THE GEOLOGY OF A PORTION OF THE COUNTRY BETWEEN THE THE KOMATI AND USUSHWANA RIVERS, NORTH-WEST SWAZILAND

BY

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CONTENTS

INTRODUCTION

This report is a study of the stratigraphy, petrology and economic geology of a group of predominantly Pre-Cambrian rocks lying along the Transvaal-Swaziland border between the Komati and Usushwana rivers, North-west Swaziland, and forming the southernmost extension of the Barberton Mountain Land.

The survey of this area was first suggested in the Progress Report of this Department for the years 1945 and 1946 where it was stated that: "From a preliminary reconnaissance near Darkton

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on Crown mineral area No. 7 it would appear that banded ironstones are present there. It is therefore possible that the haematite deposits of mineral concession No. 41 north of the Komati river, may possibly extend southwards, and obvious that at some time the intervening area must be mapped geologically" ([1], para. 56).

The area containing the iron ore deposits north of the Komati river was mapped during 1945 by A. T. M. Mehliss[2], while the area covered by this report was mapped for the purpose of correlation during the period June to November, 1947.

The first geological investigation of the area was carried out by Hall[3] in the years 1913–1916 during which period he was engaged in a survey of the whole of the Barberton Mountain Land. Although this report will differ to a great extent from Hall's conclusions, it is, in no way, meant as a reflection on his interpretations. It must be remembered that the present investigation has been carried out in much greater detail and also that, in recent years, more thorough work on particular areas of Hall's classic survey has necessitated the revision of some of his original conclusions.

Attention was first drawn to this area when Tom McLachlan and Walter Carter discovered gold in the late 1870's. In 1880 the Forbes Main Reef mine was discovered and opened up by the Forbes brothers. Within a short while a number of other mines were developed. At one stage the Forbes Reef mine was producing 2,000 ozs. of gold per month with a 40 stamp mill. In the same report mention is made of haematite occurring on Forbes' concession "with Swazi schists," so it is apparent that this occurrence was known then, although its value and extent were not appreciated[4]. Gold production was fairly constant up to 1913 when all mining ceased. Since then sporadic attempts have been made to open up the Forbes Reef gold mines but, so far, unsuccessfully. At the present time the district is once more attracting attention, only now interest is focussed on base metals.

LOCATION

The mapping covers an area of approximately 120 square miles, forming a strip along the Transvaal-Swaziland border, about 22 miles in length and averaging five miles in width, stretching from the Komati river in the north to the Usushwana (or Little Usutu river) in the south.

This strip comprises Crown mineral area No. 7 (formally mineral concession No. 75 and known as Forbes' concession); mineral concession No. 25 (formally known as Henderson's concession and now as Motjaan Mines concession); and Crown mineral area No. 14 (formally mineral concession No. 3 and known as Pullen's concession).

Crown mineral area No. 7 contains portion of Native Area No. 7; mineral concession No. 25 portion of Native Area No. 9; and Crown mineral area No. 14 portion of Native Area No. 10.

The area lies between longitudes 30° 56′ E. and 31° 09′ E. and latitudes 26° 02′ S. and 26°18′ S.

Approximately 15 miles south of the Komati river the area is traversed in a N.W.-S.E. direction by the main Mbabane-Ermelo road along which the Road Motor Transport of the South African Railways runs a daily service to the railhead at Breyten. On this road are situated the Darkton store and the Oshoek store and post office on the Transvaal-Swaziland border.

North of this road the area is served by a secondary road running past the Forbes Reef store and post office to the point on the Komati river from where it continues to Pigg's Peak and then past the Havelock mine to the railhead at Barberton in the Transvaal.

Only a track leads off south from the main road and runs as far as the Hebron Mission Station. After heavy rains this track is impassable due to the swollen condition of the many streams that cut across it.

TOPOGRAPHY

Although this area represents the southernmost extension of the Barberton Mountain Land, the topography is generally not on such a rugged a scale as occurs further north. This phenomenon may be explained by the fact that there is a decrease in the proportion of hard, resistant rocks to easily weathered types with the result that areas of comparatively gently undulating country become larger and more numerous towards the south.

The country between the Komati and Usushwana rivers is dominated by the prominent Ngwenya and Silotwane ranges of mountains. The southern extremity of these mountains occurs just on the Mbabane-Ermelo road between Oshoek and the Motshane river. From this point they continue roughly N.N.E. to a little north of the Ngwenya Trigonometrical Beacon where they bifurcate into two roughly parallel arms which are separated by the Mahlanganpeppa creek valley, also known as the Long valley. The western arm is known as the Ngwenya range and swings out into the Transvaal while the eastern arm is known as the Silotwane range. In the vicinity of Silotwane peak, the Ngwenya range swings back into Swaziland and unites with the Silotwane range to form a single unit now known as the Silotwane range. This range crosses the Komati to form the Makonjwa range with Emlembe mountain near the Havelock mine.

The trigonometrical beacon on top of the Ngwenya range has an elevation of 6,005 feet being the second highest point in Swaziland. Although the elevation of Silotwane Peak is somewhat lower than this, being 5,511 feet, it is by far the most prominent feature in the area, forming a conical peak readily visible from both the Transvaal and Swaziland sides of the range.

An idea may be gained of the deep dissection in the area immediately south of the Komati from the fact that the elevation of the junction of the Msoli and Komati rivers, just beyond the border, is 2,300 feet which represents a drop of 3,180 feet over a distance of roughly four miles between this junction and Silotwane peak.

The Silotwane range on the west is separated from the Mbutu hills on the east by the deep valley of the Malolotsha river. The elevation of this river at its junction with the Mbutu creek is 2,650 feet which gives a drop of 2,830 feet from Silotwane peak over a distance of approximately two and a half miles. The Mbutu hills rise to an elevation of 4,130 feet at the point where the Mbutu creek cuts across them giving a drop of 1,300 feet over a distance of one and three-quarter miles to the Malolotsha river. They run approximately parallel to the Silotwane range and peter out between Mhlope beacon (elevation 5,010 feet) and the Malolotsha river just north of the old Forbes Main Reef mine.

The elevation of the point where the Londosi river crosses the border into the Transvaal is 4,000 feet giving a drop of 2,005 feet down the Ngwenya escarpment slopes over a distance of two and a half miles from the Ngwenya Trigonometrical Beacon.

Due to the high rainfall, averaging 60 inches per annum, the geological structures and the variations in rock compositions, dissection of the area by rivers and creeks has proceeded to a marked degree.

The zone of deep dissection may be defined as occurring within the following limits: along the border from the Komati river to Oshoek along a line due east from Oshoek to the Motshane river; along a line north from the Motshane river to the watershed between the Malolotsha and Black Mbluluzi rivers; due east along this watershed to the old Forbes Main Reef mine; and thence due north from this mine to the Komati river again. The topography of the remainder of the area is controlled by the less severe granite hills and the flat, plateau-like country around Forbes Reef and along the Motshane river valley.

The ultimate drainage channels of the area are the Komati river in the north and the Usushwana river in the south. The Komati river has a drop of 150 feet over a distance of six miles between its junction with the Msoli river (elevation 2,300 feet), and the pont (elevation 2,150 feet). The course of neither of these rivers appears to be controlled by geological structures or formations. Numerous tributaries feed into these two rivers and, in the case of these streams, their courses are apparently more dependant on geological structures, the flow being roughly parallel to the strike or to the general alignment of the shear fractures in the rocks.

The Malolotsha river takes its rise in the granite hills north of the old Forbes Main Reef mine, curves around the Mhlope ridge, and than flows northwards to the Malolotsha falls which have a fall of 350 feet. From here it flows through the deep and wild Ekwayini gorge for a distance of about one and a half miles, after which it winds its way into the Komati river.

The Black Mbuluzi river takes its rise in the granite hills east of the Forbes Reef store and flows southwards until its junction with the Mbuluzana creek from where it turns south-east, cuts into the granite hills and continues past Mbabane.

The Motshane river takes its rise in the schist belt south of the Ngwenya Trigonometrical Beacon and flows southwards down the flat Motshane valley. This valley is flanked on the west by the eastern end of the high Lochiel granite plateau which has an elevation of 4,650 feet at Oshoek and on the east by the granite hills which stretch eastwards past Mbabane. South-east of Makwanakop the river changes its flow to a south-easterly direction, cuts into the granite hills and winds down to the Usushwana river.

The creeks which have been responsible for the wild and precipitous dissection of the Ngwenya escarpment slopes which form the eastern flank of the Steynsdorp valley, drain into the Londosi river which flows in a northern direction until its junction with the Komati river in Transvaal.

The whole of the area forms a portion of the Swaziland highveld and lies within the mist belt. It is subject to rains and dense mists throughout the summer, these becoming particularly heavy during the summer months, December to February.

GENERAL GEOLOGY

The formations which constitute the area may be ascribed to the Fundamental Complex, the Old Granite and the dykes of post-Granite age. Attention was paid particularly to the rocks of the Fundamental Complex and the Old Granite was studied only along its contacts with the older rocks and in connection with its influence on the ore deposits in the area.

The subdivision of the Fundamental Complex as proposed by van Eeden[5] will be followed by the writer as the investigation of the area definitely supports his scheme. The Onverwacht Series, Fig-tree Series and Moodies Series are grouped under the Swaziland System of the Fundamental Complex. The remaining ancient rock-types are allocated to the Jamestown Complex and the Havelock Complex, the latter of which constitutes a newly proposed series.

Although the type area of development of the Onverwacht Series lies just west of the Swaziland border in the Steynsdorp valley, no indications of this Series occurring in the area are to be found.

The Fig-tree Series is almost entirely restricted to the western slopes of the Ngwenya range. A comparatively small outcrop, surrounded by Moodies rocks, also occurs in the vicinity of the junction of the Komati and Malolotsha rivers.

The Moodies Series is responsible for the mountain ranges and hills in the area and attains its greatest development between the Komati river and the Forbes Main Reef mine. These rocks form the Ngwenya, Silotwane and Mbutu ranges, and north of the Mhlope Beacon cover the entire area from the border in the west to the granite in the east. A small outlier of the series occurs in the granite west of Beacon Loxton 2 between the Mbutu and Malanti creeks. Another outlier in the Jamestown Complex outcrops just south of the Forbes Reef store.

The Jamestown Complex is the most predominant group of rocks in the area and attains its maximum development in the Forbes Reef and the Motshane river valley which is the southern extension of the flats. Jamestown rocks are also intimately associated with the Fig-tree Series on the escarpment slopes. Numerous sill- and dyke-like intrusions of Jamestown occur in the Moodies Series.

During the course of mapping it became more and more apparent that there occurred groups of rocks scattered throughout the area which could not be classified satisfactorily as belonging to any one of the four already established series of the Fundamental Complex, viz., Onverwacht Series, Fig-tree Series, Moodies Series or Jamestown Complex. Neither did they adjust themselves to being grouped with the Old Granite or with the later intrusions. To these rocks it was proposed by Dr. H. J. R. Way, then Chief Geologist, to give the name of Havelock Complex since they first attracted attention at the Havelock mine.

The Old Granite forms typical outcrops associated with it throughout Swaziland and parts of the Eastern Transvaal. It is characterized by fairly rugged hills with smooth, bare slopes capped by large, angular boulders of granite. In this area the granite forms the eastern limit of the Fundamental Complex and, from the Swaziland Barytes mine, southwards, also the western limit.

The only remaining rock types are the dykes of varied composition, all of which are post-granite in age.

LITHOLOGY

(i) Fig-tree Series

This series is essentially the argillaceous facies of the Swaziland System although the cherts tend to form a comparatively larger percentage than to the north. The rock-types constituting the series are shales, graywackes and banded cherts. In certain areas the shales have been heavily ferruginized to form banded ironstones.

Only one horizon of shales is developed and this immediately underlies the Moodies quartzites and conglomerates with, in places, a distinct uncomformity. This unconformity is best seen about 8,000 feet northwest along the border from Beacon S.W. III where a stream has cut into the escarpment slopes to present an excellent section. Here the shales are dipping at 70° to the east while the dip of the overlying Moodies conglomerate is only 40° in the same direction. Although both series have been folded to a large extent, it is evident that this angular difference of 30° represents a true unconformity. Further indications of an unconformity can be seen at many places along the contact, although less clearly. The presence of this unconformity plus the large number of banded chert pebbles in the overlying Moodies conglomerate correspond with van Eeden's observations in the Sheba area[5] and further tend to support his argument in favour of dividing the original Moodies Series of Hall[3] into two distinct series — the Fig-tree and the Moodies Series.

Immediately south of the Komati river a small portion of this shale horizon falls within Swaziland, the remainder being in the Transvaal. Although Hall states that these shales are well ferruginized in the Komati river gorge(3), there appears no evidence of ferruginization and this is also true where the same horizon outcrops on the eastern limb of the synclinal structure in this area. However, there is no doubt that this shale horizon which crosses the Komati river is the same one in which the haematite deposits occur at Iron Hill south of the Havelock mine(2).

12,000 feet north of Silotwane peak the shales swing out completely into the Transvaal. 17,000 feet southwest of Silotwane peak this same shale horizon cuts back into Swaziland and continues as a well-defined, prominent horizon in a southerly direction to where it terminates a little north of the Oshoek-Mbabane road in the vicinity of Clarry's Camp. In Swaziland these shales have undergone marked ferruginization in at least three localities—just north of Clarry's Camp, Bomvu Ridge, where the banded ironstones show their maximum development, and north of the wild, deeply dissected Lily valley.

The normal shales are reddish to brownish in colour and are well bedded. In places they tend to become rather sandy. Minor bands of graywacke* of limited extent occur within the shale horizon. These graywackes were not recognized in the outcrops and were only exposed in trenches which were put across the shales and banded ironstones at Bomvu Ridge where this horizon attains its maximum thickness of 3,000 feet.

Underlying the shale horizon are five zones of banded cherts separated from each other by bands of Jamestown schists. Immediately south of the Komati river only two chert bands occur, but here only a very small portion of the Fig-tree Series falls within Swaziland. These cherts are marked 1 to 5 starting from the base of the series and proceeding east up the Ngwenya escarpment slopes. Of these five No. 3 band is the most persistent and continues south, well past the extremity of the shales, eventually petering out in the Jamestown schists of the Motshane river valley. No. 5 band is the least persistent and peters out 2,500 feet east of Beacon S.W. III. These bands develop the following maximum thicknesses:—

No. 1 band: 300 feet
No. 2 band: 600 feet
No. 3 band: 900 feet
No. 4 band: 600 feet
No. 5 band: 700 feet

The cherts are very fine-grained, hard compact rocks which form very conspicuous outcrops on the escarpment slopes, generally rising 20 to 30 feet above the schists on either side of each band. Northwest of Masali Peak the first chert band east of the Moodies conglomerate forms very steeply sloping cliffs falling away to the Komati river before the latter turns eastwards to its junction with the Malolotsha river. The cherts consist of alternating white, grey and almost black bands up to half an inch thick which show a remarkable persistency along the strike and the very minimum of contortion. In certain places the darker bands in the chert have been replaced by haematite to form alternating white and dark brown layers.

As mentioned previously these bands are separated from each other by talc-carbonate schists of the Jamestown Complex. Van Eeden notes a similar association between the talc and carbonate schists and the Swartkoppies bar in the Sheba area(5) and states that the origin of the schists is not clear and that they may represent either original sedimentary or volcanic rocks. However, on the Ngwenya escarpment slopes the schists show such a strong resemblance to rocks of similar composition definitely accredited to the Jamestown Complex, that there would appear little likelihood of their representing metamorphosed original shale bands of the Fig-tree Series.

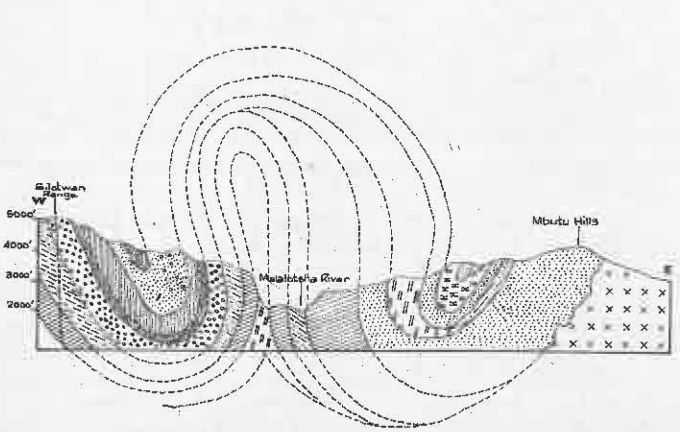
Due to the intimate association of Jamestown schists and cherts it is rather difficult to fix the base of the Fig-tree Series in this area. The westernmost horizon, No. 1 chert band, is assumed to be the base. This chert band has a bright greenish coloration due to the presence of sericite and, since none of the other bands shows this coloration, this feature tends to facilitate the recognition of the assumed base.

The maximum thickness of Fig-tree Series in the area is 5,000 feet.

(ii) **Moodies Series**

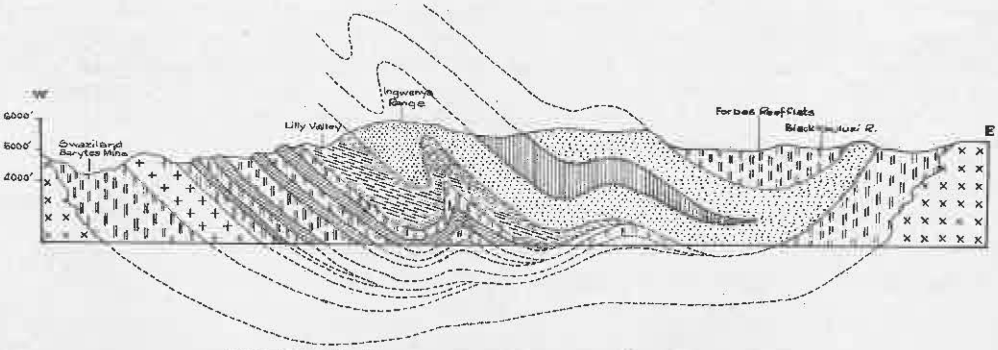
The greatest variation in the development of this series takes place between the Komati river and a line between Masali Peak and Beacon Loxton 2. The Moodies Series is the arenaceous facies of the Swaziland System and consists predominantly of conglomerates, grits and quartzites

*The presence of such rocks has not been confirmed by later work.—H.J.R.W.



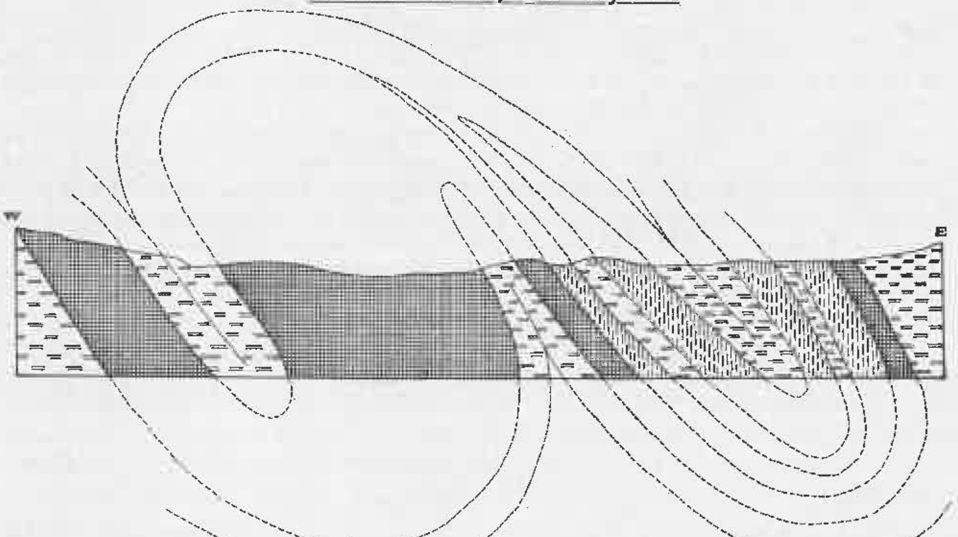
SECTION A-B FROM SILOTWAN RANGE TO MBUTU HILLS IMMEDIATELY SOUTH OF KOMATI RIVER

for scale and key see diagram I



SECTION C-D FROM SWAZILAND BARYTES MINE TO FORBES REEF FLATS

for scale and key see diagram I



SECTION ACROSS ASBESTOS BEARING SERPENTINES OF USUSHWANA VALLEY

KEY

- Serpentines
- Hornblende schists
- Talc schists

SWAZILAND GEOLOGICAL SURVEY DEPT.

GEOLOGICAL SECTIONS ACROSS THE COUNTRY BETWEEN THE KOMATI AND USUSHWANA RIVERS, N.-W. SWAZILAND

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FIGURE 1.

with shales forming only a comparatively small percentage of rock-types. Immediately south of the Komati river the succession is as follows:

Basal Conglomerate

Thickness 700 feet. This bed rests unconformably on the Fig-tree shales and consists of a well-developed conglomerate with pebbles of banded chert, dark greyish chert and quartz, with banded chert pebbles by far predominating. The pebble sizes range up to six inches in diameter with an average of about three inches. The red jasper pebbles which are such a conspicuous constituent of this horizon north of the Komati river in the vicinity of Iron Hill are completely lacking south of the river. The strong resemblance between the banded chert, pebbles in the Moodies and the banded chert bars of the underlying Fig-tree Series would indicate that the pebbles are derived from the Fig-tree cherts. This fact, which suggests a long interval or erosion between the final stages of the Fig-tree Series and the incipient sedimentation of the Moodies Series, plus the presence of an unconformity between the two are the strongest evidence in favour of van Eeden's decision to separate the original Moodies Series into the Fig-tree and the Moodies. That these features are as prominent in this area, which represents the southern extremity of the Swaziland System, as they are 30 miles to the north in the area of the Sheba hills would suggest that they are not of a local nature but are a general characteristic of the Swaziland System in the Barberton Mountain Land.

A certain amount of resilicification and replacement by iron of the pebbles and the matrix has taken place but neither are as well developed here as they are south of Masali Peak. Due to the synclinal structure this horizon is exposed along four outcrops — two on the western syncline and two on the eastern syncline (see section). On the western syncline the conglomerate passes into grits and quartzites. This would indicate that the sediments were brought in by rivers and streams flowing in a northwest to southeast direction and consequently the finer particles would be carried further than the pebbles, thus accounting for the gradual transition of conglomerate to quartzites from west to east.

On the east syncline where quartzites replace conglomerate, zones of sheared quartzites are developed in the ordinary quartzites. Four of these zones have been located, the largest of which is 500 feet wide and 21,000 feet along the strike. Thin sections reveal that these sheared quartzites consist of sheared quartz grains frequently exhibiting strain shadows with minor amounts of sericite and chlorite in the shape of fine needles orientated along the direction of shear. Pebbles are quite common in these zones and these have also been orientated along the direction of shear. This rock-type probably represents original zones of major weakness in the quartzites along which intensive shearing has taken place upon the intrusion of the granite.

Magnetic Jasper Marker

Above the basal conglomerate lies the red Magnetic Jasper Marker which has a maximum thickness of 400 feet, and which forms the most conspicuous horizon in the area and affords an excellent means of determining the major structures. The rock itself is a dense, fine-grained jasper of dull red colour and is traversed by abundant white quartz veinlets which, when they occur parallel to each other, give the rock a banded appearance. These veinlets rarely exceed half an inch in width and average one eighth inch. Specularite is commonly associated with the quartz and tends to form a very thin layer at the contact of the quartz veinlet with the jasper. In places the marker is highly magnetic but in others magnetic effects are weak or non-existent. The jasper is intimately associated with a zone of purple, sandy shales and on the eastern limb of the western syncline at Masali Peak the jasper passes into these shales gradationally and no sharp contact between jasper and shales is recognizable.

When the basal conglomerate swings back into Swaziland southwest of Silotwane Peak there is no evidence of the marker but 700 feet south of the point of crossing a well-defined horizon of jasper and shales re-appears and continues for a distance of 12,000 feet to peter out in the Lily valley. From the above and also from the absence of the marker on the eastern syncline immediately south of the Komati river, it is apparent that the Magnetic Jasper Marker does not form a continuous but rather a series of long, narrow, unconnected lenses. This same has been noted by van Eeden in the Sheba hills(5).

Second Quartzite Horizon

Above the shales and jaspers lies a zone which is distinguished from the basal conglomerate by the predominance of quartzites and grits over true conglomerates: it has a maximum thickness of 1,000 feet. Where this bed swings back into Swaziland southwest of Silotwane Peak conglomerates become more strongly developed. On the outcrop the grits and quartzites have a dirty brownish yellow colour but where fresher surfaces are exposed the colour is dark grey to black with small cubes of pyrite sometimes developed. This horizon occurs on both western and eastern synclines and, as noted in the basal conglomerate, there is a progressive decrease in grain size from west to east.

Second Shale Horizon

This has a maximum thickness of 500 feet. The core of the western syncline is formed by a zone of purple shales which is more persistent than the shales associated with the Jasper Marker. It occurs north of Masali Peak and is still found where the Moodies swings back into the Transvaal and eventually peters out in the Mahlanganpeppa creek valley. There is no apparent difference in appearance and composition between these shales and the shales of the first horizon.

Third Quartzite Horizon

This has a maximum thickness of 500 feet. The core of the eastern syncline consists of a zone of quartzites which is similar to the second horizon.

The above classification can only be applied to the area north of the line between Masali Peak and Beacon Loxton 2. Between this line and the Ngwenya Trigonometrical Beacon there is a very marked increase in the ratio of arenaceous to argillaceous components of the Moodies Series with the result that it is impossible to distinguish individual horizons. Five hundred feet north-east of the border Beacon S.W. III even the basal conglomerate peters out and grades into an ordinary quartzite, indicating that the original area of deposition of the Moodies Series is nearing its southernmost extremity. Sporadic and irregular areas of conglomerate occur in this mass of arenaceous sediments but there is no apparent interconnection between these zones.

An important feature of the conglomerate is the frequent replacement of both pebbles and matrix by limonite and haematite. The silica matrix is much more susceptible to replacement than the pebbles giving rise to a striking rock-type in which white quartz and banded pebbles are set in a deep reddish-brown matrix. This iron replacement is not limited to the conglomerates and is quite common in the quartzites, particularly in the vicinity of Silotwane Peak and in the Mahlanganpeppa creek valley. In the quartzites the iron is entirely in the form of limonite and is developed along fractures and also as a gossan-capping to the quartzites. It would appear that this iron was derived from the underlying ferruginous shales of the Fig-tree Series and has been transported by surface waters to be deposited along fractures and in the comparatively more porous conglomerates of the Moodies Series. The iron replacement becomes less intense the further away one proceeds from the shale-conglomerate contact.

In certain isolated localities the quartzites have a slight greenish colour* due to the presence of sericite giving them a strong resemblance to the quartzites of the Hospital Hill Series of the Witwatersrand System. Aggregates of black schorl tourmaline are also found in these quartzites.

South of the Ngwenya Trigonometrical Beacon two horizons of shales appear in the Moodies quartzites. The eastern horizon is well developed and attains a maximum thickness of 1,800 feet while the western horizon is only 300 feet at the maximum. These shales are similar to the shale horizons south of the Komati river except that the northern tip of the eastern horizon is well ferruginized in places. In this area the quartzites show intense resilicification so that in places the rocks resemble cherts more than they do quartzites. However, in this instance banding is absent so that these resilicified quartzites can be distinguished from the typical Fig-tree cherts.

The maximum thickness of the Moodies in this area is 8,000 feet.

(iii) Jamestown Complex

The rocks of this complex represent the highly metamorphosed products of an original ultra-basic igneous intrusion with sedimentary members playing a very minor role. The individual rock-types are extensively varied due to differences in the original intensity of metamorphism and also to original variations in the mineral composition of the magma.

*Also due to fuchsite.—H.J.R.W.

TABLE I

The Various Rock-types Belonging to the Four Main Groups of Jamestown Schists

Group	*Type*	*Mineral Constituents*
Talc schists	Talc schists	talc
	Talc-chlorite schists	talc, chlorite
	Talc-carbonate schists	talc, carbonate (ankerite)
Chlorite schists	Quartz-chlorite schists	quartz, chlorite, magnetite
	Chlorite schists	chlorite, magnetite
	Chlorite-talc schists	chlorite, talc, nests of hornblende, magnetite
Tremolite schists	Tremolite-talc schists	tremolite, talc, pyroxene cores, tremolite-talc
	Tremolite-carbonate schists	tremolite, carbonate (ankerite)
	Tremolite-hornblende schists	tremolite, hornblende chlorite, talc
	Tremolite-chlorite schists	tremolite, chlorite with hornblende cores, magnetite
	Tremolite-chlorite-carbonate schists	tremolite, carbonate: interstitial veins; talc chlorite with hornblende cores
Hornblende schists	Amphibolite	green hornblende with granoblastic texture, garnet, quartz
	Quartz-hornblende schists	quartz, green hornblende, chlorite, garnet, quartz veinlets, magnetite, titanite in quartz
	Hornblende-quartz-biotite schist	hornblende, quartz, biotite, zircon
	Hornblende-augite schists	augite, hornblende, chlorite, olivine
	Grunerite schist	grunerite, magnetite, talc

For the sake of simplification the Jamestown Complex is considered to consist of four main types of schists, viz:

(i) talc schists; (iii) chlorite schists;
(ii) tremolite schists (iv) hornblende schists.

The various members of each group are given in Table I.

The schists are ascribed to one of these four groups according to the predominant mineral. It is impossible to differentiate between the various types in the field, although, where outcrops are abundant, the members of the talc group can generally be distinguished from the members of the tremolite, chlorite and hornblende groups. Furthermore, there are no definite horizons of each group as it is found that over any distance along the strike, talc-carbonate schists, for example, grade into tremolite-talc schists, these again into tremolite-hornblende schists and these into hornblende-quartz schists. To avoid confusion on the map and also to save time and facilitate field work, the Jamestown Complex was mapped without attempting to determine the numerous limits of each group of schists.

The talc-carbonate and hornblende-quartz schists are the most widespread types. On the outcrop the talc-carbonate schists have a pinkish-brown to dirty brown colour with the planes of schistosity well shown. The carbonate, generally in the form of calcite and ankerite, occurs both interstitial to the talc and also as filling amygdale-like cavities up to half an inch in diameter orientated along the direction of schistosity. On weathering the carbonate is reduced to a dark brown, limonitic aggregate which is easily removed from the cavities giving the schists a rough, pitted appearance. At depth, the talc-carbonate schists become greyish-blue in colour with the carbonate cavities white or pink. The hornblende-quartz schists form dark green to blackish outcrops, hand specimens of which are impossible to distinguish from those of other members of the hornblende group, of the chlorite group and also of some members of the tremolite group.

Generally, the hornblende group, the tremolite group and the chlorite group occur in the vicinity of the granite-Jamestown contact and the further one proceeds from this contact the more abundant becomes the talc group. On the Forbes Reef flats, the limit of the hornblende, tremolite and chlorite schists may be taken as 3,000 feet to the west of the granite contact. West of this limit the talc-carbonate schists predominate although the schists of the other groups are by no means completely absent. In the Londosi valley hornblende and tremolite schists are the main groups and the further one proceeds up the escarpment slopes the greater the ratio of talc to hornblende schists.

The same generalization may be applied to the Jamestown Complex in the Motshane river valley. Here the amphibole and chlorite schist occur on the eastern and western slopes of the valley along the granite contacts while the talc schists are more common along the centre of the valley. As the distance between the eastern and western granite limits decreases in a southerly direction, so does the talc schist: amphibole schist ratio decrease. This is well seen in the serpentines north of the Usushwana river where the talc schists are in the minority as compared to the hornblende schists.

Shale and quartzitic bands occur in the schists but are of limited extent and small dimensions; compared to the mass of schists they are almost negligible. Patches of conglomerate occur in the schist and are so similar to those of the Moodies Series that it is highly probable that the conglomerate and also the shales and quartzites represent small xenoliths of Moodies sediments caught up in the intrusion of the original basic lava of the Jamestown Complex.

Throughout the entire area of its occurrence the Jamestown Complex is highly folded and contorted in both a vertical and horizontal direction. Neither the strike nor the dip is constant over any distance. Due to the absence of marker horizons in the schists and the intricate intermingling of the schist groups themselves, it is almost impossible to determine the general structures in the Jamestown Complex. Only a very detailed study of the subsidiary flexures and contortions might provide the information required to solve the structural features of the Jamestown schists.

Another important feature of the schists is the abundance of hydrothermal quartz veins, some of which are mineralized, intrusive into the Jamestown. Where outcrops are scarce in areas of dense vegetation or deep soil, the relative amounts of quartz float on the surface are useful as indicators as to the underlying rocks. If this float is abundant it is safe to assume that the area is underlain by the Jamestown Complex.

The prevalence of the metamorphic minerals hornblende, tremolite, chlorite, quartz, magnetite, talc, biotite and the absence of such metamorphic minerals cordierite, sillimanite, andalusite, staurolite and kyanite indicate that the Jamestown schists represent ortho-metamorphic rocks rather than para-metamorphic rocks and, consequently that the Jamestown Complex represents an original igneous group of rocks rather than sediments.

That the Jamestown magma represents a post-Swaziland System igneous intrusion can be shown by the following points:—

(*a*) The overlap of Jamestown schists and Moodies quartzites in the vicinity of the Forbes Reef store. The original magma welled up along the centre of the general syncline structure in the area and round Forbes Reef broke across the eastern and less well developed limb of the syncline of Moodies rocks to form the overlap. A comparatively thin tongue spread northwards past the eastern limit of the sediments to peter out in the Mbutu creek area. In a southerly direction the magma completely covered the sediments except for the small outlier south of Forbes Reef store.

(*b*) The fact that the distribution of the minor occurrence of Jamestown rocks is controlled by the structures of the Swaziland System. This is well seen north of Silotwane Peak where a large body of schists occurs parallel to the strike of the Swaziland System while a subsidiary off-shoot from the body lies parallel to the general direction of the fracture system. South of the Komati river the Jamestown rocks outcrop parallel to the strike of the Moodies Series and on the Ngwenya escarpment slopes parallel to the Fig-tree Series.

Van Eeden notes that the metamorphism resulting in the Swaziland System from the intrusion of the Jamestown Complex is mainly the introduction of tourmaline and a resilification of the Swaziland System rocks. The granite has also produced these effects and it has not been possible to distinguish between the widespread granite metamorphism and the Jamestown metamorphism in this area.

(iv) **Havelock Complex***

The Havelock Complex represents a suite of differentiated igneous rocks of post-Jamestown and pre-granite age. The original rocks graded from ultrabasic, olivine-bearing rocks, through pyroxenites, and gabbros to diorites. There is a possibility that the Old Granites themselves may represent the final acid stage of differentiation but insufficient work has as yet been done on this newly-defined series to render this idea anything but a supposition. Furthermore, the rocks of the Havelock Complex form a very minor group as compared with the extensive mass of granite and consequently it is proposed to treat them as an individual series rather than as a possible phase of the granite.

Zones of Havelock rocks occur throughout the entire area, the largest of which is the diorite stock in the Usushwana river valley. The serpentines are best developed along the Motshane river valley, the pyroxenites in the area immediately south of the Komati river, the epidiorites in the Usushwana river valley, the diorites in the Ngwenya range and the Usushwana river valley.

Serpentines

Two types of serpentines occur: a massive serpentine and schistose variety.

(i) Massive serpentine: the constituent minerals of these rocks are antigorite, serpophite, chrysotile, magnetite, carbonate, nephrite, cores of olivine, augite and hornblende, talc, both as interstitial material and veinlets. Where the olivine forms large cores, it is seen that replacement of the olivine by chrysotile takes place from the centre of the cores. Occasionally the serpentine is composed of alternating bands of fibrous nephrite and antigorite with fractures developed oblique to the general direction of the bands.

(ii) Schistose serpentines: the constituent minerals are antigorite, talc, magnetite, chrysotile, nephrite, clinochlore, and olivine cores.

There appears to be no mineralogical difference in composition between the two types, the only feature to distinguish one from the other being the development of planes of schistosity. It is found that the schistose variety occurs on the margins of the massive bodies, a feature which is also found at the Havelock mine where the main ore-body has a footwall and hanging wall of schistose serpentine. The nearer the serpentines occur to the granite the greater the development of schistose structures, a feature that is well seen with the serpentines just north of the Usushwana river where, as the distance between the eastern and western granite limits decreases, so does the proportion of schistose to massive serpentines increases. Both varieties carry chrysotile asbestos fibre.

Pyroxenites

There are three varieties of pyroxenites: ordinary proxenites, uralitized pyroxenites and serpentinized pyroxenites.

(i) Ordinary pyroxenites: constituent minerals; orthorhombic pyroxene, blebs of quartz in an ophitic structure; quartz veinlets with biotite cutting across the pyroxene.

(ii) Uralitized pyroxenites: constituent minerals; tremolite talc, chlorite, magnetite. Hand specimens show abundant aggregates of magnetite up to one eighth inch in width developed along fractures.

(iii) Serpentinized pyroxenites: constituent minerals; antigorite, penninite, talc, magnetite, tremolite with introduced quartz and felspar.

Banding is generally present in the pyroxenites and in some places the minerals have a granular structure so that the rocks tend to become pyroxene granulites. Each type grades into either of the other two varieties and over a distance of only a few feet all three varieties may occur.

*This is now considered to be an integral part of the Jamestown Complex, except for the gabbros and diorites which belong to the post-granite Usushwana Complex.—D.R.H.

Epidiorites

In the large diorite stock of the Usushwana river valley occur lens-like inclusions of a black, fine-grained rock which is well exposed in the rapids along the river. Thin sections show the rock to consist of albite, small amounts of andesine, magnetite and augite cores surrounded by greenish and brownish hornblende. It is evident that these minerals represent products of saussuritization and uralitization and that the epidiorite is an altered rock of gabbroidal composition.

Diorites

This phase of the Havelock Complex is represented by three dioritic bodies of comparatively large size — the stock in the Usushwana river valley; the dyke-like body on the eastern slopes of the Mahlanganpeppa creek valley, called the Long Dyke, from Hall's[(3)] naming this area the Long valley; and the Londosi Dyke occurring in the Londosi river valley, east of the Swaziland Barytes mine.

(i) Usushwana Stock: mineral constituents; green hornblende altering to penninite and andesine altering to sericite. Veins and isolated aggregates of introduced microperthite and quartz with apatite and tourmaline inclusions also occur in the diorite and have obviously been injected by the intrusion of the granite. The rock is very coarse-grained and forms flat, smooth, sheet-like outcrops which are easily liable to be mistaken for weathered granite outcrops. The extent of this stock south of the Usushwana river has not been determined accurately and has been mapped only in reconnaissance.

(ii) Long Dyke: constituent minerals; andesine altering to sericite, green hornblende altering to chlorite (penninite) and magnetite. Veins up to six inches in width cut across the dyke and consist of microperthite and quartz in graphic intergrowths, apatite inclusions occurring in the quartz and long needles of black schorl tourmaline in both felspar and quartz.

(iii) Londosi Dyke: constituent minerals; andesine altering to sericite and green hornblende altering to chlorite. Twins of hornblende are exceptionally common. Veins of quartz and calcite with occasional pyrite are intrusive into the dyke. In places this dyke is highly altered and only secondary minerals — quartz, chlorite, calcite, albite and magnetite are present. With high alteration a schistose structure tends to develop. Both this dyke and the Long Dyke are finer-grained than the Usushwana stock.

The reasons for grouping the Havelock Complex as post-Jamestown age and not as an integral part of the Jamestown Complex itself are as follows:

(i) The fact that the highly-contorted and complicated schistose structure which is characteristic of the Jamestown, is only developed to a limited extent in the Havelock rocks. Schistose structures only occur in the serpentines and very infrequently in the Londosi dyke. The pyroxenites show banding but this feature cannot be compared to the schistosity of the Jamestown rocks. Altogether, massive rocks by far predominate over schistose varieties in the Havelock Complex whereas the Jamestown rocks are entirely schistose. This indicates that the emplacement of the Jamestown Complex must have been completed and the rocks already subjected to intensive distortion and metamorphism long before the Havelock Complex was intruded.

(ii) The fact that the diorites and a certain proportion of the pyroxenites of the Havelock Complex represent original rock types whereas the rocks of the Jamestown Complex are all products of metamorphism and no occurrence of the original rock-types in this case are found.

(iii) The fact that the horizon of serpentine intrusion stretching from the Usushwana valley to the Steynsdorp valley is not limited to the Jamestown Complex but cuts across the schists into the Fig-tree Series.

(iv) The fact that the Havelock Complex represents a suite of rocks complying with the general principles of crystallographic differentiation whereas the original rocks of the Jamestown Complex appear to have been of comparatively uniform composition.

The reasons for grouping the Complex as pre-granite in age and not as belonging to one of the numerous periods of post-granite igneous intrusions are as follows:

(i) The fact that the various rock-types appear to conform to the general structures produced in the Swaziland System and Jamestown Complex by the intrusion of the granite.

(ii) The large number of quartz and pegmatite veins, frequently heavily charged with tourmaline, which are intrusive into the Complex and which owe their origin to the granite intrusion.

(iii) The fairly large tongue of granite which cuts across the Usushwana diorite stock cutting off the northwestern extremity of the diorite from the main body.

(iv) The fact that the members of the Complex, especially the serpentines and pyroxenites, show a more intensive alteration and consequently a greater age, than the dyke intrusions of definite post-granite age.

(v) **Old Granite**

Two types of granite — biotite granite and hornblende granite — occur in the area either as normal granites, granite porphyries of gneisses.

Biotite Granite

The constituent minerals are quartz, microline, biotite, oligoclase altering to sericite, chlorite, myrmekite, orthoclase, apatite and zircon. Where the granite becomes gneissic microperthite and garnet occur in addition to the above minerals and biotite is frequently absent from the gneiss.

In the granite porphyries the quartz and orthoclase often occur in graphic intergrowths and magnetite is more abundant than in the normal granite textures. The phenocrysts are formed by the felspar and where the porphyries become gneissic augen structures are developed round the felspar phenocrysts.

Gneissic structures are best developed along the contact with the older rocks and the further one proceeds from the contact the less prominent becomes the banding in the granite. However, the gneisses are not entirely restricted to the vicinity of the contacts and gneiss is to be found in the mass of Old Granite miles away from any contact with the Fundamental Complex. There appears to be no controlling feature for the distribution of the porphyries and their contacts with the granite and gneiss are always gradational. Large biotite-rich bands with only a very minimum development of quartz and felspar occur in the granites, porphyries and gneisses and are particularly well developed in the granites round Makwanakop on the western side of the Motshane river valley. These bands are orientated parallel to the direction of the gneissic structure and, where they occur in granites or porphyries, parallel to the general direction of the Fundamental Complex — Old Granite contacts. Small xenoliths of Jamestown schists and Moodies quartzites are also found in the granite.

Hornblende Granite

The constituent minerals are quartz, oligoclase altering to sericite, orthoclase, microperthite, green hornblende altering to penninite and, occasionally, augite. Gneissic structures are also well developed in this granite and the general observations made as to the distribution of the biotite-rich gneiss also apply to the hornblende gneisses. Bands of amphibole occur in the hornblende-granite in the same manner as the biotite bands.

The hornblende-granite is only found along the eastern slopes of the Motshane river valley and the Usushwana valley where the hornblende schists of the Jamestown Complex attain their maximum development and the hornblende-rich diorites of the Havelock Complex are present.

Ordinarily, the hornblende granites are ascribed to the Kaap Granite while the biotite granites belong to the Nelspruit Granite. However, van Eeden states that hornblende may occur in the Nelspruit granite at its contacts with the Fundamental Complex and also that flow bands are comparatively rare in the Kaap granite whereas they are prominent in the Nelspruit variety. Hornblende-rich flow bands are conspicuous in the granite of the Motshane and Usushwana valleys and this, plus the fact that the hornblende granite is only developed where older hornblende-rich rocks predominate, would indicate that the granite has resulted from the assimilation of hornblende-rich rocks by the Nelspruit granite and does not represent a facies of the Kaap granite.

Furthermore, van Eeden described the Kaap granite as representing a soda tonalite while the Nelspruit granite is a granodiorite. In this area the plagioclase predominates over the orthoclase in both the hornblende and biotite granites so that the rocks approach granodiorites rather than true granites. However, in neither instance is the plagioclase in such excess over the orthoclase as to call the rocks soda tonalites.

Furthermore, van Eeden described the Kaap granite as representing a soda tonalite while

Microcline loses its prominence in the granites of this area and is not so characteristic of the Nelspruit granite as it is in the Barberton area. The minor development of microcline plus the appearance of myrmekitic structures and microperthite render the granite between the Komati and Usushwana rivers very similar to the old granites of the Vredefort region as described by Willemse[6].

The intrusive contact between the granite and the Fundamental Complex can be well seen along the Mbutu creek and on the eastern slopes of the Motshane valley. In the Motshane valley tongues of granite and coarse-grained pegmatite cut into the hornblende schists. In the Mbutu creek small tongues of granite and lenticles of high temperature quartz with muscovite and garnet occur both parallel and oblique to the schistosity. In the same area the schists contain pebbles up to 12 inches in diameter orientated parallel to the schistosity. These pebbles consist of quartz, albite, biotite, plagioclase highly altered to sericite and magnetite and correspond to a granitic composition. These pebbles are obviously older than the Jamestown Complex and also consequently than the Old Granite. Van Eeden describes granite pebbles as occurring in the Moodies conglomerates in the Sheba hills and it is apparent that there was an era of granite intrusion long before the formation of the post-Fundamental Complex Old Granite.

(vi) Metamorphic Effects of Old Granite

Except for a small portion north of the Mbutu creek where the granite is in direct contact with the Moodies quartzites, the Jamestown Complex acts as a barrier between the granite and the Swaziland System and, as a result, the rocks of this latter system have only been subjected to a minor degree of metamorphism compared to the Jamestown and Havelock Complexes.

Metamorphism of Swaziland System

The Fig-tree Series has undergone very little metamorphism. Sericite has been introduced into the cherts in places to give them a greenish colour* while in the shales, the only process seems to have been the introduction of specularite associated with quartz veins and stringers. Some of the heavy ferruginization of these shales may have been produced by the metamorphic results of the granite intrusion.

The arenaceous Moodies Series has been intensely metamorphosed along its contact with granite immediately south of the Komati river. The quartzites have been completely recrystallized so that they are now sugary-grained, and sericite with occasionally muscovite occurs interstitially to the quartz grains. Along fractures in the quartzites black schorl tourmaline has been introduced, usually without quartz, and in some places the tourmaline is scattered in isolated aggregates throughout the rock without any apparent structural control. In the Mbutu hills large areas of quartzites have been sheared with the production of sericite and chlorite. Quartz veins occur throughout the entire mass of Moodies Series and in places these have introduced actinolite, felspar, diallage, talc, biotite, grunerite, chlorite and no alteration except perhaps some ferruginization. Resilification appears to have been the most important metamorphic process developed in the Moodies and is best seen in the area south of Ngwenya Trigonometrical Beacon.

Metamorphism of the Jamestown Complex

The Jamestown rocks, being in direct contact with the granite over the greater part of the area, show the most intense degree of metamorphism with the result that the original igneous rocks and their structures have been completely destroyed and only secondary rock-types and structures remain.

The original rocks of the Jamestown Complex represented an ultrabasic magma—probably a pyroxenite of composition similar to websterite with orthorhombic pyroxenes, diopside, augite and some olivine. The main process of metamorphism was one of uralitization, there being no saussuritization due to the lack of felsic minerals in the original magma. The orthorhombic pyroxenes and the augite were altered to hornblende and the diopside to tremolite with minor amounts of actinolite. As metamorphism proceeded the hornblende was altered to chlorite and the tremolite-actinolite to talc while quartz and carbonate were introduced by the solutions emanating from the granite. Any felsic minerals that were originally present were also altered to quartz and calcite and the introduced quartz accounts for the larger amounts of this mineral present in the hornblende-quartz schists. Black shorl tourmaline, garnet, muscovite and biotite were also introduced.

The metamorphism was not limited to an alteration of the rock-forming minerals alone but also produced the distortions and folding in the schists, features which, no doubt, facilitated the complete metamorphism of the rocks.

Metamorphism of the Havelock Complex

There is a gradual diminution in the intensity of the metamorphism of the Havelock Complex from the serpentine to the diorites where the only effect produced in these rocks is a partial alteration of the hornblende to chlorite and the plagioclase to sericite.

*Also due to fuchsite.—H.J.R.W.

The serpentines represent original peridotites consisting of mainly olivine and pyroxene and are the oldest rocks of the Complex which accounts for their extreme metamorphism comparable to that produced in the Jamestown Complex. The olivine was altered to the serpentine minerals antigorite, serpophite and chrysotile, and magnetite, the alteration being incomplete so as to leave residual olivine cores. The pyroxenes were altered to nephrite, hornblende, talc and chlorite also leaving residual cores of augite.

The pyroxenites have been both uralitized and serpentinized with the former process predominating. The alteration products are tremolite, talc, chlorite, magnetite and antigorite. the serpentine minerals may possibly have resulted from small amounts of original olivine in the pyroxenites as well as from the pyroxenes.

The original gabbro rocks of the Complex have undergone saussuritization and uralitization to form epidiorites while the diorites show a minimum of alteration.

Table II shows the main metamorphic minerals produced by the intrusion of the granite:

TABLE II

List of Metamorphic Minerals Produced by Intrusion of Old Granite

Group	*Mineral*
Amphibole	Actinolite Tremolite Hornblende Grunerite Nephrite
Pyroxenes	Diallage
Micas	Biotite Sericite Muscovite Margarite
Serpentines	Antigorite Serpophite Chrysotile
Miscellaneous	Tourmaline Garnet Chlorite Penninite Clinochlore Felspar Apatite Quartz Titanite Talc Magnetite Calcite

This list shows a striking similarity to one compiled by van Eeden indicating that the metamorphism of the Fundamental Complex has been relatively uniform throughout the Barberton Mountain Land. The prevalence of these minerals and the schistose structures in the Jamestown and Havelock Complexes and shear zones in the Moodies indicates that the metamorphism took place in the meso- and epi-zones and was of the dynamo-thermal kind.

(vii) **Later Intrusions**

Dykes of post-granite age are abundant in the area and particularly so in the granite itself. In the vicinity of the granite-Fundamental Complex contact these dykes either terminate at the contact or penetrate only a short distance into the older rocks, a feature which has also been noted by Hall[3] in connection with the dykes between Barberton and Kaapsche Hoop. Five types of dykes have been identified.

Diorites

The main minerals are andesine plagioclase altering to sericite and green hornblende altering to chlorite. Minor minerals are augite, biotite, magnetite, quartz and albite. Where quartz occurs it generally shows graphic textures.

Dolerites

Three varieties of dolerite occur: an olivine dolerite composed of andesine-labradorite plagioclase, augite and olivine with minor amounts of sericite, apatite, biotite, quartz and magnetite; an enstatite dolerite composed of andesine-labradorite plagioclase, augite, enstatite showing alteration to fibrous talc along fractures and occasionally minor amounts of olivine; an ordinary dolerite composed of plagioclase, diallage, augite and minor amounts of albite and talc. Compared to the other types of dykes, the dolerites are fresh and show a minimum of alteration.

Lamprophyres

These are composed of orthoclase and green hornblende which also forms very fine needles in the orthoclase. The typical panidiomorphic texture which characterizes the lamprophyres is not well developed but the mineral composition of the rock corresponds so closely to that of the hornblende lamprophyre, vogesite, that it is highly probable that the rock is a true lamprophyre in which the panidiomorphic texture has lost its prominence.

Epidiorites

Some dykes show original augite cores surrounded by hornblende rims and a highly altered andesine but the majority have been saussuritized and uralitized so that the constituents are now quartz, calcite, albite and chlorite.

Makwanakop-type Dykes

The most conspicuous and interesting dykes in the area belong to this group. In the field the rock is a fine-grained, dark grey rock in which the femic and mafic constituents can be seen with the naked eye. Set in this groundmass are large masses of clear hypothermal-type quartz over 12 inches in length in places and also, less commonly, coarse-grained aggregates of quartz and felspar which resemble fragments of pegmatites. In thin sections the rock is composed mainly of myrmekite which occasionally is replaced by graphic intergrowths of quartz and felspar. Euhedral crystals of plagioclase are set in the groundmass and show excellent zoning with the cores corresponding to andesine plagioclase and the rims to oligoclase so that these euhedral crystals become more sodic from the centre outwards. The principal mafic mineral is green hornblende which has a tendency to form large phenocrysts in the felspar-quartz groundmass. Sericite results from the alteration of the plagioclase and chlorite from the hornblende while calcite is sometimes present in small amounts. In places this rock-type resembles a hornblende granophyre but it is more probable that the original rock was a hornblende bearing type — possibly a diorite — which has been deuterically altered upon the assimilation of granitic material during the period of its intrusion.

Insufficient work has been done to determine the various ages of these dykes but it is probable that the majority are pre-Karroo in age while some of the dolerites may be of Karroo age. In the Fundamental Complex the dykes are usually orientated along the direction of the fractures in the older rocks, a feature which is well seen round Silotwane Peak. In the granite the strike of the dykes is more heterogeneous due to the more abundant and complicated sets of fractures produced.

TABLE III

Stratigraphy of the Country between the Komati and Usushwana Rivers

Age	*System*	*Series*	*Thickness*	*Lithology*
Post-granite		Intrusive dykes	100 ft.	dolerites, diorites, epidiorites, lamprophyres, Makwanakop-type dykes of mostly pre-Karroo age
Old Granite	Old Granites	Nelspruit variety or type G.1		biotite and hornblende granodiorites, porphyries, gneisses, pegmatites
Fundamental Complex		Havelock Complex	800 ft.	serpentines, pyroxenites, epidiorites, diorites
		Jamestown Complex	6,000 ft.	talc, chlorite, hornblende, tremolite schists
	Swaziland System	Moodies Series	8,000 ft.	conglomerates, jaspers, shales, grits, quartzites, sheared quartzites
		Fig-tree Series	5,500 ft.	banded cherts, shales, graywackes, banded ironstones

STRUCTURAL GEOLOGY

Where the Swaziland System attains its maximum variation in development immediately south of the Komati river, the structures existing can be more readily interpreted due to the presence of marker horizons. South of this area the Swaziland System becomes a mass of arenaceous sediments in which marker horizons are lacking while the Jamestown Complex is composed of basic schists whose differentiation is extremely difficult in the field and in which no well defined, constant horizons are produced. Consequently, over the greater part of the area possible structures can only be arrived at from a study of the strikes and dips of the rocks and where erosion has exposed geological structures.

South of the Komati river, the Swaziland System has been folded into two synclines connected by an anticline with vertical limbs. The western syncline is well exposed in the vicinity of Masali Peak. North of the peak the western limb of the syncline has an average dip of 65° to the east, the Fig-tree shales dipping at 75° producing a 10° unconformity, while the eastern limb has a vertical dip so that an asymetrical syncline is formed. Towards the south this eastern limb assumes a steep dip to the east so that the syncline tends to become roughly isoclinal.

The anticline with its vertical limbs exposes the Fig-tree Series. The eastern syncline which forms the Mbutu hills has an eastern limb dipping at 60° to the west while the western limb is vertical. In a southerly direction this limb also assumes a westerly dip so that the eastern syncline also tends to become somewhat isoclinal.

South of the Masali Peak — Mbutu hills area structures become less evident although it can be seen that there is a general synclinal structure* around the Forbes Reef flats. On the eastern margin of the flats Moodies quartzites occur and are separated from the Swaziland System of the Ngwenya range by the large area of schists. Dips indicate that these two exposures of the Swaziland System are connected by a syncline of which the Jamestown Complex forms the core. The width of outcrop of the Moodies on the Ngwenya range is so much greater than that on the east of the flats that it would appear that folding has also taken place on the Ngwenya range to cause the increased width.

West of the Ngwenya Trigonometrical Beacon, the deep erosion responsible for the escarpment slopes has exposed a well developed and easily discernable symmetrical anticline in the quartzites. This anticline proves that the Swaziland System in the Ngwenya range has undergone considerable folding and that its thickness has been greatly increased as a result.

South of the Ngwenya range, where only the Jamestown and Havelock Complexes are present, structures are also difficult to recognize. Detailed work on the serpentines just north of the Usushwana diorite stock indicates that the rocks are folded into two isoclinal synclines dipping towards the east. The schists themselves have been folded and contorted on a very large scale and these minor structures are developed along the limbs of the major structures.

The absence of marker horizons has also rendered difficult the recognition of the existence of faults. The only major fault which can be seen is the one between the Avalanche and Primrose mines west of Forbes reef where the south side of the fault represents the upthrow side. In the Moodies quartzites zones occur in which movement along fault planes appears to have taken place but the criteria are insufficient to warrant definite recognition.

The apparent absence of faults may also be due to the fact that the stresses producing distortion were not powerful enough to produce faulting. These forces may not have exceeded the elastic limit of the rocks with the result that the stresses were absorbed in the formation of the high degree of folding that characterizes the Fundamental Complex especially the Jamestown schists.

It is possible that the Jamestown Complex may have been responsible for a certain amount of the folding. It was intruded under the Swaziland System in the approximate shape of a lopolith of which the eastern end broke through the older rocks and overflowed the Moodies Series along the Forbes reef flats. This would account for the Jamestown Complex underlying the Swaziland System in places and giving the appearance of being of greater age and also for the overlap of Jamestown and Moodies at Forbes reef. The weight of the superimposed igneous rocks along the flats may have accounted for a certain amount of sagging in the underlying Swaziland System producing the initial synclinal structure of the area.

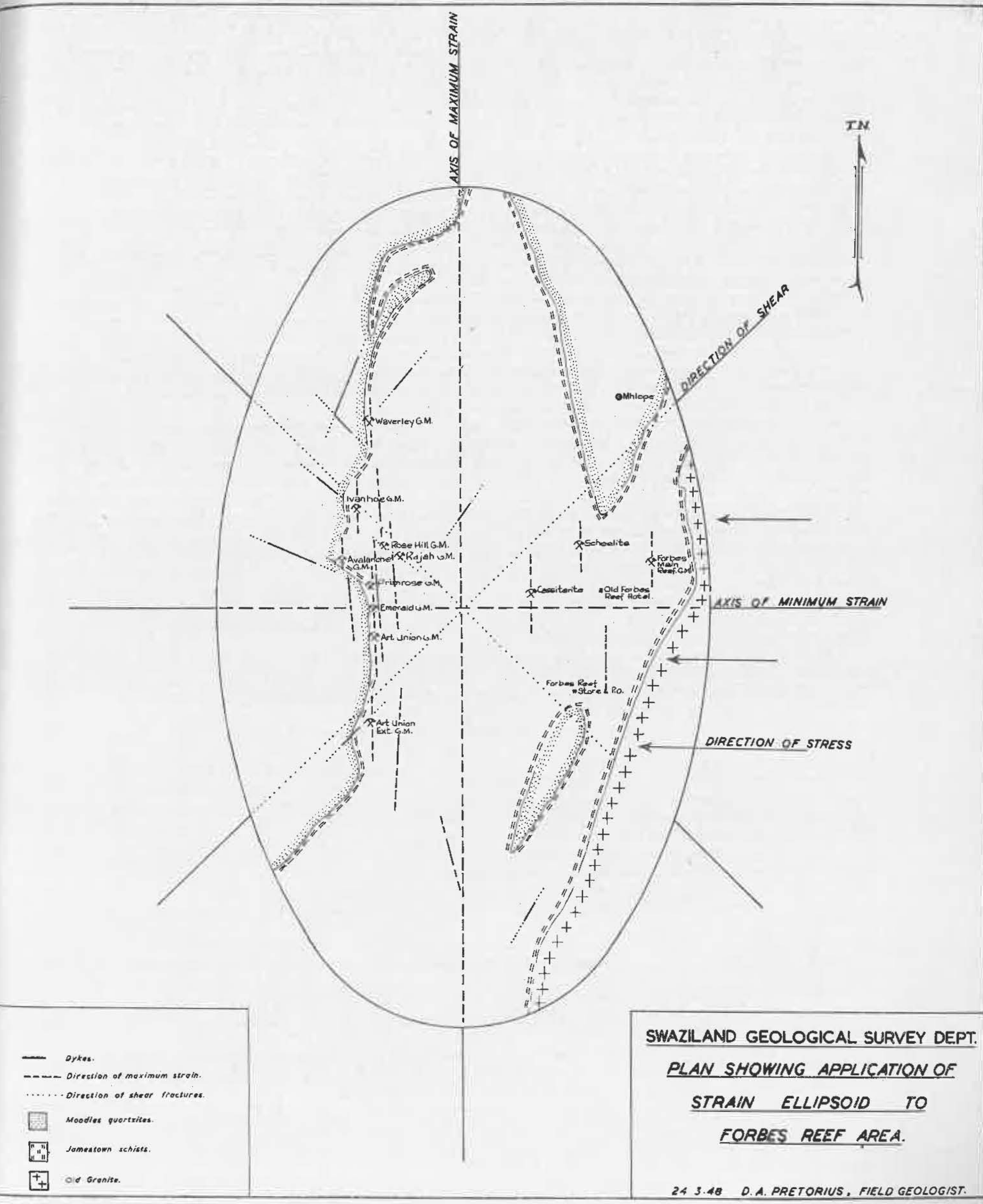
However, a study of the fracture system in the Forbes Reef area indicates that the ruptures in the Swaziland System and the Jamestown Complex have roughly the same orientation. These fractures tend approximately N.W.—S.E. and N.E.—S.W. while the dykes also follow this orientation and also a direction roughly north-south. An application of the strain ellipsoid indicates that the north-south dykes have been intruded along the axis of maximum strain while the N.W.—S.E. and N.E.—S.W. dykes have been emplaced along the direction of the shearing stress. The fault between the Avalanche and Primrose mines also runs in a N.W.—S.E. direction further supporting the supposition that this direction and one complimentary to it represent the directions of shearing stress so that the axis of maximum strain is at 45° to these directions. This indicates that this axis runs approximately north-south which is borne out by the north-south orientation of some of the dykes. Consequently the axis of intermediate strain runs east-west which means that the original stress was applied from the east and the west. To the east and to the west of the Fundamental Complex lies the granite so that it is apparent that the intrusion of the granite provided the force necessary for the folding and distortion of the older rocks. The intrusion of the Jamestown and Havelock Complexes thus played a minor role in the tectonic history of the area.

HISTORICAL GEOLOGY

Due to the absence of the Onverwacht Series in this area, an approximation of the geological history begins with the deposition of the Fig-tree Series and culminates in the intrusion of the Old Granite.

The great regularity of the banding of the cherts and the absence of distortion in the individual bands indicates that the Fig-tree Series must have been deposited under conditions of minimum

*This structure is now known to be an anticline isoclinally folded. D.R.H.



AXIS OF MAXIMUM STRAIN
T.N.
DIRECTION OF SHEAR
Mhlope
Waverley G.M.
Ivanhoe G.M.
Rose Hill G.M.
Rajah G.M.
Avalanche G.M.
Primrose G.M.
Emerald G.M.
Art Union G.M.
Art Union Ext. G.M.
Scheelite
Forbes Main Reef G.M.
Cassiterite
Old Forbes Reef Hotel
AXIS OF MINIMUM STRAIN
Forbes Reef Store & P.O.
DIRECTION OF STRESS
Dykes.
Direction of maximum strain.
Direction of shear fractures.
Moodies quartzites.
Jamestown schists.
Old Granite.
SWAZILAND GEOLOGICAL SURVEY DEPT.
PLAN SHOWING APPLICATION OF STRAIN ELLIPSOID TO FORBES REEF AREA.
24 3.48 D.A. PRETORIUS, FIELD GEOLOGIST.

FIGURE II.

distortion which would mean under deep marine conditions. Van Eeden estimates that the depth exceeded 600 feet.[5] Furthermore the lack of calcareous strata* in the Fig-tree Series indicates formation at depth rather than in shallow water in which cherts are usually accepted to have been formed. The main mass of shales which represented a slime was held in suspension until the cherts had been deposited and was then emplaced above the banded cherts.

A period of continental uplift followed which was responsible for the Fig-tree Series developing an initial dip to form an unconformity with the later Moodies Series. A long period of erosion took place after the uplift so that the cherts were broken down and formed pebbles.

The seas then encroached upon the land so that the streams flowing N.W. to S.E. discharged into shallow water. The banded chert pebbles plus pebbles from other older rocks were deposited unconformably on the Fig-tree shales to form the basal conglomerate while the finer particles were carried further eastwards to form the grits and quartzites. That the original direction of deposition was from N.W. to S.E. can be seen by the fact that there is a general decrease in grain size from N.W. to S.E. and also a decrease in variation of rock-types. These features also take place in a north-south direction which indicates that sedimentation became less prominent in this direction and that this area represents the southernmost limit of the deposition of the Swaziland System.

After consolidation of the sediments the Jamestown Complex was intruded as pyroxenite lopolith beneath the Swaziland Complex, the eastern end of the lopolith breaking through the older rocks to overlap the Moodies Series east of the Ngwenya range. These pyroxenites were later metamorphosed by the intrusion of the Older Granite, the main process being uralitization.

In the early stages some of the pyroxene may have been altered to chlorite but the bulk of the pyroxenes were altered to hornblende during the uralitization stage. During the same stage the diopside was altered to tremolite and the olivine to tremolite and talc. During the final stages the tremolite was altered to talc and the hornblende to chlorite. During the intrusion of the pyroxenite some differentiation may have taken place resulting in the concentration of the orthorhombic pyroxenes at the base of the lopolith while the monoclinic pyroxenes accumulated further up. This may account for the hornblende and tremolite schists being found in the vicinity of the granite-schist contact while the talc schists are concentrated away from the contact. However, the more probable reason for the limitation of the hornblende and tremolite schists to the vicinity of the granite is that these schists are typically formed in the mesozone of metamorphism while talc schists are more characteristic of the epizone. Naturally the mesozone of higher temperature would occur closer to the granites than the epizone and thus the hornblende and tremolite schists of the mesozone would be limited to the vicinity of the granite-schist contact while the talc would occur in the epizone further removed from the granite.

After the intrusion of the Jamestown Complex began a long period of igneous activity which resulted in the formation of the Havelock Complex and the Old Granite. While the Havelock Complex was undergoing crystallographic differrentiation, gaseous emanations and solutions began to permeate the Jamestown rocks causing alteration and deformation. These emanations and solutions were probably the forerunners of the granite. While the Jamestown rocks were being altered, the intrusion of the Havelock Complex began. Peridotites containing the olivine were the first to crystallize out and as a result were also completely altered to serpentines by the same solutions responsible for the complete metamorphism of the Jamestown schists. The orthorhombic and monoclinic pyroxenes then crystallized out to form the pyroxenites which were also subjected to alteration by the solutions but not to the same degree as the serpentines as the emanations and solutions were probably becoming less active by this time. The felspars then began to crystallize out and with the remaining monoclinic pyroxenes formed a gabbro which was later altered to an epidiorite. The last phase of the Havelock Complex is represented by the crystallization of the amphiboles and more sodic felspar to form the diorites.

Following the Havelock diorites came the period of the Old Granite intrusion resulting in the formation of granodiorites, porphyries and gneisses and which was responsible for the high degree of folding in the Fundamental Complex. The last phases of the granite intrusion were the formation of the pegmatites and the injection of hydrothermal solutions both of which acted as mineralizing agencies.

The geological history of the area was completed by the intrusion of the post-granite dykes the majority of which are probably of pre-Karroo age.

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*Lime-bearing sediments are known in the Fig-tree Series. D.R.H.

ECONOMIC GEOLOGY

The mineral deposits occurring in this area may be grouped under three separate headings: (i) the deposits which owe their origin to hydrothermal solutions; (ii) the deposits which owe their origin to pegmatitic intrusions; and (iii) the deposits whose origin is not definite and may possibly be ascribed to both hydrothermal and surface solutions. In group (i) belong the deposits of gold with their associated minerals of lead, copper, antimony and arsenic as well as the deposits of barytes and scheelite; in group (ii) belong the deposits of cassiterite, columbite and monazite; and in group (iii) belong the deposits of iron ore and chrysotile asbestos.

(i) Deposits of Indefinite Origin

Iron Ore Deposits

Iron mineralization has proceeded to a marked degree in the Swaziland System and deposits occur in both the Fig-tree and Moodies Series. However, the Moodies Series contains no potential ore deposits, the possible economic deposits being limited to the Fig-tree Series.

In the Moodies Series the iron ores found are limonite and haematite, the former occurring in the quartzites and conglomerates while the latter is mostly found in the shale horizons and the Jasper Marker. In the quartzites and conglomerates the limonite occurs either as a ferruginous replacement of the quartzitic matrix or as a gossan. In the jasper the red coloration of the rock itself may be due to very fine particles of iron but the major proportion of the iron occurs as specularite associated with small quartz veins and stringers. In places the shales have been intensively replaced by haematite to form banded ironstones.

The ferruginization of the quartzites and conglomerates is best developed in the vicinity of Silotwane Peak and along the Mahlanganpeppa valley. The Jasper Marker shows iron mineralization in both its occurrences north of Masali Peak and also north of the Lily valley. The shales have been ferruginized in the Mahlanganpeppa valley along the northern tip of the eastern shale horizon south of the Ngwenya Trigonometrical Beacon. Table IV shows the results of sampling on the various iron occurrences in the Moodies Series, the location of the samples being shown on the main map.

TABLE IV

Assay Results of Samples of Iron Occurrences in Moodies Series

Horizon	*Average Percentages*		*Locality and Remarks*
	Fe	SiO_2	
Conglomerate	56.95	2.85	Silotwane Peak, pebbles and matrix intensively replaced
Quartzites	49.10	9.82	Silotwane Peak; gossan capping and fracture filling
Jasper Marker	43.43	33.05	North of Lily valley; average of three samples
Shales	53.70	4.43	Mahlanganpeppa valley: small area of banded ironstones
	40.70	32.25	South of Ngwenya Trigonometrical Beacon; small area of banded ironstones

Although some of the above results may appear to represent ores of sufficiently high grade to warrant further investigation it must be pointed out that the distribution of each mineralized horizon is of limited extent and that the mineralization is erratic so that it is unlikely that bodies of an economic tonnage will occur in the Moodies Series.

In the Fig-tree Series some of the banded cherts show replacement by iron along certain bands so that the rocks represent true banded ironstones. However, these areas of replacement are also small and erratic and the silica content is too high to merit further investigation on the potential iron ore reserves of the banded cherts.

The most important iron-bearing horizon in the area is the zone of Fig-tree shales immediately underlying the Moodies Series. This zone commences north of the Komati river where the economically important haematite deposits at Iron Hill occur(2). It crosses the Komati river and then swings out into the Mahlanganpeppa valley. From this point it continues in a southerly direction to peter out in the vicinity of Clarry's camp on the Oshoek-Mbabane road. This shale horizon is not ferruginized along its entire length, the iron mineralization being restricted to certain unconnected zones. The limits of these zones are purely economical, the ferruginized shales showing a gradual transition to ordinary, non-ferruginized Fig-tree shales.

On the Ngwenya escarpment slopes, three such zones are developed, one north of the Lily valley, one at Bomvu Ridge and one north of Clarry's camp. From the structures of the area there is a possibility that further zones of mineralization may occur in the Transvaal where the Fig-tree shales fall outside the Swaziland border. Of these three areas the one north of the Lily valley is the least likely to prove an economic iron deposit. The iron content is lower than that of the areas to the south and the silica content very much higher. Furthermore, even if an intensive prospecting programme indicated a satisfactory grade, the extremely rugged topography and inaccessibility of the area would render the exploitation exceedingly difficult.

At all these localities the ore-bodies are almost identical, in which zones of almost complete haematite mineralization are separated from each other by zones of poor ferruginization and even barren zones. Preliminary trenching at Bomvu Ridge has revealed at least three zones of high haematite replacement up to 50 feet in thickness with intercalated zones of low grade shales. Insufficient work has as yet been done to determine the length along the strike of these zones. The haematite is of the hard, compact variety in which the original bedding of the shales can still be seen in the majority of cases. Specularite is abundantly developed in vug-like cavities in the haematite as well as in the less well mineralized shales where it often occurs with quartz stringers. Table V shows the results of outcrop sampling at the three localities.

TABLE V

Assay Results of Outcrop Samples on Fig-tree Iron Horizon

Locality	*Average* Fe	*Percentages* SiO_2	*Remarks*
Bomvu Ridge	61.00	7.38	northern portion of ore body
Bomvu Ridge	55.90	17.31	central portion of ore body
Bomvu Ridge	64.60	3.54	southern portion of ore body
North of Clarry's camp	63.70	6.11	
North of Lily valley	41.40	36.88	

The samples at Bomvu Ridge, which give an average of 60.50 per cent. Fe and 9.41 per cent. SiO_2, and at Clarry's camp were taken along the outcrops of the haematite-rich bands. It is obvious that silica must have been leached from the ore by surface waters with a consequent enrichment of iron. Thus these samples represent the highest grades of the deposit so that the average grade of the bodies will be considerably lower than these*. Trenching has also revealed at Bomvu Ridge talus and scree below which low grade horizons occur. Thus a reconnaissance of the surface indications would produce an exaggerated estimate of both tonnage and grade of the haematite deposits so that an intensive and detailed prospecting programme is required before the true potential ore reserves can be assessed.

Chrysotile Asbestos Deposits

Chrysotile asbestos fibre has been located in two bodies of serpentine in the Motshane river valley but insufficient work has as yet been done on the other known bodies of serpentine to determine the potentialities of the area as a possible producer of chrysotile. Eleven bodies of serpentine have been located in the Motshane valley and one on the Ngwenya escarpment slopes. Another outcrop of serpentine also occurs on these slopes but falls within the Transvaal.

*Since disproved by later work. H.J.R.W.

The serpentines represent the oldest rocks of the Havelock Complex and their mineralogy and composition have been discussed under the serpentines of the Usushwana valley. It is evident that the eleven outcrops have been formed by duplication due to the folding associated with the granite intrusion and it is, therefore, probable that the serpentines represent only one main horizon. Seven separate areas of serpentine development occur and in four of these areas, two outcrops are found at an average distance of 1,500 feet from each other and having similar strikes and dips. These outcrops represent the eastern and western limbs of north-south trending synclines. In the remaining three areas where only one outcrop occurs it is probable that in each case the second limb of serpentines has not been exposed, or, if so, has not been recognised in the mass of basic Jamestown schists during traversing.

Only one of these bodies has been investigated, viz., the area of serpentines immediately north of the Usushwana diorite stock. Here folding has resulted in four exposures of the same bed on the limbs of the two easterly dipping synclines. The serpentines have developed a schistose structure. Chrysotile fibre has developed along fractures of an irregular pattern and sampling across outcrops has an average fibre length of one eighth inch. In some places the fibre attains lengths of up to half an inch. A small amount of excavation on these serpentines has revealed that the fibre content and length averages the same at a depth of 30 feet. The chrysotile is frequently associated with talc and often produces hard and brittle fibres. However, these features may only be due to surface weathering and may become less pronounced at depth.

The serpentines immediately south of Clarry's camp are also fibre-bearing. The serpentine in this case is massive but the features observed as to the chrysotile in the Usushwana bodies also apply to this body. It attains an outcrop length of 1,600 feet and a width of 850 feet but fibre development has only taken place in small patches so that the greater part of the body represents barren serpentine. The average fibre content is 6 per cent. with a fibre length of one eighth inch.

Outcrops in the remaining five areas do not disclose the presence of fibre but the possibility of asbestos mineralization in these bodies cannot be eliminated until they have been investigated at depth. The serpentines on the Ngwenya escarpment slopes also appear to be barren.

Thus a reconnaissance of the serpentine outcrops in the area would indicate that asbestos mineralization has not proceeded to a marked degree and that the possibility of locating bodies of economic fibre content is in no way proportionate to the degree of serpentinization in the area. However, asbestos of suitable grade and quality does occur and a detailed prospecting programme would possibly reveal further promising bodies. Furthermore, Hall[7] has observed that, in the case of chrysotile asbestos, the fibre-bearing bodies are generally of a comparatively soft serpentine which does not form outcrops whereas the barren serpentine is much harder and forms well developed outcrops resistant to weathering. This feature can be well seen at Havelock mine where the ore is a soft serpentine with a hanging and footwall of hard, barren serpentine. Applying this generalization to the Motshane serpentines, it is possible that the outcrops for the most part belong to the hard barren serpentine while zones of softer, fibre-bearing serpentine are not exposed. Consequently a survey of the economic potentialities of the area based entirely on the surface indications would give a totally incorrect result which can only be eliminated by a programme of intensive pitting and trenching and, possibly, also diamond drilling.

Hall, as a result of investigations in the Havelock mine area[7] states that: "Serpentine formations form a good outcrop at the 'Station' referred to (some 4-5 miles west-north-west from the Pigg's Peak police post) whence they probably strike down into the valley of the Nkomazana river, towards and through the Havelock mine, to continue further on into Josefsdal: it would appear, therefore, that the basic intrusions, which subsequently passed into serpentine, occupy a definite horizon in Moodies Series, traceable for several miles along the strike and associated with equally definite and persistent bands, described above as cherts."

The serpentines of the Motshane valley conform to a definite horizon in the Jamestown schists and this same horizon cuts across the Fig-tree Series on the Ngwenya escarpment slopes and continues out into the Transvaal in a northerly direction towards the Komati river. From the intrusions and stratigraphy of the area it appears highly probable that this horizon continues in the Fig-tree Series to link up with the horizon proposed by Hall north of the Komati river, which also occurs in the Fig-tree Series, since the cherts which he ascribed to the Moodies Series have now been correlated with the former.

Consequently there exists, with the possibility of this serpentine horizon, a likelihood that further occurrences of asbestos may be located in the Transvaal between the point where the horizon cuts across the Swaziland border and the Josefsdal valley. North of the Komati river two bodies of economical proportions have been opened up at the Havelock mine in Swaziland and at the African Chrysotile mine on the farm Diepgezet in the Josefsdal valley in the Transvaal.

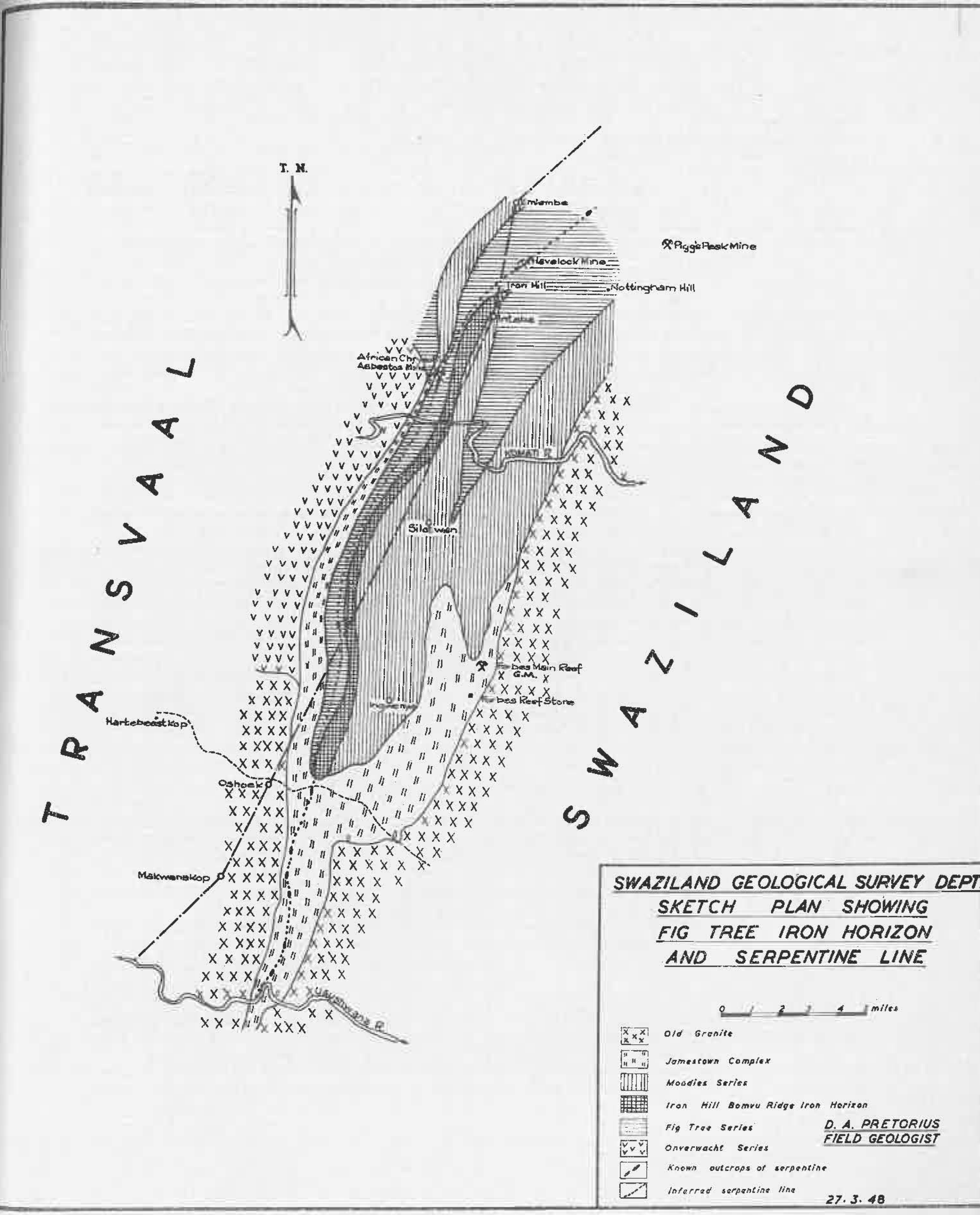
T. N.
TRANSVAAL
SWAZILAND
Pigg's Peak Mine
Nottingham Hill
Iron Hill
Sitetwen
Hartebeestkop
Oshoek
Makwenakop
SWAZILAND GEOLOGICAL SURVEY DEPT
SKETCH PLAN SHOWING
FIG TREE IRON HORIZON
AND SERPENTINE LINE
0 1 2 3 4 miles
Old Granite
Jamestown Complex
Moodies Series
Iron Hill Bomvu Ridge Iron Horizon
Fig Tree Series
Onverwacht Series
Known outcrops of serpentine
Inferred serpentine line
D. A. PRETORIUS
FIELD GEOLOGIST
27. 3. 48

FIGURE III.

Fibre-bearing bodies occur in the Motshane valley at the southern extremity of the serpentine line and so there is more than an even chance of further asbestos bodies being found along this horizon where it occurs in the Transvaal.

(ii) **Deposits of Pegmatitic Origin**

Cassiterite Deposits

Two main areas of tin mineralization occur within the portion of the country under review but neither has proved to be as extensive or as payable as the other tinfields of Swaziland which stretch from the vicinity of Mbabane in a south-easterly direction. Alluvial cassiterite occurs in the Makwanakop area west of the Motshane valley and both reef and alluvial tin at Forbes Reef.

At Makwanakop alluvial cassiterite has been exposed in the Gwili and Mtwali creeks and has been worked on the former creek at a point about 8,000 feet south-east of the Makwanakop border beacon. The cassiterite-bearing gravels rest on a bedrock of Old Granite which contains abundant lenses of acid bands of biotite-rich material and also a large number of pegmatites. Way has investigated the area[8] and states that "the gravels are erratic and their distribution is complicated by the presence of large boulders." The average metallic tin content of the cassiterite is 73 per cent. Associated with the tin in the concentrates are euxenite, monazite, magnetite, ilmenite, haematite and garnet.

Prospecting on the alluvial tin of the Mtwali creek has also revealed the presence of eluvial cassiterite of a lower grade than the alluvial. It is probable that more intensive work may reveal further areas of payable alluvial and eluvial gravel since pegmatites from which the cassiterite was probably derived abound in the area. Up to the present tin has been proved in the area between the Sandspruit and Gwili creek but little or no work has been done south of the latter stream.

Alluvial tin was once profitably worked at the beginning of the century along that portion of the Malolotsha river between the Forbes Reef mine and the Malolotsha Falls which is known as the Crown Reserve. Here the mineral association is the same as at Makwanakop, except that alluvial gold also occurs and both have been recovered. This stretch of the river has been worked so often in the past that it is probable that the economic potentialities must be near the point of exhaustion with the result that a careful and detailed examination is an absolute necessity before further attempts at exploitation can be made.

Of great interest but of smaller possibilities is the occurrence of ruby tin in reef form near the old Forbes Reef hotel. A pegmatite has been intruded into the talcose schists of the Jamestown Complex parallel to the direction of strike of the schists and has been traced over a distance of 120 feet with an average width of two and a half feet. This pegmatite is completely kaolinized along the outcrop and to a depth of about 12 feet as exposed in trenches. Scattered, ill-formed crystals of blackish cassiterite occur in this pegmatite which has a hanging and footwall of mica schist. This zone of reddish schist shows a gradual transition on both sides of the pegmatite into ordinary greyish, talc schists.

About 100 feet into the hanging wall of this pegmatite a zone of reddish mica schist is again developed and attains a maximum width of two feet. This zone is somewhat erratic, in places running parallel to the strike of the surrounding talc schists and, in others, cutting across the strike at a small oblique angle. This zone probably represents a shear fracture which has acted as a channelway for the passage of solutions, probably associated with the intrusion of pegmatite. These solutions have altered the schists into the reddish mica variety and have also introduced cassiterite of the ruby tin variety. The crystals of cassiterite are well-formed and the largest one exposed of recent years measured three inches in length by two inches in width. Crystals of much larger dimensions have been reported in the past. The tin tends to concentrate along the footwall of the fracture and forms pockets of limited extent along the strike and down the dip.

Mehliss[9] has traced this zone of reddish mica schists over a distance of 4,500 feet. Black schorl tourmaline is frequently developed as a gossan capping along the zone but the presence of this mineral is no indication as to the presence of tin. The largest tourmaline gossan measured 70 feet long by 10 feet wide and assayed 0.08 per cent. tin. There is no reason to suppose that only one zone of shearing has been developed and further prospecting into both the hanging wall and footwall may reveal further zones of cassiterite-bearing, red mica schist.

Between the pegmatite and the shear zone several pieces of float up to 12 inches in width have been located and consist of an aggregate of a radiating, platy mineral with a pearly lustre. This mineral has been identified as margarite, a member of the brittle mica group. The platy structure can be well seen in vugs developed in the float and in places the margarite is heavily charged with black schorl tourmaline. Margarite is generally found as an alteration product of corundum but the presence of this latter mineral could not be traced in the area, and it is more probable that the margarite has been intruded as a hydrothermal or pegmatitic veinlet in association with tourmaline and quartz.

Columbite Deposits

Alluvial columbite has been located on the headstreams of the Malolotsha river west of the Mhlope beacon. These streams take their rise in granite porphyries belonging to the Old Granite and which occur close to the granite-schist contact. Numerous small pegmatites can be well seen cutting across the granite outcrops in the area and in one of these small amounts of columbite have been identified. Consequently it is safe to assume that the alluvial columbite had its origin in a number of small pegmatites rather than in one large body.

The occurrence has been investigated by Mehliss[10] and it has been found that the columbite is concentrated in the gravels immediately above the granite bed-rock and which have an overburden of 4 to 8 feet. The average columbite content of the gravels is only 0.03 per cent. so that the deposit has been proved unpayable. Magnetite, ilmenite and monazite are associated with the columbite.

(iii) **Deposits of Hydrothermal Origin**

Barytes

Barytes occurs along the Londosi river just east of the Transvaal-Swaziland border and is, at the present moment, being exploited by the Swaziland Barytes Mine Ltd. The deposit is located at the head of the Steynsdorp valley and the mine is two and a half miles from the main Ermelo-Mbabane road at Oshoek. However, the mine is only accessible from the Steynsdorp road* which branches off at Hartebeestkop, well into the Transvaal, so that the property is, by road, over 12 miles distant from the main road, which renders transport the main problem in large scale mining of the ore. An attempt is being made to cut a road up the hills from the mine to Ormonde farm, which, if successful, will make the deposit more readily accessible.

The barytes occurs as tabular veins in the Jamestown schists which consist predominantly of hornblende schists with lesser proportions of talc-chlorite-carbonate and quartz-sericite schists. The schists strike roughly north-south and dip to the east an at average of 35°. The barytes horizons are concordant with the strike and dip of the schists.

Three horizons of barytes have been located, the distance between the top and bottom zones being in the vicinity of 170 feet. The upper zone attains a length of 100 feet with a maximum width of 18 inches while the middle zone has a strike length of 100 feet with an average width of 4 inches and, consequently, these two zones are of comparatively little importance as ore bodies.

The lower zone constitutes the main horizon and along it mining is now taking place. Mehliss[11] has traced this zone over a strike length of 4,230 feet with an average width of 7 feet and a maximum width of 12 feet. This width does not represent a solid seam of barytes, but rather a number of bands up to seven in number with widths from 1 to 36 inches separated from each other by inclusions of hornblende schist. The $BaSO_4$ content of this horizon calculated from run-of-mine is 84.53 per cent., while the assay of the washed and partially treated material is[11]:

	per cent.
$BaSO_4$	95.16
$CaSO_4$	0.95
SiO_2	3.48
Al_2O_3	0.46
Fe_2O_3	0.07
	100.12

There is an apparent decrease in the width of this body both towards the north and south so that it would appear to be rather a huge lens than a true vein, with the result that extensions of great length along the strike to the north and south of the present property cannot be safely anticipated, unless further lenses tend to be formed. A conservative estimate of a potential ore reserve of 200,000 tons with a $BaSO_4$ content of 89.34 per cent. was calculated in 1945, but with the increased work on the mine it is highly probable that the present figure would be very much greater.

The presence of the ore minerals, pyrite, chalcopyrite and magnetite in the barytes body, although of minor amounts, tends to support the theory that the deposit owes its origin to the

*A road to this mine has since been constructed in Swaziland. H.J.R.W.

intrusion of the granite. The area also abounds in veins of quartz and calcite of definite hydrothermal origin.

Scheelite Deposit

Very small amounts of alluvial scheelite have been recovered from the Malolotsha river while working for tin and gold but the scheelite lode itself occurs along a small creek feeding into the river and about 2,000 feet N.N.W. of the old Forbes Reef hotel. This creek flows from south to north and discharges into the Malolotsha river which at that point is running almost due east-west before turning north towards the Malolotsha Falls.

In the vicinity of this valley a zone of hard hornblende, actinolite and biotite schists up to 25 feet in width occurs in the main mass of soft, talc-carbonate schists. The biotite schists attain a thickness of up to four feet and have resulted from the alteration of the hornblende schists, generally being found at the base of the amphibole schists. Transition from hornblende to biotite schists in varying degrees of intensity may be seen throughout the zone of hard schists. The tungsten mineralization is restricted to the zone of complete biotitization, only traces occurring where the alteration is not complete, and no scheelite at all in the surrounding talc schists*.

All the schists have been folded and contorted due to the intrusion of the granite and these structures have played an important part in the concentration of the scheelite. In the hard schists an asymmetrical anticline with a westerly dip has been developed, and the scheelite is best developed along the crest of this anticline, where the maximum flexure has resulted in increased porosity facilitating the passage of mineralizers. The scheelite occurs in lenses in the schists resulting in the development of augen structures. Calcite is always associated with the scheelite and generally the higher the calcite content, the greater the proportion of scheelite. Associated with the calcite and scheelite are albite, blackish high temperature quartz very similar to that of the huge quartz reef in the old Forbes Main Reef mine, and minor amounts of pyrite, pyrrhotite and chalcopyrite. Way(12) considers the scheelite to have replaced the albite which orginally filled the lenses.

The probable tonnage of the scheelite-bearing biotite schists is in the vicinity of 500 tons of which only about 3 per cent. constitutes ore assaying 1.75 per cent. WO_3 so that the deposit appears unpayable.

Gold Deposits

The gold deposits are concentrated in the Forbes Reef area, but by no means limited to it, as auriferous quartz veins and stringers and alluvial gold occur on mineral concession No. 25 well south of the above area. At Forbes Reef there are two distinct belts of gold mineralization — the western belt running along the Ngwenya foothills and containing the numerous small mines from the Waverley in the north to the Art Union Extension in the south; and the eastern gold belt containing the solitary Forbes Main Reef gold mine, most profitable of all the mines. All these mines ceased production on any scale prior to 1913, and, although attempts have been made to re-work some of the properties since, they have all fallen into a state of disrepair which has rendered them all inaccessible except for the upper levels, and the quarries in a few cases. Consequently the geology of the mines cannot be examined in any detail at the present day without a considerable amount of re-excavation and the work of Hall(3) and Bond(13) offers the most information.

The old Forbes Main Reef mine occurs in tremolite and hornblende schists of the meso-metamorphic zone and very close to the granite-schist contact. The ore body formed a huge lens 300 feet in length with a maximum width of 100 feet, lying parallel to the strike of the schists and dipping almost vertically. The quartz was of the blue-black high temperature variety and was well mineralized with pyrite, chalcopyrite, pyrrhotite, bornite, gold and silver. It is alleged that £300,000 worth of gold was taken from the quarry in the eighties of the last century. Pannings from the old tailings dumps reveal the presence of varying amounts of tourmaline, topaz, garnet, zircon, magnetite and columbite.

At the northern end of the old quarry the original quartz lens can be seen passing into a number of pegmatite and aplite veins up to four feet in width, and which have been kaolinized to a large extent. A few small pieces of amphibole schist picked up from the waste dump reveal the presence of the very fine leaf gold developed along the planes of schistosity in a similar manner to the ore of some of the Barberton gold mines such as the New Consort mine. Although the finding of a few isolated specimens is not indicative, to any degree whatsoever, if the schists constitute payable ore, yet it refutes the belief that the country rock itself was completely barren. If ever any further work is undertaken on the Forbes Main Reef mine, the presence of leaf gold in the schists should

*Further work has shown cases of scheelite in the talc schists. H.J.R.W.

be borne in mind. Assaying of the schist samples should be carried out and not panning, as it has been found elsewhere in the Barberton area that leaf gold, due to its very finely divided state tends to be removed from the pan and not to form a distinctive tailing.

The western gold belt contains the Waverley, Ivanhoe, Avalanche, Primrose, Emerald, Art Union and Art Union Extension gold mines which form a well-defined line running along the Ngwenya foothills in a north-south direction. Two other mines — the Rose Hill (formerly known as the Windermere) and the Rajah — also occur in the western belt but are displaced slightly east of the general line.

All these mines occur in a country rock consisting of various members of the talc schist group. The Waverley-Art Union Extension line is developed close to the Moodies quartzites-Jamestown schists contact and this contact has played an important part in the concentration of the original gold-bearing solutions. The line of reefs lies parallel to the direction of the axis of maximum strain. Between the Avalanche and Primrose mines the horizon has been faulted with the upthrow side to the south so that the reef line has been displaced to the east in relation to the Avalanche-Ivanhoe-Waverley horizon. The fact that the Rose Hill and Rajah mines do not fall along this line is probably due to their being formed along shear fractures at an angle of approximately 45° to the Waverley-Art Union line of maximum strain.

This line of gold reefs can be well seen from large scale mapping of the area but is difficult to follow from mine to mine. There is a complete absence of a marker horizon in the schist country rock, and the reefs themselves consist of numerous veins and stringers tending to form lenses and of limited continuity along the strike, so that it is impossible to correlate any one reef horizon should it extend from one property to the next.

The reefs of the Waverley, Primrose, Emerald, Art Union, Art Union Extension, Rose Hill and Rajah mines constitute veins and stringers of milky white to clear bluish grey quartz concordant with the schists and dipping to the east at an average of 60°. The ore minerals present are gold, silver, pyrite and a little chalcopyrite. In the Primrose, Waverley and Rajah mines crocoite (lead chromate) also occurs with the ores and probably represents the result of solutions rich in chromic acid re-acting on lead sulphides at depth. It has been alleged that in the deepest working of the Primrose mine crocoite was absent but galena became a constituent of the ore minerals.

In the Ivanhoe mine quartz veins similar to the above occur but in this case arsenopyrite is also found in the reef. Furthermore, a certain amount of impregnation has taken place into the schists so that the actual reef is defined by assay values rather than by the limits of the quartz veins themselves. In the Avalanche mine, in addition to the ordinary veins and stringers, there occurs a very conspicuous horizon known locally as the "Erubescite Leader." This leader forms a very prominent veinlet in the schists running for a strike length of 100 feet with an average width of two inches, and easily discernible by its bright green colour due to the formation of malachite. Polished sections reveal that this leader consists predominantly of tetrahedrite with a gangue of clear quartz which tends to form large blebs rather than veinlets. The tetrahedrite contains numerous small centres of replacement of the tetrahedrite by chalcopyrite, this latter mineral being well developed along the margins of residual, eroded subhedral grains of pyrites. Small specks of a silver-coloured mineral also occur in the tetrahedrite and probably represent minute grains of silver, as assays prove that the tetrahedrite is argentiferous. Coarse grains of gold are scattered throughout the tetrahedrite and are generally concentrated along the contacts of this mineral with the quartz blebs. Where the leader is exposed to the atmosphere it becomes oxidized to malachite and more commonly develops a strong tarnish which latter feature has probably lead to the mineral being mistaken for bornite and the leader so named. Bond[13] gives an assay figure for this leader of 11 ozs. gold/ton; 650 ozs. silver/ton and 20 per cent. copper. However, the reef width is exceptionally small and furthermore the presence of considerable proportions of copper and antimony would render extraction of the gold complicated.

Alluvial gold has been recovered together with cassiterite from the Malolotsha river and has probably orginated for the most part from the Old Forbes Main Reef mine. Alluvial and eluvial gold has also been won from the Motshane river. Four thousand feet southwest of the Darkton store a group of auriferous quartz veins and stringers have been exposed in a small quarry. This reef also contains abundant crocoite occurring as well developed crystals of light vermillion, crimson and yellow hues and concentrated in cavities along the quartz-schist contact. Outcrop samples give an assay value of 13 dwts/ton over six inches but at depth of 20 feet this value has increased to 63 dwts/ton over a width of three inches. In all respects these reefs are similar to those of the western belt at Forbes Reef.

Table VI gives the gold output of the various producers in the Forbes Reef area from 1910, no reliable data existing previous to this date.

TABLE VI

Gold Production from Forbes Reef Area, 1910-1947

Mine	*Ozs.*	*Value*	*Year of Production*
Avalanche	607	£2,580	1910
Forbes Main Reef	804	£3,415	1910
Waverley	8	£34	1912
Rose Hill	455	£3,117	1933-36; 1939-40
Rajah	62	£459	1938-41
Art Union Ext.	6	£54	1941
Alluvial	462	£3,273	1934-36; 1938-41
TOTAL	2,404	£12,932	1910-1947

General Consideration of Hydrothermal Deposits

From the above descriptions it is evident that the hydrothermal deposits fall into two groups — the hypothermal deposits and the mesothermal deposits. To the hypothermal class belong the base metal deposits of barytes, scheelite and, possibly, cassiterite — some of the tin in the shear zones at Forbes Reef may be of hydrothermal rather than pegmatitic origin — and also the gold deposits of the Forbes Main Reef mine. To the mesothermal class belong the gold deposits of the western belt at Forbes Reef.

The Old Forbes Main Reef mine is so different in all its aspects from other gold deposits that it is obvious that its origin must have been different. The presence of the high-temperature minerals tourmaline, magnetite and columbite in the Main Reef ore-body and the fact that the quartz is of the high-temperature, blue-black variety indicates that the mineralization was brought about by high-temperature hypothermal solutions. The transition of the quartz lens to pegmatite and alpite veins as seen in the quarry point to a possible pegmatitic rather than hydrothermal origin. In support of this point, it may be mentioned that small amounts of gold have been panned from the cassiterite-bearing pegmatite near the hotel and, also, that columbite which occurs in small amounts in the ore has been proved to have its origin in small pegmatites to the north of the mine.

High-temperature minerals are absent from the mines of the western gold belt, and the lower temperature minerals of lead and antimony become accessories in place of magnetite, tourmaline and columbite. The quartz itself of the reefs is completely different to that of the Main Reef mine and assumes the milky white and bluish grey colours characteristic of mesothermal deposits.

Shear fractures have acted as channelways for the passage of the gold-bearing solutions from their source in the granite intrusion in the east to the western belt. When these solutions reached the quartzite-schist contact, the porosity and degree of fracturing in the Moodies rocks was not high enough to permit the further migration of the solutions, also the zone of schists in proximity to the contact had probably attained a greater degree of permeability than those to the east, due to differential movement along the quartz-schist contact upon the general folding of the area. Consequently, the solutions, striking the comparatively impermeable barrier of quartzites, spread out in a north-south direction along the zone of the higher permeability in the schists which coincided with the axis of maximum strain. As the temperature and pressure dropped the ore minerals were deposited along this zone, some deposition taking place in the original channel-ways of shear fractures as at the Rose Hill and Rajah mines. It is not clear what conditions favoured the deposition of gold at the Forbes Main Reef mine.

The distribution of black schorl tourmaline offers the best indication in determining the lateral extent of the hypothermal and mesothermal zones. A tentative line approximately north-south and 7,000 feet east of the quartzites and 7,000 feet west of the granites has been fixed as the dividing line between the two zones. The area to the east of the line in which tourmalinization has reached its maximum intensity represents the zone of hypothermal mineralization. To the west of the line is the zone of mesothermal mineralization in which tourmaline, although still present in fair amounts, shows a marked decrease in proportion to the area between the line and the granite. Tourmaline gossans obtain their maximum development along this line which feature tends to facilitate the determination in the field of this theoretical limit. In the schist belt of the Londosi valley the limit of hypothermal mineralization can also be assumed at a distance of 7,000 feet to the east of the granite.

Assuming these theoretical limits it can be seen that all the high-temperature ore deposits barytes, cassiterite, scheelite and the Forbes Main Reef gold — fall within the zone of hypothermal mineralization. The remaining gold deposits including those south of Darkton store fall within the mesothermal zone. The designation corresponds completely with the origins worked out for each deposit.

It will also be seen that the hypothermal zone of mineralization overlaps the zone of meso-metamorphism which contains the hornblende, tremolite and chlorite schists. Consequently any deposits occurring in these varieties of schist will be hypothermal deposits as is borne out by the barytes deposit* in hornblende schist, the Forbes Reef mine in tremolite schists and the scheelite deposits in biotite schists. The approximate limit of the mesometamorphic schists can be taken as 3,000 feet from the granite, between this line and the Swaziland System, talc schists of the epimetamorphism zone predominating. Since the hypothermal zone overlaps the mesometamorphic zone by more than 2,000 feet the high-temperature base metal ores will not be restricted to the hornblende, tremolite, chlorite schists — the cassiterite deposits occur in talc schists.

However, in the field where the theoretical limits cannot be established readily, the presence of hornblende, tremolite and chlorite schists will indicate the possibility of high-temperature base metals occurring and of the absence of gold deposits. The Forbes Main Reef deposit, being of hypothermal origin, is consequently less likely to be repeated than deposits of mesothermal origin. If it is of pegmatitic origin the chances of discovering a similar body elsewhere are even more remote.

If further prospecting should take place for hydrothermal ore deposits in the Forbes Reef area it may be profitable to bear the following suggestions in mind:

(*a*) the prospecting should be restricted to the basic schists of the Jamestown Complex as conditions in the sedimentary rocks of the Swaziland System were not as favourable for ore deposition;

(*b*) high-temperature base metals such as tin, tungsten, barytes,† etc., are more likely to occur in a zone between the granite and a line 7,000 feet from the granite-schist contact. The chances for payable gold deposits in this zone are not great. This zone can be recognized in the field by the presence of large amounts of black schorl tourmaline and by the predominance of hornblende, tremolite and chlorite schists over talc schist;

(*c*) gold deposits and low-temperature base metals such as lead, antimony and copper are more likely to occur in a zone between the Swaziland System and a line 7,000 feet from the sediments-schists contact; the area in close proximity to this contact is the most ideal for ore deposition; the zone can be recognized by the comparatively small amounts of tourmalinization and the great development of talc schists with other varieties almost completely absent.

The above are based mostly on theoretical considerations of field observations and cannot be taken as solving the complex economic geology of the area. At any point local geological conditions may completely upset this theory with the result that hypothermal deposits may occur in the supposed mesothermal zone and vice versa.

SUMMARY

This report is a study of the stratigraphy, petrology and economic geology of the southernmost extension of the Barberton Mountain Land, which forms a strip of country running along the Transvaal-Swaziland border between the Komati and Usushwana (or Little Usutu) rivers.

Particular attention was paid to the rocks of the Fundamental Complex. In the Swaziland System only the Fig-tree Series and Moodies Series occur, the Onverwacht facies being absent although attaining its maximum development just to the west of the area surveyed. The Jamestown Complex is extensively developed and has been divided into four main groups of schists. A new facies of the Fundamental Complex, the Havelock Complex, is defined as post-Jamestown in age and consists of igneous rocks which may constitute a basic phase of the Old Granite.

The granite belongs to the Nelspruit variety and tends towards granodiorite rather than true granite. This granite was primarily studied in relationship to the metamorphic and mineralization results produced in the older rocks by its intrusion. A general classification of the post-granite dykes is given.

*Barytes is usually considered to be epithermal or rarely mesothermal. H.J.R.W.

†See previous comment. H.J.R.W.

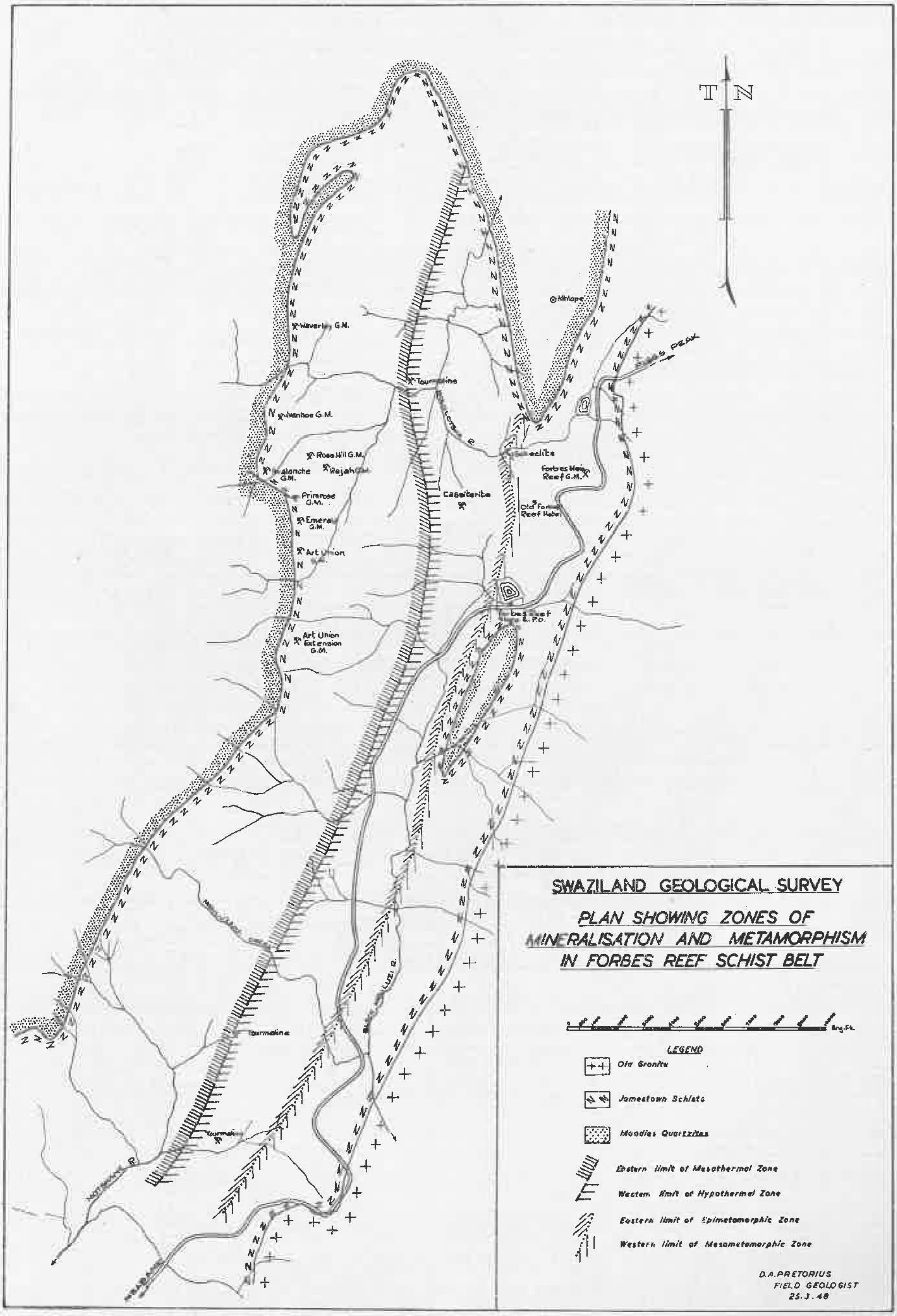
T N
SWAZILAND GEOLOGICAL SURVEY
PLAN SHOWING ZONES OF MINERALISATION AND METAMORPHISM IN FORBES REEF SCHIST BELT
Eng. Ft.
LEGEND
Old Granite
Jamestown Schists
Moodies Quartzites
Eastern limit of Mesothermal Zone
Western limit of Hypothermal Zone
Eastern limit of Epimetamorphic Zone
Western limit of Mesometamorphic Zone
D.A. PRETORIUS
FIELD GEOLOGIST
25.3.48
Waverley G.M.
Ivanhoe G.M.
Rose Hill G.M.
Rajah
Avalanche G.M.
Primrose G.M.
Emerald G.M.
Art Union
Art Union Extension G.M.
Tourmaline
Cassiterite
Forbes Main Reef G.M.
Old Forbes Reef Hotel
Mhlope
Luzi R.
R.
Tourmaline
Tourmaline

FIGURE III

The general structures in the area described and from the application of a strain ellipsoid, it is seen that these were produced by the intrusion of the granite for the most part and other causes played a minor role.

A theoretical account of the historical geology of the area is given in which the processes of sedimentation, igneous activity and metamorphism are discussed.

The economic geology is described and the ore deposits are assigned to three groups — deposits of indefinite origin, deposits of pegmatitic origin and deposits of hydrothermal origin. In the first group fall the iron and asbestos deposits. The zone of maximum ferruginization has been found to be the Fig-tree shale horizon immediately underlying the Moodies Series and this horizon is shown to be the same as that in which the Iron Hill haematite deposit occurs south of the Havelock mine. The chrysotile asbestos deposits are limited to the serpentines of the Havelock Complex and it is proposed to establish a definite line of serpentine intrusion which links up the asbestos deposits of Havelock and Diepgezet with those of the Motshane and Usushwana valleys. To the pegmatitic deposits belong the occurrences of cassiterite and columbite and to the hydrothermal deposits those of gold, barytes, scheelite, copper, lead and antimony. A tentative line defining the limits of hypothermal and mesothermal mineralization is suggested as well as one for the limits of meso- and epimetamorphism.

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