THE RELATIONSHIP BETWEEN MINERALISATION AND STRUCTURE IN THE PILGRIM'S REST — SABIE GOLD-FIELD

by

ANDRIES LOUIS ZIETSMAN

Dissertation submitted in fulfilment of the requirements for the degree of Doctor in the Faculty of Science, of the University of the Orange Free State, Bloemfontein.

NOVEMBER, 1967.

ABSTRACT

The area that was investigated, covers the metallogenetic province of the Sabie-Pilgrim's Rest Gold-field in the Eastern Transvaal. The geological formations include the Basement Granite, Godwan Formation, Wolkberg Formation, and the Transvaal System. Diabasic and pyroxenitic sills, pre-mineralisation in age, and probably genetically related to the Bushveld Complex, are present also. Three generations of dykes can be distinguished, one before, one contemporaneous with, and the other after the mineralisation.

Three types of folding are present, i.e., tectonic folds, supratenuous compaction-folds, and folds that are due to magmatic intrusion. At least two periods of tectonic folding can be distinguished, the one superimposed upon the other. The axes of the earliest folds trend approximately east, while those of the later folds trend north and northeast. Both periods of folding are due to compressional forces which can be ascribed to the intrusion of the Bushveld Complex.

Both tectonic and non-tectonic faults are encountered. The tectonic faults consist of low-angle thrust-faults, low-angle gravity-faults, and high-angle normal faults. The thrusts are probably due to the same compressional forces that were responsible for the north- and northeast-trending folds, i.e., they are probably related to the intrusion of the Bushveld Complex as well.

/Evidence...

Evidence of gravitational gliding-tectonics is provided by the presence of low-angle gravity-faults. These structures postdate the thrust-faults. The high-angle normal faults are due to tensional stresses and they are mostly post-mineralisation in age. A remarkable directional relationship between the linear structures and the folds is noticeable. The linear features, as well as the axes of the folds are orientated in three directions, namely, north, east and northeast.

The gold-bearing reefs consist of interbedded as well as, transgressive, epigenetic ore-bodies. The interbedded reefs are represented by bedding-thrusts. The localisation and development of these reefs were controlled by the presence of favourable horizons and the intrusion of sills, folding, especially superimposed folding, as well as the formation of the bedding-thrusts. The conditions necessary for the emplacement of the transgressive reefs were the presence of early planes of weakness and/or dykes which are pre-reef in age. The low-angle gravity-faults resulted in the opening of pre-existing fractures such as early high-angle faults, joints and dyke-contacts.

Two distinctly different periods of mineralisation are visualised, one preceding and the other postdating the bedding-thrusts. The first period is seen as a process of contact-metasomatism, caused by the intrusion of the basic sills. This process was probably

/localised...

localised and controlled by the folding. The second period of mineralisation was one of fissure-filling by solutions which were introduced during two phases: an early pyrite-rich phase, which was followed by a later copper- and bismuth-rich phase. The bedding-thrusts, as well as the low-angle gravity-faults, acted as channel-ways for the mineralising solutions.

The second period of mineralisation, which produced ore-minerals that are typical of mesothermal deposits, is visualised as a metal-liferous front originating from the "root" of the Bushveld Complex. The ore-minerals, including gold, are considered to have been derived from the magma-chamber itself, as well as from the adjacent sedimentary rocks.

The deposits of chrysotile in the area are considered to have been localised due to a similar structural control as that which influenced the localisation of the interbedded reefs, i.e., folding.

CONTENTS

Page

Page

Page

LIST OF ILLUSTRATIONS

FIGURES

PLATES (In folder)

I. INTRODUCTION

A. GENERAL STATEMENT

As a result of dwindling ore-reserves in the mines of the Transvaal Gold Mining Estates, Limited, a geological research programme was considered necessary. This work was commenced towards the end of 1961. It consisted of detailed geological mapping, an intensive study of mine records and underground plans, as well as geochemical prospecting in certain areas. These operations were undertaken by the geological department of the parent company, Rand Mines, Limited. The writer, assisted by a field party, was called upon to do the geological work. The purpose of the project was to determine the influence of geological features on the mineralisation.

With the kind approval of the Management of Rand Mines, the writer was able to submit a thesis for the degree of Master of Science, at the end of 1964 (Zietsman, 1964). In this thesis, the general geology of the gold-field is dealt with. Special emphasis is placed upon the stratigraphical features in the area. Certain relationships between the geological structure and the gold-bearing deposits became apparent, even during the first stages of this investigation. Research work on these relationships was continued during 1965. It is the purpose of this dissertation to present a detailed account of these relationships, as well as their influence on the ore-genesis and ore-control.

/The individual ...2.

The individual occurrences of gold-bearing deposits are described in detail. Most of the mines, however, ceased production before 1961. Many of the workings had collapsed and were inaccessible to underground examination. Some of these inaccessible mines have been admirably described by other authors. Many old records were available in the mine-offices of the Transvaal Gold Mining Estates. The underground plans of the old mines were found to be extremely useful.

The area that is dealt with in this dissertation is shown in Figure 1. Plate I is a structural map of this area; the locations of the mines and workings are also shown on this map.

B. HISTORY OF GOLD-PRODUCTION

Gold was first discovered in alluvial deposits on the farms Spitzkop 195J.T. and Hendriksdal 216J.T., south of Sabie. These discoveries were made in 1872 by Messrs. MacLachlan, Valentine and Parsons (Reinecke and Stein, 1929). In 1873 another discovery was made at Mac-Mac by a certain Mr. Jan Muller and his son. In the same year, following this discovery, a certain Alec Patterson found rich alluvial gold along the Pilgrim's Creek.

During the first few years, only alluvial deposits were exploited, and some large nuggets were found. The most famous of these were the "Breda" and the "Lilly" weighing 214 and 119 ounces 2 dwts. respectively.

During the year 1881 a Mr. D.H. Benjamin secured

/concessions....

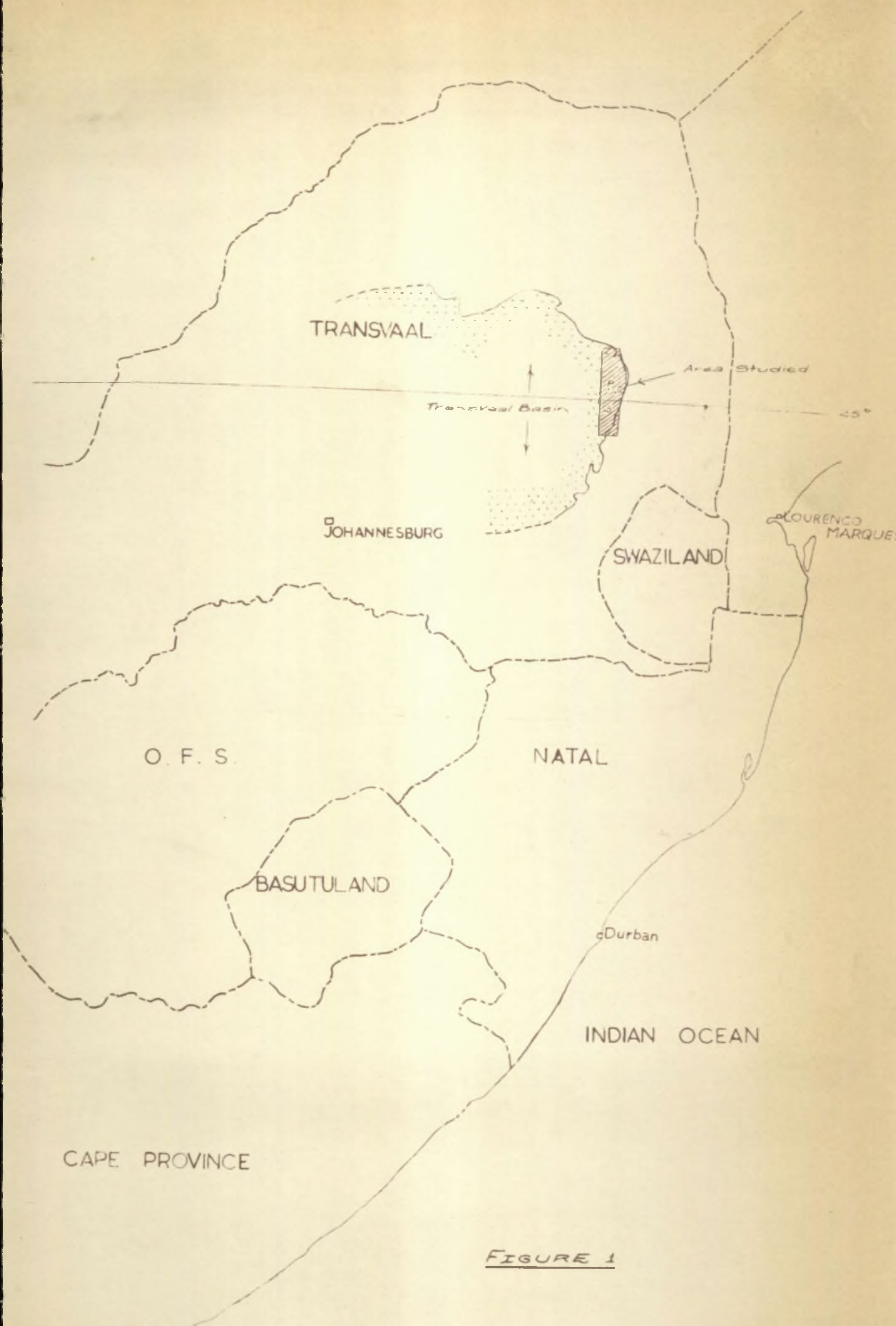


FIGURE 1

KEY MAP SHOWING AREA INVESTIGATED

concessions from the South African Republic over the farms Ponieskrans, Ledovine, Waterhoutboom, Driekop, Grootfontein 562K.T. and Belvedere. Similar concessions were later granted over Handriksdal, Elandsdrift and Spitzkop. The following mining-companies were formed: The Pilgrim's Mining and Estate Company, The Jubilee Mines, Limited, the New Clewer Estates and Gold Mining Company and The Transvaal Gold Exploration and Land Company. These companies were purchased in 1895 by the Lydenburg Mining Estates, Limited, and in 1896 the name of this company was changed to the Transvaal Gold Mining Estates, Ltd. The latter company is still in operation.

At Sabie the Glynn's Lydenburg, Limited, and Glynn's Pretoria Gold Mining Company were formed, as well as other smaller companies. These were later absorbed by the Transvaal Gold Mining Estates, Limited.

In the years following the formation of the mining companies, activities gradually shifted from the stream-beds to the slopes of the hills where the "mother lodes" were discovered.

The total production to date cannot be accurately determined. This is due to the fact that comprehensive records of the production of gold are not available. Visser and Verwoerd (1960, p.104) give a figure of 2,105,473 fine ounces for the period 1902 to 1958. The total gold output from the mines belonging to the Transvaal Gold Mining Estates, is in the vicinity of 3,900,000 fine ounces. This was extracted from over 12,200,000 tons of ore. No records are available of the production

/of alluvial...5

of alluvial gold. Since as many as 2000 diggers were at times operating in the Pilgrim's Creek, this output must have been considerable.

C. PREVIOUS GEOLOGICAL WORK

A large number of authors have made contributions regarding the geology of the Sabie-Pilgrim's Rest Goldfield. The present research is, however, the only comprehensive study of the structure and it's influence on the mineralisation. Many controversial theories and ideas regarding the genesis of the ores have been presented. The various authors either disregarded the influence of the structure on ore-control, or based their conclusions on a misinterpretation of it.

Cohen (1873 and 1874-1875), Penning (1885), O'Donoghue (1884), Kuntz (1896), Wilson-Moore (1897), Nicol-Brown (1897) and Thord Gray (1905) were among the first to comment on the geology of the gold-bearing deposits. These publications are, however, considered to be of historical interest only.

The first detailed description of the geology and the ore-bodies, was presented by Hall (1910). Hall's description of the geology and his map remained the standard work on the subject for many years. Much of his classification of the rocks is still recognised. His descriptions of some abandoned mines are extremely valuable.

Von Dessauer (1912) concluded that the bedded reefs were metasomatic replacements of siliceous layers

/in the...6.

in the sedimentary strata. He also suggested that the vertical reefs were feeders for the bedded reefs.

Frost (1912) described the characteristics of the ore-bodies of the Mali Dyke Mine.

Bell (1921) gave a general description of the ore-bodies and their stratigraphical relationships. His description of the Language Reef is very useful since these workings were inaccessible to later observers.

Wybergh (1925) gave an account of the economic geology. He added much to the general information and also produced a more detailed geological map.

Reinecke (1926) made an intensive study of the farm Elandsdrift 220J.T. for the Transvaal Gold Mining Estates, Limited. Some of his results were published in collaboration with Stein (1929). These authors ascribed the mineralisation to the intrusion of a younger batholith of granite into the sedimentary rocks. This theory was conclusively disproved by later authors (Barnard, 1958 and Visser and Verwoerd, 1960, p.34). Reinecke and Stein, however, observed some very interesting relationships between the mineralisation and the structure, particularly on the farm Elandsdrift 220J.T.

Swiegers (1948) made an intensive study of the ores of the gold-field. This study can be regarded as the standard work on the paragenesis of the ore-minerals.

Barnard (1958) made a comprehensive study of the geology and structure of the Bourke's Luck mine. His

/conclusions...7

conclusions regarding the paragenesis of the ores at Bourke's Luck, are in general agreement with those of Swiegers.

The most recent publication on the geology of a part of the area, is that by Visser and Verwoerd (1960). This work is a compilation of the observations made by Joubert, Söhnge, van Zyl, Muller and Verwoerd between 1936 and 1959. This work deals only with the mines around Sabie and Mount Anderson.

II. GENERAL GEOLOGY

The general geology of the area has been described by Zietsman (1964). Plate II shows the general sequence of the beds and their stratigraphical relationships, as well as the relative positions of the interbedded reef-horizons.

A. BASEMENT GRANITE

The floor on which the sedimentary beds were laid down, is composed of granite, which is classified as Nelspruit granite. It is a massive, equigranular rock that tends to have a somewhat gneissose texture locally. A sheetlike cover of altered, sericitised granite, 5 to 50 feet in thickness, is present locally (Visser and Verwoerd, 1960, pp. 32 - 33). These authors consider the alteration to be due to weathering that took place before the deposition of the overlying sediments, followed by hydrothermal alteration after the sedimentation.

The sedimentary rocks were deposited on an uneven surface of granite. The presence of an undulating topography is borne out by surface mapping and by certain borehole records. Reinecke and Stein (1929, p.73) interpreted this feature as being evidence of an intrusive relationship with the sedimentary rocks, and they therefore considered the granite to be a batholith of post-Transvaal age.

Later work by Barnard (1958, p.5) and Visser and Verwoerd (1960, p.34) conclusively prove the presence of a sedimentary contact between the granite and the overlying sedimentary rocks.

B. SEDIMENTARY ROCKS

1. General Statement

The sedimentation commenced with the deposition of the Godwan Formation. The depositional basin had a shoreline near Sabie (Zietsman, 1964, pp. 11-12), but deepens northwards to a depth of 1200 feet at Bourke's Luck (Plate II). South of this shoreline the Godwan Formation is present in small local basins only.

The Wolkberg Formation follows unconformably on the Godwan Beds and is confined to the main Godwan Basin.

The Black Reef Series of the Transvaal System follows unconformably on all the older rocks and rests in turn on Basement Granite, Godwan Formation and Wolkberg Formation. The Dolomite Series of the Transvaal System follows conformably

/on the ...9.

on the Black Reef Series, except in a few isolated areas south of Sabie, where it rests directly on granite. This is due to local elevations in the floor of deposition.

2. Godwan Formation

The Godwan Formation usually has a basal layer of conglomerate and/or arkose. This is followed by agglomerate, lava and tuff. From Klipkraal 170J.T. northwards, the formation varies between 100 feet and 400 feet in thickness.

3. Wolkberg Formation

This formation is composed of a layer of felspathic quartzite sandwiched between two thick layers of shale. At Bourke's Luck a layer of quartzite overlies the upper shale.

The Wolkberg Formation is as far as gold-bearing deposits are concerned, not very important economically. Some bedded ore-bodies occur near the lower contact of the upper quartzite-member. These deposits have, however, not been exploited. A few vertical reefs are developed in the upper quartzite, as well as in the upper shale-member.

Some conglomerates in the Wolkberg Formation are known to contain gold in economical quantities, i.e., in the old Haenertsburg Gold-field (Hall, 1907, pp. 33-60)

4. Transvaal System

(a) General

The Transvaal System is economically the

/most...10.

most important stratigraphical unit. It consists of the Black Reef Series at the base, which in turn is overlain by the Dolomite Series. The Pretoria Series is, strictly speaking, a separate system (Zietsman, 1964, p. 13) and constitutes the top of the formation. Only the Timeball Hill Stage is present in the area under consideration.

(b) Black Reef Series

The Black Reef Series consists of a single layer of quartzite that ranges from a few feet to 100 feet in thickness. This quartzite usually builds the edge of the Drakensberg Escarpment, and is exposed in dip-slopes and along stream-beds.

This basal member of the Transvaal System contains exploitable interbedded reefs in a few localities. Vertical reefs are present locally.

(c) Dolomite Series

The Dolomite Series occupies most of the area between the edge of the escarpment and the lower slopes of the high mountains to the west. Between Pilgrim's Rest and Graskop, the Dolomite Series is capped by several outliers of the Pretoria Series. The basal contact of the Pretoria Series represents a major plane of unconformity. This is due to intensive erosion of the Dolomite Series before the deposition of the overlying Pretoria Series (Zietsman, 1964, pp. 12-13). As a result of this erosion the Dolomite Series shows a drastic thinning from north to south (Plate II).

The Dolomite Series is divided into six zones on lithological grounds (Zietsman, 1964, pp. 27-35): Zone 1 is approximately 1000 feet in thickness, and constitutes the base of the series. This zone contains the Transition Beds which include some layers of quartzite and shale, as well as dolomite and chert. The Blyde River Quartzite and the overlying Lower Shale form the top of this zone.

Zone 2, approximately 350 feet in thickness, consists of dolomite which is relatively free of chert.

Zone 3 includes the Middle Shale Group. This group consists of dolomitic limestone with intercalated chert, several layers of black carbonaceous shale, and an occasional thin layer of sandstone. The thickness is approximately 300 feet.

Zone 4, which is approximately 350 feet in thickness, consists of dolomite and chert, capped by a layer of black spotted slate, 1 - 3 feet in thickness. This layer of slate is locally referred to as the Slate Marker. The upper 50 feet of the dolomite is known as the Bread and Butter Dolomite.

Zone 5 is approximately 800 feet in thickness, and is composed of dolomitic limestone with much intercalated chert of varying thickness. The Beehive Chert Marker, six feet in thickness, forms a very consistent marker. The Middle Chert Marker, 2-10 feet in thickness, is another prominent horizon. It occurs about 150 feet above the Beehive Chert.

Zone 6 constitutes the top of the Dolomite Series. It consists of dolomite, which is often oölitic and relatively free of chert. Several layers of calcareous shale are present also. The basal layer of shale has a maximum thickness of about 20 feet.

The deposition of these zones were followed by a major period of erosion. This resulted in a gradual removal of the various zones from north to south, with the consequence that only Zones 1 and 2 are present throughout the whole area (Plate II).

The Dolomite Series is, economically, the most important stratigraphical unit. Most of the larger and more consistent interbedded ore-bodies are found in this formation. This indicates that the Dolomite Series was more susceptible to mineralisation. It is furthermore noteworthy that interbedded ore-bodies prefer certain stratigraphical horizons. The ore-bodies are usually localised along the same stratigraphical horizon, or within the same zone, but are not necessarily continuous along strike. The stratigraphical zones in which the interbedded reefs are normally located, are characterised by pronounced lithological variations. Furthermore, the interbedded reefs are found mainly in the proximity of shale and/or quartzite (Plate II).

/(d) Pretoria Series...13.

(d) Pretoria Series

The Pretoria Series is represented by the Timeball Hill Stage, known as the Nooitgedacht Stage locally. This stage builds the slopes of the high mountains that occupy the western part of the area. Outliers of Pretoria Series cap the dolomitic hills between Pilgrim's Rest and Graskop.

The Giant Chert, which is the basal member of the Pretoria Series, is a residual sharpstone conglomerate. It is followed by the Bevett's Conglomerate and the Bevett's Sandstone. The thickness of this zone, including the Giant Chert, varies from 2-60 feet.

The Lower Nooitgedacht Shale, 1300-2000 feet in thickness, overlies the Bevett's Zone. It is followed by the Lower Nooitgedacht Quartzite (50 feet in thickness), the Upper Nooitgedacht Shale (300-800) feet, and the Upper Nooitgedacht Quartzite (100 feet).

Two economical interbedded ore-bodies are present near the base of the Pretoria Series, as well as one immediately below the Lower Nooitgedacht Quartzite. In the area west of Sabie, Visser and Verwoerd (1960, p p. 73-76) describe interbedded reefs in the Daspoort Stage.

C. INTRUSIVE ROCKS

1. Sills

In the Sabie-Pilgrim's Rest area, two types of intrusive sills are present (Zietsman, 1964, pp. 47 - 50). The sills that are found in the Pretoria Series and in the upper parts of the Dolomite Series are composed of altered pyroxenitic material. These sills show signs of differentiation. Porphyritic dunite and peridotite are present, locally. All the other sills in the Dolomite Series, as well as those in the older formations, are diabasic in composition.

The sills show certain relationships to the structure and the mineralisation. A close stratigraphical association is evident between the sills and the interbedded reefs. Plate II shows that the same stratigraphical zones were preferred by both the sills and the interbedded reefs. These intrusions are often in close proximity, either above or below these ore-bodies. In the northern area (Plate II) sills are present immediately below the Bevett's Zone and below the Upper Shale. Lower down in the succession, sills are found below the Beehive Chert Marker and above the State Marker Sills were intruded above and below the Blyde River Quartzite and above and below the Black Reef Series. In each of these zones, one or more interbedded reefs occur.

This relationship is even more pronounced in the central area, particularly in the upper zones. The largest number of interbedded reefs are found in this area.

In the southern area, sills are also found in the proximity of interbedded reefs (Plate II).

A second significant characteristic of the pyroxenitic type of sills, is their irregularity in shape and size. The sill near the base of the Pretoria Series (Plate II), transgresses repeatedly through the Bevett's Zone and is not confined to a single horizon. It often splits into two sills, one above and the other below the Bevett's Zone. It shows a tendency to pinch and swell, even over short distances. This intrusive locally assumes the shape of a laccolith. Laccolithic shapes are particularly well-developed in the central area on Columbia Hill and on Theta Hill. Another occurs in the northern area, west of the Frankfort Mine, just below the Lower Nooitgedacht quartzite. These intrusives are closely related to poorly developed anticlines. Well-developed interbedded reefs accompany the structures. Mineralised transgressive fractures or leader-reefs usually occur in the sedimentary beds above the intrusives.

Both the pyroxenitic and diabasic sills are considered to be almost contemporaneous with the mineralisation. Both types are probably genetically associated with the early plutonic phase of the Bushveld Complex.

2. <u>Dykes</u>

The dykes are mainly diabasic in composition. Some exceptions are, however, present. The dyke along the Grootfontein Fault, west of Brown's Hill (Plate I), is considered to be more syenitic (Zietsman, 1964, p. 51). A dyke

/which...16.

which crosses the Blyde River some 3 miles north of Pilgrim's Rest, has a dioritic composition. Dykes consisting of hybrid rock include the Vaalhoek Dyke (Zietsman, 1964, p. 51) and the Spitzkop Dyke (Visser and Verwoerd, 1960, p. 47).

Three distinct ages of dykes are present. Some dykes are obviously older than the mineralisation, and are displaced horizontally by interbedded reefs or low-angle faults, which are closely associated with the mineralisation. Vertical or steeply inclined ore-bodies are found in some of these early dykes, either along the contacts, or within the dykes. In some places vertical ore-bodies occur in the country-rock adjacent to these dykes. The Vaalhoek Dyke, the Dientjie Dyke, and the Nestor Dyke are all known to be pre-mineralisation in age.

The New Chum Dyke is an example of a dyke which is contemporaneous with the mineralisation.*

The younger dykes are plentiful and post-date the mineralisation. These dykes cut through the interbedded ore-bodies, often displacing them. Wybergh (1925, p. 103) observed two sets of post-reef dykes in the New Chum Mine. Von Dessauer (1912, p. 150) came to a similar conclusion in respect of the dykes that occur in the Frankfort Mine.

/Visser and...17

---

* The spelling used is according to the list of geological terms used by the Geological Survey of South Africa.

Visser and Verwoerd (1960, p. 42) records dykes that are pre-Godwan in age. They trend east and are found in the Nelspruit Granite, on either side of the Sabie River. The earlier dykes of post-Transvaal age, are considered to be older than the diabasic sills; they are probably associated with the early volcanic phase of the Bushveld Complex.

III. STRUCTURAL GEOLOGY

A. STRUCTURES IN THE FLOOR OF DEPOSITION

1. Pre-Godwan Surface

The sedimentary formations were laid down on an undulating surface of granite. This is borne out by surface-mapping and by drilling. Barnard (1958, p.p. 45-48) observed a relationship between the irregularities in the surface of the granite and the general structural trend. These irregularities are usually in the form of elongated domes or hummocks that are orientated parallel to the most prominent linear structures.

The most prominent of these domes are found on the farms Lisbon 531 K.T. and Berlyn 506 K.T. (Plate I). The western slope of the hummock is partly exposed at the bottom of the Lisbon Falls. A borehole, which was drilled in 1895 (Barnard, 1958, p. 47), some 2000 feet east of the waterfall, confirmed the presence of the structure. The shape of this ridge of granite is revealed by the structure of the overlying strata. The sedimentary beds of the Godwan Formation, Wolkberg Formation and the Black Reef Series show compaction-folding around the hummock. The sedimentary dome thus formed, has an elongated shape, and has a long axis parallel to the major linear structures in the vicinity.

Drilling revealed a similar irregularity at Bourke's Luck. A borehole near the intersection of the Dientjie Dyke and the Treur River, intersected granite at a depth of 450 feet below the top of the Black Reef Series. Farther north in the Blyde River Canyon, the top of the Black Reef Series is approximately 1200 feet above the granite. The dip of the sedimentary strata is not visibly influenced by this feature. The shape and orientation of this irregularity is, therefore, uncertain.

At Kowyn's Pass, south of Graskop, the presence of an elevated floor was revealed by mapping. The basal conglomerate of the Godwan Formation has a dip of 20 degrees west-northwest. Higher up in the succession, and farther west, the normal dip is six degrees west. The long axis of this hummock is apparently parallel to the linear structures in the vicinity.

On the farm Klipkraal 170 J.T., an inlier of granite reveals the presence of another hummock. The relationship between the granite and the overlying sedimentary beds suggests that its shape is that of a low ridge, the long axis

/which...19.

of which is also parallel to the main structural direction (Plate I).

Vertical reefs in the sedimentary rocks, as well as those in the granite, are apparently associated with hummocks such as those described above.

2. Pre-Godwan Linear Structures

The linear structures include wrench-faults and diabasic dykes.

The wrench-faults are described as shear-zones and shear-faults by Visser and Verwoerd (1960, p p. 34-35) and are characterised by an abundance of anastomizing veins and tabular masses of quartz. The faults trend either north-northwest or north-northeast; the former displaces the latter (Visser and Verwoerd, 1960, p.38).

The dykes trend in two directions, namely west, and north-northwest. The dykes are displaced by the north-northwest trending faults, but apparently not by those striking north-northeast (Visser and Verwoerd, 1960, p. 38).

These linear structures probably influenced the formation of the irregularities in the floor of deposition, but had no direct influence on the mineralisation.

B. STRUCTURES IN THE SEDIMENTARY FORMATIONS

1. General Statement

(a) Dip and Strike

Very little variation in the dip and strike of the sedimentary beds is observed. The pre-Transvaal beds have an average strike that is slightly west of north. Dips ranging from 6 - 14 degrees west were recorded. The beds of the Black Reef Series and the Dolomite Series strike north. The dip of these beds steepens from one degree west, south of Hendriksdal, to six degrees west in the Bourke's Luck area. The strata of the Pretoria Series strike slightly west of north, and their dip varies between 4-6 degrees west. The dip of all the strata increases gradually westwards towards the Bushveld Complex.

2. Linear Structures

The linear structures include joints, faults and dykes. Most of these features are post-Transvaal in age, although older structures are known to occur. East of Sabie a horst of pre-Transvaal age, is reported by Visser and Verwoerd (1960, p.55). Along the easterly one of the two faults bounding the horst, a recurrence of movement took place after the deposition of the Transvaal System.

Most of the faults are post-mineralisation in age, but a few predate the mineralisation. The latter are represented by the Rietfontein Reef,

/the fault...21.

the fault along which the Nestor Dyke was intruded, and the fault along which the Astra Reef, east of the Lisbon Falls, was emplaced.

The interbedded reefs are bedding-faults. These movements are contemporaneous with the later phases of the mineralisation.

Joints are common and conspicuous features in this area. Three joint-trends, two of which are very prominent, are present. These structures dip between 80-90 degrees.

A large number of dykes are present. They trend mainly north to northeast, although a few strike east to southeast. The dykes normally dip at high angles, although a few with low angles are present in the northern area.

2. Folds

The folds can be genetically divided into three types, viz., non-tectonic, tectonic, and folds that are due to magmatic intrusion.

(a) Non-tectonic Folds

The most conspicuous fold of non-tectonic origin is present on the farms Lisbon 531 K.T. and Berlyn 506 K.T. It is represented by an elongated dome of sedimentary rocks, folded around a granitic ridge in the floor of deposition. The lowermost sediments, i.e. those of the Godwan Formation, as well as the lower shale of the Wolkberg Formation, terminate against

/the slopes...22.

the slopes of this ridge. The upper part of the ridge is covered by the Middle Quartzite of the Wolkberg Formation. This horizon, as well as the beds overlying it, are folded around the ridge. The individual sedimentary beds show distinct thinning towards the crest of the dome. The geometry of the folding can, therefore, be described as supratenuous (Hills, 1963, p. 251). A geometry such as this is typical of compaction-folds. Furthermore, the intensity of the folding decreases from the crest of the ridge upwards. Immediately west of the crest, near the bottom of the Lisbon Falls, the strata dip about 30 degrees west, while higher up, the dip is only about 10 degrees west.

Normal faults of minor displacement occur east and west of the long axis of the dome, and they are almost parallel to it. These faults are considered to be genetically related to the dome. This assumption is based on the results of experiments in differential compaction (Nevin, 1953, p.215).

At Kowyn's Pass, the abnormal dip of the basal layers of the Godwan Formation is considered to be due to compaction-folding (Zietsman, 1964, p.39).

The beds of the Godwan Formation in Cooper's Creek dip 14-20 degrees west, while those of the Wolkberg Formation dip 10-12 degrees west (Visser and Verwoerd, 1960, p.55). Farther north and higher up in the succession the dip of the overlying strata is normal, i.e. 4-5 degrees west. Visser and Verwoerd (1960, p. 55) ascribe the variation in dip between the Godwan and Wolkberg Formations to an unconformity. This variation may, however, be due to compaction-folding, related to the granitic hummock on Klipkraal 170 J.T.

Measurements of bedding-planes in inliers of quartzite on London 496 K.T. reveal slight folding (Plate I). In this locality the dip varies between one degree east and six degrees west. Several vertical faults, showing small displacements, are present. One of these fractures is connected with the major fault west of the dome on Lisbon 531 K.T. On Ledouphine 469 K.T. a similar fold is visible in the quartzite of an inlier of the Black Reef Series (Plate I). In this locality the dip varies from one degree east to four degrees west. The origin of these folds is not clear, but is considered to be non-tectonic.

(b) Tectonic Folds

(i) General. The tectonic folds are represented by very open anticlines, synclines, domes, and depressions. The tectonic origin of the folds is indicated by the following characteristics:

/1. Most...24.

1. Most of the structures are developed stratigraphically 2000 feet above the granite and they can therefore not be due to compaction.

2. The axes of the different folds are not haphazardly orientated, but trend in fixed directions

3. These directions are closely related to the trends of other linear structures in the gold-field.

Due to the very open nature of the folds, they are usually not visible on the surface. The only localities where tectonic folds were observed are in the Sabie Gorge, on Jubilee Hill, in the shale above the Duke's Hill Mine, and in a stream-bed on the farm Ledouphine 469 K.T.

Due to surface-creep and poor exposures it is not practicable to measure bedding on surface. Compilations of reef contour-plans, however, reveal the presence of several open folds. These plans were compiled from old mine-records.

In the northern area folds are present in the Vaalhoek Mine, as well as on Ledouphine 469 K.T. The folds in the Vaalhoek Mine are, however, poorly developed; the reef contours seem to

/indicate...25.

indicate two directions of folding (Plate III). In the southern part of the mine, a structural terrace is present. The axis of the anticinal bend of this feature trends 026 degrees. Structures such as these, are typical in areas of mild deformation (Nevin, 1953, p. 38). In the River Section of the mine, another direction of folding, viz., 060 degrees is indicated.

A small anticline, the axis of which trends 067 degrees, is exposed in a stream-bed in the south-western part of the farm Ledouphine 469 K.T. (Plate I).

In the central area, three directions of folding can be distinguished, namely, 076-096 degrees, 047-057 degrees and 001-014 degrees (Figure 2).

In the Ponieskrantz North Mine, the contours on the Portuguese Reef suggest the presence of a poorly developed anticline which trends 057 degrees.

In the Jubilee Mine, northeast-trending folds are developed in the Portuguese Reef, as well as in the Lower Theta Reef. Although these two reef-horizons are over 450 feet apart vertically, the folding is remarkably similar in both horizons. Figure 2 shows that the axes of the anticlines in the Lower Theta Reef are superimposed on the axes of similar anticlines in the Portuguese Reef.

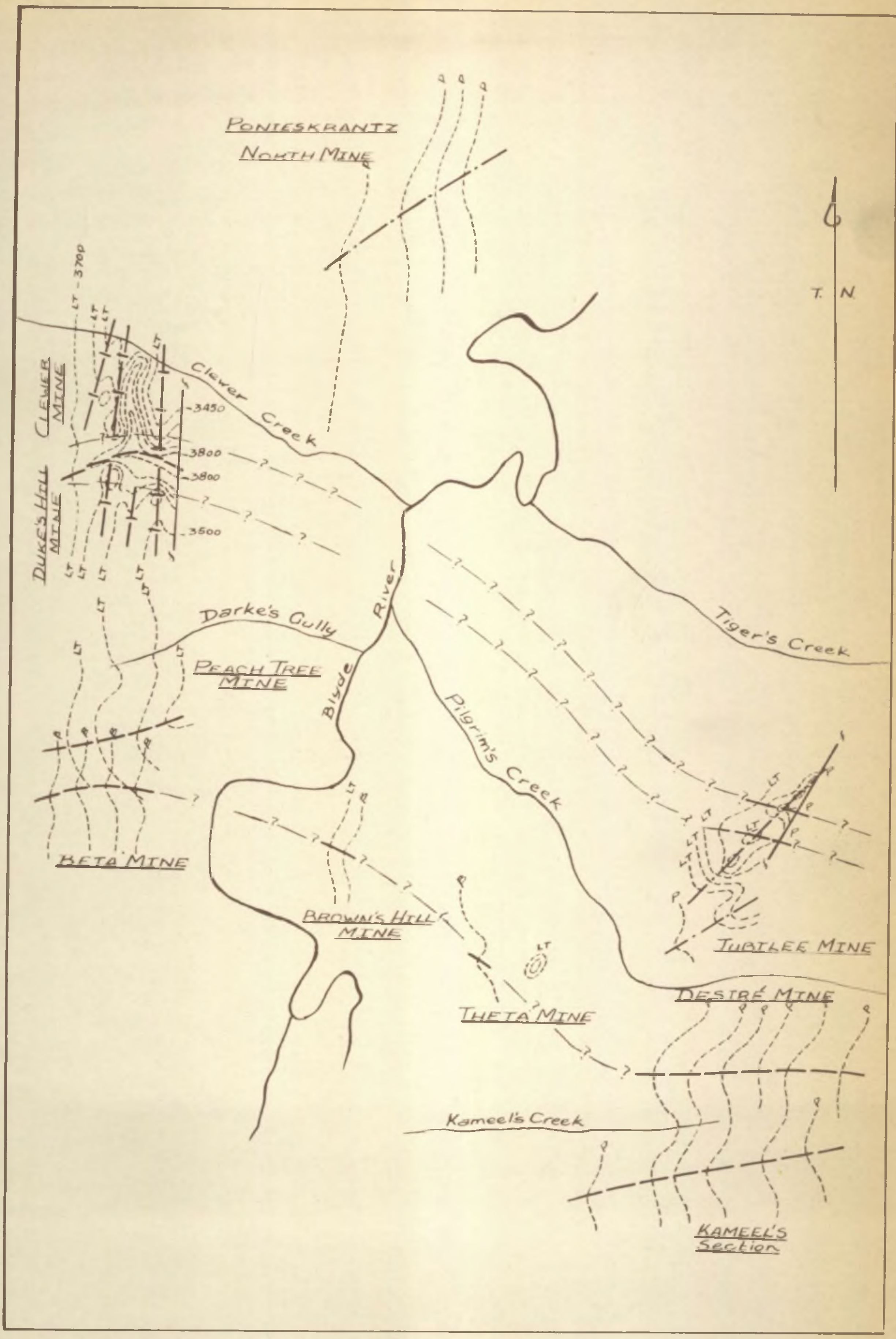


Figure:- 2:- Reef Contours in Central Area. Scale:- 1 : 30,000

Reference:-

---------P	Contour line on Portuguese Reef.
---------β	Contour line on Beta Reef.
---------LT	Contour line on Lower Theta Reef.
——·——	E-W Fold Axes.
—·—·—	NE Fold Axes.
—I—I—	N-S Fold Axes.
—?—?—	Estimated Extension Lines of Fold Axes (Anticlines).

This probably indicates that the axial-planes are vertical. Folds that trend east are present also but the inclination of the axial planes could not be determined.

In the Desiré Mine, the trend of the folding is approximately east. The presence of two parallel anticlines is revealed by reef-contours on the Portuguese Reef (Figure 2).

In the Theta Mine the structure of the Lower Theta Reef is considerably disturbed by sub-surface solution and subsequent slumping of the dolomite. The presence of a dome in an undisturbed area could, however, be determined (Figure 2). A poorly developed anticline is also present in the Beta Reef.

Anticlines occur in the Lower Theta Reef, as well as in the Beta Reef in the Brown's Hill Mine (Figure 2). The axes of these structures trend approximately east; the axial-plane is apparently vertical.

In the Peach Tree and Beta Mines, anticlines that trend east are present in the Lower Theta Reef, as well as in the Beta Reef. Although these reef-horizons are only 300 feet apart vertically, the structure in the Theta Reef is 1500 feet north of that in the Beta Reef. It seems therefore, that they represent two different structures. In the Duke's Hill and the Clewer Mines two directions of folding can be deducted (Figure 2). The most prominent direction trend 001-014 degrees. The presence of several domes and basins, however, indicate another direction of folding (De Sitter, 1964, p. 260). The axis of a large irregular basin suggests an easterly trend. It is concluded that the east-trending folds were deformed by those which trend 001-014 degrees, and this resulted in the formation of the domes and basins.

In the southern area, two directions of folding are encountered, namely 000-024 degrees and 078-114 degrees. South of the Sabie River the folding is revealed by contour-lines on the Glynn's and Elandsdrift Reefs (Figure 3). North-trending anticlines occur in the Glynn's Lydenburg Mine, as well as in the eastern part of the Compound Hill Mine. Between the latter mine and the Malieveld Section, the contours indicate the presence of a structural terrace. The axis of the anticlinal bend of this feature strikes north. Domes are developed in the northern part of the Glynn's Lydenburg Mine, as well as in the Compound Hill Mine. A small dome is also present in the Elandsdrift Mine. In this mine, the structure is disturbed by sub-surface solution of the dolomite.

An anticline is visible in the gorge of the Sabie River. The axis of this structure

/trends...

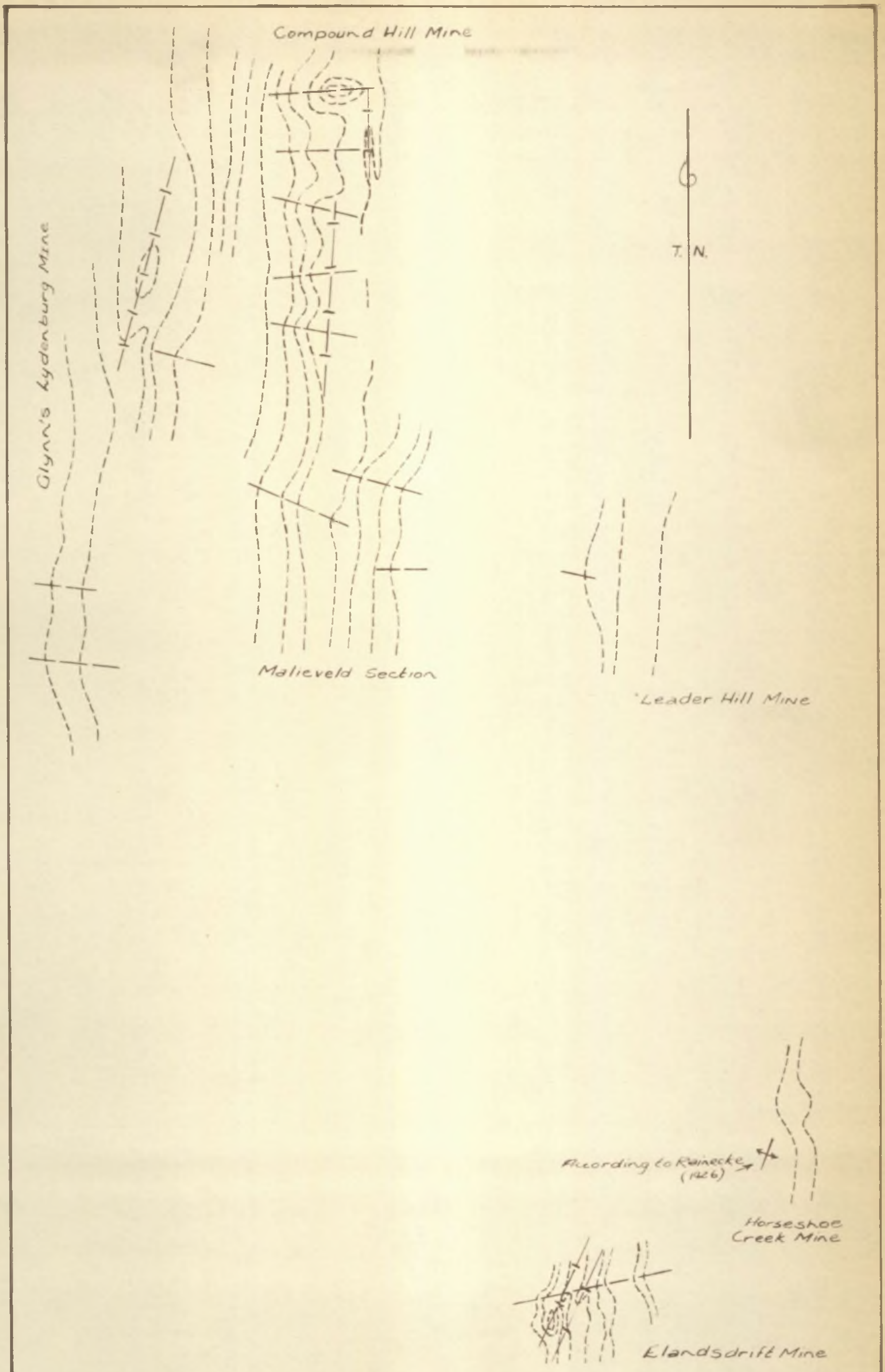


Figure 3 :- Plan of Reef Contours in the Southern Area. Scale:- 1:30,000

Reference:-

G------ Contour line on Glynn's Reef

E------- Contour line on Elandsdrift Reef

T------ Contour line on Top Reef

Dom

—— E-W Fold Axes

—|—|— N-S Fold Axes

trends approximately north.

Folding is also present north of the Sabie River. At the Nestor Mine two parallel anticlines occur, one in the southern and the other in the northern section of the mine (Plate IV). The axes of these structures trend 080 degrees.

A dome, the long axis of which trends 003 degrees (Plate IV), is exposed at the Rex Mine.

(ii) Discussion. There are three directions of folding, namely 078-100 degrees, 000-024 degrees, and 045-070 degrees. The axial traces of the latter two directions are usually straight, while those of the former are often curved (Figure 2). This indicates more than one period of folding, the one superimposed upon the other (Ramsay, 1958, pp. 271-307). The geometry of the folds which resulted from the first period of folding is altered by the later folding.

The folds that trend east are considered to have preceded the other two directions. Because of the apparently undeformed character of the latter directions they may be related to either one or two different periods of deformation, or they may have resulted from different pulses of the same period of folding.

/The folds... 31.

The folds are concentric in character. Folds such as these are of necessity the reaction of a layered mass to compression (De Sitter, 1964, p. 168). The folding may be genetically related to the intrusion of the Bushveld Complex.

The contours in Figure 2 do not give a complete picture of the folding in the vicinity of Pilgrim's Rest, but show the structures in isolated areas only. Due to practical difficulties, the results obtained from the reef-contours could not be supplemented by direct measurements in the field. It is considered, however, that the east-trending axial traces are continuous as shown by the speculative axial traces in Figure 2. These lines are based on topographical features which are considered to be due to structural features. The axial traces of the anticlines coincide with the crests of preciptous spurs, which are bounded by streams i.e. Pilgrim's Creek, Tiger's Creek, Clewer Creek, Darke's Gully and Kameel's Creek.

(c) Folds Due to Magmatic Injection

Domical structures that are due to magmatic injection are found in the central area, on Columbia Hill and on Theta Hill. In the northern area, a similar structure is found in the western part of the farm Frankfort 509 K.T.

The best example of this type of fold is present on Columbia Hill. It is caused by the intrusion of a pyroxenitic sill which locally

/assumes... 32.

assumes a laccolithic shape (Figure 4). A similar intrusion is present on Theta Hill.

On Frankfort 509 K.T. similar doming was observed in the vicinity of the workings on the Language Reef (Plate I). Northeast of this point and lower down in the succession, another fold is visible in a krantz, immediately above a pyroxenitic intrusion.

The anticlinal axes of these domes coincide with the "axial traces" of the elongated laccoliths. These "axial traces" again are related to the tectonic fold-directions: in the northern area it is approximately parallel to the 060 degree -, and in the central area to the 078-096 degree-trend.

This probably indicates that the formation of the laccolithic intrusions was controlled by pre-existing fold-structures.

3. Faults

(a) Non-tectonic Faults

The faults which are related to irregularities in the floor of deposition are considered to be non-tectonic in origin. They probably formed as the result of readjustments due to differential compaction in the sedimentary rocks.

At the Lisbon Falls, several high-angle normal faults are developed along the flanks

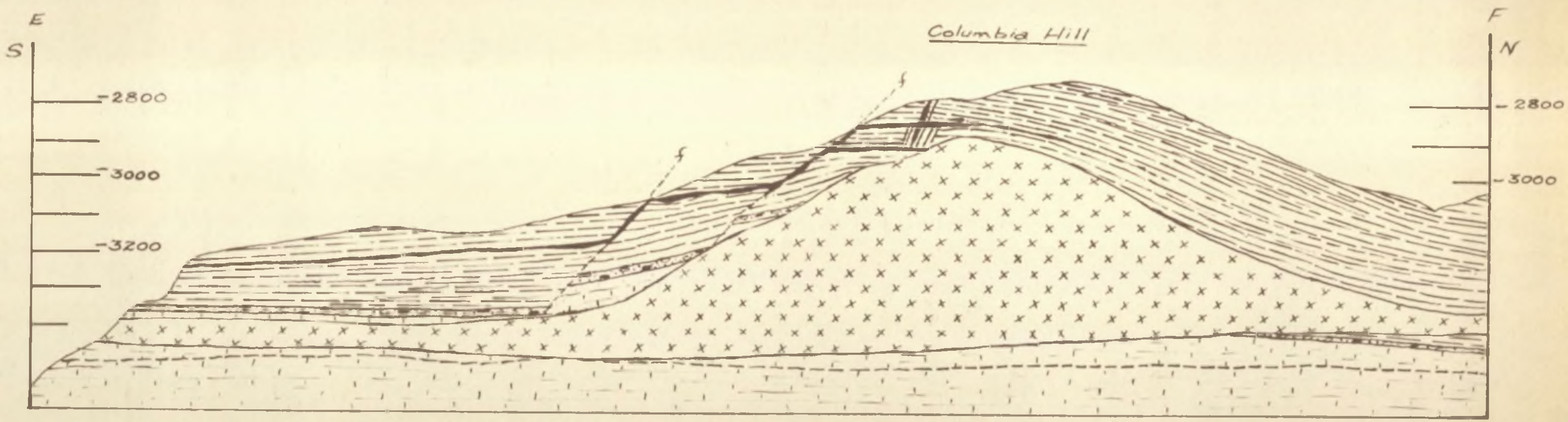


Figure 4 :- Schematic section E - F through laccolithic sill on Columbia Hill.

Scale : 1 : 5000.

Pyroxenite.

Shale (Pretoria Series)

Bevell's Zone.

Dolomite and Lower Theta Reef.

Shale Reef.

Leader Reefs.

of a granitic dome, and are roughly parallel to the long axis of the dome. They are all gravity-faults and show displacements in the order of 20 feet.

One of these faults, i.e., that west of the waterfall, shows a displacement of over 250 feet. This fault can be traced southwards beyond the Sabie River and northwards to beyond the Treur River, a distance of over 30 miles. The Nestor Dyke (Plate I) is intruded along this structure. It is clear that this fault cannot be due to compaction alone, but represents later tectonic movement along a plane originally due to compaction.

The fault near Sabie, which predates the Transvaal System, and which is described by Visser and Verwoerd (1960, p. 55) may have a similar origin.

(b) <u>Tectonic Faults</u>

There are three types of tectonic faults, namely, low-angle thrust-faults, and high-angle normal faults. High-angle reverse faults are not present. This is to be expected, as no large magmatic intrusions (Hills, 1963, p.194) occur in the area.

(i) <u>Low-angle Thrust-faults.</u> The low-angle thrust faults are represented by the inter-bedded reefs and they are, therefore, bedding-thrusts. Evidence that the interbedded reefs occupy bedding thrust-faults, is provided by the displacement of an earlier dyke in the Malieveld Section of the Glynn's Mine (Visser and Verwoerd, 1960, p. 69). This dyke which trends 025 degrees, terminates against the lower contact of the Glynn's Reef in one locality, and is continued above the reef, farther to the southeast. Further evidence of movement along the planes of the interbedded reefs, is the presence of slickensides and breccias along these planes. Small flexures, due to faulting, have been observed in the Beta Reef.

As these structures are not associated with major folding (Hills, 1963, pp. 196-201), they are considered to be genetically related to the intrusion of the Bushveld Complex.

(ii) Low-angle Normal Faults. These faults are found at Bourke's Luck in the northern area, as well as in the Duke's Hill Mine in the central area. They are nearly parallel to the regional strike, and dip west at angles slightly steeper than the interbedded reefs. Low-angle normal faults occur also on Columbia Hill, where they are associated with a laccolithic

/intrusion... 36.

intrusion (Figure 4). In this locality the strike is approximately east, i.e. parallel to the "axial-trace" of the intrusion, and the dip is 35-45 degrees south.

According to the dynamics of faulting, only high-angle normal faults can result from a horizontal relief of pressure (Anderson, 1951, p.16). The low-angle normal faults must, therefore, be ascribed to a condition in which only gravity is active, i.e. gravitational gliding. In gravitational gliding tectonics, the instability may be associated with earlier primary tectogenesis, but the final movement is due to sliding under gravity (Hills, 1963, p. 212). Structures such as these may be formed by gliding down the slope of an uplifted geotumor, or gravitational gliding in a sedimentary basin (Hills, 1963, p. 337). Examples of this type of deformation are described by De Sitter (1964, p p. 238-254).

The origin of the low-angle normal faults in the area under consideration, may also be ascribed to gravitational gliding. The structures at Bourke's Luck and in the Duke's Hill Mine are considered to be related to the sagging of the floor of the Bushveld Complex. The faults on Columbia Hill (Figure 4) are believed to have resulted from gravitational gliding, along the slopes of a domical structure which was caused by the intrusion of a laccolithic sill.

i) <u>High-angle Normal Faults.</u> The faults that are most commonly present, are high-angle normal faults. Although faults of this type occur throughout the gold-field, they are most abundant in the central area. They are often associated with diabasic dykes, but it is not clear whether the dykes have intruded along the faults, or whether the faulting occurred after the intrusion. The high-angle normal faults are shown in Plate I.

Two fault-directions are present, namely 352-030 degrees and 070-130 degrees. The majority of the faults have dips steeper than 80 degrees. The east-trending faults are characterised by small displacements, i.e., up to 20 feet, and they are sometimes associated with anticlinal folds. The other faults show displacements that vary from 20-600 feet. These faults are often accompanied by minor synthetic and antithetic faults.

The high-angle normal faults gave rise to a number of gräben and horsts. The most prominent of these structures, is the so-called Fraser-Morgan Graben at Pilgrim's Rest. It is bounded on the west by the Grootfontein Fault, which shows a downthrow of 300 feet east (Zietsman, 1964, p. 56), and on the east by the Morgan Fault, which shows a downthrow of 600 feet west. Several minor parallel faults occur between the two major structures. Of these the Fraser Fault is the most important. The faults that constitute the graben all show maximum displacements immediately south of Pilgrim's Rest. Most of the high-angle faults show maximum displacement in this area.

A downfaulted block is present west of the Beta Dyke, on the west bank of the Blyde River (Plate I). The faults do not continue beyond the Clewer Creek (Zietsman, 1964, p. 56). They are more pronounced southwards where they become part of a graben. On the farm In De Diepte 164 J.T. and southwards, beyond the boundaries of the investigated area, this graben is very prominent; Visser and Verwoerd (1960, p. 56) erroneously refer to it as the Fraser-Morgan Graben.

Another prominent graben is present on the farms Frankfort 509 K.T., Rotunda Creek 510 K.T., and Krugershoop 527 K.T. (Plate I). Small, local gräben occur in the northern area, one on Hermansburg 495 K.T. and one on London 496 K.T. South of Sabie, a graben is developed near the head of the Golden Valley Creek. All the above gräben trend approximately north. A number of small local gräben and horsts, which trend east, are located in the eastern part of the area, along the edge of the escarpment.

The trends of both the low- and high-angle normal faults are illustrated in Figure 5. The low-angle thrust-faults are not included. The azimuth of the most prominent trend, which shows very little variation from north to south, is 352-030 degrees. A less prominent trend, which is confined to the northern and central areas, has an azimuth of 070-130 degrees. The trend in the northern area varies from 070-090 degrees, and that of the central area 090-130 degrees. This change in trend is considered to be due to lithological differences in the sedimentary rocks.

There are two conditions necessary for normal faulting, viz. relief of pressure in all horizontal directions, and maximum pressure in a vertical direction (Nevin, 1953, p. 100). According to Anderson (1951, p. 16) the faults that result from these conditions, have angles steeper than 45 degrees. The vertical pressure is provided by gravity, whereas a relief of the horizontal pressure is created by tensional stress, or by the relaxation of compressional stress.

The high-angle normal faults, trend in

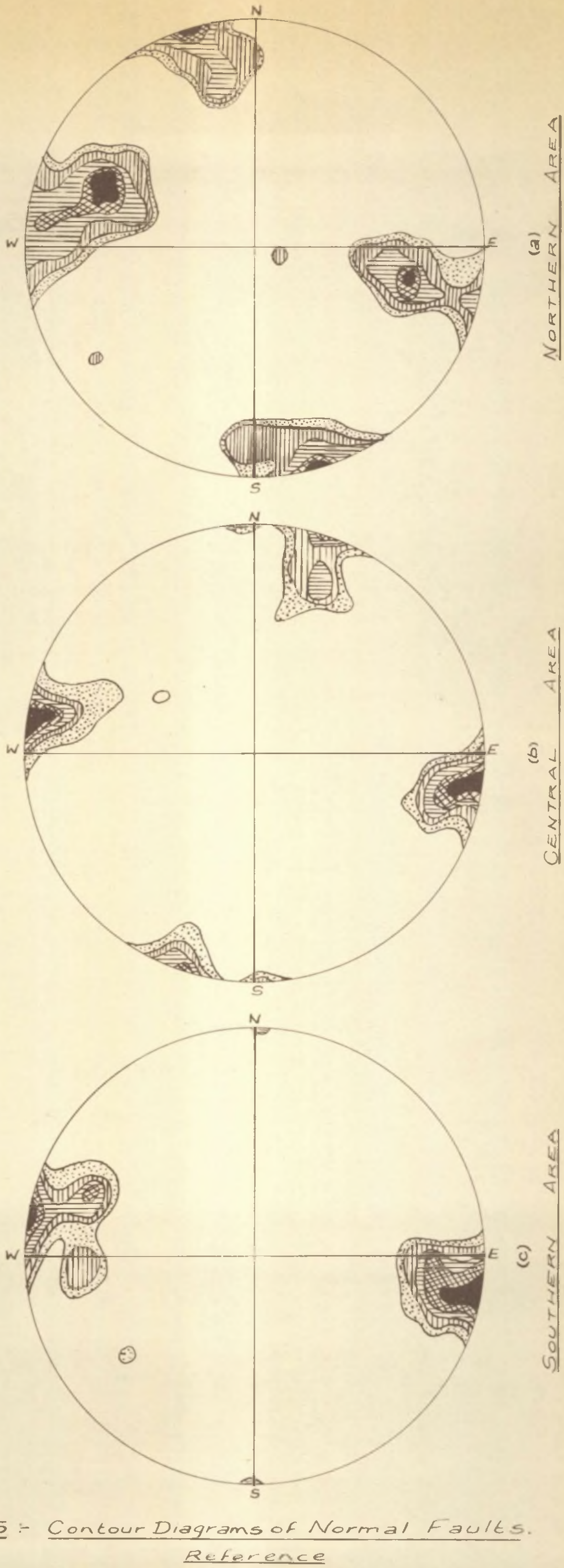


Figure 5 :- Contour Diagrams of Normal Faults.

Reference

21 - 25% 16 - 20% 11 - 15 % 6 - 10 % 1 - 5 %

two perpendicular directions. Both these directions had been subjected to compressional stress, as is evidenced by the directions of folding. Normal faults, due to the relaxation of compressional stress could, therefore, develop in both of these directions. All the faults of major displacement, as well as the gräben, trend approximately north. The greatest relief of the horizontal pressure was, therefore, directed east-west. This may have resulted from the sagging of the floor of the Bushveld Complex. Tensional stresses were, however, also active after the deposition of the Karroo System. Evidence of this is the presence in the Central Transvaal of post-Karroo faults which have the same orientation as the major faults in the Sabie-Pilgrim's Rest Gold-field. The high-angle normal faults in the area under consideration are, therefore, considered to be post-Bushveld in age, or they may even postdate the Karroo System.

4. Joints

Joints occur in great abundance and are shown in Plate I. These structures were mapped with the aid of aerial photographs, and the results were controlled by field-observations. Because these structures are so abundant, joint-sets and-systems only are shown.

The joints are very conspicuous in the

quartzitic horizons. As the beds of dolomite often displays very poor outcrops, not many joints could be mapped in these horizons. Joints are not very prominent in the shaly beds.

The intensity of the jointing decreases perceptibly from north to south. The intensity and trends of the northern, central and southern areas are, therefore, shown separately (Figure 6).

(a) Northern Area (Figure 6(a))

Two very prominent directions of jointing can be distinguished. The one direction strikes 350-060 degrees and the other 075-140 degrees. The directions of strike in the dolomite vary 10-20 degrees from those in the quartzite.

(b) Central Area (Figure 6(b))

The most prominent direction of jointing is 090-120 degrees. The joints belonging to this group are found mainly in the vicinity of Pilgrim's Rest, i.e. in the area where the greatest concentration of mineralisation occurs. A second, less prominent direction of jointing is 355-030 degrees. The trends of both sets are influenced by the lithology.

(c) Southern Area (Figure 6(c))

Only one important direction is developed in this area, viz. 090-135 degrees. Interesting, however, is the gradual change

/in trend...

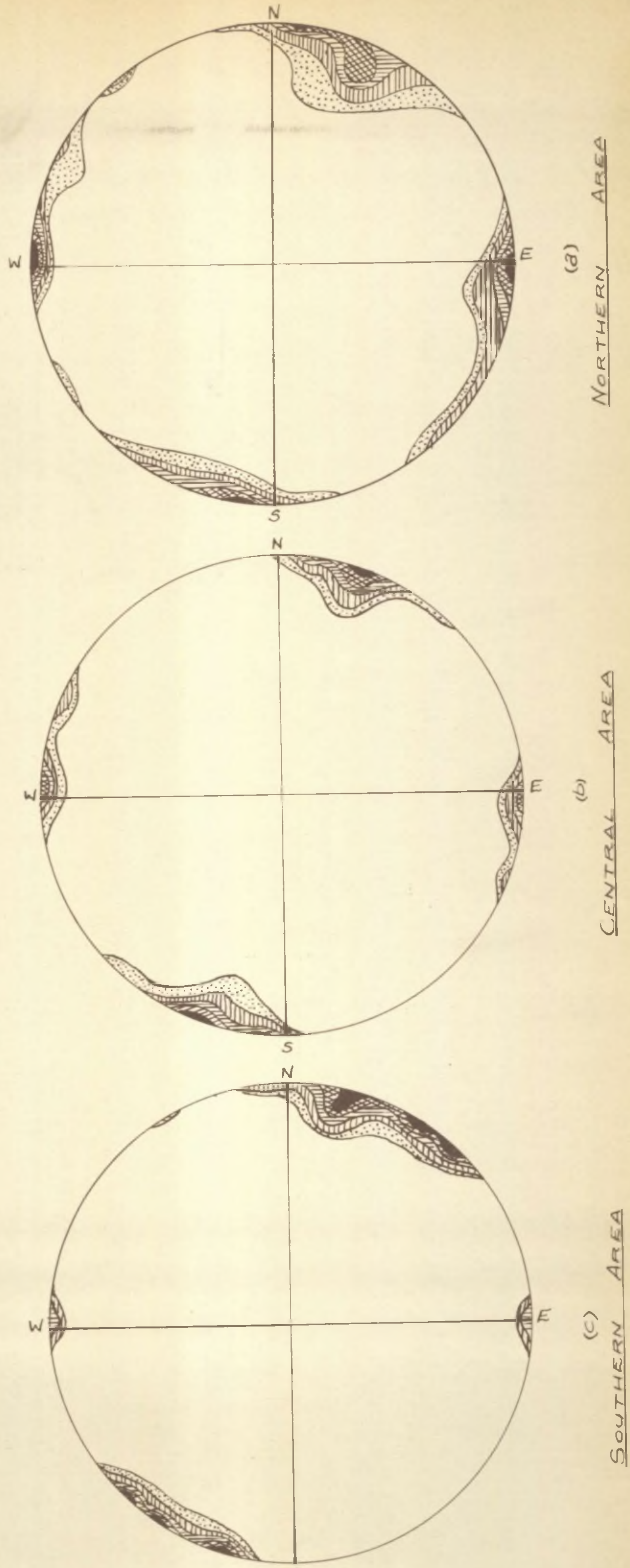


Figure 6.- Contour Diagrams of Joints

31-60% 21-30% 11-20% 6-10% 1-5 %

in trend from north to south. This change is not due to a change in the structural pattern but to a difference in lithology: the joints in the northern area were mapped mainly in quartzite, those in the central area in quartzite and dolomite, and those in the south mainly in dolomite.

5. Dykes.

The main trends of these intrusives are shown in Figure 7. These diagrams reveal that the main trend remains almost unchanged from north to south. The directions correspond with the main directions of faulting and jointing. This indicates that the dykes were intruded along zones of weakness in the sedimentary and basement rocks.

There are two trends: the dominant one has an azimuth of 350-065 degrees, whereas the azimuths of a very subordinate group of dykes vary between 100-125 degrees. In the northern area the dominant trend can be subdivided into three separate directions which are shown in Figure 7. These dykes were intruded along fractures which strike 000-030 degrees, 350-000 degrees and 045-070 degrees respectively (Plate I). The first direction is the dominant trend and coincides with the main structural trend. The second direction is restricted mainly to the northern area. The so-called "transverse" dykes in the Vaalhoek and Bourke's Luck Mines, belong to the third direction; this in turn is parallel to one of the directions of folding.

/6. Discussion...

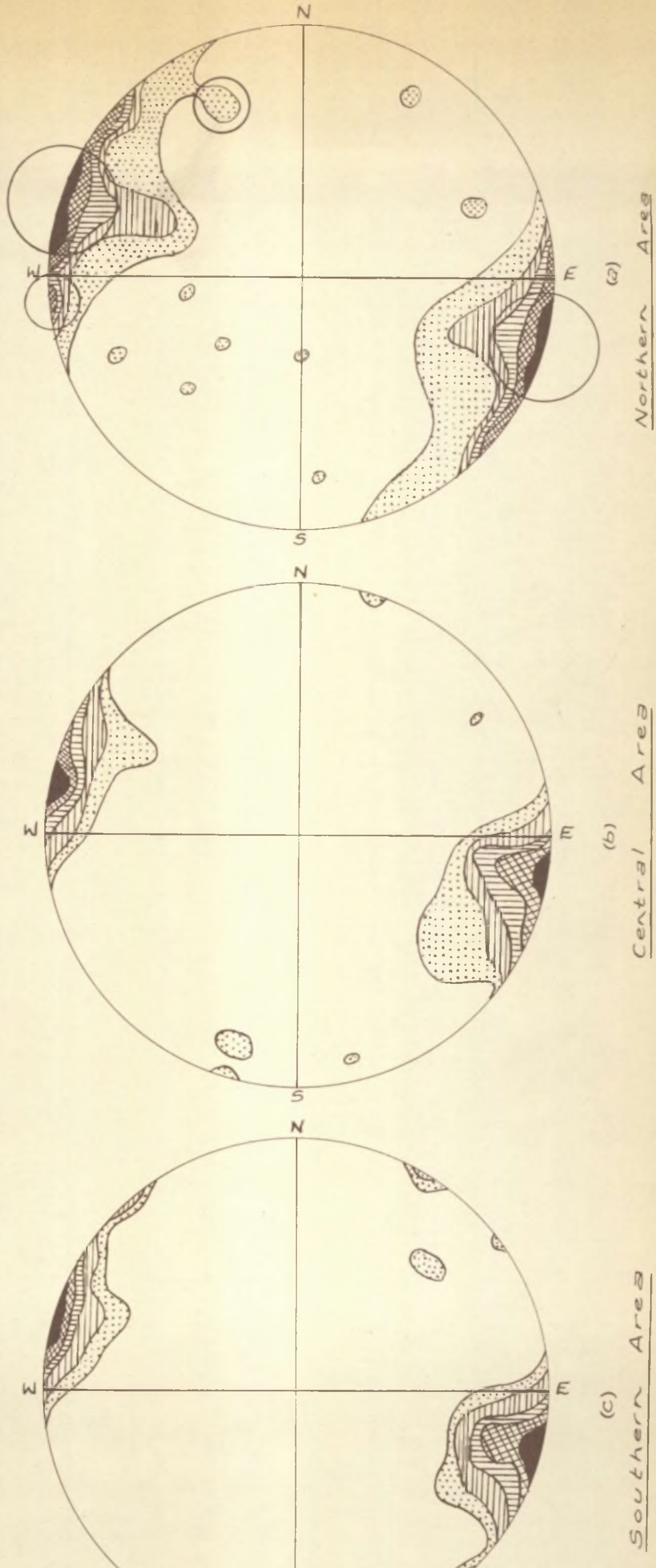


Figure 7:- Contour Diagrams of Dykes

21 - 30% 16 - 20% 11 - 15% 6 - 10% 1 - 5 %

6. Discussion

(a) Structural Interrelations

The relationships between the various linear structures, viz. faults, joints and dykes are illustrated in Figure 8. They all show two main trends, which have azimuths of 350-030 degrees and 090-130 degrees respectively. The former is apparently the most prominent direction. Interesting is that the easterly trend is much less conspicuous in the faults and dykes. A third, much less prominent trend is present, namely 045-070 degrees.

A remarkable resemblance exists between the trends of the linear structures, and the directions of folding. This probably indicates that the directions of the linear structures were influenced by the folding.

(b) Structural Evolution of the Transvaal System

The Transvaal System was deposited in a basin, the long axis of which strikes north-east, i.e., parallel to the axes of practically all the other sedimentary basins in South Africa. This direction is parallel to many pre-Cambrian orogenies in Africa (Brock, 1959, p. 335). Visser (1957, p.xxxi) visualises the deposition of the Transvaal System in two interconnected basins. This conclusion is considered to be erroneous. An inspection

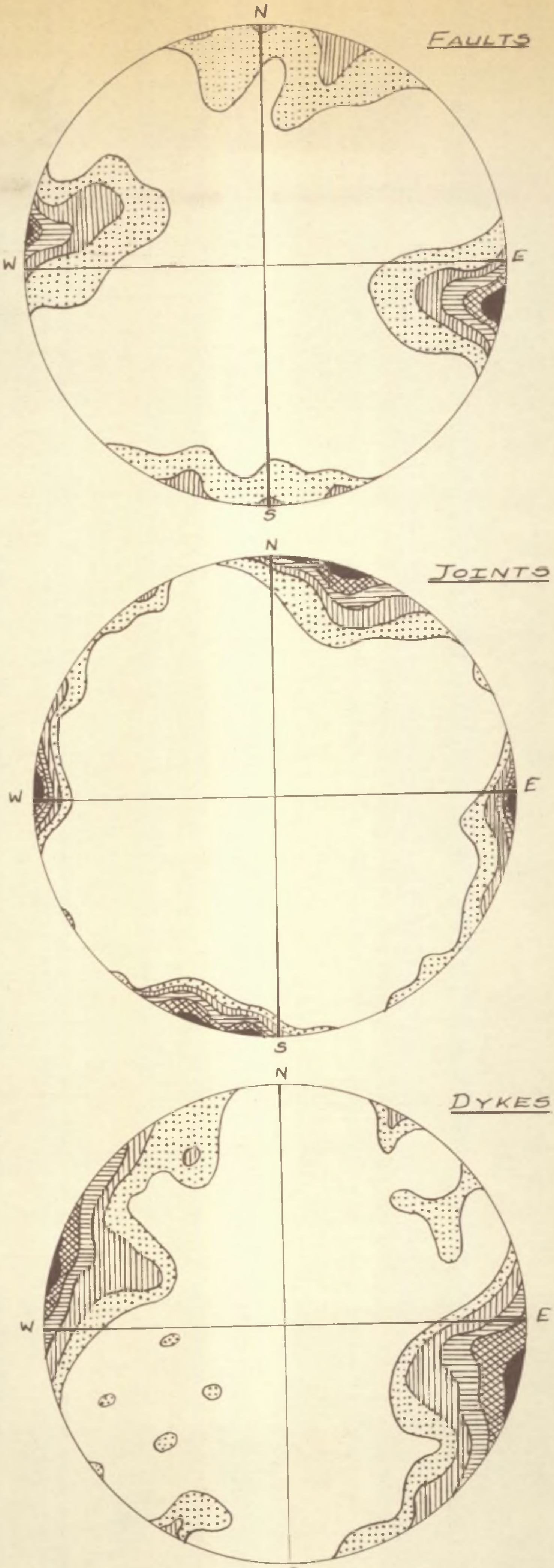


Figure 8:- Contour Diagrams of Linear Structures

21 - 30% 16 - 20% 11 - 15 % 6 - 10% 1 - 5 %

of the geological map of South Africa, shows that the Transvaal System was folded along axes which strike parallel to the long axis of the basin of deposition. Subsequent refolding along an axis nearly perpendicular to this direction resulted in the present structural setting. The effect of the superimposed folding, therefore, gives the impression of two separate sedimentary basins of Transvaal age.

The structural evolution of the Transvaal Basin is visualised as follows:

(i) The sedimentation commenced with the deposition of the Black Reef Series, followed by that of the Dolomite Series. After the deposition of the latter, the basin was elevated to above sea-level, with subsequent erosion. This is indicated by a major unconformity, i.e. the Bevett's Conglomerate and Giant Chert (Zietsman, 1964, p.41).

(ii) The period of erosion was followed by the subsidence of the basin with the subsequent deposition of the Pretoria Series.

(iii) The prolonged subsidence of the Transvaal Basin was sufficient to weaken the subcrust to such a degree that volcanic activity commenced. These outbursts took place in four stages during the sedimentation of the Pretoria Series, and finally culminated in the magmatic activity of the Bushveld Complex (Visser, 1957, p. xxxiii).

(iv) The intrusion of the Bushveld Complex commenced with the emplacement of the mafic rocks and was concluded with the intrusion of the granite. The deformation of the Transvaal System was closely connected with, and to a great extent controlled by, the emplacement of the Bushveld Complex. The pyroxenitic and diabasic sills, as well as some of the dykes, i.e. the Vaalhoek, Dientjie, New Chum, Nestor and Mali Dyke, are considered to be contemporaneous with the early magmatic phase of the Bushveld Complex. The long axis of the main Bushveld Basin trends east. This direction is parallel to the east-trending folds in the area under discussion. According to Visser (1957, p. xxxv) the emplacement of the rocks of the Critical Zone was followed by compression from the north, due to the collapse of the central part of the Bushveld Basin and the tilting and rising of the beds on the northern side. This compression gave rise to east-trending folds. This conclusion is contradicted by Brock (1959, p. 341), who contends that the overall picture is due to subsidence and not to magmatic activity related to the

/Bushveld...50.

Bushveld Complex. He states that the rigidity of the floor of a basin is reduced rapidly by subsidence, followed by collapse which gives rise to horizontal compression. This mechanism is similar to the jaws of a nut-cracker (Brock, 1959, p. 344), i.e. it is the linearity of a trough that directs the pressure normal to its length.

Important is the fact that the eastward extension of the long axis of the Bushveld Basin passes through Pilgrim's Rest. The presence of east-trending folds at Pilgrim's Rest indicates that compressive forces had acted normal to this axis. It is concluded that the forces were the result of the subsidence of the Bushveld Basin, similar to the hinge-effect (nut-cracker) as explained by Brock (1959, p. 344). As the conclusion is drawn that the mineralisation is structurally associated with the folding, this mechanism will also explain why gold-mineralisation is localised mainly near this axis, i.e., only in the Sabie-Pilgrim's Rest area of the Transvaal Basin.

The formation of the low-angle bedding-thrusts postdates the east-trending folds. These thrusts are due also to compressional forces, which are considered to be related to a later phase in the magmatic activity. The forces acted from west to east, resulting in the formation of the bedding-thrusts, as well as the north-trending folds. The pre-reef dykes, i.e. the Nestor Dyke and several others, are displaced by the bedding-thrusts.

The low-angle gravity-faults are considered to be associated with tensional stresses which superseded the compressional forces that gave rise to the bedding-thrusts and north-trending folds. The high-angle normal faults postdate all the other structures and may be post-Bushveld, or even post-Karroo, in age. There is no evidence for Visser's conclusion (1957, p. xxxvi) that the tension-faults were formed during the emplacement of the Bushveld Granite. As the emplacement of the dykes of diabase postdates the formation of the high-angle normal faults, they are considered to be post-Bushveld in age.

IV. MINERALISATION

A. GENERAL STATEMENT

Gold, as well as deposits of asbestos and manganese are present in the area. The latter is, however, not relevant and is not considered. The occurrence of asbestos and gold within the same area is considered to be significant. Although no direct

/relationship...52.

relationship could be established, it is believed that both are structurally controlled.

The different mineral-localities are shown in Plate I.

B. GOLD-BEARING ORE-BODIES

1. Classification

The gold-bearing deposits are divided into two main types. The first is an interbedded, roughly sheet-like body, referred to as an interbedded reef. This type of deposit is found on more than twenty different stratigraphical horizons. They occur in the Wolkberg Formation, as well as in the three members of the Transvaal System. Most of these are found in the Dolomite Series. Swiegers (1948, p. 83) ascribes this to a higher reactivity of the dolomitic limestone However, little or no replacement of the dolomite is observed, and the above phenomenon is therefore considered to be due entirely to stratigraphical control.

The second type of deposit is represented by transgressive ore-bodies. These are locally known as cross reefs, and are sub-divided into simple fissure-veins, sheeted zones, stockworks, dyke-veins, ladder-veins, dyke-contact veins, dyke-lodes, fault-plane deposits and tabular ore-shoots (Swiegers, 1948, pp. 87-88). Visser and Verwoerd (1960, p. 62) offer a more general classification, namely, vertical reefs, leaders, blows, and irregular ore-bodies.

2. Interbedded Reefs

(a) General Characteristics

The distribution and stratigraphical relationships of the interbedded reefs are shown in Plate II. It has already been shown that the mineralisation preferred planes of weakness in the sedimentary beds. Due to the topography, the outcrops of the reef-horizons are sinuous and can be traced along the hill-slopes for considerable distances.

The interbedded reefs can be described as mineralised bedding-faults of great lateral extent. The presence of wall-rock fragments, striations and slicken-sides is evidence that these reefs were emplaced along bedding-faults (Zietsman, 1964, p. 61). In a number of places, intraformational movement has caused the displacement of pre-reef dykes and faults. Apart from the dyke in the Malieveld Mine described by Visser and Verwoerd (1960, p. 69), a dyke in the Nestor Mine, and a pre-reef compaction-fault in the Astra Mine are likewise displaced.

During these displacements the movements were evidently not confined to a single plane, but occurred along several closely spaced bedding-planes. The material between these planes of movement, which included early sulphides and gangue-minerals, was subjected to intense brecciation and, locally, also to flexuring. The disturbed zone was subsequently mineralised by later mineral-bearing solutions. The contacts of an inter-bedded reef are, therefore, almost invariably defined by slickensided planes of movement.

The visible striations on the planes of movement indicate a southeasterly direction of movement, i.e. approximately perpendicular to the 060 degrees structural trend.

Although the horizons of certain reefs can be traced for many miles in all directions, interbedded reefs are developed locally only. Where a potential inter-bedded reef is developed into a true ore-body, it is known locally as an ore-shoot. An economical ore-shoot is referred to as a pay-shoot. Ore-shoots are usually developed along the crests of very open anti-clines and domes. The shoots are generally between 500-1000 feet in width and they may be several miles long.

Interbedded reefs usually have an average thickness of 10-20 inches. In localities where they reach exceptional thicknesses of over 8 feet, the reefs are usually associated with domes. Interbedded reefs are characterised by considerable variations in thickness. The thickness within an ore-shoot is seldom less than two inches, and commonly swells to more than 12 inches. Away from the ore-shoot the swells become less conspicuous, with the result that the reef is eventually represented by a carbon-parting or thin layer of brecciated rock only.

The characteristics of a swell are illustrated in Figure 9. It is lenticular in cross-section and is marked by an abundance of massive ore- and gangue-minerals. In the constrictions between adjacent swells, hardly any massive mineralisation is found.

The layers of chert in the hanging- and foot-wall are curved in sympathy with the swells (Figure 9). Joints and fractures are usually present in the wall-rock above and below the swells. The lenses are of limited lateral extent, and are elongated in an east-southeasterly direction.

Structures similar to those described above are due to irregularities in the original plane of faulting (Hulin, 1929, pp. 15-49). These irregularities will cause certain parts of the fractured surface to rub together during movement, while other parts will pull apart (Newhouse, 1942, p. 6). This is admirably illustrated by Stočes and White (1935, p. 296).

The lenticular character of the interbedded reefs can therefore be ascribed

/to slight...57.

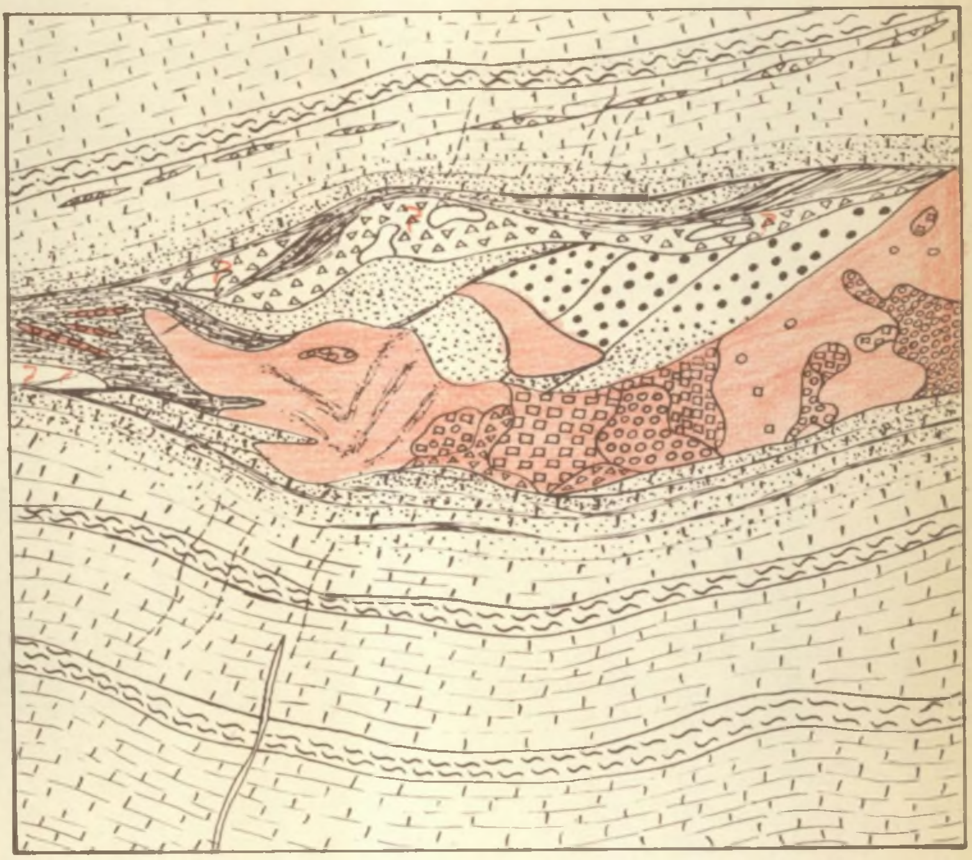


Figure 9 :- Section of Beta Reef in the Beta Mine.

Reference :-

Scale :- 1 inch = 1 foot

- Massive tetrahedrite.
- Massive pyrite.
- Vein-quartz with blebs of massive pyrite and tetrahedrite.
- Barren Vein-quartz.
- Barren Calcite
- Coarse disseminated pyrite in dolomite.
- Slickensides of graphite
- Fine disseminated pyrite in dolomite.
- Dolomitic limestone
- Chert
- Quartz vein
- Joints filled with calcite
- Second period of mineralisation

to slight undulations in the original planes of movement. These undulations may have been tectonic in origin, or they may have been present in the rocks before the deformation. The apparent orientation of the lenticular bodies, however, suggest that the undulations were due to tectogenesis.

The abundance of massive mineralisation in the lenticular bodies is considered to be due to the following conditions: In a fissure, the presence of relatively large open spaces, which are fed through a constricting conduit, creates favourable conditions for a steep gradient of precipitation (Newhouse, 1942, p. 6). These conditions include a sudden decrease in the hydrostatic pressure and temperature, as well as a decrease in the flow-speed of the mineralising solutions. An interbedded reef may split into two or more reefs, separated by a few feet of country-rock. Disconnected reefs may develop locally a few feet above and/or below the main reef-horizon. Mining-experience has shown that in areas where two or more reefs were present, the subsidiary reefs, as well as the main horizon, were found to be inferior, both in thickness and in gold-content.

The carbon-content of the reefs is apparently influenced by the lithology. The variations are considered to be due to the presence or absence of shale. The reefs in the

/shale....58.

shale of the Pretoria Series, for instance, are characteristically carbonaceous. The reefs in Zone One of the Dolomite Series, which contain numerous layers of shale, are generally more carbonaceous than those higher up in the succession where shale is relatively scarce. The Sandstone Reef, which occurs in quartzite, is practically free of carbonaceous matter.

(b) Mineralogy of the Ore

The interbedded reefs are composed of gangue- as well as ore-minerals. The following gangue-constituents are found in the sulphide-zone: quartz, calcite, dolomite, siderite, sericite and, less frequenctly, apatite. Secondary quartz and calcite are often distinguished from their hypogene counterparts. Apart from these, gypsum and associated sulphur are occasionally present in the oxidised zone (Swiegers, 1948, p. 119).

The hypogene ore-minerals are pyrite, arsenopyrite, pyrrhotite, chalcopyrite, tetrahedrite, bismuthinite, native bismuth and scheelite. The supergene sulphides chalcocite and covellite are present also. The supergene ore-minerals in the oxidised zone are limonite, cuprite, native copper, malachite, azurite, chrysocolla, tenorite and bismuth-ochre.

The precious metals gold and silver are present in various proportions as electrum.

(i) <u>Ore-minerals</u>. Pyrite is the most abundant ore-mineral and is found in macroscopic quantities in all the interbedded reefs. Two types of pyrite could be distinguished: disseminated pyrite which sometimes occurs as lumps of sugary pyrite; and dense massive pyrite.

The mode of occurrence of the minerals present in an interbedded reef, is illustrated in Figure 9. Disseminated pyrite is found in the wall-rocks, in fragments of wall-rock within the ore-body, as well as in the graphitic shale. It is seldom present in quartz and calcite. Lumps of sugary pyrite, associated with irregular bodies of quartz, are found in some ore-bodies. These bodies are invariably intersected by numerous graphitic slickensides, which indicates that this type of mineralisation predates the bedding-thrusts.

The massive pyrite occurs as small blebs, massive aggregates of irregular shape, as well as veins in the gangue. It is often found in admixture with other sulphides, and less commonly, as tiny veinlets in the wall-rocks adjacent to the ore-body.

A definite difference in age between the disseminated or sugary pyrite and the

/massive...60.

massive pyrite could be established. The former type is clearly earlier than the deformation. It is commonly present in wall-rock fragments and in graphitic shale, but never along slickensides or any other planes of movement. The presence of slickensides in masses of sugary pyrite furthermore suggests that movement took place after this pyrite was formed. The massive type of pyrite, however, often occupies cracks and shear-planes in the ore-body. It replaces dolomite and disseminated pyrite in fragments of wall-rock. This type of pyrite, therefore, postdates the bedding-thrusts, i.e. it is later than the disseminated or sugary type of pyrite.

A difference in character between the disseminated pyrite and the massive pyrite was also observed by Barnard (1958, pp. 23-24) in the ores of the Bourke's Luck Mine. He noticed that the crystals of the disseminated type occasionally showed pressure-shadows and were often compressed, the longer axes of the crystals being parallel to the foliation of the matrix.

Pyrite has grown essentially at the expense of gangue and country-rock, and nowhere does it replace other sulphides (Swiegers, 1948, p. 98).

Arsenopyrite occurs in much the same way as pyrite in some of the interbedded reefs. It is most abundant in the ores of the Frankfort Mine, both in the Bevett's Reef and in the Frankfort Reef. Two types of arsenopyrite are present, namely a disseminated variety and a massive type. The disseminated or sugary variety is earlier than the massive arsenopyrite, and was emplaced prior to any deformation. Massive arsenopyrite sometimes replaces massive pyrite (Swiegers, 1948, p. 98), and is therefore later than the pyrite. The arsenopyrite is in turn replaced by chalcopyrite or tetrahedrite. The massive arsenopyrite is present in almost all the ore-bodies in the gold-field, while the disseminated or sugary variety is restricted to the ore-bodies on Frankfort 509 K.T.

Pyrrhotite is not plentiful and is restricted to the Mamre Mine, where it constitutes the dominating ore-mineral.

Chalcopyrite is the most important copper-mineral in the ores of the gold-field (Swiegers, 1948, p. 99). This mineral is encountered in all the reefs but is most conspicuous in the Beta and Glynn's Reefs. Swiegers (1948, pp. 100-101) observed the following characteristics and relationships in polished specimens of chalcopyrite: the mineral is invariably anhedral in form and occurs as irregular replacement-bodies. Where the interstices between crystal-aggregates of idiomorphic pyrite are completely replaced by chalcopyrite, pseudo-crystalfaces may develop . The corners of the crystals of pyrite are usually rounded, due to replacement by the chalcopyrite.

The replacement of calcite by chalcopyrite is essentially controlled by the directions of cleavage. In cases of advanced replacement, evenly scattered rhomblike islands of carbonate remain in the sulphide. The chalcopyrite metasomes are irregularly developed in chert and quartz.

Veins and vein-systems of chalcopyrite are frequently encountered in gangue or in early sulphides, especially pyrite, arsenopyrite and pyrrhotite. Composite or broken veins containing chalcopyrite and tetrahedrite or bismuthinite, or both, are commonly found in crystals of pyrite. This suggests a more or less simultaneous deposition of these three sulphides.

Irregularly rounded grains of chalcopyrite are almost invariably present in massive tetrahedrite. Evenly scattered, elongated inclusions of chalcopyrite in

/bismuthinite...63.

bismuthinite, may resemble an intergrowth of the two.

Tetrahedrite is an important ore-constituent in the mines around Pilgrim's Rest. It occurs as large aggregates or as small eyes in quartz in the lower levels of the Beta Mine (Figure 9). It is found also in admixture with other massive ore-minerals like massive pyrite and chalcopyrite.

Swiegers (1948, p. 103) found that tetrahedrite replaced pyrite, arsenopyrite and gangue. In general, pyrite is more readily replaced by tetrahedrite than by chalcopyrite.

Bismuthinite is less commonly found in the interbedded reefs. It usually occurs in the form of isolated elongated crystals up to two inches in length. Native bismuth is usually found to be associated with bismuthinite and is often included in the latter mineral.

Other ore-minerals of minor occurrence are, galena, bornite, sphalerite and scheelite.

(ii) <u>Supergene Sulphide-minerals</u>. The sulphides which are secondary in origin, are chalcocite and covellite. They are formed at or just below the water-table. The chalcocite is associated mainly with chalcopyrite and, less frequently, with tetrahedrite (Swiegers, 1948, p. 111). This author observed that the degree of replacement of chalcopyrite by chalcocite ranged from microscopical veinlets of chalcocite in solid chalcopyrite, to masses of chalcocite with occasional remnants of chalcopyrite. Pyrite is occasionally also replaced by chalcocite. The covellite is extensively developed in tetrahedrite, chalcopyrite and chalcocite. It also replaces arsenopyrite and bismuthinite.

(iii) Supergene Oxide-minerals. The oxides of iron are the most common oxide-minerals. They are usually earthy mixtures of limonite, goethite and hematite; pseudomorphs after pyrite are sometimes present (Swiegers, 1948, p. 117).

Cuprite, malachite, azurite, chrysocolla and tenorite are the products of oxidation of sulphides. They usually occur in close association with each other.

Bismuth-ochre, which is pseudomorphous after bismuthinite, was observed in some of the oxidised ores. It is particularly abundant in the Portuguese Reef.

(iv) Gangue-minerals. Quartz is the most common gangue-constituent in the interbedded reefs. Other important minerals are calcite, siderite, dolomite and graphite. Minor quantities

/of chlorite...65.

of chlorite, sericite and apatite are present also.

Three generations of silicification can be distinguished, one before and the other two after the intraformational movement. The former is characterised by the presence of disseminated pyrite. In some localities massive pyrite is present in fractures in this quartz. Its relationship to fragments of wall-rock in the Beta Reef (Figure 9) suggests that it is pre-movement in age.

Quartz which postdates the bedding-thrusts is present in the form of replacement-bodies in fragments of wall-rock, as well as in earlier quartz. Inclusions of disseminated pyrite in graphitic shale have been observed in this later quartz. The quartz is intimately associated with the massive ores and is extensively replaced by them.

A third generation of silicification is indicated by veins of quartz which transect all the other minerals.

The carbonates grade in composition from pure calcite to siderite, with varying proportions of magnesia and manganese (Swiegers, 1948, p. 108). A close association exists between the carbonates and the quartz; intergrowths are often encountered, and, as in quartz, three generations of carbonates

/can be...66.

can be distinguished.

Carbonate, which is pre-movement in age, is present in the Pigeon Reef at the foot of the Lisbon Falls. The bulk of the ore-body in this locality is composed of siderite which is sheared and filled by late ore-minerals.

Figure 9 shows a body of barren calcite with intergrowths of quartz, partly enclosing a layer of graphitic shale. It is not clear whether movement took place prior to the emplacement of the calcite. A thin fracture along the upper contact of the shale, also intersects the calcite, indicating slight movement after the deposition of the calcite.

A third period of carbonatisation is revealed by veins of calcite which intersect gangue - as well as ore-minerals of all previous generations.

Graphite is present in most of the interbedded reefs. This mineral predates the formation of the bedding-thrusts. The abundance of graphite in shaly horizons suggests that it was derived mainly from the shale. Barnard (1958, p. 33) came to a similar conclusion in connection with concentrations of graphite in the Trixie Lode.

Chlorite, sericite and apatite are minor constituents of the interbedded reefs, and are of local occurrence only.

(v) Precious Metals. The precious metals in the interbedded reefs occur as an alloy of gold and silver, i.e. electrum. The ratio of gold to silver is characteristic for the interbedded reefs, and differs from that of the transgressive reefs. The ratio in the interbedded reefs varies between 7-15 parts of gold to one part of silver. Swiegers (1948, p. 124) concludes that the ratio is constant for any particular ore-body but that it varies from one ore-body to another. This ratio is apparently influenced by the relative abundance of disseminated pyrite.

The precious metals occur in association with sulphides. Crystalline growths, veinlets and vein- systems-irregular replacements in pyrite, spikes and blades in bismuth-ochre, and intergrowths of gold and sulphide-minerals, were observed under the microscope (Swiegers, 1948, pp.127-128). Visible gold is practically absent.

The relationship between the gold and the disseminated pyrite is rather obscure. No gold is visible in this mineral under the microscope. Assay-results, however, show that the pyrite contains gold; values of up

/to ...68.

to 12 pennyweights are encountered. It must therefore be concluded that the gold is present in sub-microscopic particles similar to some of the Barberton ores (Schweigart and Liebenberg 1965). In the later sulphides, however, the precious alloy can be distinguished under the microscope. It is generally more closely associated with chalcopyrite and tetrahedrite than with massive pyrite. In the ore of the Trixie Lode, however, the relationship between copper-minerals and gold is directly influenced by the association between chalcopyrite and pyrite. Where chalcopyrite is found in combination with the pyrite, moderate gold-values may be associated with high copper-values. Where chalcopyrite is not associated with pyrite, no gold is present (Barnard, 1958, p. 27).

(vi) Relationship Between Reef-thickness and Gold-content. The gold-content of an interbedded reef is directly related to the relative abundance of ore-minerals which postdate the bedding-thrusts. In reefs where only disseminated pyrite is found, the average gold-content is not influenced by the thickness of the ore-body. The sulphide-minerals, other than the disseminated pyrite, are concentrated largely in the lenticular swellings, and the conditions which were responsible for the steep precipitation-gradient of these minerals, also controlled the precipitation of the gold. The gold in interbedded reefs is therefore concentrated mainly in the lenticular bodies, i.e., the gold-content is related to the thickness of the ore-body. This is illustrated in Figure 10.

High gold-values are sometimes encountered in the thin parts of oxidised reefs, whereas the thicker parts yield inferior values. This is probably due to secondary redistribution of the gold.

(vii) Alteration of the Wall-rock. The alteration of the wall-rocks yielded the following minerals: quartz, calcite, graphite, pyrite, and small quantities of chlorite and sericite. The dolomite may show local recrystallisation. These minerals are, however, considered to be the products of metamorphism rather than hydrothermal activity.

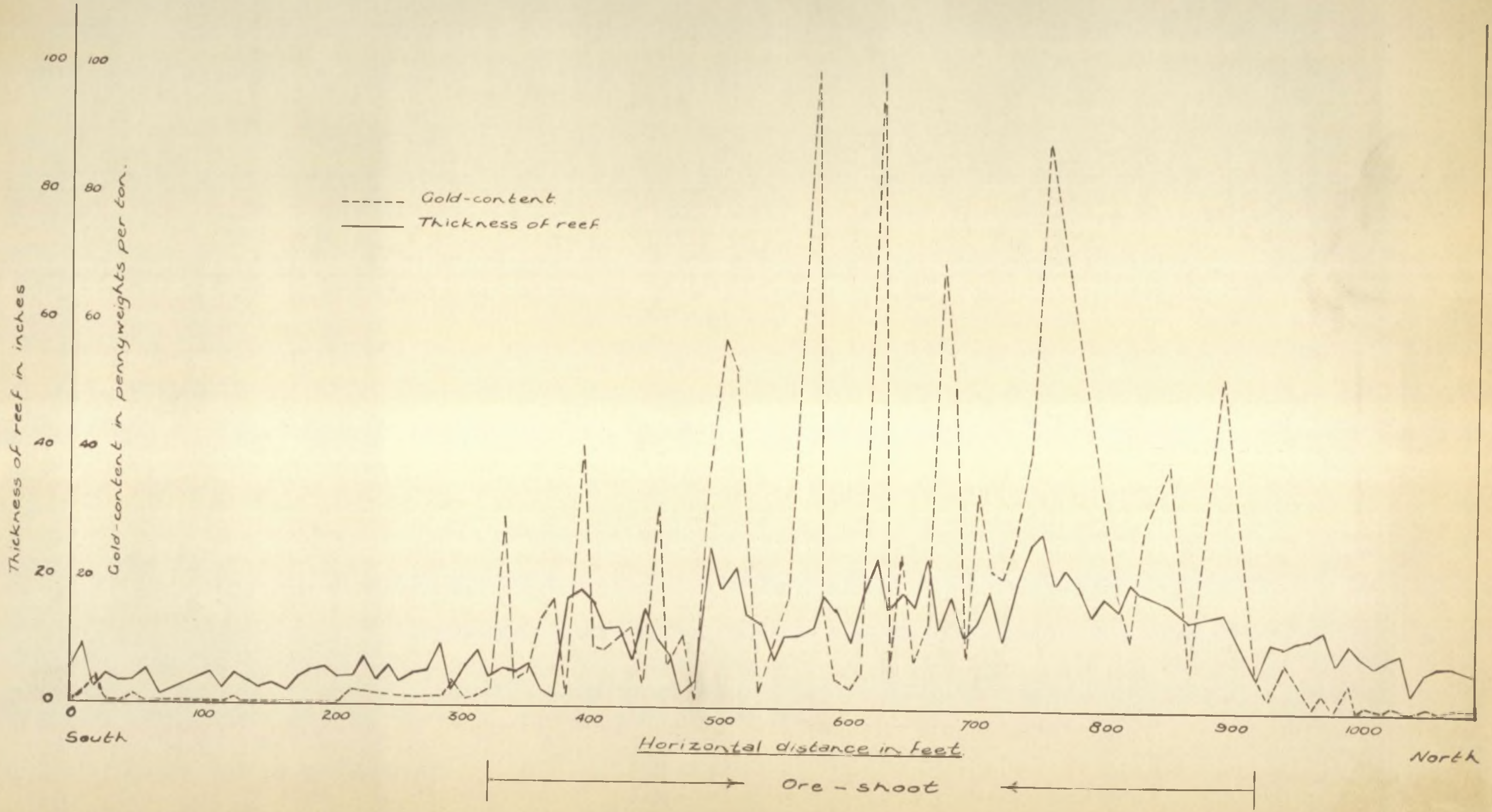


Figure 10:- Relationship between gold-content and thickness of reef section across Peach Tree Mine

The alteration of the country-rocks adjacent to the interbedded reefs, which are invariably located near sills, is illustrated in Figure 11. The wall-rock adjacent to interbedded reefs located within dolomite, is usually characterised by abundant disseminated pyrite. The pyrite decreases rapidly away from the reef and usually disappears completely within 5 feet of it. The pyritic zone is also characterised by numerous "eyes" and interbedded lenses of calcite which result in a spotted appearance of the dolomite. Abundant graphite occurs near the contact of the reef, but is represented only by a few interbedded stringers away from it.

An example of wall-rock alteration in shale is represented by an ore-body in the Fraser-Morgan Mine (Figure 11). This ore-body is located immediately above a pyroxenitic sill and also penetrates 6-15 inches into it. The ore-zone is composed of sugary pyrite with interlocking quartz. Both the quartz and the pyrite are intensely brecciated in the shale, but not in the sill. Graphite is present in great abundance, especially along slickensides. Both graphite and disseminated pyrite decreases away from the ore-body. Numerous stringers and lenses of quartz are present within 5 feet of the ore-body.

/3. Transgressive...73.

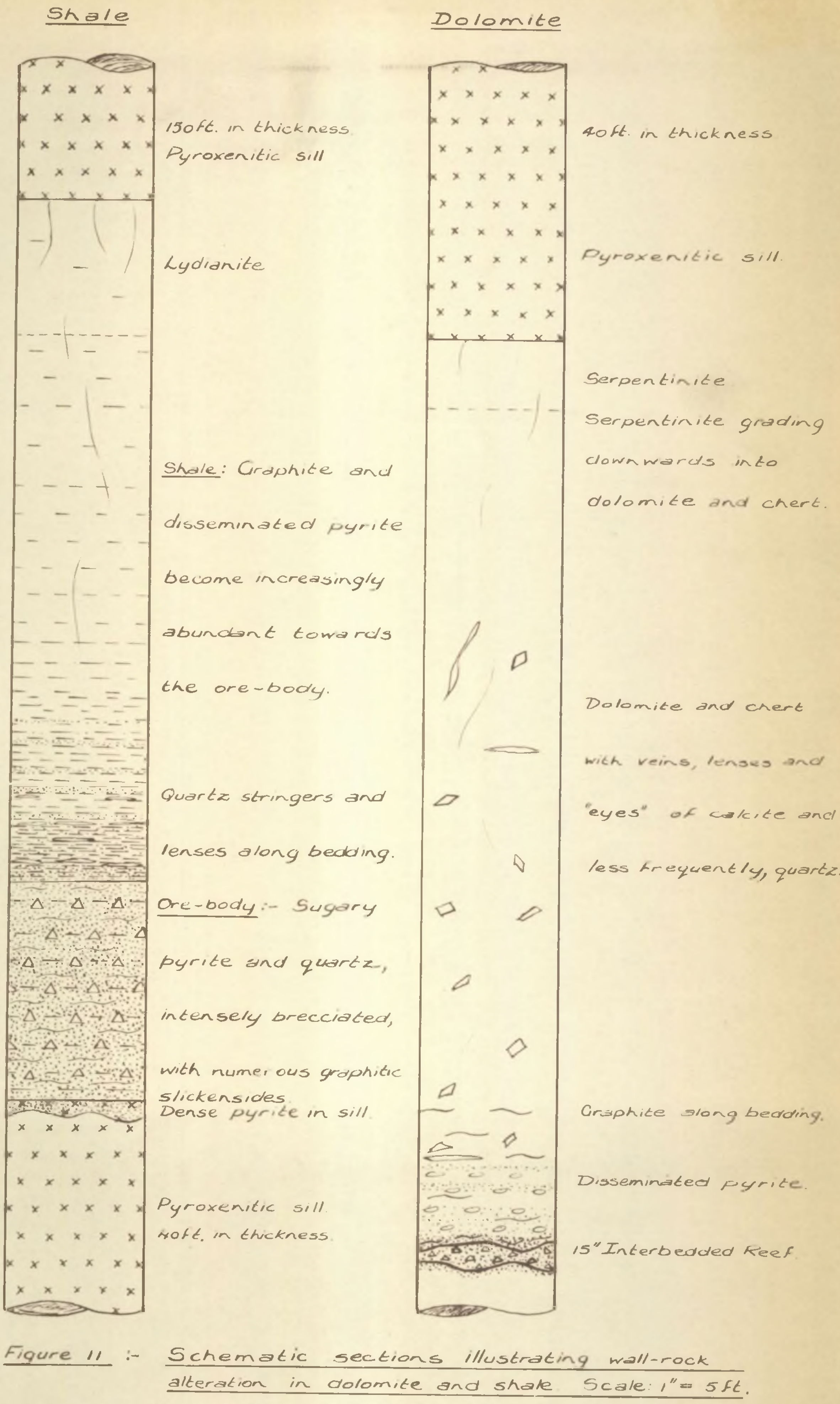


Figure 11 :- Schematic sections illustrating wall-rock alteration in dolomite and shale Scale: 1" = 5 ft.

Note:- Sections from Fraser-Morgan Mine

3. Transgressive Ore-bodies

(a) Classification

(i) Vertical Reefs. The vertical reefs are fissure-veins of great lateral as well as vertical extent. They vary between a few inches and 20 feet in thickness. These reefs are either vertical or steeply inclined, and have strikes that vary between 004-020 degrees.

The vertical reefs are represented by the Rietfontein, Sunlight, Astra and Hepta Reefs. Uneconomical ore-bodies are the Bokwa and Gregory Reefs.

Vertical reefs occupy old fault-planes or were emplaced along tension-fractures which show no displacement.

(ii) Leader-reefs. They are steeply inclined ore-bodies of small vertical extent. They vary between one inch and several feet in thickness, and they may extend for over 1000 feet along strike. Leader-reefs are usually characterised by smooth, well defined walls.

(iii) Dyke-reefs. These ore-bodies are intimately associated with dykes. They may be emplaced along the contacts or within the dyke itself. They are either parallel or perpendicular to the contacts.

/The Trixie....74.

The Trixie Lode in the Bourke's Luck Mine is a dyke reef that cuts at an oblique angle through the Dientjie Dyke.

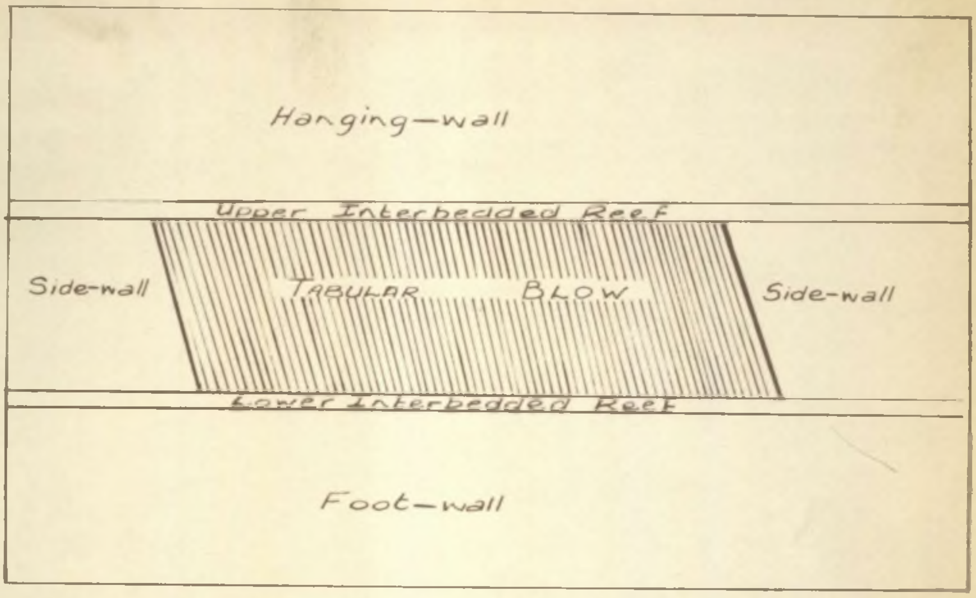
The most important dyke-reefs are found in the northern area. At Bourke's Luck they are represented by the Trixie Lode, Contact Reef and Dyke Reef. At Vaalhoek the Thelma Reefs are closely associated with the Vaalhoek Dyke, while farther south, several ore-bodies of minor importance occur along this Dyke. A few ore-bodies of lesser importance are found along the New Chum Dyke and a dyke parallel to it.

A few dyke-reefs are also present in the central and southern areas, i.e. along the Mali and Nestor Dykes.

(iv) Blows. The blows are thick ore-bodies which are greater in lateral than in vertical extent. These bodies have dimensions in the order of 5-20 feet in height, up to 200 feet in width, and to over 3000 feet in length.

Two types are encountered, namely, tabular blows that are developed between two parallel interbedded reefs, and ore-channels which extend downwards from a reef-plane (Figure 12). The former type is characterised by relatively smooth contacts. Blows of this type may be described as steeply inclined leaders that are greater in lateral

/than in ...76.



Scale: 1 inch = 10 feet.

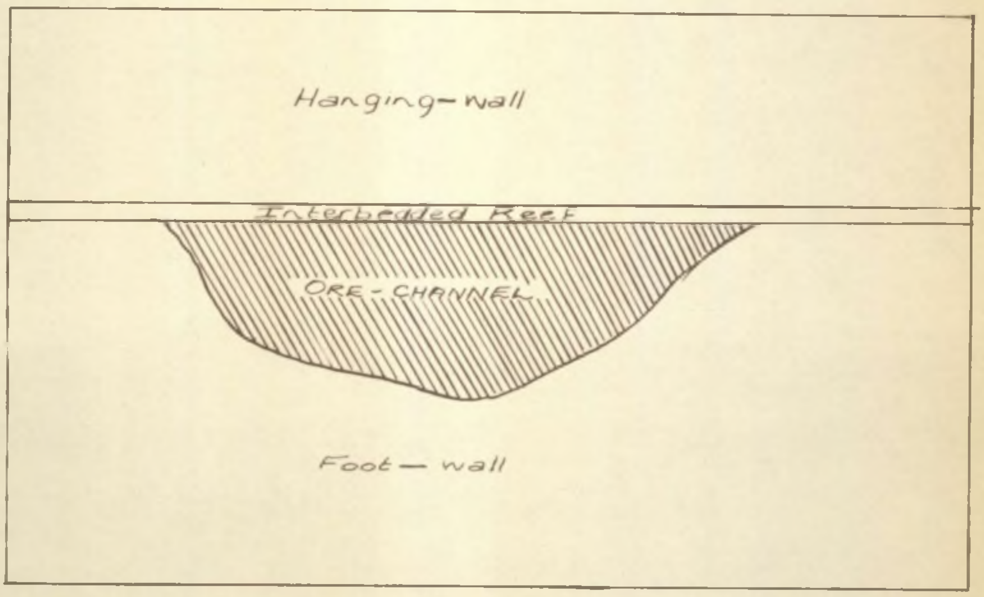


Figure 12:- Diagrammatic sections illustrating difference between tabular blows and ore-channels.

than in vertical extent; in cross-section the shape resembles a parallelogram. The ore-channels are boat-shaped in cross-section (Figure 12).

The most important tabular blow is the Elandsdrift Blow south of Sabie. The Copper Blow in the Nestor Mine is another example of this type of ore-body. Several similar, although much smaller, tabular blows are present on London 496 K.T. and Ledouphine 469 K.T.

The Spitzkop Ore-channel is the most important example of the second type. This ore-body is genetically associated with a low-angle gravity-fault.

(a) General Characteristics

(i) Stratigraphical Relationship. While the interbedded reefs are present predominantly in relatively incompetent beds of dolomite and shale, the prominent transgressive reefs are located in competent rocks such as granite, diabase and quartzite. A close stratigraphical relationship exists between the interbedded and transgressive ore-bodies.

The leader-reefs and the blows are invariably associated with interbedded reefs, and they are often developed between two interbedded reefs. Dyke-reefs occur within or along the contacts of dykes, at elevations which usually coincide with the stratigraphical horizons of interbedded reefs.

Vertical reefs in sedimentary rocks show enrichment in their gold-content, at elevations which coincide with the horizons of the interbedded reefs.

(ii) Age-relationship. The age-relationship between the interbedded and transgressive reefs is best illustrated in the area around the Lisbon Falls. In the Little Gem Mine an early high-angle fault is displaced horizontally along the plane of an interbedded reef. The plane of the high-angle fault was opened and mineralised after the horizontal displacement took place. In the Astra Mine the same high-angle fault-plane was also displaced by a low-angle gravity-fault, prior to the mineralisation of the fault-plane.

The low-angle gravity faults in other parts of the gold-field postdate the interbedded ore-bodies, but predate the transgressive reefs. It is concluded, therefore, that the transgressive ore-bodies are younger than the interbedded reefs.

(c) Mineralogy

(i) Ore-minerals. The ore-constituents in the transgressive reefs are predominantly massive sulphides and consist of pyrite, chalcopyrite, bismuthinite and native bismuth. The transgressive ore-bodies are characteristically rich in copper. Arsenopyrite was encountered in the Rietfontein Reef only. Galena is restricted to some leader-reefs on Columbia Hill, and bornite was found in the Contact Reef at Bourke's Luck. Tetrahedrite is completely absent in this type of ore-body.

The disseminated and sugary varieties of pyrite are generally not represented in the transgressive ore-bodies. The Trixie Lode at Bourke's Luck, however, is an exception to this rule. Disseminated pyrite commonly occurs in the marginal zones of this ore-body (Barnard, 1958, p. 23). Two types of massive pyrite is present in the Trixie Lode, namely a coarse subhedral type, which occurs in grains of up to half an inch in diameter, and a very fine, compact variety. The coarse variety is considered to be contemporaneous with the sugary pyrite of some interbedded reefs. This is supported by the fact that the coarse subhedral pyrite occupies the marginal zones in the Trixie Lode, and, it is replaced by the fine compact type, which forms the core of the ore-body (Barnard, 1958, pp. 23-24).

/The supergene...79.

The supergene products of oxidation are the same as those of the interbedded reefs.

(ii) Gangue-minerals. Quartz is the dominant gangue-constituent in the transgressive bodies. Carbonates are seldom encountered, except in the Trixie Lode where it is present in the upper and lower parts of the lode. Chlorite and sericite are found in appreciable quantities, but in dyke-reefs only. Epidote, hornblende, serpentine and specularite are present in minor quantities in the Trixie Lode (Barnard, 1958, pp. 33-34). Graphite is encountered in the Trixie Lode only, and in this ore-body the graphite is not distributed throughout the lode, but is restricted to the upper and lower ends, i.e. near the contacts of the Dientjie Dyke. Intergrowths of quartz and calcite are closely associated with this graphite (Figure 13).

(iii) Precious Metals. The precious metals gold and silver are present as electrum in the transgressive reefs. Coarse gold is commonly present: nuggets weighing up to 80 ounces were found in the Hepta Reef (Wybergh, 1925, p. 101). The distribution of the gold is, however, very uneven, with the result that poor

/values.....81.

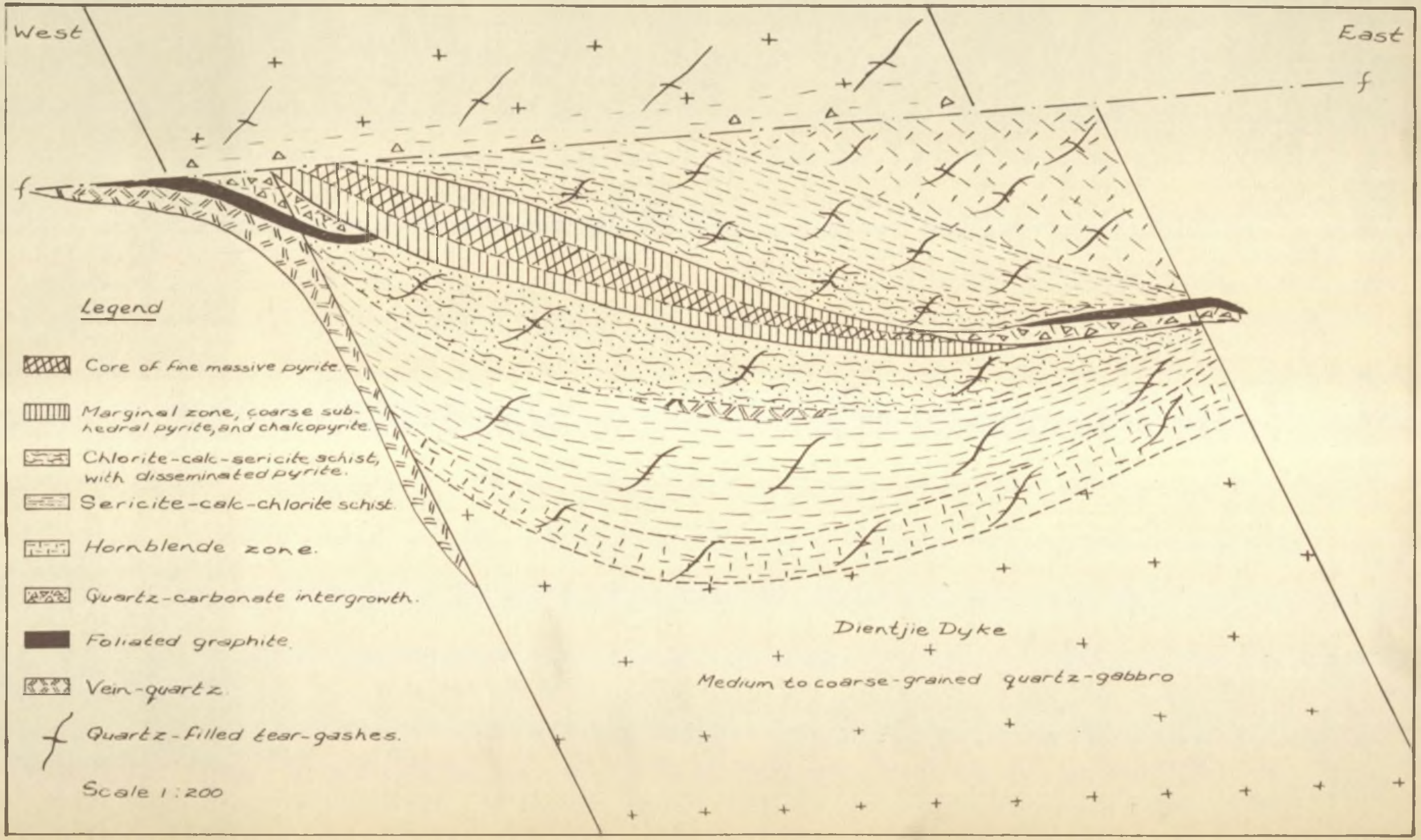


Figure 13 :- Schematic transverse section across Trixie Lode at 93 Raise, Bourke's Luck Mine.

(After K. J. Barnard, 1958)

values may be encountered in some localities, while in others, one prospector's pan of ore may yield several ounces of gold.

The ratio of gold to silver is characteristically low. Ratios calculated from figures supplied by Swiegers (1948, p. 124) show a ratio of 4.3:1 for the Rietfontein Mine and 1.1:1 for the Bourke's Luck ores.

The gold is usually associated with the ore-minerals, but in some transgressive reefs, especially in blows and leader-reefs, it may occur in vein quartz.

(d) Alteration of the Wall-rock

The country-rocks adjacent to most of the transgressive reefs are relatively unaltered. Thin sections of specimens of quartzite taken at various distances from the Astra Reef, appeared to be identical in composition and texture (Swiegers, 1948, p. 89).

The Trixie Lode at Bourke's Luck is the only transgressive ore-body that shows appreciable alteration of its wall-rocks. Barnard (1958, pp. 36-38) found that this alteration resulted in the zoning of the adjacent country-rocks (Figure 13). The first 5-10 feet adjoining the ore-body is composed of chlorite-sericite schist in which chlorite is the dominant constituent.

Disseminated pyrite, which is similar to that in the wall-rocks of the interbedded reefs, is present in this zone. In the next zone, which is 9-15 feet in thickness, sericite dominates over chlorite. The outer zone is characterised by an abundance of hornblende. Numerous tear-gashes are present in all three these zones of alteration.

Barnard (1958, p. 38) contends that the chlorite, sericite and hornblende were not introduced by hydrothermal solutions, but resulted from the hydrothermal alteration of the diabase, which constitutes the wall-rocks of the reef.

(e) Classification of the Trixie Lode

Although this ore-body is structurally classified as a transgressive reef, it differs in certain mineralogical properties from all the other transgressive bodies, but shows a remarkable resemblance to the interbedded reefs. The resemblance to interbedded reefs is borne out by the following:

(i) The Trixie Lode contains disseminated pyrite and coarse, subhedral crystals of pyrite which are considered to be contemporaneous with the early pyrite in the interbedded ore-bodies. This type of pyrite is absent in the other transgressive reefs.

/(ii) Graphite... 83.

(ii) Graphite and intergrowths of quartz and calcite are prominent gangue-constituents in the Trixie Lode. They are found also in the interbedded reefs, but are absent in the transgressive reefs.

(iii) The wall-rocks of the Trixie Lode are altered to a considerable degree without showing any evidence of the introduction of foreign material. The wall rocks of the interbedded reefs are likewise altered, while those of the transgressive ore-bodies show very little alteration.

It is concluded, therefore, that the Trixie Lode was formed contemporaneous with the interbedded reefs.

4. Discussion

The structural characteristics of the interbedded and transgressive reefs indicate that they are not quite contemporaneous. This is borne out also by the distinct differences in their mineral-assemblages. The first period of the mineralisation of the interbedded ore-bodies predates the bedding-faults. The second period is contemporaneous with that of the transgressive ore-bodies. Two distinct periods of mineralisation, different both in age and in origin, are therefore present.

(a) First Period of Mineralisation

The minerals that were formed during

this period are quartz, carbonates, graphite, pyrite and arsenopyrite. During the emplacement of these minerals the following processes were involved: serpentinisation, carbonatisation, silicification, graphitisation and pyritisation. These processes are considered to be genetically related to the intrusion of the pyroxenitic and diabasic sills.

According to Van Biljon (1964, p. 650) the serpentinisation of dolomite along the contact of a sill is influenced by the abundance of chert and the temperature of the rock during the intrusion. In the presence of sufficient silica and water, serpentine will form directly if the temperature is below 500 degrees Centigrade. Above this temperature, however, forsterite will form instead, and this mineral will be converted to serpentine if the temperature drops below 500 degrees. A conversion such as this will result in the formation of talc and serpentine. As no appreciable talc is found in the Pilgrim's Rest Area, it is considered that serpentine was the initial product and that the temperature did not rise above 500 degrees Centigrade. This reaction is represented by the following equation:-

$$3Ca\ Mg\ (CO_3)_2 + 2\ SiO_2 + 2\ H_2O = Mg_3\ Si_2\text{-}$$
$$O_5\ (OH)_4 + 3CaCO_3 + 3CO_2$$

The $CaCO_3$, as well as the CO_2 thus formed may be driven out of the zone of serpentinisation, i.e. away from the source of the heat, and some of this material may be emplaced as calcite and graphite along favourable horizons. Although pyrite may be extracted from the dolomite during contact-metamorphism the presence of gold cannot be ascribed to this process, as very little gold is present in calcareous rocks (Clarke, 1924, p. 657).

Lindgren (1933, p. 699) contends that magmatic solutions will enter the rocks adjacent to a magma and will produce a series of metasomatic changes, the character of which will depend upon the composition of the solutions and their temperature, as well as upon the type of country rock that is exposed to the hot solutions. Dolomite and calcareous shales are easily invaded and are very susceptible to mineralising fluids even at low temperature. If the solutions contain enough silica, sulphur, iron, and carbon dioxide, the emplacement of an ore-body consisting of quartz, pyrite and graphite will occur.
In shale or other sedimentary rocks, the intrusion of a magma will cause abundant silicification, thus rendering the rock more competent and, therefore, more receptive to brecciation and introduction of fluids (Park and MacDiarmid, 1964, p. 144).
According to analyses shown by Clarke

/(1924, p. 657),..86.

(1924, p. 657), both gold and silver are more abundant in diabase and gabbro than in sedimentary rocks. Highly acidic rocks, such as granites, are not always accompanied by ore-deposits of the contact-metamorphic type, although they may preduce widespread effects of metamorphism and a later mineralisation of veins of quartz. Gold and auriferous arsenopyrite is present in a deposit near the contact of gabbro with limestone at Hedly, Alaska (Goldschmidt, 1954, p. 198). An example of metallisation due to the intrusion of diabase is found at Cornwall, Pennsylvania (Lindgren, 1933, p. 702).

In the Sabie-Pilgrim's Rest Area, practically all the interbedded reefs are located in the proximity of sills. It is considered, therefore, that the early mineralisation of the interbedded reefs can be ascribed to contact-metamorphism and contact-metasomatism. The intrusion of the sills is probably contemporaneous with the first period of folding in the area. The localisation of the early mineralisation is therefore, controlled by the presence of favourable horizons, as well as folds. Mineralisation of the first period is conspicuos only where anticlinal structures exist. Away from these structures, the reef-horizon is characterised mainly by an abundance of graphitic material and occasional small bodies of quartz and calcite.

/(b) Second Period...87.

(b) Second Period of Mineralisation

(i) General Statement. The first period of mineralisation was followed by brecciation due to the formation of bedding-faults along the mineralised zones. This was followed by a second period of mineralisation, due to the introduction of hydrothernal solutions. Most previous authors recognised only one period of mineralisation. Swiegers (1948, p. 131), ascribes the mineralisation entirely to precipitation from hydrothermal solutions. He provides the following evidence for a mesothermal origin of the ores:

(1) The coarsely crystalline massive texture, rough banding and the occasional presence of vugs suggest intermediate temperature- and pressure-phenomena.

(2) The wall-rocks had undergone but slight alteration, which indicates a moderate temperature for the mineralising solutions.

(3) The mineralogical composition of the ore is characteristic of the intermediate type of hydrothermal deposit. Only this conclusion is considered to be reliable proof of a mesothermal origin, as the other properties are not necessarily characteristic of mesothermal deposits only.

/(ii) Sequence of Minerals..88.

(ii) Sequence of Minerals. The sequence of the minerals of the second period of mineralisation is as follows:

(1) The early gangue-minerals preceded the introduction of the ore-minerals and were emplaced in channelways provided by the brecciation of the ore-locus of the first period. The introduction of these constituents was evidently accompanied by the partial replacement of the breccia thus formed. The minerals that were emplaced are mainly quartz and carbonates, the former being locally replaced by the latter (Swiegers, 1948, p. 120).

(2) The early ore-minerals pyrite and arsenopyrite, accompanied by gold, commonly replace the early gangue-minerals, as well as the brecciated material of the first period of mineralisation. These constituents are invariably massive, in contrast to the disseminated or sugary character of the suphides of the first period. Arsenopyrite crystallised after the pyrite.

(3) The late ore-minerals are mainly pyrite, chalcopyrite, tetrahedrite, bismuthinite, native bismuth, galenobismutite and the precious metals. It is difficult

to derive a definite order of succession from the association of these ingredients and they are therefore considered to be contemporaneous in age (Swiegers, 1948, p. 121).

(4) The late gangue-minerals, consisting of quartz and calcite, occupy veins and fractures in all the other minerals.

(5) The supergene sulphides chalcocite and covellite resulted from the alteration of the copper-minerals in the sulphide-zone. The oxide-minerals in the leached zone are contemporaneous with the supergene sulphides.

(iii) Sequence of Events. The minerals of the second period of mineralisation show very little deformation. This deformation is restricted to two distinct phases. The first is represented by fractures in the pyrite and arsenopyrite, which are filled with late ore-minerals. The presence of late gangue-minerals along fractures in the late ore-minerals is indicative of the second phase. The sequence of the events during the mineralisation of both the interbedded and transgressive reefs are thus visualised as follows:

(1) The infilling of openings and partial replacement by quartz and carbonates.

/(2) This...90.

(2) This phase was followed closely by the precipitation of auriferous pyrite and arsenopyrite.

(3) Slight movement resulted in a mild shattering of the early minerals.

(4) Precipitation of late ore-minerals as well as gold along fractures within the earlier sulphides and gangue.

(5) Recurrence of mild shattering.

(6) Precipitation of the late gangue-minerals along fractures in the early sulphides and gangue, as well as in the late ore-minerals.

(7) Supergene alteration of the above minerals, resulting in oxides, carbonates, silicates and supergene sulphides.

Swiegers (1948, p. 119) offers a somewhat different interpretation of the paragenesis of the ore. He contends that the first phase was one of initial infilling of fractures by gangue-minerals, followed by precipitation of pyrite and arsenopyrite, both disseminated and massive. According to Swiegers (1948, p. 119), no mineralisation was present before the formation of the bedding-faults, and the alteration of the wall-rocks was caused by hydrothermal solutions which postdate these faults. This is, however, not in accordance with the facts: the presence of gangue and sulphides, as well as the products of wall-rock alteration, which were emplaced prior to the faulting, was established beyond doubt.

The interpretation by Barnard (1958, pp.35-36) of the paragenesis of the Trixie Lode, is in general agreement with the interpretation by the present author. Barnard recognised the presence of two generations of pyrite, and he ascribed the origin of both to hydrothermal action. It is considered however, that the first generation of pyrite and gangue was caused by a process of contact-metasomatism, followed by two later generations of hydrothermal origin.

(c) Precipitation of Gold and Silver

The precious metals are considered to have been precipitated during three different phases. The first phase is contemporaneous with the contact-metasomatic period of mineralisation. During this phase the only sulphides generated were pyrite and arsenopyrite. The second introduction of gold and silver was contemporaneous with the hydrothermal

/deposition...92.

deposition of pyrite and arsenopyrite, i.e. after the brecciation of the early ore-minerals had taken place. The third, and most important phase is contemporaneous with the precipitation of copper- and bismuth-minerals.

All three generations of gold are present in the interbedded reefs, while only the hydrothermal generations occur in the transgressive bodies. This conclusion is supported by the fact that the ratio of gold to silver in the interbedded reefs differ distinctly from that of the transgressive reefs.

C. ASBESTOS

1. Distribution

Occurrences of chrysotile-asbestos are found in several localities in the gold-field. It is particularly interesting that the more important of these are present in areas where interbedded gold-bearing reefs are developed. Plate 1 shows the workings of asbestos in relation to gold-bearing deposits. The bodies of asbestos are, however, small and generally not economically exploitable.

The largest occurrences are those on the farms Olifantsgeraamte, Graskop and Normadale. These deposits were economically exploited between 1951 and 1954. During the second world war prospecting operations were carried out on an extensive scale. Minor quantities were found in several places on the farm Ceylon, along the banks of the Lone Creek as well as below the Bridal Veil Falls. Prospecting disclosed poorly developed fibre on the banks of the Blyde River on the farm In De Diepte. In the mines at Pilgrim's Rest, asbestos of inferior quality was frequently found in cross-cuts and in inclined shafts. These were usually restricted to patches of slip-fibre. Small lenticular patches of fibre occur west of Vaalhoek, on the farms Frankfort, Sacramento Creek and Normadale. On the farm Kaspersnek, sporadic bands and lenses of asbestos were prospected on a small scale.

2. Mode of Occurrence

The development of fibre is restricted to the zones of contact-metamorphism adjacent to some of the sills. With the exception of the occurrence at Graskop, all the asbestos in the area is found in serpentinised dolomite adjacent to pyroxenite sills. They are, therefore, confined to the calcareous rocks, i.e. to the upper part of the Dolomite Series. The fibre in the Graskop Chrysotile Mine is present in a serpentinised zone located along the upper contact of a diabasic sill. The stratigraphical position of this sill is about

50 feet below the Blyde River Quartzite.

The length of the fibre is usually very short, i.e. less than ¼ inch. In a few places fibre of up to 1½ inches in length was observed. The asbestos occurs in lenses which are not continuous along strike. Most of the fibre occurs within 25 inches of the contact of the intrusive sill. Farther away only scattered "eyes" of fibre are present. In some localities, serpentinisation is present within the pyroxenitic sills, usually along the contacts of the sills. In these localities chrysotile may be present within the intrusive rock.

3. Relationship to Gold-deposits

It is considered significant that, although all the intrusive sills in the Dolomite Series are accompanied by serpentinisation of the dolomite, chrysotile has developed in certain areas only. It is furthermore an interesting fact that well-developed, although not necessarily payable, interbedded gold-bearing reefs are often found in the neighbourhood of fibre-occurrences. This probably suggests that a genetic relationship exists between these two very divergent types of mineralisation.

Whereas serpentinite is practically ubiquitous along the contacts of basic sills, chrysotile asbestos is only locally developed. There are three possible modes of growth of chrysotile fibres (Van Biljon, 1964, p. 662). Firstly, the fibres could have grown in open cavities, in which case growth must have taken place from both sides, and the chrysotile should therefore have a parting where the fibres meet. Secondly, the fibres could grow at the expense of the wall-rocks, i.e. replacing the serpentinite during its growth (Dresser, 1913). The third possibility is that the fibre grew in fractures, either by pushing the walls apart (Taber, 1916a, 1916b, 1917, 1924 and 1926), or during the gradual separation of the walls of the fractures under the influences of other forces (Keep, 1929).

Evidence from the present area suggests that the asbestos is the result of tension, i.e. the fibres of chrysotile grew during the gradual opening of the fractures (Van Biljon, 1964, p. 664). Tension-fractures such as these may develop along certain portions of shear-faults, in the tensional region of folds, or as a result of the cooling of igneous rocks (Newhouse, 1942, p. 10). Van Biljon (1964, p. 665) observed that the horizons of fibre at the Munnik Myburgh Mine near Kaapsehoop appeared to be related to folding.

Around 1958 a certain Mr. Charles Bekker did some prospecting at the Graskop Chrysotile Mine. During his operations he formulated a theory regarding the localisation of exploitable fibre. He ascribed the lenticular character of the fibre-bodies to local tensional and compressional forces

/after...96.

after the intrusion and cooling of the sills. He observed that lenticular bodies of chrysotile were associated with slight rolls in the contacts of sills.

The deposits of chrysotile in the Sabie-Pilgrim's Rest Gold-field are not necessarily associated with faults. The tension must therefore have been caused, either by folding or by the cooling of the sills. As fibre is not everywhere developed, its formation is considered to have been controlled by the folding. It is concluded that the same structural conditions which controlled the localisation of the gold-bearing deposits in the interbedded reefs, resulted also in the formation of the fibres of chrysotile.

V. ORE-CONTROL

A. GENERAL STATEMENT

In order to determine the relationships between the mineralisation and the structure, it is necessary to describe the geology and the structure of each deposit. For practical purposes the gold-bearing occurrences are divided into six groups. This classification is based on the association of the ore-deposits with regional structures which had apparently influenced the localisation of the ore. It must be pointed out, however, that this classification is not necessarily based on genetical considerations as some ore-bodies are related to more than one structure.

The first group consists of deposits that are closely associated with the Vaalhoek and Dientjie Dykes. The occurrences of the second group are found along or near the Nestor Dyke, or the fault into which this dyke was intruded. The third group comprises the ore-bodies in the central Pilgrim's Rest area. The ore-deposits of the Mount Anderson Area are classified with the fourth group. This group also includes the deposits in the Elandsdrift Area, i.e., all the occurrences that are found near the Hoppe's and Elandsdrift Dykes. The fifth group includes those occurrences which cannot be grouped with any of the major structural features. These deposits are associated with local structures of limited extent and they are usually of minor economic significance. The last group constitutes the vertical reefs along or near the edge of the escarpment.

The above classification is illustrated in Figure 14. If the main structural lines in this figure are extended, a rough parallelogram is obtained. It is conspicuous that all the important gold-deposits in the Transvaal System of the Eastern Transvaal are located approximately within this parallelogram, which indicates special structural conditions. The deposits that fall outside the parallelogram are relatively

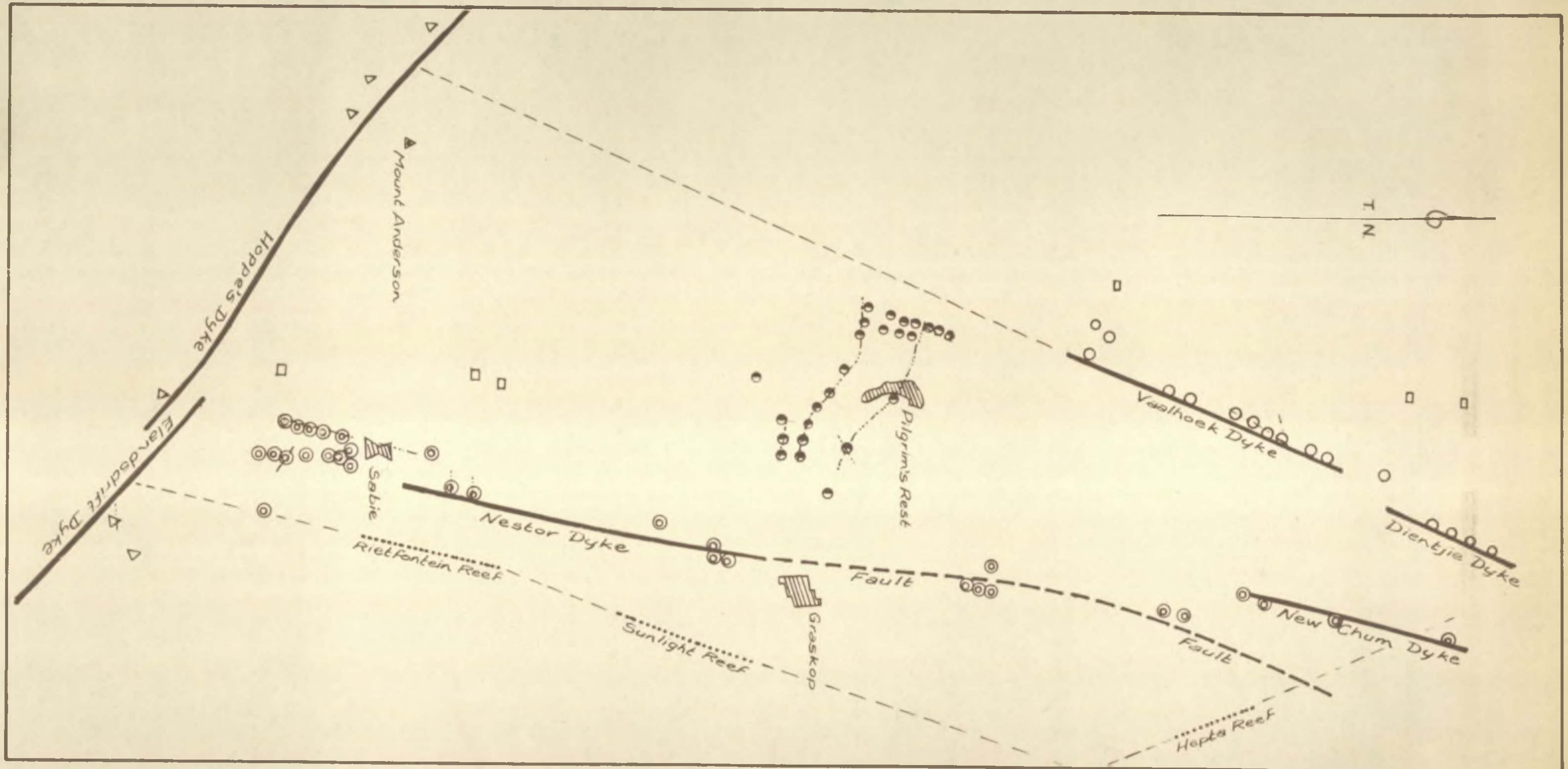


Figure 14:- The localisation of gold-deposits in the Sabie-Pilgrim's Rest Area.

Scale: 1:250,000

Legend of Deposits

○ Group I ◎ Group II ◐ Group III △ Group IV □ Group V •••• Group VI unimportant, except the Rietvallei Mine. This mine is situated far to the south of the area, but is located on the approximate southward extension of the Nestor and/or Rietfontein structural features.

Another interesting observation is that the centres of mineralisation are often localised at or near the intersections of the lines that describe the parallelogram. This applies also to sympathetic lines inside the parallelogram. The mineralisation at Bourke's Luck is found near the northwestern corner of the parallelogram. The deposits in the Mount Anderson Area occur near the southwestern corner. The Elandsdrift and Horseshoe Creek Mines are situated near the southeastern corner. The Hepta Reef represents the northeastern corner. At Pilgrim's Rest the largest concentration of gold-bearing mineralisation occurs near the intersection of the directions of Groups I and III. Farther east, along the direction of group III, transgressive bodies are found near the intersections of Groups II, III and VI. This phenomenon is considered to illustrate, on a regional scale, the close relationship between the structure and the localisation of the mineralisation.

/B. ORE-DEPOSITS..100.

B. ORE-DEPOSITS RELATED TO THE VAALHOEK AND DIENTJIE DYKES (GROUP I)

1. Deposits at Bourke's Luck

(a) Geological Environment

The ore-deposits of the Bourke's Luck Mine are closely related to the Dientjie Dyke. The dyke transects the Blyde River near the upper end of the Blyde Canyon, and the Treur River near its confluence with the former.

The stratigraphical sequence, as revealed by boreholes, is as follows: The surface of the granitic floor of deposition occurs at a depth of 440 feet below the top of the Black Reef Series. The granite is overlain by 400 feet of quartzite of the Wolkberg Formation. This quartzite contains occasional shaly and gritty layers, as well as, four diabasic sills, 10 feet, 15 feet, 9 feet and 70 feet in thickness, respectively. The quartzite of the Black Reef Series, overlying the Wolkberg Formation, has a thickness of 40 feet. To the north, in the canyon of the Blyde River, the upper quartzite of the Wolkberg System is underlain by a layer of shale, which overlies a lower quartzite-member of the Wolkberg Formation, as well as the Godwan Formation. Here the granite occurs at a depth of over 1200 feet below the

Black Reef Series. This indicates the existence of a hummock of granite in the floor of deposition. The sedimentary strata locally dip to the west at an angle of about six degrees.

The gold-bearing deposits are associated with the Dientjie Dyke and occur at an elevation which coincides with certain stratigraphical horizons in the Wolkberg Formation. These horizons are located at elevations which vary from 260-350 feet below the top of this formation. The emplacement of the ore at Bourke's Luck was controlled largely by faulting and fracturing; control due to folding could not be established.

(b) Dientjie Dyke

This dyke can be traced, on the surface, from near the southern boundary of Willemsoord 476. K.T. northwards to beyond the Blyde Canyon and the edge of the escarpment. To the south the dyke becomes obscured by alluvium. Farther south, east of the Blyde River, several dykes occur along the line of the Dientjie Dyke. These dykes are, however, slightly different in composition and texture, and they are apparently younger in age.

The Dientjie Dyke is described

/by ....102.

by Barnard (1958, p. 18) as an altered quartz-gabbro. It is approximately 120 feet thick and it dips 65-70 degrees to the east. The dyke is distinctly older than the earliest stages of the mineralisation. This is indicated by the fact that a fracture-plane in the dyke, i.e., the Trixie Lode, is occupied by ore-minerals which belong to the earliest stages of the mineralisation. The Dientjie Dyke is intersected by several younger dykes of diabase.

(c) Ore-bodies

Figure 15 is a schematic section across the Dientjie Dyke just north of its intersection with the Blyde River. The section illustrates the relationship of the ore-bodies to the dyke.

(i) Trixie Lode. This is the most important gold-bearing ore-body in the Bourke's Luck Mine. It is a lenticular body within the Dientjie Dyke and reaches a maximum thickness of 7 feet. It strikes between 020 and 025 degrees and dips 20-30 degrees east (Barnard, 1958, p. 17). The ore-body followed and exploited for nearly 19,000 feet along the dyke. At its northern end the lode fingers out into several inferior veins and stringers of quartz. To the south, mining operations were terminated due to water-difficulties and prohibitive operational costs.

/The Trixie...104.

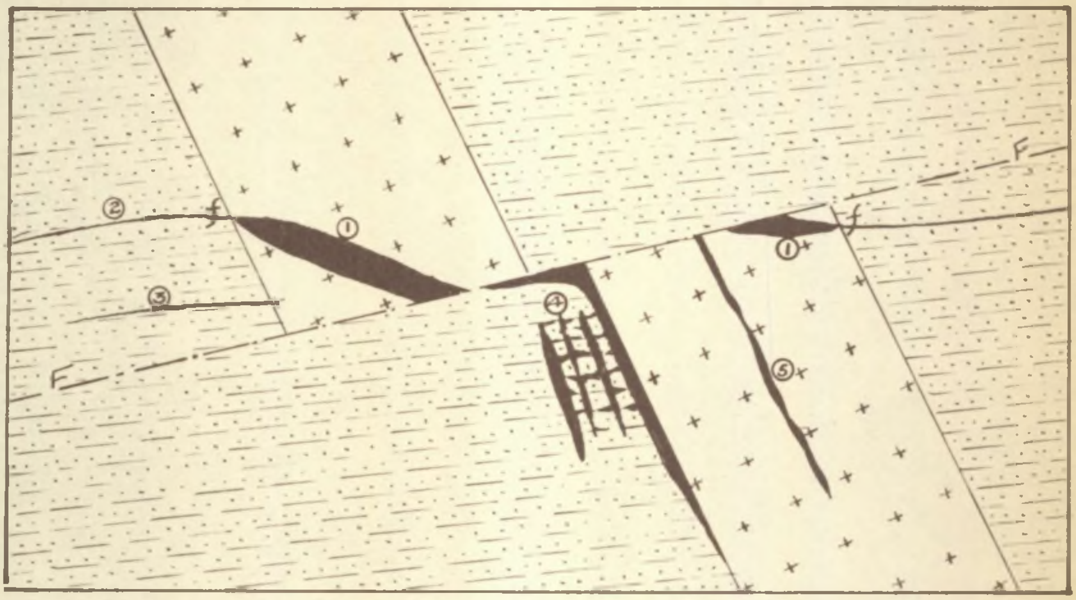


Figure 15:- Schematic section across the Dientjie Dyke.

(From old records)

Scale :- 1 : 1000

Reference

+ + +	Dientjie Dyke.
(stippled)	Sedimentary rocks of the Wolkberg Formation.
①	Trixie Lode.
②	Bourke's Luck Reef.
③	Fern Reef.
④	Contact Reef and Stockwork.
⑤	Dyke Reef.
f	Early fracture.
F	Low-angle gravity fault.

The Trixie Lode occupies a fracture-plane in the dyke which merges into an interbedded reef in the adjacent quartzite. The interbedded reef is represented by the Bourke's Luck Reef. It seems therefore, that the Trixie Lode merely represents the continuation of an interbedded reef which had undergone deflection along a pre-existing fracture. This conclusion is supported by the fact that the Trixie Lode resembles the interbedded reefs, rather than the transgressive reefs, in mineralogy.

The Dientjie Dyke, as well as the Trixie Lode is displaced horizontally by a low-angle gravity-fault. This fault divides the Trixie Lode into a so-called I-lode above, and an E-lode below the fault-plane. The fault has a dip of 13 degrees to the west, which is slightly steeper than the dip of the quartzite. As the strike of the fault is 030 degrees and that of the dyke 020 degrees, it follows automatically that the E-lode will grow at the expense of the I-lode as one goes northwards. Eventually the latter lode disappears completely. In the north, therefore, the E-lode represents the whole of the undisplaced Trixie Lode. Southwards, the opposite effect is obtained. The displacement along the fault increases from a few feet in the southern part of the mine, to more than 100 feet in the north.

/(ii) Bourke's Luck Reef..105.

(ii) Bourke's Luck Reef (Figure 15). This interbedded reef was exploited on a very limited scale. Although it contains some very rich patches of ore, it is generally not payable. In the River-section of the mine the reef is exposed on the banks of the Blyde River, on both sides of the Dientjie Dyke.

(iii) Fern Reef (Figure 15). This ore-body is described by Barnard (1958, p. 13) as a flat reef with an average thickness of 5 inches. It occurs at a stratigraphical position which is some 40-50 feet below the Bourke's Luck Reef, and some 25 feet above the fault.

(iv) Contact Reef and Stockwork (Figure 15). The Contact Reef occurs below the fault-plane , along the western contact of the dyke. It spreads out immediately below the fault and follows the bedding for a short distance. The Contact Reef is usually accompanied by a stockwork of lenticular leaders located to the west of it. In some places these leaders merge with the Contact Reef to form solid mineralised bodies of up to 15 feet in thickness. The Contact Reef was exploited for about 5000 feet along the dyke, in the northern part of the mine.

The Contact Reef and Stockwork are characteristically rick in copper-minerals such as chalcopyrite and covellite, as well as pyrite (Barnard, 1958, p. 15).

(v) Dyke Reef. This is a vertical reef in the foot-wall part of the displaced dyke. It is roughly parallel to the walls of the dyke, varies in thickness between 3 inches and 2 feet, and has a vertical extent of over 90 feet (Barnard, 1958, p. 15).

The mineralogy of the reef is typical of the transgressive ore-bodies in the area. Alteration of the wall-rock is practically absent.

(d) Discussion

(i) Ore-control

Barnard (1958, p. 10) contends that the structural conditions which were necessary for the intrusion of all the dykes are closely related to the conditions necessary for the localisation of the ore. This statement is considered to be rather vague. Although the general structure, as well as the mineralisation, is considered to be genetically related mainly to the intrusion of the Bushveld Complex, the localisation of the ore-bodies was controlled by specific conditions of structure. At Bourke's Luck this condition is the presence of an early dyke of considerable thickness.

It has already been shown that early lines of weakness may have resulted from compaction-folding over hummocks of granite. It is possible therefore, that the fracture along which the Dientjie Dyke intruded was caused by an irregularity in the floor of deposition. Although the rupture, and consequent mineralisation of the Dientjie Dyke were due to tectonic adjustments that accompanied the intrusion of the Bushveld Complex, the localisation of the ore-bodies was controlled by the presence of the dyke.

(ii) Sequence of Events

The sequence of the tectonic events in the mineralisation of the ore-bodies is visualised as follows:

(1) The formation of the fracture which constitutes the Trixie Lode, was the result of shearing stresses which caused rupture on encountering the transgressive, competent Dientjie Dyke (Barnard, 1958, pp. 44-45). The present author contends that these forces were provided by the intrusion of the sills, which is approximately contemporaneous with the early folding. This structure is not considered to be a fault-deflection associated with the bedding-thrusts as the deflection is downwards and not upwards as is normally the case.

/(2) This...108.

(2) This event was followed by the contact-metasomatic mineralisation of this structure as well as the Bourke's Luck and Fern Reefs.

(3) The shattering of this ore-body contemporaneous with the low-angle thrust-faults.

(4) The introduction of massive pyrite and gangue from hydrothermal solutions. It is considered that these solutions were fed through the Bourke's Luck Reef.

(5) The formation of a low-angle gravity-fault, resulting in the displacement of the Dientjie Dyke. During this event a fissure within the dyke, as well as fissures along the western side of it, were opened in the foot-wall of the fault. Mild shattering occurred within the Trixie Lode.

(6) The solutions which contained the late ore-minerals found their way into these fractures to form the Dyke and Contact Reefs and the Stockwork. The Trixie Lode and interbedded reefs were enriched by these fluids. The presence of ore-minerals along the gravity-fault suggests that the solutions flowed through this structure (Barnard, 1958, p. 44).

/2.Vaalhoek Mine...109.

2. Vaalhoek Mine

(a) Geological Environment

The ore-bodies of the Vaalhoek Mine are developed between 80 and 150 feet below the Blyde River Quartzite. This reliable marker occurs about 1000 feet above the base of the Dolomite Series. The mineralisation at Vaalhoek appears to be closely related to the Vaalhoek Dyke, as well as to very open folds which are present to the west of the dyke.

(b) Vaalhoek Dyke

The Vaalhoek Dyke is considered to be a hybrid rock (Zietsman, 1964, p. 51). It can be traced on the surface from the Nek Section of the Vaalhoek Mine (Plate III), southwards to the central part of Rotunda Creek 510 K.T. (Plate I).

The dyke varies between 100 and 180 feet in thickness. It has a strike of approximately 020 degrees and a dip of 60-70 degrees east. At the Nek Section it shows a downthrow of about 125 feet to the east. From here the displacement decreases rapidly southwards. At No. 1 Shaft it is only 25 feet (Barnard, 1958, p. 8), while south of No. 2 Shaft no displacement can be observed.

The intrusion of the Vaalhoek Dyke

/predates....110.

predates the first period of mineralisation. It is transected by several younger dykes of diabase, the most important of which are the so-called transverse dykes. Both these dykes show a downthrow of 10 feet to the north.

The Vaalhoek Dyke has certain characteristics in common with the Dientjie Dyke. Both dykes predate the formation of the interbedded reefs, and both are similar in thickness, strike and dip. Apart from these likenesses, both have also been displaced by low-angle gravity-faults, Figure 16 illustrates the displacement of the Vaalhoek Dyke by a low-angle fault.

In view of the similarities mentioned above, the Dientjie and Vaalhoek Dykes could possibly represent a single intrusion. Their present positions may have been the result of a horizontal displacement, but due to an extensive cover of alluvium the exact relationships could not be determined.

(c) Structural Features

The joints in the vicinity of the Nek Section show a very distinct pattern. Three directions are distinguished, namely 325, 020 and 055 degrees. The first is the

/most ...112.

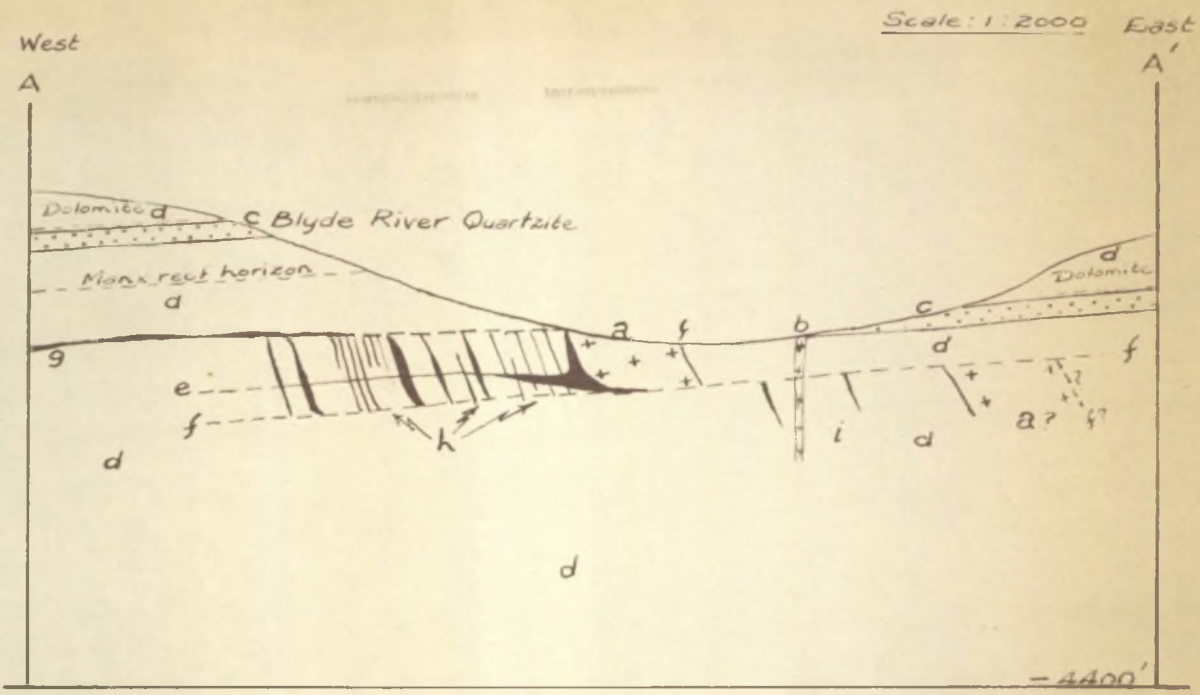


Figure 16(a): Section across the Vaalhoek Dyke in the Nek Section.

a Vaalhoek Dyke.
b Younger diabasic dyke
c Blyde River Quartzite.
d Dolomite and chert.
e Bedding-plane, sometimes mineralised.
f Fault.
g Vaalhoek Reef.
h Thelma Reefs.
i Leaders below low-angle fault.

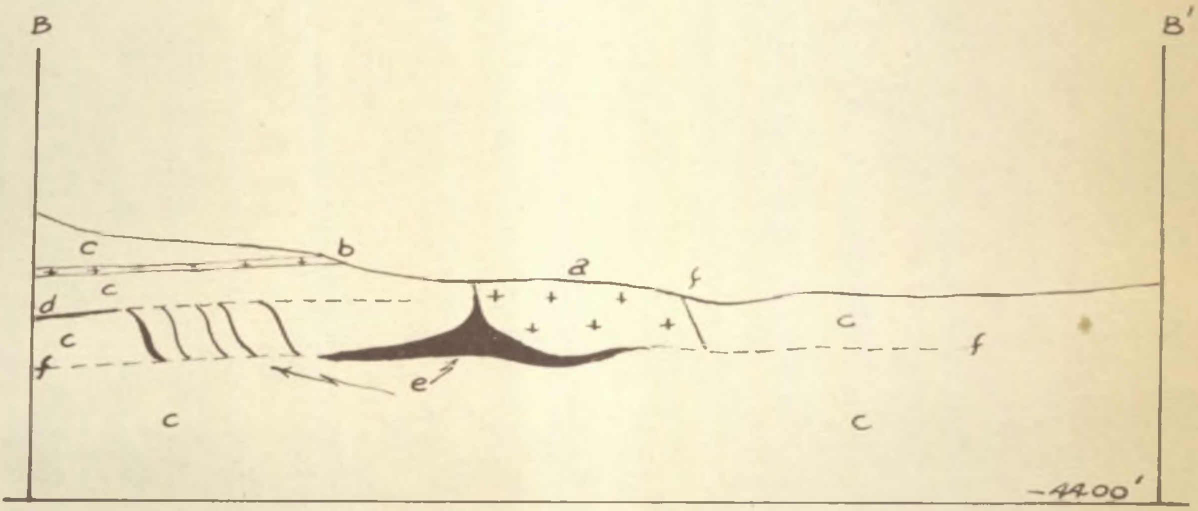


Figure 16(b): Section across the Vaalhoek Dyke in the River Section.

a Vaalhoek Dyke.
b Diabasic sill
c Dolomite and chert.
d Vaalhoek Reef.
e Thelma Reefs.
f Low-angle fault

(From old records)

most prominent direction, the second is parallel to the Vaalhoek Dyke, and the third is approximately parallel to the transverse dykes. Many of the leaders of the Thelma Reefs have a strike that varies between 320 and 330 degrees, i.e. parallel to the most prominent direction of jointing.

The reef-contours of the Vaalhoek Reef (Plate III), reveal the presence of a few very open folds. A structural terrace, the anticlinal bend of which has an axis that trends 030 degrees, is present to the west of the Vaalhoek Dyke, in the southern part of the mine. Farther north, between the two transverse dykes, an anticline and syncline have axes that trend approximately 055 degrees.

(d) Ore-bodies

(i) Vaalhoek Reef. This ore-sheet was previously correlated with the Glynn's Reef at Sabie. Although no justification exists for this correlation (Zietsman, 1964, p. 66), the reef is still generally referred to as Glynn's Reef. The Vaalhoek Reef was exploited north of the Blyde River in the Hill Section, and south of the river to beyond No.2 Shaft. It was worked on the western side of the Vaalhoek Dyke only. Another interbedded reef is present in places, some 50 feet above the Vaalhoek Reef. This reef, which is probably the Manx Reef, was never exploited.

According to Wybergh (1925, p. 92), the Vaalhoek Reef in the River Section ranges from a mere stringer to 13 feet in thickness. South of No. 1 Shaft (Plate III), the reef has an average thickness of about 10 inches. The reef consists of two distinctly different layers (Wybergh, 1925, p. 93). The bottom layer, which varies between half an inch and 12 inches in thickness resembles the normal interbedded reefs of the district. The upper layer shows abnormal variations in thickness and a higher degree of mineralisation, especially by ore-minerals of copper. This upper layer is absent to the south of No. 1 Shaft. The Vaalhoek Reef in this area shows the characteristics of a normal interbedded reef.

From a structural point of view, the most important single factor in the formation of the Vaalhoek Reef, is the folding west of the Vaalhoek Dyke. This is shown by the fact that economically exploitable mineralisation in the No. 2 Shaft Area is confined to the axial zone of an anticlinal fold which trends 030 degrees (Plate III). The Vaalhoek Dyke apparently had no influence on the localisation of the ore in the area.

It is significant that the Vaalhoek Reef is nowhere payable in the vicinity of the Vaalhoek Dyke, although the Thelma Reefs contain exploitable gold in the proximity of the dyke. This phenomenon may be due to leaching of the Vaalhoek Reef.

(ii) Thelma Reefs. These are transgressive ore-bodies which sometimes have off-shoots along the bedding (Figure 16). They occur between the Vaalhoek Reef and the low-angle fault, and are considered to be younger than the fault. This is shown by the development of reef along the fault-plane (Figure 16(b)). The leader-reefs are confined mainly to the hanging-wall of the fault, and they are genetically related to the fault, although their localisation is due to the presence of the dyke.

The mineralogy of the Thelma Reefs is typical of the second period of mineralisation. Ore-minerals of copper are well-represented. The mineralisation caused very little alteration of the wall-rocks.

The Thelma Reefs are mineralogically and structurally very similar to the Contact Reef and Stockwork at Bourke's Luck. Both are genetically related to displacements of early dykes by low-angle faults.

/(e) Discussion...115.

(e) Discussion

An interesting feature is that the high-grade mineralisation is confined mainly to the area between No.1 Shaft and the Nek Section. Interbedded ore-bodies of unusual thickness are developed immediately above the normal Vaalhoek Reef in this area. Numerous leader-reefs, some of which are of considerable thickness, as well as several caves, are present also. Leaders are scarce and economically unimportant north of the Nek Section and south of No.1 Shaft.

All these features are considered to be due to special structural conditions which had existed in this area. These conditions were caused by the culmination of several folds against the Vaalhoek Dyke (Plate III). The combined influence of the folding and faulting, as well as the presence of a pre-existing dyke-structure, resulted in large-scale deposition of ore.

3. Willemsoord West Mine

The Willemsoord West Mine is situated about one and a half miles north of the Vaalhoek Mine, to the west of the Blyde River. The main workings are on the Manx Reef which is developed about 50 feet below the Blyde River Quartzite. The orebody is entirely within the oxidised zone, and due to extensive weathering, large-

/scale ...116.

scale caving of the mine-workings has taken place. The structure of this deposit can therefore not be determined. The underground workings apparently terminated against a dyke with a strike of 030 degrees.

To the west, and immediately above the workings on the Manx Reef, the Blyde Reef was exploited to a limited extent. This reef is developed along the lower contact of the Blyde River Quartzite (Plate II). The reef is very thin and contain erratic values of gold.

A vertical leader-reef, known as the Shirly Reef, is present about half a mile to the north of the workings on the Blyde Reef. This reef has a strike which is approximately perpendicular to the Vaalhoek Dyke. It has a vertical extent of approximately 80-100 feet, i.e., between the Vaalhoek Reef and the Blyde River Quartzite. The Shirly Reef shows its best development in the proximity of the horizon of the Manx Reef.

A direct relationship between the above ore-bodies and the Vaalhoek Dyke could not be established. The outcrop of the Manx Reef is about 1000 feet west of the dyke.

4. <u>The Frankfort Mine</u>

(a) <u>Geological Environment</u>

The Frankfort Mine, which is known

also as the New Lisbon-Berlyn Mine, is situated some 7 miles north of Pilgrim's Rest. Only interbedded ore-bodies, which are more or less confined to a zone immediately above and below the base of the Pretoria Series, were exploited in this area. The Frankfort Reef occurs immediately below a pyroxenitic sill in the Dolomite Series, and is located 150 feet below the base of the Pretoria Series (Plate II). The Bevett's Reef is situated along the upper contact of the Bevett's Conglomerate. The Shale Reef is developed in the shale of the Pretoria Series, about 20 feet above the Bevett's Reef.

(b) Structural Features. The pyroxenitic sill is considered to have a localising influence on the ore-bodies. This is suggested by the fact that the sill has a thickness of over 100 feet in the immediate vicinity of the ore-bodies but thins to less than 30 feet away from it.

Several dykes of diabase transect the workings on the Frankfort Reef. One of these dykes is pre-reef in age (Von Dessauer, 1912, p. 150). This is indicated by the fact that the interbedded reef passes through the dyke. The dyke is, however, not displaced along the plane of the reef,

/which ...118.

which indicates that little or no movement accompanied the emplacement of the reef. This is in contrast to most other interbedded reefs.

It is interesting to note that the fold-axis in the southern part of the Vaalhoek Mine, if extended, will pass through the Frankfort Mine. The pay-shoots in this mine are, furthermore, parallel to this direction. Due to a lack of reliable underground-data, however, the existence of folding could not be established.

(c) Ore-bodies

(i) Frankfort Reef. This reef was correlated previously with the Theta Reef in the Pilgrim's Rest Area. Plate II illustrates that the reef at Frankfort is developed at a higher stratigraphical elevation. It crops out along the hill-slopes on either sides of a small tributary of the Rotunda Creek.

The reef was extensively exploited in the oxidised zone. It is similar in thickness to most interbedded reefs. The sulphidic ore of the reef is, however, highly refractory, due to an abnormally high contend of arsenic. The sugary variety of pyrite and arsenopyrite are well-represented, while the late sulphides

/are ...119.

are relatively scarce. Tetrahedrite, and occasionally chalcopyrite, are infrequently present.

(ii) Bevett's Reef. This interbedded body occurs above and slightly to the west of the workings on the Frankfort Reef. Owing to an average thickness of about 20 inches, it was profitably exploited in the oxidised zone. In the sulphide-zone, however, the ore is of an even more refractory nature than that of the Frankfort Reef. Arsenopyrite, together with early pyrite, constitutes the bulk of the ore.

(iii) Shale Reef. The Shale Reef is well-developed in several localities on Frankfort. The gold-tenor of the reef is, however, low. Only a small patch of this ore-body was found to be economically exploitable. This occurrence is situated a few miles to the north of the Frankfort Mine.

(d) Discussion

The relatively high content of arsenic, which occurs in the form of sugary arsenopyrite, is considered to be significant. In the paragenesis of the ore this type of arsenopyrite was introduced prior to the bedding-thrusts. The later sulphides, as well as most of the gold, entered the

/ore-bodies...120.

ore-bodies after this event. The undisplaced pre-reef dyke, which is present in the workings of the Frankfort Reef, indicates the absence of movement along the bedding. This probably explains the scarcity of the later sulphides, which in other ore-bodies are . associated with intense brecciation due to thrusting. The first period of mineralisation in the Frankfort Mine must have been extensive. This is indicated by the fact that the ore-bodies are composed mainly of sugary pyrite and arsenopyrite. The proximity of a thick pyroxenitic sill provided favourable conditions for the contact-metasomatic emplacement of ore in the Frankfort Reef, as well as in the Bevett's and Shale Reefs.

5. Other Occurrences Along the Vaalhoek Dyke

Apart from the deposits described above, mineralisation occurs at several other localities along the western contact of the Vaalhoek Dyke. Most of these are transgressive in their nature, and they are all developed at or near the stratigraphical horizons of interbedded reefs.

(a) Leaders Near the Horizon of the Portuguese Reef

A zone of leaders occur near the northern boundary of Frankfort 509 K.T. This zone, which is approximately 50 feet wide, is situated near the western contact of the

Vaalhoek Dyke. The leader-reefs are parallel to one another, but have strikes slightly oblique to that of the dyke. They extend to a height of 30 feet above the horizon of the Portuguese Reef. The stratigraphical position of the latter is shown in Plate II. Although they are well-mineralised, the leaders are thin and are therefore of little economic importance.

(b) Mineralisation Below the Frankfort Reef

In a number of places on Frankfort 509 K.T. eluvial deposits of gold-bearing ore are present along the western side of the Vaalhoek Dyke. These eluvial deposits are always found just below the horizon of the Frankfort Reef. This reef is apparently not developed in these localities, as no reef in situ could be found.

A mineral occurrence near the northern boundary of Rotunda Creek 510 K.T., may, however, throw some light on the origin of these deposits. The Frankfort Reef is developed locally along the western side of the Vaalhoek Dyke. The dolomite is intensely jointed along the contact of the dyke. The intersections of the joint-and bedding-planes have been mineralised by quartz and pyrite. The pyrite is extensively altered to limonite, and pseudomorphs up to 6 inches in diameter are present.

/It...122.

It is considered that a deposit such as this will yield an eluvial deposit on weathering.

B. ORE-DEPOSITS RELATED TO THE NESTOR STRUCTURE (GROUP II)

This group comprises all those deposits which are apparently related to the Nestor Dyke, the fault west of the Lisbon Falls, and the New Chum Dyke. South of the Nestor Mine, mainly interbedded reefs are developed, wheras transgressive ore-bodies are the dominant structures north of the mine. With the exception of the Ledouphine Mine, all the mineral-occurrences are located within 200 feet of the base of the Dolomite Series.

1. Glynn's Reef South of Sabie (Plate V)

(a) Stratigraphical Relationship

The extent of the mineralised area south of Sabie is only slightly smaller than that of the Pilgrim's Rest Area. All the mineralisation here is confined to the Glynn's Reef. The stratigraphical position of this interbedded reef ranges from 145 to over 200 feet above the base of the Dolomite Series (Visser and Verwoerd, 1960, p. 67). Two sills of diabase are present near this horizon, one above, and the other below the reef. In some localities the two sills may be 150 feet apart, with Glynn's Reef

/occupying...123.

occupying any position between them (Visser and Verwoerd, 1960, p. 68). A thin layer of quartzite is developed 50-70 feet above the reef. This quartzite was formerly assumed to be the Blyde River Quartzite (Hall, 1910, p. 115). The quartzite-marker in the Sabie Area is, however, considered to be the equivalent of the Diggers' Sandstone of the northern area (Zietsman, 1964, p. 66). Thin layers of quartzite and black shale are present in the dolomite, above and below the reef. This suggests that the Glynn's Reef is located in the Transition Zone between the Black Reef and the Dolomite Series.

(b) Structural Features

Owing to the fact that the mines south of Sabie were abandoned and therefore inaccessible, no data could be collected underground. Some information could, however, be compiled from underground-plans and records.

A close relationship between the structure and the mineralisation is shown in Plate V. The two main ore-shoots are roughly parallel to local faults and dykes. This direction is parallel also to the main structural trend of the area. Minor pay-streaks within these ore-shoots, are reported by Visser and Verwoerd (1960, p. 68).

Linear features which predate the reefs, are considered to be present. Two dykes, which are displaced by the interbedded reef, occur (Visser and Verwoerd, 1960, p. 69). One is found in the T.G.M.E. Malieveld Section, and the other near the South Shaft in the Glynn's Lydenburg Mine. The former dyke is considered to be the continuation of the Nestor Dyke.

A study of the underground-plans provided the contour-lines shown in Plate V. The contour-lines suggest two directions of gentle folding, i.e. an early east-west direction and a later northeasterly direction. Several small domes are present, and are considered to be the result of this superimposed folding.

(c) Character and Mineralogy of the Ore-body

The Glynn's Reef usually consists of two layers, separated by up to 4 feet of chert and dolomite. The upper layer is from 6 inches to more than 3 feet in thickness. The lower layer, which may be absent in places, does not exceed 6 inches in thickness (Wybergh, 1925, p. 29). The dolomite that separates the two reef-layers, may contain a network of quartz-stringers in places. These may locally develop into a solid mineralised mass (Wybergh, 1925, p. 31). Above the upper layer of the reef, thin vertical veins of barren calcite extend for a few feet into the hanging.

Wybergh's (1925, p. 31) description of the Glynn's Reef indicates that it is typical of the normal interbedded type of ore-body. Early gangue-quartz shows a laminated appearance due to thin layers of pyrite which probably belongs to the first period of mineralisation. Later quartz, with associated massive pyrite, is more frequently found where the reef is wider. According to old mine-records the copper- and bismuth-minerals are well-represented also.

2. <u>Rietvallei Mine</u>

The Rietvallei Mine is situated about 20 miles south of the investigated area. It occurs along the same line as the deposits of Group II. The Rietvallei ore-body is an inter-bedded reef which is developed some 50 feet above the Black Reef Series. In one locality in the mine, the reef lies directly on a sill of diabase. Stringers of gold-bearing quartz branch off into the sill in this locality (Visser and Verwoerd, 1960, p. 66). A prominent ore-shoot, the axis of which coincides with the axis of a shallow, but distinct, anticlinal structure in the reef, is present also (Visser and Verwoerd, 1960, p. 67). The direction of this axis is approximately north, i.e. parallel to the Nestor-structure.

/3. Sandstone...126.

3. Sandstone Reef (Plate IV)

(a) Stratigraphical Relationship

Although the Sandstone Reef is present in many localities in the district, it is economically exploitable in the area north of the Sabie River only. It was mined on an extensive scale in the Nestor Mine, as well as in the Rex Mine (Plate IV). In the Nestor Mine the reef is developed 20 feet below the top of the Black Reef Series. In the Rex Mine its position is somewhat nearer to the top of the quartzite. A layer of laminated shale, 2-6 inches in thickness, is present about 2 feet below the reef. This layer is usually overlain by a thin layer of quartz and pyrite.

(b) Structural features

The mineralisation of the Sandstone Reef is confined to the western side of the Nestor Dyke. This mineralisation apparently terminates and spreads out against this structure, as indicated by a narrow zone of mineralisation located along the western contact of the dyke (Plate IV). The information obtained from a short tunnel driven into the dyke, suggests that the dyke is displaced along the Sandstone Reef. The North Section of the mine terminates against a normal fault which parallels the Nestor Dyke (Visser and Verwoerd, 1960, p. 64). This fault also intersects the South Section of the mine, but in this area high gold-values are present on both sides of the fault-plane.

Underground-examination of the Nestor Mine reveals that the Sandstone Reef is payable only along two east-trending open anticlines. The northern anticline constitutes the North Section of the Nestor Mine, and the southern anticline, the South Section; the ore-body is apparently unpayable in the syncline between these two structures.

At the Rex Mine the mineralisation is likewise closely related to folding, in this instance a dome in the quartzite of the Black Reef Series (Plate IV).

(c) Character and Mineralogy of the Ore-bodies

The Sandstone Reef normally varies between 2 and 30 inches in thickness, although figures of 40 inches and over were recorded in the Rex Mine. The Sandstone Reef consists mainly of quartz and pyrite (Visser and Verwoerd, 1960, p. 63). Copper-minerals are only present in the thicker parts of the reef. The refractory nature of the ore is probably due to the presence of either pyrrhotite or marcasite.

Two blows, which are intimately associated with the interbedded reef, are

/present...

present. The Pyrite Blow is a tabular body, 3000 feet in length, 25 feet in width, and about 12 feet in height. It is developed above the interbedded reef only. The blow consists of large massas of sugary pyrite in places. In other localities it is composed of quartzite which is intensely inpregnated with disseminated pyrite.

The Copper Blow occurs to the south of the Nestor Mine, and on the western side of the Nestor Dyke. It strikes roughly parallel to the Pyrite Blow. The ore is composed of massive quartz, containing late suphides, and gold (Visser and Verwoerd, 1960, p. 86). An underground examination at the northern end of this ore-body shows that it consists of a zone of steeply inclined leaders. These leaders are, like the Pyrite Blow, only developed above the Sandstone Reef. The leaders along the edges of the ore-body measure only a few feet in height, but become progressively higher towards the centre of the ore-body. The central part of the blow consists of a massive mineralised body of quartz which is approximately 20 feet in height. This massive part of the blow is probably a coalescence of leaders.

In view of the divergent nature of the mineralogy of the Pyrite and Copper

Blows, they are considered to be different in origin. The Pyrite Blow is probably related to the first period of mineralisation, while the Copper Blow is related to the second, or hydrothermal period of mineralisation.

4. Area Around Mac-Mac

The Glynn's Reef was exploited in a relatively small area, about one mile northwest of the Mac-Mac Falls. The workings terminate against the eastern side of the Mac-Mac Dyke (Plate I). According to a description by Frost (1912), the reef was well-developed and well-mineralised. Immediately south of the workings, the Mac-Mac Dyke is transected by a transverse dyke (Plate I). This dyke contains an abnormally high percentage of pyrite in the area between the Mac-Mac Dyke and the Nestor Dyke. Very little pyrite is present outside this zone.

Transgressive Reefs are present along the western contact of the Nestor Dyke.

In the area west and southwest of the falls, evidence of extensive eluvial workings is found. These workingsare situated between the Nestor and Mac-Mac Dykes. They occur at a horizon which is stratigraphically just below that of the Glynn's Reef. This reef, however, does not exist here, the outcrop being farther to the west. The presence of the eluvial workings therefore

/suggests...130.

suggests that the Glynn's Reef was present and mineralised between the two dykes, but that subsequent erosion eliminated the ore-body, resulting in the formation of a residual deposit.

5. Malidyke Mine

(a) General Character of the Ore-bodies

The ore-bodies of this mine are closely related to the Mali Dyke, and are situated southwest of Graskop, between the Diggers' Creek and the Mac-Mac River. The Mali Dyke, which is pre-reef in age, is approximately parallel to the Nestor Dyke.

Old mine-records reveal that the ore-bodies consisted of lenticular veins along both contacts of the dyke. Ladder-veins, and sometimes a stockwork of leaders, were developed within the dyke itself. Observations in an accessible part of the workings corroborate this description.

No records of the mineralogy of the ore are available, but small remnants of the ore-bodies in certain parts of the mine consist of massive vein-quartz and limonite.

(b) Stratigraphical Relationship

During the exploitation of the ore-bodies, extensive mining was carried out by means of opencasts. An interesting feature, however, is that the location of these workings suggests that the ore-bodies were payable along a certain stratigraphical zone only. This zone is in the proximity of the horizon of the Glynn's Reef, and is probably located immediately above it. This fact is borne out also by the elevations of the underground workings.

The Glynn's Reef forms an outcrop on the eastern bank of the Mac-Mac River, east of the northern end of the Malidyke Mine. This reef is, however, mot payable in this locality, although it contains much quartz and limonite.

6. Area Around the Lisbon Falls

The area around the Lisbon Falls is very interesting, especially from a structural point of view. From an economical point of view, however, the area is relatively unimportant. The interbedded reefs are represented by the Gould's Reef, the Betty Reef, the Bott's Reef and the Pigeon Reef; the transgressive reefs by the Astra Reef and some leader-reefs to the northwest of the falls.

(a) Stratigraphical Relationships

The stratigraphical positions of the ore-bodies are shown in Figure 17. The Pigeon Reef occurs near the base of the Wolkberg Formation;

/the...133.

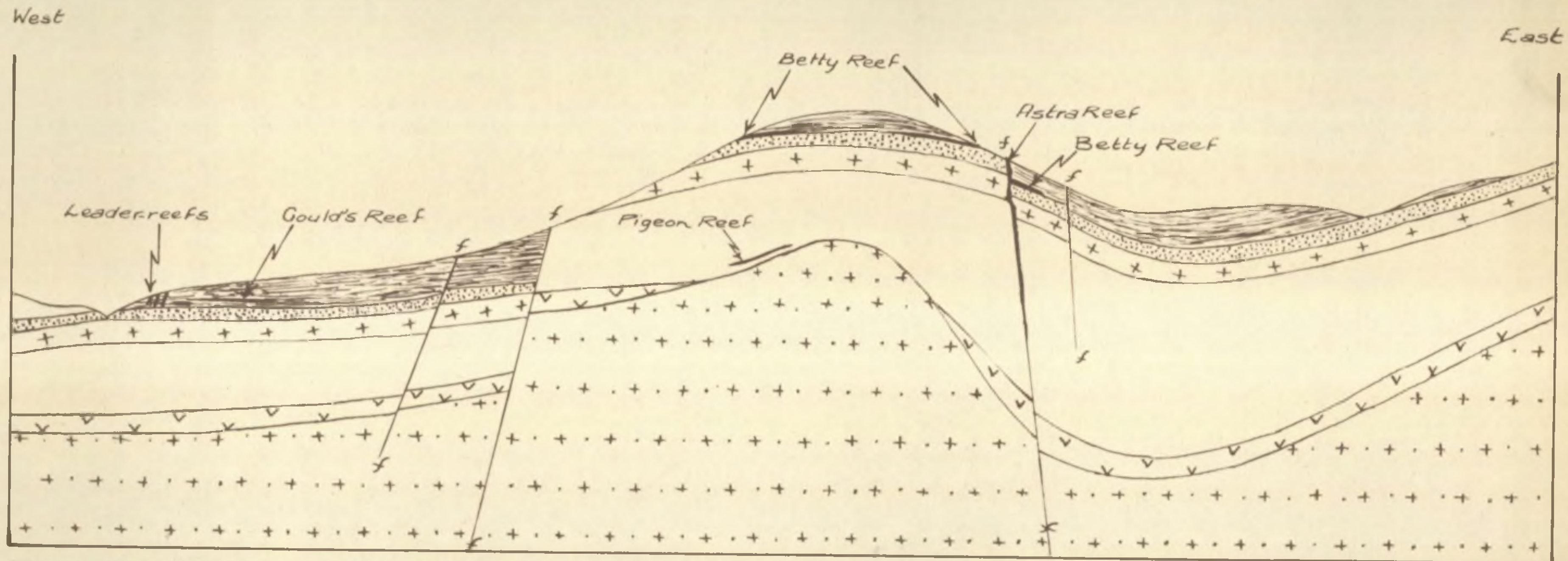


Figure 17: Generalised schematic section at the Lisbon Falls

Approximate Scale: 1 inch = 1000 feet.

Reference

Transition Zone.

Black Reef Series

Diabasic Sill

Wolkberg Formation

Godwan Formation

Granite (Floor of deposition)

the Betty Reef is developed along the upper contact of the Black Reef Series; the Gould's Reef is located in the Transition Zone of the Dolomite Series, about 12 feet above the Betty Reef; the Bott's Reef occurs in the Transition Zone, about 30 feet above the base of the Dolomite Series.

The Astra Reef is a vertical reef which is developed from the top of the Black Reef Series, downwards for a vertical distance of over 200 feet. The leader-reefs to the northwest of the falls are located in the Transition Zone of the Dolomite Series. They do not exceed 30 feet in height.

(b) Structural Features

The most pronounced structural feature is a granitic ridge, which is Pre-Godwan in age. The axial trace of this feature trends approximately 010 degrees. Due to compaction the overlying strata were folded around this structure. During the process of compaction displacement of the strata occurred on both sides of the ridge. These faults strike approximately parallel to the axial trace of the ridge, and some of them have been subjected to recurrence of movement.

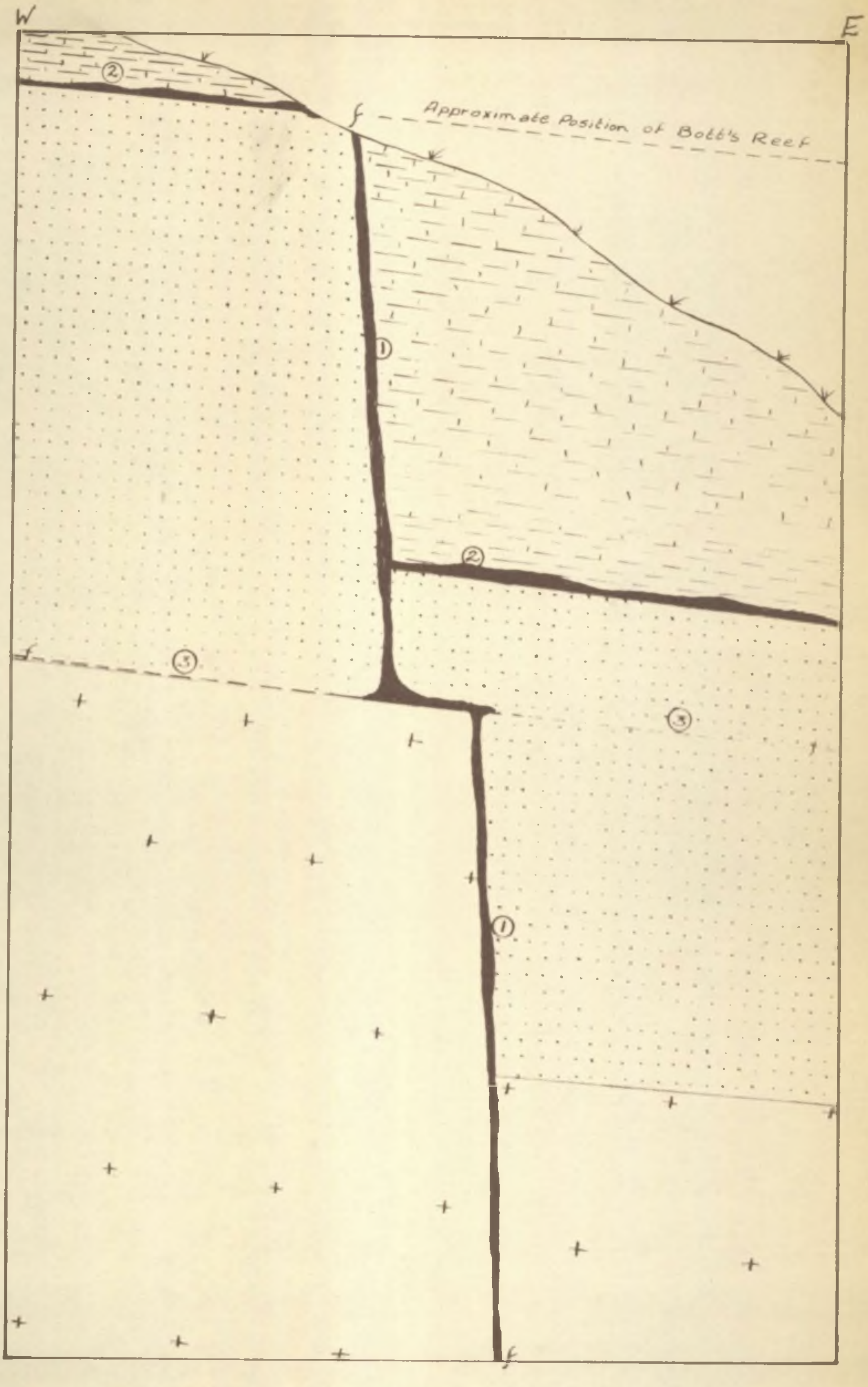


Figure 18 :- Schematic section across the Astra Reef.

Approximate Scale : 1 inch = 20 feet.

Reference

[+ +]	Sill of diabase	①	Astra Reef
[dashes]	Transition Zone of the Dolomite Series.	②	Betty Reef
[dots]	Quartzite of Black Reef Series	③	Interbedded fault.

A fault east of the Lisbon Falls is occupied by the Astra Reef. An underground examination in the Astra Mine revealed that this fault was displaced horizontally along a bedding-fault, prior to the mineralisation, as is illustrated in Figure 18. The transgressive fault which is a high-angle normal fault, shows a downthrow of over 50 feet to the east. This fault predates the mineralisation of the interbedded reefs. This is indicated by the fact that an interbedded reef in the Little Gem Mine, south of the falls, continues, without displacement, through the fault-plane. That the transgressive reef, which occupies the fault-plane, is displaced by the interbedded reef is indicated by the fact that the former apparently terminates against the lower contact of the latter (Wybergh, 1925, p. 99). The interbedded reef occupies the upper contact of the Black Reef Series, west of the fault, but it is developed some 30 feet above the contact, on the eastern side of the fault.

The interbedded fault in the Astra Mine has a dip of 6 degrees east. The Astra Reef, which occupies a high-angle fault, shows a displacement of 10 feet towards the west. The interbedded fault, therefore, resembles a low-angle thrust.

The low-angle thrusts in the rest of the area, however, show a relative displacement towards the east. The inter-bedded fault in the Astra Mine is therefore not a true low-angle thrust, but only resembles one due to the local easterly dip of the strata (Figure 17). Farther east and west along the same plane of movement, the displacement will be that of a low-angle gravity-fault.

The other linear structures in the area around the Lisbon Falls, trend mainly in two directions, namely 010 and 060 degrees. They are represented by faults, dykes, and leader-reefs (Plate I).

(c) Ore-bodies

(i) Pigeon Reef. This reef was exploited on a very limited scale near the bottom of the Lisbon Falls. An examination revealed that the reef is a true inter-bedded ore-body which occurs near the contact between the Wolkberg Formation and the underlying granite. This conclusion contradicts Wybergh's (1925, p. 99) statement that the Pigeon Reef is a transgressive reef. The ore-body dips about 30 degrees to the west, but the dip is parallel to the bedding which is disturbed locally due to compaction (Figure 17). The Pigeon Reef has an average thickness of 10 inches. The bulk of the ore-body is composed of early siderite which is sheared and filled with later quartz and calcite, as well as chalcopyrite.

(ii) Betty Reef. This reef is developed over a large area at Lisbon Falls, but it was economically exploitable only in a narrow zone along the eastern contact of the Astra Reef. Although it is well-developed along the western contact of the vertical reef, it shows inferior values. The Betty Reef on this side of the Astra Reef occurs at a higher elevation (Figure 18).

The Betty Reef is normally composed of quartz and limonite, but also contains copper-minerals to the east of the Astra Reef.

(iii) Gould's Reef. This interbedded reef is developed only to the west of the Astra Reef. It was exploited in a few small areas to the south of the falls, but was worked on a larger scale in the Gould's Mine, some 3000 feet to the west of the falls. The average thickness of the ore-body is about 15 inches. The ore consists of quartz and pyrite.

(iv) Bott's Reef. This Reef, which was referred to also as the Little Gem Reef

/Wybergh, 1925, p.99)...

(Wybergh, 1925, p. 99), was mined on a relatively small scale in the Little Gem Mine where it reached a thickness of 4 feet (Wybergh, 1925, p. 96). It is developed about 30 feet above the base of the Dolomite Series, to the west of the Astra Fault and to the south of the Waterval River (Plate I). The ore consists of quartz and limonite. This reef can be traced westwards through the Astra Reef, where it then occupies the stratigraphical position of the Betty Reef.

(v) Astra Reef. The Astra Reef occupies a fault-plane, as shown in Figure 18. It is exposed along strike over a distance of nearly one mile. The ore-body consists of milky quartz with massive pyrite, chalcopyrite and bismuthinite. Little or no alteration of the wall-rocks can be observed. Although the fault-plane is displaced along a bedding-fault, the ore is undisturbed by this movement. This suggests that the ore was deposited after the interbedded faulting occurred. The ore-body has an average thickness of 20 inches but reaches a thickness of over 3 feet in places.

A distinct association exists between the interbedded fault and the gold-content of the transgressive ore-body. A study

/of the...139.

of the assay-plan of the mine shows that the economical gold-values were encountered only from about 10 feet below the inter-bedded fault to about 40 feet above it. Within these limits the reef maintained an average gold-content of about 13 penny-weights per ton. Above this zone, the values diminish gradually. The reef is exposed in vertical winzes to a depth of over 100 feet below the payable zone. It maintains a reasonable thickness but shows a sudden decrease in its gold-content with depth.

This relationship probably suggests that the mineralising solutions entered the transgressive fault-plane through the bedding-fault. The fact that the Betty Reef is payable only to the east of the Astra Reef, suggests that it was enriched by the same solutions which mineralised the vertical reef. The Betty Reef which is developed to the west of the Astra Reef, occupies a relatively higher elevation and was therefore far away from the source of the mineralisation. This explains the unpayability of this part of the reef. This phenomenon is also further proof that the mineralisation postdates the displacement caused by the high-angle fault.

(vi) Leader-reefs. A series of leader-reefs are present to the northwest of the Lisbon

Falls (Plate I). These reefs are located near the base of the Dolomite Series. They are approximately 30 feet in height, 30 inches in thickness and can be followed along strike for distances of more than 3000 feet. They strike approximately 055 degrees, and dip 60 degrees to the southeast. One of these ore-bodies extend to the west of the Waterval River, where it is reported to have been very rich in gold. This leader-reef, is known as the Wet Leader. The highest gold-values were usually encountered in the lower parts of the reef, i.e. near the horizons of the Betty and Gould's Reefs.

7. Eendrag Mine

The Eendrag Mine is situated in the central part of the farm London 496 K.T. The workings are very limited in extent, and are located 1000-4000 feet to the west of a group of faults which represents the northward-continuation of the Nestor Fault (Plate I). Small tabular ore-bodies, associated with bedding-faults, were exploited in three small areas. The stratigraphical position of these ore-bodies is 100-150 feet above the base of the Dolomite Series. This horizon corresponds roughly with that of the Willemsoord Reef (Plate II).

The bedding-faults, which are also slightly mineralised, are about 2 feet apart. Several small, parallel, tabular ore-bodies are present between the faults. The ore-bodies resemble leader-reefs that are greater in width than in height, measuring from 2-6 feet in width. The ore consists of quartz and calcite with oxide-minerals of iron and copper.

8. Hoyer's and Walther's Workings (Plate I)

Tabular ore-bodies, similar to those described above, are present approximately 10,000 feet farther north (Plate I). These workings are situated near the southeastern boundary of the farm Ledouphine 469 K.T. The ore-bodies are located between two slighly mineralised bedding-faults, about 50 feet above the Black Reef Series. The bedding-faults are developed above and below the Digger's Sandstone, a quartzitic marker of about 2 feet in thickness. Where the tabular bodies are developed, the quartzite appears to be replaced by ore- and gangue-minerals. The ore-bodies have sharply defined contacts, and in cross-section, they resemble tabular blows. The ore-bodies strike 050 degrees and dip 60 degrees to the southeast.

A leader-reef, which is known as Tucker's Leader, is present some 800 feet to the south-east of Hoyer's Workings. It strikes parallel

/to the...142.

to the tabular bodies, and it was followed for more than 1000 feet along strike. It has a thickness of 15-20 inches and is about 6 feet high. The dip of this body is parallel to that of the Hoyer ore-bodies.

The ore consists of calcite and quartz with copper-bearing ore-minerals. This ore-body is reported to have been extremely rich in gold (Wybergh, 1925, p. 110).

9. New Chum Mine

The workings of the New Chum Mine are situated on the southwestern side of the Treur River, on the farm Ledouphine 496 K.T. (Plate I). The workings are inaccessible at present.

(a) Geological Environment

The ore-bodies are leader-reefs which are developed in the Transition Zone of the Dolomite Series. The leaders are all located within a zone which varies between 45 and 160 feet above the base of the Dolomite Series. This zone consists of dolomite, chert, and some layers of shale. A poorly mineralised interbedded reef, which can be correlated with the Willemsoord Reef (Plate II), occurs near the top of the zone. The Digger's Sandstone, which is 18 inches in thickness, is present near the bottom of the zone. Several dykes of diabase are present in the area.

(b) Ore-bodies

The ore-bodies consist of two parallel sets of thin, but very rich leader-reefs (Wybergh, 1925, p. 101), striking 045 and 065 degrees respectively. They all dip 45 degrees to the southeast. These leader-reefs are 2-3 inches in thickness, up to 120 feet in height and could be followed for distances of up to 650 feet along strike.

Wybergh (1925, p. 103) observed a very distinct stratigraphical control of the gold-content of the reefs. He found that the reefs were economically exploitable only where they intersected horizons of shale, and also immediately above and below the Digger's Sandstone.

(c) Structural Features

The leader-reefs are apparently intimately related to the New Chum Dyke, which predates one set of reefs, but postdates the other set (Figure 19). A dyke which is parallel to the New Chum Dyke, is considered by Wybergh (1925, p. 102) to be contemporaneous with it. These dykes are cut by several younger dykes which postdate all the reefs.

/10. Other Occurrences ...144.

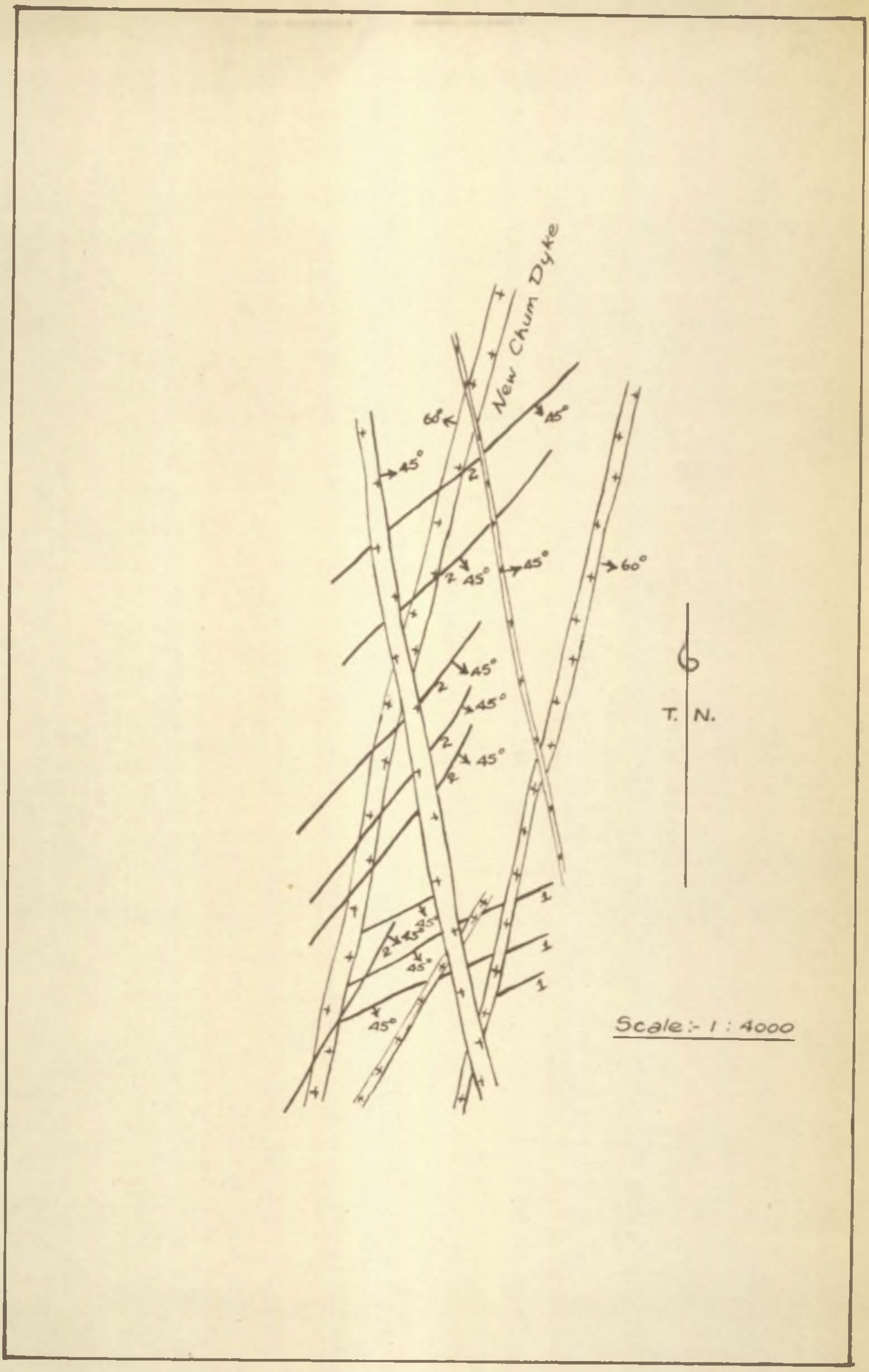


Figure 19 :- Sketch plan of diabasic dykes and leader-reefs in the New Chum Mine. (After Wybergh, 1925, p.103)

Dykes of diabase

1. Leader-reefs older than New Chum Dyke.

2. Leader-reefs younger than New Chum Dyke.

10. Other Occurrences of Group II

Certain interbedded reefs are developed in the northern parts of the area along both sides of the New Chum Dyke. In the valley of the Treur River, outcrops of the Sherwell Reef are found to the northeast of the New Chum Mine. This interbedded reef occurs in the shale of the Wolkberg Formation, about 20 feet below the Black Reef Series. The reef has an average thickness or 6 inches but do not contain gold in economic quantities. The reef was exploited immediately below the edge of the escarpment, farther north along the New Chum Dyke. The reef had a thickness of 2 feet in this locality (Wybergh, 1925, p. 100).

Near the southern boundary of Ledouphine 469 K.T., the Vaalhoek Reef was exploited on a small scale in the Ledouphine Mine. In this locality the reef was mined on both sides of the New Chum Dyke.

West of the Eendrag Mine, the Willemsoord Reef is developed on the western side of the New Chum Dyke. In places the reef reaches a thickness of more than 12 inches. It was, however, found to be unpayable.

Two reefs, located along the western contacts of dykes, are known to exist in

/the ....146.

the northern part of the area. These dykes occur on both sides of the New Chum Dyke and are parallel to it. The one ore-body, which is located to the west of the Hoyer's Workings, consists of bluish quartz and subordinate limonite. The other reef was worked on a limited scale near the Ledouphine Mine.

C. ORE-DEPOSITS AROUND PILGRIM'S REST (GROUP III)

1. General Statement

The mining-area around Pilgrim's Rest is by far the most important part of the gold-field, and is also the most extensively mineralised. The greatest variety of interbedded ore-bodies are found here, and some of them were very rich in gold. Transgressive reefs are of minor importance, and are restricted to leader-reefs that are confined mainly to the Pretoria Series. They are seldom more than a few inches in thickness and are very limited in vertical extent. All the nuggets that were found in the area, are believed to have been derived from the leader-reefs, as coarse gold is not encountered in the interbedded reefs.

2. Geological Environment

The area around Pilgrim's Rest is

/characterised..147.

characterised by a highly dissected topography. High hills and ridges are separated by deep gulleys and valleys. In these valleys and along the hill-slopes, the Dolomite Series is exposed from the Middle Shale Zone (Plate II) upwards to the base of the Pretoria Series. The higher parts are built by the rocks of the latter series. Interbedded ore-bodies are found at fixed horizons throughout the exposed part of the Dolomite Series. In the Pretoria Series, however, they occur near the base of the formation only. The stratigraphical relationships of the different interbedded reefs are illustrated in Plate II.

3. Structural Features

The ore-bodies are intimately associated with certain structures, the most important of which are the folds.

(a) Folds

The folds are not readily observed on the surface. This is due mainly to the fact that the folds have a very open nature and that they are usually confined to topographical spurs. The outcrops of the rocks along the slopes of these spurs are often disturbed by surface-creep.

The folds were, however, revealed by a detailed study of the reef-contours in the various mines. In a few localities folds could be observed in outcrop.

At least two periods of folding are present; this superimposition gives rise to the formation of domes and depressions (Figure 2).

(b) Laccolithic Structures

These structures are confined to the pyroxenitic sill at the base of the Pretoria Series (Figure 4). The best examples are present in the area immediately south of Pilgrim's Rest, i.e. on Columbia Hill and on Theta Hill.

It is considered that the "laccolith" on Theta Hill and Columbia Hill is genetically related to the east-trending anticline south of the Pilgrim's Creek. This is borne out by the fact that the axial trace of the intrusive body is parallel to, and nearly superimposed upon the axial trace of the fold. The pyroxenitic sill transgresses through the Bevett's Zone, along a line which is roughly parallel to, and slightly south of the axis of the anticline. North of this line the "laccolith" occurs above the Bevett's Zone, but is present in the Dolomite Series to the south of it.

A pyroxenitic intrusion, which may be similar in shape to the above structure is partly exposed on Kaalkop, to the north of Theta Hill (Plate XI).

The shapes of the pyroxenitic sills on Desiré and Jubilee Hills, could not be accurately determined. They are, however, very irregular in shape and do not appear to behave like normal sills.

(c) Linear Structures

The linear features around Pilgrim's Rest are represented by faults, dykes, and joints. All the dykes and the high-angle normal faults postdate the mineralisation. At least one low-angle gravity-fault, which is contemporaneous with the mineralisation, is present, i.e. in the Duke's Hille Mine.

The most prominent faults and dykes are parallel to the main structural trend. These features often show major displacements, which decrease rapidly northwards and southwards. The faults that strike perpendicular to this direction are usually associated with the folds and show minor displacements only. The most prominent direction of jointing is also perpendicular to the main trend.

4. Ore-bodies

(a) Mohlalabu Reef

This reef is developed immediately below the lowermost shale-member of the Middle Shale Zone. It was exploited on a small scale to the east of the Ponieskrantz North Mine.

(b) Portuguese Reef

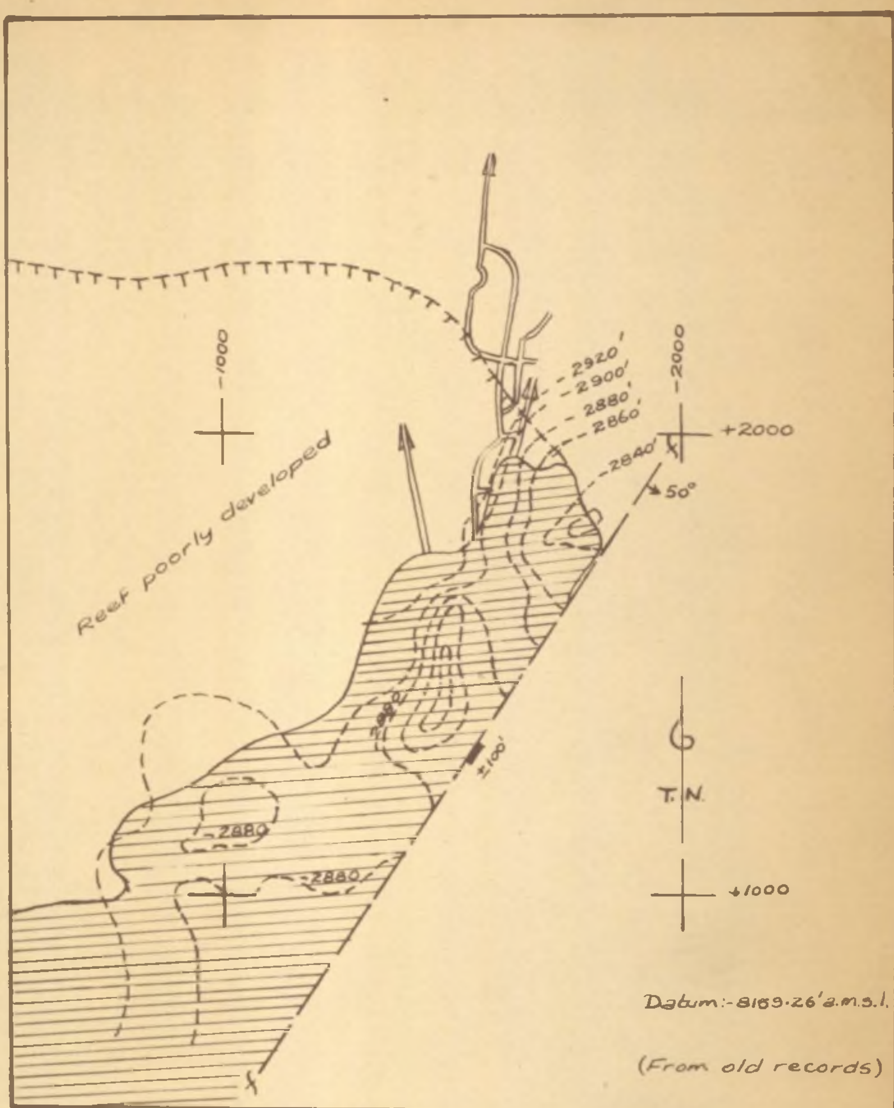
This interbedded ore-body is located about 100 feet below the Slate Marker (Plate II). A diabasic sill is present a few feet below the reef, and in places the reef is developed along the upper contact of the sill. Another sill of diabase, about 10 feet in thickness, is present locally, some 20 feet above the reef.

The Portuguese Reef was extensively exploited in the Ponieskrantz North Mine, in the Jubilee Mine and in the Desiré Mine. It was worked also south of the Kameel's Creek in the Kameel's Section, and farther south in the Grootfontein South Mine. The reef crops out along the northern slope of Monument Hill, but contains little gold in this locality. The Portuguese Reef is present also in Darke's Gully, but is not economically exploitable.

The thickness of the ore-body in the Ponieskrantz North Mine varies between 2-24 inches (Wybergh, 1925, p. 78). It consists of two layers which are separated by approximately 2 feet of dolomite and chert. Of these, only the lower reef was exploited. It consists of laminated dolomite and chert, impregnated with pyrite, and it contains a body of younger quartz which sometimes have nests of pyrite (Wybergh, 1925, p. 78). This indicates the presence of at least two periods of mineralisation, one before, and the other after movement along the plane of the reef.

The payability of the ore-body is apparently related to a very open anticline, as indicated by reef-contours (Plate VI). An examination of the assay-plan of the mine revealed that the reef was generally thicker in the vicinity of the axis of the anticline.

The relationship between the thickness of interbedded reefs and the folding is well-illustrated in the Jubilee Mine. The reef-contours in Figure 20 shows that several domes are



J U B I L E E   M I N E

Scale:- 1:5000

Figure 20:- Plan showing reef-contours on the Portuguese Reef in the North-Section

Reference

Adit and development off reef.

Exploited area.

Fault, downthrow indicated.

Reef contour-lines.

Outcrop of Portuguese Reef.

present in the northern part of the Jubilee Mine, and that the Portuguese Reef was best developed in the vicinity of the domes, as shown by the reef-thicknesses in the overlay. A similar conclusion was made by Wybergh (1925, p. 79), who observed that the reef reached a thickness of up to 8 feet where folding was present.

The Protuguese Reef was extensively exploited in the Desiré, Chi, and Chi Extension Mines (Plate VII), where the payability of the ore-body is closely associated with anticlines. Sagging and slumping of the formation, due to weathering, resulted in very unfavourable mining-conditions. The ore-body in the Kameel's Section, to the south of the Kameel's Creek, is characterised by narrow pay-shoots which are parallel to the axis of the anticline.

(c) Slate Reef

The Slate Reef is developed locally along the upper contact of the Slate Marker. It was explored along the northern side of Darke's Gully where the ore-body was proved to be thin, and, although well-mineralised, not payable.

(d) Beta Reef

The Beta Reef is located 150-170 feet above the Slate Marker. Diabasic sills are

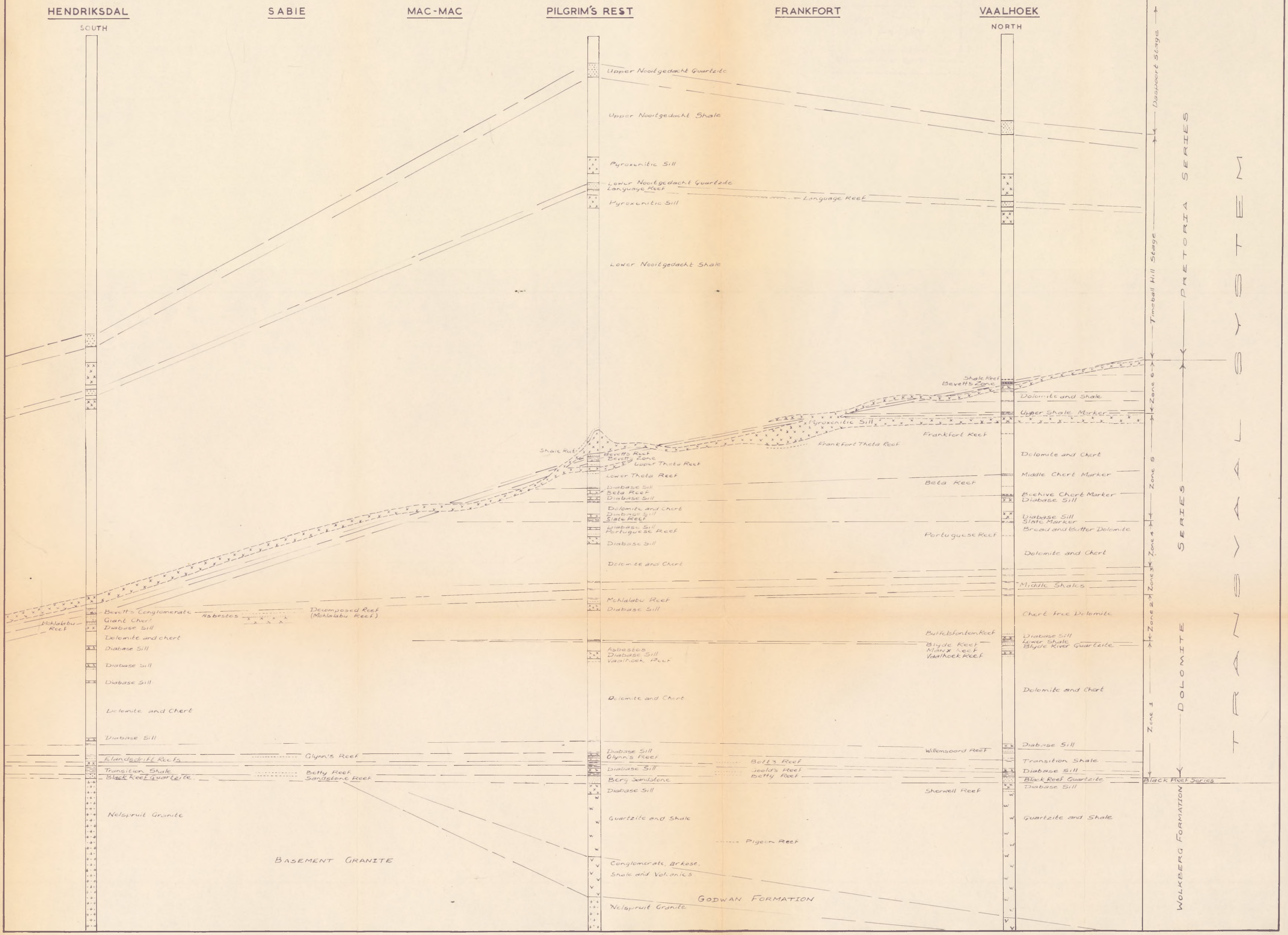

NORTHERN AREA
CENTRAL AREA
SOUTHERN AREA
Vaalhoek Mine
Clewer Mine
Rex Mine
Hill Mine
SABIE
BLYDE
PLATE I
MAP SHOWING
THE
STRUCTURAL GEOLOGY
OF THE
SABIE–RILGRIM'S REST GOLDFIELD
SCALE 1 : 50,000
Reference
River Terrace and Alluvium
Recent
Pretoria Series:- Quartzite, Shale, Bevett's Quartzite and Conglomerate and Sharpstone Conglomerate
Unconformity
Dolomite Series:- Dolomite with Interbedded Chert, Shale and Quartzite. Few prominent layers of Chert
Black Reef Series:- Quartzose Sandstone or "Berg Sandstone"
Transvaal System
Wolkberg Formation - Felspathic Quartzite, Grit, Arkose and Shale
Witwatersrand System
Godwan Formation - Lava, Tuff, Agglomerate, Conglomerate, Shale and Arkose
Dominion Reef System
Nelspruit-type Granite
General Strike and Dip of Strata
Joints
Anticlinal Axis
Domes
Synclinal Axis
Dykes (Downthrow Indicated)
Dykes (Not accurately located)
Fault (Downthrow Indicated)
Fault (Not accurate)
Farm Boundaries
Rivers, Streams and Gulleys
Roads
Railway Line
Trigonometric Beacon
Exploited area on interbedded reef
Blow
Transgressive reef
Asbestos

PLATE II

GEOLOGICAL COLUMNS

SHOWING RELATIVE THICKNESS OF STRATA AND LATERAL VARIATION FROM SOUTH TO NORTH

SCALE: VERTICAL :: 1:5000
HORIZONTAL :: 1/2 = 1 MILE



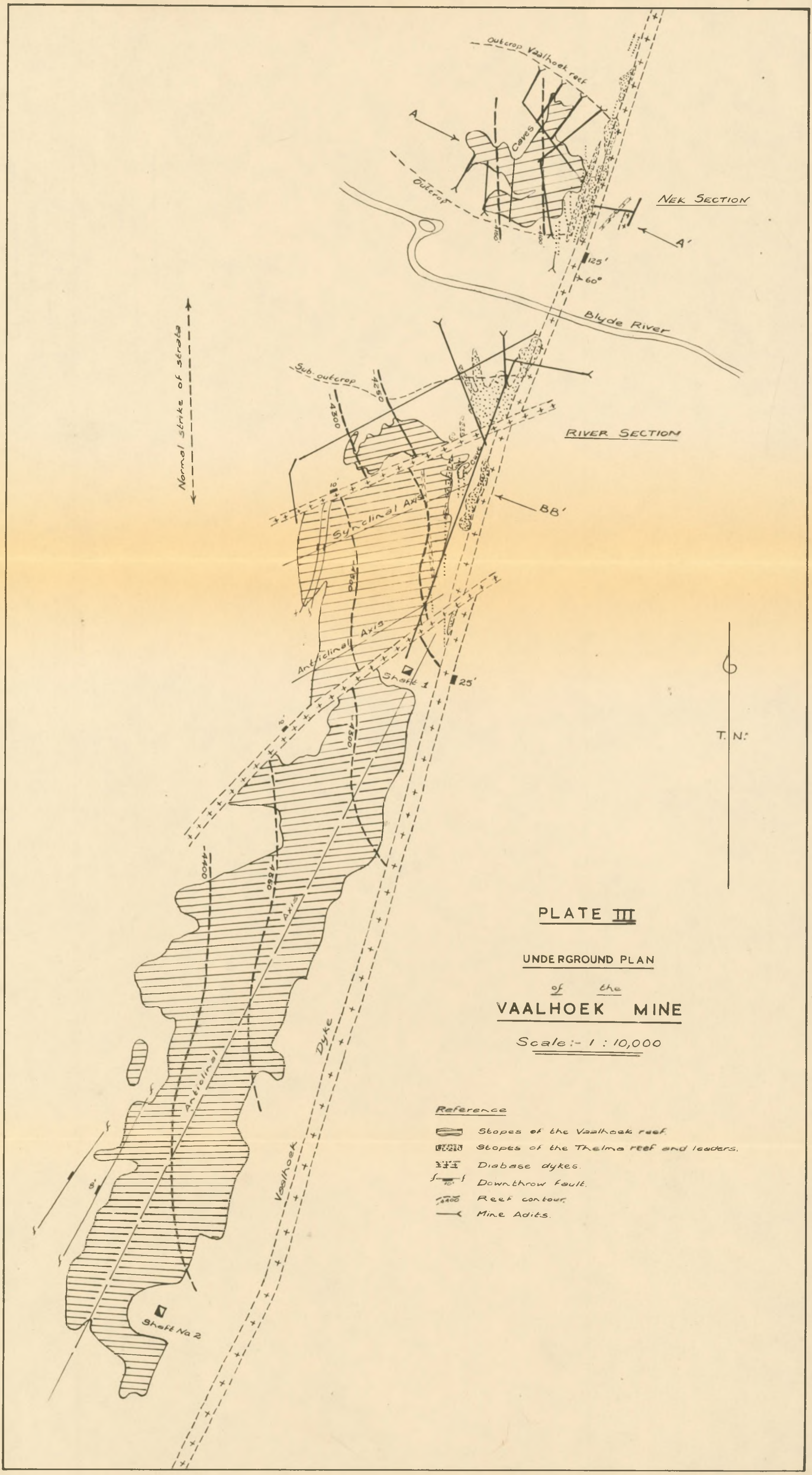


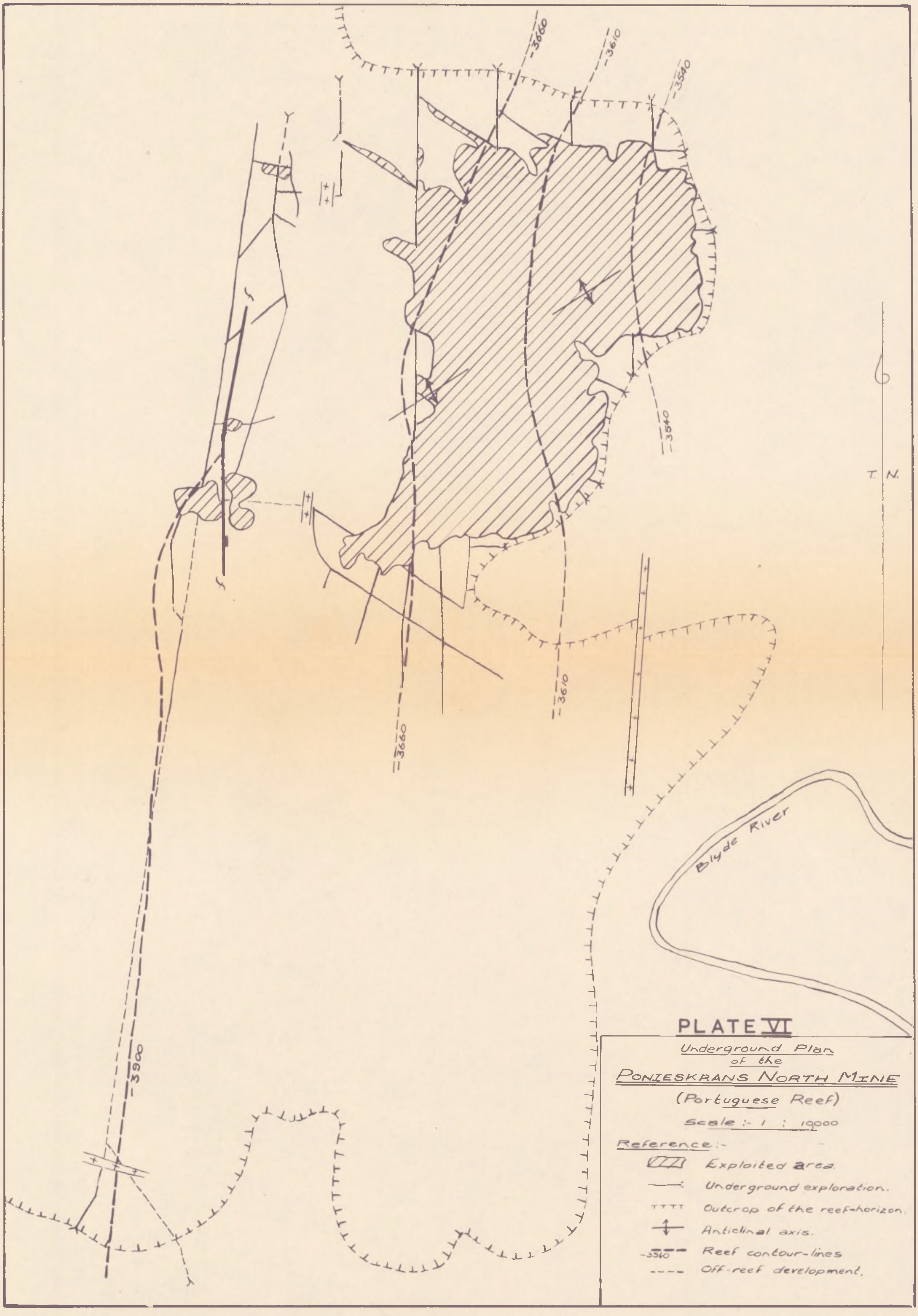
PLATE III

UNDERGROUND PLAN

of the

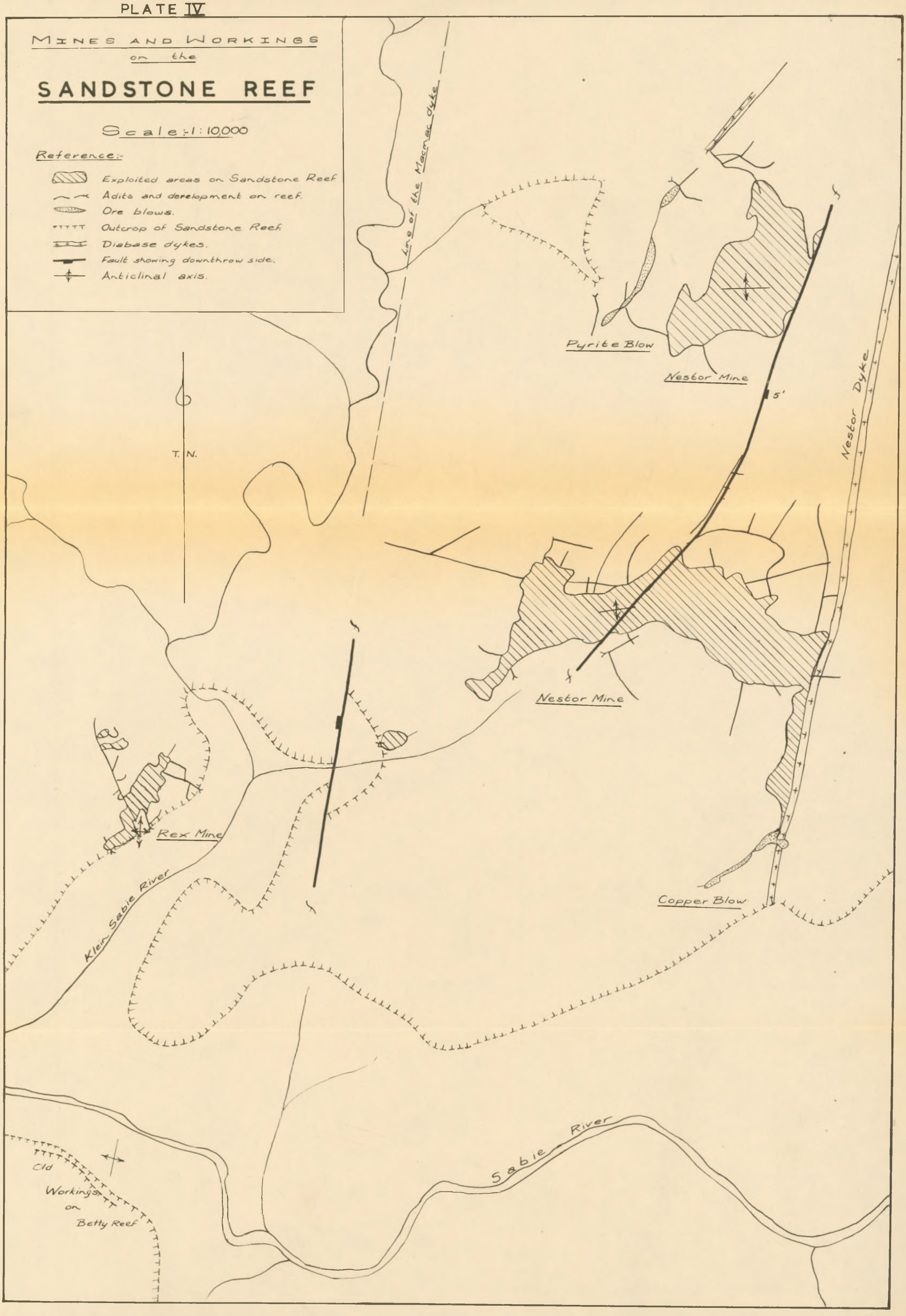
VAALHOEK MINE

Scale :- 1 : 10,000



-3660
-3610
-3540
-3540
T. N.
-3610
-3660
Blyde River
-3900
PLATE VI
Underground Plan
of the
PONIESKRANS NORTH MINE
(Portuguese Reef)
Scale :- 1 : 10000
Reference :-
Exploited area
Underground exploration.
Outcrop of the reef-horizon.
Anticlinal axis.
-3540 Reef contour-lines
Off-reef development.

PLATE IV



MINES AND WORKINGS
on the
SANDSTONE REEF
Scale:- 1:10,000
Reference:-
Exploited areas on Sandstone Reef
Adits and development on reef.
Ore blows.
Outcrop of Sandstone Reef.
Diabase dykes.
Fault showing downthrow side.
Anticlinal axis.
Line of the Macmac dyke
T. N.
Pyrite Blow
Nestor Mine
5'
Nestor Dyke
Nestor Mine
Rex Mine
Klein Sabie River
Copper Blow
Sabie River
Old Workings on Betty Reef

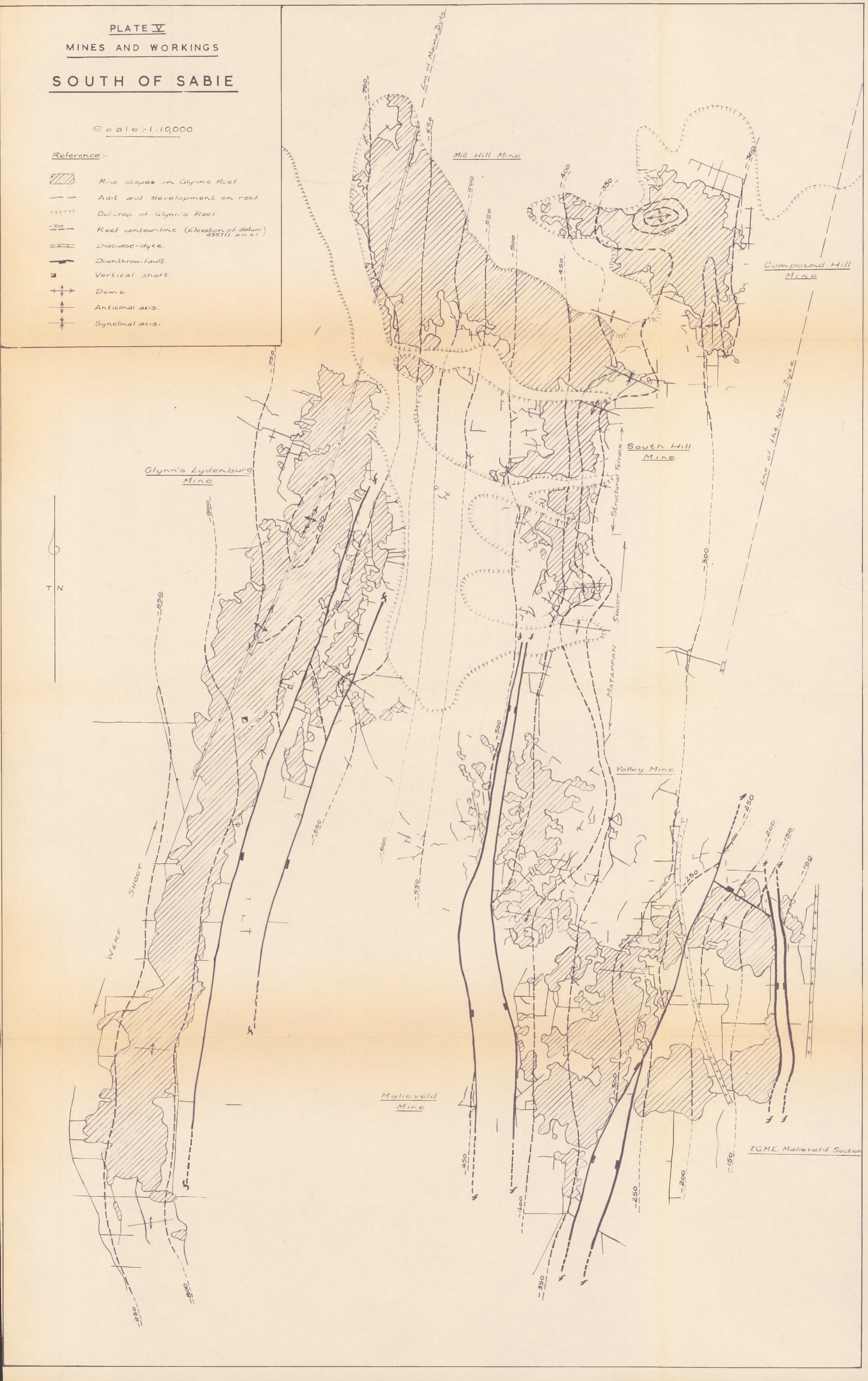


PLATE V
MINES AND WORKINGS
SOUTH OF SABIE
Scale:- 1:10,000
Reference:-
Mine stopes on Glynn's Reef.
Adit and development on reef.
Outcrop of Glynn's Reef.
Reef contour-line
Diabase-dyke.
Downthrow-fault.
Vertical shaft.
Dome.
Anticlinal axis.
Synclinal axis.
T.N.
Line of Macmac Dyke
Mill Hill Mine
Compound Hill Mine
South Hill Mine
Structural Terrace
Line of the Nestor Dyke
Glynn's Lydenburg Mine
MATAPPAN SHOOT
South Shaft
Valley Mine
WERF SHOOT
Malieveld Mine
T.G.M.E. Malieveld Section

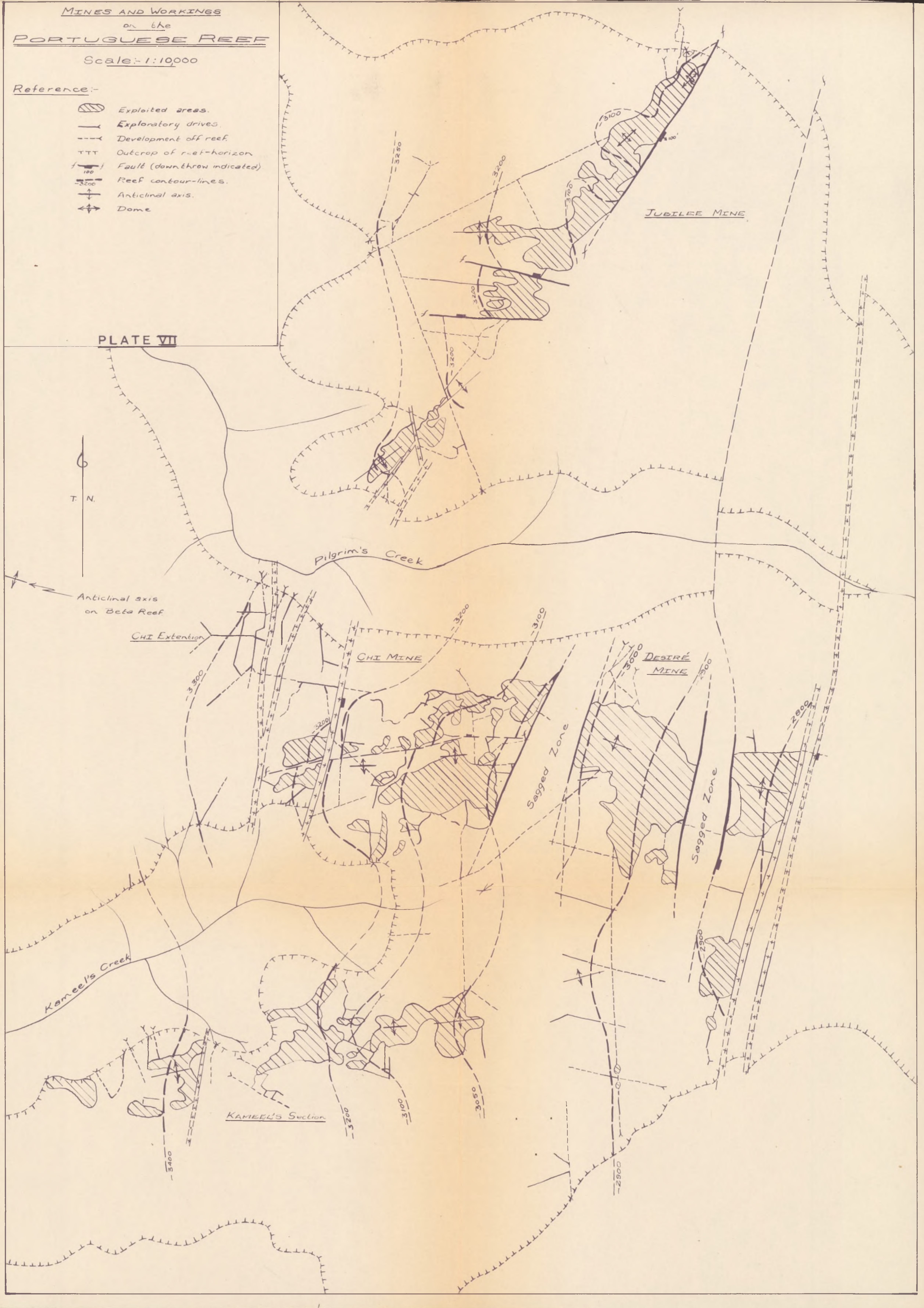

MINES AND WORKINGS
on the
PORTUGUESE REEF
Scale:- 1:10,000
Reference:-
Exploited areas.
Exploratory drives.
Development off reef.
Outcrop of reef-horizon
Fault (downthrow indicated)
Reef contour-lines.
Anticlinal axis.
Dome
PLATE VII
T. N.
Anticlinal axis on Beta Reef
Pilgrim's Creek
Kameel's Creek
JUBILEE MINE
CHI Extention
CHI MINE
DESIRÉ MINE
Sagged Zone
Sagged Zone
KAMEEL'S Section
3250
3200
3100
3300
3050
3000
2900
2800
3400


PLATE VIII
MINES AND WORKINGS
on the
BETA REEF
Scale:- 1:10,000
Reference:-
Exploited area.
Adit and reef-drive.
Adit and off-reef development.
Approximate outcrop of reef-horizon.
Fault with downthrow indicated.
Diabasic dyke.
Reef contour-line.
Anticlinal axis.
BETA MINE
BROWN'S HILL MINE
THETA MINE
Beta dyke
Peach Tree Creek
Blyde River
Pilgrims Creek
Kameel's Creek
Grootfontein Fault
Fraser Fault
Morgan Fault
T N
4200'
4100'
4000'
3900'
3100
3110
3200'
350'
600'
20

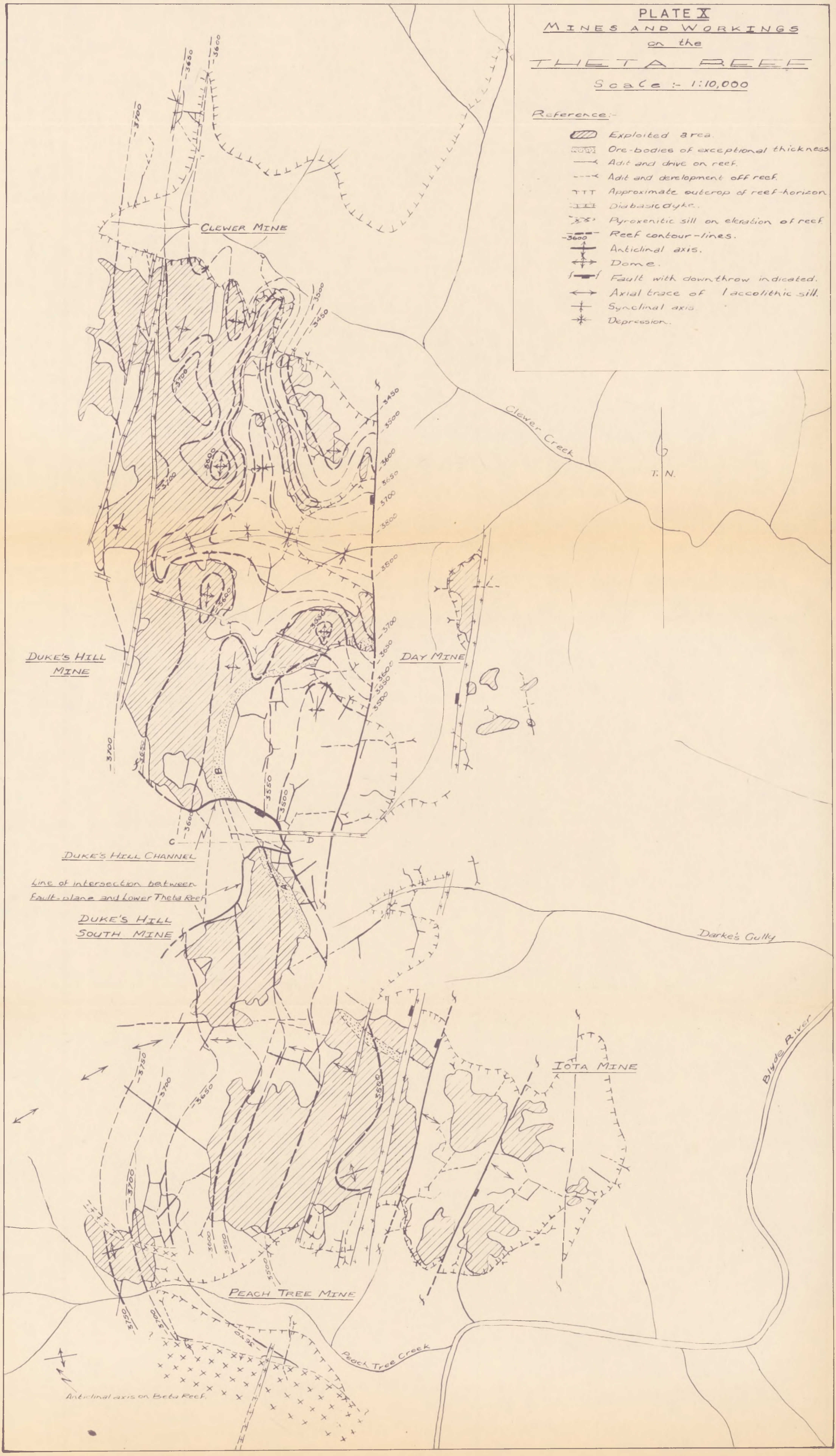


PLATE X
MINES AND WORKINGS on the THETA REEF
Scale :- 1:10,000
Reference:-
Exploited area.
Ore-bodies of exceptional thickness
Adit and drive on reef.
Adit and development off reef.
Approximate outcrop of reef-horizon.
Diabasic dyke.
Pyroxenitic sill on elevation of reef.
-3600 Reef contour-lines.
Anticlinal axis.
Dome.
Fault with downthrow indicated.
Axial trace of laccolithic sill.
Synclinal axis.
Depression.
CLEWER MINE
Clewer Creek
T. N.
DUKE'S HILL MINE
DAY MINE
DUKE'S HILL CHANNEL
Line of intersection between Fault-plane and Lower Theta Reef
DUKE'S HILL SOUTH MINE
Darke's Gully
IOTA MINE
Blyde River
PEACH TREE MINE
Peach Tree Creek
Anticlinal axis on Beta Reef


PLATE XI
MINES AND WORKINGS on the UPPER THETA, BEVETT'S AND SHALE REEFS
Scale 1:10,000
Reference:
Exploited area
Development on reef
Development off reef
Opencast-workings
Approximate outcrop of base of Pretoria Series
Outcrop of pyroxenitic sill
Diabasic dyke
Leader-reefs
Reef contour-line
Fault
Anticlinal axis on Portuguese-horizon
Anticlinal axis on Beta-horizon
Anticlinal axis on Lower Theta-horizon
Axial trace of laccolithic sill
T.N.
COLUMBIA HILL MINE
Shale Reef Leaders
Shale Reef
Upper Theta and Bevetts
Leaders
Bevett's and Shale Reefs
IOTA HILL
Darke's Gully
Blyde River
Pilgrim's Creek
Peach Tree Creek
Fraser Fault
Morgan Fault
KAALKOP
Leader Reefs
Upper Theta Reef
BROWN'S HILL
THETA HILL
Bevett's Reef
THETA MINE
JUBILEE HILL
DESIRÉ HILL

PLATE XII


MINES AND WORKINGS
ON
ELANDSDRIFT 220 J.T.
Scale:- 1: 10,000
Reference:-
Exploited area.
Adit and development on reef.
Adit and development off reef.
Zone of leader-reefs.
Blow.
Approximate outcrop of the Elandsdrift Reef.
Diabasic dykes.
Reef contour-lines (Datum 8159' a.m.s.l.)
-3400
Anticlinal axis.
Monoclinal axis.
Fault.
T.N.
Dawkin's Gully
Main Creek
Horseshoe Creek
HORSESHOE CREEK MINE
Elandsdrift Reef
Top Reef
ELANDSDRIFT MINE
Elandsdrift Blow
EASTRIDGE MINE
Natural caves
Elandsdrift Dyke
Elandsdrift Reef
Elandsdrift Creek
-3450
-3415
-3400
-3700
-3600
-3550
-3650
-3750
-3740
-3730
-3720
-3710
-3690
-3680
-3670

PLATE IX

SECTION OF THE BETA REEF ON THE 18 TH. LEVEL IN THE BETA MINE

SCALE:- HORIZONTAL: 1 INCH = 20 FEET, VERTICAL: 1 INCH = 10 FEET