheba Siding
- (iii) ● plunges of isoclinal folds in the Lily Mine
- (iv) ● poles to axial plane cleavage, schistosity and bedding.

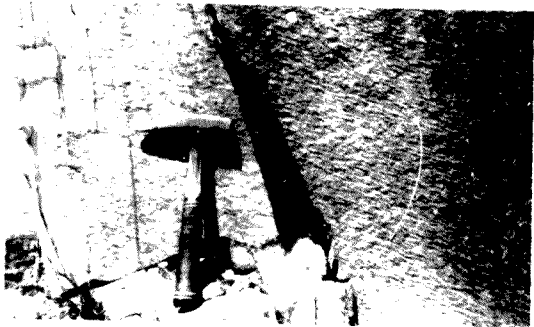
The axial planes of the isoclinal folds in the area are all steeply dipping or vertical suggesting that a strong horizontal compressive stress field was responsible for the fold formation. Large amplitudes and narrow wave lengths are encountered in the Lily Mine but folding on a larger scale is responsible for localized disturbance in the railway cutting to the southwest of the Scotia Talc Mine. Here the Onverwacht and Fig-tree successions are tightly folded with the axial planes dipping at approximately 80 degrees to the northeast. The folds plunge to the southeast at approximately 30 degrees. The fold axial trace again trends northwest - southeast i.e. similar to the Eureka Synclinal axial trace. Also included within this broad fold are numerous minor folds of the crenulation and conjugate type.

(d) Lineations

In the area mapped there are two main types of lineation. The first are those lineations produced by folding on a microscopic scale. This variety is manifest in the brittle quartz-sericite schists of the Onverwacht Series. As has previously been mentioned the crenulation folds have almost horizontally inclined axial planes. These folds produce a lineation that plunge to the west at angles seldom greater than 10 degrees (see Fig. 13). The second type of lineation is caused by the elongation of fragments such as individual grains, groups of grains and small inclusions. On a slightly larger scale elongated pebbles also result in a linear symmetry. Lineations of this second type are the more frequently encountered variety and occur in practically all the rock successions.

To the northeast of Eureka Siding well developed lineations occur in the sheared quartz-sericite schist horizons (see Plate 26). Dimensional orientation of elongated fabric elements, in this instance, quartz fragments and quartz 'nests' produce an alignment of differentially weathered constituents. On weathered faces the clear linear fabric is seen to plunge to the west at angles varying between 20 and 30 degrees (see Fig. 15). These lineations show an interesting relationship with the intrusive granites. Plate 27 indicates that the granite post-dates the formation of the lineations as no linear fabric has been transmitted to the intrusive vein.

In the Sheba Siding area outcrops of the Basal Conglomerate of the Eureka Syncline display elongated pebbles that also produce a lineation. The pebbles have been flattened in the bedding plane and are elongated in the 'a' direction and plunge almost vertically (see Fig. 15). The conglomerate pebbles of the Lily Syncline are also flattened and associated with the cleavage but there is seldom any



26. A large, dark, cylindrical object, possibly a pipe or a large bolt, protruding from a rough, textured surface. The object has a flange or head at the top.



27. A rough, textured surface, possibly a wall or ground, showing a large, dark, irregular shape that appears to be a shadow or a deep crevice. The surface is uneven and cracked.

development of a lineation except in isolated instances, for example, north of the Scotia Talc Mine where they plunge to the southeast.

In the Lily Mine individual amphibole and chlorite crystals are aligned with their long axes at right angles to the greatest deformative forces. They are elongated in the plane of the bedding but are not always aligned in the third dimension and, therefore, can only be regarded as producing a planar fabric and not a lineation.

The lineations northeast of Eureka Siding and the flattened pebbles at Sheba Siding are probably related to the same process that produced the folding in the Lily Mine. In Figure 15, it can be seen that plots of all three parameters lie on a great circle and have a fairly wide spread probably indicative of superposition on an irregular surface. The great circle that these points fall on is coincident with the axial plane cleavage, schistosity and bedding throughout the area.

Further lineations occur along the Contact Belt (see Plates 28 and 29). On the farms Perl, Lovedale and Naude's Rust they are manifest in the granites but are confined to the immediate contact. They are entirely absent less than a quarter of a mile to the north. The lineations that occur in the above-mentioned area are best seen, however, in the instructive cutting in the Kaap over at Honeybird. All these lineations plunge to the southwest (Fig. 14). Towards the west near the Bar 5 beacon strongly developed lineations occur in the sheared intrusive granites and in the neighbouring quartz-sericite schist horizons. These plunge to the southeast as do the occurrences in the adjacent Joe's Luck Siding granites and hornfelses (Fig. 14).

In these bodies along the granite margins the parallel surfaces are determined by alignment of individual crystals of mica, hornblende and other elongated inclusions or aggregates.

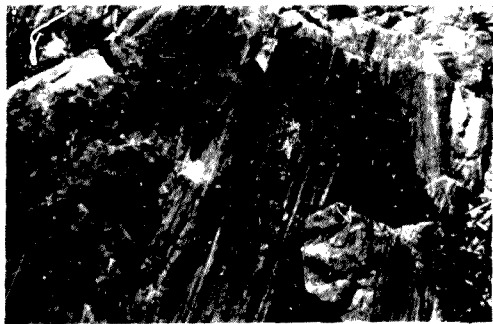
Plots of the lineations from the two separate localities along the contact differ considerably in plunge direction but nevertheless, form two maxima. These concentrations are seen to lie on the axial plane of the late phase contact granite folding (see Fig. 14). It would, therefore, appear logical that the formation of the linear fabric and the folding along the contact were contemporaneous.

(e) Deformed Conglomerate Pebbles

Two localities exist where basal conglomerates of the Moodies System are flattened and deformed. The first of these is the Lily



(Plate 28)
 Lineations in the
 folded contact, granites.
 Kaan River cutting,
 south side.



(Plate 29)
 Strongly lineated
 granites. Contact well
 exposure near the Kaan
 River --- north side.



(Plate 28)
 Lineations in the
 folded contact granites.
 Raan river cutting,
 Honeybird Siding.

(Plate 29)
 Strongly lineated
 granites. Contact belt
 exposure near the Raan
 River --- Honeybird.



Syncline where a great thickness of the formation is composed of conglomerates and quartzites. The second locality occurs to the south of the Lily Syncline and comprises the basal conglomerate of the Eureka Syncline. The basal conglomerate forms the lowermost unit of the Moodies System.

The conglomerates in the Lily Syncline have acquired, in addition to the flattening, a foliation, due to the "dragging out" of the pebbles into elongated, as well as boudinaged forms.

The components are tightly cemented together and few individual pebbles can be extracted without them breaking. It was thus impossible to acquire any specimens for the purpose of studying the extent of deformation.

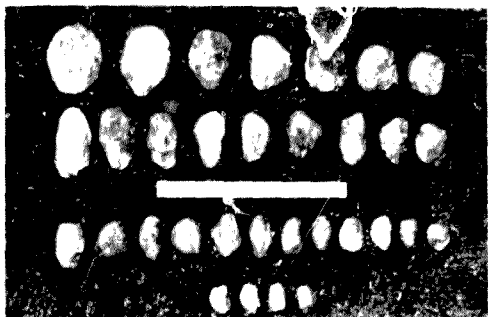
The second occurrence is entirely different, in that the pebbles are contained in a less compact, more friable matrix of impure shale and quartzite, with the result that on weathered surfaces pebbles may be fairly easily freed. However, owing to their extremely fractured nature, only a few are unbroken on removal.

The pebbles exposed in the road cuttings near Sheba 31'ing vary considerably in size and shape (see Plates 30 and 31). They consist of a great variety of rock types (see Moodies System). Most common are pebbles of chert. It was noted that different rock types exhibited different amounts of deformation.

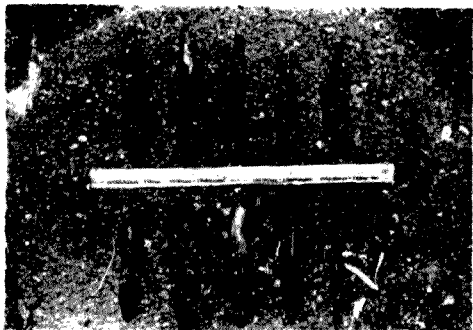
The chert pebbles are most extensively elongated and flattened while quartzitic and quartzitic pebbles retain a more rounded shape. The exposures are extremely weathered and the granitic pebbles were generally too decomposed to extract from the conglomerate.

The pebbles are aligned with their long axes (A) being plunging nearly vertical. The 'ab' planes of the pebbles are parallel to the plane of the bedding. 28 representative deformed chert pebbles were obtained from the cutting and the measurements of their major (A), intermediate (B) and minor (C) axes were noted.

Undeformed basal conglomerates of the Moodies System occur at the Barberton Shis-lo-Ngubu Dam road and numerous pebbles from this horizon were obtained by M. J. Viljoen and the writer, for the purpose of comparing them with the deformed pebbles. The pebbles collected consisted of cherts, banded cherts, graywackes, quartzites and granites.



30. A collection of small, light-colored, rounded objects, possibly seeds or small stones, arranged in three rows on a dark background. A white horizontal scale bar is positioned in the center of the middle row.



31. A dark, textured surface, possibly soil or a rock face, with a white horizontal scale bar placed horizontally across the middle.

A graph was drawn with the A : B and A : C ratios plotted for the combinations of

- (i) chert and banded chert
- (ii) quartzite, graywackes and granite.

The mean ratio A : B : C for undeformed chert pebbles was found to be 5 : 4 : 3, while the ratio for the granites and quartzites was found to be 5 : 4 : 3.5 (see Fig. 16).

A second graph was constructed and the A : B and A : C ratios of the deformed cherts were plotted. Here the mean ratio 5 : 3 : 1.2 was obtained (see Fig. 17). Using these results the percentages of deformation in the A, B and C directions for the cherts were calculated. The assumption is made that the pebbles in a conglomerate are not spherical since non-distorted pebbles are invariably triaxial ellipsoids. The values for A, B and C were calculated using the formula for a unit ellipsoid (Volume of ellipsoid = $\frac{4\pi}{3} A \cdot B \cdot C$)

by first substituting the ratio for the deformed and then the undeformed chert pebbles.

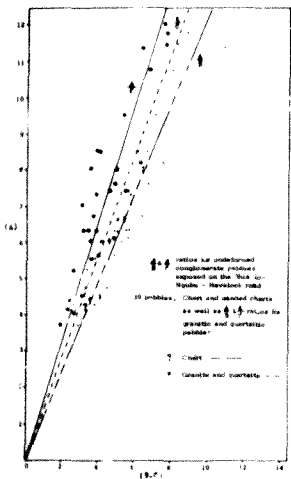
Note:- The actual formula for calculating the volume of an ellipsoid is $\frac{4\pi}{3} a \cdot b \cdot c$, where a, b and c represent the half-axes of the unit ellipsoid. By using the values A, B and C obtained from the graphs, the problem is in no way affected as ratios are involved. The calculations using the formula $\frac{4\pi}{3} A \cdot B \cdot C$ would merely necessitate the halving of the values for A, B and C. The ultimate answers in percentages remain unaffected.

Example: $A_1 : B_1 : C_1 = 5 : 3 : 1.2$ (deformed)

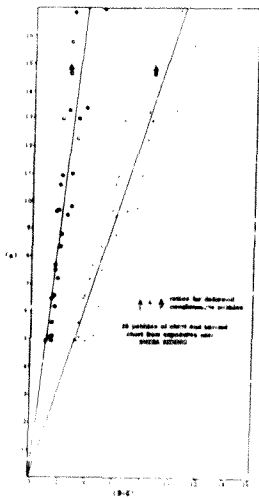
$$\text{i.e. } A_1/B_1 = \frac{5}{3} ; B_1/C_1 = \frac{15}{6} ; A_1/C_1 = \frac{25}{6}$$

$$100 = \frac{4\pi}{3} A_1 \cdot B_1 \cdot C_1$$

(Fig. 16) Graph showing the relationships between the A, B, and C axes of undeformed conglomerate pebbles.



(fig.17) Graph showing the relationships between the A, B, and C axes of deformed conglomerate pebbles from Sheba Siding.



- 80 -

$$100 = \frac{4 \sqrt[3]{A_1} \times 3 A_1 \times 6 A_1}{3 \times 5 \times 25}$$

$$100 = \frac{24 \sqrt[3]{A_1}^3}{125}$$

$$A_1 = \frac{\sqrt[3]{12500}}{75.3}$$

$$A_1 = 5.49$$

similarly for B_1 and C_1

For the undeformed pebbles $A : B : C = 5 : 4 : 3$

$$\text{i.e. } A/B = 5/4, B/C = 4/3, C/A = 3/5$$

$$100 = \frac{4 \sqrt[3]{A \cdot B \cdot C}}{3}$$

$$100 = \frac{4 \sqrt[3]{A} \times 4 \sqrt[3]{B} \times 3 \sqrt[3]{C}}{3 \times 5 \times 5}$$

$$A = \sqrt[3]{\frac{2500}{16}}$$

$$A = 3.68$$

and similarly for B and C.

The percentage deformation in A, B and C directions was then calculated using the relationships:

$$\frac{A_1 - A \times 100}{A}, \frac{B_1 - B \times 100}{B}, \frac{C_1 - C \times 100}{C}$$

Example: $A = \frac{5.49 - 3.68}{3.68} \times 100$

$A = \frac{1.81}{3.68} \times 100$

$A = 49.2$ representing an extensive increase of 49.2%.

In the same way values for B and C were calculated. The values for the cherts from Sheba Siding were thus:-

1. for A an increase of 49.2 per cent.
2. for B an increase of 12.25 per cent.
3. for C a decrease of 40.03 per cent.

These results coincide very closely to those obtained by M. Viljoen (personal communication) for the deformed conglomerates between Joe's Luck Siding and Noordkaap.

Ramsay (1963) found the orientations of undeformed pebbles to be in the plane of the bedding. He also noted that the deformed pebbles south of the Kaap River had a preferred linear orientation within the plane of slaty cleavage resultant from intense tectonic elongation overprinted on the initial sedimentary fabric. The Sheba Siding conglomerates were found to lie with their long axes parallel to the cleavage-bedding plane which in this case was coincident.

It is, therefore, possible to show from the formula $\frac{A_1 - A}{A} \times 100$,

where A_1 = long axis of deformed pebbles and
 A = long axis of undeformed pebbles,

that the values above represent an absolute minimum value of the percentage deformation because the ratio $\frac{A_1 - A}{A}$ would increase should the value A tend towards C, the shortest axis of the pebbles.

In addition to the flattening, certain pebbles indicate further disturbance subsequent to the flattening deformation and some of the larger pebbles especially exhibit a slightly twisted or buckled 'ab' plane (see Plates 32 and 33). The long axes of the pebbles in the Sheba Siding and cutting were found to plunge steeply in the plane of the bedding and produced a lineation (see Fig. 15). Also shown in the figure is the plane of bedding. The maximum stress direction 'c', coincides with the bedding poles.



Plate 32. The five small white stones, the three
conglomerate stones, the three small white stones, the
small white stones, the small white stones, the small white stones.

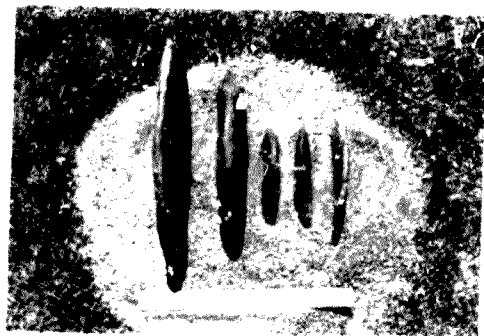


Plate 33. The five small white stones, the three
conglomerate stones, the three small white stones, the
small white stones, the small white stones, the small white stones.

(f) Faults

Faulting is not very evident in the area and only minor dislocations occur that are associated with the folding or the intrusions. Mention has been made, both in the sections on the Lily Mine and the Economic Geology, of the proposed addition to the existing geological map of the area, of a further longitudinal thrust fault, viz. the Lily Fault. Reasons for assuming the presence of this fault are also given and it was mentioned how such a fault would fit into the existing pattern of faulting in the Barberton Mountain Land.

There is some field evidence to support the idea of a fault immediately north of the quartzite-conglomerate horizon of the Lily Syncline. Much of the area is, however, obscured due to masking by scree falling back and covering the critical zone. The quartzitic rocks of the Lily Syncline are frequently mylonitic along the contact with the basic rocks. Mention has been made by de Sitter (1956) of thick mylonitic zones near or adjacent to thrust faults. The proposed fault in the area mapped would be conformable with the southern limb of the syncline.

The argument in favour of the presence of the fault has been strengthened by the work done in the adjacent section of the Lily Syncline between Noordkap and Joe's Luck Siding. Here Viljoen (verbal communication) mapped a strong fault (the Main Southern Fault) that truncates the quartzite block of the western extremity of the Lily Syncline. The fault trace was found to be filled with vein quartz. In addition the sequences to the south of the fault were found to be a complete repetition of the stratigraphy as it occurs to the north of the quartzites. The fault is considered to be a high angle longitudinal thrust fault with the underlying successions upthrown to the south.

The presence of the fault provides the most suitable explanation of the stratigraphical picture presented in the field.

The occurrence of intrusive serpentinite in the areas to the northeast and northwest of Eureka Siding may represent intrusive bodies emplaced along the zone of faulting.

Graded bedding in the shales and graywackes of the Fig-tree Series was of use in determining the direction of younging from the basic schists but it could not be used elsewhere.

Figure 7 indicates, diagrammatically, sections through the area. The relationship of the faults to the synclines and anticlinal divide are also illustrated.

(g) Other Structures

Additional structures in the area are essentially of a localized nature and were produced contemporaneously together with the major structures. The folding is practically all of a cleavage or similar type where compression has been the maximum deformative force. Often associated with these folds are boudinaged structures on the flanks that are produced by the extension and breaking up of the more competent unit layers. Minor parasitic folding is concentrated in the crests of the larger folds. Typically these small scale structures are W or M shaped in the hinge itself while on the fold limbs they are Z or S shaped. Structures of this type were noted both in the Lily Mine and in the Keep River cutting.

From both field observations and thin section study it is certain that there has been a considerable amount of flattening and shearing with the resultant formation of a strong schistosity that has a fairly uniform regional trend. Recrystallization in the form of mica takes place in the cleavage planes. Advanced schistosity is manifest when fine bedding is totally obliterated by recrystallization of quartz as well as mica. The strong recrystallization in the amphibolite zones is mostly due to thermal action resultant from magmatic activity. The texture of the rock however, is probably due to dynamic forces. The deformed fabrics are dominated by a schistosity which is more readily correlated with compression normal to, rather than with shear parallel to the schistosity plane.

Plates 6 and 7 show compositional banding of the schists in the contact amphibolite zone and the development of boudins.

Jointing, mentioned elsewhere in this report, is frequently seen and has a constant direction over most of the area. It was shown that the joints favour a trend at right angles to the granite contact and are especially manifest in most of the rigid rocks. The joints may be regarded as 'a-c' tension joints indicating that the general stress necessary for their formation probably came from the direction of the granites. The stress producing many of the joints was not the same as that responsible for the foliation as joint planes cut the foliation and even act as small fractures along which there has been movement (see Plate 4).

The jointing, or at least some of it, was probably one of the latest events in the area as it is seen in all formations and in the intrusive dykes. Two or even three directions of jointing may sometimes be seen in the same outcrop (see Plate 5).

Along the intrusive contact there is a prevalence of pygmatic structures and contorted granitic and pegmatitic veins. They are generally seen meandering about the dark contact amphibolitic schists. The pygmats appear to be independent of the texture of the host-rock and although the veins appear to be folded about axial planes that are consistent and regularly aligned, the amphibole schistosity seems unaffected except around the margins of the pygma itself (see Plates 34 and 35). de Sitter (1956) attributes the cause of this peculiarity to the different reaction in the stress field of vein and host rock material; each possessing differing physical properties.

(h) Regional Structure Effects on the Mineral Localization

Between Sheba Siding and Louw's Creek it is believed that the gold mineralization was introduced along the Lily Fault zone by hydrothermal solutions associated with the Nelspruit Granite intrusion. A look at the regional map indicates that the geological structures in the area are fairly regular and that no apparent controlling factors are evident to explain the localization of the gold into workable ore deposits such as those of the Lily and Rose's Fortune Mines.

Prospecting has taken place in a westerly direction from the Lily Mine and two other small but very erratic occurrences have in the past been mined on the farms Avoca and Crystal Stream east of Eureka Siding. These deposits also occur in apparently regular formations and an explanation of their whereabouts is not easy to explain. A further difficulty involved is that the mineralized fault zone occurs in a valley where outcrops are far from ideal for the attainment of data relating to the deposits.

All that can be attempted in an explanation is to point out certain "localized disturbances" that may escape attention on the geological and structural maps accompanying this report. The largest of these so called "disturbances" occurs immediately north of the Lily Mine where the quartzite-conglomerate horizon has a slight inflection. There is a marked difference in bedding orientation over a short distance within the inflected zone and the strike alters from E.N.E. to N.N.E.

It is not unlikely that the effect of the gentle warping might have been transmitted through the adjacent rocks to the south and into the Fig-tree rocks in the mine area. The brittle quartzite schist north of the mine also displays minor oblique folding that may be related to the disturbance. The small fault zone is quartz filled but there is no evidence of any displacement of

the formations. The exact effect such a small disturbance as outlined above would have on the provision of suitable loci for mineral concentration is difficult to imagine, but it is likely to have contributed to or assisted in the rearrangement and dislocation of the formations, thus making them more acceptable to subsequent deposition and concentration of ore forming fluids.

It may simply be coincidence but the fact remains that each of the exploited deposits to date are located immediately south of features (however slight they may be) seen in the rocks north of the Fig-tree succession.

North of the Rose's Fortune Mine the Onverwacht sequence of quartz-sericite schists branches into two separate units with basic schists filling the wedge between the two limbs. No evidence to explain this split could be found, but the structure may represent the anticlinal divide between the Lily Syncline and the formations to the south.

A further example of gold deposits accompanied by a corresponding irregularity in the northerly formations can be seen east of Eureka Siding. Here the Lily Syncline is gently buckled in a great arcuate shape convex to the successions in the south (see Plate 3). The Lily Syncline and the Eureka Syncline are nearest to one another in this area and the intervening Onverwacht and Fig-tree rocks are narrowest along this compressed zone. The old workings of the Mexican and Cleopatra Mines occur in this locality.

(1) Tectonic History

It is clear from earlier mentioned structures that there are several varieties and styles of deformation existent in the area. In the New Consort Mine - Joe's Luck Siding area these structures are well developed and were first investigated by Ramsay (1963) who was able to recognize three phases of deformation. Later M. Viljoen's investigations led him to believe that four periods of deformation in fact, existed in this area.

Although occurring adjacent to this exceptionally tectonized zone the Sheba Siding - Louw's Creek area is comparatively devoid of structural parameters. The writer who worked in close collaboration with M. Viljoen was able to recognize certain style similarities in the minor structures that were common to both regions mapped. It is largely with these similarities in mind that an attempt was made to correlate the structural events.

It is generally accepted by most geologists who have examined the structure of the Barberton Mountain Land, that the regional trend of the Precambrian formations in the area was initiated by the first diastrophic event.

(1) First Phase

The first stage of deformation was responsible for the development of the major synclines that trend in a northeast-southwest direction, the compression being directed from the northwest and southeast. The major high angle longitudinal thrust faults are thought by Ramsay (1963) to be coincident with the first period of folding. The Lily Syncline is considered to have originated during this period. Ramsay (1963) mentioned the difficulty of recognizing the structures on the northern side of the Eureka Syncline. He believed however, that two large first folds existed there. These are the Woodstock Anticline and a syncline which he thought might possibly be the continuation of the Lily Syncline.

As the principal stress direction was operative at right angles to the regional trend, the geological successions in the area underwent considerable folding, shortening and flattening.

The first phase cannot directly be seen in the area investigated but it may be assumed or deduced from the spread on a great circle of parameters belonging to the second phase. This spread indicates that irregular surfaces existed before the strong development of a cleavage, schistosity, flattening and metamorphism. The Lily Fault and the Main Southern Fault among others can probably be associated with the first folding. It is also considered likely that the basic and ultrabasic rocks in the area were emplaced early in the postsynclinal tectonic history of the Mountain Land. Many large basic bodies often occur as masses or sheets concordant with the structure of the enclosing strongly folded rocks. In a few instances the basic rocks are known to intrude into the Ventersdorp System rocks, but cross-cutting relationships are generally absent. The ultrabasic rocks may have been squeezed up along major dislocations developed in the postsynclinal basement during the onset of folding as pictured by Jones, Benson and Hess (quoted in Turner and Verhoogen, 1960).

(2) Second Phase

The second stage of deformation involved compression from an

approximate NNW - SSE direction. The tight folding of the Lily Syncline and Fig-tree Series, initiated in the first stage, was intensified. The compression was probably responsible for differential variation of movement in the 'a' direction of the isoclinal folds in the Lily Mine and adjacent Fig-tree rocks.

Lineations were produced early on in the quartz-sericite schists north of Eureka Siding and a strong foliation and schistosity in the formations was initiated by the dynamic influences.

Ramsay (1963) attributed the numerous fabrics developed over the whole area as largely resulting from strain suffered by the rocks during the second phase of deformation. He showed regionally that this second phase produced a slaty cleavage that cross-cut the first formed folds and was best seen in the Eureka and Ulundi Synclines.

Within the area discussed in this report indications of this phase are seen in the elongation and orientation of the long axes of the conglomerate pebbles at Sheba Siding. The pebbles are flattened in the plane of the bedding and produce a lineation that plunges steeply (see Fig. 15). Ramsay noted similar deformed and linear orientated pebbles south of the Kaap River, west of Joe's Luck Siding.

Although cleavage is apparently absent it is likely to be contained within the bedding planes. The differential shearing of the strata in the Lily Mine is coincident with bedding plane cleavage (see Plate 14). It has also been shown earlier (Fig. 15) how it is considered that the folding in the Lily Mine, the lineations north of Eureka Siding and the pebble lineations at Sheba Siding are inter-related.

Ramsay also postulates the introduction at this stage of the Malspruit Granite intrusion and the main period of mineralization. He found strong structural conformity between the slaty cleavage in the unmetamorphosed sediments, the schistosity of the phyllitic rocks and even within the granites themselves. Well developed tectonic structures probably developed while the granite was crystallizing. Events are thought to have been broadly synchronous during the second phase deformation because there is evidence north of Eureka Siding of a granite or aplitic vein cross-cutting and, therefore, post-dating the lineations in the quartz-sericite schist horizon. The lineations probably formed early on in the history of the granite emplacement and the vein seen in the quartz-sericite schist very likely represents a late phase intrusive. A further late phase event is probably manifest in the folding of the granites along the contact.

This folding, clearly seen in the Kaap River cutting was responsible for the production of lineations that appear to be confined solely to the contact zone. The folding, of a similar type, is thought to have been produced in the granites and amphibolites while the intrusives were in a semi-plastic state.

The intrusion of the Nelspruit Granite was responsible for the production of the metamorphic fabrics in the adjacent formations. The intensity of the thermal aureole decreases away from the granite contact.

In the Lily Mine the alignment of individual amphibole crystals was partly developed by dynamic metamorphism and flattening due to compression and partly due to thermal metamorphism associated with the introduction of the hydrothermal mineralizing solutions.

(iii) Third Phase

The major event in the Mountain Land during this stage was the great inflection of the Eureka and Ulundi Synclines. Ramsay (1963) found slaty cleavage and schistosity folded by large and small scale folds. The compressive stresses were found to be at right angles to the earlier deformations viz. from the northeast and southwest. The Lily Syncline was probably involved in a swing from NE - SW to an approximate east-west direction.

In addition to the major folding it is likely that the folding of the area northwest of Scotia Falc Mine can be related to the same period of disturbance although it should also be borne in mind that the introduction earlier of the basic intrusive mass probably had the greatest influence in the local deformation of the region.

(iv) Fourth Phase

Ramsay (1963) considered that the development of conjugate folds was synchronous with the formation of the arcuate structure of the Eureka and Ulundi Synclines. He was however, not emphatic about this and suggested that they may post-date the 3rd Phase and be related to a fourth period of deformation. Subsequent to Ramsay's work several investigators have mentioned the occurrence of conjugate folds producing similar stress directions. The conjugate folds were noted from widely separated areas throughout the Mountain Land and it would appear that they represent a phase subsequent to that of the third deformation.

In the report area numerous crenulation folds, often accompanied by a few conjugate folds, were noted. It has been shown earlier how these minor structures indicate that a vertical or near vertical stress field existed in the area. Although the maximum stress appears to have been operative in the hinge zone of the Eureka Syncline and areas to the north, it is nevertheless manifest to a lesser degree in adjacent regions.

Finally at a much later stage jointing affected the formations and late intrusives. It is likely that all the phases of deformation are related to one continuous diastrophic event possibly connected with the updoming of the granites. The Swaziland Geological Survey (Hunter, 1961) recognizes the fact that the G5 granites are the youngest intrusive granites southeast of the Barberton Mountain Land. They are dated at between 2,200 - 50 m.y., and 2,680 - 340 m.y., by Allsopp, Roberts and Schreiner (1962). The intrusion of these granites therefore, may have been responsible for the vertical pressures that produced the horizontal axial planes in the minor fold structures. Each successive event either rejuvenated previous structures such as faults and fractures or obliterated earlier formed phenomena. Continuous re-orientation of stress fields produced by differential movement of the upwelling mass might explain the varied structures seen in the field today. Subdivision of the diastrophism into successive pulses or phases serves the useful purpose of emphasizing the main events that took place and relates them chronologically to one another.

X. ECONOMIC GEOLOGY

(a) Introduction

Apart from the gold occurrences in the area there are several localities where the non-metallic minerals magnesite and talc have been mined in the past. The Scotia Talc Mine near Sheba Siding is at present being worked on a small scale.

Interest was again shown in the nickel occurrence northwest of Sheba Siding on the farm Bon Accord, described by Partridge (1942).

It is proposed in this section to briefly mention the various ore deposits and their economic implications.

(b) Magnetite

Magnetite occurs near Sugden Siding on the farm Annex Riverbank. It is found as a compact or amorphous variety in veins replacing the altered basic serpentinite. Two magnetite bearing zones were noted within the serpentinite body. These zones had an approximate east-west strike direction and displayed only irregular showings of magnetite. Numerous trenches and prospect winzes occur in the area but the mineral was only mined from two small quarries, one in the east and the other, and larger of the two, in the west near to Sugden Siding. The deposits were described by van Zyl et. al. (1942) and since that time little or no further mining has taken place.

The easterly quarry did not appear to be of any significance and more attention was devoted to the westerly occurrence. The quarry and trenches display "zebra ore", i.e. alternating narrow seams of weathered serpentinite and magnetite (see Plate 22).

The magnetite seams vary from a $\frac{1}{4}$ -inch to 2 inches in width and are inclined at shallow angles to the north. The seams are separated by dirty brown altered serpentinites 3 to 4 inches in width. Thicker vertical or near vertical, seams of magnetite intersect the narrow seams at right angles. Although a shaft exists in the centre of the quarry there is no evidence of the depth of the body. Abundant magnetite still remains exposed in the quarry. Much of it is pure white but the greater part is discoloured due to impurities. The pure magnetite has a porcellaneous texture while the remainder is earthy.

In thin section the weathered serpentinite shows abundant antigorite, magnetite and carbonate material. In addition several altered clivine crystals were noted.

The magnetite has apparently formed from an original ultrabasic intrusive by processes involving chemical weathering and the infiltration of carbonate waters which have reacted with the magnetite rich serpentinites.

In addition to the occurrences near Sugden Siding further indications of magnetite were found to the northwest of the Scotia Talc Mine. Magnetite bearing serpentinite is exposed on the west bank of the river cutting. Much of the serpentinite has been altered to a yellowish brown earthy colour and the magnetite on surface outcrop appears impure.

(c) Talc

Large serpentinite intrusive bodies occur in the western portions of the area. Not infrequently associated with these serpentinites are zones of talc. Prospect trenches are frequently encountered and are centred around the Scotia Talc Mine.

The deposit at Scotia Talc is situated between two quartzite-conglomerate bands of the Lily Syncline in a zone of intrusive, altered serpentinite.

The mine was developed early this century and was worked recently by Union Corporation. It is at present being worked privately.

The talc occurs as lenticular bodies that pinch and swell from surface outcrops to an unknown depth. These bodies, of which there are two known occurrences, consist of talc in a variety of green and gray colours. The lenticular bodies are seldom wider than 30 feet and an average width of 15 feet is estimated. In contrast with the wall rocks of serpentinite and calcareous serpentinite the ore zone is intensely folded and shows slickensided surfaces indicative of strong shearing stresses. The contact between the commercially recoverable talc and the wall rock is sharp in the lower levels. Lateral gradation into impure talcose material of uneconomic grade occurs in the upper reaches of the deposit.

The two lenticular bodies known as the North and South bodies respectively, are separated from one another by a narrow band of whitish carbonate-rich serpentinite. Gradation into talc-carbonate schist was also encountered.

The North body, the larger of the two, widens out from surface with increasing depth and at the same time the quality of the talc increases sympathetically.

The talc mined is of a fairly high quality, the only deleterious impurities being the black schorlite tourmaline that at times is very abundant, especially in the dark green talc ore. The best quality talc is gray or pale green in colour.

Talc is regarded as an alteration product from mild hydrothermal metamorphism perhaps aided by dynamic metamorphism and not from weathering (Bateman, 1958).

It is apparent that the Scotia deposit has largely been controlled by intensive shearing and hydrothermal replacement from solutions that probably emanated from the intrusive granites.

(d) Nickel

An occurrence of trevorite, situated approximately 1½ miles northwest of Sheba Siding on the farm Bon Accord was first described as a new mineral by A. F. Crosse in 1921. He showed it to be an oxide of iron and nickel. Partridge (1943) on re-examination of the deposit, noted and described also for the first time, the mineral nepoultite, a nickel-magnesian-hydrated silicate. Some detailed mineralogical work was carried out on this ore and Partridge described trevorite being replaced by magnetite. He also noted a transparent mineral and the nickel sulphide millerite. He concluded that the ore was a replacement deposit formed by the introduction of nickel bearing solutions. Detailed properties of the new mineral nepoultite were given and assays indicated that this mineral contained a high percentage of nickel and was therefore desirable as an ore of nickel.

Renewed interest in this deposit was shown in 1962 by Rand Mines who undertook exploratory drilling and have subsequently abandoned work in the locality.

Briefly the geology of the area is as follows. Intruded into the quartzites of the Lily Syncline is an ultrabasic body now almost totally altered to serpentinite. The intrusive mass probably caused considerable updoming of the steeply dipping regular successions and resulted in the splitting up and separation of the quartzite horizons which now dip at shallow angles to the southeast.

It is considered likely that the nickeliferous material was introduced into the area as an original constituent of the ultrabasic intrusive. Subsequent shearing took place in the area providing suitable channels for the introduction at a later stage of hydrothermal solutions associated with the Nelspruit Granite emplacement. The hot aqueous solutions are thought to have been responsible for the solution and precipitation of the nickel bearing constituents within these shear zones. In the neighbourhood of the trevorite nickel deposit near the Bar 3 beacon the serpentinite has been sheared and is schistose in certain zones. The trevorite occurs in the shear zone underlying the quartzite horizon but is no more than a few feet wide.

North of the Scotia Talc Mine in the serpentinites that occur between the contact amphibolites and the quartzites and conglomerates, further magnetic rock outcrops were encountered indicating that the occurrence described earlier is not an isolated one but that there may be several smaller deposits in the area.

It is also reported that trevorite has been found within the Scotia Talc Mine and is no doubt related to the same period of mineralization as those to the northwest.

(e) Gold

(a) Lily Gold Mine

The Lily Gold Mine was, until recently, one of the few remaining small scale gold mines still in operation in the Barberton District. The mine occurs about 3 miles south of Louw's Creek Station and is situated on rocks belonging to the lower part of the Fig-tree Series. This Series abuts up against talcose rocks to the north. Along the contact is the zone known as the Main Reef Zone. The proposed Lily Fault occurs within the Main Reef Zone, a zone marked by sheared, silicified and brecciated rocks.

The Fig-tree succession consists of narrow alternating bands of shale, banded ironstone, cherts, graywackes and their metamorphic alteration products.

In addition to the Main Reef there are several other reefs to the south consisting of vein quartz. These veins fill shear zones in the vertically dipping strata. In the central portion of the mine is a plunging pipe-like ore shoot that pinches out with depth. The shoot structure is complex, consisting of brecciated country rock with replacement veins of quartz filling the fractures and breccia cavities.

The formations in the mine are deformed and are folded into tight isoclinal structures. The bedding is in all cases vertical or steeply dipping and is affected by two sets of fracture systems, the one vertical and the other a cross-cutting flat fracture type. In some instances the intersection of the two fracture systems was found to have a direct bearing on the occurrence of pay zones.

Although the Main Reef Zone has proved to be the most consistent lode in the mine, several other reefs often containing free gold, were worked. These reefs nearly always proved to be erratic.

Exceptionally rich "bonanza" gold pockets were recovered from the pipe-like ore shoot, and between July, 1958, and March, 1963, 7,510 fine ounces of gold were recovered from 6 rich pockets. This amounted to approximately 40% of the 18,843 fine ounces of gold produced in the mine during that period. It is thought that secondary enrichment may be responsible for the unusually high values encountered at times.

The mine workings were initially open cast along the Main Reef Zone, but later, adits were driven into the hillside and underground development continued along the strike of the Main Reef. In addition drives along strike were begun along 4 other reefs intersected by initial crosscut tunnels. The pipe-like ore shoot was only recently discovered and exploited.

The mining has almost entirely been carried out in oxidized rock and only in a few instances was sulphide ore investigated. The fresh rock mineral assemblage consists mainly of pyrrhotite with minor amounts of arsenopyrite, pyrite, chalcopyrite and accompanying gold.

A more detailed account of the geology, structure and mineralogy of the Lily Mine is given in the following chapter.

(b) Rose's Fortune Gold Mine

Approximately one mile to the east of the Lily Mine is another small producing mine known as the Rose's Fortune Gold Mine.

The deposit is once again situated at the base of the Fig-tree succession and corresponds to the same horizon as that on which the Lily Mine is situated. Again, to the north, the succession is followed by talc schists.

Work on this mine dates back as early as 1887 and the ore was obtained from quarrying. Later 2 adits were driven into the hillside on the reef. An additional adit has been started recently from Louw's Creek itself. As the dip of the formation is nearly vertical all three reef drives are almost directly above one another. (See Fig. 28, diagrammatic N/S section).

The ore thus far exposed is all oxidized and decomposed. This decomposition has almost entirely obliterated the bedding and structural relationships in the mine. What is evident however, are the flat lying fractures that intersect the reef. Again a notable increase in values were recorded in the immediate vicinity of the intersecting loci.

(c) Additional Gold Occurrences

Between Joe's Luck Siding and Louw's Creek numerous old workings consisting of trenches, adits and shafts define a zone of mineralization that has a strike length of over 12 miles.

The mineralized zone occurs at the base of the Fig-tree succession and also corresponds to a lateral extension of the Lily and Rose's Fortune ore horizons. Along this zone about two miles to the east of Louw's Creek is the old Kimberley Imperial Mine, while to the west of the Lily Mine two smaller occurrences, namely the Mexican and the Cleopatra are to be found on the farms Avoca and Crystal Stream respectively.

Recent trenching on the eastern portion of the farm Crystal Stream has proved the occurrence of gold in this area but values are erratic.

Near Joe's Luck Siding in the Kaap River Valley, further indications exist that the auriferous horizon is continuous into this area. Outcrops are very poor along the valley but 'bar' development, i.e. development of a silicified and mineralized shear zone, is at times discernable. A few old trenches and shafts show the sequence which is very similar to that exposed near the Lily Mine.

It is considered likely, that the frequent occurrence of gold mineralization along the same recognizable stratigraphic horizon has largely been determined by structural control and in this regard it is justifiably felt that the inference of a longitudinal fault, the Lily Fault, is not entirely unwarranted. The envisaged fault would have acted as a channelway for the ore-bearing solutions and in this manner would not be unlike the other major faults in the Barberton Area that are known for their controlling influence on the mineralization.

It has been mentioned elsewhere in this report that the Lily Mine Main Reef ore horizon is brecciated. The succession in the Rose's Fortune Mine too, is disturbed in the form of a narrow zone of decomposed breccia. In addition the lower Fig-tree succession in these zones and elsewhere on surface outcrop displays evidence of shearing and local metamorphism. Also along the envisaged fault there are bodies of talc schist and what may be intrusive serpentinites. The former may also be a rock type of intrusive origin that has subsequently undergone alteration due to processes of heat, pressure and chemical weathering. Finally, 'bar' development along the contact may be indicative of secondary replacement along a faulted

zone. These factors, together with the accompanying gold and sulphide mineralization, are the essential points around which the idea of a fault has been construed.

Large tracts of the mineralized zone are covered, and therefore obscured from view, by arable and scree covered lands. Earlier investigators and prospectors were thus deprived of considerable outcrops. Future prospecting may be confined to the narrow zone indicated on the accompanying regional map.

Additional but erratic gold was panned from the banded ironstone and silicified zones to the southwest of the Lily Mine.

The Consort Contact, occurring mainly in the adjacent area was traced eastwards for a distance of over 5 miles to a point near Bar 5 beacon where the horizon narrowed and finally pinched out. The Consort Contact, on which is situated the New Consort Gold Mine, consists of a zone of differential shearing between the base of the Fig-tree succession and the underlying Onverwacht rocks. The shear zone has become silicified and mineralized probably due to hydrothermal solutions introduced at the time of the emplacement of the Nelspruit Granite. The silicification has resulted in 'bar' development and the horizon can be followed continuously except where pegmatite and granite bodies have intruded and disrupted the regularity of the sequence.

CHAPTER 3.

THE LILY GOLD MINE

A. INTRODUCTION

A brief summary of the locality, mode of occurrence and mineralogy of the various gold deposits in the Barberton Area is given together with a description of the structural environment of the Lily Mine. This is followed by a detailed study of the mine itself and finally an attempt is made to show how the deposits can be woven into the overall mineralization pattern of the District.

(a) Locality of Mineralization in the Barberton Area

It is well known, that throughout the Barberton Mountain Land most of the gold occurrences are located on or very near to regional fault planes. A glance at the diagram (Fig. 1) shows the distribution of the more important mines and their relationship to the major faults in the area. Two faults in particular are prominently studded with mines, some of which are no longer worked due to the depletion of oxidic ore. These important faults are the Sheba and Barbrook lines of disturbance. Two of the largest mines in the District occur along the Sheba Fault, viz. Fairview and Sheba Gold Mines.

These large longitudinal faults, represented in addition by the Scotsman Fault near Three Sisters, the Saddleback, Imyoka and Kamlabane Faults to the southeast of the Mountain Land, probably served as major channelways for circulating hydrothermal solutions. Secondary channels or fractures branch from these fault lines extending the mineralization to adjacent areas.

Much of the mineralization, it will be noticed, is essentially restricted to those regions nearer to the granites yet it is equally significant that very few deposits occur within the granites, themselves. The few occurrences found in the granites are essentially quartz vein fillings of shear zones or isolated sedimentary xenoliths containing gold and copper mineralization, e.g. the Overton Mine on Mountain View Farm 2 miles north of Honeybird Siding and an occurrence on the farm Caraceto northwest of Revolver Creek.

The larger mines, notably the Agnes Mine, Fairview, and New Consort Mines are disposed about the Kaap Valley Granite pluton (Read,

1951). The mineralization appears to decrease in amount away from the granites - that is, towards the southeast. The mines away from the contact zones are also characterized by low-grade sulphide ore.

(b) Types of Mineralization Occurrences in the Barberton Mountain Land

Gribnitz (1961) describes three types of ore bodies in the Barberton Area. He first mentions metasomatic replacements of foot and hanging wall rocks in faulted areas. Sulphides and non-metallic gangue mineral replacement has taken place in brecciated and mylonitized zones. He quotes New Consort, Fairview, Sheba and Agnes Mines as being examples of this type.

The second type of occurrence are the gold/quartz vein deposits. The gold is distributed finely in white or black quartz with occasional zoning suggestive of vug deposition. Mines falling into this category include the Fortuna and Pioneer.

The third type are pipes formed by mineral stoping. The famous Cathedral shoot at Sheba is cited as an example together with other smaller examples from the same mine. The latter are smaller and breccia filled.

(c) Mineralogy of the Barberton Gold Deposits

Some detailed work has been done on mineralogy of the ore deposits in the District. In 1957, de Villiers attempted a classification and discussed the mineralogy of the more important deposits. He concluded from paragenetic evidence that the gold occurrences were all formed during a single metallogenic age. Both he and van Eeden (1941) were in agreement with the idea that the mineralizing hydrothermal solutions were derived from the Nelspruit Granite. Hearn (1943), however, was of the opinion that the Kaap Valley Granite was largely responsible for the introduced solutions.

de Villiers sub-divided the deposits into 4 main types of sulphide ore:

1. ores containing arsenopyrite and pyrrhotite in which the paragenetic sequence appeared to be arsenopyrite, pyrrhotite and then chalcopyrite.
2. pyritic ores with arsenopyrite first to form

followed by pyrite, second generation arsenopyrite, pyrrhotite and chalcopyrite.

3. lead ores with pyrite, sphalerite, tetrahedrite, chalcopyrite and galena, forming in that order
4. antimonial ores with pyrite or arsenopyrite forming early followed by berthierite, marcassite, stibnite and finally metallic antimony.

Gangue minerals were generally found to be early in the sequence with gold one of the last minerals to be introduced.

Gribnitz (1961) added a 5th type - not a sulphide classification however, but gold-quartz ore.

The regional distribution of the types has only been mentioned in an extremely generalized manner by Gribnitz (1961) quoting C.A. Strauss. He mentions that arsenopyritic ores become rarer in occurrence south and southwest of New Consort Mine. Next in the zonal arrangement of the ore types are pyritic deposits with very small crystals. These are followed by coarsely crystalline pyrites forming large impregnation zones. The gold-quartz veins are mentioned as occurring near to the Kaap Valley Granite. Antimonial ores occur in pockets in the first three zones.

de Villiers (1957) considered most deposits to have formed at moderate temperatures and depths and states that the pyrrhotite and arsenopyrite ores of New Consort and Lily Mines were due to introduction at high temperatures and great depth. de Villiers further classified the Eagle's Nest Mine, New Consort Mine and Lily Mine together as all having ore of the arsenopyrite-pyrrhotite group.

The Eagle's Nest Mine worked mainly oxidized ores. Sulphides were encountered in brecciated zones along or near the contact of ferruginous banded chert and sericite schist. The main sulphide was pyrite with arsenopyrite, pyrrhotite and chalcopyrite.

The New Consort mineralization occurs along folded and silicified contacts of altered shale overlying basic schists. The gold is associated mainly with arsenopyrite and lesser amounts of pyrrhotite. Chalcopyrite, stibnite, tetrahedrite, galena, trevorite, pentlandite, niccolite, maucherite and native bismuth also occur to a lesser degree.

(d) Structural Environment of the Lily Mine

The Lily Mine occurs approximately three miles south of the nearest granite exposure at Louw's Creek. It is also north of both the Sheba and Barbrook Faults. Mapping within the mine itself together with regional mapping has brought to light certain features that suggest the presence of an additional fault, the "Lily Fault". This aspect has been discussed under the Economic Geology of the area where it is shown that numerous old workings could possibly define a further mineralized line - the "Lily Line".

It will be noticed on consulting the existing Geological Survey Map of the District that two faults (Sheba and Barbrook Faults) occur in the anticlinal divides between major synclines. The Sheba Fault separates the Eureka Syncline from the Ulundi Syncline while the Barbrook and the nearby Saddleback Faults separate the Ulundi Syncline from the Saddleback Syncline. A further example of major faulting associated with synclines occurs near Three Sister where the Scotsman Fault strikes in an east-west direction parallel to the northern limb of the Lily Syncline. A precisely similar arrangement appears to exist between Sheba Siding and Louw's Creek where the Eureka Syncline and the Lily Syncline are separated by the Lily Fault.

The Kaap River has eroded much of the area immediately north of the Eureka Syncline thus destroying and obliterating the fault trace. The rocks in the river valley are mainly composed of soft basic schists with occasional shale and chert bands providing the only resistance to the erosive cycle.

The Lily Fault zone runs past the area south of Joe's Luck Siding and continues for a short distance on the northern bank of the Kaap River. It then crosses the river and appears to join up with the mineralized Woodstock Fault.

A further fault extending from just north of Joe's Luck Siding to the area north of Iborakaap was mapped. The fault plane is well defined and is usually occupied by a large quartz vein. This fault named the Main Southern Fault runs north of the Kaap River and truncates the quartzite block of the western extremity of the Lily quartzite line. In the area near Joe's Luck Siding the behaviour of the fault is not clear but it is considered likely that it continues along the southern edge of the quartzite-conglomerate horizon past the Scott's Fair Mine and east towards Louw's Creek (M. Viljoen, verbal communication). Evidence for the fault is poor, but the quartzites are mylonitized along the entire length of the Lily Syncline probably

indicative of shearing associated with the faulting which is considered to be of the high angle thrust fault type.

B. DESCRIPTION OF THE MINE AND REEFS

(a) Mine Layout

Plate 36 gives a general view of the Lily Mine looking east. The mine is situated on rocks belonging to the lower portion of the Figtree Series. The banded ironstones and shales abut up against talcose rocks in the north. Along the contact is the zone known as the Main Reef Zone. The Main Reef was first worked from surface where the ore was quarried. The mine is situated on the slope of a hill and as the quarry became deeper it was found necessary to drive several cross-cutting adits northwards into the hill to intersect the ore zone at a lower level.

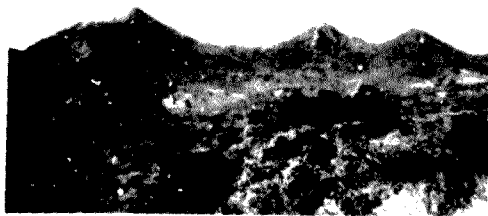
The cross-cuts intersected several other reefs to the south of the Main Reef. In the central portion of the mine on 1 Level, 4 such reefs were located and developed laterally. The Mill Adit in the east was started as a crosscut but then reverted to a drive parallel to the formations that continued to the area immediately below the development of 1 Level. The 2 Level workings are in oxidized rock for some distance but as the tunnel proceeds west into the hillside, sulphide or fresh rock takes over.

Higher up in the Mine above the 1 Level workings are several intermediate levels the more important of which have proved to be the 70 Ft. Level and the Surface Level. Both these levels and the intermediate levels occur in oxidized rock and development has been curtailed in the west by the presence of sulphide rock.

The reefs consist of vein quartz filling shear zones in the strata. The Main Reef Zone is partly brecciated as is a zone or shoot in the central portion of the mine south of the Main Reef. The shoot opens out near the surface and has also been quarried, while with depth the plunging structure narrows and finally appears to pinch out below 2 level. The term "shoot" is generally employed to describe concentrations of ore of hypogene origin as distinguished from supergene concentrations. However, pockets, nests and bonanzas may refer to either supergene or hypogene conditions and fall into the definition of ore shoots. (Bateman, 1958).



(Plate 36) General view of the Lily Mine. Top left: explosives magazine; Centre: Main Quarry; Centre right: mine office, Lily Abit and native compound.



(Plate 37) View looking east across the Lily Syncline (left, the Overwacht zone, centre, and Flip-tree Series (right), as seen from Crystal Street.

The Main Reef Zone has proved to be the most consistent lode with an average grade in the oxidized ore of between 3 and 5 dwts. The 70 Ft Level reef was more erratic but contained abundant free gold. The remaining reefs in the mine have all proved to be very erratic. Values are generally unpayable but extremely rich pods containing free gold were encountered at intervals along the veins.

The main shoot provided the loci for about six "bonanza" gold pods while the brecciated material gave ore with a good average grade. (see Table II). The term "bonanza" is commonly used to designate an exceptionally rich shoot or bunch of ore and is particularly applicable with reference to gold or silver. (Bateman, 1958).

TABLE II.

TABLE OF OUTPUT AND ORE TONNAGE

The following table represents the annual tonnages of ore milled and the gold output in fine ounces for both the Lily Mine and the Rose's Fortune Mine together. No separate figures were kept for the two mines but approximately 80 per cent of the ore was obtained from the Lily Mine.

<u>Period</u>	<u>Tons Milled</u>	<u>Fine Ounces Gold</u>
1st July 1958 - 30th June 1959	17,288	2,470.10
1st July 1959 - 30th June 1960	10,660	6,729.84
1st July 1960 - 30th June 1961	10,469	4,903.52
1st July 1961 - 30th June 1962	10,713	2,740.83
1st July 1962 - 31st March 1963	9,146	1,999.19
<u>TOTAL</u>	<u>53,276</u>	<u>18,843.48</u>

FOOTNOTE:-

Regarding the tonnage milled during the period 1st July 1962 to 31st March 1963, 2,375 tons of ore from the Rose's Fortune were treated, and the balance (6,771 tons) were derived from the Lily Mine. The average grade was approximately 3.5 dwts.

The "bonanza" gold pockets were extracted between December 1959 and November 1960, when approximately 5,480 fine ounces were recovered and between January 1961 and October 1961, when approximately 2,030 fine ounces were obtained. It can be seen from these figures that 7,510 fine ounces of gold or approximately 40% of the total output between 1st July 1958 and 31st March 1963, were recovered from

about 6 rich pockets. Flates 38 and 39 show an example of the manner of occurrence of the "bonanza" gold. The position of the "bonanza" pockets in the ore shoot can be seen in the east-west section of the mine (Fig. 6).

(b) Rock Types

The Fig-tree sediments in the mine consist of narrow alternating bands of shale, banded ironstone, cherts, graywackes and other metamorphic alteration products. To the north of the mine and well exposed in the main quarry are sheared talcose schists probably belonging to the Jamestown Complex, although the possibility of them being altered basic rocks of the Onverwacht Series cannot be discounted. The schists grade laterally and northwards into other basic rocks consisting of either talc-carbonate schist, talc-chlorite-carbonate schist, quartz-chlorite-carbonate schist or tremolite-actinolite schist. The talcose schists in the Main Quarry show evidence of gentle buckling. North of the quarry in the basic rocks are remnant quartzitic horizons and quartz-tourmaline veins. The quartzitic horizons are essentially quartz-sericite schists with local cherty zones. They have been trenched to the northeast of the Lily Mine. Stratigraphically these rocks probably belong to the Onverwacht Series. More talc schist occurs immediately north of the Rose's Fortune Mine near Louw's Creek. Quartz-chlorite and quartz-talc schists are found south of the occurrence in the quarry and are located conformably between Fig-tree shales and graywackes while in the Rose's Fortune, talcose schists also occur conformably with the shales south of the Main Reef.

Koen (1947) suggested that certain talc-chlorite schists found in the Fig-tree rocks were probably ascribable to intensely sheared and altered graywackes. The schists in the Lily Mine can probably be related to Koen's findings. The mine may be situated on rocks similar to the Zwarte Kopie Zone in the Sheba Valley (see earlier).

The proposed Lily Fault occurs within the Main Reef Zone south of the talc schists. The fault zone is marked by a sheared, brecciated and oxidized zone approximately 30 feet wide in places. In this zone are cherty bands and masses of vein quartz in disturbed argillaceous and ferruginous sediments. South of the Main Reef the formation becomes more regular and is apparently little disturbed. The rocks consist of alternating light and dark shales and graywackes folded and sheared extensively. The shear zones parallel to the strike of the formations are ferruginized by altered iron oxides (limonite and goethite), and are frequently replaced by hydrothermal vein quartz containing some gold mineralization. The veins vary in

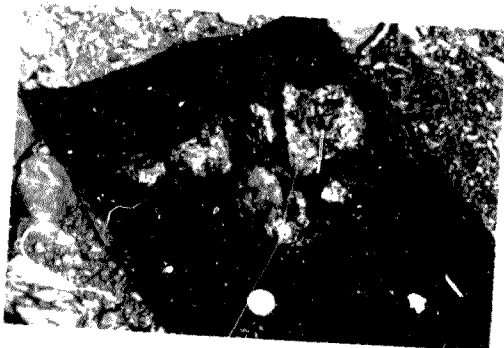


Plate 38. View of rock in water (approximately
15 to 20 ft. deep). Level with water.



Plate 39. View of rock in water (approximately
15 to 20 ft. deep). Level with water.

thickness from a few millimeters up to several feet across, pinching and swelling along the entire length of the shear planes. The quartz is of more than one age and occurs in several colours and textures. Some is massive and vitreous ranging from clear to white, gray and blue-gray, while other veins are more chert-like with a fine granular texture. Well rock alteration on either side of the veins is almost non-existent indicating that the hydrothermal solutions were low to moderate in temperature. No dimensions of the reefs can be given as they pinch and swell erratically and sometimes disappear completely only to reappear again within a matter of a few feet.

(c) Metamorphism

Practically all the rocks in the mine have undergone metamorphic alteration. Those rocks least affected are the shales and graywackes exposed at the entrance to the Lily Adit and the Mill Adit. These graywackes are fine-grained and in thin section consist of poorly sorted quartz fragments together with variable amounts of feldspar (orthoclase and albite), sericite, chlorite and mica. The rock shows little or no evidence of bedding and adjacent shales often contain tourmaline indicating that there has probably been some alteration.

Thin section study of shales taken at random throughout the whole mine indicated a wide variety of different metamorphic and other minerals. Generally present was quartz, sericite, chlorite, and the iron ores (hematite, magnetite, limonite and goethite). Much of the original sediment has been altered to a biotite-amphibole hornfels. The amphiboles are orientated with their long axes roughly parallel to the foliation. They are invariably tremolite or actinolite in composition but locally grunerite may be developed where there is an abundance of iron. Grunerite crystals were seen radiating from a narrow magnetite-hematite band intercalated between cherty quartz (see Plate 59).

Spotted shales and siltstones are commonly developed indicating a fairly low grade of metamorphism (Harker, 1956). Reconstitution of original material in the sediments has formed new minerals, one of the most prominent being biotite. The biotite is generally responsible for the spotted nature of the shales. There is often some sign of the original bedding in the rock and the aggregates or 'nests' of mica are aligned parallel to the foliation but within the individual 'nests' the flakes display decussate structures. The remaining phyllosilicates 'flow' around each of the little mica clusters. The original sediments must have contained just sufficient aluminous material and alkalis to form the micas as there is very little andalusite present. Where andalusite does occur the crystals are feebly developed and can easily

be overlooked due to their diffuse nature and the presence within them of abundant unexpelled inclusions.

Locally developed garnet-bearing hornfels occur with a marked crystal alignment. The garnets are small and have poeciloblastic or "sieve" structure. Magnetite and garnet porphyroblasts have pushed aside the matrix of sericite, mica and quartz into a microscopic boudinage pattern.

The presence of tourmaline in practically all the rocks examined suggests that boron pneumatolysis probably was related to the metamorphism or the hydrothermal solutions. There was a noticeably marked concentration of tourmaline in disturbed shear and breccia zones as well as in other less dense or compact permeable zones, e.g. in the 70 Ft. Level stopes.

Silicification, chertification and mylonitization is noticeable where slickensiding and shearing is evident. In the shear zones the shales have been formed into a shiny black compact brittle clay. Mylonitization is evident in some of the crush zones and successive stages in the formation of a true mylonite can be distinguished in thin sections.

Some quartz veins are sporadically cherty and the microcrystalline texture is often only interrupted by radiating tremolite clusters (see Plate 42). A few diamond drill holes yielded core from these rock on 2 Level. This core was partly brecciated and partly undisturbed. It was well mineralized especially in the Main Reef and in the brecciated shear area. The rocks when examined in thin section are composed of quartz, chlorite, carbonate, tremolite and magnetite. The tremolite forms in zones around the cherty quartz and is accompanied by calcite. At times the impression obtained is that the tremolite needles are growing from the calcite particles. Carbonates are fairly abundant in the rocks of the breccia zone and shear planes are often replaced or filled by well formed rhombic calcite veins. In the unaltered zones carbonate veins were not seen but are probably masked by alteration of adjacent material.

Near the 2200 Adit there are developed some chalcidonic and opaline patches in a rock not unlike pumice in appearance and texture. The chalcidony fills cracks, joint planes and other cavities and has formed by the leaching of silica from the surrounding altered shales which have become extremely porous.

In thin section the leached rock consists of a dark vitreous substance and the material newly formed in cavities consists of quartz and fibrous aggregates of chalcodony (see Plate 58), with prominent spherulitic crosses. In addition there is a little opal with the chalcodony.

The metamorphic assemblages in the mine are of a low grade type of regional metamorphism falling into the category of the greenschist facies. Metamorphism was probably the result of diastrophism coupled with effects of heat provided by the intrusive rocks in the area. van Heden (1941) considered that the Jamestown Complex was partly the cause of the metamorphism of the rocks into which it intruded as well as being responsible for the silicification or chertification of many of the successions.

It was mentioned earlier that the talc schists north of the Lily Fault may have originally been basic intrusives of the Jamestown Complex. The conformable succession has been used as a factor against the intrusive origin of these rocks but the possibility should not be discounted that the basic rocks intruded into or along the fault plane.

Locally, the metamorphic minerals found are indicative of slightly higher grades of metamorphism but hydrothermal solutions responsible for the introduction of the mineralization may have contributed towards their formation. The nearest granite body is about two and a half miles to the north and the mine may be regarded as falling into the peripheral outer zone of contact metamorphism produced by the granite intrusion.

C. STRUCTURE OF THE MINE

During the course of mapping the mine a detailed structural examination was undertaken and the items listed below were investigated fully.

- (a) Folds.
- (b) Fractures.
- (c) Bedding.
- (d) Schistosity and cleavage.
- (e) Brecciation and rock fracturing.
- (f) Boudinage.
- (g) Joints.
- (h) Possible relationships between the structures in the mine.

(a) Folds

Throughout the mine the folds are of a tight isoclinal nature. The folding is all of a similar type, i.e. the distances between the bedding units parallel to the axial plane remain constant while the distances measured at right angles to the same units are variable. The fold axes are mostly steeply dipping but show a spread in the axial plane. A pole diagram plot indicates a concentration of poles that dip both north and south and also a great circle with vertical fold axes. (See Fig. 9). The folds plunge steeply to the east and also show a spread of poles possibly indicating either differential compression of the folds and a variation of movement in the 'a' direction, or superimposed folding. The folds are characterized by large amplitudes and narrow wave lengths (see Plates 40 and 42). Ramsay (1962b) developed a method to estimate the amount of flattening in folds based entirely on the thickness of a competent bed measured at any point in the fold, and the observed angle of inclination between the bedding and the axial plane of the fold. The photographs (Plates 40 and 42) were enlarged several times and used in an attempt to determine the approximate amount of flattening in the Fig-tree succession. The values obtained were plotted on a graph (see Fig. 18) and the resultant curves gave the percentages of flattening to be 37% and 46% respectively. An average value, 41.5%, represents the flattening additional to the original 36% shortening of the flexure fold. The entire succession has therefore undergone an approximate shortening and flattening combined of about 62.56 per cent. This figure was derived as follows:- The original unit length was assumed to have been 100. Shortening of 36% reduces the unit length to 64. Subsequently, the additional flattening of 41.5% reduces the unit length 64 to 26.56. The combined shortening and flattening is therefore $36 + 26.56$ or 62.56 per cent. Around the folds and sometimes included in them are quartz veins of both primary and secondary origin. The primary quartz veins are generally disturbed by tension joints in the crests of the folds. Where no quartz accompanies the folding the altered or metamorphosed shales exhibit tension cracks that have subsequently been filled by secondary weathered material. The entire formation is clearly folded but due to the great amplitude of individual folds it was only locally, and by chance, that crosscuts exposed the hinge zones. An attempt was made to correlate the fold zones on the various levels but this was not found possible due to the complete absence of any favourable marker horizons.

Folding expresses itself in a milder form where it gently buckles the sediments. The axial planes of these folds are roughly horizontal and coincide with the vertical stress field of the fourth phase of deformation mentioned earlier under Structural geology. The



Plate 40.

Light band of calcite
in dark grey shale.

Scale 1/2 in.



Plate 41: Recumbent folds in banded calcite of the
fig tree series. Scale 1/2 in.



(Plate 42) Tight isoclinal
folds showing narrow wave
lengths and large
amplitudes. Fig-tree shales
2 Level crosscut
Lily Mine.

(Fig 18) Graph showing the
percentage flattening of
the Fig-tree succession
in the Lily Mine.

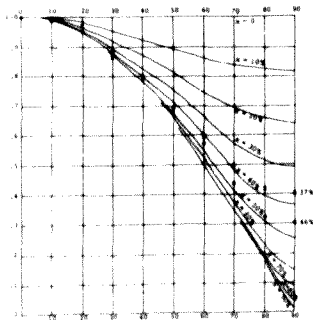


Fig. 18. Graph showing the relationship between the percentage flattening of the Fig-tree succession and distance from the fold axis. The heavy dots represent data from the fold shown in plate 42. The curves, data from the fold shown in plate 40. Graph after Sawyer, 1922.

buckling or warping also accounts for many of the irregularities in bedding dip and strike (see Fig. 10).

(b) Fractures

Two sets of fractures exist in the mine.

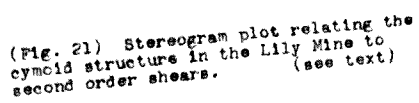
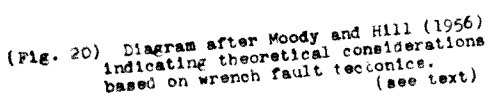
- (i) Vertical fracture system.
- (ii) Cross-cutting flat fracture system.

(1) Vertical Fracture System

From the point of view of reef development the most important fractures in the mine are those that occur parallel to the strike of the formations. Invariably these planes have been filled or replaced by hydrothermally introduced quartz. The veins pinch and swell and constitute the ore zones for they are frequently accompanied by gold mineralization. Most of the development undertaken during the mine's history has been confined to following these vertical or near vertical, roughly east-west trending quartz filled fractures. The Main Reef Zone has quartz vein development along the entire length and is one of the most consistent reefs. Another strongly developed economic quartz filled fracture has been stoped from 1 Level upwards to the 70 Ft Level and then on to the surface.

The central portion of the mine has the most intense network of quartz filled fractures and altogether 4 reefs were mined. The reefs, however, merge with depth and apparently disappear below 2 level. Characteristic of certain of the vertical fractures formed by strike-slip or shear movement is a shape that may be conveniently termed a cymoid loop or curve (McKinstry, 1955). "This is a reverse curve in which a line or fracture swerves from its course and then swings back again resuming a direction parallel to its former course, but not in line with it. The two branches enclose a lens of wall rock shaped like a cam - a cymoid lens".

The fracture pattern in the mine behaves very similarly to the description given above and forms in the third dimension a pipe-like ore shoot. The structure described is complex and involves the splitting up of veins into several smaller veins, which may either continue along the same general course, or may curve abruptly away from it, forming what is called "horse-tailing". The ore shoot plunges to the east at approximately 50 degrees (see accompanying diagram of fracture pattern of the main workings, Fig. 19).



the same plane as that contained by the bedding and master linear. H is also represented as the P intermediate stress.

The poles A of the cymoid structure and E and E' of the vertical shear, lie on a great circle or 'ac' plane. The point I or maximum compressive force is located on this plane, making an angle of 30 degrees to the shear plane FG. The minimum stress J lies 90 degrees away from P max. also on the 'ac' plane.

The pole to the cymoid loop (point A) and E' the pole to the master shear plane (FG) make an angle with one another of 38 degrees. This is 7 degrees less than the theoretical value of 45 degrees as calculated for the angle (DCF) between the second order shear and the main fault in figure 20.

The cymoid loop is thought to be a second order structure resultant on reorientated stresses adjacent to the main east-west strike-slip shear.

Further lateral movement along the shear plane in the mine could explain the flattening out of the structure into a cymoid loop, the angle of which has a lesser value than that based on theoretical calculation.

The geometry of the veins has no doubt played some part in the localization of the "bonanza" gold pockets. Unfortunately most of these "strikes" were made before this study was undertaken and the exact nature of the veins could only be roughly estimated. In this connection the miner, Mr. R. Thomson, was of help in explaining the mode of occurrence of the deposit. The majority of the gold was encountered together with the quartz in the plunging veins and it appears that slight changes in the attitude of the veins produced favourable structural loci for gold concentration. The largest and richest of the pockets was encountered in the breccia shoot just above 1 Level (see Fig. 6). Approximately 3,000 ounces were extracted from an area roughly 25' x 12' x 2'. Above this several smaller finds of less than 100 ounces were made. Where the shoot entered the quarry another $\pm$ 200 ounce pocket was discovered. Below 1 Level scattered visible gold was encountered and a few feet below 1 Level $\pm$ 900 ounce "bonanza" was mined from an area roughly 15' x 8' x 1'. A few feet away another $\pm$ 100 ounces were located. Continuing down the shoot between 1 Level and 2 Level the rock becomes progressively fresher. On 2 Level there is no oxidized rock in the shoot.

Between 1 Level and 2 Level a pocket of $\pm$ 800 ounces in the form of a tabular core was extracted from an area of 12' x 1' x 1'. In the sulphide zone just above 2 Level a small pocket ($\pm$ 250 ounces) was found together with smaller isolated patches of visible gold. The gold extended to about 10 feet below 2 Level and from this point down no further visible gold was encountered. The shoot apparently pinched out below 2 Level.

The zone of brecciation was roughly delimited by drilling on 2 Level and in places down the shoot it was found confined to a narrow section between the undisturbed regular sedimentary layers. The rock in the lower levels is well mineralized as a result of the replacement and ease of entry of solutions into the disturbed zones.

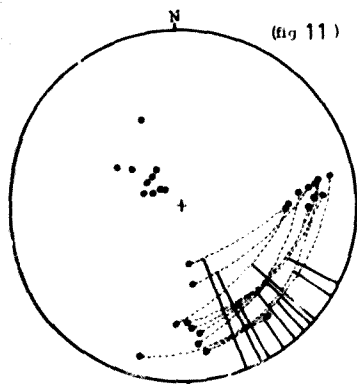
Drilling also indicated that the Main Reef Zone on 2 Level was brecciated and replaced by sulphide mineralization. Narrow fracture planes in the winzes and in the main crosscut on 2 Level are filled by calcite veins.

From the investigation it would appear that the shearing was post folding in age and that subsequently, quartz veins were introduced into the fracture and shear planes.

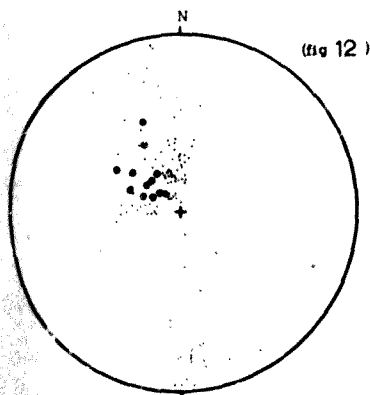
(11) Cross-cutting Flat Fracture System

Difficulty was often experienced in obtaining a three dimensional plane of fractures that crosscut the sedimentary layers. Apparent strike and dip measurements of the fractures had therefore to be taken by measuring two vectors in the fracture plane. From these readings true dip and strike values were derived using a Wulff's stereographic net (see Fig. 11). Poles of the true dips and strikes lie in the northwest quadrant of the diagram indicating a flattish south-easterly dip and a north-east - southwest strike for the majority of the fractures. The plot of apparent poles to fractures lie around the true dip poles defining a V-shaped pattern (see Fig. 12). As the true dip poles bisect the V it may safely be assumed that the overall dip direction of a vast majority of the fractures is to the southeast at angles varying between 20 and 40 degrees.

These fractures post-date the folding as they were seen cutting through some hinge zones of isoclinal folds. Movement along the fractures is generally small or absent and the planes themselves, in the oxidized zones, are commonly mud filled or contain a dark brown resinous to greasy quartz. Frequently biotite flakes in the fracture planes are well developed and probably were produced by the heat of



- Point representing direction and inclination of apparent fracture lineation
- Poles to true (derived) dips of fracture planes
- Direction of dip of fracture planes (derived)



- Poles to apparent dip planes of fractures
- Poles to true dips of fracture planes

hydrothermal solutions and shearing.

A few other fractures occur that dip more steeply but these appear to be connected with the vertical fracture system and are quartz filled. The flat-lying fractures do not extend far through the sediments but "jump" strata and straighten out, re-appearing again lower down.

In certain sections of the Lily and Rose's Fortune Mines the flat fractures were found to have a direct bearing on the occurrence of pay zones. In general values were found to be greater at the intersection of a vertical "reef fracture" and a flat fracture.

The increased values were especially noticeable in the Rose's Fortune Mine. Instead of always stoping the vertical reefs, development was often solely confined to the intersection of a cross-cutting flat fracture with the vertical ore zone of the Main Reef. No records of the actual differences in values between these zones of intersection and the vertical stopes were ever kept by the mine. Owing to the limited scale of operations, selective mining methods had to be employed to maintain economic payability.

(c) Bedding

Bedding dips and strikes were recorded throughout the mine and diagrams were plotted. These combined gave the overall pattern of the bedding attitude in the mine (see Fig. 10). The bedding was normally very steeply dipping but a few readings did not coincide with the general concentration of poles. The poles define a good great circle. The bedding plots also show the isoclinal nature of the folds and the uniform orientation of the limbs. The variations may be ascribed to slump features mainly on the hillside and the buckling and folding of the sediments in the mine itself. The trend of the formations coincides with the east-west regional trend and although the regional dip is approximately 75 degrees to the south the variations are largely found in the Fig-tree Series.

(d) Schistosity and Cleavage

Schistosity is a form of cleavage and is used to describe parallel fabric patterns in rocks. The term schistosity is applied to those megascopically conspicuous parallel fabrics of metamorphic origin that have imparted to the rocks a definite fissility (Turner and Verhoogen, 1950).

Needles of amphibole are commonly found with their long or 'c' axes roughly parallel to the bedding planes and in this respect may be regarded as a planar fabric. The crystals as seen in the 'ac' plane are well aligned and the prismatic crystal outline is clearly defined together with some basal sections. The 'ab' plane, however, displays randomly orientated prismatic sections alone.

The talcose schist to the north of the mine has a schistosity developed parallel to the regional trend of the formations. It is also developed parallel to the axial planes of the folds in the Fig-tree shales to the south. The fabric was thus probably developed by compression normal to the plane of schistosity.

Cleavage in the sedimentary layers is apparently absent but is possibly in the bedding plane. There is thin section evidence of minute bedding plane slip (see Plate 14).

(a) Brecciation and Rock Fracturing

Brecciation is largely confined to the Main Reef Zone and the plunging ore shoot but does occur in a milder form in practically all the fracture zones and where folding of brittle components has caused the hinge zones to shatter. The brecciation consists of fragmentary shales and slates in a matrix of fine red clay, quartz particles and irregular quartz veins. The breccia in the sulphide zone is replaced by quartz, sulphides and carbonate material while that in the oxide zone is largely decomposed to rubble.

Mylonitization and slickensiding occurs in crush zones and original mineral constituents are pulverized and have been ground into a compact black brittle clay. This clay appears to have acted as a lubricant in many fracture planes.

The massive shale and graywacke units are more conducive to rock fracturing than the narrowly bedded layers due probably to their decreased ability to adjust themselves to the stress by bedding plane movement.

(f) Boudinage

Boudinaged quartz veins are frequently seen intercalated with the sediments and were probably formed during folding. The attitude of the lineations thus produced were found to be unsystematic

but the fact that they exist does indicate that some of the quartz veins found in the mine were present in the sedimentary successions prior to deformation.

(g) Joints

Jointing and rock fracturing seem to be closely related in that both phenomena are largely restricted to the massive sedimentary units. The tight isoclinal folding displays shear jointing in the steep flanks of the fold where lateral shortening has been extensive and tension jointing in the crests of the folds. The joints in both the hinge and flanks of the folds dip towards the fold axes.

(h) Possible Relationship Between the Structures in the Mine

As has been shown, the formation of thinly bedded Fig-tree rocks in the mine is intensely folded, shortened and flattened. This deformation was produced largely during the formation of the major synclines of the Barberton Mountain Land, i.e. coincident with Ramsay's (1963) 1st period of folding. Synchronous with the fold development was the faulting on a regional scale. The Lily Fault - a zone of shearing at the contact between Fig-tree and underlying Onverwacht rocks provided the channel of entry for the hydrothermal mineralizing solutions.

The initial deformation produced tight isoclinal folds that plunge steeply to the east. The variable spread of the plunges can be ascribed either to differential movement in the 'a' direction of folding produced by variable compressive stresses, or the superimposition of folds on an already deformed or folded succession. There is however, no conclusive evidence in the area or in adjacent areas of an earlier period of folding, but the Geological Survey (Visser, 1956) as shown previously, do mention the occurrence of contorted pebbles of Fig-tree rocks in the younger Moodies conglomerates. This does indicate the possibility of some previous uneven surfaces.

The major or vertical fracture system was developed after the folding and corresponds to Ramsay's 2nd phase events in the Barberton Area. The crosscutting flat fractures post date the first folds as well and are thought to be second order shears associated with the main vertical fracture system. The crosscutting fractures are generally poorly developed, often displaying little or no movement in the fracture plane.

The shearing or strike-slip movement produced coincident cleavage-bedding relationships in the Fig-tree sediments of the mine. The intrusion of the Nelspruit Granites was found by Ramsay (1963) to have taken place during the 2nd phase of deformation.

If the hydrothermal solutions from the intrusion are assumed to have been the source of the gold found throughout the District then the mineralization of the Lily Mine must have taken place subsequent to the fracture development, i.e. either late during the 2nd phase or during the 3rd phase.

D. MINERALOGY

(a) Introduction

In recent years the opening up of the mine has led to further development of existing sections in addition to work elsewhere in the mine. Due to the limited scale of operations it was always found necessary to cease mining in the sulphide or fresh rock. However, in certain instances the abundance of pyrrhotite and quartz warranted investigation and analysis and development continued for a while. In this regard the development of the two winzes below 2 Level was undertaken following indications of folding, brecciation and sulphide mineralization. The possibility existed that visible gold lodes might be encountered in this zone. The winzes represented projections of the ore shoot in higher levels but little success was encountered with increasing depth and work was curtailed.

A few drill holes were designed to probe the sulphide breccia pipe and the Main Reef to the north. The core, in several instances greatly brecciated, contained many suitable mineralized sections for study. Sulphide mineral specimens were also obtained from the westerly portion of the 70 Ft. Level and 1 Level. The remaining samples studied were obtained from oxidized or partially oxidized sections of the mine. The specimens containing visible gold were collected from all levels. Altogether 45 polished sections were examined.

In addition to the Lily Mine ore, a few samples were obtained from the Mexican prospect near Eureka Siding and from the nickel deposit on Bon Accord Stock Farm north of Sheba Siding. The mineralogy associated with these deposits is briefly described.

The ore suite from the Lily Mine contained ten minerals in addition to the gangue or country rock. The most abundant sulphide noted was found to be pyrrhotite and this was followed in relative abundance by arsenopyrite, magnetite, pyrite, melnikovite-pyrite, chalcopyrite, hematite, limonite, goethite and gold. Apart from the pyrrhotite and arsenopyrite the remaining minerals were only present in small amounts.

The gangue varied considerably throughout the mine but generally consisted of quartz, carbonates, amphiboles, tourmaline, quartz-chlorite-carbonate material and the clay minerals. The quartz occurred in several forms and varied from white to blue-gray and was either frosted or translucent. Massive bodies of cherty quartz were encountered in all sections of the mine.

(b) Ore Minerals

(i) Extraction Test

Before discussing the mineralogy of the mine it is of interest to note the results of an extraction test done on two samples of Lily Mine ore in order to gain some idea of the various elements present for metallurgical purposes. The tests were carried out in March, 1935, by the Consulting Metallurgist for Eastern Transvaal Consolidated Mines Limited. Ref. No. Q.562.

2 bags each 2,000 lbs. weight.

- | | |
|-----------------|----------------|
| 1. Sulphide ore | 2.16 dwts. Au. |
| 2. Oxide ore | 4.02 dwts. Au. |

Analysis of the oxidized ore gave the weight percentages of the constituents. From these results the cation percentages have been calculated (see Table III).

TABLE III

Constituents	Weight %	Cation %
Silica and Insoluble salts (SiO_2)	71.5	85.00
Al_2O_3	1.6	1.12
MnO	0.1	0.10
Fe_2O_3 (ferric)	18.2	8.05
FeO (ferrous)	2.2	2.35
Pyrite (FeS_2)	0.5	0.30
Arsenic As.	0.2	0.20
Antimony Sb.	0.1	0.58
Bismuth Bi.	trace	-
Copper	trace	-
Nickel	trace	-
Cobalt	trace	-
Zinc	0.1	0.01
CaCO_3	0.8	0.68
MgCO_3	0.3	1.78
Carbon C	4.4	-
Water and soluble alkali ($\text{H}_2\text{O} - 3.5$)		
TOTAL	100.0	100.17

From the cation percentages it can be seen that silica makes up about 85.0% but this does not entirely go to make up quartz. Some of it combines with the alumina and magnesia to form amphibole. The ore minerals constitute a mere 1.08 per cent and the balance is made up of manganese oxide, magnetite and hematite (10.90%).

(11) Pyrrhotite

Practically all the sulphide ore examined contained pyrrhotite. In places it occurred as massive replacement bodies, especially in the brecciated ores on and below 2 Level. Veins, irregular masses and particles with allotropic form are encountered throughout the mine. It is often concentrated in bands and is interstitial to laths and radiating needles of tremolite-actinolite amphibole. Pyrrhotite was seen either replacing or being replaced by most of the ore and gangue minerals in the suite. (see Plates 47, 49, 52). Good textural relationships with quartz and amphiboles were seen (see Plates 43, 44

[illegible]

44. The following table shows the number of people who attended the 2000 Summer Olympics in Sydney, Australia, by country. The data is presented in a table with 2 columns: Country and Number of People. The countries listed are Australia, Brazil, Canada, China, France, Germany, Greece, Italy, Japan, Korea, Mexico, Russia, South Africa, Spain, Sweden, Switzerland, Taiwan, Thailand, United States, and Zimbabwe. The number of people for each country is listed in the second column.



(Plate 45) Photomicrograph showing pyrrhotite
(white, replacing quartz).
2 Level Lily - 100 (reflected light x75)



Plate 46. Photomicrograph showing radiating clusters
of pyrrhotite in a matrix of fine quartz. 100x
Lily - 100 (reflected light x75)

and 45) and gangue material was invariably found to precede the sulphides leaving relict crystals or aggregates trapped within the pyrrhotite. The replacement of chert often produced a mosaic with the spaces between the individual quartz grains providing the most favourable replacing environment.

Euhedral crystals and fragments of arsenopyrite are replaced or entirely surrounded by the later pyrrhotite. Etching of the corners of arsenopyrite is common but replacement is seldom complete (see Plate 47). The pyrrhotite itself, lacks external crystal form and is usually moulded within its surroundings, or is pseudomorphous after earlier ore minerals and gangue.

Frequently seen associated with the pyrrhotite aggregates are small irregular particles of exsolved chalcocopyrite. Pentlandite, a common associate of pyrrhotite is entirely absent from the Lily ore suite. In only rare instances was pyrite seen together with the pyrrhotite. The former mineral generally occurred as "islands" surrounded and replaced by the latter. In the partially altered zones on 1 Level and in some sections on 2 Level both pyrite and melnikovite-pyrite replace pyrrhotite.

(iii) X-Ray Diffractometer Investigation of Lily Mine Pyrrhotite

The possibility of applying the $d(102)$ value/composition relation to natural pyrrhotite was investigated by Arnold and Reichen (1962). The X-Ray method was found to be a convenient and reasonably accurate method of measuring the metal content of hexagonal natural pyrrhotites. Arnold and Reichen (1962) found experimentally that the determinative curve could be applied to natural pyrrhotite containing less than a total of about 0.6 per cent by weight of nickel, cobalt and copper in solid solution, over a composition range 46.5 to 47.7 atomic per cent iron. The uncertainty in the compositions determined chemically and by the X-Ray method is taken to be 0.1 atomic per cent iron.

Pyrrhotite was thus used to obtain a rough estimate of the temperature of formation of the ores. Polished section study indicated that the pyrrhotite was generally free of impurities; some having minor amounts of chalcocopyrite in what appeared to be a mutual association of the two minerals. Three specimens were chosen that were free of visual impurities.

The pyrrhotite was crushed and prepared for spectroscopic analysis. This was carried out to get an indication of elements other than iron and sulphur that might be present. The examination indicated that cobalt, nickel and copper were present in trace amounts only. The percentages were therefore, too small to affect the lattice parameters as determined by Arnold and Reichen (1962).

Specimens were also prepared for X-Ray analysis and equal proportions of analytically pure potassium chloride were mixed with the sulphide for use as an internal standard. Measurements were made with a Phillips X-Ray Diffractometer equipped with an automatic chart recorder.

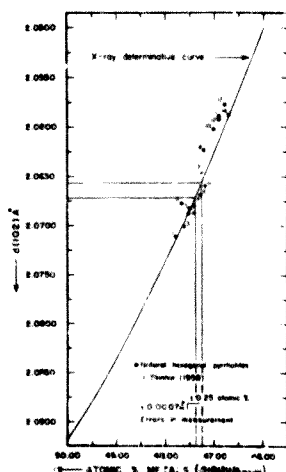
Each (102) reflection was measured relative to the (220) and (222) reflections of the analytically pure KCl, located at $56.6 \text{ } 2\theta$ for $K\alpha_1$ and $64.42 \text{ } 2\theta$ for $K\alpha_2$.

Scanning and chart speeds were $\frac{1}{2}$ degree per minute and 2 inches per degree. Peak positions were measured to $\pm 0.1^\circ 2\theta$. Standard deviations of the mean 2θ (102) values and the corresponding $d(102)$ values were $\pm 0.0004 \text{ } \text{\AA}$ respectively.

The $d(102)$ values obtained were 2.0658, 2.0658 and 2.0672. These values correspond to values of 47.3, 47.3 and 47.4 atomic per cent iron, (see Fig. 22), and these in turn give approximate temperatures of 240°C and 320°C. (see Fig. 23).

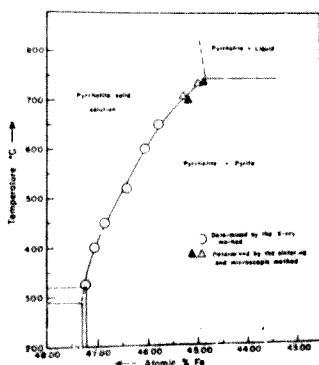
This takes into account a pressure of about 10 bars. The effect of pressure usually results in the raising of the temperature of formation but this seldom exceeds 10 to 20°C, even at pressures of several thousand atmospheres. (Edwards, 1954).

The temperature of formation of the pyrrhotite mineralization at the Lily Mine would, therefore, be of the order of 330°C. Arsenopyrite was found to be earlier than the pyrrhotite on examination of numerous polished sections and therefore, it was assumed that a rough maximum temperature not exceeding 350° - 400°C existed at the time of the deposition of ore solutions. This is in accordance to the scale and intensity of rock alteration in the mine. Needles and slender crystals of tremolite or actinolite together with muscovite, biotite, chlorite and magnetite occur with and in the neighbourhood of the sulphides. These are all low grade, low temperature metamorphic minerals, (Harker, 1956), and would fall into Migglé's epizone also indicative of low temperature and low hydrostatic pressures. (Turner and Verhoogen, 1960).



(Fig 22) Graph after Arnold 1962 showing the experimentally derived X-ray determinative curve for natural hexagonal pyrrhotites. Superimposed in red are d(102)A values for pyrrhotites from the Lily Mine and the derived atomic %Fe (metals).

(Fig 23) Graph after Clark (1960) showing the experimentally derived curve of Atomic %Fe against Temperature in °C for naturally occurring pyrrhotites. Superimposed in red on the graph are Atomic %Fe values of pyrrhotite from the Lily Mine together with the temperatures of formation thus derived.



It was mentioned by de Villiers (1957) that he considered the Lilly occurrence to be a high temperature deposit formed at great depth. Although giving no actual temperature value it is considered by the writer that the experimental work done on the pyrrhotites, together with mineralogical and petrological evidence, would tend to favour a lower temperature than that implied by de Villiers.

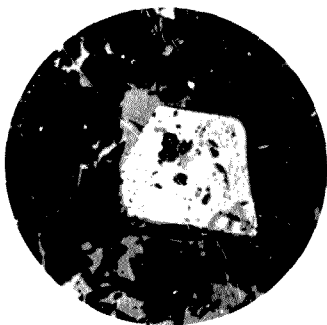
(iv) Arsenopyrite

Arsenopyrite commonly accompanies pyrrhotite but never in any great amount. The greatest concentration of this mineral was found in a raise off the westerly drive along the Main Reef Zone of 1 Level. The ore has been partly altered yet is deleterious to the extraction process at the mill. The arsenopyrite like the pyrrhotite may form bands in the ore but this is rare. The mineral occurs essentially as individual or aggregate groups of idiomorphic crystals. Movement within the ore body during ore deposition has often resulted in this mineral being fractured. There is evidence of intense shearing along bedding planes with subsequent deposition of later minerals. The fractures in the sulphide grains may have been channels used by ore solutions for the localization of the gold.

The arsenopyrite is easily distinguished from other sulphides by its colour, anisotropism and hardness. Surfaces usually take on a good polish and the relief of the mineral also aids in its identification. It is fairly resistant to replacement but pyrrhotite was seen corroding corners of certain crystals and penetrating fractures (see Plate 47). In addition idiomorphic arsenopyrite grains entirely surrounded by massive pyrrhotite were noted.

Pyrite replaces arsenopyrite in ore obtained from the semi-oxidized portion of 2 Level and the textures can still be discerned in spite of the alteration. Colour differences between the pyrite and arsenopyrite were not clearly apparent but the strong anisotropism of the latter mineral was distinctive.

A specimen obtained from a mineralized quartz vein below 2 Level showed a pinkish variety of arsenopyrite replaced by veinlets of gold. The mineral was tested chemically and indicated the presence of both arsenic and antimony. X-Ray patterns however, confirmed it as being arsenopyrite. There is a probability that this mineral represents a member of an isomorphous series containing variable amounts of arsenic and antimony. The antimony bearing member of this series is the mineral gudmundite (FeS₁₅).



(Plate 47) Idiomorphic arsenopyrite crystal
being replaced around the edges by pyrrhotite.
2 level 114 line (reflected light x100)



(Plate 48) colliform banding of arsenopyrite.
2 level 114 line.
(reflected light x100)

The crystal's unusual colouration may also partly be due to the presence of highly reflective gold (see Plate 51). The gold veins and isolated specks within the gudmundite probably indicate a contemporaneous origin for part of the gold ore.

A few samples were obtained from dumps at the old workings of the Mexican prospect near Eureka Siding. These consisted essentially of weathered arsenopyrite crystals having good idiomorphic shapes. The gangue consisted of radiating laths of tremolite with fine microcrystalline and isolated coarse grains of quartz.

(v) Chalcopyrite

This mineral is nearly always associated with pyrrhotite but never occurs in great amounts. Its presence was suspected prior to microscopic examination due to the minute displays of iridescence seen on tarnished ores. Laths of irregular, intimate intergrowths of the chalcopyrite with pyrrhotite seen under the microscope show mutual boundary relationships and suggests contemporaneous formation of the two minerals. Chalcopyrite was also seen together with pyrite and melnikovite-pyrite where it occurred replacing the latter mineral.

(vi) Pyrite

In only a few instances was pyrite noted in the ores. Its colour and hardness made it distinctive except where it occurred with some of the arsenopyrite. Specimens from 2 Level contained pyrite together with pyrrhotite and melnikovite-pyrite. The mineral occurred as aggregates or individual crystals of allotriomorphic to idiomorphic form. Pyrrhotite being later in the paragenetic sequence of ore deposition surrounded the pyrite "islands" but generally the relationship between the two minerals was not clear.

The pyrite often exhibited replacement textures and a few idiomorphic crystals were suggestive of pseudomorphism after arsenopyrite. The evidence for this was limited but the textures were identical to similar ores wherein melnikovite-pyrite and pyrite replace arsenopyrite to a limited extent.

(vii) Melnikovite-pyrite (gel of FeS and FeS_2) $\pm$ As.

This mineral is not very common and is mostly found in zones of partial alteration. It is closely associated with pyrite, arseno-

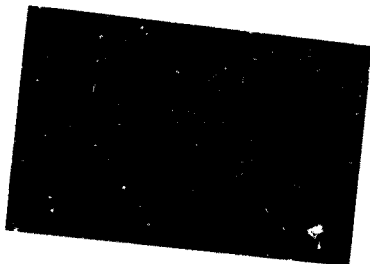


Plate 49. Thin section
of a mineral specimen.

reflects light.

Plate 50. Thin section
of a mineral specimen.
Limonite coating
above the vein.

reflects light.

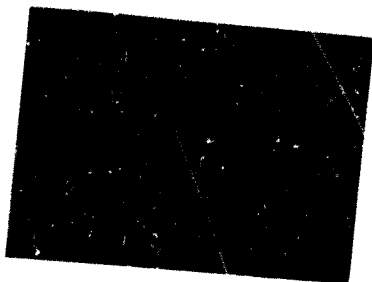
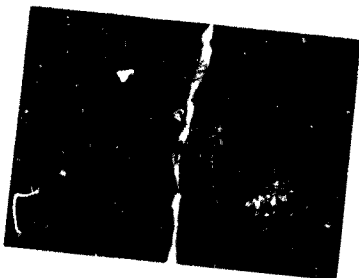


Plate 51. Thin section
of a mineral specimen.
Limonite coating
above the vein.

reflects light.

Author Anhaeusser C R (Carl Robert)

Name of thesis The Geology Of The Lily Syncline And Portion Of The Eureka Syncline Between Sheba Siding And Louw's Creek Station, Barberton Mountain Land. 1963

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