A STUDY OF THE WORKING HOLDINGS OF THE CHIEF GOLD PRODUCER

OF THE BARBERTON DISTRICT, EASTERN TRANSVAAL.

A Thesis presented for the Degree of Doctor of Science in
the University of the Witwatersrand, Johannesburg, by

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Scope of this Study

The mining district of the Barberton area is of considerable extent, and presents a bewildering variety of problems in ore deposition. In addition to this, the rocks of the area, being of extreme age, and having suffered intense alteration, constitute in themselves matter for a great deal of investigation, offering what is probably the finest material of its kind in South Africa. The structure of the district is a great deal more complex than is generally realised, and it is unfortunate that up to the present, little or no detailed geological work has been done or recorded, even on the mines. It is therefore obvious that a detailed study of the type of this dissertation must necessarily be confined in its scope.

It is proposed to deal with the two areas constituting what is now known as the New Consort Gold Mines, Ltd. This Company operates the New Consort Gold Mines in the Jamestown rocks at Noordkaap, and the New Consort Gold Mines -- Sheba Section in the Moodies rocks at Sheba. This latter is actually a separate mine, but is operated for ease of control as a section of the New Consort Mines.

As the ore deposits in the mines under consideration are complex, this report will deal with the rocks in their immediate vicinity only, with the ores themselves, and with their mode of occurrence. The general structural relations of the rocks in the district have been recently examined by members of the Union Government Geological Survey, but their findings have not yet been published. As this study is concerned with the mining properties only, it is not possible to enter into a detailed discussion of the tectonics of the district, since insufficient field information of the necessary detailed nature is available. Where some aspect of the regional tectonics is exposed by the mine structures, this will be mentioned.

It is unfortunate that more detailed work has not been done on the gold deposits in the Primitive Rocks of the Union, as such work would be of undoubted value in connection with studies of the Rand ores.

Historical Notes on the District

The Barberton Goldfield, though not by any means the earliest in the Union, has been worked since the year 1884, when the Natal colonist, Graham Barber, discovered gold-bearing quartz veins in the hills near the present site of Barberton.

Until 1886, the diggers worked mainly in the hills of the Moodies area, but in that year Edwin Bray discovered the original Sheba Mine in the highly dissected area now known as the Sheba Hills. A tremendous rush followed this discovery, and mining activities spread all over the district.

Many "mines" sprang into being, and of course the majority did not survive the test of time. The increase in the price of gold has led to the reopening of many of these abandoned workings. Recent work has shown that lack of gold or discontinuity of the deposits has not by any means always been the reason for their abandonment.

Later, the ore body constituting the Sheba Section of the present New Consort Gold Mines was discovered in the Zwartkopje Valley. See Plate III.

The main Consort ore bodies were not discovered until some time later, when work started on the "Shires" reef, and some very rich ore was mined.

The discoveries of gold in the Barberton District gave a tremendous fillip to prospecting throughout the country, and thus led finally to the discovery and exploitation of the Rand deposits.

The following are some interesting figures of gold output from the Barberton District in the early days:-

1885-6	17,269 oz.
1887	25,817 "
1888	49,491 "
1889	35,002 "
1890	33,710 "
1891	66,598 "
1892	69,761 "
1893	70,282 "

Since the Barberton Goldfields had such a great influence on the early expansion and opening up of the Union, it is regrettable that more knowledge of the early history of the field is not available. Occasionally, fragments of fact and legend emerge to show that the Barberton District had an intensely interesting early history.

One of the reasons for the abandonment of many of the mines in the district has undoubtedly been the fact that the ore below the water table has almost invariably been refractory. This is due in part to the presence of refractory minerals, and in part to the fact that the gold frequently occurs in minute particles enclosed in gangue material.

SECTION I

New Consort Gold Mines, Noordkaap

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Historical

The early history of what now constitutes the New Consort Mine is somewhat obscure. It apparently consisted of several mines: the Consort Mine, the Entente Mine, the Prince Consort and the Maid of de Kaap Mines.

Not long before 1929 it consisted of two properties, the Maid of de Kaap and the Consort Mines, the latter including the Prince Consort and Entente Mines.

In April, 1929, the two properties were combined, forming the New Consort Gold Mines, Ltd.

Prior to April, 1929, the Consort mill had crushed 224,140 tons at an average grade of 17.1 dwts./ton, to recover 122,600 fine ounces of gold. The old Maid of de Kaap mill had then crushed 147,660 tons at an average grade of 21.38 dwts./ton, to recover 132,640 ounces of fine gold.

Since April, 1929, the two mines have been combined as the New Consort Gold Mines, Ltd. From April, 1929, to June, 1933, the combined mill crushed 304,146 tons at an average grade of 10.9 dwts./ton, to yield 133,665 ounces of fine gold. From that time to the end of June, 1941, 768,157 tons were crushed at an average grade of

5.5 dwts./ton, to yield 170,225 ounces of fine gold.

Thus from the commencement of operations to June, 1941, the mines now constituting the New Consort Gold Mines, Ltd. have crushed a little under 1,500,000 tons of ore, and produced 560,129 ounces of fine gold.

As the ore from the New Consort Gold Mine contains an appreciable proportion of arsenopyrite and gold in the form of minute particles, it has always been more or less refractory. For some time concentrates were roasted, and arsenious oxide was produced and marketed. Now, however, the sands only are roasted, and no by-product is produced.

Situation

The New Concort Mine is situated at Noordkaap, some 11 miles due north of Barberton. It is on the southern slopes of the foothills of the Crocodile Poort granite ranges, in the northern mountainous border of the De Kaap Valley.

The elevation of the mine offices is 2250' above mean sea level, so that the mine is not in what is strictly defined as the Low Veld, which includes the country from sea level to an elevation of 2000'.

Physiography and Drainage

As has been stated above, the New Consort Gold Mine is situated on the southern slopes of the foothills of the Crocodile Poort Ranges. Between these foothills and the De Kaap Valley runs the Noordkaap River, which is just within the southern boundary of the property (see Plates I & II.) This river runs, in general, due east, and the drainage of the mine property is therefore southwards, for the most part, towards the river. The area is highly dissected, and the creeks are generally dry for the greater part of the year.

Plate I shows the location of Noordkaap and the New Consort Mine, and the Geological Plan, Plate II, shows the drainage system. The Photograph on Plate XXVII is a view of the New Consort Mine from the rising ground between the Noordkaap River Valley and the De Kaap Valley. This indicates the nature of the terrain.

Climate

In summer, shade temperatures of over 100° F. are frequently recorded, and the fairly heavy rainfall takes the form mainly of severe storms experienced during the months from September to April. The winter climate is ideal, being seldom too hot for comfort, and freezing temperatures are rarely experienced. Malaria fever and horse sickness are fairly common during summer months, particularly in the lower lying ground.

General Geology of the Area

The New Consort Gold Mine is situated in the belt of Jamestown rocks which stretches from the Drakensberg near Kaapsche Hoop east-southeastwards towards the Sheba Hills. Plate I shows clearly how this belt is bounded both north and south by the "Old Granite". That to the north of the Jamestown rocks is known as the Crocodile Poort or Nelspruit Granite, and that to the south as the De Kaap Valley Granite. Plate I is a copy of the map issued by the Geological Survey with Memoir No. 9, with some alterations in the Sheba Hills area, where mapping of the mine property has proved this to be necessary.

The Jamestown rocks in this area consist of basic schists, serpentines, and allied rocks with some quartzites and thin bands of conglomerates. In the vicinity of the Consort Mine there is also a stratum of black shaly rocks, altered to hornfels, etc., which are stated by Hall[1] to belong to the Moodies Series.

The Jamestown rocks show evidence of intense thermal and dynamic metamorphism, which must be due to the intrusion of the "Older Granites"[2] which Hall[3] shows are intrusive into both Jamestown and Moodies

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[1] Geological Survey Memoir No. 9, p. 114.
[2] This term is preferable to "Old Granite".
[3] Op. cit., p. 111.

rocks of the Swaziland System.

It has been pointed out[1] that the Nelspruit and De Kaap Valley Granites show several different characteristics, and Hall concludes, therefore, that "special conditions of consolidation existed over the De Kaap Valley area." This is true, but it will be shown later that the De Kaap Valley Granite is younger than the Nelspruit type, probably considerably younger.

The rocks around the New Consort Mine have thus been first intruded, folded and altered by the Nelspruit Granite. Later came the intrusion of the De Kaap Valley boss, the effects of which were superimposed upon those of the Nelspruit Granite. It is largely this latter intrusion which has given rise to the complex structural conditions observed in the workings of the New Consort Gold Mine. It is also the latter intrusion which has been responsible, for the most part, for the mineralisation of the district.

Within the mine boundaries, the rocks exposed are of two main types, viz.:- a lower basic schistose series and an upper altered shaly series, now largely recrystallised to a jointed hornfels. The contact zone between these is the horizon upon which the

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[1]Geological Survey Memoir No. 9, p. 114, p. 136.

mining is done.

The general structure appears to be that of a syncline pitching gently eastwards. The mine workings are situated on the northern slopes of the Noordkaap River valley, as can be seen by reference to Plate II. The general dip in this area is southwards and south-eastwards. The area south of the river has not yet been thoroughly examined, but it is known that there are outcrops of what would seem to be the south limb of an overturned syncline, on the northern limb of which the workings are situated. This structure, together with the intricate minor folding exposed in the workings, is probably due to the intrusion of the De Kaap Valley Granite, with the older Nelspruit Granite mass acting as the stationary jaw of the "vice".

Hall[1] considers the footwall basic schists to be intensely metamorphosed basic rocks intrusive into the Moodies sediments, to which latter group he assigns the hanging wall "shales" of the Consort area. There is no evidence in the Consort Mine workings to support this idea. The contact between the rocks is often sharp, but it is equally frequently gradational, showing alternating laminations of the two types as thin as ¼". There are lenses of the shaly rock within the schists, and here again both sharp and gradational contacts may

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[1] Op. cit., p. 107, p. 114.

be observed. The laminations and other internal structures of the rock in these lenses are parallel to the general stratification. Nowhere have apophyses or veinlets of the lower basic rocks been found penetrating the hanging wall, and nowhere have any phenomena been observed which might be interpreted as indicating an intrusive relationship. Negative evidence of this kind is not necessarily conclusive, but it must be borne in mind that the mine workings have thoroughly exposed the contact over a considerable area. Little work has been done in the hanging wall rocks, but that which has been done also discloses nothing which could be interpreted as indicating an intrusive relationship.

Within the footwall schists, apart from the lenses of hornfelsic rocks of a type similar in every way to the hanging wall rocks above mentioned, there occur beds of quartzitic and conglomeratic rocks. These relations tend rather to indicate that the schists are altered basic lava flows, alternating with sedimentary types. It is also somewhat doubtful if the hanging wall rock belongs to the Moodies Series. It seems far more likely that it is one of the sedimentary beds of the Jamestown Series. The area between the New Consort Mines and Eureka should be subjected to further careful examination in order to check Hall's statement[1] to the effect that a portion of the "Lily Line" branches off and finally passes as a long tongue of highly altered sedimentary rocks into the Jamestown Series at Eureka.

Thus it would seem that Hall's tabulation on page 107 of Memoir No. 9 of the Geological Survey requires some revision.

Metamorphic effects in the rocks exposed on the mine property appear to bear little or no relation to the De Kaap Valley Granite, and are probably mainly due to the older Nelspruit Granite intrusion. (Cf. Geological Survey Memoir No. 9, p. 164.) The schistosity often shown in the footwall rocks is parallel to the contact of the De Kaap Valley Granite when this intrusive is within a mile, and where the structure is not complicated by the presence of other rocks.

Near the western and southwestern boundaries of the property is a prominent exposure of quartzites and conglomerates, apparently conformable with the schists which they underlie. South of the Noordkaap River these strike southeast, but northwards the strike becomes north-south with an easterly dip, and finally apparently turns again towards a north-east strike.

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[1]Op. cit., p. 114, p. 203.

This indicates that the general structure is that of an easterly pitching syncline.

At most places the contact zone between the schists and the overlying hornfels shows signs of considerable hydrothermal alteration. This usually takes the form of intense silicification and replacement of the hornfels at and near the contact. The process sometimes extends as much as 100 feet into the hanging wall hornfels, though the average is some 4 to 8 feet. This process results in an intensely hard, brown to black or greenish cherty band, locally known as the Consort "bar". This silicification is related to the mineralisation of the contact zone.

The footwall rocks are locally known as "schist" and the hanging wall as "shale".

"Dykes" of pegmatitic material are commonly found cutting both "schists" and "shales". Some of these constitute a parallel system, and others of similar type occupy faults of considerably later age than the mineralisation. These pegmatites are therefore considerably younger than the period of mineralisation. The intrusions would seem to have been formed by processes of partially replacement and partially intrusive nature. They are not always strictly dykes, as isolated lenses of pegmatitic material are sometimes found aligned in a common plane.

The Footwall Rocks

Underlying the "shales", these rocks are very persistent and of considerable thickness, up to 8,000 feet.

In general, the upper part of the footwall rocks is more or less without intercalations of other rocks, with the exception of thin bands and lenses of silicified "shales", of which further mention will be made subsequently. Towards the lower part of the footwall rocks, however, bands, lenses and layers of quartzitic and conglomeratic rocks of varying thickness become gradually more abundant until north of the northernmost mine boundary line these become the predominating rock. These quartzitic and conglomeratic rocks, however, occur to a negligible extent within the mine property.

Towards the hanging wall contact, however, thin bands of "shales" become fairly common. Most of these bands are lenticular, and most are only a few inches to a few feet in thickness. One has been exposed with a thickness of over 100 feet, but the average is much smaller. In some places these bands become so frequent near the "contact" that the latter becomes more or less gradational. The average thickness of these intercalated bands of hornfelsic material decreases as the main "shale" body is approached, thus still further accentuating the gradational nature of the contact.

Such conditions sometimes make contact development, such as is practised on the New Consort Mine, somewhat difficult. These bands and lenses within the footwall rocks have almost all been so silicified as to adopt the characteristics of the Consort "bar" material. In some places, where the contact zone is in the form of an alternating series of "schist" and "shale" laminations from $\frac{1}{8}$" to $\frac{3}{8}$" in thickness, the whole mass has been silicified, resulting in a rather handsome rock with alternating green and chocolate coloured cherty bands. This rock is known as "Bastard Bar". The bands and lenses of altered "shale" in the schists conform to the general structure.

For the most part, however, the "schist-shale" contact is well defined and sharp, usually with a thin layer of talcose matter on the contact plane.

The "schist" is mostly a crystalline rock, and is massive, without foliation. Such portions are generally better named amphibolites. In places, however, where intense local shear has been active, the rock has become talcose and thoroughly foliated. See Plate XXIX, Fig. 4.

The commonest facies found among the footwall rocks is one which is fairly hard and tough, is a greenish gray colour, and is as a general rule without schistosity. This rock almost invariably shows more or less parallel undulating planes which are coated with a thin layer of talc. These may be ½" to 1½" apart, and are evidently planes along which some movement has taken place at the stage just past that at which flowage relieves the strain.

This rock consists almost entirely of a felted mass of greenish needles which are easily distinguishable in the hand specimen. They range from ½mm. to 4mm. in length, and frequently occur in radiating groups. Sometimes they are arranged in all azimuths in parallel planes, producing a fairly well marked schistosity. This, however, is not usual.

In thin section this rock is seen to consist mainly of felted masses of radiating tremolite needles. These are generally colourless, but occasionally show very faint pleochroism, from colourless to a pale green. The tremolite needles are generally bent, and show signs of considerable strain. Sometimes there is some colourless isotropic material interstitial to the tremolite, and this usually shows distinct signs of crystallisation to form antigorite, which is also seen here and there replacing tremolite. Frequently an appreciable proportion of andesine felspar occurs with the tremolite. This has well developed cleavage, but, as is usual in such rocks, the polysynthetic twinning is poorly developed. Magnetite as irregular grains, sometimes within the tremolite cleavages, and as minute octahedra, is universal, as is also rutile, usually in the form of minute needles.

Rarely the rock has an almost doleritic texture, with andesine laths, and well developed crystals of augite. This latter mineral exhibits several types of twinning, of which the commonest is simple twinning on (100), as illustrated in Figure 1. Common is another type which is sometimes simple and sometimes lamellar and polysynthetic on (110).

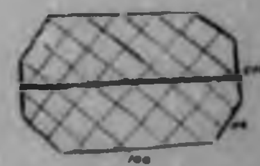

Figure 1.

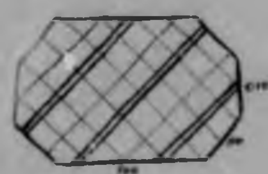

Figure 2.

Figure 2 is a typical basal section of such a crystal. A third type is a compound twin, with planes parallel to the cleavages, giving a crystal of the type illustrated in Figure 3. Lamellar twinning on (001) has not been observed.

Figure 3.

When this augite is observed, it is seen frequently to be in course of replacement by tremolite needles. Occasionally the augite and the tremolite can be seen in course of replacement by green chlorite and small amounts of brown pleochroic biotite.

Very commonly the tremolite can be seen to be in course of alteration to talc. This is particularly well shown when the rock shows many shear surfaces.

Some specimens of the rock consist mainly of green, strongly pleochroic hornblende, with green chlorite.

Fairly common in sections of the footwall rocks is zoisite, and occasionally patches rich in epidote are found. The occurrence of this epidote is interesting, in that it has occasionally given rise to confusion in prospecting operations where valuations are made by means of a pan. When patches rich in epidote are sampled in the oxidised material exposed in surface prospecting, panning sometimes yields a "tail" of what at a cursory glance appears to be gold. Closer inspection reveals it to be epidote. For some unknown reason this material has come to be known locally as "bismuth".

In places where the footwall rocks have been subjected to intense shear, i.e. near faults or folds, the rock sometimes becomes a highly fissile and schistose mass of talc, and is very soft and "soapy". Where the shear has not been so intense, sections show tremolite being replaced by fine masses of talc.[1] In the extreme case the rock is so soft and fissile as to be self-supporting only over a very narrow span. A section of this rock cut parallel to the schistosity is mainly

[1] Geological Survey Memoir No. 9, p. 202.

more or less isotropic, with needle-shaped crystals of talc here and there. A section cut at right angles to the schistosity reveals that the rock consists of bands of coarse and fine talc. The fine bands consist of minute plates of extreme thinness, lying in parallel planes, while the coarse bands consist of talc crystals up to ½mm. diameter, lying in all directions, but mainly at right angles to the planes of schistosity. These crystals or plates are those which give rise to the needle-like forms seen in the sections cut parallel to the schistosity. The talc plates show the usual cleavage, low relief and high birefringence. It is biaxial negative with an axial angle of about 30°. This rock is a talc schist.

Very rarely, near the southwestern boundary of the property, specimens are found which show the rock to have been subject to pneumatolysis and high temperature hydrothermal agencies. Here the rock consists of a mass of matted crystals of green, highly pleochroic chlorite, some of which show the characteristic blue interference colours of penninite. Large idiomorphic crystals of tourmaline are abundant. These have an average diameter of 3mm. and a length of up to 2cm. They occur individually, very rarely as radiating groups. The tourmaline is in section strongly pleochroic from light brown to dark greenish brown, the inner parts of the crystals being much lighter in colour than the outer. Along the boundaries of the tourmaline crystals is a selvedge of brown biotite. The tourmaline has the properties of the iron-rich schorlite variety. A specimen of this rock is shown in Fig. 2 on Plate XXIX.

Near the western boundary of the property another specimen has been found showing evidence of pneumatolysis. This rock is a strikingly handsome salmon pink with irregular yellowish patches, and contains abundant crystals of green tourmaline. These occur individually, very rarely as radiating groups. On the weathered surface the tourmaline crystals stand out well, producing a rock of striking appearance. Examination of the fresh surface of the rock shows the matrix to be exceedingly fine-grained and occasionally finely banded. This banding does sometimes persist in the form of lighter and darker bands directly across the tourmaline crystals, which average 4mm. in diameter and 2cm. in length, though crystals up to 1cm. x 2cm. have been seen. Figure 4 shows more or less the appearance of the banded areas. In thin section the tourmaline is colourless and not pleochroic. It is uniaxial negative, and its refractive

Figure 4 (Natural size)

indices and birefringence fall within the dravite range. The matrix consists mainly of finely fibro-lamellar antigorite, with fairly abundant tiny crystals of a mineral which is pleochroic from light mauve to colourless. This mineral occurs only in tiny grains, and is clouded with sericite; its optical properties have therefore not been determined. It occurs in bands and strings in the matrix, and these persist through the tourmaline crystals, constituting a beautiful example of helicitic structure. Refer to Plate XXIX, Fig. 1.

All sections of the footwall rocks show the presence of more or less antigorite developing at the expense of the tremolite. In some areas this process has developed to the point of complete replacement of the tremolite, resulting in a massive serpentine rock. The tremolite rock passes gradually over to the serpentine. The distribution of these areas of replacement is irregular, and the causes of this process are not apparent.[1] As there is no sharp contact between the tremolite rock (amphibolite) and the serpentine, specimens showing all stages of replacement are readily found, and some of the intermediate stages show the presence of muscovite and sericite, both of which

[1]Geological Survey Memoir No. 9, p. 202.

frequently persist into the serpentine. In the massive serpentine rocks occasional very thin cross-fibre veinlets of chrysotile are found, but these are very poorly developed within the boundaries of the mine property. At one point in the mine workings a specimen of chrysotile asbestos with fibres 9 inches long was found, but this was in the form of an isolated "pocket". The serpentine as typically developed is a soft green rock, consisting of a fibrolamellar mass of antigorite, containing a few small irregular grains and octahedral crystals of magnetite. These sometimes show palimpsest pyroxene forms, and sometimes those of olivine, though this mineral itself has not been found in the sections. Fairly commonly found in the serpentine rock are small grains of muscovite mica. Very rarely in the serpentine bastite pseudomorphs after pyroxene can be seen.

Another type sometimes noticed among the footwall rocks is one consisting of tremolite needles, with sericite and muscovite mica. This rock is more or less schistose, and lying in all directions in the planes of schistosity are tourmaline crystals averaging 2mm. x 2cm. This tourmaline is black in the hand specimen, and in thin section is strongly pleochroic from light brown to dark green-brown. This rock is illustrated in Fig. 3, Plate XXIX.

The footwall rocks as a general rule weather fairly deeply, and in the valley of the Noordkaap River outcrops are not plentiful. Here there is a fairly deep soil which is generally quite heavily impregnated with white to brown magnesite, which also occurs as veinlets in cracks. On the hill slopes these rocks, though weathered, form many boulders and loose rocks lying embedded in the soil.

The "footwall rocks" or "schists" of the New Consort Mine thus consist of a number of allied types which may be listed as follows:-

Amphibolites
Tremolite-andesine rocks or plagioclase amphibolites
Chlorite schists
Serpentine and antigorite schists
Chlorite-tourmaline schists
Talc schists
Altered doleritic rocks?
Tremolite-talc schists, etc.

Thin sections of all these rocks show evidence of intense stress.

Tremolite schists or amphibolites of the type found on the mine are generally formed in one of two ways: by metamorphism of siliceous magnesian limestones, or of pyroxenites, etc. The original rock is not always determinable. The occurrence of zoisite here and there argues the presence of a lime felspar in the criginal rock. These tremolite rocks, therefore, are probably derived from a system of rocks of pyroxenitic and noritic types.

Chlorite in metamorphic rocks of the kind found in this area is usually the result of mineralogical changes in pyroxenitic and amphibolitic rocks.

It is evident that olivine was not common in the original rocks, on account of the almost complete absence of carbonates except where later mineralising solutions have been active. Most of the serpentine has been formed either directly from pyroxenes or from the tremolite. Owing to the fact that the direct formation of antigorite from a pyroxenitic or peridotitic rock requires a considerable access of water, which is not available under the circumstances obtaining, talc is formed as well, so that in various stages antigorite-talc rocks and tremolite-antigorite-talc rocks result. Most of the talc in the form of the talc schists found is essentially a stress mineral developing under more localised conditions, as is shown by the parallel arrangement of the flakes.

The occasional occurrence of a rock consisting of a green hornblende with andesine felspar shows that at least parts of the original rock were of basic composition. This hornblende-andesine combination constitutes the rock classed as a plagioclase-amphibolite, which is characteristic of the higher grades of metamorphism of basic rocks.

The epidote is generally developed at an earlier stage from the same rocks, in the form of albite-epidote-chlorite schists which later develop into albite-epidote-hornblende schists. In the more advanced stages the hornblende develops further with the result that the felspar becomes more basic, passing to andesine. The epidote, however, usually survives, at least in part, in the most advanced stages of metamorphism.

It is to be expected that folding, crushing and heating of rock masses such as takes place during intrusion and concomitant metamorphism would facilitate the penetration of gases and liquids into the intruded rocks. This is commonly enough recognised, in so far as mineralisation is concerned. It is, however, common in metamorphic aureoles to find evidences of pneumatolytic effects some distance from any exposed intrusive. Such are the development, for example, in places on the New Consort property, of rocks consisting almost entirely of chlorite and tourmaline. The development of such rocks argues the introduction of considerable quantities of fluorine and boron, which can best be brought about by pneumatolysis.[1]

In view of the somewhat varied nature of the rocks locally known as "schists", further reference to

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[1]Harker, A., Metamorphism, p. 118, p. 209.

these rocks will be made under the name "footwall rocks."

The photomicrographs on Plate XXXI are of thin sections of the footwall rocks.

The Hanging Wall Rocks.

These rocks are locally called "shales", but as this term is far from correct, it will no longer be used.

The rock constituting the hanging wall of the Consort Reef is that which is shown on the map accompanying Geological Survey Memoir No. 9, and on Plate I of this volume, as branching off from the Moodies Series near Eureka into the underlying Jamestown rocks. Mention of this point has already been made. On the Map and Plate I, these rocks are shown as vaguely ending at a point west of the New Consort Mine. Reference to Plate II will show that this does not truly represent the position. It can be seen that these rocks rest upon the "footwall rocks" with a highly folded contact, which actually constitutes the Consort Reef. The attitude of this contact shows that the general structure is that of an overturned syncline, the trough of which is occupied by the hanging wall rocks.

The formation of this syncline in the rocks previously intruded, tilted and metamorphosed by the Nelspruit Granite is evidently due to the intrusion of the nearby De Kaap Valley stock. The intrusion of this mass has produced compression effects in the New Consort area and in the Sheba Hills. In the New Consort area, this has mainly taken the form of uptilting, overturning and fracturing of the rocks to the north of the boss. The axis of this overturning is within the New Consort Gold Mines property, and strikes a little south of east, pitching eastwards.

Details of the structures on the mine property will be dealt with in a subsequent chapter.

The hanging wall rocks are of relatively very homogeneous character; that is, no intercalations of different types have been exposed within the mine boundaries though slight changes within the rock mass itself are common enough. These rocks as generally exposed are fine grained, hard, dark gray to brown-black crystalline. They frequently show distinct stratiform features which are of inestimable assistance in interpreting structures. Much of the "stratification" seen in these rocks is actually foliation due to oriented biotite flakes. Irregular jointing is sometimes so well developed as to make the attitude of the rocks difficult to determine. In many cases no sign of jointing or stratification remains, and the rock is massive and crystalline.

These rocks weather fairly deeply and near the surface such features as jointing, "stratification" and foliation become accentuated, sometimes to such an extent as to give the rocks a distinctly shaly appearance. The massive varieties sometimes, on outcrops, show peculiar surface features due to their mineralogical composition.

The hanging wall rocks generally consist mainly of completely recrystallised quartz, sometimes crowded with minute liquid inclusions and sometimes clear, but always showing definite signs of intense strain. The quartz occurs both as irregular shaped grains and as lenticles, which are aligned in the foliation planes. There is always a considerable amount of brown, highly pleochroic biotite, varying from some 15% to 70% by volume, and averaging about 25%. The biotite, when in low proportion relative to the quartz, is interstitial to the latter, and vice versa. Always, however, the biotite has a very well defined parallel arrangement. This produces a definite schistosity which is usually parallel to the general stratification. Small amounts of pale green pleochroic chloritic mica are almost always present, generally as an alteration product of the biotite. Magnetite as dust and as minute octahedra is always present, as are zircons. These latter are generally enclosed in the biotite, in which they have given rise to very well developed pleochroic haloes. The zircons show signs of waterworn edges.

Almost universally found in these rocks is an amphibole occurring as acicular crystals, often in radiating groups, and arranged without regard to the parallelism of the quartz lenticles and biotite flakes; that is, giving a distinct decussate structure. These needles can often be seen in hand specimen. This mineral is colourless in thin section, and shows the usual amphibole cleavages and cross-sections. The crystals are almost always simple twins, with (010) as the composition plane. Occasionally this twinning is lamellar. There is a distinct (001) parting, and extinction Z C is about 22°. It has high birefringence, and is biaxial positive with an axial angle of some 65°. This mineral is probably pargasite.

Common, though not universal, is andalusite, occurring as irregular and bladed crystals, usually much corroded, without regard to the general parallel arrangement. Grains of this mineral invariably contain inclusions of quartz, muscovite, etc., but no crystals of the chiastolite type have been observed.

Cordierite is very common, occurring as fairly large crystals, containing inclusions of quartz and biotite, and altering to biotite.

Occasionally tiny crystals of andesine can be discerned.

In the massive and less distinctly foliated occurrences the weathered surface sometimes shows peculiar irregular ridges up to ⅛" high and ¼" wide. These are generally due to the cordierite. (See Plate XXX, Fig. 1.) Sometimes in the strongly foliated types, andalusite crystals give rise to peculiar weathered surfaces.

This rock can generally be best described as a quartz-biotite schist, while the massive varieties, without distinct parallel arrangement of the biotite, may be classed as hornfels.

In some areas the rock is crowded with pink, completely isotropic dodecahedra of almandine-spessartite garnet, usually with many minute inclusions in the centre, and of average diameter about 1mm. These frequently occur as metacrysts in strings parallel to the general foliation, which is usually sharply bent in their immediate vicinity. This type would best be called a quartz-biotite-garnet schist.

Somewhat rarely found in the hanging wall rocks are small crystals of pleochroic brownish green schorlite tourmaline.

Sericite is very frequently found, generally in association with cordierite, and bladed crystals of chloritoid are generally though sparsely distributed.

At one place, namely in the Witkoppies section of the mine, the hanging wall rock contains a great number of white bodies, giving the rock a maculose texture. These average 4mm. diameter and are up to 1mm. in thickness. They always lie with the large dimensions in the general foliation planes. The matrix between the spots is the usual foliated aggregate of quartz and biotite, with tourmaline, magnetite, zircon, pargasite, garnets, etc. The white spots are aggregates of very fine grained quartz, cordierite, zoisite, apatite, sericite and muscovite, usually with a little magnetite dust, and completely without biotite. The muscovite in these spots is generally aligned parallel to the general schistosity. The boundaries of the spots grade off into the matrix over a distance of about ½mm. Fig. 2 on Plate XXX illustrates a specimen of this rock.

In some places the hanging wall rocks contain considerable amounts of diopside, and where this is the case the rock locally consists almost entirely of quartz and diopside.

In hard specimen, the rock is sometimes well banded, with alternating medium and fine grained laminations, averaging about ¼" in thickness. The boundaries between these are sharp. The coarser grained bands consist of the usual quartz-biotite schist, while the finer grained parts consist mainly of very fine biotite with a little interstitial quartz. In these fine laminations the biotite flakes show parallel arrangement in the plane of general lamination and foliation.

Weber[1] has described the typical "shale" as a felspathic mica schist, sometimes containing microcline and microperthite. This opinion was probably based upon information gained from badly selected specimens, as felspars are in general very rare in these rocks, except in the close proximity of pegmatitic intrusions.

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[1]Private Report.

W.E.N. Kelly[1] refers to the hanging wall rock as a "hard, dark, compact chert or silicified hornstone, which in places gives way to a dark chiastolite slate." Almost all of the sections of these rocks show a very well defined schistosity due to the quartz-biotite alignment; nowhere has a cherty texture been seen, and the name "chiastolite slate" is clearly a misnomer, probably adopted from the Geological Survey Memoir No. 9[2]. Such andalusite as is present is not of the chiastolite form. This name probably originated due to the appearance of some hand specimens of the rock, in which needles of pargasite amphibole are very frequently visible. It is interesting in this connection to examine the "microphotographs" on Plate LV in the Geological Survey Memoir No. 9, in comparison with Fig. 1 on Plate XXXII of this work.

Hall refers[3] to sillimanite in a description of these rocks. This mineral has not been observed in any of a large number of sections cut from specimens taken on the New Consort Mine property. He refers also in the same place to "biotite hornfelses" and "chiastolite slates" as occurring in this area. Neither of these

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[1] Memoir of Geological, Mining and Metallurgical Conditions at New Consort Gold Mines, Ltd., dated at Noordkaap, 24 March, 1930. P. 1

[2] Pp. 155, 203, 245.

[3] Op. cit., p. 159.

names is well chosen. On page 163 of the same work he states that there is much chiastolite in long needles or lozenge-shaped cross-sections in these rocks. Reference to this point has already been made above.

The study of metamorphism, giving rise to rocks of the type exemplified by these, usually requires postulation of conditions concerning which knowledge is very scanty. Certain conclusions concerning the nature of the original rock and the processes by which it has reached its present condition can, however, be drawn without too much risk.

In general, for reconstitution, recrystallisation and alteration of rock masses, solution must necessarily enter into the processes, if only as a local, temporary and transitional phase. It must, in fact, be local and temporary, otherwise the identity of the rock would be completely destroyed at an early stage, and this is the case only at an advanced grade of metamorphism. Solution and recrystallisation processes must be of very restricted nature, as diffusion is limited to a relatively small scale. Thus rocks originally of fine grain and with narrow laminations are more easily and rapidly reconstituted than those with coarse grain and broad bands. The composition of the original rock may vary from point to point and this property, owing to the narrow limits of diffusion, frequently persists right through to advanced stages of metamorphism. Thus the hanging wall rocks show bands of the usual quartz-biotite schist, with occasional bands of very fine grained, mainly biotitic material. These latter probably were laminations of more sericitic and chloritic nature, with little quartz.

It must also be borne in mind that schistosity due to alignment of tabular or columnar minerals in metamorphosed rocks need not necessarily be due mainly to growth of crystals with their maximum dimensions at right angles to the direction of an imposed stress. Such schistosity can easily be developed by the application of heat only, without stress taking any really significant part.

Thus in a rock with a marked fissility, the production of tabular minerals such as biotite at an early stage of metamorphism produces a schistose structure which is parallel to the original bedding, due to the tendency of the crystals to grow along bedding and lamination planes as being the line of least resistance. Sometimes as metamorphism advances schistosity is a new property with direction imposed by external forces. Thus the New Consort hanging wall rocks generally have a definite schistosity, due to alignment of biotite flakes and quartz lenticles, parallel to the original stratification. Here the schistose structure follows the folding and has not been induced directly by external forces. When the structure of the original rock has been more or less obliterated and fissility is reduced, due to the formation of more or less interlocking crystals, decussate structure results from the growth of such columnar minerals as the pargasite amphibole at higher grades of metamorphism in a definite expedient to minimise the production of internal shearing stresses.

Argillaceous sediments, unless they have a calcareous content, are generally poor in lime and richer in magnesia. This is due to the fact that in the course of dest[illegible] of the primary rocks a considerable proportion [illegible]he lime is carried away in solution as carbonate, while the magnesia is not so easily removed, and therefore passes into the argillaceous product. Limonite also passes into the argillaceous product in similar manner. Most of the constituents of argillaceous rocks result from processes of weathering including chemical actions taking place at low temperatures and over relatively long periods, and as they exist in a fine state of division, are generally in equilibrium. Metamorphism thus takes the form of gradual readjustment to rising temperature, and usually to increasing pressure.

The limonite is at an early stage reduced to fine grains and octahedra of magnetite, which for the most part persist into the higher grades of metamorphism with little further change. One of the first new products formed is biotite, from the chlorite, sericite, iron ores and rutile of the sediment. The formation of this biotite in alignment at lower pressures or at an early stage has already been mentioned. If kaolin is present, some of the minerals formed at an early stage are aluminium silicates, such as andalusite, cordierite, or both. Andalusite is formed by the decomposition of kaolin, but cordierite requires also the presence of chlorite. From the first these minerals, unlike the biotite, take large crystal forms enclosing portions of undigested rock material. Whereas cordierite with its feeble force of crystallisation generally fails to acquire crystal form and eject its inclusions, andalusite at higher grades of metamorphism takes on definite crystal forms and ejects or segregates its inclusions to become the chiastolite type. Metamorphism in this area cannot, therefore, have advanced to any very high grade. This gives some support to the idea that the metamorphism is in the main due to the Nelspruit Granite mass.

The quarts content of the original rock generally recrystalliises at a stage soon after the formation of the biotite and becomes a mass of more or less interlocking crystals with the biotite flakes, etc., interstitial to them.

Muscovite is common in such rocks only near granite or pegmatite contacts where more or less pneumatolytic agencies have been operative.

As the metamorphism progresses beyond the stage above outlined, the nature of its course depends upon the ratio of alumina to magnesia; that is, on the proportion of sericitic to chloritic constituents in the original rock. It is mainly from these that new minerals are formed in the early stages, and the later course of the reactions depends upon which is exhausted first. In this connection it must be remembered that diffusion and solution take place within a restricted range, and therefore localised areas will show slightly differing series of reactions. If chlorite is abundant the andalusite begins to change to cordierite, and the formation of new ferromagnesian silicates commences. These usually are a rhombic pyroxene and almandine-pyrope garnet. If lime is present an amphibole forms in place of the rhombic pyroxene. Within the restricted limits of diffusion, pyroxene and andalusite are mutually exclusive, and pyroxene does not form until the andalusite has gone. In the case under consideration there has evidently been enough lime present for the formation of the pargasite amphibole. It is here of interest to remark that the andalusite crystals in these rocks are almost always corroded to such an extent that a crystal outline is rare. The amphibole has been formed at the stage where the rock has lost its original fissility, and thus occurs in all directions, giving the decussate structure.

Garnet and cordierite are also mutually exclusive, and the former is usually formed only where the occurrence of cordierite is separated, at least beyond the limits of diffusion. Thus cordierite is most abundantly found in the more massive facies of the rock in which garnets are very rare, and the garnets are found mainly in the schistose types in which cordierite is sparse.

Garnet is definitely a stress mineral and it is, under the circumstances obtaining in the area under consideration, usually a mixed almandine-spessart type. The formation of garnet is generally facilitated by the presence of more or less manganese, in this case sufficient to yield a garnet of mixed alman[illegible]e-spessartite variety. The fact that garnet is usually a stress mineral is interesting in that it indicates that as the grade of metamorphism rose, the effect of stress increased; hence the bending and folding of the biotite-quartz schistose folia about the garnet crystals.

The occasional presence of diopside in a rock consisting almost entirely of quartz and diopside indicates that spots in the original rock had a considerable lime-magnesia content.

The process of solution and recrystallisation is gradual throughout the rock mass and passes through definite stages only at given points. It is apparently active at localised points, and its effects spread and migrate at a rate controlled by the temperature-diffusion rate function. Where the process is interrupted at a very early stage the result is usually a spotted slate, with the spots consisting mainly of an amorphous glassy material which has not had a chance to recrystallise. When the temperature and cooling conditions are suitable it is possible that this material may crystallise sufficiently to yield recognisable minerals.

The spotted rock seen in the Witkoppies area is unusual in that the "spots" are superimposed upon and evidently were formed after the constitution of the quartz-biotite schist rock. In this area there is a considerable occurrence of pegmatitic material in the footwall and it can only be supposed that this intrusion took place at a stage when the main metamorphism was completed but before the rocks had cooled appreciably. It is thus conceivable that this later intrusion was able to produce a sufficient rise in temperature to cause the formation of the "spots" within the already altered rock. It must be borne in mind in this connection that a metamorphosed rock is only in equilibrium at the last stage of the metamorphic process, and ceases to be so when the temperature falls again. The presence of muscovite within the "spots" suggests that pneumatolytic agencies from the pegmatitic material assisted in the general solution and recrystallisation processes occurring in the incipient "secondary" metamorphism. As this spotted rock is not found anywhere else, it is evident that the pegmatitic material of this area is either of slightly earlier age than that found in the "dykes" elsewhere on the property, or is of considerably greater extent than one is led to suppose by the exposures.

It is thus evident that the original rocks which went to form what is now the New Consort Mine hanging wall series of quartz-biotite and quartz-biotite-garnet schists and hornfels was a fissile argillaceous rock with occasional finer laminations, and containing iron ores, rutile, sericite, much chlorite and quartz, kaolin, a little lime, and in places lime-magnesia minerals. This would therefore be a more or less normal sandy shale.

The photomicrographs on Plate XXXII are of thin sections of the hanging wall rocks.

The Consort "Bar"

At the contact of the hanging wall and footwall rocks, whether there is metallic mineralisation or not, there is almost always a development of what is known as the Consort "Bar". This may be anywhere from 1 inch to 80 feet in thickness, but is more usually from 2 to 6 feet.

In its commonest form this "bar" is an exceedingly hard, dark brown rock with very fine grain. It is generally of cherty appearance, though individual grains of vitreous quartz can frequently be distinguished in hand specimen. It generally has a more or less conchoidal fracture and is translucent in thin chips. In some cases it is so fine grained as to take on a distinct "chocolatey" appearance. Usually this rock is finely laminated with some bands of brown cherty quartz, and others of more or less vitreous quartz. These laminations range from 1/16" upwards in thickness, and are often individually persistent over several feet. The "bar" is frequently intensely folded and fractured, and is sometimes mineralised.

The brown bands in this rock consist mainly of equigranular quartz, with a great many minute flakes of brown pleochroic biotite. These biotite flakes are arranged parallel to the banding. Other minerals present are zoisite, muscovite, rutile, a little apatite, sericite, a little greenish-brown tourmaline, and magnetite, both as fine dust and as minute octahedra. Occasional grains of zircon can also be found. The "chocolatey" varieties are merely finer grained than the others, and contain possibly a little more biotite. It is evidently the minute flakes of biotite combined with the fineness of the quarts grains that are responsible for the appearance of the rock.

The bands of vitreous quartz seen in hand specimen can be seen in thin section to consist of veinlets of almost clear vein quartz. This is a good deal coarser in grain than the remainder of the rock, and the grains are mostly more or less free from inclusions. This vein quartz and the other show some signs of strain. The veinlets are parallel to the general "stratification".

In some places there is a little pyrrhotite disseminated throughout the rock, and where this is the case the proportion of greenish-brown pleochroic tourmaline is higher. This is obviously due to somewhat later hypothermal agencies.

It is evident that this rock has been formed by the intense silicification of the hanging wall rocks in a narrow zone on the contact, by the passage of solutions of fairly high temperature and high silica content up the contact under the impervious blanket of hanging wall rocks. The silicification process has replaced with fine grained quartz most of the minerals in the rock, with the general exception of some of the previously oriented crystals of biotite, of which vestiges still remain. Simultaneously with the general silicification in the "bar" zone, the solutions have penetrated and passed along fractures on the foliation planes of the quartz-biotite schist, depositing thin quartz veinlets.

The solutions responsible for this silicification were apparently post-pegmatitic, but mainly pre-mineralisation. In places the later stages of "bar" formation have been overlapped by the metallic mineralisation stage, resulting in banded mineralised bar, a specimen of which is illustrated on Plate XXX, Fig. 3. Deposition of economically important minerals has, as shall be seen later, occurred in some places and not in others. In the mineralised areas it is sometimes evident that the mineralisation stage has considerably overlapped the "bar-forming" silicification stage, resulting in intensely mineralised bar material with bands, stringers and veinlets of the arsenopyrite-gold deposition. It seems, therefore, that the solutions responsible for the "bar" silicification were a part of the mineralisation cycle, but belonged to the early stage when they were highly siliceous. Deposition and replacement by silica took place with greater ease, and consequently was more widespread than the later deposition of metallic minerals, owing to the fact that silica was in higher concentration in the solutions in the earlier stages than the metallic compounds in the later ones. Thus while "bar-forming" silicification and replacement was widespread, the deposition of metallic minerals in economically important amounts required the occurrence of locally favourable conditions.

As has been mentioned previously, the contact between hanging- and footwall rocks has sometimes been gradational over several feet, the contact zone consisting of alternating laminations of the two rock types. In such areas the "bar" development has embraced the contact zone, resulting in a handsome rock made up of alternate chocolate-brown and bright green laminations. This type is locally called "Bastard Bar". Sometimes where this is developed, the true "bar" exists on its hanging wall side, on the lower contact of the main body of hanging wall rocks, but more often the solutions have not penetrated through the contact zone, and no "bar" has been developed.

In hand specimen the "Bastard Bar" is very hard, and has a more or less conchoidal fracture. The width of the alternating hard brown cherty bands and bright green softer bands varies from ⅛" to 1" or more. The brown cherty bands are of similar nature to the ordinary brown bar, but the green ones are seen in thin section to be composed mainly of a very pale green muscovite mica, with sericite, biotite, minute octahedra of magnetite, zoisite, a little apatite, and some rutile. There is usually also a fair amount of green chlorite. In many places these green bands are impregnated with fine grains of quartz, by which mineral the others are in course of replacement. Most of the minerals in these laminations are oriented in the plane of banding, probably due to shearing forces active before and during alteration and silicification. These forces have also resulted in a good deal of minute folding in the softer green bands. Thin veinlets of more or less clear vein quartz are also found in this rock in both green and brown laminations. Some specimens show remnants of unreplaced tremolite in the green parts of the rock.

On the outcrops this banded rock often presents a peculiar appearance due to the fact that the softer green parts weather out, leaving the harder cherty and siliceous portions.

The "Bastard Bar" has evidently been formed in the same manner as the ordinary bar, except that in the former case the contact zone consisted of thin laminations of hanging- and footwall rocks.

In some places in the mine there are bands of hanging wall rock, from 2 to 15 feet in thickness, occurring within the footwall rocks, near the main contact. This results in a sort of magnified transition zone up to 80 feet wide. In such cases the true contact has the normal "bar" development, while the bands of hanging wall rock below are generally completely transformed into "bar" material. Where late faulting has taken place in such areas, contact driving is troublesome, as a good deal of cross-cutting is required to make certain that the work is being done on the main contact.

Mention has already been made of the fact that layers and lenses of hanging wall rock sometimes occur well within the body of the footwall rocks. Except where they are very thick, these also are usually completely altered to "bar" material. So far no metallic mineralisation of importance has been found in connection with these occurrences, but such might quite possibly exist. Further reference to this point will be made later.

In one or two places in the mine, notably where there are occurrences of "South Reef" (which will be dealt with later,) the bar is very thick, sometimes up to 80 feet. In such cases the rock is usually black and distinctly vitreous, showing in certain lights definite banding, which in hand specimen can be seen to be due to slight differences in grain size. This type, like the others, consists mainly of small grains of vitreous quartz. In thin section this rock can be seen to be composed almost entirely of quartz. Some laminae are crowded with minute particles and crystals of magnetite, biotite, tourmaline and muscovite, and consist of fine interlocking quartz grains. Here and there are narrow zones containing large amounts of magnetite and biotite. The other laminae consist of the coarser vein quartz, with but few inclusions. The boundaries between the various bands are very sharp. This type of "bar" is evidently formed at points where the silicification and replacement have been abnormally intense, resulting in the almost complete replacement of all inclusions other than the magnetite. This process is probably connected with the formation of the South Reef, and will be further discussed later.

Photomicrographs on Plate XXXIII illustrate specimens of the Consort "Bar" [illegible] Bastard Bar."

<u>The Pegmatite "Dykes"</u>

These have two modes of occurrence, both later than the mineralisation cycle. One form is that in which the pegmatites consist of dykes occupying faults which often have a considerable displacement on the mineralised horizon. This type may be up to 200 feet thick and may be persistent for 1000 feet or more on strike. No faulting has been found which cuts and displaces the pegmatites, and as there has been a considerable amount of faulting of different ages in the area, these pegmatites must be considerably younger than the mineralisation cycle.

The other type of occurrence is in the form of irregular and apparently isolated lenses of pegmatitic material occurring along definite zones. These are on a strike of about 40° east of north, and have various irregular dips. These zones are not parallel to any definite faulting system and generally have no displacement. In fact, a drive passing through one of these zones between lenses of pegmatite revealed no disturbance in the rocks. In another case a drive following a reef horizon in the footwall cut across the "line" of one of these pegmatites, and no fracturing or disturbance could be found. These pegmatites cut across mineralised horizons with no effect other than local mineralogical changes in their vicinity, so they too are later than the mineralisation cycle.

Disturbance in the country rocks on either side of the pegmatitic intrusions is frequently noticed in the form of folding, usually of a very localised nature. This folding is generally in the form of drag and compression folds near the pegmatite contact. This type varies in thickness from 20 feet to 150 feet, but averages some 50 to 80 feet.

The rock forming both these types is apparently the same, and they are probably of similar age.

The second type, as its mode of occurrence would suggest, is exceedingly irregular in thickness, persistency and attitude. In fact, the only feature of a more or less regular kind evidenced is that of occurrence along certain fairly well defined zones. It is, of course, possible that the exposures are such that the pegmatite lenses in a given zone may be interconnected, but most of the information seems to point to an occurrence of irregular disconnected lenses. If this is so, it is difficult to postulate their mode of formation and method of entry and emplacement.

The pegmatite bodies of both modes of occurrence are occasionally very coarse grained. Towards the middle of a large dyke, individual crystals of felspar may reach 10cm. in diameter, though this is exceptional. Flakes and books of muscovite up to 2cm. in diameter are fairly common in large bodies. Generally speaking, however, the grain size ranges from 1mm. to 1cm. and is exceedingly irregular. The fresh rock is usually very hard and of a medium gray colour, generally with easily distinguishable crystals of plagioclase, quartz and muscovite. Some of the quartz has in hand specimen a definite dull cherty appearance. Small flakes of biotite are rarely found.

These pegmatites usually have a very sharp contact with the country rocks. Along the contact plane there is frequently a vein, some ½" in thickness, of clear vitreous quartz. It is sometimes evident in the case of the lenticular bodies occupying no recognizable fracture or fault, that there has been some movement on the zone of intrusion prior to injection. This takes the form of definite drag in the country rock, and the development of gouge layers between the pegmatitic matter and the distorted country rock. As has been pointed out above, such movement must have been local and very limited.

Signs of alteration of the country rocks are usually to be found in the neighbourhood of the pegmatites, but this extends generally for only a few feet. Occasionally, in the footwall rocks, alteration may extend 30 feet from a pegmatite body only 15 feet thick. Such cases, however, are not common.

In thin section the pegmatite rock is seen to be composed of quartz, oligoclase, orthoclase and muscovite, with a little sphene and very rarely biotite. Occasionally the muscovite content is as high as 40%, but generally it is much lower. Occasionally zircons can be seen, and in the muscovite they are surrounded by haloes which are pleochroic from almost colourless to a pale blue. Sericite is fairly common, often as an alteration product of orthoclase, though the rock is generally very fresh.

All specimens of these pegmatites show evidence of intense crushing and strain. The quartz crystals always show strain shadows, and are frequently made up of interlocking lenticular grains of crushed and partially recrystallised material. Many of the felspar crystals are broken up, and the fragments more or less scattered and bent, while the muscovite is usually much bent and often crushed and comminuted. Mortar structure is very beautifully shown throughout, and the crushed "mortar" frequently occupies areas as great as or greater than those occupied by the larger crystals. The areas which have a cherty appearance in hand specimen are made up of this material.

It is likely that these characteristics are due to some movement having taken place along the zones and faults occupied by the pegmatites subsequent to their intrusion.

The degree of alteration of the country rocks which has taken place in the vicinity of the pegmatites varies greatly, and generally does not extend more than a few feet from the contact. The usual alteration of the footwall rocks takes the form of the appearance of a little muscovite, sometimes aligned in the planes of schistosity, some orthoclase and sericite, and the partial replacement of tremolite by biotite.

As has been mentioned above, the alteration sometimes extends far into the footwall rocks. In such cases the altered rock consists almost entirely of biotite flakes, 1 to 2mm. in diameter, without zircons, and containing remnants of unreplaced tremolite, with a little muscovite, chlorite and rarely zoisite. Tourmaline of the green-brown schorlite variety is also sometimes seen in this rock, while the original minor minerals, such as magnetite, remain more or less unaltered.

Alteration of the hanging wall rocks usually results in a peculiar mixture of strained quartz, with orthoclase, oligoclase, a little muscovite, tourmaline and magnetite. At a glance this rock in thin section is very similar to the pegmatites themselves. Almost always, however, it shows palimpsest schistosity, contains tourmaline, and more magnetite, is less intensely crushed, and is finer grained than the pegmatites. In hand specimen, its appearance is not much different from that of the unaltered hanging wall rock farther away from the contact, except that it is coarser grained, has a more vitreous lustre, and is less distinctly schistose.

The pegmatites, as would be expected, produce little effect on the "bar". The only alteration which can be seen is in a belt some 2mm. wide along the very sharp contact which the intrusions have against the "bar". This belt consists of exceedingly fine grained, crushed, cherty quartz with tiny grains of muscovite, oligoclase, orthoclase, sericite and sphene. More than 2mm. away from the contact the "bar" is unaltered. This alteration is largely due to the crushing of the "bar" in the immediate vicinity of the contact. Such crushing and comminution allow the entrance of solutions for a short distance, but these fail to penetrate farther than the width of the crushed zone.

No metallic mineralisation has been found associated with the intrusion of the pegmatites. Gold values were found in pegmatite rock at one point, but this was apparently due to a fragment of mineralised country rock "enclosed" within the intrusive material in the nature of a small "horse".

The pegmatite rock is locally known as "granite".

Photomicrographs on Plate XXXIV are of thin sections of these pegmatites, and of their wall rocks.

Structural Geology and the Relation of the Structures to Zones of Mineralisation

The mine workings are situated on the northern or lower limb of what would seem to be a complicated overturned syncline pitching in a direction some 30° south of east.

Little or nothing is known about the southern or upper limb, as very little work has been done there. The reason for this will be seen when the nature of the ore deposition and the reasons for its localisation are pointed out. It is known, however, that the area south of the Noordkaap River, on the southern limb, is highly complex, probably more so than that on the northern limb.

In general, outcrops are not easily followed, not only because the "bar" often does not outcrop conspicuously, but also because of the slope of the ground surface. Outcrops often "creep" considerable distances down the hill slopes, and talus and rubble frequently confuse the surface geology. Fortunately, the "bar" outcrop has often been trenched, and there are a great many old adits and surface winzes which are of inestimable value in tracing structures on surface. The presence of a good deal of thick grass and thorn scrub also makes surface mapping difficult. Surface geology must therefore be to a certain extent inferred from underground exposures, but as there are a great many of these liberally distributed over the property at shallow depths, this is unlikely to cause serious error.

In this description, constant reference will be made to the geological map on Plate II and to the vertical cross-sections on Plates V to XI. The positions of these sections are marked on the map.

The mine is divided into two main parts by a large fault zone known as the Bluejacket Fault. This fault is sometimes a fairly clean break, but is more often a series of fractures occurring more or less parallel to one another within a zone some 200 feet wide. It does not have a straight course, and is partially occupied by pegmatite. This fault is post-mineralisation in age, but is among the earlier of the faults belonging to this stage. It has a horizontal displacement of some 3500 feet, and its vertical displacement, though reverse in direction, is not definitely known in amount. The rocks approaching the fault show the effects of drag for considerable distances. At one point in the Bluejacket zone, about midway between the displaced "bar" blocks, a horse exists between the two main fracture planes in this area. This horse is a portion of the contact zone, containing hanging- and footwall rocks and a portion of bar. This block is intensely folded, as would be expected, but, being broken off from the Ivaura Section (see Maid of de Kaap Section on Plate II), it is mineralised. The outcrop of this horse is marked by a small open cast working, and there is also some underground development and stoping. It is said that some of the finest specimens of visible gold from the mine were found in this area, but the Bluejacket has not been worked in recent years.

As the Bluejacket Fault has fractured a more or less mineralised area, some of the gold bearing material has naturally been dragged into the fault zone. Phenomena of this type, as will be seen later, are exceedingly common in this area. The result of this process is that the fault gouge, breccia and crushed material are sometimes sufficiently rich to be of economic value. This is, of course, not so common in the case of the Bluejacket Fault as it is in the case of the other faults with smaller displacement, where dilution is less. One of the branches of the Bluejacket Fault, however, some 400 feet northwest of the Bluejacket workings, has been worked to a small extent on surface.

The block north of the Bluejacket Fault constitutes what is now known as the Maid of de Kaap Section. Before the amalgamation of all these workings this was the well-known Maid of de Kaap Mine, figures of whose production have already been given.

This part of the mine is relatively simple as compared with that south of the Bluejacket Fault; such folding as exists is not complex, and the faulting is relatively simple. The curves seen in the outcrops mapped on Plate II are due almost entirely to the topography.

Though there are a great many faults, both normal and reverse, in the Maid of de Kaap Section, there are only two worthy of mention, namely, the Ivaura Fault and the Main Reef Fault. These are both shown on plan and sections. They are steep south-dipping, the Ivaura Fault at some 50-70°, and the Main Reef Fault at some 60-70°. Both are more or less parallel to the Bluejacket Fault, both have reverse throws, and both are later than the Bluejacket, though probably formed by later adjustments connected with it.

The Main Reef Fault, which is also known as the MacDonald's Fault, has been traced on surface for some 3000 feet. On Plate II its outcrop is shown fairly straight from the east end to the MacDonald's open cast working, from where it turns southwards. This is due only to the effect of the topography. As can be seen from the sections, this fault pursues a by no means straight course; it is, however, remarkably regular in comparison with the others. The horizontal and vertical components of its displacement decrease from the surface downwards, but this decrease is not rapid.

This fault traverses and displaces the mineralised zone known as the Main Reef Section of the Maid of de Kaap. This Main Reef Section, therefore, consists of a mineralised zone, not continuous, cut and displaced by a reverse fault into two parts. On the outcrop both parts have been worked open cast, forming the North and South Quarries. The occurrence of this fault within the mineralised zone is probably due to the fact that the mineralisation in this area, forming ordinary and South Reef, is associated with complex systems of fractures, which have caused a zone of weakness, and this zone has yielded to the stresses causing the fault. As the fault has occurred to a great extent within a mineralised zone, a good part of it in the vicinity of the "bar" horizon contains material rich enough to be of economic value. This is often the case between the two faulted blocks, and in such cases the fault has been stoped as well as the contact blocks on each side. This gives rise to peculiar Z-shaped stopes.

Contrary to what would be expected, fault material containing gold in stopable amounts occurs in the fault zone outside the area enclosed by the two contact blocks. This can be seen in the MacDonald's Section, and on the section on Plate VII. This is proof that the present displacement on the fault is only the resultant of several movements, and that at one time the displacement was much greater than it is now. The movement on this fault was, therefore, of an oscillatory nature. At first sight the mineralisation at the MacDonald's Section, where there is an open cast and considerable amounts of underground stoping, is difficult to explain on the assumption that the fault is of post-mineralisation age. It can be seen, however, in the section on Plate V, that MacDonald's 4 Level, the lowest, is not far below the position where the contact zone was before erosion. The nature of the material stoped at MacDonald's also proves this to have been dragged into the fault zone, which is here some 6 to 10 feet wide.

It is, of course, impossible to state whether the oscillatory movement on this fault was such that mineralised material might have been dragged into the part above the contact where both fault walls consist of hanging wall rock, though this is quite possible. No work has been done on the fault in this zone. It is likely, however, that any such occurrence which might exist would be of less value than similar ones in the footwall as, owing to the more resistant nature of the hanging wall rocks, the fault shear zone is only a matter of inches wide where both walls consist of the latter.

The Ivaura Fault has not been traced as far on surface as has the Main Reef Fault. This is due to creep on the hillside, weathering and the presence of talus. In the west, it appears to end against the pegmatite dyke occupying the Bluejacket Fault. This fault has in general a slightly flatter dip than the Main Reef Fault, but it is far less regular, and dip and strike vary greatly, as can be seen on the sections.

The vertical displacement on this fault decreases fairly rapidly from the surface downwards; the horizontal component, on the other hand, increases considerably. Nowhere has the effect of these faults on the pegmatites been seen. The occurrence of this fault in a mineralised zone is similar to that of the Main Reef Fault.

Mineralised material has been found on the Ivaura Fault between the displaced "bar" segments, but has generally been too low in value to be of any importance. Nowhere has such material been found on this fault outside the zone of displacement. These two facts combine to show that the movement on this fault has been far less of an oscillatory nature (with consequently less grinding effect) than that on the Main Reef Fault.

The contact block south of the Ivaura Fault is known as the Ivaura Section, while that north of it is termed the Ivaura A or O'Dowd's Section. The Ivaura A Section is the same as the O'Dowd's, but in the early days these were not connected, and were not thought to be the same fault block. Reference to the sections shows that this should have been obvious. It was also not known until direct underground connection was made some years ago that the Ivaura A is the same as the south block of the Main Reef Section. The part of the mine north of the Bluejacket Fault can thus best be divided into two parts: the Ivaura and the Main Reef Sections, each consisting of a faulted, irregularly mineralised zone.

The Ivaura Section thus comprises the Ivaura and Ivaura A, or O'Dowd's. At present the lower levels of the north block are called Ivaura A and the upper levels, above 8 Level, O'Dowd's. The southern portion of the Ivaura Section has been worked on surface in the form of a small open cast, which is known as the "Granite Quarry" because a considerable number of stringers of pegmatite from the nearby Bluejacket Fault were encountered. The stoping on this contact extends from the quarry in irregular patches to 13 Level, as shown on Plates V and VI. This stoping is, however, not by any means continuous. The largest stoped area is between 5 and 13 Levels, but this does not show clearly on Plate V, as the shoot pitches eastwards. It is clear, however, from Plate V that the main stoping is associated with areas in which distinct folding and steeper dips occur. Actually, this mineralisation is associated with fracturing in the footwall rocks just below the contact. The fracturing is irregular, and forms a complicated branching system, mineralising a width sometimes up to 15 feet. Some branches converge on the "bar", while others branch off into the footwall, and recently considerable amounts of reclamation have been done on these latter in the old stopes.

Where there is a disturbance in the rocks, such as that at and below the "Granite Quarry", and that in the vicinity of 5, 8 and 10 Levels, such fracturing, as would be expected, is more intense, with consequently more intense mineralisation. In areas where the rocks are relatively little disturbed, the fracturing is but weakly developed, with consequent weak mineralisation. Where there has been folding, the fracturing and shearing which occur generally only in the footwall rocks as being less resistant to such stresses, tend to concentrate, naturally enough, in the neighbourhood of the contact and the "bar". In other places where there has been little or no folding, such fracturing as has acted as passages for the hydrothermal solutions has not been concentrated in any one zone, being rather scattered and, of course, far less intense. Thus intense mineralisation of economic value is associated generally in this part of the mine with gentle folding in the "bar" horizon, with consequent fracturing in the weaker footwall rocks. Elsewhere, sporadic values are occasionally found near the contact, and well in the footwall on irregular and impersistent fractures. In the lower section of the mine, as will be seen later, where the folding is far more intense, the relative movement between hanging- and footwall rocks in the vicinity of the contact has resulted in an intensely sheared and fractured zone just below the "bar". Passage of solutions in this area, therefore, has been confined to a zone just below and within parts of the "bar", with the hanging wall rocks acting as an impermeable blanket. In this area, therefore, the hanging wall rocks have confined the solutions to the contact zone by virtue of their impermeability, while in the Maid of de Kaap Section the solutions have been less closely confined to the vicinity of the contact, and then only by virtue of the fact that the footwall rocks near the contact fracture and shear under stress with greater ease than do the hanging wall rocks above.

In the O'Dowd's Section, the association of economic mineralisation with gentle folding at and below the quarry is clearly shown on Plate V. The quarry is actually on a series of fractures below the contact. In the Ivaura A Section this association is startlingly clearly portrayed. The main stoping is between 11 and

12 Levels. On the way down the Ivaura A inclined shaft from 10 Level, it is readily seen that the dip is some 35-40° down to a point just above 11 Level. Between 11 and 12 Levels the dip is nearer 50°, and the whole area is stoped out. Below 12 Level the dip drops sharply to some 30°, and the stoping stops abruptly. A little distance east of the shaft there is a small area between 12 and 13 Levels where the dip is steeper, and here again there is a considerable amount of ground stoped out.

The two parts of the Main Reef Section, north and south of the fault, have both been worked extensively from open cast workings on surface more or less continuously down to 8 Level. Plate VI shows very clearly the relation between disturbance on the contact and the extent of stoping. In this area the stoping has continued some distance from the fault on both north and south sides, and it is evident that the disturbed and mineralised zone has extended farther on strike here than in the Ivaura area. In some places in the Main Reef Section, fractures from the footwall rocks just below the contact have penetrated the bar into the hanging wall rocks. In some cases these fractures, produced by relative movement in the vicinity of the contact in disturbed areas, have persisted in the hanging wall rocks just above the "bar" for quite considerable distances. These fractures have been mineralised in the Main Reef Section, giving rise to a blotched type of mineralisation locally known as South Reef. This has been extensively stoped in some places. (See Plates VI and VII.) Occasionally in such areas four parallel horizons, one above and one below the "bar" in each fault block, have been worked, as is shown on Plate VII.

Between 12 and 16 Levels in the Main Reef Section, as is seen on Plate IX, there is a considerable amount of fracturing just below the contact near the Main Reef Fault. This has been opened up relatively recently, and in places has proved to be exceedingly rich. This zone is also more or less along the line of intersection of the Main Reef Fault and the contact horizon.

Farther east in the Maid of de Kaap Section, where there has been little or no disturbance, there has been similarly little or no mineralisation.

Thus in that part of the mine north of the Bluejacket Fault, the main faulting is probably due to yield to stress in areas which have been previously weakened by gentle folding, fracturing and mineralisation. It is more or less characteristic of this part of the mine that the faulting is fairly simple, the folding gentle, and the mineralisation associated with systems of fractures which are related to the folding.

The dips of the contact horizon in the Maid of de Kaap Section range from vertical to 20° south.

The fracturing in this part of the mine, though often complex, remains definitely in the category of fracture systems, while the corresponding zones in the lower part of the mine, which is much closer to the de Kaap Granite and therefore far more intensely overfolded and faulted, belong to the category of sheared zones. As would be expected, the fractured and consequently mineralised areas in the upper section of the mine yield a much smaller tonnage per claim over the area than do the intensely folded and sheared areas nearer the granite. This is compensated, however; the shear zones below the contact in the southern part of the mine offer a wider and freer passage for solutions than do the tight and often talc-lined and gouge-filled fractures of the northern part. Mineralisation along these fractures is, therefore, where conditions are rendered unusually favourable by fracture intersection or "forking", often of amazing richness. Recently places have been found on these fractures where there is a solid zone of rock up to 1 inch wide, so impregnated with fine native gold as to possess a dull yellow colour. Such places are sometimes as much as 50 feet by 10 or more. It is on record[1] that one stope in the old Maid of de Kaap Mine assayed 12% of gold for

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[1] Mineral Resources of the Union of South Africa, 3rd Edition, 1940. P. 165.

a short time. This richness of the northern part of the mine is reflected by the past production figures already given, as well as by recent returns. Parts of the southern section of the mine have also yielded fabulously rich ore, but this is not so common as it is in the Maid of de Kaap Section.

South of the Bluejacket Fault the structures are much more complex, becoming increasingly so toward the south, that is, toward the de Kaap Valley Granite. These structures also increase in complexity from west to east, as can readily be seen by a glance at the sections on Plates V to XI.

Broadly speaking, the structure south of the Bluejacket Fault is a series of anticlines and synclines, in places complicated by faulting. For purposes of description it will be best to start from the Prince Consort Section, just south of the Bluejacket Fault, and work progressively southwards and southeastwards, examining each fold in turn. In this way the continuity of the structures from the Maid of de Kaap southwards to the Noordkaap River will best be brought out.

The whole process of mineralisation of this lower and intensely folded part of the mine hinges upon the series of anticlines and synclines. As has been stated on page 68, "the shear zones below the contact in the southern part of the mine offer a wider and freer passage for solutions than do the tight and often talc-lined and gouge-filled fractures of the northern part."

It is clear from what has been stated that the footwall rocks yield more easily to stress than do the harder and more resistant hanging wall rocks. Thus when folding takes place, drag and differential movement are bound to occur in the footwall rocks, in the vicinity of the contact. The more intense the folding, the more pronounced will this effect be. The result of this is that the footwall rocks below the contact in the highly folded southern part of the mine are not traversed by a series of anastomosing fractures as they are in the Maid of de Kaap Section, but rather become intensely sheared for from 4 to 8 feet below the contact. This shearing sometimes takes the form of vast numbers of closely spaced shear planes, more or less parallel with the contact; sometimes the rock is reconstituted to become a talc schist, and sometimes it becomes a tremolite schist with a high proportion of talc, and with the tremolite needles lying in all asimuths in planes parallel to the contact. Mineralisation of such rocks results in a banded ore of the type illustrated on Plate XXX, Fig. 3.

The result of all this, as is stated above, is a shear zone from 1 to 10 feet wide just below the bar, which offers a relatively free passage for hydrothermal solutions which impregnate the sheared and fractured rock. This shearing is, of course, bound to affect the "bar" to a certain extent, and the lower part of the latter also sometimes shows the effects of the movements. The process of "bar" formation was more or less contemporaneous with the later part of these movements, and the earlier part of the mineralisation cycle also overlapped these processes to a certain extent. Contemporaneous with the shearing, a certain amount of fracturing also takes place.

As the sheared and folded areas offered a fairly easy passage for solutions, while confining them beneath the impermeable hanging wall, the crests of the anticlines were the sites of a certain degree of slowing up and stagnation of solutions, with consequent deposition. Papenfus[1] has mentioned this principle of the confinement of solutions beneath an impermeable hanging wall in connection with the Consort Mine. It follows, therefore, that though a certain amount of mineralisa-

[1] Trans. G.S.S.A., Vol. 37, 1934. Pp. 279-287

tion took place at odd locally favourable spots, the heaviest deposition took place within the crests of the anticlines. This is found to be the case throughout the southern folded portion of the mine, and though mineralisation leading to ore of economic value naturally does not occur all along the anticlines, it is nevertheless the case that the richest and best ore is found on and near the crests of anticlinal folds. The shape of these folds has to a certain extent been modified since mineralisation, and this occasionally leads to some anomalies. In these cases the metallic minerals can be shown to have been deposited after at least the major part of the folding had taken place.

As the rocks cooled somewhat, residual stresses superimposed faulting on the folds as the zone of plasticity began to recede. This has resulted in some minor faults which carry mineralisation not of the "dragged in" variety. Of course, after the mineralisation cycle had been completed, a good deal of minor faulting of various kinds took place, and these later faults have added considerably to the complexity of the position. Many of them took place very shortly after mineralisation had been completed, and "reef" has occasionally been dragged considerable distances into the fault zones. These have often constituted ore bodies of no minor importance.

The Prince Consort Section, a part of the old Consort property, is still relatively little disturbed. It can be seen on Plates II and XI in section and plan respectively. This area has been fairly thoroughly opened up, but has yielded only a relatively small tonnage of ore. The areas which have been stoped show that the major part of the mineralisation was associated with fractures some 5 to 30 feet below the "bar". In some places where development on the "bar" has shown no values, cross-cuts into the footwall have intersected fractures carrying payable values. This is particularly the case in the gently flexed area just north of the point where the Prince Consort outcrop crosses from the north to the south bank of the Consort Creek, some 1000 feet along the outcrop from the Bluejacket Fault. Towards the east end of the Prince Consort Section, the effect of drag on the Bluejacket Fault is very much in evidence. The average dip of the reef horizon in the Prince Consort area is some 45° south.

Not far below the bottom of the Prince Consort workings the contact turns up again to an east dip on the north flank of the Betty Quarry Anticline. This fold is not sharp, and does not appear to be very persistent, though there is insufficient data concerning its behaviour in depth. Its south flank dips south at some 35°, and it has a fairly steep pitch in a southeasterly direction. On the crest of this anticline on surface there is a small open cast working, from which the fold has been named. There is little known about this fold below the floor of the quarry, though it is said that fairly good values were found in the quarry itself.

South of the Betty Quarry, the outcrop turns sharply south, and takes on a dip ranging from east through vertical to some 80° west on the northeast flank of tho Hard Cash Anticline. This latter is a closed overturned fold which can be traced on surface for some 1500 feet. Little work has been done on the east limb, but a considerable amount of development, some stoping and some open cast work have been done on the west limb, which is generally nearly vertical. The point at which the crest of this anticline pitches below surface has not been definitely located, as it is on a fairly steep hill slope, and is covered by surface debris. The stoping in this area in the Hard Cash workings has been done mainly in the "bar" itself, which at this point is some 5 to 15 feet thick and carries most of the mineralisation. Values in these workings are in general low, being of the order of 3 to 4 dwts./ton. Plates II, X and XI show the relations of the Prince Consort, Betty Quarry and Hard Cash occurrences. The axis of the Hard Cash

Anticline runs about 12° east of south, and the pitch is irregular to the south. No work has yet been done on the crest of the fold underground, though this is one of the prospects which should be followed up. The west limb of this anticline runs parallel to the east limb until it reaches a point southeast of the Witkoppies Quarry. From here the outcrop turns westwards, maintaining a west to southwest dip to the Witkoppies workings, in which the dip is some 25° south.

The Witkoppies workings are situated near the trough of the overturned syncline, of which the south limb forms the north and lower flank of the overturned Intermediate Anticline. This, as will be seen later, is not a particularly favourable location for mineralisation, and values have generally been low. The syncline on the lower limb of which the Witkoppies workings are situated has a definite flexure in the vicinity of the workings, and it is probably the associated fracturing in the footwall rocks which has been the cause of such mineralisation as has taken place in this area. This structure is shown on Plate II, from which can also be seen the way in which the upper limb of the Witkoppies Syncline turns to form the northeast flank of the overturned Intermediate Anticline. It is the hanging wall rocks in the Witkoppies Syncline above the workings which show the spotted characteristic already described.

and it is in the area surrounding the Witkoppies, Betty Quarry and Prince Consort workings that most occurrences of the epidote locally known as "bismuth" have been found.

The Intermediate Anticline, which is overturned, and whose axial plane generally dips west at about 35°, is almost parallel to the Hard Cash Anticline. Nowhere has any work been done on the former fold, whose occurrence and form are shown on Plates V to XI. The pitch is irregular in a south-southeasterly direction.

As can be seen from the Plates, the Intermediate Anticline flows smoothly into the almost symmetrical fold known as Shires' Anticline. The flanks of this fold dip at some 30-40°, and the axis lies in a southeast direction, with a pitch of some 10-20° to the southeast. The Shires' Anticline has been split more or less parallel to its axial plane by a fault which here and there contains sheared and crushed material, rich enough to be mined. This fault is thus in one respect similar to the Main Reef Fault. There is but little displacement of the fold. The Shires' workings, which are situated on the crest of the anticline and are known as Shires' East, were among the first to be operated in this area, and though no records are available, it is stated that the ore mined from the top of the fold was rich enough for direct export to England.

The stoping has been done from an adit in the creek bed, and is on the crest of the fold itself, just to the east of section GH in Plate VIII. The stope is fairly flat, and follows the fold underneath the "bar" along the axis.

Just west of the creek a little stoping has been done on the south flank of the Shires' Anticline, in what is known as Shires' West. These workings did not yield such high grade ore as those in Shires' East, as they are somewhat too far down the flank of the fold.

South of the Shires' Anticline is a symmetrical syncline which in turn gives way to what is known as the C Winze Anticline, the last of these folds which can be seen on surface.

The C Winze Anticline pitches down below surface some 500 feet east of No. 1 Shaft, which is sunk on the south flank of the fold. No. 6 Shaft, as can be seen on Plate II, is sunk in the hanging wall rocks above the fold. At 1½ Level, this shaft meets the contact. This anticline has been much broken up by faulting, and is complicated by a certain amount of minor folding. Plates IX, X and XI illustrate this feature. These characteristics have considerably enhanced the difficulties attendant upon opening up this area. None of the faulting is on a large scale, but it is sufficient to make development difficult.

In the early days of mining a good deal of development and stoping, both underground and open cast, were done on and near the crest of the C Winze Anticline, from which fairly high grade ore was obtained. As this work was near surface in more or less weathered material, much of it has become inaccessible, due to caving. Plate X shows an area in which examination of the Shires' Anticline has commenced from a cross-cut from the workings on the C Winze Anticline. This cross-cut traverses the syncline between the two folds, and shows a beautiful cross-section of the structures. Such cross-cuts do away with much useless development around the troughs of synclines, and can be used where the structures are reasonably well understood.

It is the south flank of the C Winze Anticline, with the folding developed on it, that has been most thoroughly opened up and is best known. This constitutes what is known as the Queen Consort Section of the mine.

West of No. 1 Shaft, shown on Plates II and VII, this section of the mine is little disturbed, and that almost entirely by minor strike faults, mostly with a reverse throw of from 3 to 25 feet. In the vicinity of No. 3 Shaft and westwards, the dip is some 40° south at surface, flattening to about 25-30° around the 9th level.

Generally speaking, the stoping which has been done west of No. 1 Shaft has been on small isolated "blobs" of mineralised ground. These have evidently been formed at localised points where conditions have been favourable for deposition. Most of the ore from this part of the mine was of medium grade. At one place west of No. 3 Shaft, there is a stope covering a large area. Records show that the ore was medium to low grade, but as no work has been done in this area for some years, little is known concerning the conditions of mineralisation. West of this shaft the ground is undisturbed, apart from the gentle flattening in the dip. The workings do not go far enough west to give any definite information concerning the structures towards the trough of what would appear to be the main syncline. The only indication found underground with regard to this point is the consistent general decrease in dip southwards, on the lower levels. From No. 1 Shaft eastwards the structures rapidly assume bewildering complications.

Plate VII, drawn on the axis of No. 1 Shaft, shows the contact to maintain a steady dip from surface, at the outcrop of the south flank of the C Winze Anticline, down to a point some 30 feet above 6 Level. Above this point a little stoping has been done here and there, but none of it is very extensive. At the point mentioned (about the elevation of 5 Level) complications suddenly appear in the form of a fault zone at the northern limit of a well-defined anticlinal structure. This fold first becomes noticeable above 6 Level, some 200 feet west of No. 1 Shaft. Here it starts as a local flattening, becoming more compressed eastwards as the shaft is approached.

This fold, which is now known as the 7 Level Fold, pitches gently but erratically eastwards, and has been followed some 700 feet east of No. 6 Shaft. Its axis strikes about 30° south of east, and it becomes steadily more complicated towards the east; that is, towards the area in which all the folds from the Hard Cash Anticline southwards would seem to be converging. This area is likely to produce some interesting structural problems, and probably also a good deal of ore.

The 7 Level Fold in the vicinity of No. 1 Shaft is split along the crest line by a vertical fault, which at this point has a down throw on the south side of some 4 to 5 feet. This displacement increases rapidly eastwards, and the anticline thus becomes split into two distinct parts, of which the upper extends some 350 feet eastwards without noticeable pitch, before it "flattens out" and becomes indistinguishable in the maze of strike faults between 4 and 6 Levels, just west of No. 6 Shaft. This upper half of the anticline has been fairly thoroughly stoped out, and it is known that the stopes in the folds in this area and above No. 1 Shaft were exceedingly rich. Eastwards from this shaft the vertical fault splits into several branches which persist with varying dips to a point at least 500 feet east of No. 6 Shaft. Such conditions superimposed on increasingly complicated folding naturally result in very complex structural conditions. When, as is the case here, the folds are mineralised and the faults often contain "dragged in" reef matter of economic value, the workings become very complicated and difficult to understand without long and painstaking examination.

The fault which splits in two the 7 Level Fold near No. 1 Shaft has a displacement of some 40 feet at a point about 300 feet east of the shaft. Here the southern half of the anticline is, by reason of its eastward pitch and the increased displacement on the fault, below the elevation of 6 Level, while the northern half remains just above 4 Level. In this area, therefore, the existence of the southern half of the fold was not recognised until recently, with the result that it had not been opened up between this point and that at which its pitch brings it to the elevation of 7 Level, some 500 feet farther east. In this vicinity, also, it was found recently that on the fault between the mineralised northern and southern halves of the fold there was rich reef matter dragged from the displaced elements. This was stoped in an area where, as far as the contact zone was concerned, there was a "blank" on 6 Level for a considerable distance. Fig. 5 (p. 83) illustrates the conditions in this area.

It is probable that stoping on 4 Level stopped at the point A, partially owing to decrease in grade, and partially owing to the difficulty of handling broken ore. At the point B in the fault stope there is an interesting exposure of a system of tension jointing, brought about by the flexure near the fault. 6 Level drive passed from south to north through the fault zone at a point a short distance west of the section plane of Fig. 5. At this point it so happened that the fault carried no mineralised material.

Approaching No. 6 Shaft, the northern half of the fold disappears, while the southern half pitches down to 7 Level and gradually becomes more complex and overturned toward the south, due to an "underthrust" from that direction. Eastwards, as can be seen on Plates IX, X and XI, the overturned fold becomes recumbent and more nearly closed, with considerable complication due to minor post-mineral faulting. The upper or north limb of this fold has been a fairly consistent and high grade gold carrier for a distance along the axis of some 700 feet. Payable values are also associated with the lower limb in the vicinity of the area shown on Plate XI.

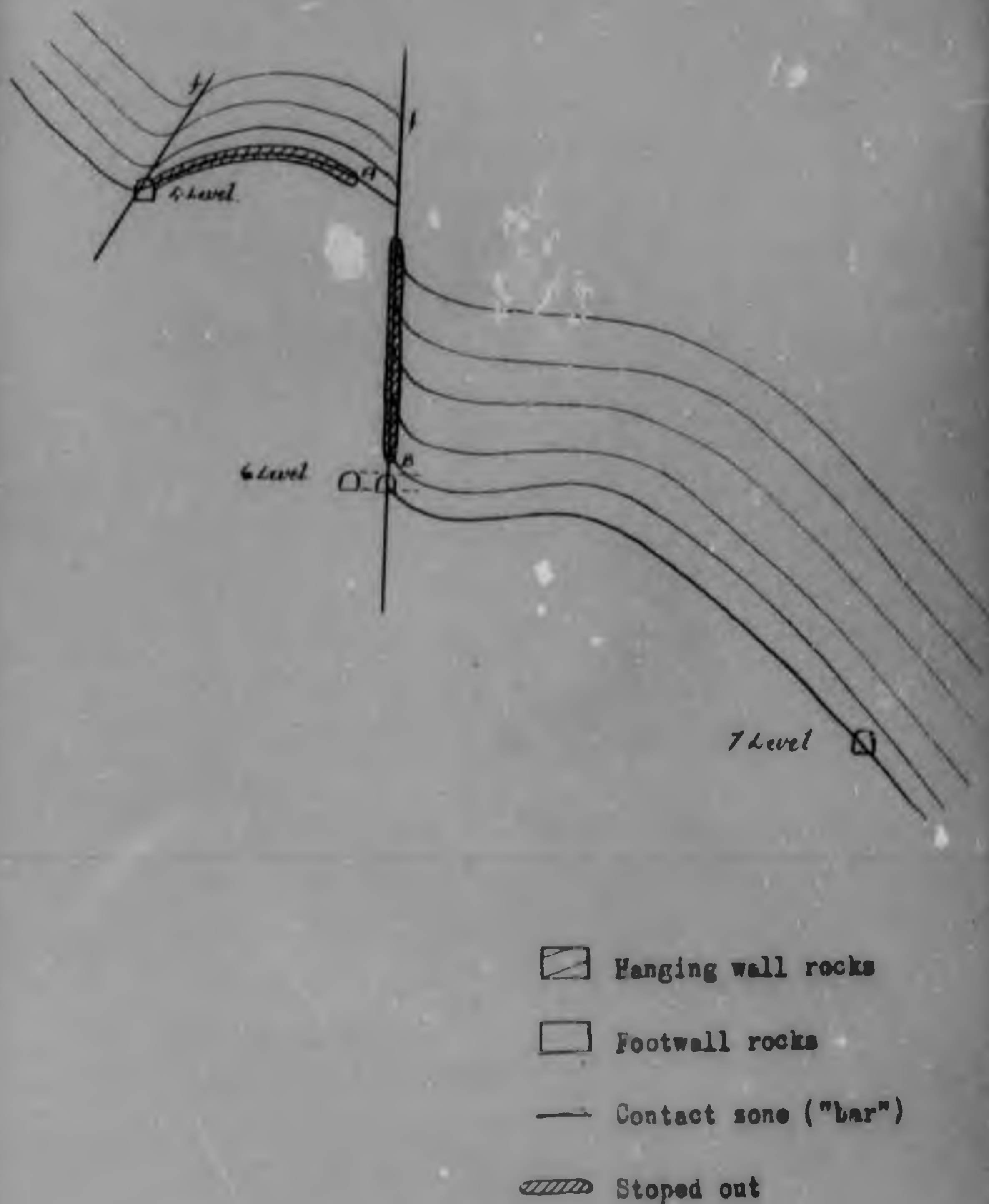
4 Level
6 Level
7 Level
Hanging wall rocks
Footwall rocks
Contact zone ("bar")
Stoped out

Fig. 5

This is probably due to the abnormally intense sheering and tension fracturing in this area. One part of 7 Level east of Section MN on Plate XI is confusing on account of the fact that here the recumbent fold suddenly pitches upwards toward the east for a short distance, and the workings, which for some distance west of this point are on the upper limb, are suddenly found to be on the lower; that is, the stope hanging wall changes suddenly from hanging wall rocks to footwall rocks. This change takes place over a horizontal distance of about 20 feet. In this connection it must be noted that in this area the lower and upper limbs are separated only by about 10 feet of footwall rocks.

Work is at present in progress in an attempt to follow this fold eastwards. It becomes increasingly complex, and is much disturbed by faulting in all directions.

Just east of No. 6 Shaft on the elevation of 3 Level, another fold begins to take shape, becoming more well defined as it is followed eastwards. This fold, known as the 3 Level Anticline, pitches gently but erratically eastwards, and the axis lies in a southeasterly direction. The crest area of this anticline has been stoped at odd points east of No. 6 Shaft. (Cf. Plate X.) Southeastwards, the 3 Level Anticline converges with a branch of the steep strike fault previously mentioned in connection with the 7 Level Fold. This relation is seen just above 4 Level, which is here on the fault. (See Plates X and XI.) At one point enough mineralised material has been dragged down on the fault for the latter to be stoped from 4 Level.

Still farther east, the fault has split into several branches which have broken up the fold in a manner which, owing to insufficient exposures, is not yet fully understood. 4 Level at this point is still below the crest, and the fault here exposed consists of a zone some 10 feet wide, in which there are very distorted horses of highly mineralised "bar" and footwall rock, dragged to the elevation of 4 Level by oscillatory movements. Fig. 6 is a sketch (not to scale) of the appearance of the fault zone as exposed in a winze following it down from 4 Level. Owing to

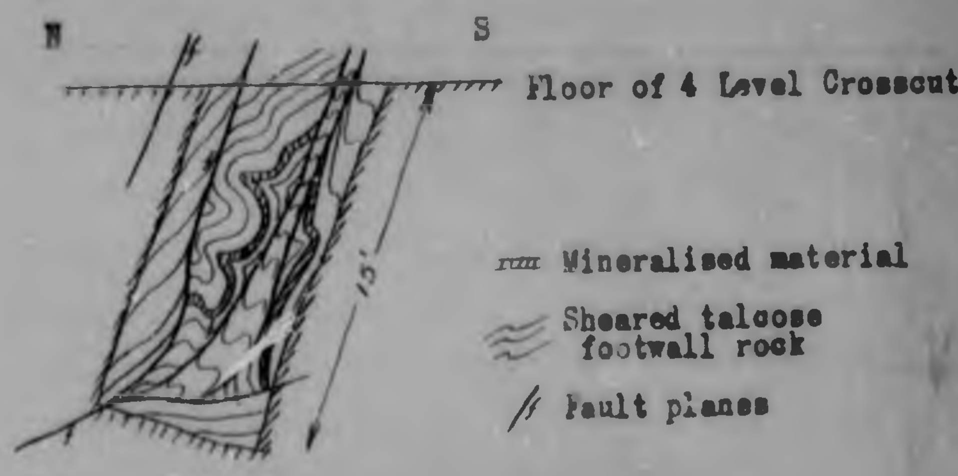

Fig. 6

the nature of the occurrence, it cannot be expected to persist any distance below this level.

On Plate IX a large stope is shown between 2½ and 3 Levels, well in the footwall. This stope does not reach the "bar" and is wholly within the footwall rocks. The mineralised zone at this point was some 50 feet wide and extended for a distance of some 200 feet on strike. As can be seen in the section, the occurrence is in an area which is but little folded. The mineralised zone consisted of a great many branching and interlacing fractures, all more or less parallel to the contact, which at this point is not mineralised. This is evidently an occurrence of a type similar to those found in the Maid Main Reef Section, and such bodies may be expected to occur at odd points where folding is not intense, in the part of the mine south of the Bluejacket Fault.

It has been mentioned that at some places well within the footwall rocks there occur lenticular bodies of hanging wall rocks which have, for the most part, been converted to "bar" material. On Plate IX there is shown a long cross-cut north on 7 Level. This passes through footwall rocks for its entire length, with the exception of one or two thin and impersistent bands of hanging wall rock which have been converted to brown cherty "bar".

Just east of this section there is, on 8 Level, a similar cross-cut north which extends some 800 feet. Most of the rock exposed is footwall rock, except towards the end, where the last 150 feet or so of the cross-cut are in hanging wall rock and "bar" matter. The laminations in this rock show that its south dip is decreasing northwards; that is, it is conforming more or less to the general anticlinal structure of the contact above it. As this band of impermeable rock appears to be fairly persistent, it was considered likely that mineralisation of the same type as that on the main contact might exist on a smaller scale in the vicinity of its lower contact. A drill hole confirmed this idea when it yielded core containing some gold from the footwall rock just below this band, which here would seem to have a true thickness of some 100 feet. This area has not yet been opened up and examined, and though the size of any ore body here would definitely be controlled by the extent of the lens of hanging wall rock, etc., it should be investigated.

The above shows that throughout the mine the occurrence of payable ore bodies is intimately related to the structures, and that even with a complex set of conditions such as are above described, certain areas in which ore bodies are likely to be found can be selected and examined, while others may be more or less neglected in the knowledge that any occurrences therein are likely to be small, of lower grade, and therefore not to be deliberately sought for by closely spaced development.

In a mine exhibiting structures and faulting conditions such as are exposed in the New Consort Gold Mines, Ltd., the construction and maintenance of more or less simplified glass sheet models is of inestimable assistance in the mining operations, as well as in the solution of the geological problems, which are of daily occurrence.

The following statement relative to the New Consort Gold Mines, Ltd., "The dip being fairly flat, ore shoots have appreciable areal extent, thus approaching flat reef conditions of the Sabie--Pilgrim's Rest region"[1]

requires no comment, except that it has obviously been made in complete ignorance and without even the slightest basis of investigation. Immediately subsequent to the above-quoted statement appears the following: "The locality being disturbed by fairly large faults, some doubt exists whether only one horizon is being exploited." From the foregoing description it can be readily appreciated that any such doubt can have but little

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[1]Mineral Resources of the Union of South Africa, 3rd Edition, 1940. P. 165.

foundation.

Hall states, "In spite of the nearly always very regular structure an occasional roll in the dip is noticed, extending over a few yards only and associated with higher values in the reef."[1] Such a statement can apply only to very limited parts of the Queen Consort Section, which is the subject of his description. He states further, with regard to the "bar", "It is a very uniform undifferentiated rock, free from or showing only the slightest trace of mineralisation, and consisting wholly of silica."[2] With regard to the first and last parts of this statement, the description of the "bar" already given shows that these are not correct; with regard to the middle part, it must be repeated that in the Hard Cash Section the mineralised band is wholly within the "bar", and in the other parts of the mine the lower part of the "bar" is frequently intensely mineralised.

On page 248[3] Hall states that the date of the folding in the Consort area is posterior to that of the reef as well as to that of the underlying basic rock. In this connection it must be borne in mind that the "reef" is actually basic footwall rock which

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[1]Geological Survey Memoir No. 9, p. 247.

[2]Ibid.

[3]Op. Cit.

has been mineralised along fractures and shear zones formed as a corollary of the folding. He actually also notes here that folding is associated with higher gold values. Immediately afterwards he states, "the payable shoots.....assume the shape of lenses, which are not defined by any structural features..."

Hall states on page 249[1] that the reef itself is probably a metamorphosed and mineralised sedimentary rock, signs of the original bedding of which are still occasionally seen. The nature of the reef renders this statement exceedingly unlikely, as the mineralised shoots grade off laterally and away from the bar into footwall rocks, and as will be seen later, it is actually made up of these rocks, mineralised and altered. His whole discussion on the origin of this reef does not stand under recent investigation. He asserts[2] that the presence of "granitic veins" in the Top Mine, which now constitutes Shires', Witkoppies, Hard Cash and Prince Consort, "shows that they are the ore bringers." These "veins" or pegmatites can everywhere be shown to be later than the mineralisation, and they bear no relation to its kind or degree.

The Entente Mine, which Hall describes on pages

[1]Op. cit.

[2]Op. cit., p. 249.

249 and 250[1], is now known as the Witkoppies Section. He states here, "There is no defined reef, but gold occurs in small amount more or less all over the workings, is usually free milling and not visible; this would apply to a thickness of about 40 feet." As has been mentioned before, these workings are situated under a flexed overturned syncline, and the mineralisation is probably due to the tension fracturing associated with the flexure.

Hall gives no description in Geological Survey Memoir No. 9 of the Maid of de Kaap Mine, one of the most important in the district.

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[1] Op. cit.

The Ore Bodies: their Modes of Occurrence.

Four types of ore body have been enumerated as occurring in the New Consort Gold Mines, Ltd. These are:-

(1) The Contact Type

(2) The Fracture "Reefs"

(3) The South "Reef"

(4) The Fault "Reefs"

The relation between these types has already been described, and their mode of occurrence outlined. In this chapter they will be discussed in further detail.

(1) The Contact Type of Ore Occurrence

General

This type of mineralisation is found mainly in the southern parts of the mine, e.g., Prince Consort, Betty Quarry, Hard Cash, Shires' and Queen Consort. It is typically developed in areas where the folding is fairly intense, with the consequent development of shear zones in which the ore is developed under and partially within the "bar". The occurrence of this type of ore development is intimately associated with the folded areas, not only in so far as the development of the shear zone solution passage is concerned, but also in the matter of localisation within the anticlines.

(It frequently happens that where the intensity of the folding locally decreases, the zone of shear gives way to systems of definite fractures which yield ore bodies of Type 2 in the foregoing list. This is known to occur in the Queen Consort Section between 2½ and 3 Levels at No. 6 Shaft, in one place in the Shires' North workings, in Witkoppies and in Prince Consort.)

The type of ore occurrence here under review has been the source of most of the ore mined from the Consort area, and has been the source of all but a little of that mined from the portion of the mine south of the Bluejacket Fault.

This contact type of ore development is characterised by an indefinite lower limit, as the intensity of the mineralisation grades off downwards into the footwall rocks. The payable zone is, however, seldom more than 5 feet wide, and is usually some 3 to 4 feet. The upper limit is more sharply defined, for though the mineralisation shades off upwards into the "bar", the gradation is naturally more rapid.

In some places the "bar" is completely barren, but this is generally the case where mineralisation has not been very intense and gold values are of the order of 3 to 5 dwts./ton over the stope width. In such cases no sign of mineralisation is visible to the naked eye, though the presence of arsenical minerals is shown by the fact that the rock gives off the characteristic garlic odour when it is struck with a pick. In these places the shearing has not been unusually intense, or there has been no stagnation of solutions, and the mineralisation has been confined to the footwall rocks just below the contact.

The common case in the more highly mineralised areas is that in which fine grained sulphides, mainly arsenopyrite, are visible in the footwall rock, while there are bands and stringers of the same mineral in the lower part of the "bar". Such areas may show gold values up to 40 dwts./ton in places.

Rarely the lower part of the "bar" presents a banded appearance in which there are alternating bands, up to 1 inch wide, of almost massive arsenopyrite and the "bar" material. In such cases the footwall rock below the "bar" also contains bands and stringers of fine grained sulphide. Occasionally in intensely mineralised areas of this type, gold associated with the sulphides can be seen with the naked eye. Such occurrences are, of course, characterised by fabulously high gold values.

As has been mentioned above, the mineralised band frequently includes a part of the "bar" as well as the sheared zone in the footwall rocks just below. In hand specimen, mineralised "bar" is the usual very hard, brownish, laminated cherty rock with the addition of bands, stringers and lenses of sulphides. These lenses are always parallel to the original lamination, and range from a series of tiny grains to solid massive layers of sulphide, sometimes up to 1 inch in thickness. In the less intensely and moderately mineralised areas the arsenopyrite which constitutes the chief sulphide can almost always be seen to occur as acicular crystals from 1-5mm. in length and from ·1-·5mm. in thickness. These are sometimes so numerous as to result in a felted mass within the sulphide layers, which individually are seldom more than ¼" thick. Such a mineralised zone in the "bar" may be a foot or more thick, and the alternating bands of colourless vitreous vein quartz, brown cherty quartz, and matted arsenopyrite needles result in a very handsome rock. This occurrence of arsenopyrite needles constitutes what is locally known as "needlepoint" ore, and is frequently rich in gold.

Occasionally where the "bar" is not very thick, the impregnation has extended locally for a few inches into the overlying hanging wall rock. In such cases the mineralisation of this rock is not intense and usually takes the form of odd arsenopyrite needles arranged in all directions in the planes of schistosity.

The nature of the mineralised footwall rock in the sheared zone depends upon the nature of the rock before mineralisation, the degree of shearing to which it has been subjected, and the intensity of the mineralisation in that particular area.

Usually the shearing in the area just below the "bar" is not severe enough to form the talc schist seen sometimes in the vicinity of faults, but where it has done so that area has generally not been mineralised. This is in some cases probably due to the fact that the intensely sheared and recrystallised talc rock offers little freedom of movement to the solutions, which would tend to go where the passage is easier.

The common case is that in which the various types of footwall rock have yielded along more or less undulating planes parallel to the contact. These are in the nature of gliding or shear planes, and their number depends upon the intensity of the shearing, which in turn is related to the degree of folding; they are spaced at distances ranging from ½" to 2 or 3 inches. Thus the zone up which the solutions have passed consists of more or less unaltered footwall rock traversed by a fairly large number of cracks and shear planes, in general parallel to the contact with the impervious hanging wall. The result of mineralisation, therefore, is the formation of stringers and veinlets of quartz, arsenopyrite, etc. parallel to the contact. A certain amount of replacement of the rock takes place between the passages. The degree of development of sulphide layers naturally depends upon the intensity of the mineralisation, which varies greatly from place to place.

Where mineralisation has been weak, no distinct bands or lenses of sulphide are formed, only grains and acicular crystals scattered throughout the rock. In hand specimen such rocks are dark gray, fairly hard, and usually massive, though the shear planes can often still be seen.

The arsenopyrite occurs in these rocks in a manner similar to that in which it is found in the "bar".

Sometimes where mineralisation of the footwall rocks has been very intense, much chlorite and pale green mica have been formed, and in such cases the rock consists of alternating layers and lenses of green chloritic matter and felted masses of arsenopyrite needles.

Petrography of the Ores

The most abundant sulphide is arsenopyrite. The occurrence of this mineral depends upon the degree to which the mineralisation has progressed. Where this has not been very intense, arsenopyrite exists mainly as scattered needles, most of which lie with their long axes in the foliation and shear planes in the "bar" and footwall rock. The gangue minerals have been replaced without regard to grain boundaries or cracks.

The only control exerted over the orientation of the needles appears to have been the foliation and shear planes, which in the "bar" are not really very distinct planes of weakness. The arsenopyrite needles are of all sizes, from 1-5mm. in length, but maintain a ratio of length to maximum lateral dimension of about 10:1. Their terminations are usually indistinct, while the cross-sections are the normal diamond shape to be expected from their orthorhombic habit. The only crystal form observed is the prism. No signs of any twinning have been observed, but there is an occasional parting plane parallel to the base.

Where the mineralisation has been intense, the arsenopyrite needles merge together, interfering with normal crystal development, and resulting in fairly solid masses. Such masses very often include particles of unreplaced gangue. All gangue minerals, with the exception of tourmaline, appear to be subject to replacement by arsenopyrite. In cases where the latter mineral has become more or less massive, it has occasionally cut the gangue, in the included particles and outside the mass, in the form of thin veinlets along strong cracks. Cleavages in the biotite and tremolite are only rarely the sites of such veinlets.

In the folded areas small drag folds from ½" to 2 feet in width are often found in the "bar" and the underlying footwall rocks. In such cases the bands and lenses of arsenopyrite follow the contortions faithfully, though varying in thickness from crest to trough, as is natural. In such cases the arsenopyrite needles in the vicinity of the axial plane of the fold are almost invariably aligned with their long axes in the planes of shear, and parallel to the fold axis. On the limbs of the folds, on the lines of minimum bending, the needles lie with their long axes in all directions, in planes parallel to the lamination and shear planes. Nowhere, even in the sharpest of these drag folds, have any arsenopyrite needles showing such features as bending, strain or fracturing been observed.

In cases where these drag folds have been heavily mineralised, the more or less massive arsenopyrite bands, veinlets and lenses often contain rounded grains of gangue minerals. In some cases such grains are cut by a series of cracks in directions radial to the fold axis. These are obviously due to the tensile stresses set up during folding, and are filled with thin veinlets of arsenopyrite.

The above facts prove that the deposition of at least the arsenopyrite was later than the folding, which exerted some control over it. This lends support to the general statement that the mineralisation is subject to considerable control by the folding.

A relatively small proportion of the arsenopyrite present, where it is not massive is in the form of irregular grains without crystal outlines. Where the arsenopyrite occurs in this form it also more often exists as veinlets along gangue mineral boundaries, which it penetrates while disdaining the cleavages.

Arsenopyrite generally occurs by itself, being rarely in contact with other sulphides.

The second sulphide present, in order of abundance, is pyrrhotite, which, however, occurs in very much smaller amount than the arsenopyrite; in fact pyrrhotite is in general rare, though locally abundant. This mineral is usually associated with much smaller amounts of chalcopyrite. These two minerals appear to be of much the same age, though it is possible that deposition of chalcopyrite persisted a little longer than did that of pyrrhotite. This latter can often be found without the former, but chalcopyrite has not been seen apart from pyrrhotite.

Enclosed in, and occurring as irregular elongated bladed crystals parallel to one of the crystallographic directions of the pyrrhotite, is pentlandite. This mineral is very uncommon, and has been seen occurring only in the manner above mentioned. It usually occurs as minute grains similar to those from Sudbury, pictured on Abb. 54, p. 126 of the second volume of Schneiderhöhn and Ramdohr's "Lehrbuch der Erzmikroskopie."[1]

Pyrrhotite is found only as irregular grains, usually interstitial to the gangue minerals, which it penetrates as very fine veinlets along cracks and cleavages. It very often penetrates far into the cleavages of mica and tremolite, replacement of which progresses outwards from these veinlets. Chalcopyrite is often associated with the pyrrhotite, both in the larger allotriomorphic grains and in the fine veinlets.

The arsenopyrite is later than and replaces both pyrrhotite and chalcopyrite. Sometimes the arsenopyrite, in replacing the latter two minerals, assumes its characteristic crystal form, and it is not possible to say from such instances whether the pyrrhotite is being replaced by, or is moulded on the arsenopyrite. There are many examples, however, in which the arsenopyrite has not assumed crystal outlines at its contact with pyrrhotite, and here the convex boundary relations of the former to the latter mineral show the relationship. In such cases it is sometimes evident that the chalcopyrite is not so easily replaced by the invading arsenopyrite, which engulfs the surrounding pyrrhotite, encloses islands of chalcopyrite, and is indented by

[1] Berlin, 1931.

promontories of the same mineral. In cases where the arsenopyrite has not assumed the crystal form, it sometimes replaces pyrrhotite veinlets in cracks in the gangue, and sometimes also penetrates the main pyrrhotite masses in the form of short, irregular veinlets.

Near the surface in some of the workings, pyrrhotite is being replaced by irregular and rounded zoned particles of marcasite. This is the usual course of alteration of pyrrhotite masses near the water table.

In some places, particularly in the Queen Consort Section, stibnite occurs in spots which fortunately are relatively small and rare. In such places this sulphide is often far more abundant than the others, and may constitute up to 40% of the ore rock. Masses of practically pure stibnite 1 foot by 4 inches have been found. When such places are met with, the ore is stacked underground, as the stibnite, if sent to the plant, has an appreciable detrimental effect on the extraction processes.

Polished specimens of this ore show the stibnite to occur as irregular masses and veinlets interstitial to and replacing the gangue minerals, and moulded on arsenopyrite, which it does not appear to replace. It frequently occurs as veinlets along the boundaries of arsenopyrite needles. The stibnite masses generally consist of a large number of irregular interlocking grains which are strongly anisotropic, and often shew polysynthetic twinning.

Sometimes enclosed in the stibnite are small rounded grains of tetrahedrite, veinlets of which can also be seen cutting the former. This mineral has not been found elsewhere than in the areas in which stibnite occurs. A large number of specimens of the contact type of ore have been polished and examined, but nowhere has pyrite been seen. This is probably the only hydrothermal gold deposit in the country which contains no pyrite.

Gold is not often seen in polished sections, except in those cut from particularly rich selected specimens. When one considers that a 20 dwt./ton ore is regarded as rich, and that of it the gold actually makes up a very small proportion by volume, this is not surprising.

Most of the gold particles seen in the sections are in the form of rounded blebs, of average diameter about 7-10μ, with many smaller and a few larger, up to about 30μ. These are usually in the gangue minerals, and not directly associated with any sulphide. They are usually crowded on the shear planes, which are about ·5mm. to 2mm. in width. These gold particles are usually associated in the shear planes with quartz, muscovite, sericite, talc, a little calcite and biotite. It is likely that if these minute particles were enclosed in some such gangue as quartz, instead of the cleaved minerals with which they are associated, the residues in the cyanide plant would be a good deal higher than they are. In this connection it is interesting to note that:

4 µ	corresponds to a standard screen mesh of	3000/inch
6 "	" " " " " " "	2000/inch
8½"	" " " " " " "	1500/inch
13 "	" " " " " " "	1000/inch
16 "	" " " " " " "	600/inch
35 "	" " " " " " "	400/inch
46 "	" " " " " " "	300/inch

Many of these gold particles are therefore well beyond the practical grinding range, and most would not be liberated or exposed, were they not associated with minerals possessing good cleavage. There are, of course, a good many particles of size much larger than the above, as is proved by the fact that gold can sometimes be seen with the naked eye in hand specimens. The commonest, however, are such as those above described, and it must be remembered that these were seen in sections cut from selected rich ore. It is likely that many of the difficulties encountered in the treatment of gold ores in the Barberton district are due to the extremely fine state of division of the gold, which seems to be the case to a greater or lesser extent in all the mines.

Less commonly, rounded and irregular shaped blebs of gold are found enclosed in arsenopyrite. This is usually the case where the sulphide is more or less massive. Particles occurring in this way are generally larger than those enclosed in gangue, but are not so numerous. These average in diameter some 25μ.

Sometimes gold is found in veinlets cutting arsenopyrite, but this is rare. Much more common, though not often encountered, are composite grains of gold and arsenopyrite. In such cases gold particles up to 40μ in mean dimension have been seen. The junction line between the gold and arsenopyrite in these grains is usually straight, apparently being one of the arsenopyrite crystal faces. The nature of the particles is such that they suggest that deposition of the gold and arsenopyrite was more or less simultaneous, with the arsenopyrite forming a crystal face against the gold. The other boundaries of the arsenopyrite grain against the gangue are usually not crystal faces, but are irregular.

These facts indicate that the deposition of gold was more or less contemporaneous with that of arsenopyrite, though probably persisting somewhat longer. It is, at any rate, true that gold values are usually more or less proportional to the amount of arsenopyrite present in the rock.

Fig. 7 shows the probable order of deposition of the metallic minerals in the contact type of ore, the thickness of the lines indicating roughly the amount of the minerals concerned.

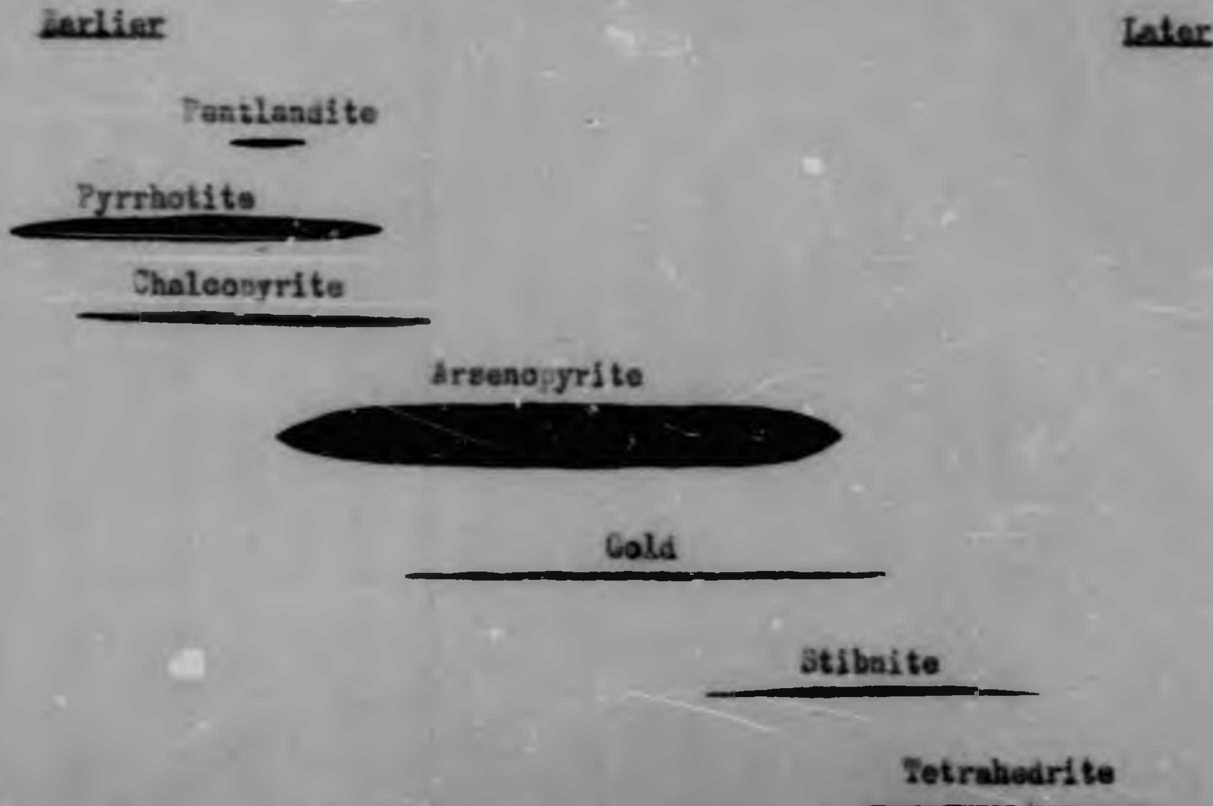
Earlier
Later
Pentlandite
Pyrrhotite
Chalcopyrite
Arsenopyrite
Gold
Stibnite
Tetrahedrite

Fig. 7

Rock Alteration

The question of alteration of the rocks surrounding these ore bodies is not quite of the usual type, since these bodies are really in the nature of a more or less intense impregnation of a shear zone. This being the case, the actual ore bodies have their upper and lower limits defined only by payable gold values. Thus the intensity of mineralisation and impregnation grades off gradually into hanging- and footwall rocks. Sulphides and gold do occur outside the ore bodies, but in small quantities. Within the ore bodies themselves there is, therefore, much material which comes under the head of altered country rock; that is, all the laminations of rock between the bands, stringers and lenses of sulphides are actually merely an intensely altered parallel of the less altered material outside the limits of the economically valuable zone.

Thus the study of country rock alteration resolves itself into an examination of the changes brought about in the "bar" and the footwall rocks by the passage of hydrothermal solutions, and this includes the gangue material within the ore zone itself. The gangue minerals in the mined ore are thus for the most part the same as those in the "wall rock".

The most noticeable effect of the passage of mineralising solutions along the "bar" itself is the introduction of tourmaline, which usually takes the form of crystals of all sizes from ·1mm. to 2mm. in length. These occasionally show crystal boundaries, but generally do not. The tourmaline is of the green-brown pleochroic and zoned schorlite variety, and seems to have been deposited at about the same time as the pyrrhotite and chalcopyrite, with which it is very frequently associated. (Cf. page 44 of this volume.) Tourmaline is replaced by the later sulphides only on very rare occasions, and then only in an incipient manner along cracks. Grains of tourmaline are sometimes enclosed in masses of sulphides. The sulphides and tourmaline are sometimes found only in the clear quartz veinlets, and sometimes only in the brown cherty layers.

Some quartz appears to have been introduced more or less throughout the period of mineralisation, and it is this quartz in the form of veinlets along shear planes which sometimes contains tourmaline and sulphides. It seems likely also that a certain amount of recrystallisation of quartz existing in the "bar" prior to mineralisation has taken place, as the grains in the mineralised "bar" usually show somewhat less strain and are larger than those in the unmineralised specimens.

The biotite, frequently including zircons, which is sometimes found in the "bar" is in general little affected, except by pyrrhotite, which tends to form veinlets in its cleavage planes.

Other minerals found in small amounts are muscovite, apatite, rutile, chloritoid, magnetite, and sericite.

It is clear, therefore, that the passage of the mineralising solutions has had but little effect on the "bar", apart from the introduction of the sulphides with accompanying tourmaline and quartz.

In the "Bastard Bar" the passage of solutions has had practically no effect on the cherty siliceous layers, and very little on the softer bands which prior to mineralisation consisted mainly of muscovite, sericite and chlorite, with a little biotite, etc. Most of the sulphides in mineralised "Bastard Bar" occur in the soft laminations together with tourmaline and some quartz. These softer green bands in mineralised specimens contain more green chlorite than do those in unmineralised examples.

Before the footwall rocks were penetrated by mineralising solutions they were sheared near the contact, and the effect of this shearing was to increase the amount of talc present.

Besides sulphides, a good deal of quartz and the same green-brown tourmaline as mentioned above have been introduced during mineralisation, replacing the pre-existing tremolite, antigorite, talc, etc. Mineralised specimens of these rocks contain a good deal of green chlorite, formed chiefly at the expense of the tremolite. Sometimes where this replacement is in its incipient stages, the tremolite needles have taken on a pale green colour, and become slightly pleochroic. Biotite is also sometimes found replacing tremolite. The other minerals present are small amounts of muscovite, sericite, epidote, zoisite, rutile, chloritoid, and magnetite.

Calcite veinlets due to a much later period of activity are sometimes found cutting the rock and replacing tremolite, chlorite, etc.

The passage of mineralising solutions through these rocks, therefore, has had very faint effects upon the minerals existing in the neighbourhood of the channels. The main result of mineralisation has been the introduction of material without bringing about drastic changes in the constitution of the surrounding rocks.

F. H. Hatch[1] gives a brief general description of the New Consort ore bodies. It must be noted in this connection that at that time it was not recognised that ore bodies of different types existed on the property, and his description refers to the "contact" type of deposit.

W.E.N. Kelly[2] also failed to notice the presence

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[1] South African Mining Journal, 1894, pp. 304-5. "Notes on the de Kaap Goldfields."

[2] Memoir of Geological, Mining and Metallurgical Conditions at New Consort Gold Mines, Ltd., dated at Noordkaap, 24 March, 1930.

of different types of ore bodies, and, at the same time, did not appear to recognise the fact that the mineralised zone is part and parcel of the two rock types, namely, the hanging wall and footwall rocks.

Hall[1] states, "the metallic compounds comprise pyrites, pyrrhotite, arsenical pyrites, and probably also antimonite, copper pyrites, and bismuth ore." One of the noteworthy features of the ore is the absence of pyrite, and while bismuth ore may be present in minute quantities, none has been observed by the present writer. Hall also describes the reef as a metamorphosed and mineralised sedimentary rock, "of which the original bedding phases can still be traced."[2] It is considered that the description given in this volume is more probable.

The gold deposits of the Barberton district have been classified by Hall[3] into two types, the second of which he calls "Impregnation reefs, with no definite hanging or footwall—Maid of de Kaap type." He describes "Impregnation reefs" as mineralised sedimentary zones that shade off into the country without clearly marked structural limitations. The Maid of de Kaap

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1Geological Survey Memoir No. 9, p. 247.

2Ibid., p. 249.

3Trans. G.S.S.A., Vol. 37, 1934. Pp. 171-204. "Mineral Wealth in the Outside Districts of the Transvaal."

Reef he describes as a black mineralised hornfels. These statements do not constitute an entirely satisfactory description of the conditions.

Photomicrographs on Plates XXXV and XXXVI illustrate specimens of the contact type of ore.

(2) The Fracture "Reefs"

General

This typo of occurrence has yielded a somewhat smaller tonnage of ore than the contact reefs. In compensation, however, the ore from the former has, in general, been of higher grade than that from the latter type. This is reflected in the tonnage and grade figures, given on page 5 of this volume, for the Maid of de Kaap and Consort Mines. Most of the ore from the former mine has apparently come from fracture "reefs", while the contact ore bodies yielded most of that from the old Consort Mine.

As already stated, the fractures which have given rise to most of the ore bodies in the Maid of de Kaap Section are usually associated with zones of minor folding. They are planes along which the relative movement between hanging- and footwall rocks, brought about by the folding, has occurred. As this folding is not intense, the series of fractures has not developed into the sheared zone characteristic of the southern part of the mine, but has gone only to the stage where there is a series of cracks and fractures in the footwall rocks, more or less parallel to the contact. The width of the zone affected is usually from 5 to 12 feet, but may exceptionally reach 30 feet. Within this zone there occurs a complex series of anastomosing fractures, branching, splitting and rejoining in a bewildering manner. Sometimes there may be four or five within a width of as many feet, and occasionally only one may be found. Talc is usually present on the fracture planes, but the rock on either side has been little affected, owing to the fact that there has been but little movement. Occasionally branches split off into the footwall for 30 to 40 feet, sometimes carrying gold all the way. In other places fractures may penetrate the "bar" and give rise to mineralisation in the overlying hanging wall rocks. This is the type of ore body known as South Reef.

A common case is that in which two or more branches coalesce at the lower contact of the "bar", which they may then follow for considerable distances. The intensity of the fracturing is usually greatest within a few feet of the "bar", often on its lower contact.

In places where the fractures are widely separated, the impregnation of the walls due to the passage of solutions along the fracture passages has not overlapped, and "channels" of waste are then included between mineralised zones.

Usually there is no "filling" in the fractures, so that the ore bodies are not veins. Sometimes in zones of abnormally intense shear, fracturing or brecciation, that is, in the vicinity of fracture intersections and splits, some quartz is found in the nature of a filling or "cement"; this, however, is always of limited distribution and meagre development.

In general, the ore bodies consist of impregnated and mineralised footwall rock on either side of a fracture, or within and outside a fractured zone. Usually the fractures are visible as cracks with slight signs of drag in the rock for an inch or so on either side, and with films of talc on the planes of movement. Impregnation of the walls may extend as much as 10 feet above and below a fracture, but the average distance is nearer 3 feet. Often the zone of impregnation on the hanging wall side extends up to, and sometimes an inch or so into, the "bar", though this is generally mineralised only when the fractures are very close to it.

In the low and medium grade ore the rock presents little or no evidence of alteration to the naked eye, but when the degree of mineralisation is high the ore can be seen to contain a considerable number of rounded blebs of arsenopyrite, averaging about 1-2mm. in diameter. These are generally irregularly and somewhat sparsely distributed. It is only in the very high grade ore in the vicinity of fracture intersections and splits that arsenopyrite becomes nearly massive. Such cases are not very common, and it is therefore a very noticeable feature that the fracture ores in general do not contain as high a proportion of arsenopyrite as do the contact ores of similar gold content. It is unusual to see layers or stringers of arsenopyrite in fracture ore, which more commonly contains this mineral as irregularly distributed blebs. In this ore, too, arsenopyrite in the acicular or "needlepoint" form is rare. It is obvious that more intense shearing, with consequent greater ease of passage for solutions and impregnation of the rock favour deposition of arsenopyrite in greater proportion, and allow the attainment of crystal forms.

Pyrrhotite can often be seen in the fracture ores, usually as a film on shear planes, and in cracks and cleavages. This mineral is often present in the absence of arsenopyrite and gold, which are generally co-existent, and which exhibit a more or less constant ratio in amount.

In the richer fracture ore bodies, ill-defined zones occur in which the mineralisation has taken an extraordinary turn. In these zones gold occurs in large amounts and is often the only "metallic" constituent. It generally occurs on the fracture planes, and has penetrated along cracks and cleavages, sometimes as much as an inch into the walls, producing an irregular zone of impregnation, in which the gold occasionally coats the walls of the shear planes for several square feet with a thin continuous film known as "paint gold". Many exceedingly beautiful specimens have been found in such areas. The only unusual feature which is observed in these zones of gold impregnation is that the rock is generally a coarse grained amphibolite, but nothing has been seen which would account for such local precipitation of gold, almost entirely without the sulphides which are elsewhere always associated with it. In the immediate vicinity of the gold-impregnated zone, the amphibolite is often more or less bleached.

It is apparent that the differences between the contact and fracture types of "reef" in mode of origin and of mineralisation, though considerable, are only really a matter of degree.

Petrography of the Ores

The gangue minerals in the fracture ores are for the most part those found in the unaltered footwall rocks. The tremolite has been little altered except in the immediate neighbourhood of the fracture planes, where a certain amount of talc has been developed. Chlorite can sometimes be found replacing tremolite and biotite in the neighbourhood of the ore minerals. Sometimes chloritisation of the tremolite gives it a definite green colour and faint pleochroism. Antigorite is common, occurring between the tremolite laths. Chloritoid occurs as lath-shaped crystals, most often seen in the antigorite masses, and biotite is common, though not plentiful except in the vicinity of the pegmatites. Magnetite as minute octahedra and as irregular grains is almost universal, as are tiny needles of rutile.

In all specimens of the ores there is a considerable amount of green-brown pleochroic tourmaline, associated with the sulphides which have impregnated the fracture walls. It generally does not show definite crystal boundaries, but is distinctly zoned, with the cores of the grains a slightly lighter colour than the edges. This mineral was apparently deposited in the earlier and higher-temperature stages of mineralisation, and is penetrated along cracks by later sulphides which are sometimes also moulded on it. Grains of biotite are sometimes bent round the tourmaline crystals. Topaz was also evidently deposited in the earlier stages, and often occurs in association with and poikilitically included by grains of sulphide. It is usually found in abnormally intensely mineralised areas. A little muscovite is found here and there, sometimes in parallel intergrowth with biotite, especially in specimens taken in the vicinity of the pegmatites. Here and there, aggrogates of epidote, zoisite and sericite have apparently been formed at the expense of felspars.

In the heavily mineralised areas at fracture intersections, etc., quartz is very common, mostly as veinlets from 1/16" to 1" in thickness. This mineral does not appear to have penetrated the fracture walls to any extent, but occurs as a filling or cement in the fractures and fracture breccia, associated with tourmaline, chlorite, biotite, rutile, topaz, muscovite, and ore minerals. It sometimes shows signs of shear along the vein, showing that movement has occurred, probably during the early stages of mineralisation. In the "closed" fractures quartz does not occur. Within and on the edges of the quartz veinlets, arsenopyrite sometimes occurs as acicular crystals up to 2mm. in length. This is the only condition in which arsenopyrite in this form is found in the fracture ores. The acicular crystalline form of arsenopyrite is evidently developed in this area where intense shearing or local brecciation have resulted in more or less freedom for growth without restriction. In such areas it is natural that mineralisation would be unusually intense. The old time miners' idea that "needlepoint" arsenopyrite was a sign of high gold values, therefore, has some sound basis.

Specimens of ore from the vicinity of pegmatites show the tremolite in course of replacement by biotite, and to a lesser extent by muscovite, which is sometimes in parallel intergrowth with the biotite. This latter, when replacing tremolite, is often optically parallel to it; that is, its cleavages in thin section are parallel to those of the grain of tremolite being replaced. Many of the veinlets of sulphides found in biotite cleavages have in this manner been "taken over" from the tremolite, which is often replaced by sulphides along its cleavages. This process can be seen in intermediate stages in many sections of the ores. In other places where the replacing biotite is not parallel with the tremolite, the cleavage veinlets of sulphides enclosed by the latter penetrate into the biotite, cutting across its cleavages. Zircons, surrounded by pleochroic haloes, are sometimes found in this biotite. These must have been introduced by the pegmatites, as they are not normally found in the amphibolite.

Calcite, evidently considerably later in age than the mineralisation, is often found as films on shear planes, and in cracks and joints.

The most abundant metallic mineral is again arsenopyrite, but, as has already been mentioned, its mode of occurrence in these ores is different from that in the contact ores. In the moderately mineralised areas arsenopyrite occurs as rounded blobs, generally more or less ovoid in shape. These usually have a mean diameter of some 1.5mm., though some up to 8mm. in diameter have been found. In polished section they can be seen to consist of aggregates of allotriomorphic individuals. The blobs almost always have "frayed" outlines, due to the presence of many minute veinlets penetrating some 50 μ into the surrounding gangue material. The growth of the blobs has evidently taken place by a process of replacement, starting from these veinlets which are generally more or less tangential to the main mass. Blobs of arsenopyrite are sometimes in contact with the other sulphides and gold, but most of them are isolated. In the more highly mineralised areas these grains of arsenopyrite sometimes coalesce to form masses which usually include particles of gangue.

Arsenopyrite in these ores often occurs as thin veinlets in cracks and cleavages in the gangue minerals. This feature is probably due to the fact that the cracks and cleavages have been "sprung" in the rock without its having been sheared on a wholesale scale, and so allowed indiscriminate growth and replacement. Similar phenomena, as will be seen later, have also affected the deposition of the gold in the same way.

Where mineralisation has been very intense; that is, where the rock has been abnormally intensely fractured and brecciated at fracture intersections and splits, arsenopyrite is found within and on the edges of quartz fillings in the needle form. The needles are about 1.5 by .15mm. This gives further support to the idea that for the development of such crystal forms the arsenopyrite requires considerable freedom for growth. Where such freedom exists, gold tends to form as more or less spherical blebs, showing that there has been little or no external control exerted over its growth. When its development is subject to external interference, it responds immediately and conforms to the openings available. Details of the occurrence of the gold under these conditions in the fracture "reefs" will be given later.

Pyrrhotite is common, though not abundant, in this type of ore. It generally occurs as thin veinlets in cracks and cleavages in the gangue minerals, often associated with lesser amounts of chalcopyrite. These two minerals seem to be of about the same age, though in these ores deposition of chalcopyrite appears to have persisted longer than was the case in the contact ores. Rarely blades of cubanite can be seen in the chalcopyrite. Elongated and oriented crystals of pentlandite can also sometimes be found enclosed in the pyrrhotite. In these ores similar relations between arsenopyrite and pyrrhotite to those in the contact ores can be observed. Here and there, however, pyrrhotite and chalcopyrite veinlets can be found cutting across blobs of arsenopyrite. This shows that there has been rather more overlap in the times of deposition of these minerals in the fractured areas than was the case in the sheared contact ore bodies.

Stibnite is said to occur in the fracture "reefs", but no specimens were found for examination. Galena was found in one place in the Ivaura A Section. As this mineral was observed in only one polished section, nothing is known about its distribution, other than that it is rare. It is evidently later than arsenopyrite, which it penetrates as thin veinlets, and whose grain boundaries are a favourite site of deposition.

Sphalerite is also occasionally found, usually associated with pyrrhotite and chalcopyrite.

Gold is occasionally found in the gangue minerals as rounded blebs of average diameter about 15 μ. Such occurrences are not common, and appear to be confined to the shear planes on the fractures. This mineral is often found associated with heavy arsenopyrite mineralisation, both as isolated particles and associated with the sulphide grains. When enclosed in arsenopyrite, the gold occurs as irregular grains and blebs ranging in size from 2μ to 30μ, and as minute veinlets from 1μ to 10μ in thickness. Much of this is liberated for extraction only by the roasting to which much of the milled ore is subjected. Some gold occurs as irregular masses interstitial to the tremolite needles. In such cases masses up to 200μ in mean dimension have been seen. The commonest mode of occurrence exhibited by gold is that of thin veinlets in tremolite and biotite cleavages and partings. In some places, particularly where gold occurs in the absence of other sulphides, these are so numerous as to impart a dull yellow colour to the rock over a width of an inch or more. These veinlets range in thickness from 4μ to 8μ and are largely liberated for solution in the reduction plant by virtue of their occurrence on cleavage planes. Sometimes more or less continuous veinlets of gold 6 to 8μ thick are found on the fracture planes.

In these ores irregular shaped particles of gold up to 30μ in average diameter are often found in intimate association with both pyrrhotite and chalcopyrite. This feature was not observed in the other ore types. In this connection it is interesting to note that pyrrhotite and chalcopyrite are often found in cleavages and on fracture planes in rock barren of gold.

Here again, pyrite was not observed in the large number of specimens examined.

Rock Alteration

It is evident from the above description that in this case, as in that of the contact ores, the question of wall rock alteration does not arise. This is due to the fact that the ore body is an ill-defined zone of impregnation which grades off in intensity into hanging- and footwall. The wall rocks are virtually those which occur outside the area in which mineralisation is sufficiently intense to constitute economically valuable ore.

"Rock alteration", therefore, can refer only to the effects produced on the pre-existing rocks by the passage of mineralising solutions; this phenomenon occurs both inside and outside the ore bodies, in different degrees of intensity, and includes the introduction of gold and other metallic minerals.

Therefore, this question has been adequately dealt with in the foregoing text.

Weber, in a private report made on specimens submitted for microscopic examination in 1932-3, mentions the presence of pyrite. Although some 100 specimens were polished and examined by the writer, no occurrences of this mineral were observed in the contact or fracture ores. In the same report, Weber described the tremolite as "non-pleochroic hornblende". He also notes the presence of bornite and covellite, neither of which were observed by the present writer. Bornite and pyrrhotite are usually mutually exclusive, while covellite is generally of supergene origin. Weber mentions also that analyses of the ores showed a trace of lead, though he observed no lead mineral in his sections. This lead is probably due to the small amount of galena occasionally present. In his report, Weber states that the mica (biotite) has varying refractive indices, other optical properties and composition, and he suggests as the reason the conjoint occurrence of muscovite and paragonite. The existence of the latter mineral is somewhat doubtful, and the peculiarities observed by Weber are probably to be accounted for by the intricate parallel intergrowth of muscovite and biotite micas, together with a certain degree of chloritisation. It is evident that the specimens sent to Weber were unfortunately selected, as his description shows that almost all of them were from abnormal spots, either near pegmatites, or in unusually intensely fractured, sheared, and consequently altered areas. He makes the common mistake of trying to deduce too much from microscopic data without the assistance of field evidence of any kind.

All previous descriptions of the Consort area show that no distinction between the "contact" and "fracture" types of ore body was observed. This is strange in view of the considerable differences exhibited between these types, as seen in the southern and northern parts of the mine, respectively.

Photomicrographs on Plate XXXVII are of specimens of fracture ores. They show the differences in the nature of mineralisation between this type and the contact type.

(3) The South "Reef"

General

Little or no South "reef" is being worked at present,[1] but a considerable tonnage was mined from ore bodies of this kind in the upper levels of the old Maid of de Kaap Mine some years ago. These workings can be seen on the geological sections, Plates V-XI. In some cases stoping was done on both the fracture "reefs" below the "bar" and the South "reef" above. Where this happened in the vicinity of the Main Reef Fault on 6 Level, the workings become somewhat complicated, especially when work has also been done on the fault plane.

[1] October, 1942.

The relation between occurrences of South "reef" and structures is similar to that between the fracture "reefs" and structures, as it seems that South "reef" is merely a local auxiliary of the fracture "reefs". In places, fractures in the footwall rocks cut at an acute angle across the "bar", and then persist along the upper contact of the latter and the hanging wall rocks. It is apparently such fractures that have given rise to South "reef" mineralisation. Nothing of the type of South "reef" has been found in those parts of the mine in which the contact type of ore has been developed.

It is a generally, though not universally, applicable rule that where South "reef" occurs the "bar" is abnormally thick, sometimes up to 100 feet, and is of a slightly different character from the normal chocolate-brown or banded type. In these areas the "bar" is generally dark grey or almost black, well-jointed, has a conchoidal fracture, a more or less vitreous lustre, and shows indistinct laminations. It is the type described on pages 48-9 of this volume as consisting almost entirely of quartz, with a slight difference of grain size in the laminations and with thin bands, stringers and chains of minute crystals of tourmaline and occasionally of biotite. It is evidently an unusually intensely silicified form. Fig. 3, Plate

XXXII, is a photomicrograph of a specimen of this type of "bar".

It is probable that certain areas, due to local weakness, were more susceptible to fracturing and silicification than others. This resulted in both the abnormal thickness and the unusually intense silicification of the "bar" at these points. By the same token the fractures in the footwall rocks in the slightly folded areas were enabled in these places to spread up into and along the hanging wall rocks near the contact. These fractures were then later mineralised to form South "reef" at the same time as were those in the footwall rocks which gave rise to the fracture "reefs". It is quite possible, of course, that this fracturing extending into the hanging wall rocks was partially responsible for the locally intense silicification. In this connection it has already been stated that the "bar" formation, folding, fracturing and metallisation were more or less continuous and overlapping processes.

Individual bodies of South "reef" have apparently never persisted for any great distance on either strike or dip, and their gold values have generally been more erratic and not as high as those of the fracture and contact "reefs". Such features would be expected from the nature of their origin, and from the fact that they occur in but slightly fractured hanging wall rocks, which at the best are not exactly favourable host rocks for hydrothermal mineralisation.

The width of the mineralised zone in bodies of South "reef" is, as would be expected, relatively small, seldom over 2 feet. In hand specimen the ore is hard, dark gray to almost black, is composed mainly of more or less fine grained vitreous quartz containing thin veinlets and flattened blebs, some 1-2mm. in mean diameter, of sulphides arranged along easily discernible fracture planes. The occurrences are generally along the upper contact of and just within the thick blackish "bar". The fracture planes are, in general, more or less parallel to the contact.

All the known occurrences of South "reef" are in the Maid of de Kaap Section of the mine. Apparently in the southern part, nearer the de Kaap Valley Granite, the relative movement induced at the contact by the folding was taken up in the shear zone in the footwall rocks; no significant fracturing extended into and along the hanging wall rocks, which were in this area deeper in the "plastic zone", and consequently less susceptible to cracking and fracturing.

Petrography of the Ores

The gangue material of these ores is that of the "bar" previously described on pages 48-9. It consists of a mosaic of more or less clear quartz in alternating laminations of finer and coarser grain, with strings of tiny crystals of green-brown tourmaline and minute remnant flakes of biotite, with chloritoid, rutile and muscovite. The tourmaline was evidently deposited in the foliation planes by the solutions which brought about the "bar" silicification and introduced the foliation veinlets of coarser quartz.

Cutting this material parallel to the foliation and lamination planes are fractures, which can be clearly seen in thin section. Along the fracture planes are strings, veinlets and aggregates of small grains of the same green-brown tourmaline. This mineral was evidently introduced in all the New Consort Mine ores by the earlier mineralising solutions, both during and after the "bar"-forming stage. Associated with the tourmaline [illegible]nlets, grains, aggregates and rounded blebs of [illegible]des, and aggregates of topaz. The veinlets and elongated crystals of sulphides have their major dimensions in and parallel to the fractures, while the rounded blebs, averaging some ½mm. x 1mm. in size, are flattened in the direction of the fracture planes. A few well-crystallised needles of arsenopyrite are found lying with their long axes in all directions in the fractures. There appears to have been little penetration of the fracture walls by the introduced minerals, though the quartz in the vicinity is coarser in grain and less strained than that in the unmineralised parts, indicating a certain degree of rearrangement and recrystallisation.

The sulphide veinlets, crystals and blebs consist almost entirely of arsenopyrite. The veinlets and crystals have sharp, clean-cut boundaries, but the blebs have "frayed" outlines similar to those found in the fracture ores, and frequently include particles of gangue minerals, generally topaz and/or tourmaline. The occurrence of arsenopyrite is limited to the fracture planes and a zone some 2mm. on each side, while the individual fractures may be ¼" to 1" apart over a width of 1 foot or so.

A little pyrrhotite, associated with a lesser amount of chalcopyrite, is always present, generally as irregular particles interstitial to the tourmaline grains, as veinlets on the fractures, and in the gangue minerals in the walls. It is mostly earlier than and subject to replacement by arsenopyrite, though in some places the two are apparently contemporaneous.

Gold is found as irregular grains ranging in mean diameter from about 15 to 25 in the fracture planes, both alone and enclosed in arsenopyrite.

Rock Alteration

The remarks on this subject in the section on the fracture "reefs" apply equally well in this case. In the case of the South "reef" there has been very little penetration of the walls of the individual fractures within the fracture zone, and the most noticeable change found is a slight increase in the grain size of the quartz mosaic. Most of the alteration associated with the mineralisation takes the form of the introduction of tourmaline, topaz, etc., and sulphides, along the fracture planes.

As the penetration of the walls (a matter of a couple of millimetres only) has been very much less in this case than in that of the fracture "reefs", the upper and lower boundaries of the mineralised zone are fairly sharp. Outside this zone no effects of the passage of the mineralising solutions as distinct from the earlier "bar"-forming solutions are visible.

No mention of the South "reef" occurrences has been made in previous literature.

(4) The Fault "Reefs"

General

These occurrences cannot really be regarded as a separate and distinctive type of mineralisation, as they are formed by the faulting of the types already described, and should therefore be regarded as a local variation of the primary ore type concerned. For convenience of description, however, they are here treated as a separate type of occurrence.

In the Maid of de Kaap Section there are several occurrences of this type, chiefly on the Main Reef Fault, as has been mentioned before.

They are commonest, however, in the Queen Consort Section of the mine, where the ore bodies have been subjected to a considerable degree of faulting. (Cf. Fig. 5, page 83.) It is mainly these occurrences in the Queen Consort Section that will be dealt with, because they offer better facilities for examination, and because the primary ore type concerned is of such nature as to simplify the determination of the main object of the examination, viz., the nature and mode of origin of the occurrences.

Where faults have cut the ore horizon in the New Consort Gold Mines, Ltd., drag phenomena are almost always present, and in the case of the Maid of de Kaap Section, oscillation on the faults has given rise to a fairly wide sheared zone, containing reef matter dragged in and crushed up. Most of the faults in the Queen Consort Section have apparently not had an oscillatory movement, and when the faulted zone on the contact had previously been mineralised, reef matter can often be traced directly from the fault block on one side, continuously through the drag area, along the fault, to the fault block on the other side. This is probably due to the faults' having taken place very shortly after the rocks had emerged from the plastic zone into the zone of fracture; that is, very shortly after mineralisation. When such phenomena are encountered, the first impressions produced are those of sharp monoclinal folds. The fault zones can, however, be found in the hanging- and footwall rocks above and below, and the fact that the faults in these areas have not been mineralised fixes their age as post-mineralisation. It is probably true that the approximate relative age of these faults, dated from the emergence of the rocks from the plastic zone, can be determined by the relative amounts of drag phenomena produced, when no other age criteria are available. Figure 5, page 83, gives a fairly good idea of the general conditions prevailing.

Where the faults have had oscillatory movements, the reef material dragged into the fault zones may occur outside the area enclosed by the contact horizons in the fault walls. This is the case on the Main Reef Fault and on several in the Queen Consort Section, for example, that illustrated in Fig. 6, page 85, in which the contact horizons on both sides of the fault zone are above the elevation of 4 Level. Naturally enough, specimens of reef matter taken from faults of this type show more evidence of crushing and shearing than do those taken from faults which have not been the sites of oscillatory movements.

As the reef material dragged into the faults is the same as that of the faulted ore bodies, it is not necessary to describe in detail the petrography of the ores in these bodies, except in so far as such features as throw light on their mode of origin are concerned.

Petrography of the Ores

The main features in which the gangue minerals in these ore bodies differ from those in the primary types are, firstly, the fact that signs of intense crushing and strain are always visible in the quartz present, and secondly, the abnormal amount of talc in the ores. The quartz in all specimens of the fault ores in which it is found shows, as is only to be expected, such characteristics as the development of a little intergranular "mortar", crushing and squeezing out, and wavy extinction to a strikingly well developed extent. The development of abnormal amounts of talc where much of the fault ore body consists of footwall rock is also to be expected. This is sometimes so far developed as to make mining of the bodies difficult, since the high talc content lessens the coherence and consequently the strength of the rock, and causes sloughing off of slabs from stope hanging- and footwalls.

The tourmaline crystals in the ores are often broken, and the parts displaced relative to one another. Such phenomena are, of course, much more marked in the case of faults having oscillatory movements than in the case of those with simple movements. Where the crystals are cracked and the parts but little displaced, the cracks are occupied by quartz, calcite (a late mineral), and sericite.

In many of the "simple" faults in the Queen Consort Section the movement has evidently been more or less gradual and "gentle", since the banded "contact" ore can be traced with its laminations practically unbroken, though somewhat thinned out, from the undisturbed area into the zone of fault reef. In such cases the attitude of the arsenopyrite needles lying with their long axes in all directions in the shear and lamination planes is retained in the still banded fault ore. Many of the needles, however, are bent, and some cracked and broken, with their component parts displaced relative to one another. The bent ones usually show wavy extinction under crossed nicols in polished section. The pyrrhotite, chalcopyrite and gold, of course, show no recognisable evidence of the distortion. Some of the arsenopyrite needles have had the sharp edges, which were exposed to the grinding action of the relative movement in the rock, rounded off so that basal sections present the appearance of flaser structure in the sheared matrix.

One specimen was found in which there was a considerable amount of pyrite. This is the only one from this mine in which pyrite was observed, and it came from a fault on 6 Level in the Queen Consort Section. Examination in polished section revealed the presence of a good deal of pyrrhotite with chalcopyrite, occurring in the usual manner as veinlets and irregular blobs, arsenopyrite in the form mainly of slightly rounded off and distorted needles, and a considerable amount of pyrite in the form of well developed cubes, pyritohedra, and combinations of both, with an average size of ½mm. The pyrite occurs in zones, some ½" wide, following the general banding of the rock, replaces pyrrhotite, and surrounds but apparently does not replace arsenopyrite.

In view of the number of sections of the ores cut and examined, it is impossible to escape the conclusion that this pyrite is considerably later than and does not belong to the main mineralisation process which gave rise to the various types of ores found in the New Consort Gold Mines, Ltd.; it cannot therefore be properly included in a description of the primary ores.

No mention of the occurrence of ore matter in fault zones on this mine has been made in previous literature.

The photomicrographs on Plate XXXVIII are of specimens of fault zone ores, and illustrate some of the features described above.

Conclusion

Classification and General

From the foregoing it is evident that the course of the mineralisation reflects a more or less continuous hydrothermal process starting at high temperatures and pressures, probably towards the end of the folding and crumpling brought about by the intrusion of the de Kaap Valley boss. Steady decrease in pressures and drop in temperatures are also reflected by the sequence of minerals deposited, though the end of the main process took place at temperatures and pressures still fairly high. Hall[1] classes this as a "contact deposit" depending for its origin on the Older Granite in whose contact aureole it occurs. In general this deposit may be classed as partially pyrometasomatic and partially hypothermal, chiefly the upper limit of the latter. Few deposits of similar type have been described.

Most of the complexity of the area is due to the folding, metamorphic and mineralisation processes caused by the de Kaap Valley Granite, superimposed upon the metamorphic effects due to the pre-existing Nelspruit Granite.

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[1]Geological Survey Memoir No. 9, p. 249.

Throughout the district the vast majority of the gold deposits may be directly attributed to the intrusion of the de Kaap Valley Granite, around whose contact they are grouped. Many of those which are not in close proximity to this intrusion are associated with structures produced by it, and are superimposed upon features which may be attributed to the Nelspruit Granite -- apparently of the same or similar age as the Swaziland Granite. Thus the major gold metallisation is due to the de Kaap Valley Granite, showing that its volatile products were of a somewhat different nature from those of the older Nelspruit and Swaziland intrusions. It seems reasonable, therefore, to assume greater differences in origin between the two granite intrusion cycles than is implied by Hall's statement,[1] "the difference between the granite of Barberton and that around Nelspruit supports the impression that special conditions of consolidation existed over the de Kaap Valley area." Further treatment of these points will be found later in the portion of this report dealing with the Sheba Section of New Consort Gold Mines, Ltd.

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[1]Geological Survey Memoir No. 9, p. 114.

Future and Exploration

The workings, particularly the stoping, near the outcrops and near the surface in general are fairly extensive, while those at greater depths are not so large. This has caused some to express the opinion that surface enrichment has been operative, and others the opinion that values in general are decreasing in depth.

The first opinion is based upon ignorance, for no signs have been found to suggest that processes of surface enrichment have affected the ore bodies, and no evidence in support of such an idea is apparent.

In connection with the idea that gold values are decreasing in depth, it must be remembered that the surface workings, or those close to surface, represent in themselves a considerable vertical range (actually about 1000 feet, even neglecting the effect of the Bluejacket Fault, and this is large in comparison with the depth of working over which gold values are supposed to be decreasing.) Also it must be borne in mind that the areas on and near surface have been subjected to more rigorous prospecting than those at depth. There appears to be no reason to suppose that gold values are decreasing as the distance from the surface increases and as the source of the mineralisation is approached, firstly on account of the nature of the deposit, seconaly because gold deposition depends upon the presence of suitable structural conditions, and thirdly because the distances examined below the present surface bear no relation to the depositional range at the time of intrusion of the de Kaap Valley Granite.

It is considered that if favourable structures of the type described are followed up in a determined and intelligent manner, there is no doubt that gold production from the New Consort Mine may continue for a considerable period. Conditions for the deposition of large and valuable ore bodies appear to be particularly favourable in the area southeast of the collar of No. 6 Shaft, and south of the Main Reef and Ivaura A bodies.

The area southeast of the collar of No. 6 Shaft could best be opened up from one or more of the lower levels of the Queen Consort Section by driving, if necessary blindly, into the area, followed by diamond drilling, and later by up- and down-dip development. In general, however, the ore bodies have greater strike than dip dimensions, and are therefore most economically exposed by direct and frequent "down-dip" development, as opposed to the past system of long drives at level intervals of 80 feet or so. Such development would also yield cheaply the information required concerning the depth of the trough of the main Consort Syncline, whose south limb appears to crop out south of the Noordkaap River.

SECTION II

New Consort Gold Mines - Sheba Section.

Section II

New Consort Gold Mines - Sheba Section

Historical

Many years ago, the group of workings, mainly in the Zwartkopje Valley, now known as the New Consort Gold Mines - Sheba Section, was a part of the old Sheba Mine, and was worked in conjunction with the group of mines in the Sheba Valley. The old Sheba Gold Mining Company went into liquidation in 1927.

After 1932, however, work in the Zwartkopje Valley was resumed as a separate concern under the name of Western Exploration (Pty.) Ltd. In 1937, the property was taken over by the Eastern Transvaal Consolidated Mines, Ltd., and has since been worked as a section of the New Consort Gold Mines, Ltd.

From 1887 to 1898 mining at Sheba was confined to the Old Sheba or Golden Quarry area, then owned by Messrs. Lewis and Marks. It was not until 1899 that mining commenced in the Zwartkopje Valley.

These workings were at one time apparently operated by separate small workers, but the early history is vague, and no records can be found. It is not possible to obtain accurate figures for the early production from the Zwartkopje Valley mines, as their records are included with those of the mines in the Sheba Valley. From January, 1887, to August, 1936, however, it is known that 1,354,547 ounces of fine gold, valued at nearly £6,000,000 had been produced from the Sheba area.

From June, 1937, to June, 1941, i.e., while operations were under the control of the Eastern Transvaal Consolidated Mines, Ltd., the New Consort Gold Mines - Sheba Section milled 203,960 tons of ore at an average grade of 5.01 dwts./ton to produce 25,257 ounces of fine gold in concentrates.

Situation, Physiography and Drainage

These workings are near the Old Sheba or Golden Quarry Mine. The position of the various workings round Sheba relative to the New Consort Mine and to Barberton can be seen by reference to Plate I. The aerial haulage transporting ore across the Sheba Hills[1] to the New Consort Mine, where the concentrator is located, is 6 miles long.

The Old Sheba or Golden Quarry Mine and its associated workings, vis., Edwin Bray, Nil Desperandum, Annie's Fortune, Orient, Mamba and Margaret, are situated on the northern slopes of the Sheba Valley, while the

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[1]This term is used in the sense in which it is employed by Hall in Geological Survey Memoir No. 9. See p. 37.

workings of the Sheba Section of New Consort Gold Mines, Ltd. are situated on the southern slopes of the same valley, in the tributary valley occupied by Snyman's Creek, and at the head of Golden Valley. These locations can be found on Plate III.

The country in and around the area in question is very highly dissected, with hill slopes in places at an angle of 50°. For the most part the hills are more or less smooth and covered by grass and sparse bush, the latter abundant and luxuriant in the creeks on the hillsides and in the valleys. The geological structure, as will be seen later, has exerted a very definite control over the physiography and the drainage.

The general drainage on the mine property is Snyman's Creek, flowing from west to east. Near the east boundary it turns northwards to join the west-to-east-flowing Sheba Creek. These united are called Fever Creek, which flows eastwards to join Figtree Creek; this, in turn, finally joins the Queen's River at Sheba Siding. The slopes of the valleys occupied by these creeks are very steep and considerably cut up by intermittent tributary streams.

The Golden Valley Creek flows in general northwards to join the Noordkaap River. The features mentioned above can best be understood by reference to Plate III.

Climate

The Sheba Section mine offices are 3400' above mean sea level, considerably higher than those of the New Consort, but the climate is much the same. In the summer the valleys, owing to the steepness of their walls, are frequently oppressively hot, while in winter, though cold snaps are experienced, the climate is generally more or less ideal.

After the heavy summer storms, which make up the greater part of the considerable annual rainfall, the creeks become for a few hours raging torrents, which may cause considerable damage to roads and other structures.

The photograph, Plate XXVIII, is a view of the Zwartkopje Valley, looking east from the head of Snyman's Creek.

Malaria fever is common in the Sheba area in summer months, though apparently not so much so as it is in the vicinity of Noordkaap.

General Geology of the Area

The area embraced by the mine property includes a conformable series of rocks, some of somewhat doubtful origin. This conformability continues through intense folding. The nature and occurrence of the rocks will be discussed in detail later. At certain horizons occur persistent beds, ranging from cherts to quartzites, which are more resistant than the intervening rocks. Tracing of these beds, which have become known as "bars", reveals very clearly the complex structures of the area.

The mine boundaries include a relatively small portion of the Sheba Hills, and a description of this part alone cannot give a true idea of the general state of affairs. Plate III is a structural and drainage map of the greater part of the Sheba Hills area. It shows mainly the bars, with some additional detail in the vicinity of the mine property. The portion of this map outside the confines of the mine boundaries has been compiled from aerial photographs and from rough reconnaisance mapping, and therefore shows little in the way of details. The positions of the bars have been marked to bring out the folded structure of the area. This plan shows strikingly clearly the control which has been exercised by the resistant bars over the drainage and general physiography.

Hall[1] has described the folded structures exhibited in the Sheba Hills, and in so far as the area north of the Sheba Bar is concerned, nothing has been noticed in the sketchy reconnaissance surveys made by the writer that would throw doubt upon his conclusions. From the Sheba Bar southwards, however, particularly within the small area enclosed by the mine boundaries, Hall's mapping as shown in his sketch on page 173 of Geological Survey Memoir No. 9 must be modified to a considerable extent.

Hall[2] has assigned the rocks in the whole of the Sheba Hills to the Moodies Series. It is believed, however, that the recent examination made by members of the staff of the Union Government Geological Survey has resulted in further subdivision, to include a portion of the rocks in what they have called the Figtree Series. This does not, in fact cannot, affect the area within the mine boundaries, and as the report of this recent work by the Geological Survey has not been published[3] no further reference to this point will be made.

The detailed work done by the writer was confined to the area shown on Plate IV, so that only general

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[1] Geological Survey Memoir No. 9, p. 170.

[2] Idem.

[3] October, 1942.

remarks can be made in connection with areas outside these limits.

The rocks within the area studied in detail are mainly black to dark gray, well bedded argillaceous types, locally called shales. There occur also persistent, hard, black and banded cherty horizons ranging in thickness from 5 to 100 feet, and commonly known as the "bars". Associated with the bars are gray talcose schists and green siliceous rocks locally known as "green schists". These rocks occur as a conformable series, and mapping of the bars therefore reveals the general structure of the area.

In his sketch[1] and on the map accompanying the Memoir, Hall has shown the Southern Cross and Zwartkopje Bars as repetitions by folding of the Sheba Bar. He has also made a statement to this effect.[2] A quite different state of affairs is shown on Plates III and IV of this work.

From Plate III it can be seen that the Sheba Bar in this area appears to end indefinitely at a point near the confluence of Fever and Figtree Creeks. Actually, as will be seen later, it becomes somewhat indefinite in places just east of the Golden Quarry.

[1]Geological Survey Memoir No. 9, p. 173.

[2]Ibid.Pp. 190, 251, 253.

South of the Sheba Bar near Figtree Creek there is found an indefinite banded ferruginous cherty horizon upon which are situated the workings of the Royal Sheba Mine. There appears to be no connection between the Sheba Bar, which where it is well developed is usually a light grayish banded chert, and the Royal Sheba Bar.

The Southern Cross Bar cannot be traced farther east than is shown on Plates III and IV. Towards the Fairview Mine in the west, the Southern Cross and Zwartkopje Bars approach one another, and finally coalesces to form a vortex, as is shown on Plate III. This fact, together with the repetition of the rocks between these bars shows that the Southern Cross and Zwartkopje Bars are one and the same horizon repeated by isoclinal folding. The Fairview Mine is situated in the disturbed area in the shales on the axis of the fold, and has not exposed any of the "bar" rocks in its workings, showing that the pitch of the fold is not low towards the west. The Zwartkopje Bar ends indefinitely at the point shown on Plate III.

South of these bars occurs that known as the Ulundi Bar, a banded ferruginous chert horizon not unlike the Royal Sheba Bar.

The most important omission in Hall's maps is that of the Hospital and Hospital North Bars and their associated rocks, shown on Plate IV. These bars are identical with, though not as persistent as, those occurring in the Southern Cross - Zwartkopje group, and are associated in the same way with an exactly similar suite of rocks. On the south contact of the Zwartkopje Bar, and on the north contact of the Southern Cross Bar there occurs a zone from 1 to 12 inches wide, in which is found strongly sheared shale such as would be produced by the relative movement consequent upon such folding as would cause the repetition of the beds seen on Plate IV. Exactly similar phenomena are found associated with the Hospital Bars. The sheared zone on the Zwartkopje Bar-shale contact is locally known as the Z.K.O. (Zwartkopje Outcrop), and when intersected by mineralised fractures is sometimes itself of economic value.

As can be seen on Plates III and IV, there is a sharp zig-zag fold in the Ulundi Bar at a point south-southeast of the Zwartkopje Shaft. This structure is not duplicated in the Zwartkopje - Southern Cross group, and it cannot be followed in the shales north of the Ulundi Bar, owing to "creep" on the hillside, and to fairly deep weathering. South of the Zwartkopje Bar, however, and due west from the Intombi Quarry, Plate IV shows the occurrence of a single black chert horizon some 20 feet thick, which exhibits a structure similar in sise and shape to that on the Ulundi Bar. The black chert horison gradually gives place eastwards to a hardened zone in the shales.

Some 300 feet east of the coordinate line x = -32000' there occurs on the Zwartkopje Bar a peculiar zone in which the chert thickness is some 90 feet, as compared with the normal thickness of 30-odd feet on either side of it. In a cross-cut underground this thickening can be seen to be due to internal isoclinal folding. Extraordinarily enough, a drive on the north contact of the bar in this area showed no abnormal disturbance.

Almost directly north of this area the Southern Cross Bar shows a peculiar structure on the outcrop. In this case underground work in the vicinity south of the Southern Cross Bar also showed no abnormalities. This structure, due to the presence of talus and to there having been a certain amount of "creep" on the hillside, cannot be sufficiently clearly seen on the outcrop to allow of its being thoroughly examined and its nature determined. It is in this vicinity that the rocks associated with the Hospital Bars appear to lose their identity on surface.

The significance of these minor structures in the Ulundi, Zwartkopje and Southern Cross Bars, and in the chert horizon just south of the Zwartkopje Bar, is difficult to see, chiefly because they cannot be followed up in the adjoining rocks either on surface or underground. It is possible that they are merely local irregularities produced by the southward bending which affects all the rocks in the Sheba Hills toward the west.

Hall[1] has described the duplication of the bars, and decided that it is produced by strike folding, as opposed to dip folding. Nothing has appeared in the recent work to throw doubt upon this general conclusion, or to suggest an alternative. He has decided also that the folding is due to the compression of a portion of the Moodies Series by the intrusion of the de Kaap and Crocodile Poort or Nelspruit Granites. This is true enough as far as it goes, but it does not tell the whole story. There are also some points of interest in connection with the folding which Hall has either missed, or failed to bring to notice.

The Woodstock Bar has apparently not been duplicated by the isoclinal folding which has affected most of the area. The next bar southwards is the hard quartzite horizon known as the Clutha Bar. This bed shows evidence of the intense pressure by a form of doubled isoclinal fold, giving rise to four duplications, viz.,

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[1]Op. cit., Pp. 172-179.

from north to south: the Joe's Luck, Baviaanskop, Intermediate, and Victory Hill Bars. South of this series, however, occurs another more or less unfolded horizon, the Sheba Bar, and next in order southwards are the Hospital North, Hospital, Southern Cross, and Zwartkopjs Bars. Direct folded relations between these can be seen only in the case of the latter two, but the general nature, occurrence and relationships of these horizons are sufficient justification for the assumption that they are one and the same horizon, duplicated by isoclinal folding more or less similar to that which has effected the duplication of the Clutha Bar. The Hospital and Hospital North Bars cannot be traced to any points where direct relationship with the Zwartkopje and Southern Cross Bars, or with one another, can be established. As has been stated before, however, in the case of the almost exactly similar Zwartkopje - Southern Cross group, a definite relation between the two bars can be shown. The occurrence of the Hospital and Hospital North Bars is somewhat puzzling, particularly toward the west where, together with their associated schist and other rocks, they appear to die out. So far, insufficient underground openings have been made to enable the position to be clarified, and accurate surface observation is not possible. Their nature, relations and associations, however, are such that the conclusion that the Zwartkopje, Southern Cross, Hospital and Hospital North Bars are merely folded repetitions of one more or less continuous horizon is amply justified. It seems possible that the indeterminate westward ending of the Hospital - Hospital North series is a partially hidden vortex which may have been brought to its present position by more or less closed oblique dip folding of the already strike-folded series. Thus the Fairview vortex of Southern Cross and Zwartkopje Bars would be merely one of two outcrops of the same strike fold vortex. If this is the case, it is possible that irregularities in the intensity of the dip folding might cause the Hospital bar to meet the Southern Cross Bar below the Insimbi workings, and then later to separate from it again, to form at greater depths the dip fold vortex which would probably have a low angle of pitch. Such a condition seems to be suggested by the work so far done on the lower levels of the Insimbi workings.

It is interesting to note here that in the north-south zone some 600 feet east of the x = -36000' co-ordinate line, both the Zwartkopje - Southern Cross and the Hospital - Hospital North groups show evidence of intricate minor isoclinal folding superimposed upon the main structure. Plate IV shows this feature.

Fig. 1 illustrates diagrammatically the hypothesis above outlined, and shows how the peculiar structures on the Southern Cross and Zwartkopje Bars some 300 feet east of the coordinate line x = -32000' might account for the indeterminate westward ending of the Hospital - Hospital North group.

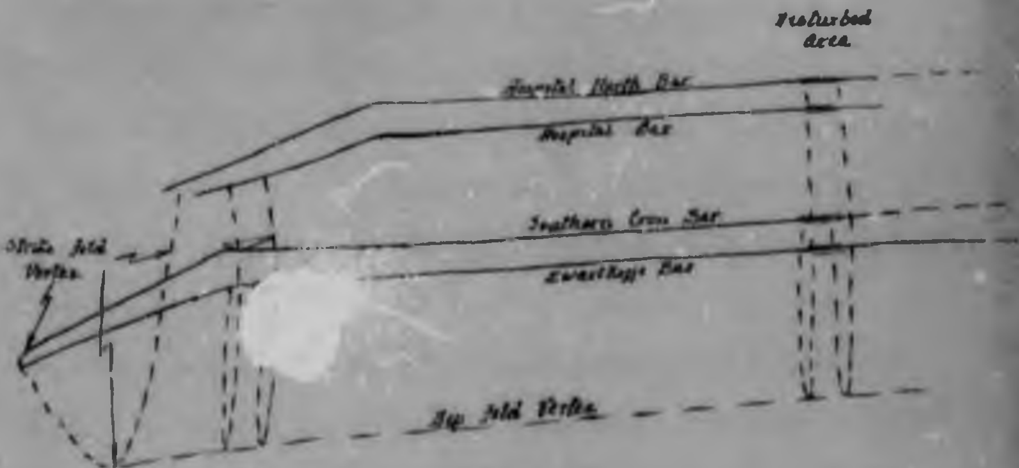

Fig. 1

South of the Zwartkopje Bar occurs the Ulundi Bar, another more or less unfolded horizon. No satisfactory explanation has been found for this apparently ordered succession of "unfolded - intensely folded - unfolded - intensely folded - unfolded" horizons. It is clear, however, that the rock mass as a whole has not been uniformly folded en masse, but different portions have been affected to different degrees.

The entire series from the Woodstock Bar through to the Ulundi Bar exhibits a distinct curvature, convex to the northwest. This feature becomes progressively more sharply defined and less gradual from northwest to southeast resulting, in the case of the Zwartkopje - Southern Cross group, in a sudden change of strike from almost true east-west to some 25° south of west, as seen on Plates III and IV. Plate I shows that south and southeast of Barberton another distinct and opposite change in strike takes place, with the result that in the Moodies Hills area southwest of the town the strike is again more nearly east-west. Local compression folds seen in the Victory Hill Bar in Golden Valley have been caused by this bending.

Readjustment of the stresses giving rise to this folding has resulted in the fractures occupied by the series of doleritic dykes seen on Plates III and IV to be lying in planes more or less radial to the curvature.

The mineralised fractures in the New Consort Gold Mine - Sheba Section are independent of the isoclinally folded structures of the rocks, and are apparently of considerably later age than most or all of this folding. Furthermore, as will be seen later, the nature and displacement of these fractures is such that they cannot have been caused by a compressive stress acting in an east-west direction. They would seem, however, to have been effected to a certain extent by the later bending, flexing and consequent relative movement described on pages 157 and 158.

Only one fault of any importance has been found in the mine area, viz., Mac's Fault, which has on the bare a normal displacement whose horizontal component is some 80 to 100 feet to the south, on the footwall or east side. This fault strikes more or less northwest-southeast, and dips at some 70-75° to the southwest. It can be traced on surface, and can be found on all the underground levels down to and including Zwartkopje 11 Level. Throughout this vertical range its dip, strike and displacement are relatively uniform. On Zwartkopje 12 Level, some 70 feet vertically below 11 Level, no sign of the usual strong break has been found, and the usual displacement is not seen in the contact horizons there exposed. So far no explanation of this condition has been found. Mac's Fault is later in age than the mineralised fractures and has itself not acted as a passage for mineralising solutions; it is therefore probably later in age than the mineralisation period.

It is evident, as will be shown later, that the system of mineralised fractures has been formed by a shearing stress acting in a north-south direction, apparently with a clockwise rotational effect, as seen looking from east to west. These stresses must have taken place after the completion of the isoclinal folding, when the rocks had emerged from the plastic zone in which this deformation took place. It is likely, therefore, that there was some lapse of time and probably some cooling off in these rocks between the periods of isoclinal folding and of fracturing. Apparently the whole rock mass was subjected to a renewed stress after the abatement of the folding movements. The general mass of rocks in the Sheba Hills area is more or less argillaceous and homogeneous, apart from the narrow zones occupied by the bars and their associated rocks. These bars and the rocks with them are structurally stronger and more competent than the s[illegible]es and fine grained, almost argillaceous quartzites containing them. It is natural, therefore, that the greater part of such fracturing as occurs would be centred around and generally associated with the bar occurrences.[1] This is, in fact, the case, and though some minor fracturing occurs well away from the bars, most of it is intimately associated with them.

Apart from the bar occurrences above described, there are found large numbers of bands and lenses of cherty and quartzitic bar material of relatively small extent, throughout the rocks in the Sheba Hills. Most

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[1]Geological Survey Memoir No. 9, p. 234.

of these occurrences are to be found in the shaly rocks south of the Sheba Bar.

In general the dip of the rocks in the Sheba Hills area is southwards and southeastwards. The Sheba Bar generally dips at about 45-60°, the Hospital Bar group at about 55-65°, and the Southern Cross - Zwartkopje group at about 65-75°. In the area enclosed by the mine boundaries east of the coordinate line x = -32000', the strike of the Zwartkopje - Southern Cross group is very steady and almost exactly east-west. To the west, of course, the strike turns more towards the southwest.

The bars in general have been the controlling factor in the development of the physiography of the area, especially in the case of the quartzite bars north of the Sheba Bar. The mountain ranges in the Sheba Hills, therefore, follow the bar structures, and such streams as cross these ranges, e.g., Golden Valley, do so along lines of weakness produced by faulting, by minor drag and compression folding, and by local thinning out of the resistant horizons. In the photograph on Plate XXVIII the range to the left of Snyman's Creek has as its "spine" the Zwartkopje - Southern Cross group of resistant rocks.

Accurate mapping in this mountainous country is somewhat difficult unless there are a fair number of underground workings or deep trenches exposing the rocks beneath the zone of weathering and "creep". An excellent illustration of this is provided in the adit on 4 Level in the Birthday Section. The portal of this adit is on the south slope of the Zwartkopje Valley, and the cross-cut goes due north to the Zwartkopje Bar. Here, as has been mentioned before, the dip is some 70° south, but where exposures on surface are found the dip is uniformly about 50° north. This feature extends some 40 feet into the adit cross-cut to a point where it can be seen to be due simply to surface creep and overturning on the south-sloping hillside.

The history of the rocks of the Sheba Hills area after deposition of a more or less conformable succession is probably more or less as follows: a portion of the Moodies (and Figtree) rocks were caught up and embraced in the intrusion of the oldest of the Old Granites, and compressed between the masses now constituting the Crocodile Poort or Nelspruit Granite in the north, and the Swaziland Granite in the south. This compression brought about the metamorphism and intense isoclinal folding found in the Sheba Hills area, probably taking place as a series of surges causing the successive stages of the folding. This compression in a north-south direction gave rise to a series of tight folds with their axes in general in an rocks beneath the zone of weathering and "creep". An excellent illustration of this is provided in the adit on 4 Level in the Birthday Section. The portal of this adit is on the south slope of the Zwartkopje Valley, and the cross-cut goes due north to the Zwartkopje Bar. Here, as has been mentioned before, the dip is some 70° south, but where exposures on surface are found the dip is uniformly about 50° north. This feature extends some 40 feet into the adit cross-cut to a point where it can be seen to be due simply to surface creep and overturning on the south-sloping hillside.

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After a further lapse, not of long duration, the injection of the de Kaap Valley boss took place. This caused a heating up of the surrounding rocks, and apparently took place as a "forcing aside" process rather than as a transgressional intrusion. This produced the southward bending of the western portion of the Sheba Hills rocks, and at the same time gave rise to the folding, and consequent shearing and fracturing, of the rocks in the Noordkaap area.

During the closing stages of the emplacement and consolidation of the de Kaap Valley Granite, the hydrothermal emanations impregnated the surrounding rocks, depositing gold, sulphides and silicates of various kinds wherever conditions happened to be favourable. Though the nature of the emanations may have varied to a certain extent from place to place, it is probable that the difference in the kinds of deposits found in different areas is due to the differences in local external conditions affecting deposition. There are, as will be seen later, certain features common to most of the deposits in the district, and such similarities are easily accounted for by the above hypothesis.

Later readjustments are probably the cause of the fractures occupied by the dykes found in the vicinity of the Sheba workings.

The Rocks Present in the Area

The Shales

Plates IV and XII-XXVI show the distribution and apparently little disturbed mode of occurrence of these rocks. They constitute by far the commonest rocks in the area included by the mine boundaries.

On the surface, these rocks are usually fairly soft, and of a brown colour due to weathering. They are very well bedded, but not sufficiently fissile to be classed as slates, and they have two perfectly developed systems of joints. These vary in dip and strike, but are generally at angles of 40-60° to one another, and to the bedding planes. Weathering accentuates the joints to depths of 100 feet or so, and near the surface perfect rudely rhombohedral-shaped joint blocks are very common.

In some areas there is found a system of strong joints striking roughly in the magnetic meridian and dipping steeply east or west. In a few cases there appears to have been a very little movement on these planes, which then constitute a variety of sheeted zone. This is evidently a late phenomenon, at least post-fracture, and probably in many cases post-mineralisation in age. This type of fractured zone or fracture is one of those used in a remarkable "theory" which has been developed in a misguided attempt to account for the gold distribution in certain areas in the Barberton district. This "theory" is virtually to the effect that there are several systems of fractures which occur over considerable areas and which are found at exactly regular intervals, to be measured to the foot by tape. These fractures, according to the "theory", apart from their occurrence at regular intervals, have a constant dip and strike, and so may be "projected" for considerable distances. (As can be seen on the maps and sections accompanying this work, the known auriferous fractures are subject to rapid and considerable changes in dip and strike.) Some of these are supposed to "bring in" the arsenopyrite along certain zones confined to the underside of others; still others are held responsible for the introduction into the ore bodies of a particular type of fine grained, massive pyrite, known as "controlling fracture pyrite", and of gold, while yet another type is regarded as the source of a green talc, and so on. According to the "theory", these various fractures need not necessarily carry their particular mineral themselves, but only introduce it into mineralised zones on other fractures. In fact, they apparently do not even need to be visible, but are "there" if the mineral concerned is present. For example, if one of the known auriferous veins or fractures is barren in some parts and mineralised in others, as is usually the case, and if in one of the mineralised zones there occurs "controlling fracture pyrite", then the mineralisation in that zone or shoot is said to have been "brought in" by a "controlling fracture", one of the types used in the "theory". In such cases the "controlling fracture" can often not be pointed out, and does not itself carry either gold or the pyrite. Intersections of the various types of "fractures" are plotted on paper, and then searched for at regular intervals. This "theory" was for a time applied at the Shebe Section of New Consort Gold Mines, Ltd., and some work was done with it as a basis. Under careful scrutiny, however, it failed to stand, in spite of, or perhaps because of, its vast and intricate ramifications and modifications. The strong north-south joints mentioned above were one of the systems of fractures used, and were known for the purposes of the "theory" as "Main Cross Fractures". They are undoubtedly sometimes found in the wall rocks of gold bearing veins in the vicinity of rich shoots, but this association is probably accidental; they are apparently a later manifestation of the zone of weakness which has been the cause of the locally intense brecciation near the vein fracture. This locally intense brecciation is often the site of intense mineralisation rich in gold. The "Main Crosses" themselves, however, do not carry gold and show no signs of ever having acted as solution channels. In fact, in some cases they can be seen to extend through the mineralised area, and to cut the vein filling.

The ramifications of the "theory" are such that it can be made to account for almost any mineralised patch or shoot without much difficulty. This "theory" has been applied to several mines in the Barberton district, generally to the disadvantage of their owners, who have in some cases become pathetically convinced of its infallibility, even while losing profits. If the discovery of rich gold bodies were as easy as the exponents of the "theory" would have it, mining in the Barberton district would be a far less risky venture than it is.

Though it is of no practical value, and is without any sound basis, this "theory" and some of its fallacies are explained here, since it has apparently been condoned by the Geological Survey in connection with the New Clutha Mine.[1] Careful and critical examination will certainly prove it to have as little value there as it had in the Sheba Section of New Consort Gold Mines, Ltd.

When fresh, the shales are black or dark gray, very well bedded rocks of shaly character. Some portions are exceedingly fine grained, while others are almost arenaceous. These types alternate in layers from

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[1] Mineral Resources of the Union of South Africa, 3rd Edition, 1940. P. 165.

1 inch to 50 feet in thickness, and do not show gradational facies, but have sharp contacts on bedding planes. The fine grained type is usually black and finely laminated, while the more coarse grained layers are a dark gray, sometimes a brownish colour, and more massive.

The folding of the rocks in the Sheba Hills by the de Kaap Granite has been the cause of a series of slide planes or fractures in the shales parallel to the bedding. These are known as "formation" fractures, and though having little displacement, are sometimes persistent either individually or as groups for considerable distances. They are in places mineralised, but owing to their being parallel to the bedding, and to their small displacement, they have but little brecciation and crushing associated with them. The shales are, of course, poor host rocks for hydrothermal mineralisation, and allow of heavy deposition only in such areas where more or less intense brecciation permits easy entry and passage of solutions. The "formation" fractures, therefore, are not usually sufficiently mineralised to be of value, though they have in many places acted as solution passages, and do occasionally show small gold values. The same applies to some joint planes which have been opened and filled with some of the vein minerals. Where "formation" fractures intersect other older fractures which usually cut across the bedding in both strike and dip, they show some little displacement, and the intersection zone is sometimes intensely mineralised, and carries high gold values. This is often the case even when the older fracture itself does not carry gold in sufficient quantities to repay mining away from the intersection zone. Such phenomena are obviously due to the locally intense crushing and brecciation of the shales, which has taken place in the vicinity of the intersection of the fractures.

The shales in general conform accurately to the general east-west strike and south dip of some 70°, and show no internal disturbance apart from the "formation" fractures, and the fold mentioned before in connection with the chert band south of the Zwartkopje Bar. This shows that in the first deformation they must have been well in their plastic zone, and folded easily as a body.

No false bedding in the coarser layers, ripple markings, or other such signs of shallow water deposition have been found.

On account of the intense folding to which the area has been subjected, it is not possible with the data available to determine with any degree of certainty the age relations of the rocks present.

In thin section the only difference between the coarse and fine grained layers in the shales is that of grain size.

The coarser grained layers consist mainly of rounded and subangular grains of very clear quartz and finely crystalline chert. These particles are mostly equidimensional and have an average diameter of 0·15mm. Those which are sensibly elongated have their longer dimensions in the bedding planes. The matrix is exceedingly fine grained and appears to consist mainly of quartz and sericite. There are present a few flakes of pale green chloritic mica and of muscovite, while there is an appreciable amount of rutile as minute needles, tiny irregular masses of brownish iron oxides, grains of hematite, and some irregular grains of what appears to be graphite.

Many of the quartz grains are cracked, and all show strain phenomena. Additional evidence that the rock has been subjected to shear and compression is provided by the fact that the matrix is curved around the quartz and chert grains. This shear and compression is probably to be attributed to the folding which has affected the area.

The fine grained layers are identical in constitution with the coarser grained parts, except that the size of the quartz and chert particles averages about 0·01 - 0·02mm., and there is a slightly higher proportion of the dark minerals. A higher proportion of the particles are elongated in the bedding planes than is the case in the coarser grained material.

The contact between the two types is very sharp, and is a bedding plane. There is apparently no gradational zone at the contact of the two types, though each displays a certain degree of variation in grain size. As a general rule there is a zone some 0·03mm. wide in the fine grained layer at the contact which is very dark coloured. This is due to a local increase in the amounts of iron oxides and graphite present.

No mass recrystallisation such as that characteristic of the Consort Mine area is evident in these rocks. This is natural enough in view of their greater distance from the intrusive granites, though this is not really enough to account for the great difference in the nature of the rocks.

In the proximity of the bars, these rocks show unmistakeably the effects of the shear due to the relative movement on the bar-shale contact, induced by the folding. Evidence of this is the rounding of the grains with resultant more lenticular shape, development of a great many shear planes, and alteration by hydrothermal solutions which have impregnated those zones effected by the shearing. These solutions have been responsible for sericitisation, removal and re-deposition, apparently as pyrite, of a good deal of the iron oxides, with consequent lightening of the colour, and the introduction of considerable amounts of calcite. The calcite has for the most part replaced the matrix, but has in many places also begun to corrode the quartz and chert grains.

Where pyrite has been deposited it is usually in the form of aggregates of pyritohedra, and in thin section these can be seen to have in places a border some 0·01mm. wide, of radiating, fibrous quartz and chloritic mica. Such borders occur on those boundaries of the pyrite masses cutting across the bedding, not on those parallel to the bedding; that is, the radiating quartz has its elongation in general parallel to the bedding.

These rocks are in general probably best called indurated shales.

Hall[1] refers to these rocks variously as "shaly carbonaceous or graphitic black rocks", "black slate" and "black shales".

Photomicrographs on Plate XXXIX are of thin sections of the shales.

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[1]Op. cit., pp. 256, 259, 260, 261.

The Bars

The bars occurring within the mine property are, from north to south: the Sheba Bar, shown in the northwest corner of the map, Plate IV; the Hospital North Bar; the Hospital Bar; the Southern Cross Bar; and the Zwartkopje Bar.

All but the Sheba Bar are usually black, black and white, or black and pale green, finely laminated chert horizons. The Sheba Bar where it occurs on the mine property is usually a gray or gray and white banded chert horizon, usually somewhat coarser in grain than the others.

The Sheba Bar occurs on the mine property over a relatively short distance on strike. Over this length it has an average thickness of some 20 feet, and dips at 50° to the southeast. Some prospecting has been done in the rocks underlying the horizon, but the only work at present[1] in progress in this area is some distance north of the bar in the fine grained shaly quartzites.

The Hospital North and Hospital Bars occur as shown on Plate IV. Their average thickness is some 10 feet. Towards the eastern part of the property they are continuous on surface, but towards the west they become

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[1]October, 1942.

lenticular and discontinuous. This is particularly so in the case of the Hospital Bar. The group of rocks including these two bars is in one place, east of the coordinate line x = -36000', affected by minor internal isoclinal folding which results in the complicated series of outcrops shown on Plate IV. On the surface these bars are conspicuous, owing to their resistant character. They are, however, not as conspicuous as the others, owing to their smaller thickness and to their discontinuous nature. For some reason, so far not known, no fractures of economic importance have been found associated with this group. This is probably the reason why they have hitherto escaped notice.

The Southern Cross Bar, within the limits of its occurrence, is continuous both on surface and underground, with the exception of one place toward the west edge of the map, Plate IV. Its thickness varies from 5 to 100 feet, but the average is about 20 feet. Its strike and dip are in general very steady, though there are small local variations, as can be seen on Plates XII - XXVI, and on Plate IV. East of the point where Snyman's Creek crosses the Zwartkopje - Southern Cross group, the Southern Cross Bar thins out and disappears. Just west of the point where the creek crosses the Southern Cross Bar, the latter shows evidence of minor isoclinal folding similar to though not as extensive as that affecting the Hospital Bar group. This phenomenon has complicated the conditions in the underground workings on the Malvina Fracture. Some 500-odd feet west of the coordinate line x = -36000', a portion of the Southern Cross Bar splits off into the overlying green "schist". The peculiar structure seen on the Southern Cross Bar some 300 feet east of coordinate line x = -32000' has already been mentioned. Near the west edge of the map, Plate IV, the Southern Cross Bar thins out and disappears, but reappears again farther west near the vortex already described.

The Zwartkopje Bar is in almost every respect similar to the Southern Cross Bar except that it persists over a greater distance on strike and does not at any point within its limits thin out and disappear, either underground or on surface. In general occurrence and in appearance it is exactly similar to the Southern Cross Bar. In fact, all four of these bars are exactly similar in nature and appearance. Such irregularities as occur on the Zwartkopje Bar have already been mentioned. Its strike and dip, like those of the Southern Cross Bar, are very steady.

An examination of the sections, Plates XII-XXVI, will convey a good idea of the general occurrence of these rocks. Their contacts against the other rocks are invariably very sharp, and in the case of the bar-shale contact there are, as has been mentioned previously, considerable signs of shear.

In the green "schists" occurring in the Hospital - Hospital North and the Zwartkopje - Southern Cross groups, there are invariably stringers and lenses of black chert identical with that of the bars. These stringers and lenses vary in length from 6 inches to 100 feet, and in thickness from ¼ inch to 5 feet. The number of such occurrences in the green "schist" decreases away from the bars, and they are not usually found extending more than half way to the gray schist. In attitude they conform to the general bedding and lamination, and by their intricate folds ranging in width from ½ inch to 4 feet show the extent and nature of the internal folding and deformation of the rocks in these groups.

Almost all of the fractures on which mining operations have been successfully conducted on the Sheba Section of New Consort Gold Mines, Ltd. are more or less directly associated with the Zwartkopje - Southern Cross group of rocks. The fact that the relative persistence, continuity, and degree of development of these bars is more or less in the following descending order: Zwartkopje Bar, Hospital North Bar, Southern Cross Bar and Hospital Bar, seems to lend some support to the hypothesis outlined in connection with Fig. 1 (page 157).

These rocks, owing to their well developed formation jointing and cleavage, occasional cross jointing and resistant nature, generally give rise to blocky outcrops, which in the case of the Zwartkopje - Southern Cross group occupy the crest of a very prominent ridge dividing the Zwartkopje and Sheba Valleys. On the outcrop they are sometimes dark, but more usually light coloured, owing to incipient bleaching and lime incrustation. Underground, however, they are almost always jet black, and the formation jointing and cleavage are clearly visible. Between joint planes the rock is massive and has a conchoidal fracture. It is very hard, though brittle. In most cases it consists of a mass of very fine grained black chert, criss-crossed by innumerable thin veinlets of clear vitreous quartz. In some places the bar material consists of alternate laminations from 1/16 inch to 1 inch wide, of black and pale green chert, while in other cases the laminations are alternately black and white, and the rock is often very handsome. The contacts of the various laminations are always very sharp.

In some cases, usually where the chert is very fine grained and jet black, it contains laminations from 1/16 inch to ½inch in thickness, which have a faint brassy "opalescence."

The chert stringers which have already been mentioned as occurring in the green "schist" are never banded, and are always black and more or less homogeneous.

One case has been found in which a chert stringer in the green "schist" underlying the Hospital Bar is black and contains vast numbers of white concretions or spheroids of average diameter about 1-1½mm. These are often flattened, occur in well defined bands in the chert, and can sometimes be seen with the naked eye to have a concentric structure.

In the shales stringers of black chert similar to that in the bars are very commonly found. These vary in thickness from 1 inch to 2 feet, and in length from 2 feet to 40 or 50 feet, and they occur always parallel to the shale bedding. Their contacts with the shale above and below are sharp, while along their length they thin out gradually and disappear. The chert band previously mentioned as occurring south of the Zwartkopje Bar and shown on Plate IV is larger than the others. Eastwards its character changes; it becomes coarser in grain and finally gives way to a hardened siliceous band in the shale. It is thus evident that the conditions which gave rise to the chert deposition on the bar horizons were locally present from time to time during the deposition of both the shales and the green "schist."

In hand specimen the black chert frequently shows faint lamination due to slight changes in grain size. In general this material consists of microcrystalline chert with an average size of individual grain ranging from 0.006 to 0.02mm. It contains a great many minute inclusions of other minerals, notably rutile, green-brown tourmaline, graphite and hematite. It is always criss-crossed in all directions by veinlets of clear quartz. These have an average thickness of some 0.06 to 0.1mm., and are evidently due to filling of cracks caused during the fracturing of the surrounding rocks, or during the folding. Most of these veinlets cut across the direction of bedding, and when the chert is fairly well laminated or foliated, due to alignment of inclusions, these veinlets bulge and branch out into and between the foliae.

In many specimens the inclusions show peculiar characteristics which would appear to suggest an organic origin for part of this material. In a great many specimens round and flattened blotches of average diameter about 0.2mm. are visible in thin section. Within these blotches the proportion of inclusions is much higher than it is in the surrounding material, and the chert within the rounded spots is much finer grained than that outside. In some places these spots are so numerous that they are in contact with one another, and the coarser and clearer chert occupies the interstitial spaces. In other places, spots of similar size and shape, but almost free of inclusions, are found. In these cases the chert in the spots has about twice the grain size of that outside.

There are invariably a great many isolated crystals of calcite present in the chert. These are usually seen in thin section as well developed diamond- or parallelogram-shaped crystals. Generally the nuclei of the calcite crystals consist of aggregates of small grains, while the borders are continuously crystalline. The centre and outer parts are in optical continuity, and the average size of the solid grains is some 0.15 to 0.2mm. Many of these grains have a chert core in the nucleus, and some of those of this type are incomplete. The skeleton crystals are usually about twice the size of the solid ones.

Pyrite as well developed crystals and as rounded grains is almost always present, and appears to have been introduced into the pre-existing cherty material. Such pyrite particles are almost always partially surrounded by a border some 0.02mm. wide of radiating fibrous quartz and chloritic mica. These borders are generally developed only on those bounderies of the pyrite which cut sharply across the chert bedding; that is, the fibres appear to be able to develop along, and not across, the chert laminations.

As has been mentioned before, some parts of the chert contain laminations which have a faint brassy colour. In thin section such specimens can be seen to contain vast numbers of spherical opaque inclusions, generally arranged parallel to the laminations. These inclusions have an average diameter of 0.002mm. and are proved by examination of polished sections to consist of pyrite. These are evidently of origin contemporaneous with that of the chert and are probably due to the action of bacteria. Chert of this type does not show the larger rounded spots described above, but does contain later calcite and pyrite crystals of the same type, and is also cut by numerous thin clear quartz veinlets.

The pale green laminations seen in many specimens of the bars, as distinct from the chert stringers in shale and green "schist", consist of chert which is freer from inclusions and coarser in grain than the black variety. Such inclusions as there are appear to consist mainly of small flakes of chloritic and white mica. Graphite and other black opaque inclusions are absent. These laminations have very sharp contacts against the black laminations with which they occur. These pale green laminations contain calcite and pyrite crystals, and are cut by quartz veinlets in the same manner as the other types.

In some places (see above) the bars consist of alternating black and white laminations. Thin sections show that the white laminæ consist of quartz. At the contacts with the black laminations this material is cherty, but there is a progressive increase in grain size inwards, and in the middle the quartz grains exhibit crenulated boundaries with a little mortar and strain phenomena, and have an average diameter of some 0.4mm. Close to the contacts with the black laminations are tiny lenses of the black chert enclosed in the white material. These lie parallel to the contacts. The mode of origin of these white laminae is difficult to see, and the only possibility which fits in with the facts would seem to be that of rapid deposition along formation cracks by hot solutions with an abnormally high silica content - so high, in fact, as almost to constitute a silica melt.

One thick chert stringer in the green "schist" underlying the Hospital Bar exhibits an unusual feature in that it contains white concretions. The chert is the usual very fine grained black type containing a great many minute inclusions of hematite, rutile, graphite, etc. It also contains round and flattened spots up to ½mm. in diameter, in which the chert grain is abnormally fine, and in which the proportion of minute dark inclusions is unusually high. Some parts of this chert, however, also contain round and slightly flattened white concretions, spheroids or oölites. The bands of chert which contain these bodies are sharply defined against those which do not, and apart from the presence of the round white bodies, show no abnormal features. The white bodies consist mainly of masses of zeolites, with occasionally some zoisite, in radiating masses. The arrangement of these minerals suggests that the development of the zeolites started at the boundaries, and from the nucleus when there is one. Many of these bodies contain round chert nuclei, while some have a nucleus consisting of a small radiating fibrous quartz spheroid, and others are only partially complete. A few of these bodies consist of alternating shells of finer and coarser chert with intervening rings of zeolites.

These bodies are obviously not in their original condition, and the zeolites have evidently replaced some other mineral. The spheroids are frequently cut by thin veinlets of quartz and calcite. These veinlets often contain also a pale green chloritic mineral, and tiny crystals of green-brown tourmaline.

It seems justifiable to conclude from the above evidence that the chert horizons (bars and others) exposed on the mine property are at least partially of organic origin. It is probable that they are due partly to the action of sulphur and silica bacteria, and partly to the activities of silica-secreting organisms. The spheroids described above may originally have been oölitic in character.

Hall's description[1] of these bars is confused to a certain extent by his correlating the Sheba Bar with the Southern Cross and Zwartkopje Bars, while the description of the microscopic features is somewhat sketchy and incomplete, and so gives no information for comparative purposes.

Photomicrographs on Plate XL are of sections of the bars.

The "Z.K.O."

This is the name given to a narrow zone of shear on the bar-shale contacts. It means "Zwartkopje Outcrop", and applies particularly to the zone on the contact of the Zwartkopje Bar and the shales. It refers here, however, to the shear zones found on the other bar-shale contacts as well, and is used to designate the rock in the zone as well as the zone itself.

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[1] Op. cit., pp. 190-191.

The Z.K.O. is found on the bar-shale contacts of all the bars on the mine property with the exception of the Sheba Bar, whose shale contact shows no such phenomenon. It will be shown later that the Z.K.O. owes its origin to shearing along the plane of weakness formed by the bar-shale contact. Its formation is due to the relative movement which has taken place at this horizon consequent upon the isoclinal folding. It has already been pointed out that Hall's interpretation[1] of the relation between the Sheba Bar and the other bars is incorrect, and that the isoclinal folding which has caused one chert horizon to give rise to the bars, from the Hospital North Bar to the Zwartkopje Bar, has evidently not affected the Sheba Bar. This statement is borne out by the fact that the relative movement which has given rise to the formation of the Z.K.O. has apparently not been active on the Sheba Bar-shale contact, which is just as much a plane of weakness as that on the Zwartkopje and other bars. In this connection it is interesting to note that the conglomerates and other rocks overlying the Sheba Bar at the Golden Quarry Mine are not present in the area shown on Plate IV. Altogether, therefore, the occurrence of the Z.K.O. lends support to the suggestion already

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[1]Op. cit., p. 173.

made to the effect that the rocks in different parts of the Sheba Hills have been affected to varying degrees by the folding, and have not been all folded together. The mechanics of the process by which this took place, however, are not apparent from date obtainable on the mine property.

The Z.K.O. is a zone of altered rock on or very close to the bar-shale contact, as explained above. It varies in width from an inch or two to 2 or 3 feet. The bar at the contact is generally not noticeably affected, and the shearing has therefore taken place within the physically weaker shale. The intensity of the alteration and other effects of the shearing decrease gradually away from the contact, but the name Z.K.O. refers to that band which is distinguishable in hand specimen. Occasionally a narrow band of shale is found just within the bar, and in such cases this appears to have been the site of most of the relative movement, and has assumed the characteristics of the Z.K.O. In some cases where mineralised fractures traverse the sheared zone, the latter is sufficiently mineralised to be of local economic value. Rarely, a branch of a mineralised fracture will follow the Z.K.O. for a short distance, and in such cases gold values are fairly good. It seems probable that the original gold discovery on surface was of this type.

This occurrence, on being followed up, proved to be impersistent, but led to the opening up of the main Zwartkopje fracture system. It is likely that it was in this way that this horizon came by its name.

The rock in the intensely sheared and altered parts is usually a soft fawny brown material, which even in hand specimen shows distinct evidence of its origin by shearing. It generally has a somewhat soapy "feel", owing to its talc content. This material does not grade off into the apparently unaltered shale, but is generally sharply defined against it. The relative movement was almost all taken up in a narrow zone, and its shearing effect within this zone was therefore very severe. The apparently unaltered shales bordering on the Z.K.O., however, do show evidence of shear, as is described on page 172 of this work.

Thin sections of the Z.K.C. proper show it to consist mainly of fine grained chloritic and sericitic matter. This material occurs as a mass of minute flakes all oriented in the direction of shear; that is, parallel to the bar-shale contact. A thin section of this rock, under crossed nicols, therefore extinguishes as a mass. There are a considerable number of minute opaque inclusions, and these have been arranged in strings, enclosing lenticular and "rolled in" masses of the rock material, thus showing quite clearly that the relative movement which has formed this rock has been considerable, and the shear intense. Here and there flakes of talc up to 0·4mm. in maximum dimension have been formed, and they invariably occur with their long dimensions in the shear planes. Quartz is fairly common in the form of lenticles flattened in the same direction. These lenticles have been so sheared and crushed that vaguely defined areas within them extinguish in irregular and shadowy manner, giving the mineral a peculiar "spotty" appearance. These particles are evidently the remains of crushed and sheared quartz and chert grains in the original shale.

Very little calcite has been introduced into this rock by the later solutions which have affected the less intensely sheared shales nearby. This is to be expec[illegible] since the nature of the material is such th[illegible]uld not be easily penetrated by solutions; [illegible]obably also the reason why mineralisation in the [illegible].R.O. is seldom intense, usually patchy, and does not persist very far.

The Green "Schists"

This is the name given to a peculiar group of rocks of which some mention has already been made. They occur in four main horizons on the mine property, and are the host rocks of some of the most important zones of mineralisation.

Plates IV and XII-XXVI show the mode of occurrence of these rocks, adjacent to the bars which separate them from the shales. The green "schists" are the most important members of the Hospital - Hospital North and Zwartkopje - Southern Cross groups, and their distribution supports the conception of isoclinal folding as the origin of the repeated succession. The four main horizons of green "schist" are therefore actually repetitions of one bed, and are persistent as far as the exposures on the mine property show. All four horizons show the same general and microscopic characteristics.

A rock of somewhat similar character underlies the Shoba Bar at the head of Golden Valley. This "schist", however, is apparently not persistent for any great distance on strike, as it is not present in the workings of the Golden Quarry Mine.

The green "schists" when fresh are usually very hard, and of a more or less siliceous character. Their nature varies greatly from place to place, as will be described later, but they have almost always a more or less bright green colour. Fresh specimens seldom exhibit such characteristics as are suggested by the name they bear locally, but such foliation as parts of them possess is accentuated by weathering which generally results in a reddish and greenish, more or less foliated outcrop.

In the Zwartkopje - Southern Cross group the south green "schist", that is, that underlying the Zwartkopje Bar, has an average thickness of some 80 to 90 feet, though variations from 40 to 150 feet do occur. The north green "schist", that is, that overlying the Southern Cross Bar, shows similar variations in thickness, but the average is somewhat smaller than that of the south "schist". The two green "schist" horizons occurring in association with the Hospital and Hospital North Bars are in general of somewhat smaller thickness than those in the Zwartkopje - Southern Cross group.

The contact between the bars and the green "schist" is invariably sharp, though exhibiting a good deal of complication due to minor drag folding, directly related, probably, to the main isoclinal folds. As has been stated before, however, lenses and stringers of bar material are almost always found in the green "schist", often as far as 40 to 50 feet from the bar contact. Similar occurrences of green "schist", however, have never, to the knowledge of the writer, been found within the bars.

The contacts of the green "schist" horizons with the intervening gray "schists" are less definite. In some cases these contacts are very sharp, but by far the more common case is that in which there occurs a transition zone anywhere from 6 inches to 10 feet in width, in which alternating laminations and lenses of the two rock types, from ½ inch to 1 foot or so in thickness, occur. Very often such transition zones show evidence of considerable shear and relative movement, and are traversed by large numbers of thin veinlets of clear vitreous and light gray, more or less opaline or cherty quartz, of which more will be said later. These veinlets are in general parallel to the contact zone.

Sometimes, as is shown on Plates XIII and XVIII, a lens of gray "schist" is found within the green. Such occurrences are apparently not common, though they are probably more so than is suggested by the relatively few openings. These lenses vary from 2 feet to 10 or 15 feet in thickness. Of much more frequent occurrence are lenses of green "schist" enclosed in the gray. Such are shown on Plates XII-XXIII. These are of thickness varying from 1 foot to 20 feet or more, and are probably of greater abundance than is shown on the Plates, since openings in the gray "schist" are not numerous. In some cases the gray "schist" encloses bodies of green "schist" which themselves enclose lenses of the gray rock, and in a few places in the upper levels of the Zwartkopje workings the gray "schist" zone contains more of the green rock in the form of thin lenses than it does of the gray. Cases have also been found in which portions of the gray "schist" branch off into the green. These may be normal stratigraphic relations, or they may be due to the tight folding which has affected the area.

The rock type most commonly found in the green "schist" zones is a pale green, very hard, more or less siliceous material. It has in general a conchoidal fracture and a dull cherty appearance. It is sometimes traversed parallel to the stratification direction by bands of white or light gray quartz of cherty appearance. These are often lenticular in form and average about ½ inch in thickness. The rock is usually also traversed in all directions by thin (1/16 inch) veinlets of later vitreous vein quartz and calcite. Mention has already been made of the fact that lenses of black chert are often found in this rock.

Thin sections show the massive pale green rock to consist mainly of irregular quartz grains, all of which show undulating extinction and other evidence of intense shearing and crushing to a marked degree. Some of the quartz grains are up to 2mm. in diameter, while others occur as aggregates of interlocking grains. All contain vast numbers of minute liquid inclusions, generally arranged in two directions at about 60° to one another. These lines of inclusions are frequently bent and curved. Mortar is often found between the quartz grains, and consists of sericite, small flakes of muscovite, a good deal of pale green chlorite, some rutile needles, and quartz. Masses of sericite, chlorite, etc. are always found interstitial to the quartz grains and along their boundaries.

There are occasionally found small fresh grains of oligoclase-andesine felspar, showing both Carlsbad and albite twinning.

Calcite and dolomite as well formed, often sound crystals, and as fine grained aggregates, replace the other minerals in all specimens to a greater or lesser extent. These minerals as well as quartz frequently occur as thin veinlets cutting across all the other minerals.

In some places aggregates, up to 1mm. across, of minute needles of rutile occur. These are usually associated with abnormally large amounts of pale green chlorite, tiny octahedra of magnetite, cubes of pyrite, and masses of sericite.

In many places the rock has a banded appearance, with bright green folia from 1/16 inch to 6 inches in thickness, parallel to the main stratification. In some cases the more or less massive rock contains many thin folia of this type close together. Bright green bands are of common occurrence in this rock, and are occasionally up to 1 foot in thickness, though they are more often about 2 inches. This material has a well developed schistosity; is bright green, fairly soft, and the folia are often covered with films of brown rutile. There is thus a gradual transition from the massive pale green rock to the foliated vivid green type. This latter is probably the source of the name, green "schist".

The transitional type in which the more or less massive rock contains layers and lenses of bright green schistose material yields in thin section information which gives a clue to the origin of these rocks. The bright green schistose laminations consist of green chlorite, sericite, flakes of muscovite and talc with a great many very thin stringers and films of minute grains of rutile. Very little quartz and calcite occur in these layers, which owe their form to intense shear combined with hydrothermal agencies. The material is so foliated and the minerals so arranged that the section extinguishes as a mass under crossed nicols. These bright green layers often contain lenticles and rounded and flattened masses of quartz, which also occasionally occurs as lenticular stringers. All these quartz masses are elongated in the direction of movement, and their nature is of considerable interest. At first sight they appear to be a coarse chert. Careful scrutiny, however, reveals that they are crushed, sheared and comminuted quartz grains and aggregates. Sometimes the outer parts of the quartz masses are very fine grained, or apparently continuous, while in other cases the whole mass has been comminuted, and the individual particles more or less rotated relative to one another, by the action of the shear. In some cases the core or nucleus can be seen to have been crushed up, but the individual particles have suffered hardly any relative rotation. Thus the crushed and comminuted character of the central portion of the grain can only be seen when it is near the extinction position. In other positions relative to the vibration directions of the polariser and analyser, the relative rotation which has affected the tiny comminuted particles is insufficient to show under crossed nicols, and the mass does not appear to be abnormal. In some cases the individual tiny particles extinguish just after one another, giving the mass as a whole an undulatory extinction. This feature is obviously the next stage after ordinary unduleting extinction in a grain which has not yet been actually crushed.

Occasionally what at first sight appears to be a mass of coarse chert shows interlocking areas in which the individual particles extinguish at nearly the same position. Such cases are evidently masses of interlocking quartz grains which have been comminuted, but in which the individual crushed grains have not been sufficiently rotated by the shearing movement to obliterate the original texture. Recrystallisation has taken place to a small extent during the crushing and shearing, so that the crushed and comminuted particles interlock with one another.

When the bright green schistose material is of fair thickness, that is, more than ¼" or so, it often contains rounded and flattened masses of quartz scattered through it. These are invariably so severely crushed as to show no sign of their original structure. Frequently, however, the soft vivid green rock contains no quartz. In a few cases, later and probably hydrothermal activity has apparently caused the solution of some of the intensely strained quartz masses, with redeposition of the silica as radiating masses of chalcedonic material. Such masses, often more or less spherulitic, are quite common in some specimens.

Thus the massive rock, without the schistose bands, shows relatively little sign of crushing; that is, such signs are limited to the undulatory extinction of the quartz and the development of a little mortar.

As the schistose, obviously intensely sheared folia are approached, the massive material shows the effects of more severe strain. In a mass of green "schist" which contains a high proportion of the soft bright green layers, the effects of shear are everywhere evident, and in some cases quartz grains and aggregates are crushed and comminuted even in the massive pale green material. This is, of course, due to the fact that the shear stresses have been relieved in the soft schistose layers, and the neighbouring rock has naturally been affected to a certain extent.

Here and there in the massive rock, grains of what is clearly microcrystalline chert of the bar type are found. This fact, together with the occurrence of the abovementioned black chert stringers in the green "schist", points to the conclusion that the succession of the rocks is: shales, bar, green "schist" parent rock, and gray schist parent rock, in that order.

It seems likely from the above that the rocks which finally became what is now locally known as the green "schist" were a sedimentary group. It would seem that this group consisted chiefly of a sandy sediment containing a good many impurities, including some ferromagnesian constituents, "black sand", and clayey material. Here and there a local resumption of the conditions giving rise to the bar deposition was the cause of the many black chert stringers. Here and there, there occurred layers or patches and lenses of more or less impure muddy material containing iron, titanium, magnesium, and aluminium minerals, in a clayey mass. These occurred sometimes as thin laminations and sometimes as layers a foot or more in thickness, and would naturally contain odd sand grains.

During folding and metamorphism the first process affecting this group after consolidation was apparently incipient recrystallisation. During the period of isoclinal folding, however, a good deal of internal movement with consequent internal stresses resulted. The intricate folding of the thin black chert stringers shows this very clearly. Naturally enough, most of the internal stresses were relieved by movement in the clayey or muddy, and mineralogically more complex layers, which were less resistant than the more massive sandy parts. This process, together with a certain amount of internal chemical reaction and recrystallisation, resulted in what are now the bright green schistose portions of the rock. The sandy layers would be less affected, with the results described above. After or during the latter part of these processes there was a stage when the rocks were affected by hydrothermal solutions which introduced quartz and carbonates in cracks, and caused a certain degree of rearrangement of the minerals in the rocks.

In places, notably near the contact with the gray schist, this last process has sometimes resulted in the almost complete replacement of the rock by sericite, carbonates, and secondary quartz. This type is fairly soft, massive, and has a colour which can best be described as "khaki". Much of the carbonate in this type is siderite, and this is probably the source of the colour.

In some places recrystallisation has completely reconstituted the rock, with the result that its original features have been completely obliterated. After the recrystallisation, which must have taken place late in the metamorphic processes, hydrothermal action has so altered the rock that the products of recrystallisation have been changed until their original nature is unrecognisable. This rock is generally more or less massive, hard, and has a very pale green colour. Lying in all directions in the massive groundmass are elongated crystals which are more or less transparent in hand specimen, and which have a darker green colour than the groundmass, and vary in length from 2mm. to 5cm.

In thin section the groundmass is seen to be composed mainly of fine grained cherty quartz with a good deal of sericite, chlorite, and rutile needles, the whole mass being dusted with minute opaque inclusions. Calcite and dolomite, the latter as isolated, generally zoned, crystals, are abundant, the calcite frequently occurring in the form of thin veinlets.

The elongated crystals are distinguished in thin section only by virtue of the fact that the microcrystalline quartz which makes up the greater part of them has a slightly coarser grain size than that in the groundmass, that the sericite is less abundant but occurs as masses, that some small flakes of muscovite are present, and that the opaque inclusions are almost completely absent. No trace of the original nature of the metacrysts remains.

No descriptions of these rocks have been found in previous literature, and the only reference to their nature which has been discovered is that made by Hall[1] wherein he states that the green "schists" are probably a form of "siliceous slate".

Photomicrographs on Plate XLI are of specimens of the green "schists".

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[1]Geological Survey Memoir No. 9, p. 256.

The Gray "Schist"

Some mention of the occurrence of this rock has already been made in the previous chapter. It occurs between the north and south green "schist" horizons in both Zwartkopje - Southern Cross and Hospital - Hospital North groups. In the former group its thickness averages about 100-110 feet. In some places it contains bands of green "schist", and in others itself occurs as bands in the green rock.

The nature of the contacts between the grey and green "schists" has already been described. In general, the former is a soft rock of gray to grayish fawn colour, and when it is normal, it is usually more or less massive, but has occasional white laminations and veinlets of calcitic material. As a rule it has a slightly soapy "feel", due to the presence of a small amount of chloritic or talcose matter. Where it has been subjected to locally intense shear, however, e.g. in the vicinity of a fault or fracture, it is usually strongly foliated, apparently talcose, and has a well developed schistosity. This type is unusually soft, and has little coherence in mine openings.

The general occurrence of this rock suggests that its shape, etc., have been largely controlled by the neighbouring harder green "schists", and that it has always been more plastic and less resistant than these rocks.

For the most part the grey rock is not schistose, except where it has been locally more intensely sheared. This occurs near faults and fractures, and in irregular zones where the relative movement due to the folding has caused it to yield.

This rock as a general rule weathers to a far greater depth than do the green "schists", and it yields, under the influence of surface processes, a soft medium brown mass of chloritic clayey material, finely divided carbonates, and iron oxides.

The gray "schist" horizon associated with the Hospital - Hospital North group is in every way similar to that occurring in the Zwartkopje - Southern Cross group, except that its variations in thickness are somewhat greater. This stratum is locally distinguished as the "soapstone" horizon, though it is strictly not a steatitic rock at all. Where roads intersect it, it is occasionally the source of some trouble during the rainy season, on account of the very slippery surface it forms when wet.

As has already been stated, there occurs under the Sheba Bar at the head of Golden Valley a stratum of green "schist". Immediately underlying this latter bed there is a belt of rock, 50 to 80 feet thick, very similar to the Zwartkopje gray "schist". This, like the green "schist", is not found in the Golden Quarry workings, and is therefore apparently not as persistent on strike as are those similar rocks occurring in association with the Zwartkopje - Southern Cross and Hospital - Hospital North groups.

In thin section the massive gray "schist" is seen to consist almost entirely of carbonates, mostly calcite with some dolomite and a little of what is apparently siderite. Calcite occurs as irregular aggregates; as masses of interlocking grains, individually up to 1mm. in diameter, forming a mosaic; as isolated crystals in quartz masses; as irregular grains interlocking with a quartz mosaic; interstitial to quartz grains; and as later thin veinlets. Dolomite generally occurs as well developed, generally zoned and often isolated crystals, while siderite occurs as irregular grains scattered indiscriminately throughout the rock.

Quartz in a fine mosaic sometimes occurs as irregular masses, as little patches, and as individual small grains enclosed in the carbonate masses.

Irregular grains and crystals of pyrite are fairly common, and are usually associated with some pale green chlorite. In the vicinity of such areas a few tiny grains of magnetite are also usually to be found.

Universal in all specimens of this rock are aggregates and stringers of minute rutile needles.

Almost all specimens of the gray "schist" are criss-crossed by veinlets of calcite and clear quartz approximately 1mm. wide, while in a few specimens veinlets, about ·01mm. wide, of a pecul[illegible] unidentified isotropic mineral are fairly common.

Universal though infrequent in the general mosaic are isolated clear grains of oligoclase-andesine felspar.

Occasional tiny crystals of pleochroic green-brown tourmaline can be found in most specimens.

Approaching a fault, fracture, or other sheared zone, the rock becomes less massive and more nearly schistose. In specimens which have not yet acquired a good schistosity, thin sectio[illegible] how the quartz grains and mosaics to have been somewhat flattened; the presence of a considerable amount of a peculiar, very nearly colourless, chloritic mineral with exceedingly low bi-refringence is also shown. This mineral usually occurs in stringers on what are probably shear or glide planes, and its elongation is generally along the directions of these planes.

Where the rock has been intensely sheared, it acquires a well defined schistosity, and it is, of course, this type which has given it its name. Specimens of this sheared type usually show in hand specimen a spotted appearance, with more or less clear spots up to 1mm. in diameter in a soft, "soapy", fine grained matrix. Examination of thin sections shows that the carbonates and quartz no longer form a mosaic, but occur as more or less isolated, rounded and flattened blobs in a matrix of the peculiar chloritic mineral described above. It is these blobs which give rise to the spotted appearance. Sometimes between two blobs or lenticles in the plane of shear there is a string of minute calcite and quartz particles, probably ground off the grains of these minerals.

Talc is rarely found as small flakes in this rock.

The carbonate and quartz grains in such sheared specimens always show such phenomena as strain shadows, etc.

It seems fairly clear that the gray "schist" is a more or less recrystallised impure carbonate rock, and that much of the recrystallisation took place at least partially under the influence of hydrothermal agencies. It is schistose and deserves its name only where it has yielded locally to intense shear, with the consequent change and reconstitution above described.

The only reference to the nature of the gray "schist" which the writer has been able to find in previous literature is that of H. Freedman.[1] He appears to regard this rock as intrusive into its neighbours, but fails to state

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[1]Private report, 1936.

whether the two occurrences in Zwartkopje - Southern Cross and Hospital - Hospital North groups are the same or two different intrusions. His conclusion is obviously erroneous, and is probably based on the fact that what appear to be "apophyses" of the gray rock occasionally extend into the green, as has been stated above. These are probably due to the effects of the folding, though it is possible that they are normal stratigraphic relations. It is evident that Freedman did not have access to microscopic data.

Figure 1 on Plate XLII is of a specimen of the gray "schist".

The Dykes

As can be seen on Plate IV, there are three dykes which cut across the rocks on the mine property. All these are practically vertical, and strike a little west of true north. This deviation in strike from true north increases gradually but progressively from the eastern to the western dykes.

The most easterly of the three has an average thickness of some 4 to 6 feet, is exposed at several points underground down to Zwartkopje 7 Level, and can be traced without much difficulty on surface, except where it is in shales on a steep hill slope.

The next dyke westwards is known as the Edwin Bray Dyke, on account of its occurrence in the Edwin Bray, or first, workings on the Sheba Bar. This dyke has an average thickness of some 25 feet on the New Consort Gold Mines - Sheba Section property, and is exposed at numerous points down to Zwartkopje 12 Level. On Zwartkopje 11 Level a branch of this intrusion some 8 inches thick is exposed.

The most westerly of the three dykes has an average thickness of roughly 30 feet, and is exposed in the Intombi, Birthday and Western Cross workings.

These intrusions weather deeply to form a soft yellowish-brown clayey material.

The point where the most westerly dyke crosses the Zwartkopje - Southern Cross group of bars and "schists" is marked by a distinct gap in the ridge formed by these rocks. This, the thickest of the three dykes, has had a minor control over the surface drainage south of the road to the Fairview Mine, as is shown on Plate IV. This dyke branches in two places: in the Intombi, and in the Western Cross workings. In the lower Intombi levels, a fairly persistent branch some 5 feet thick is exposed, about 25 feet west of and more or less parallel to the main intrusion, while in the Western Cross workings, the dyke "forks" into two practically equal parts, of which the westerly one can be easily traced, at least to the point where it intersects the Sheba Bar.

All these dykes are made up of more or less massive, fine grained, dark gray, doleritic material, and show well developed chilled margins of a light gray colour up to about 8 inches in width. The thin branch of the Edwin Bray Dyke already mentioned as exposed on Zwartkopje 11 Level is entirely made up of this light gray chilled material.

The rock in these dykes has well developed, blocky jointing parallel to and at right angles to the walls. These joints are generally filled by thin films of white calcitic and magnesitic matter.

The contacts of the dykes with the country rocks almost always carry water to a greater or lesser extent, and this results, even in the case of the deep exposures, in more or less oxidation and alteration in the vicinity of these planes. The "damming up" of surface water by the dykes often results in locally luxuriant vegetation and lines of trees along their outcrops.

The reason for the occurrence of these dyke-filled fractures, more or less radial to the later bending of the isoclinally folded rocks, has already been referred to on page 158 of this volume.

Hall[1] has discussed this point, and his conclusions

[1] Trans. Geol. Soc. of S.A., Vol. XX, 1917. Pp. 1-36. "The Contact Belt of the Older Granite."

are of similar nature to those expressed above.

The fractures and the intrusions filling them are later than, and bear no relation to the mineralised fractures, or to the processes which have led to the economic mineral deposition.[1]

C. J. Alford[2] apparently considered these dykes to be of pre-mineralisation age.

As a general rule, the dyke intrusions have had little direct effect on the wall rocks, as far as can be seen with the naked eye. Such direct effects as they do have appear to be confined for the most part to the presence of thin veinlets of soft chloritic matter in cracks in the wall rocks nearby. These effects are noticeable in the shales, the green "schists", and the gray "schists", but not in the bars, which appear to have been more or less impermeable to emanations from the intrusions. None of the country rocks show any noticeable effects of heat in the vicinity of the dykes.

Indirectly, however, the wall rocks, with the exception of the bars, have suffered considerable alteration, which is due to the effects of the move-

[1] Cf. Geological Survey Memoir No. 9, p. 235.

[2] Witwatersrand Mining and Metallurgical Review, Vol. I. 1890. No. 2. "Geological Features of the De Kaap Goldfields."

ment of meteoric waters and solutions along the dyke contacts.

Thin sections cut from specimens taken well inside the dykes show that the rocks were of a doleritic nature prior to their alteration by later, mainly meteoric but possibly partially late magmatic, solutions. Plagioclase felspar grains up to about 0·4mm. diameter constitute a considerable proportion of the rock, but they are saussuritised and replaced by calcite as fine masses and aggregates to such an extent that they are barely recognisable, and no crystal sufficiently free from alteration to allow of definite determination was found in any of the writer's sections. All that can be stated is that the plagioclase is of the predominantly calcic group. No original ferromagnesian minerals remain, though their past existence is easily enough seen; they have been completely replaced by fine masses of an almost colourless chloritic mineral with very low birefringence. These chloritic masses form pseudomorphs after pyroxenes and occasionally after amphiboles, and are easily seen in thin section under plane polarised light, on account of the fact that they only rarely contain calcite, and consist of practically pure chloritic matter.

Minute irregular grains and octahedra of magnetite are fairly common, as are small grains and aggregates of pyrite.

The rock is usually cut by thin (about 0·15mm.) veinlets of calcite, with subordinate clear quartz.

Some 4 to 6 inches from the walls of the intrusions, that is, in the inner part of the chilled border, the rock consists chiefly of a felted mass of bunches of needles, apparently plagioclase nearing completion of crystal form, under control of the albite twinning law. This mass is, of course, also highly saussuritised and to a considerable extent replaced by calcite, which, when it occurs as individuals from 0·1mm. in diameter upwards, exhibits perfect palimpsest textures of the replaced felspar groups. The ferromagnesian minerals have been replaced by chloritic matter in the same way as have those in the normal rock, the only difference being the smaller size of the chloritic pseudomorphs concerned. Magnetite and pyrite occur in these parts of the dykes in the same manner as they do in the inner, more completely crystallised parts.

Examination of sections cut from near the outer edge of the chilled margin shows this material to consist chiefly of a light brownish-grey glassy material, containing a considerable number of minute elongated crystals, probably of plagioclase felspar. This rock is to a very great extent replaced by irregular masses of calcite, quartz and the very pale chloritic mineral.

Microscopic examination of the country rocks close to the dyke contacts shows the presence of irregular masses and veinlets of the chloritic mineral already mentioned, a high degree of replacement by calcite, and an abnormal content of pyrite, pyrrhotite, and occasionally chalcopyrite in the form of small irregular masses. Farther away from the dyke contacts, the amounts of calcite and sulphides decrease rapidly, but the chlorite, in the form mostly of thin veinlets, persists for much greater distances from the intrusive.

It seems probable that the chlorite veinlets are the altered remains of veinlets of various types emanating more or less directly from the dykes. The formation of the chloritic matter in these veinlets, and in the intrusions themselves, mainly at the expense of ferro-magnesian minerals, is most probably due to late magmatic solutions, while the calcite impregnation and replacement is to be accounted for by the circulation of meteoric solutions in the fractured contact zones.

Figure 2 on Plate XLII is a photomicrograph of a specimen taken from one of these dykes.

The Ore Bodies: Their Relations

The Aerial Fracture

The occurrence of this fracture is shown on Plates IV and XII-XX.

In so far as tonnage mined is concerned, the Aerial Fracture itself has not the importance of some of the others, but from a structural point of view, an understanding of its occurrence and relations is of great value on account of its connection with the Zwartkopje Fractures, from which a very large tonnage of high grade ore has been mined.

The outcrop of the Aerial Fracture is in the shales north of the Southern Cross Bar; its strike is roughly as shown on Plate IV, and it dips south-southwest at an average of some 40°. Underground operations have shown it to have a very regular strike, and the curvature shown on the outcrop is due to the combined effects of the topography and the attitude of the fracture.

The outcrops of fractures in the shales cannot be easily traced without trenching, since the fracture filling is usually more or less insignificant, and is not recognisable on surface, particularly on a hillside, where the relations are obscured by creep and by deposits of talus.

It is probable that this fracture extends farther towards the west than is shown on the Plates, but underground exploration has not been extended farther on account of low gold values. The fracture carries payable gold values in the shales over a relatively short distance on strike, as is shown by the stoping intersected by vertical sections IJ and KL. Why the payable gold values are confined to this narrow zone is not apparent, partially, perhaps, because little information can be obtained, as the fracture has not been stoped in the shales in recent years. Both east and west of this area, development north of the Southern Cross Bar has revealed nothing of interest.

The mineralised shoot extends continuously in the shales from the outcrop to the Southern Cross Bar, and has been thoroughly stoped in this area. The average stoping width is some 40 inches.

Eastwards the extent of the fracture is uncertain, since gold values in the vicinity of the Southern Cross Bar and in the north green "schist" east of the shoot are too low to justify further development. It does seem likely, however, that the stoping and quarrying on and near the Zwartkopje Bar at the Zwartkopje Quarry are on a mineralised zone which owes its existence to the Aerial Fracture, or one or more of its branches. As this area strictly falls within the province of the Zwartkopje workings, it will be more fully dealt with later. It is shown on section AB (Plate XII.)

As the Aerial Fracture approaches the Southern Cross Bar down dip, it splits into two and sometimes three branches. This characteristic is shown on the sections, particularly on Plate XVI. The various branches cut the bar and pass into the north green "schist", and thence through the gray "schist" towards the Zwartkopje Bar, each of them exhibiting a tendency in the "schist" zone to split up into several branches. In some cases two or more of the primary branches have been exposed and followed. [illegible] the uppermost has been stoped to a considerable [illegible] in the north green "schist", and even in the gray "schist" zone, which is unusual. In this case it is probably due to the fact that in this area the gray "schist" zone contains as bands and lenses a high proportion of the green rock, which is the host of almost all the economic mineralisation in the "schist" zone.

All the fractures in this region show a marked tendency to suffer "refraction" on passage from one rock type to another with different physical properties. This is only to be expected, but is evidenced in a very striking manner in the case of fractures passing from green to gray "schist", and vice versa. This "refraction" does not affect the strike to the extent to which vince of the Zwartkopje workings, it will be more fully dealt with later. It is shown on section AB (Plate XII.)

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All the fractures in this region show a marked tendency to suffer "refraction" on passage from one rock type to another with different physical properties. This is only to be expected, but is evidenced in a very striking manner in the case of fractures passing from green to gray "schist", and vice versa. This "refraction" does not affect the strike to the extent to which it does the dip, and the fractures generally have a much smaller dip in the green "schist" than they do in the gray. This phenomenon is to be explained by the tendency of the green "schist" to fracture cleanly along the smallest possible distance across its thickness, and that of the gray "schist" to slide and shear vaguely in any direction, but predominantly along its "stratification" direction.

All the branches of the Aerial Fracture, like other fractures which will be described later, are the sites of a marked displacement on their wall rocks. This, of course, can be seen by the drag evident in the shales and "schists", but most clearly on the bar horizons. The bars generally fracture "clean", brecciate to a very small extent, and seldom show the effects of drag. The displacement of all south-dipping fractures in the area is normal, as can be seen on the Plates, and ranges from 5 feet to 80 feet. In the case of the branches of the Aerial Fracture, it is generally from 5 feet to, exceptionally, as much as 40 feet, horizontally along the fracture strike.

It is obvious that the line of intersection of the Aerial Fracture zone and the Southern Cross Bar will have a more or less flat westerly pitch, and this state of affairs is brought out by a glance at the sections.

Plates XV to XXIII. In the area west of section OP (Plate XIX) the Aerial Fracture is not definitely known to occur on or near surface, but the fractures related to it and occurring in the "schist" group in the Zwartkopje workings are known to persist much farther down the westerly pitching Aerial Fracture-bar-"schist" group intersection zone. This can be seen on Plates XX-XXIII.

These fractures constitute what is known as the Zwartkopje system. H. Freedman[1] has stated that after the fractures have passed through the gray "schist" from the south green, they enter more green "schist", and the values reappear. In this connection note the reference on the next page to another statement he has made in the same report.

The Zwartkopje Fractures

This system of fractures has yielded at least as large a tonnage of ore as has any other fracture or system of fractures on the property, and the gold content of the ore mined from this system has probably not been surpassed by that mined from any other.

The stoping on this system of fractures is confined almost entirely to that part of it which is included by

[1]Private report, 1930.

the south green "schist", though a small proportion is in the Zwartkopje Bar, and in the shales a few feet south of the bar. The Zwartkopje workings are not on any one fracture, but are on a series of fractures which, with the exception of one, the lowest or Main Haulage Fracture, can be shown to be directly related to the Aerial Fracture. The Main Haulage Fracture, that is, that which is exposed for some distance along the 7 Level bar drive, has been followed up to the Southern Cross Bar (see Plate XIX), and no direct relation between this and the Aerial Fracture is apparent. (H. Freedman[1] states that the fractures have not been proved to extend beyond the gray "schist" from the south green.) It does, however, have all the characteristics common to the other Zwartkopje fractures, and on further exploration would probably be found to be a branch splitting off the Aerial Fracture nearer to surface. Plates XVII-XXIII illustrate the conditions applying.

The general trend in the Zwartkopje workings has a flat westerly pitch, parallelling, as would be expected, the intersection zone of the Aerial Fracture system and the bar-"schist" group. At first sight, the Zwartkopje workings would seem to be on a system of independent fractures, and the stopes on the various individuals

[1]Private report, 1936.

appear to be successively off-set towards the west on the lower members of the group. Careful examination, and the preparation of the series of vertical sections, however, leads to the explanation outlined above.

The eastern end of the Zwartkopje workings is the discovery site of these ore bodies, and now forms the Zwartkopje Quarry. At this point and some distance towards the west, the stoping, some 6 to 8 feet wide, is in and under the Zwartkopje Bar, and not across the south green "schist". This is due to the habit of some of the fractures of turning down on approaching the bar, and then following down the bar itself, or the bar-green "schist" contact for some distance. This characteristic is also shown at a lower level, as can be seen on Plates XIII-XVI.

When the Aerial Fracture system passes from the north shales through the bar-"schist" group, it splits into many branches, and becomes highly complex, each individual itself often splitting up. The branches sometimes rejoin lower down, and the system is complicated by the presence of complementary north-dipping, more or less impersistent, fractures such as are shown stoped out on Plates XVII, and XIX to XXII. Hall's description[1] of the Zwartkopje shows that no general

[1]Geological Survey Memoir No. 9, page 255.

inter-relationship of the fractures was recognised. Most of these branches show the "refraction" feature already referred to, when they pass from one rock type to another, and the main changes in dip and strike take place in the vicinity of the Zwartkopje Bar.

Some of the main fractures pass straight through the bar into the shales, but a great many tend to turn down into, or along the footwall contact of, the bar. Others steepen considerably when they approach the bar, while others flatten, for example, the Main Haulage Fracture. In some cases the fractures flatten on approaching the bar, through which they then cut, to turn up and assume a north dip in the south shales; in others the fractures split up into several branches immediately they enter the shales. The conditions described are best understood by reference to Plates XIII-XXIII. All those fractures which actually cut the Zwartkopje Bar have on it a normal displacement of some 5 to 30 feet.

The complementary north-dipping fractures do not as a general rule persist on strike for more than 150 feet or so, and these have a reverse displacement on the bar, usually of the order of 5 to 10 feet.

The relations between the north- and south-dipping fractures are such as would be expected from a complementary system in which one member is far more strongly developed than the other; that is, the north-dipping fractures are definitely subordinate to the main south-dipping ones, and are generally bounded approximately along strike lines by the latter. Sometimes the north-dipping fractures seem to branch off the main south-dipping ones, which they also occasionally, but very rarely, cut and displace. In some cases the complementary systems are so developed as to result in a step-like succession of fractures in the green "schist".

Towarde the west, the whole system gradually dies out until no further trace of it can be followed west of the section line YZ (Plate XXIV.)

A great deal of stoping and development has been done on this highly complicated system of fractures, and on each fracture the stoping is naturally somewhat irregular, as the gold values are by no means consistent. The ultimate result is that the workings are a veritable labyrinth, which must be very carefully studied before any semblance of order emerges from the apparent chaos. As the sections show, however, the ore bodies belong to a definite, and by no means chaotic, system, and almost every one can be shown to be directly related to the others. A generalised view of the Zwartkopje "shoot" is that of a broad wedge, with the apex at surface at the Zwartkopje Quarry. Here the extent of the work on strike is a few feet, while the lowest fracture in the system, the Main Haulage Fracture, has been continuously stoped for some 900 feet along the strike. The "shoot", however, consists, of course, of a series of overlapping and off-set ore bodies which are directly interconnected and inter-related, usually north of the ore zone which is within the south green "schist".

Most of the ore has been mined from the overlapping system of south-dipping fractures in the south green "schist". These have dips varying from 20 to 55°, and are often stoped continuously on dip from the bar to the green-grey "schist" contact. As can be seen on the sections, however, many of the fractures have been mined from the bar into the green "schist", but not all the way to the gray "schist". Many of these fractures turn down into or under the Zwartkopje Bar, and in several cases the stoping has followed them down, with such results as are shown on Plates XII-XVI. In general, stopes on a single fairly well mineralised south-dipping fracture in the green "schist" have widths of from 40 inches to 15 feet, averaging some 5 to 8 feet. Where the stoping is in or just under the bar, its width is usually about 8 to 10 feet.

In many cases the fractures pass straight through the bar into the south shales, and in such cases they have occasionally been stoped continuously through the bar into the shales. No definite rule can be stated in regard to the variation of gold values in passing from green "schist" into shale except that values south of the bar are generally not as high as those north of it.

The Main Haulage Fracture turns up after passing through the Zwartkopje Bar on 7 Level, to assume a north dip. This part of the fracture has been stoped some 30 to 50 feet into the shales for some 600 feet on strike.[1] (See Plates XIX-XXII.)

A few of the north-dipping fractures have been stoped to some extent, and in some cases have yielded high grade ore. In general, however, they do not constitute the potential value which the south-dipping fractures do. This is, of course, due to their smaller number and comparatively weak development. At the intersection of north and south fractures, great chambers have sometimes been stoped out. This is accounted for by the fact that the country rock has been far more intensely crushed, brecciated, shattered and strained in such areas than is the case near a single fracture, and that a certain degree of stagnation of solutions will occur at such points. These conditions promote more intense solution, replacement and deposition, with consequent more intense metallisation. It seems

[1] Cf. the sketch on page 256 of Geological Survey Memoir No. 9.

likely that unrelieved internal strain in the wall rocks is one of the main factors promoting these processes. Nothing of the nature of the condition shown by Hall in Fig. 23 on page 259[1] has been seen by the writer.

The same remarks apply to areas in the vicinity of splits in a south fracture, and here the abnormally intense strain and brecciation have resulted in such mineralisation that the stopes have assumed the proportions of tremendous chambers. (One near the collar of the Zwartkopje sub-incline shaft has a width perpendicular to the fracture dip of at least 40 feet, a length down dip of 70 to 80 feet, and a strike dimension of 200 feet or more.)

There are some places in the Zwartkopje workings where only the intersection zone of two fractures has been stoped, the ore bodies away from the zone being too low in grade to repay mining and treatment.

The fractures shown on the plan, Plate IV, and on the sections, Plates XII-XXVI, do not, of course, represent the sum total of those present in the Zwartkopje area by any means; those shown are those which have been mined, or are otherwise of importance. There are many more, generally of small known length on strike and dip, which carry little or no gold, and have

[1]Geological Survey Memoir No. 9.

therefore not been mined. It is possible that some of these may carry gold in payable quantities where they are not exposed, but they generally do not warrant opening up, and besides, there are too many for them all to be examined thoroughly without more encouragement than they offer.

As has already been stated, most of the fractures have been stoped right up to the green-gray "schist" contact. The gray "schist" itself is apparently inert, and is almost never the site of economically important mineralisation. The reason for this is probably partially chemical, but mainly physical. It is possible that there is some chemical characteristic which inhibits mineralisation of the economic kind in the gray "schist", but whereas fracturing of the green "schist" seems always to be accompanied by more or less crushing, shattering and brecciation, the gray "schist" appears to yield rather by internal folding, deformation and shearing, so that opportunities for impregnation and replacement in the latter rock are rarely anything but poor. At the same time there would seem to be some chemical characteristic, of parts at least, of the green "schist" which promotes impregnation and replacement by hydrothermal solutions, with consequent economically valuable mineral deposition. Fig. 2 illustrates the conditions found on one important fracture in the region of displacement of the green-gray "schist" contact.

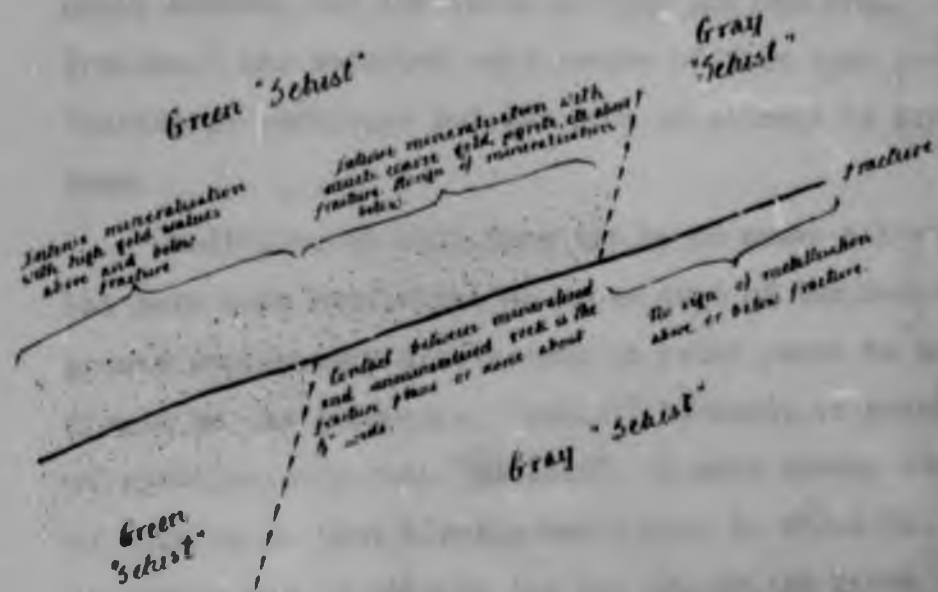

Fig. 2 (Scale about 1" = 5')

As a consequence of the abovementioned factors, there appears to have been in some cases a sort of "damming up" process active in the vicinity of the fractures at and near the green-gray "schist" contact. This has resulted in fabulously high gold values for a few feet south of the contact, and in the conditions shown in Fig. 2. Such conditions may in part be due to the fact that the fractures in the gray "schist" are "tight", and tend to slow up movement of the solutions with consequent stagnation near the contact. A condition of this sort combined with the greater amenability of the strained, crushed and brecciated green "schist" to replacement and impregnation, and the inhibition of these processes by the gray "schist" would account for the facts as they are observed. H. Freedman[1] has reported occurrences of this type in the Zwartkopje workings, but has made no attempt to explain them.

Conditions of this type are by no means universal, but have been sufficient to cause some of the underground exploratory development in later years to be placed on the green-gray "schist" contact, in search of spectacularly rich "pockets". A more common state of affairs is that already mentioned, in which the fractures are payable on the bar and in the green "schist", but not in the vicinity of the green-gray "schist" contact. It is, therefore, more logical to place exploratory development on or near the Zwartkopje Bar-green "schist" contact, because if a mineralised fracture is intersected, it can be followed up dip to the gray "schist", whereas in the other method, a barren fracture intersected in the drive may mean anything or nothing, and it is in any case easier to raise up a fracture than to winze down it.

Local very rich pockets such as are occasionally found on or near the green-gray "schist" contact have been the subject of much juggling on the part of the

[1]Private report, 1936.

"Controlling Fracture Theory" exponents, in an effort to account for them after they have been exposed. The occurrence of these pockets has, however, been predicted on the basis of this "theory" on singularly rare occasions.

In some places a band or lens of green "schist" up to 10 or 15 feet in thickness has been found in the gray "schist" close to the contact. In such cases the gold values on a fracture stop short at the contact, but if the fracture is followed up into the lens of green "schist", high values over a short distance on dip may again be found. Such occurrences have been the source of a considerable tonnage of ore reclaimed from the old workings, which stopped at the green-gray "schist" contact.

It seems perfectly likely that gold values would be found in the north green "schist" on a fracture which has been stoped in the rocks south of the gray "schist". For this reason the Main Haulage Fracture has been followed by a raise through the gray "schist" into the north green and to the Southern Cross Bar. This venture has so far had no success, but in view of the fact that fractures such as the Aerial, Malvina, and Insimbi penetrate the gray "schist" and carry payable values in the green "schist" and shales north of it, this principle should be followed up and vigorously examined, because, as can be seen in the sections, several of the south-dipping fractures in the Zwartkopje workings offer opportunities for such exploration.

In the lower levels of the Zwartkopje Section, where much of the development is on the green-gray "schist" contact, south- and north-dipping fractures of a type similar to those mined above 7 Level have been intersected. Most of these, as can be seen by reference to Plates XVIII-XXIV, are apparently not directly related to the Aerial system, though some of them, for example, a few of those shown on Plates XXI and XXII, undoubtedly are. The great majority of the fractures exposed in these lower levels are barren, and it seems probable that development along the lines of that conducted on these lower levels should be reduced in extent, and the energy devoted to searching for some such occurrence as that mined above 7 Level. Further reference to this point will be made later in connection with the Insimbi Fracture.

The ore bodies on the green "schist" have indefinite upper and lower limits, and in these directions are bounded only by the passage from payable to unpayable gold content. The fractures, even the largest and most persistent, are often visible only as cracks, while sometimes they have a quartz filling which is seldom more than 3 inches thick. This quartz is usually clear, vitreous, has a dark gray colour, and seldom contains much in the way of sulphide or other metallic minerals, which tend to occur rather as disseminations in the green "schist" walls to a distance of 3 to 15 feet from the fracture. Gold is sometimes visible in the form of irregular grains and nuggets up to ½ inch or, rarely, as much as 1 inch in diameter. Pyrite and arsenopyrite, usually as minute needles, with a little pyrrhotite, are the sulphides most commonly found.

In the shales the fractures invariably contain a filling, from ½ inch to 6 inches in width, and composed of white quartz and carbonates, with a little sulphide as grains and masses. The sulphides also occur finely disseminated in the wall rocks.

The same fracture can often be followed directly along a stope face from the green "schist" to the shales, and the transition from the one type of mineralisation to the other is as abrupt as the change of wall rock. In the bar the fractures are generally a narrow crack with sulphides disseminated a few inches on each side.

A state of affairs such as that described above is almost undoubtedly caused mainly by the chemical nature of the fracture walls, but partially also by the degree of "effective permeability" of the wall rocks. The "effective permeability" depends upon the degree of brecciation and amount of residual strain, the extent of the movement on the fracture plane, the degree of plasticity, and the general physical and petrological charecteristics of the wall rocks. These factors control the extent to which the fracture zone is filled with gouge or similar material.

The Z.K.O.

A few tons of ore have been mined from this horizon on the Zwartkopje Bar-shale contact in the Zwartkopje, Z.K. Fissure, and Birthday Sections. (See Plate XXVI.) For the most part it has been of low grade and narrow width.

This horizon in itself has not acted as a passage for mineralising solutions, and carries sulphides and gold only in the vicinity of its intersection by an auriferous fracture. Where one of the gold bearing fractures passes through the Z.K.O. horizon, impregnation has extended up and down the latter in some cases for 30 or 40 feet. Occasionally such impregnations carry enough gold to repay mining and treatment, but generally they contain scattered pyrite grains and very little gold.

Where one of the fractures turns down in the bar near the Z.K.O., the latter is sometimes of economic value over greater areas. Generally speaking, however, this horizon is of very little value, and is of purely incidental importance, not, in most cases, to be deliberately followed and explored.

The Insimbi Fracture

With the exception of the Intombi, this has been the source of a larger tonnage of ore than any other single fracture. It has been worked since the early days, and was discovered on the outcrop on the south side of the Sheba Valley, somewhere west of the Edwin Bray Dyke. The nature of the original surface showing is not known, but it is likely that it was discovered by panning up the hillside, since these fractures usually have no conspicuous or recognisable outcrop, except perhaps in an area washed clean of soil by heavy rains. The occurrence of this fracture is shown on Plates IV and XXI-XXVI.

Its general occurrence and attitude are very similar to those of the Aerial Fracture, except that its strike deviates a little farther from east-west, and it is less regular in dip. A good deal more is known about the occurrence and mineralisation of this fracture in the shales than is the case with the Aerial Fracture, since the former has been recently worked in this zone, and is, in fact, still being so worked.[1]

The Insimbi Fracture has been thoroughly opened up and almost completely stoped out in the shales from surface to the seventh level, and from the Hospital Bar group to the Edwin Bray Dyke.

Below 7 Level the values have not been so consistent, and so far only isolated spots have been stoped. The area so worked is more or less a truncated triangle with its base on the outcrop, and its apex on or just below 10 Level, in the vicinity of section A_1B_1 (Plate XIV.) Down to 7 Level the fracture has been almost continuously worked up to the Hospital Bar, or the "soapstone", where the bar or bar and green "schist" are absent. When it enters the "soapstone", that is, the gray "schist" horizon in the Hospital - Hospital North Bar group, the Insimbi Fracture seems to turn more or less parallel with the stratification, and becomes so indistinct that it cannot be followed with any degree of certainty. Several attempts have been made to discover whether the fracture passes through the "schist" group into the shales to the north, and if so, where. These attempts have been made on surface as is shown by the trenches marked on Plate IV, and underground by driving westwards in the shales

[1]October, 1942.

north of the Hospital North Bar. These attempts have had no success, and the conclusion is that if the fracture does cut through this group of bars and "schists" it must first go for some distance parallel to the stratification before emerging into the shales on the north side. It does seem possible, however, that it does not emerge, and that the movement on the fracture plane has been absorbed by internal shearing and deformation in the "soapstone".

On the east side the workings in the shales down to 5 Level and against the Edwin Bray Dyke, which is here very deeply weathered and somewhat difficult to drive through. Thus there is a triangular-shaped block of ground on the fracture east of the Edwin Bray Dyke and north of the Southern Cross Bar which has not been opened up. Though apparently no values were found on the outcrop, this block is of considerable extent, and should be examined. Below 5 Level on the east side, the Insimbi Fracture has been stoped to the Southern Cross Bar down to 7 Level.

The Hospital - Hospital North Bar group in this area has a relatively flat dip, and converges on the Southern Cross Bar. For this reason the line of intersection of the former group of bars and "schists" and the Insimbi Fracture lies almost directly down the dip of the fracture. In the case of the Southern Cross Bar, with its steep dip, the line of intersection with the fracture pitches westwards at some 35°. Thus the apparent end of the Insimbi Fracture in the shales would appear to be at or just below 10 Level on the section line A_1B_1 (Plate XXV.) Attempts have been made to open up the Insimbi Fracture in this area, with little success; the fracture is irregular, and is one of several, while the Southern Cross Bar and the Hospital Bar appear in unexpected places. This would be due to the disturbance in this vicinity referred to in the chapter on the General Geology of the Area. Unfortunately, values on the Insimbi Fracture appear to be most sporadic in this area, and this complicates the exploration problem, since there are other barren fractures in the vicinity. Without gold values as a correlating feature, it is often impossible, short of direct underground connection of the workings, to be certain that a drive is on the right fracture. This problem, incidentally, crops up throughout the property; if a main fracture carries no gold values at the particular point at which it is intersected, it cannot be distinguished from the many other barren fractures, which are all too numerous.

On the east side, on 5, 7 and 8 Levels, the Insimbi Fracture has been followed through the Southern

Cross Bar, upon which it has a normal displacement of some 80 feet horizontally along the fracture strike, and which shows well developed drag phenomena, into the north green "schist" as far as the gray "schist". On 5 Level, after passing through the Edwin Bray Dyke, again owing to lack of gold values, there was some doubt about the identity of the fracture, even though the break occupied by the dyke usually has no displacement on its walls. On 7 Level it was followed to the gray "schist", and occasional gold values were found. Below 7 Level in the north green "schist", a very rich patch was exposed, apparently in the vicinity of the intersection of the Insimbi and a minor fracture. On 8 Level tremendously rich ore was again encountered in the north green "schist", also in the vicinity of the intersection of the Insimbi and another fracture.

In view of the relation between the Aerial and the Zwartkopje Fractures, it seems logical to suppose that the Insimbi Fracture might lead to something of a similar nature in the south green "schist" under the Zwartkopje Bar. It is at least a possibility worth investigating as thoroughly as possible, since its importance, if this supposition should be correct, cannot be overestimated.

Though they are not shown on the plan and sections, there are a great many branch fractures which split off the Insimbi into both hanging and footwall. These seldom persist for more than 40 or 50 feet, and they rarely carry economically important gold values for more than a few feet from the main fracture. They are, however, of considerable importance, since the location of the richer patches is directly related to them. The shales have apparently acted as a relatively poor host rock for hydrothermal mineralisation, except where unusually intense shattering and brecciation have taken place, and it is a general rule that the brecciation associated with a splitting of the fracture, or with an intersection of the main fracture with another, is the site of intense mineralisation leading to the deposition of gold in high concentration. The presence of a large number of branches, forming a system of minor cracks associated with the main fracture, appears to be necessary for consistent gold values over any appreciable area. In the case of the Insimbi, such conditions have been brought about mainly by the unusually large amount of movement which has taken place on the fracture.

This, like other fractures in the shales, almost always has a filling composed of white vein quartz and carbonates. This filling is commonly only ½ inch thick, but may be up to 8 inches, and in the thicker examples almost invariably shows comb structure, or rhythmic deposition of carbonates and quartz, or both. Sulphides, chiefly pyrite and subordinate arsenopyrite, and gold, occur in the filling and disseminated as tiny particles in the wall rocks. Such disseminations may extend as much as 5 feet on either side of the fracture, but are usually of economic value for lesser distances. In fact, the average stoping width is some 4 to 5 feet. Visible gold is exceedingly rare in the shales, and this is also due to the fact that it is, except under conditions of unusually severe crushing and fracturing, e.g., near an intersection of two or more fractures, a relatively poor host rock for hydrothermal impregnation.

The barren parts of the fracture in the shales usually carry a filling composed almost entirely of white to gray carbonates with little quartz, and frequently with a little more or less coarsely crystalline pyrite, but with no arsenopyrite. In the vicinity of splits or intersections the filling consists mainly of white quartz with subordinate carbonates lining the walls of the vein, a fair amount of more or less massive fine grained pyrite, a little arsenopyrite and gold, while the metallic minerals are also disseminated in the wall rocks. There is thus a definite depositional relationship between the white vein quartz, the form of the pyrite, arsenopyrite, and gold. These conditions are identical with those exhibited in the case of the Intombi Fracture, and as the occurrences are better developed and more clear cut in the case of this fracture, further detailed descriptions will be given in the chapter dealing with the Intombi Section.

In the green "schist" the type of mineralisation found on the Insimbi Fracture is exactly similar to that on the Zwartkopje Fractures in the south green "schist".

The Malvina Fracture

This fracture is shown on Plate IV, in the shales north of the Southern Cross Bar, just west of the point where the bar is crossed by Snyman's Creek.

In general occurrence the Malvina Fracture is similar to, though not as strongly developed as, the Aerial and Insimbi Fractures. It has been opened up from an adit in the bank of the creek, and a fair tonnage of ore has been stoped from it in the shales. The fracture has been followed down dip through the Southern Cross Bar, upon which it has a normal displacement of some 15 to 20 feet, horizontally along the strike of the fracture. Some stoping has been done in the north green "schist", and the fracture has been followed down to the gray "schist". Little work has been done in recent years, and values appear to have been somewhat sporadic. West of the stoped area the fracture has been off-set by a fault, and recently attempts have been made to follow it up, but with little success. The two main reasons for this lack of success are: the number of other and barren fractures present in the area make identification of the main one almost impossible; and the local intense folding of the bar-"schist" group, with consequent repetition of strata, causes difficulties due to the fact that the rock succession cannot be used as a guide.

Attempts have now been made to intersect this fracture by development at a lower elevation from Zwartkopje 7 Level. So far[1] no conclusive result has been attained.

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[1] October, 1942.

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Attempts have now been made to intersect this fracture by development at a lower elevation from Zwartkopje 7 Level. So far[1] no conclusive result has been attained.

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[1]October, 1942.

The Battery Reef

This is the name given to a fracture of somewhat similar general mode of occurrence to the Aerial, Insimbi and Malvina Fractures. It occurs in the north shales, north green "schist", and Southern Cross Bar, about 600 feet west of the Malvina Fracture.

It has been opened up from an adit on the road from the offices to the living quarters, and there have been a couple of hundred feet of development done on it. None of this work was done in recent years, and so little is known about the general conditions, except that a few gold values were found; they are, however, insufficient to warrant further work, at least at the present time. No stoping was done.

If the Insimbi or Malvina Fractures lead to anything of particular value, further examination of this fracture, and of others of similar kind which are known at various places on the property, would immediately be warranted.

The Birthday Fractures

A considerable tonnage of ore has been stoped in the Birthday Section, some of it exceedingly rich. A part of the workings is shown on Plates IV, XXV, and

and XXVI. The openings extend from a point some 100 feet east of section A_1B_1 (Plate XXV) to a point some 500 feet west of the large dyke which cuts across the Zwartkopje - Southern Cross group at the flexure. Most of the work is in the near vicinity of the green-gray "schist" contact, is very steep, and extends from the surface to a little below 5 Level, which is the same as the Insimbi 5 Level, an average vertical distance of some 500 feet.

The fractures responsible for the mineralisation in this section of the mine form a highly complex system which is not thoroughly understood. The most important is actually a complicated branching system, which runs in general parallel to the green-gray "schist" contact, and occurs in a zone up to 20 feet wide, from the contact into the green "schist". Many of the branches pass off into the gray "schist", while others fade out into the green. This condition is shown on Plates XXV and XXVI. From 3 Level up to the outcrop this system has a great many branches, and is consequently fairly consistently mineralised over a considerable area. Thus from the surface to 3 Level, a large area has been fairly thoroughly stoped, on and near the green-gray "schist" contact. It has been said that it is the contact itself which is mineralised, but a careful examination of the workings shows that it is the wandering, branching fracture system which has been followed and stoped. When the main fracture happens to be on or close to the contact, the gray "schist" is exposed in the stope footwall, giving the impression that it is the contact itself which has been mined. There are a great many places, however, where the fracture system has been followed and stoped into the green "schist", and there is then no gray exposed. It is seldom, however, that the fractures are more than 20 feet from the contact. Associated with this system in some places are flat north-dipping fractures. These are irregularly distributed, and generally have a dip of some 15-20°. Where these north-dipping fractures intersect the steep fracture system, there is sometimes a zone of intense mineralization around the intersection lines. The north fractures themselves usually do not carry payable values for more than 15 feet or so from the intersection zone. Steep fractures, dipping east or west, and striking more or less due north, are also found associated with the main fracture system. These as a rule do not carry significant gold values, but their influence on the main fracture system is seen in the presence of steep, narrow, rich shoots of ore along the intersection zone.

Both these latter fracture types, that is, the flat north-dipping and the steep cross fractures, are of more frequent occurrence below than above 3 Level. This feature is much more noticeable in the case of the steep cross fractures than it is in that of the flat north-dipping ones.

Below 3 Level the main fracture system is not so well developed, and is not as complex as it is from 3 Level to the outcrop. As a result, its gold values are somewhat sporadically distributed, and it has been stoped to a much smaller extent. In fact, almost the only payable values found below 3 Level are in intersection zones, where some other fracture is present as well as the steep or "contact" fracture system.

Between 3 and 5 Levels, almost all of the stoping has been done on intersection zones, in which the fractures present are usually the steep or "contact" fracture, which in this area is commonly single or simple, and steep west-dipping cross fractures. The gold values in these narrow shoots are often very high indeed, but they seldom extend for more than a few feet from the lines of intersection. Thus the stopes on these shoots are commonly of more or less cylindrical form, and seldom have a diameter of more than 20 to 25 feet. The main shoots of this type which have been worked in recent years pitch to the west, more or less parallel to the green-gray "schist" contact, at an angle of from 45 to 65 degrees.

The ore mined from these pipe-like shoots, as has already been mentioned, is often very rich in gold, values up to 400 dwts./ton being not uncommon in individual samples. The gold present is, however, in general, finely divided, and is therefore seldom visible to the naked eye; in fact, "visible" gold is the exception in the Birthday ores. It is peculiar that this ore, which is in green "schist", exhibits this feature, when Zwartkopje ore of equal gold content frequently contains this metal as particles easily visible in hand specimen. As a general rule, the ore consists of green "schist" containing pyrite and arsenopyrite disseminated throughout, the former often as masses of fine grained sulphide, and the latter as minute needles, often as felted groups. Masses of stibnite are commonly found in these ores, often lining vugs, but in the aggregate the proportion of this mineral in these ores is fortunately low.

Meteoric waters penetrate the fractured rocks in the vicinity of intensely broken-up intersection zones, with the result that a certain amount of oxidation has taken place in the ores mined, and cracks and joints are commonly filled with a red ferruginous mud. Later carbonates have also been introduced by the circulating surface waters.

South-dipping fractures of the Zwartkopje type were, up to the beginning of 1942, almost unknown in the Birthday Section. In fact, the only one exposed up to that time showed little or no signs of economic mineralisation. During the early part of 1942, however, a fracture of this type was exposed in the green "schist" near the Zwartkopje Bar on 5 Level, and exploration on it gave highly encouraging results. Conditions in the area are, however, complicated by the presence of other fractures in the shales south of the Zwartkopje Bar, and of faults, with the result that exploration was rendered somewhat difficult. It is the opinion of the writer that such an occurrence is very encouraging, and if it is at all persistent, should augur well for the pros- [illegible] of the Birthday Section, since it seems likely [illegible] is the fore-runner of others of similar type [illegible] elevation.

The reason for the difference in the types of fracturing in the Birthday and Zwartkopje Sections of the mine is not readily explained, though it seems likely that the difference in the attitude of the rocks in the two areas, and the sudden change of strike of the Zwartkopje - Southern Cross group in the Birthday area, are not unrelated to the problem.

The peculiar Z-shaped fold seen on Plate IV in the hardened shale zone south of the Zwartkopje Bar has no counterpart in the bar-"schist" group, and this movement must therefore have been absorbed in the rocks somewhere in the western part of the Birthday area, probably on the Zwartkopje Bar-shale contact. A possible explanation of the peculiar system of fractures found in this area would be that conditions of strain different from those applying in the Zwartkopje Section were thus set up in the rocks in the vicinity of the Birthday workings, with the result that the fracturing in this latter part of the mine assumed a different form.

The Intombi Fracture

This fracture has been the source of a very large proportion of the ore which has been mined on this property, and is, in fact, the chief source at the present. Much of the ground stoped from the Intombi Fracture in previous years was of a high grade, but at present it is mostly of medium (4-6 dwts./ton) value. A few relatively small blocks of fairly rich ore are being worked at present, but they make up a small tonnage.

The occurrence of this fracture and some of the workings on it can be seen on Plates IV and XXIII-XXVI.

As shown on the plan, Plate IV, the outcrop of the Intombi Fracture curves a good deal. This is misleading, and is due to the combination of rugged topography with steep slopes, and the south dip of 75 to 80° on the fracture. That part of the fracture southwest of the Intombi Quarry has a very regular strike of some 35° south of west, while northeast of the Quarry it has a similar regular strike. In the immediate vicinity of the open cut working, however, its strike is some 60-70° south of west. Thus north and south of the Quarry it suffers on surface an abrupt change of direction. Its dip, however, remains remarkably steady throughout.

The Insimbi Fracture had been mined for some time before it was found necessary to put in the 5 Level adit from the north side of the Zwartkopje Valley, through the hill, to intersect the Insimbi north of the Southern Cross Bar. The portal of this adit can be seen on Plate IV, about midway between sections WX and YZ, and about 130 feet south of the y = +26000 coordinate line. When work was commenced on the adit some excavation in the hillside to the west was made, to accomodate a drill-sharpening shop. This excavation exposed a fracture carrying high values, which, on being followed up, were found to persist. The original prospecting winze which was started on the outcrop by the drill shop became later the shaft on the fracture which received the name Intombi. This shaft is steeply inclined (78°), and is now[1] being sunk below the 14th Level, a vertical distance of some 1500 feet below the collar.

Almost all of the stoping on this fracture is west of the shaft, and that which is to the east reaches only down to the 3rd Level, and extends about 200 feet on strike. Ore has been stoped from the outcrop to 12 Level, and from the shaft about 1000 feet west. This is, of course, not a rectangular stoped-out block, and on the lower levels it encloses a good many patches which are barren, or almost so. The over-all average stoping width is some 48 inches, though in places, as will be described later, far greater widths have been found to contain payable ore.

West of the shaft the fracture has been followed on 1 Level to a point west of the dyke. Here, however, it seems to be getting weaker, which is a feature more or less to be expected, since all the fractures probably owe their origin to the presence of the Zwartkopje - Southern Cross group of resistant rocks, and are likely to be less well developed at considerable distances from this group. It is known from the drag phenomena visible

[1]October, 1942.

in the fracture walls that the footwall block has moved westwards relative to the hanging wall, but there are no markers present whereby the amount of the displacement can be measured.

In recent years, attempts have been made to follow the Intombi Fracture from the shaft eastwards towards the Zwartkopje Bar. Up to October, 1942, it had been traced definitely to a point some 350 feet east of the shaft on the upper levels. Farther east a fracture which is possibly the Intombi has been followed from an adit to the bar, but it carries few gold values. The lower levels have followed the fracture progressively nearer to the Zwartkopje Bar, but faulting and "formation fractures" have so complicated conditions on the intermediate levels, i.e., from 4 to 11, that no success has so far resulted from this work. Diamond drilling is more or less useless for prospecting in this area, on account of the impossibility of recognising the main fractures in the cores, if they happen not to be mineralised.

Faulting of various kinds has complicated development on the Intombi, particularly on the lower levels. Between 7 and 9 Levels, there is a flat-dipping fault of small throw which has somewhat complicated the stoping in this area. The most troublesome type of faulting is that which is of frequent occurrence around 9 and 10

Levels. These faults have a strike and dip almost exactly the same as those of the fracture, and are often filled with white carbonates and quartz similar to the fracture filling. Thus, when the fracture is barren in spots, it is difficult to be certain that development is always on it, and not on the faults. Exploration below 12 Level has been complicated by faults of several types, none with a very large displacement. The displacement is, however, sufficient to add considerably to the difficulties attendant upon development.

The sharp "kink" in the Intombi already noted as occurring in the Quarry area persists, with modification, down to the lowest levels at which the fracture has been exposed. With increase in depth, however, the length along strike of the curve or "kink" on the Intombi increases fairly rapidly, until on the 12th Level it occurs over a distance of some 700 feet, while on the outcrop its length is some 130 feet. The abruptness of the change in strike, however, decreases as the length of the curve increases. As will be seen, these changes in strike have an important bearing on the distribution of gold values. Fig. 5 (page 253) is a diagrammatic illustration of this condition. The figure represents a rough plan of the strike lines of the fracture at various levels.

places near these zones, signs of intense shear are visible in the shales, and the shear planes are generally coated with a film of graphitic material.

In the straight part of the Intombi, that is, west of the "kink" area, auxiliary fractures with their accompanying shoots of ore are relatively widely separated. In the "kink" area, however, local unequal strains induced by the changes in strike of the Intombi Fracture have given rise to great numbers of auxiliary fractures. As the "kink" flattens out downwards, such strains are smaller, and consequently the number of auxiliary fractures is smaller. The ultimate result is that the "kinked" area has in general been highly mineralised, and the intensity of mineralisation is directly proportional to the abruptness of the changes of strike. Thus a plan showing gold distribution on the Intombi not only shows accurately the extent of the "kinked" area, but also reflects, by the change in average gold content from the outcrop to the bottom levels, the gradual flattening of the curve. At the same time the more sparse distribution of auxiliary fractures in the lower levels due to the less abrupt nature of the "kink" is reflected in the sporadic gold values recorded. This is on account of the fact that as the groups of auxiliary fractures become more widely separated, the min-

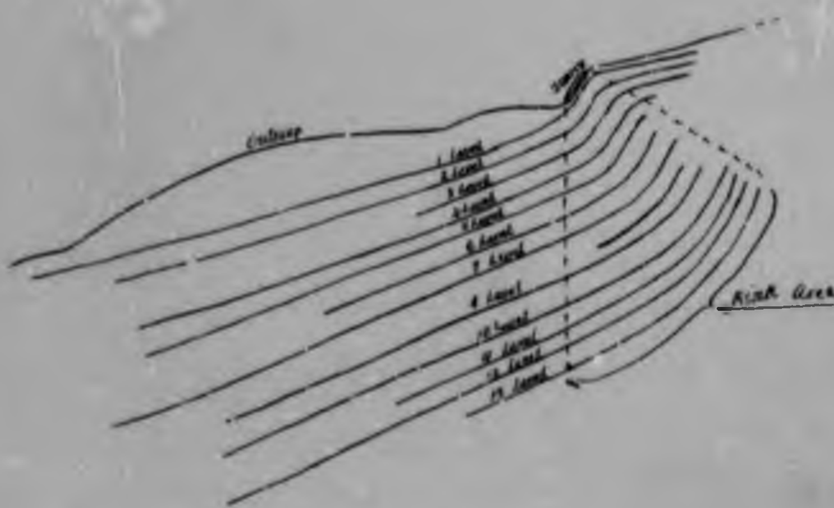


Fig. 3

Where the fracture has a constant strike and is not associated with branch or auxiliary fractures, it usually has a filling from ½ inch to 6 inches in thickness, composed of light to medium gray carbonates with sometimes a little pyrite, and is almost invariably barren. Fig.4 is a sketch of the appearance of the vein under such conditions. The main fracture is, however, often associated with auxiliary fractures which have a strike and dip more or less parallel to that of the shales. These are probably cracks dragged open on planes of weakness in the

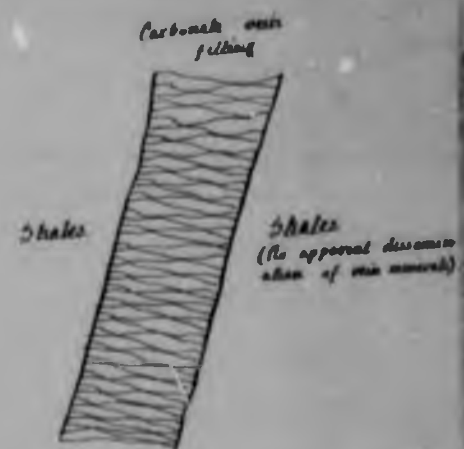
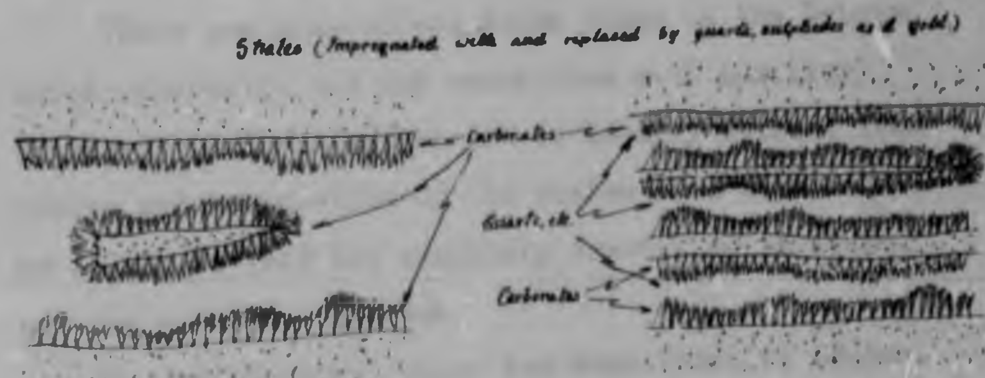


Fig. 4

shales. Their occurrence is usually as shown diagrammatically in Fig. 5, though there are often more than one on each side of the main fracture.

Fig. 5

In such areas the degree of strain and brecciation of the shale is unusually great, with the result that zones of this sort form favourable locations for the passage of solutions and for impregnation of the walls, which is rare in the absence of auxiliary fractures on account of the relative impermeability of the shale when it is only slightly brecciated and strained. Also, in the absence of auxiliary fracturing the main fracture is tight, and its effectiveness as a solution passage is rapidly eliminated by the deposition of the early carbonates. Thus the later solutions carrying silica and the metallic minerals have their passage limited to the more open zones in the vicinity of auxiliary fractures. As a result the area between A and B on the Intombi Fracture in Fig. 5 contains, besides carbonates, the later white vein quartz, fine masses of pyrite, arsenopyrite, and gold, while the wall rocks have been more or less replaced and impregnated by the same minerals. In such areas the vein often shows well developed crustification, with the carbonates lining the walls, and the quartz and other minerals in the middle. Occasionally fragments of shale are enclosed in the vein filling, and these are also usually coated by a layer of carbonates. In some cases the fracture is compound, and then the above described conditions are repeated in each part. Fig. 6 shows some of the conditions found in such fractures.



(a) (b)

Fig. 6

Thus the vein is often barren of metallic minerals until a zone such as AB in Fig. 5 is encountered, whereupon gold values, often very high, are found. In many eralised zones associated with them fail to overlap, leaving barren or poor areas in between.

The auxiliary fractures themselves sometimes carry payable gold values as much as 20 feet from the main fracture, and in faulted areas this feature adds to the difficulties encountered in development work.

Many of the auxiliary fractures persist for as much as 250 feet down the dip, but of course, little is known of their persistence on strike. Two which were followed by drives on one of the upper levels were shown to extend for about 50 feet on strike. It is evident that a great many are much smaller than those described above, as their effects in some cases persist for only 50 feet or so along the zone of intersection with the Intombi.

There are mineralised zones found on the Intombi which apparently are not associated with auxiliary fracturing. These may be due to locally intense fracturing and brecciation of the shales in a weak zone, or it may be that the auxiliary fracturing is there, but has not been observed.

No satisfactory reason has been found to account for the change of strike of the Intombi in the "kinked" area. Some parts of this zone in the shales contain an abnormal number of "formation fractures" and the "kink" might therefore be explained as "refraction" of the fracture in passing through a shale zone with different physical properties from those possessed by the rock on either side. Such an explanation, however, does not completely satisfy the conditions imposed, firstly by the increase in width of the "kinked" zone on the lower levels, and secondly by the presence of similar "kinks" on the Southern Cross and Z.K. Fissure Fractures in a different zone in the shales. (Cf. Plate IV.)

The Southern Cross Fracture branches off the Intombi into the footwall, and the line of intersection of these two is marked by wide stopes, in which the records show gold values to have been high. The reason for the occurrence of these high values is the same as that accounting for the mineralisation associated with auxiliary fractures. In fact, in all parts of the mine, the intersection zones of fractures and fracture systems are, as is only to be expected, the sites of relatively intense mineralisation and heavy gold deposition.

Hall[1] states that the Intombi and Southern Cross Fractures dip at 60°, but coalesce at the 7th Level. This does not give a true impression of the state of affairs, since the line of intersection of these two fractures is irregular, but in general pitches steeply to the east, and as yet the Southern Cross Fracture

[1]Geological Survey Memoir No. 9, page 259.

has not been definitely identified on the 7th Level. (Cf. Plates XXIV-XXVI.)

The Southern Cross, Z.X. Fissure, and Amadoda Fractures

These fractures are more or less intimately related to one another, and have somewhat similar general modes of occurrence. The Southern Cross is the most important; it has provided a larger tonnage of ore than the other two together.

Its nature, as a branch into the footwall from the Intombi Fracture, is shown on Plates IV and XXIII-XXVI.

The Southern Cross Fracture has a slightly flatter dip than the Intombi, and its strike deviates a little farther from west. Thus it gradually leaves the Intombi Fracture towards the east, and its line of intersection with the latter fracture pitches very steeply eastwards, but is somewhat irregular. As has already been mentioned, this line of intersection has frequently been the site of locally intense mineralisation, with consequent wide stopes. The Southern Cross Fracture duplicates more or less the "kink" in the Intombi, but in the case of the former, the change of strike is not so abrupt. The "kinked" area on the Southern Cross Fracture has been stoped, but is highly complicated and difficult to work, owing to the presence of many other fractures and branches, "formation fractures" and faults. The "kink" on this fracture is in a different shale zone from that in which the Intombi "kink" occurs, as is shown on Plate IV.

The lowest point at which the Southern Cross Fracture has been definitely identified is 4 Level, which is the same as Intombi 4 Level, and while attempts to follow the Intombi Fracture to the Zwartkopje Bar have met with little success, the Southern Cross Fracture has been traced on 1 Level (the same elevation as Insimbi 5 Level) right through to the gray "schist". On this elevation the fracture has been stoped to some extent in the south green "schist" under the Zwartkopje Bar.

The mineralisation characteristics of the Southern Cross Fracture are similar to those of the Intombi.

The fracture known as the Z.K. Fissure (or Zwartkopje Fissure) Fracture branches off into the footwall from the Southern Cross Fracture in much the same way as does the latter from the Intombi. The Z.K. Fissure is in most respects similar to the Southern Cross Fracture, except that it is not so strong, and is rendered much more complicated by splitting and branching. Although some fairly high-grade ore has been stoped from the former, it is chiefly remarkable for the difficulties encountered in exploration and development.

A little ore has been mined from the Amadoda Fracture on 7 Level Zwartkopje, where it has been followed from the Zwartkopje Bar to the Intombi Fracture, in whose footwall it lies, and from which it splits off in a manner similar to that in which the Southern Cross Fracture does. In general, however, this fracture has yielded little more than encouragement to do further work on it. A similar fracture has been opened up from Intombi 4 Level, and these two are correlated with the Southern Cross Fracture. Such a correlation, without definite through connection of mine openings, is open to considerable doubt, since in an area of this kind, where there are so many fractures of similar type, it is quite possible for two unconnected drives, one as little as 30 feet above the other, to be on altogether different fractures, even though all available information suggests that they are following the same one. This is, of course, due to the abrupt changes in dip and strike to which all these fractures are subject, as well as to their tendency to split into two or more branches.

The Umfaan Fracture

On 7 Level Zwartkopje, a drive eastwards extends along the green-gray "schist" contact from a point directly north of the Zwartkopje Shaft for some 250 feet, when it cuts diagonally southeastwards across the green "schist" to the Zwartkopje Bar, whose lower contact it then follows for some considerable distance. In this bar-"schist" contact drive there was encountered a disturbance which, on being investigated, turned out to be the point of intersection of a fracture of the Intombi type in the shales south of the bar, and the bar itself. This fracture was given the name "Umfaan Fracture", and was followed up to a point just south of the Zwartkopje Shaft. (See Plate XII.) Up to this point the fracture had had a very regular strike similar to that of the Intombi, and a south-southeast dip of some 75°. Just south of the shaft, however, it merged into a "formation fracture", and it has not been possible to follow it further. In general the fracture was very steady, showing few irregularities and also few payable gold values. Those that were recorded, however, were followed up and stoped.

In the cross-cut from the shaft to the Zwartkopje Bar on 5 Level, a fracture similar to the Umfaan, and in about the right position, was found and followed eastwards, but did not give any encouragement in the way of gold values. This fracture has been correlated with the Umfaan, but the remarks previously made in connection with other similar cases apply equally well here.

The Western Cross Fractures

This series of fractures occurs in the shales north of the Zwartkopje - Southern Cross and Hospital - Hospital North groups, in the vicinity of the point at which the most westerly of the three dykes forks into two more or less equal branches.

A fair amount of exploration has been done from adits near a creek bed, and at least three main fractures have been exposed. The adits are shown on Plate IV. A little ore has been stoped from the Western Cross Fractures, but the work has been abandoned on account of the irregularity of the gold values, and there appears to be no reason to expect such conditions to change in the area.

One fairly strong south-dipping fracture has been exposed on two levels, and has yielded a little ore, but it appears to carry payable values only near intersections with other fractures, notable of which is one which is vertical, or dips steeply north. Along the line of intersection of these two fractures, both of which strike in general east-west, patches of rich ore have been exposed and mined. These patches have, however, been too small to warrant further work in the vicinity. One other fracture, striking north-south, and dipping at some 50° west, has also been opened up, but this again carries values only in the vicinity of intersections with other fractures.

In the shales both north and south of the Zwartkopje - Southern Cross group, in the western part of the mine property (that is, west of the coordinate line x = -32000) a great many fractures have been exposed in trenches and road cuttings. Some of these fractures carry fair gold values in places, but for the most part they are too patchy to warrant further attention. These fractures often occur in groups, the individual members of which strike and dip in all possible directions. One such group which is now[1] being opened up will be briefly described under the heading of "Prospecting".

Sheba West

Most of the workings known by this name fall outside the area included by the map, Plate IV.

A number of south-dipping fractures of similar

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[1]October, 1942.

general character to the Zwartkopje Fractures have been opened up on both sides of the Golden Valley, in the rocks underlying the Sheba Bar. Part of this area is shown in the northwest corner of the map. Most of these fractures occur in the somewhat poorly developed green and gray "schists" which are found under the Sheba Bar in this area, but none of them has shown more than spasmodic low values, and they are not now being prospected.

The only fracture in the area which has yielded ore of payable grade occurs in the fine and rather sandy quartzites, some 1000 odd feet north of the bar. This fracture has a strike about normal to that of the Sheba Bar, and dips east at some 80°. A relatively narrow shoot has been followed and stoped from the outcrop about 200 feet straight down the dip, and seems to be in some way connected with the occurrence of another fracture which strikes nearly east-west, and dips steeply northwards. The main fracture has been opened up over a considerable distance on strike, and the only payable values found have been in the one shoot, which is apparently associated with the intersection of the two fractures mentioned.

The nature of the mineralisation of these quartzitic rocks in the Sheba West area is very similar to that associated with the Zwartkopje Fractures in the green "schist"; that is, the fracture is usually a mere crack without, or at least with very little, filling, and the ore is formed by impregnation of the wall rocks. Thus the width of the mineralised zone is indefinite, and the ore contains a fine dissemination of gold and sulphides, the latter consisting chiefly of pyrite.

Prospecting

As has already been stated, the shales, particularly in the western part of the mine property, contain a vast number of fractures of different types, most of them not persistent for any distance. Many of these contain gold in payable quantities, usually in small patches, but in most cases these patches are so small as to put the fracture concerned out of consideration as a working proposition. Those which show gold values, even though it may be at only one point, are generally opened up in one way or another, in order to determine the extent of the payable mineralisation, if any. Thus from time to time various prospects are worked in various places, almost all of them to be abandoned after a short time.

The most promising of these prospects to be examined in 1942 consists of two main fractures associated with several minor ones. The main fractures are practically vertical, strike about at right angles to the Zwartkopje - Southern Cross Bar group, and occur some 300 feet north and west of the point whose coordinates on Plate IV are x = -30000 and y = +27000. Both of the main fractures have been opened up by driving, and by winzing from surface, and both have yielded encouraging values. The more westerly of the two has been followed by driving just under the surface to the Zwartkopje Bar. All the ground so far[1] opened up is in the oxidised zone, so that little is known of the nature of the mineralisation, or of the relations of the fractures to one another.

It is known, however, that the distribution of gold values, as is usual, is more or less dependent upon fracture intersections. At this spot, however, payable values are more widely distributed than has generally been found to be the case on the irregular fractures previously examined in this area.

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[1]October, 1942.

The Old Sheba or Golden Quarry Mine

The area embracing this mine does not strictly come into that covered by this work, and the writer's knowledge of these workings is confined to the little which can be gathered during the course of a few short visits to the property. Some brief notes on this area, however, will be of interest for the sake of comparison with that owned and worked by the New Consort Gold Mines - Sheba Section.

The Old Sheba Mine has yielded by far the greater part of the gold which has been mined from the Sheba Hills area, and the workings, shown on the mine plans, are extensive. At present, however, only those openings which are above the level of Sheba Creek are accessible, the rest being flooded.

The workings constituting this mine are partially just above, but mainly below, the Sheba Bar. Above the bar, which in this mine is a somewhat indeterminate cherty band, a horizon known as the Edwin Bray has been worked to a small extent. It appears to be a fracture which wanders somewhat, but which in the Quarry workings usually marks the hanging wall of the bar. Just below the bar the workings are very extensive, and large open chambers have been stoped. One particularly large one, locally known as the Cathedral, is still accessible in that part which is above the water level. The large stopes extend for some 50 feet into a peculiar gray siliceous rock in the footwall, and are worked mainly on a fracture which runs along or close to the footwall contact of the cherty bar horizon. The wider parts of the stoping are associated with a series of cross fractures, most of which strike at least 40° off east-west, and dip from 20 to 60° to the east. Here again, therefore, the heaviest mineralisation is associated with fracture intersections. In this case the multiplicity of fractures has resulted in a wide and more or less continuously impregnated zone.

The green and gray "schists" found in the Golden Valley area are absent in the Quarry workings, but it is understood that they occur in the Orient Mine workings, west of the Quarry.

The Sheba Bar in the Golden Valley area, and in the workings west of the Quarry, is evidently a fairly well defined chert horizon, but in the Golden Quarry workings it is poorly developed, and not always distinguishable. East of the Quarry it can be definitely traced on surface for a short distance only, when it loses its identity and is no longer seen on the mine property. Still farther east, towards the Royal Sheba area, it apparently is again distinguishable on surface, but the writer has not examined it in this part.

Some fractures lying in various attitudes have been worked in the shaly quartzitic rocks north of the Sheba Bar, among them those known as the Margaret, Mamba, Tit-Bits, and Eureka City Fractures. Others are now in process of examination. These fractures occur in large numbers throughout this area, from the Sheba Bar to points north of Eureka City, but most of them appear to carry gold values only in small patches.

The Ores: Various Types of Fracture Mineralisation

(1) In the Green "Schists"

General

The fractures in the green "schists" are sometimes easily visible as distinct cracks which often have no true filling of any kind, and sometimes are practically impossible to determine exactly, owing to the fact that alteration and replacement of the wall rocks have progressed to such a point that the break itself is almost completely obliterated. Those which are visible as distinct breaks or cracks have usually been the sites of some little movement during mineralisation. This movement is probably directly due to the stresses set up by the intrusion and subsequent consolidation of the de Kaap Valley boss, and may not necessarily be in the same direction as the original movement which gave rise to the fracture displacement. Many of the largest Zwartkopje fractures show this feature, and in some cases the break is visible inside a dark quartz filling, which may be only ⅛ inch, or up to 18 inches wide. There are many cases where the fractures have fillings in which no such evidence of movement during mineralisation is evident. These are often barren of gold. In some cases, where local crushing and residual unrelieved strain are abnormally severe, e.g., near fracture intersections or splits, the replacement and alteration of the wall rocks have been so extensive as to render the detection of individual fracture planes virtually impossible. This is generally the case in the Birthday area, where the multiplicity of fractures leads to circumstances favourable to such conditions.

Where the "schists" show the schistose or laminated structures already mentioned, drag phenomena are generally associated with the fracture planes. These phenomena seldom extend more than a foot above and below the fracture, and are more commonly visible only 3 to 4 inches from the plane of movement. In some cases extensive alteration and replacement of the wall rocks have obliterated such structures.

It is evident from a general inspection of the fractures and the ores associated with them that at least the major part of the gold deposition took place at a fairly late stage in the mineralisation, and that where fractures have a massive quartz filling some later movement, or at least more intense crushing, etc., then is usually associated with a single or simple fracture, has very often been necessary for gold to be deposited in economically valuable quantities.

The fractures which do not contain gold in payable proportions unfortunately outnumber the more intensely metallised ones by a considerable ratio. These barren fractures usually contain a filling from ¼ inch to 14 inches wide, composed mainly of dark gray to almost bluish vitreous quartz, with subordinate carbonates. This filling seldom shows signs of movement having taken place during mineralisation, is therefore generally massive, and has a vitreous lustre. In the filling small crystals of pyrite are almost invariably found, while tiny tourmaline needles and large blotched masses up to ¼ inch in diameter of arsenopyrite are not rare. The wall rocks are generally more or less silicified, and also contain small scattered crystals of pyrite. It is generally accepted on the mine that scattered pyrite occurring as well formed crystals is not associated directly with payable gold values unless other types of mineralisation are also present. As will be seen later, this is borne out by microscopic evidence.

Those fractures which are associated with payable gold values also often contain a filling of quarts and subordinate carbonates. This filling may be from ¼ inch to 18 inches in thickness, is usually a grey to bluish colour, is not so massive, and has not so vitreous a lustre as that found in the barren fractures. These latter features can generally be ascribed to the fact that movement has taken place on the fracture plane during mineralisation. In fact, such movement has often given rise to a distinct shear zone or fracture plane within the filling, and the crushing associated with it is the reason for the somewhat dull lustre of the filling material. The filling in such cases often contains scattered pyrite crystals, together with masses of fine grained pyrite, felted masses of minute arsenopyrite needles, and, exceptionally, particles and nuggets of gold, coarse enough to be visible in hand specimen. The gold may be found free in the quartz, or enclosed in or associated with the masses o[illegible]ained pyrite.

The wall rocks are generally t[illegible]e of intense impregnation and replacement, to distances of up to 15 feet from the fracture. This is indicated by the obvious silicification, deeper green colour due to the formation of a good deal of chlorite, and by the dissemination of masses of fine grained pyrite, arsenopyrite needles, and occasionally small particles of gold. In some cases the wall rocks have been so intensely altered as to assume a very dark green, almost black colour. Such conditions are associated with abnormally high gold values.

The movement which took place on any fracture during mineralisation, and the crushing associated with the original fracturing, apparently varied to a great extent from place to place. Thus one fracture will show in different parts the characteristics of both barren and mineralised types described above. Thus the movement and readjustment to altered conditions was not uniform throughout the extent of any one fracture, with the result that the "effective permeability" of the fracture passage varied a great deal from point to point, especially during the later (gold-depositing) stages of the mineralisation phase, when some considerable quantities of other material had already been deposited in and near the passages. Such conditions may have been controlled to a certain extent by local changes in the character of the green "schist" wall rock. Of course, the "effective permeability" of the fracture passage would not in any case be uniform all over the fracture plane, and in some parts the crushing and fracturing of the wall rocks would be a good deal more intense than in others. Thus the conditions controlling the nature of the deposition in the fracture passage and in the surrounding rocks are highly complicated, and the conditions leading to deposition of economic importance in different places on a fracture or system of fractures show little or no regularity, and are not generally predictable in detail. In general, however, favourable areas can sometimes be localised by the nature of the fracturing to be expected therein.

The filling in the fractures usually is not sharply defined against the wall rocks, but tends to grade off into more or less silicified material. Remnants of highly altered wall rock matter can always be found in the filling, more especially towards the edges of the latter, and it is evident that the filling has been formed rather by replacement of intensely crushed and strained material in and near the fracture plane or zone than by filling of an open passage. In this respect these fractures differ from certain of those in the shales, where deposition in open passages has been a relatively important factor. In the green "schist" ore bodies, residual strain and locally intense fracturing and crushing have been the main factors controlling deposition of economic importance.

In places, notably in the Birthday area, fracture filling is not conspicuous. In such areas the mineralisation has taken the form rather of impregnation and replacement of a rock mass which has been intensely crushed, brecciated and strained in the vicinity of a complex branching or intersecting system of fractures. In places of this kind the ore itself contains scattered pyrite crystals, masses of fine grained pyrite, fairly large quantities of arsenopyrite in the form of minute needles, and gold, generally not coarse enough to be visible in hand specimen. In such zones of relatively complex but individually impersistent fractures, the amount of arsenopyrite deposited is generally higher than is the case where the fractures themselves are less complex, but individually constitute more continuous passages. At the same time, coarse gold is far less common, and stibnite becomes more frequent in occurrence. Areas of this kind are found not only in the Birthday, but also occasionally in the Zwartkopje, where the fracturing is locally very complex.

As has already been mentioned, the gray "schist" is completely inert. A fracture which carries high values in the green "schist" becomes quite barren immediately it enters solid gray "schist". The fracture continues into and through the latter rock, and sometimes contains a narrow (¼ to ½ inch) filling of white quartz and carbonates, but is not associated with significant replacement and impregnation of the walls. Occasionally scattered, well formed crystals of pyrite are present both in the filling and in the wall rocks nearby, but it is apparent that the soft, plastic nature of the fracture walls has resulted in no crushing such as that which has been the site of the impregnation and replacement leading to bodies of economic value in the relatively hard and brittle green "schist".

The question of wall-rock alteration in the case of the green "schist" ores is similar to that in the case of the New Consort ores. Strictly speaking, the area which comes up for consideration under the heading of "wall rock alteration" is that outside, above and below, the fracture plane or filling. In cases of this sort, however, these zones in the wall rocks of the fractures constitute the ore bodies themselves, since when there is a filling it is generally of minor importance, and the main volume of ore is in the wall rocks. Such a position must necessarily arise where the ore body itself consists of a zone of impregnation, the intensity of which diminishes gradually away from the source - in this case the fracture itself. The upper and lower or, in general, the outer limits of the ore bodies are indefinite, and are demarcated by gold values only. Thus the wall rocks of the ore bodies are those which are outside the zone of payable mineralisation. The alteration and replacement of these wall rocks are, therefore, almost exactly the same in nature, though not so pronounced, as those of the rocks constituting the ore bodies proper. The question of wall rock alteration thus does not arise in the case of these ores, since the effects of these processes will already have been dealt with in the discussion of the ores.

The above statements apply more strictly in the case of the green "schist" and bar ores than in that of the shale ores, since in the latter case the main gold values are more closely associated with the vein filling. In the case of the shale ores too, however, mineralisation of economic value occurs in the fracture walls, and the ore bodies proper, therefore, include a part of these walls in the form of impregnated and replaced shale. Here again, therefore, the outer limits of the ore are defined by gold values only, and are more or less indefinite. Thus no distinction other than that of intensity of the processes active can be made between ores and wall rocks.

Petrography of the Ores

In the very low grade or barren fractures the filling consists mainly of an interlocking mosaic of quartz grains of an average cross-section of about 1mm. The quartz is generally little strained, and almost invariably contains minute liquid inclusions as well as tiny flakes of sericite. In the middle of the filling this quartz mass also contains interstitial masses of sericite, calcite and dolomite crystals, a fair amount of pale green chlorite, some grains of a peculiar colourless chloritic mineral, some zeolites, and scattered crystals of pyrite, which vary in size from 0·2 to 1.0mm. The mass is generally cut in various directions by thin veinlets of later quartz, sometimes with some carbonates.

Towards the outside borders the filling takes on a greenish colour, as opposed to the gray colour predominant in the middle. This is due to the presence of still recognisable remnants of the green "schist". These remnants are usually highly sericitised and chloritised, and contain grains of crushed and comminuted quartz from the fracture wall rocks. As the green "schist" borders of the fracture filling are approached, the number of these remnants increases.

Small particles of magnetite and strings and masses of rutile, usually associated with talc, green chlorite, etc., are found in the wall rock remnants, and in their vicinity.

When one or both fracture walls are gray "schist", the proportion of carbonates in the filling increases towards the edges of the filling. The amounts of zeolites and the colourless chloritic mineral also generally increase towards the gray "schist" walls. These features show that the filling has been formed largely or entirely by replacement of crushed, strained and brecciated material in, or in the vicinity of, the fracture plane or zone. As would be expected from the nature of the gray "schist", its boundary against the filling is usually sharp and is marked by the presence of an abnormal proportion of zeolitic minerals. These minerals are often found in hydrothermal deposits which have been formed at low to medium temperatures, where the wall rocks contain a high proportion of carbonates.

It is noteworthy that zeolites do not occur to any significant extent in the impregnated green "schist".

The pyrite found in the filling usually occurs as small but well formed crystals, apparently contemporaneous in origin with the quartz in the filling and that introduced into the fracture walls. Occasionally the pyrite occurs as hollow shells or skeletal bodies, but this is rare in the vicinity of fractures which are not of economic value. Massive fine grained pyrite is almost never found in such places.

Some of the quartz in the fillings in these fractures has a slightly fibrous or bladed radiating habit, which is generally rather poorly developed. Many of the larger pyrite crystals have a narrow border of radiating fibrous or bladed quartz. This border is usually developed on those edges of the pyrite crystals which are almost at right angles to the fracture plane. This type of occurrence is identical with that already described in connection with the bars. This pyrite evidently belongs to an early stage in the deposition when conditions were not yet suitable for gold deposition because, as will be seen later, it is earlier than the gold, and is not directly associated with it.

Most of the carbonates in the filling of the poorly mineralised fractures are not of hydrothermal origin; that is, they are residual from the crushed wall rock material.

The green "schist" close to the fracture filling is generally intensely sheared, and as a result has a more or less schistose texture. It is generally more vivid green than that farther away from a fracture, on account of the formation of green chlorite under the influence of hydrothermal processes. In hand specimen most of the quartz present can be seen to have a greenish tinge due to this chlorite, and is also more or less dull and cherty. This is owing to the shearing and comminuting effect of the original folding processes and of the fracture movement. The quartz is generally more or less finely comminuted and strained, except that which has been introduced by impregnating solutions, and this is clear and unstrained. There are usually large amounts of green chlorite, sericite, carbonates, the pale chloritic mineral, and a little topaz present in this sheared and altered green "schist". Pyrite occurs as scattered crystals averaging about 1mm. in diameter. These are generally pyritohedra, and often have the fibrous quartz borders already described. The strings of rutile and the grains of magnetite in the original "schist" appear to have been unaffected by the hydrothermal processes. Some of the introduced quartz has a radiating bladed or fibrous habit. As a general rule the fracture wall rocks are criss-crossed by thin quartz veinlets.

The physical effects of the shear on the fracture, and the effects of the impregnating solutions, gradually diminish away from the fracture, and usually no trace of the results of these processes can be found 5 or 6 feet from the fracture plane.

The gray "schist" is generally little affected by the passage of hydrothermal solutions along the fracture, and such effects are generally limited to the introduction for a foot or so of scattered pyrite crystals, masses of zeolitic minerals, and the colourless chloritic mineral.

The fractures which are associated with gold values of economic importance show most of the features described as found in an examination of unmineralised fractures, and their environs, but with other and more interesting effects superimposed. It is evident that the more heavy metallisation related to the auriferous fractures is due to the effects of a later stage of hydrothermal activity. Such minerals as tourmaline and topaz belong to the earlier stage, poor in metallic products. It is apparent from the following description that the later phase of hydrothermal activity which gave rise to the deposition of gold and its associated metallic minerals took place at considerably lower temperatures and pressures, and the effects of this phase are noticeable only in the areas where such features as abnormally intense crushing, brecciation and strain allowed the solution passages to maintain sufficient permeability for the later solutions to reach them. Thus the effects of these later solutions are far less widespread than are those of the solutions of the earlier stage, when little or no gold was deposited. This accounts for the fact that though there are present a great many fractures which have obviously acted as solution passages, only a few carry gold in payable quantities, and those only where the effective permeability of the passages was maintained to a very late stage. Hence the close association, throughout the area, of gold values and abnormal physical conditions.

The general characteristics of all auriferous fractures in the green "schists" are more or less the same, particularly when comparatively simple fracturing is considered. For example, the general characteristics of the mineralisation of the Zwartkopje fractures are similar to those shown by the Aerial and Insimbi fractures in the north green "schist". In the case of the Birthday Section, however, as has already been mentioned, the ores show some notable differences, and this fact can probably be best ascribed to the different conditions of fracturing there existing. For this reason the following description will deal first with the ores of the Zwartkopje type, and second with those of the Birthday type.

The fracture filling in intensely mineralised areas is an interesting and somewhat peculiar rock. It is generally a grayish colour, but often has a green tinge, owing to the presence in it of unreplaced remnants of the green "schist". The replacement by quartz of the crushed and brecciated rock in the fracture zone has very rarely been complete. The filling often has a dull cherty appearance due to crushing and comminution, consequent upon movements during mineralisation. It is often criss-crossed by veinlets about 1mm. in thickness of clear vitreous quartz, evidently belonging to a late stage of the mineralisation process. In some cases the filling has a banded appearance due to incomplete replacement along shear planes in the fractured zone.

The main mass of the filling generally consists of a mosaic of quartz grains of average size about 1mm. The quartz usually contains vast numbers of tiny liquid inclusions, together with many minute flakes of sericite, and is almost invariably intensely strained, sometimes even crushed and broken up. The grains are often separated by a mortar, consisting chiefly of quartz and sericite. In many places the quartz mass contains recognisable remnants of green "schist", which are more plentiful near the edges of the filling than they are near the centre. These remnants may consist of masses of the crushed and comminuted quartz with chlorite, magnetite, rutile and talc, or of lenses and irregular masses of bright green chlorite with talc, rutile and magnetite. These remnants are generally cut across in several directions by thin veinlets of clear quartz. They are evidently relatively unaffected and resistant parts of the country rock which have been neglected in the general replacement of the crushed matter in the fracture zone by the quartz vein material.

Chlorite occurs in the filling as irregular masses, veinlets and stringers, often in considerable abundance around pyrite grains and masses.

Calcite and dolomite are sometimes fairly plentiful, both as isolated grains, crystals and masses, and in the form of veinlets. The latter sometimes have narrow selvedges of talc. The carbonates are more abundant in the vein matter near the grey "schist" when this rock forms one of the walls. It is probable, therefore, that some of the carbonates are of origin similar to that of the green "schist" remnants.

Topaz sometimes occurs in the form of small irregular grains, often associated with very pale green-brown pleochroic tourmaline needles. These two minerals apparently belong to the early stages of mineralisation, as they are often found around country rock remnants and around crystals of pyrite of the widespread early barren variety.

As has already been mentioned in connection with the barren fractures, small masses of zeolites are occasionally found, usually near the gray "schist".

The peculiar, almost colourless, chloritic mineral found throughout the Sheba area is also present in the fracture filling, especially near to the gray "schist". Some of this mineral has evidently been formed by alteration of the gray "schist", but some is apparently not formed in this way, as masses of it are present in and near the fractures at considerable distances from the main gray "schist" bodies, particularly where the mineralisation has been locally very intense. This mineral is apparently earlier in origin than most of the pyrite, and is unaffected by the latter mineral, which is often moulded on it.

The occurrence of the pyrite and its relation to the other metallic minerals in these ores is extraordinarily interesting. In the fracture fillings, and in the impregnated rocks on either side, this mineral occurs in two ways. The first is that which is found in all the rocks, whether they are the hosts of economically important mineralisation or not: almost always as small, well formed crystals, generally pyritohedra or combinations of the pyritohedron and cube. These crystals vary in average dimension from 0.1mm. to 1.5mm., and have already been noted as occurring in all the rocks in the area. These often have narrow borders of fibrous or bladed quartz along one or two boundaries, and are not genetically associated with gold or intergrown with other sulphides. At least, it is well known that the occurrence of such pyrite is not associated with gold values, and the writer has not seen it directly associated with gold in any of the polished sections of the rocks and ores. Hall[1] has also noted this feature.

The second type generally does not exhibit crystal outlines, and its occurrence is almost always associated with the presence of more or less gold. This type occurs sometimes as skeletal grains or hollow shells around quartz grains as nuclei. Generally such grains have an irregular outline, and usually project narrow vermicular veinlets into the quartz cores. A very common mode of occurrence is that of a shell around a nucleus consisting of a well formed crystal of the first type of pyrite. In such cases the shell assumes an outline parallel to that of the core, so that it presents an apparent crystal

[1]Geological Survey Memoir No. 9, p. 257.

shape. Sometimes there is a narrow zone of quartz between the first type core, and the second type shell. Such cases sometimes show almost perfect examples of rhythmic deposition. Very commonly a series of disconnected gangue inclusions takes the place of the intermediate quartz zone, so that the result is a composite pyrite grain with zonally arranged, poikilitically enclosed gangue particles. These zonal inclusions and intermediate zones of gangue are almost always penetrated from the outside by minute vermicular veinlets of the second pyrite. This second type of pyrite often also forms solid grains without a core or nucleus, and such grains never present crystal outlines. The outside boundaries of grains of this pyrite are often surrounded by a very narrow selvedge of chlorite, practically never with the fibrous or bladed quartz often found associated with crystals of the first type.

Compound or zonal grains of pyrite often occur as masses up to 2 inches by 1 inch, and these constitute the fine grained massive pyrite often seen in specimens of the ore. In these masses are also found skeletal and solid grains of the second type of pyrite.

Gold is very commonly associated with pyrite of the second generation, and usually occurs as irregular blobs from 3 to 150μ in average dimension, enclosed in or on the inside borders of shells of this pyrite, as zonal inclusions in compound grains of the two types, or irregularly distributed throughout solid grains of the second generation type. There are a very large number of gold particles in the size range from 3 to 8 μ in the pyrite masses. In some cases gold is moulded on crystals of pyrite of the first generation. It is only in exceedingly rich specimens that any significant quantity of gold occurs free of pyrite, and then it generally takes the form of irregular blobs from 2 to 200 μ, and exceptionally up to 15mm. in size. There are, however, in such cases, a large number falling in the smaller size ranges. In connection with the microscopic relation between gold and second generation pyrite, it is interesting to note Hall's[1] statement, "Visible gold is occasionally seen, but the gold lies mainly in the pyrites, because when this is removed from the sand and slimes no gold is left."

In some cases the free gold occurs as narrow wedge- and lath-shaped grains interstitial to particles of the peculiar colourless or nearly colourless chloritic mineral, when the latter occurs as aggregates. The gold grains in such cases have average dimensions of about 10 x 60 μ. Gold has never been seen included in or

1Geological Survey Memoir No. 9, p. 257.

intimately associated directly with pyrite of the first generation.

Chalcopyrite is often also associated with pyrite of the second generation. In fact, it occurs in amounts little in excess of that of gold, and in an exactly similar manner. In very rich specimens, chalcopyrite occurs free, and intimately intergrown with gold away from pyrite grains. Gold and chalcopyrite are often associated with one another in zonal inclusions in compound pyrite grains, and in inclusions in masses of second generation pyrite.

Arsenopyrite is sometimes seen in the fracture ores, generally as tiny irregular grains, but also as well formed needles, of average size about 0.1 x 0.5mm. These usually occur isolated, but sometimes the second generation pyrite is moulded on them, while they in turn are moulded on crystals of pyrite of the first generation. Gold is but rarely associated with the arsenopyrite grains, and only very few cases have been seen of the former enclosed in the latter. Masses of arsenopyrite needles are not usually associated with simple fractures, but are generally found in areas of highly complicated fracturing, e.g., in places in the Zwartkopje area where fractures split and branch in an intricate manner, and in the Birthday Section.