

THE UPPER DIVISION OF THE  
WITWATERSRAND SYSTEM IN  
THE VIRGINIA AND MERRIE-  
SPRUIT MINING AREAS.

by

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## A B S T R A C T

This treatise provides a record of the stratigraphy and structure in the southernmost extension of the Witwatersrand System and is based on the results obtained from bore-hole cores and from detailed mapping underground. Several disconformities encountered in these sediments are interpreted as marginal disconformities of a geosynclinal basin. It is contended that the bankets were formed in neritic and littoral environments closely associated with profiles of equilibrium, such as disconformities, where conditions favour the concentration of heavy minerals, including gold and uraninite.

The composite radiometric log of the area south of the Sand river, drawn up by Dr. D.J. Simpson in 1951, is revised by including into it the portion of the log of bore-hole K.A.2 in which the Intermediate Reefs occur.

Chloritoid is confined to the Lower Footwall beds, the Khaki Shale Marker and the Upper Shale Marker. The variation of the optical properties of chloritic minerals indicate that a wide range of these minerals exist in the sediments. Pyritic stringers appear to be natural concentrations of such heavy minerals as pyrite, ilmenite, chromite and zircon.

Heavy mineral investigations, to be of correlative value, in the case of the Witwatersrand System would require considerable basic research.

Intrusive rocks have been classified under the following types ranging from the youngest to the oldest:- dolerite, epidiorite, uralite diabase, pyroxene diabase, chlorite diabase and Ventersdorp diabase.

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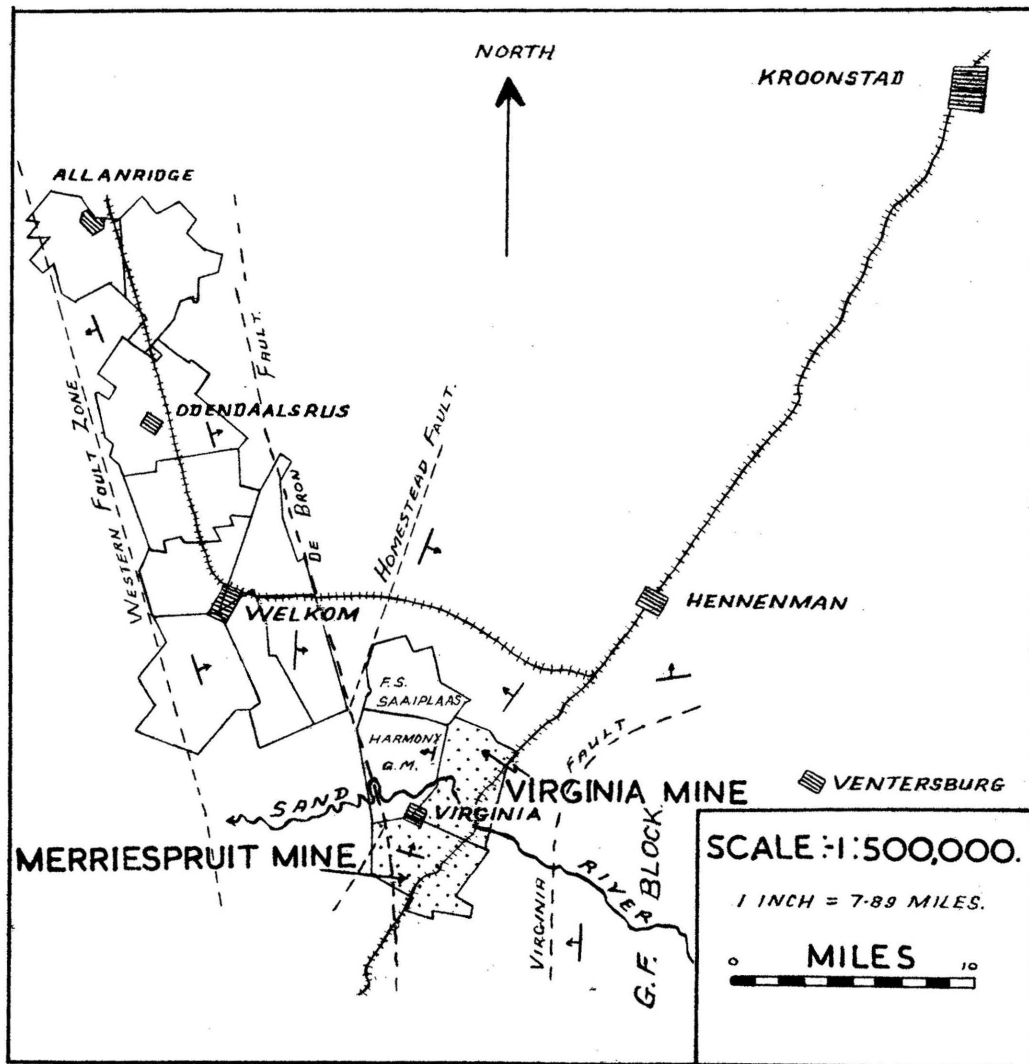


FIG. 1.

Locality map of Virginia and Merriespruit Mines.

## C H A P T E R 1 .

### INTRODUCTION

#### A. AREA AND PHYSIOGRAPHY.

Virginia and Merriespruit are the two southernmost mines exploiting auriferous bankets of the Witwatersrand System. (See fig. 1.) They surround the town of Virginia in the Orange Free State, and are bounded to the north-west by the Harmony Mine.

The town of Virginia is situated on the banks of the Sand river, where the main railway line between Bloemfontein and the Transvaal crosses it. The stream is intermittent. The flat highveld plateau slopes down gently from about 4,500 feet above sea-level to about 4,200 feet near the river. Incised meanders, steep soil embankments 30 to 50 feet high, and occasional dongas leading from almost level vleis indicate sluggish flow for a considerable period of time in the past and perhaps a recent slight rejuvenation. Local inhabitants, however, state that the vleis are occasionally flooded after heavy rains. Low sandstone and dolerite krantzies form part of the northern bank. The area is grass-covered and has limited sandstone and dolerite outcrops. Near the river and its tributaries thorn-bush abound.

#### B. RELATIVE POSITION IN FREE STATE GOLD-FIELD.

Generally, the Witwatersrand rocks in the Free State Gold-field form a large north-plunging syncline and an anticline in the West. This structure is complicated by many large and small faults. Two of the largest faults, the Western fault-zone and the de Bron or Welkom Fault, bound the so-called "Odendaalsrus Graben". (Borchers 1950, p.p 81-82, Feringa 1954, p.p. 19-33). Others are the Homestead fault and the Virginia fault..



The Witwatersrand System in the Virginia-Merriespruit area was preserved from subsequent denudation, because of the large downthrow of the Homestead fault. The regional dip of the Witwatersrand System in this area is towards the west. Further to the east, another block of the Upper Witwatersrand sediments, known as the G.F. Block, has been thrown down by the Virginia or Railway fault.

C. HISTORY.

Before the Second World War, options were taken up on several farms on both sides of the Sand River near the station and village of Virginia, by Middle Witwatersrand (W.A.) Limited, the prospecting Company of the Anglo-Transvaal Group. After the cessation of hostilities in 1945, active prospecting commenced.

Before drilling started in the Sand river area, fourteen bore-holes have been drilled to the east of the de Bron fault. Seven of these passed through the Leader-Basal Reef-horizon without finding payable gold-bearing beds. Most of them were drilled to the north of the present Saaiplaas Gold-mine. These bore-holes nevertheless indicated a possible extension of the Upper Division of the Witwatersrand System to the south in the direction of the farms held under option.

On the strength of these indications, it was decided that four bore-holes would be drilled, two in collaboration with Union Free State Coal and Gold Company Limited, who held options in the area, and that the options on farms not yet taken up, would be acquired. Accordingly the four bore-holes: R.U.1, H.1, M.1 and D.1, were sited in an approximate north-south line down the centre of the ground, then held by the two Companies.

Drills were in great demand at that time, because

options acquired before the war, were due to lapse a year after the cessation of hostilities. When the machines finally became available, drilling had to be done in a great hurry. The core was transported to Klerksdorp, where it was logged and sampled.

Bore-hole R.U.1 was the first to intersect the "economic horizon". The composite Leader-Basal Reef intersected in this bore-hole was unpayable. A single pebble in the core ten feet below the Leader Reef in bore-hole M. 1 was not recognised as the Basal Reef during routine logging, but because the precaution was taken to sample not only the beds of conglomerate, but all the quartzite as well, the assay results revealed that the Basal Reef had been intersected. As it was the policy to split the core lengthwise and to store the one half, the split core could be re-examined and it was confirmed that it was indeed the Basal Reef. The gold value of 4.3 dwt. per ton over a sample width of 24 inches was unpayable, but it was encouraging in that it was an indication that potentially payable Basal Reef existed in the Sand river area. At that stage the options were due to lapse, and the Consulting Geologist, Dr. Hearn, recommended that the mineral rights be bought. Two weeks later, bore-hole H.1 intersected the Basal Reef, which assayed 20.9 dwts. gold per ton over a corrected width of 56.4 inches. Bore-hole D.1 passed from the Karroo System into footwall beds of the Basal Reef. Further drilling was then resorted to.

The writer assisted in the logging of nine of the bore-holes under the guidance of Mr. J.F.M. Luyt and afterwards of Messrs. D.J. Sadie and P.P. Venter. He has mapped portions of all five existing shafts, and large portions of the underground workings. The cores of the original bore-holes have all been re-examined and critical sections re-logged.

## C H A P T E R II.

### GENERAL

#### A. CORRELATION.

##### (1) Basis of Correlation.

In the Orange Free State, the geologist is primarily dependant on bore-hole cores for data. Lately, this source of data is being supplemented by information obtained from underground exploration.

The problems of correlation peculiar to the Witwatersrand System have been summarised by Nel (1939 p.36-37) and have also been quoted by Baines (1949, p.316):

"In this venerable mass of sediments, estimated to be about 25,000 feet thick near Parys, no fossils have been found. The classification and correlation of these beds, therefore, are dependant upon a detailed study of their lithology and sequence."

The correlation of the strata as proposed in this treatise is based on the following :

- (a) Marker beds, as described in the paper by Borchers and White (1943), are indentified by their lithological character.
- (b) The sediments above and below the marker beds are compared and given their zonal designation, evidence of changes in facies being noted.
- (c) The true thicknesses of the beds are calculated from the cores of each borehole and compared. Isopach maps are drawn to reveal the magnitude of discontinuities.
- (d) Radiometric logs are compared with the descriptions of bore-hole cores.
- (e) The distribution of gold in the sediments of the Upper Division of the Witwatersrand System is examined.
- (f) The ratio of gold to radioactive minerals in different reefs are investigated.
- (g) Microscopical characteristics of rocks of diagnostic value are noted.
- (h) Heavy mineral concentrates are prepared and investigated for significant differences

The results of these investigations are described in later chapters.

## (2) Schemes of Correlation.

Although the regional correlation has been fairly well established, there are differences of opinion on some of the details. The accepted boundaries of the Main-Bird and Kimberley-Elsburg Series as defined by Mellor (1915, p.13) are not considered to coincide with the major "breaks" in the succession as revealed by recent discoveries in the Klerksdorp and Orange Free State Gold-fields. Sharpe (1949) and Feringa (1954) have tentatively proposed new subdivisions for the Upper Division of the Witwatersrand System. The writer is of the opinion that, although there is a strong case for the use of the new subdivisions, the accepted division into series should be retained. Mellor (1915, p.13), when he decided upon the division of the Witwatersrand System into series, based his classification on lithology and sequence. At the same time he realised that there were breaks in the sedimentation that did not coincide with his boundaries. To change his subdivision would create unnecessary confusion and would set a precedent for changing the existing formational boundaries in other geological systems in the country.

A further argument against changing the existing bases of subdivision is that most of the disconformities are discontinuous. The failure of Sharpe to recognise this fact has led him to the correlation of the Vaal-Basal Reef with the Main Reef (Sharpe 1949, p.286). It is well-known that disconformities may disappear as one proceeds down the dip from the margins of sedimentary basins. (Krumbein W.C. and Sloss, L.L., 1953, p.20). The lack of disconformities in the Vredefort area may be explained in this way.

The draw-back of the accepted subdivision of the Witwatersrand System is that, owing to the mass of data now available, the need is felt for greater detail. Feringa (1954, p. 8) has broken away from convention by including four series in the Upper Division, as

TABLE I

SCHEMES OF CORRELATION ORANGE FREE STATE GOLD-FIELD

Q

BORCHERS & WHITE 1943		FROST, ETC. 1946	BAINES & SHARPE, 1949	BORCHERS 1950	FERINGA 1954	SUBDIVISIONS NOW PROPOSED	
						Zone Symbol	Reef Designations
V.S.1 V.S.2 V.S.3 V.S.4 V.S.5	Ventersdorp Sediments	Ventersdorp Basal Conglom.	Upper Elsburg Beds Middle Elsburg Beds	V.S.1 V.S.2 V.S.3 V.S.4 V.S.5	V.S.1 V.S.2-4 V.S.5	V.S.1 V.S.2/3 V.S.4 V.S.5	V.S.5 Conglomerate Gold Estates Leader
T.1 E.C.1 E.C.2	Transition Quartzite Big Pebble Conglomerate	St. Helena Reef Zone Gold Estates Series Upper Witwatersrand System Ventersdorp System?	Lower Elsburg Beds	T.1 E.C.1 E.C.2	Upper Kimberley U.K.1 U.K.2 U.K.3 Middle M.K.1 M.K.2 Kimberley M.K.3 M.K.4	U.K.1 U.K.2 U.K.3 M.K.1 M.K.2 M.K.3 M.K.4	"A" Reef Alpha Reef? Big Pebble Reef Big Pebble Reef
E.C.3 E.C.4				E.C.3 E.C.4	Lower Kimberley L.K.1 L.K.2 L.K.3	L.K.1 L.K.2 L.K.3	"B" Reef
E.S.1 E.S.2 E.S.3	Upper Shale Marker Leader Reef at base	St. Helena Series Lower Ventersdorp or Upper Witwatersrand System?	Kimberley Beds Main-Bird Beds	E.S.1 E.S.2 E.S.3	Kimberley Shale Upper Bird Series	E.S.1 E.S.2 E.S.3	Leader Reef
E.L.1 E.L.2 E.L.3	Khaki Shale Marker Basal Reef	Upper Witwatersrand System?		E.L.1 E.L.2 E.L.3	Bird Group	E.L.1 E.L.2 E.L.3	Basal Reef
E.F.1		Speckled Footwall Quartzite Kimberley Elsburg Quartzite Prairie Quartzite	Main-Bird Series Basal Reef	E.F.	Lower Bird Group Main Reef Quartzite Group Main Reef Conglomerate Group	U.F.1 U.F.2 U.F.3 U.F.4 M.F.1 M.F.2 M.F.3 L.F.1 L.F.2	Intermediate Reefs Commonage Reef Ada May Reef - Main Reef
			Jeppestown Series		Jeppestown Series	M.R.F.	

four series in the Upper Division, as indicated in his scheme in table I. These detailed subdivisions form a very satisfactory framework on which stratigraphical descriptions can be based, and his scheme for the Kimberley beds have proved to be the most practical one for this area. The last column in table 1 represents the adaptation that will be used in this thesis.

The zone-symbols proposed by Borchers and White (1943, p.p.134-144, also p.p.150-151) have been widely used in the Free State. (Table I.) In common with the practice of others (Baines 1949, p.307, Borchers 1950, p.30) these symbols will be retained; although it must be emphasised that they are no longer considered as abbreviations of a time-rock scheme of classification, but merely as local rock units of division. (Krumbein and Sloss 1953, p.23).

The zone-symbols used for the footwall beds of the Basal Reef have been adopted from an unpublished column drawn up by Mr. G.W.S. Baumbach. A similar scheme, with minor differences is used by the geologists of the Anglo-American Group. For the sake of uniformity, therefore, the scheme according to Baumbach will be used in this treatise.

The Kimberley-Elsburg Series has been subdivided into a Kimberley Stage and an Elsburg Stage on the basis of a distinct difference in the character of the sediments of the two stages, a difference which has been remarked upon in most of the publications dealing with the stratigraphy of the Witwatersrand System in the Free State.

## B. DEFINITIONS.

As in most metallogenetic provinces, local terms which differ in meaning from the strict scientific term have also arisen in the Free State Gold-field and as there are discrepancies in the usage and definition of certain terms among authors on sedimentary rocks, it appears

advisable to define some of those in use.

Regarding the grain-size of sediments, the Wentworth grade-scale corresponds closely to the one used in this thesis, but with additional subdivisions. (Table II)

TABLE II.

<u>Wentworth</u>	<u>Additional subdivisions</u>
Boulders	
256 mm.	
Cobbles	
64 mm.	Large      ..... 44 mm.
	Medium     ..... 22 mm.
	Small
4 mm.	
Granules	
2 mm.	
Sand	Coarse     ..... 1 mm.
	Medium     ..... $\frac{1}{2}$ mm.
	Fine
1/16 mm.	
Silt	
1/256 mm.	
Clay	
0.0001 mm.	

For a sedimentary rock composed of granules, the term "grit" is widely applied among geologists on the Witwatersrand Gold-fields.

The texture of a sedimentary rock is the size, shape and arrangement of the component particles.

Structure deals with the large features of the rock such as bedding, ripple-marking, etc.

Roundness is a measure of the sharpness of the edges and corners of particles. The visual method of judging the degree of roundness and the sphericity of sedimentary

particles described by Rittenhouse (1943, p.p. 79 and 81) (Krumbein and Sloss, 1953 p. 81) have been applied in the treatise.

The term "mineralisation" with qualification, is used as a measure of the quantity of pyrite, other sulphides, thucolite or gold that is visible in the pebble-band or reef. As pyrite is predominant, the amount of this mineral serves as an indication of the degree of mineralisation thus:

Poor mineralisation	is represented by approx.	1%	pyrite
Fair	"	"	"
Good	"	"	"
Very Good	"	"	"

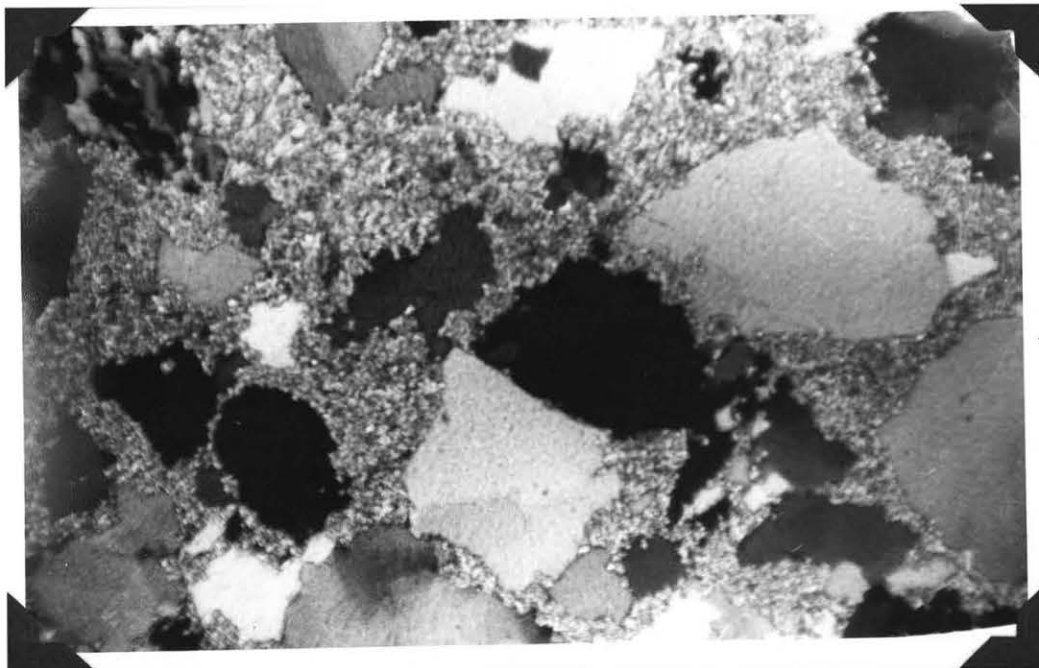
When the matrix of a quartzite or conglomerate is rich in sericitic and chloritic material, the term "argillaceous" is applied. "Siliceous" designates that the cement of a quartzite consists predominantly of silica.

The term "carbon" for the uraninite-bearing hydrocarbon mineral "thucolite" is still widely used. These terms have, therefore, been used interchangeably.

As there is considerable confusion regarding the use of terms relating to non-conformable contacts, the following extract from "Stratigraphy and Sedimentation" by Krumbein and Sloss, 1953, p. 97, is included to define the terms used in this treatise:-

"An unconformity is a surface of separation between two groups of strata, representing an interruption in sedimentation. Several types of unconformity are recognised for the purpose of taking account of the magnitude or importance of the break. An interruption in sedimentation accompanied by some disturbance of the rocks, and followed by subaerial erosion, is an angular unconformity. Withdrawals of the sea followed by subaerial erosion, but not accompanied by folding, produce a disconformity. Minor interruptions in sedimentation, which may represent merely a cessation of deposition, give rise to a diastem."



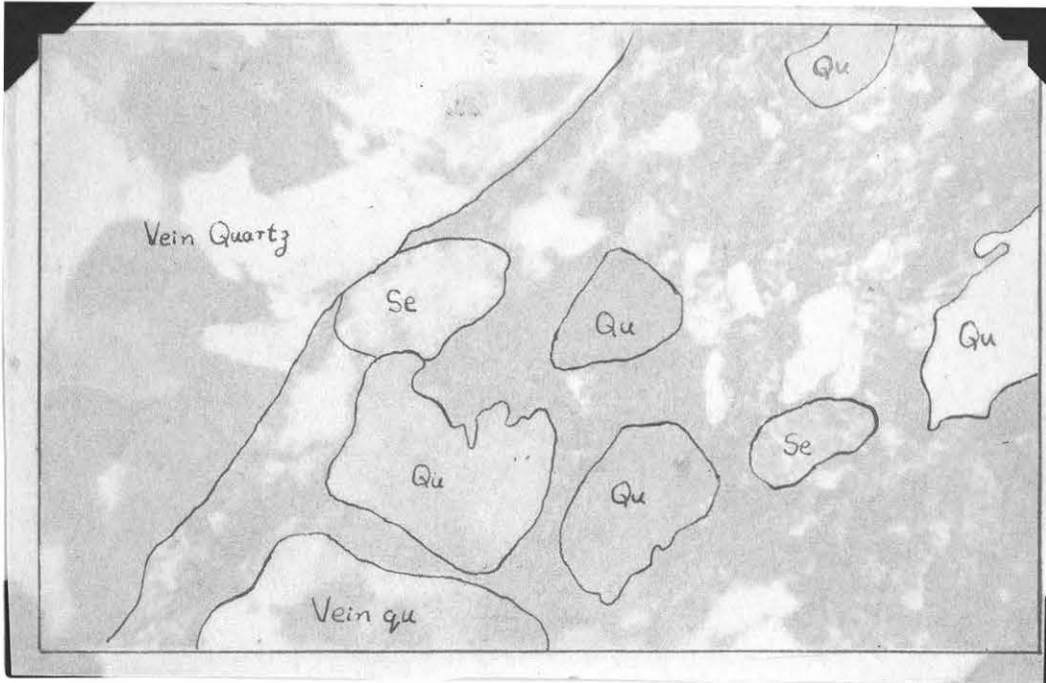


Photomicrograph 1.

Quartzite, zone L.K.2. Sericitic minerals  
replace borders of quartz grains.

Crossed nicols (X 55)

Section 28.



Photomicrograph 2.

Subgreywacke, zone V.S.1. Poorly rounded grains, mostly quartz, are embedded in a chloritic and sericitic matrix. Partly replaced grains of sericitic and chloritic rocks lie near the centre. Part of a large grain of vein-quartz appear in the top left hand corner.

Crossed nicols (X 55)

Section 36.

C. MICROSCOPICAL OBSERVATIONS.

Although it is not the purpose of this treatise to provide a detailed petrographical analysis of the Witwatersrand sediments, certain general characteristics were revealed by microscopical work on thin sections and will be described before dealing with the stratigraphy.

(1) The Quartzite of the Upper Division of the Witwatersrand System.

The grains of the quartzite of the Upper Division consist predominantly of quartz, chert being the most important other constituent. They range in shape from subrounded to angular, but a false impression of angularity is given in instances where the quartz grains have been corroded and partially replaced by sericitic minerals (photomicrograph 1, section 28).

In beds where the grains are closely packed, they are "welded" together, and frequently form sutured contacts. The "welded" effect is probably the result of partial solution of silica under pressure. The silica recrystallised between the quartz grains and formed a cement of secondary chert and microcrystalline quartz. (section 2).

It is possible that most of the quartz cement in a quartzite has formed during diageneses.

Most commonly a layer of sericitic and chlorite minerals separate the grains. In the argillaceous quartzite beds, the grains are widely separated. (sections 3 and 4).

In some sections (section 36, photomicrograph 2) cut perpendicular to the stratification, a faint directional orientation of the grains is discernable. This orientation is caused by grains settling on their largest surfaces.

Grains of chert consist of microcrystalline to cryptocrystalline aggregates of quartz. Common impurities and inclusions in the chert are chlorite, serite and rutile. Banded chert contains layers of grains of different sizes

and different degrees of purity. The occurrence of secondary chert has been described above. Even in quartzite containing abundant sericitic material, chert has been deposited in the matrix. The distinction between authigenic and allogenic chert is difficult in examples where sericite and chlorite have replaced the edges of existing chert grains.

Grains of red jasper, which abound locally, raises an interesting question regarding their origin. It is significant that pebbles of red jasper are most abundant close to the surface of pre-Karoo erosion, whereas the same horizons away from pre-Karoo outcrops contain mostly pebbles of black chert. There are jasper pebbles with red cores and others with red rims. In one thin section (section 5), there are two grains of red jasper, in one of which the core only is red, although a faint red dust is discernable around the periphery. The other grain contains a black dusty impurity, which appears red when light is allowed to fall onto the upper surface of the slide. Dust, reflecting black, appears in some chert grains in a section cut from a slightly lower horizon in the core of bore-hole W.N.1 (section 6). Some chert pebbles are partially replaced by pyrite.

It is suggested that jasper was introduced into the sediments in the oxidised state, reduced to black jasper during a period of pyritisation, and subsequently oxidised a second time where the sediments were exposed to weathering. Some of the pebbles resisted complete change and remained partially altered. Black rims on many jasper granules close to the sub-outcrop below the Karroo System indicate that the reducing conditions again prevailed to a slight extent in post-Karoo time.

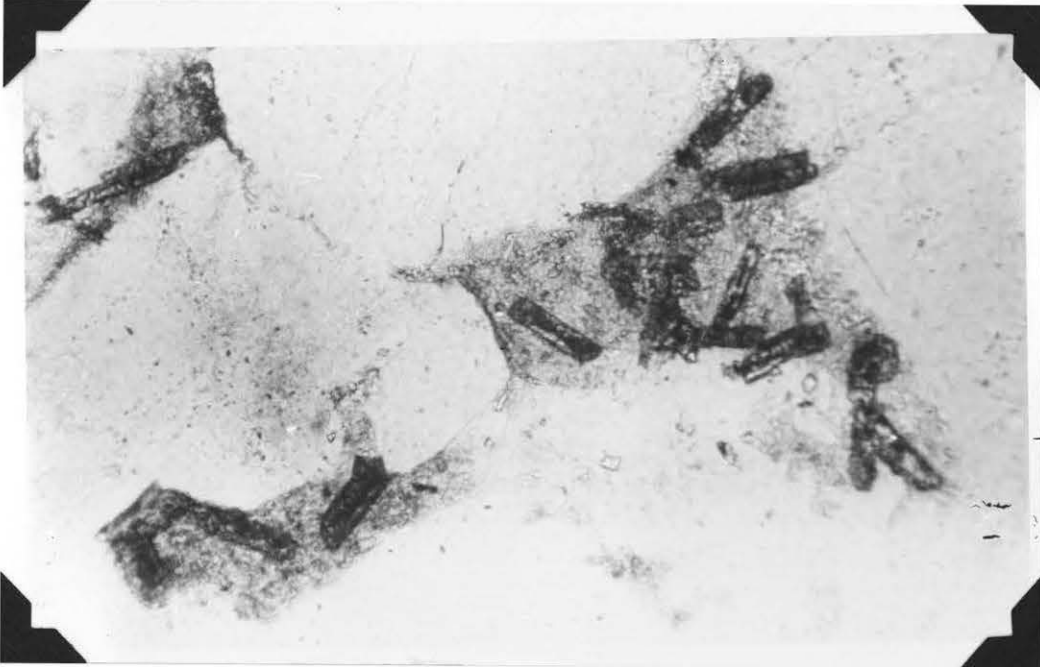
It may be mentioned here that argillaceous quartzite forming pre-Karoo outcrops is oxidised to various shades of maroon to as much as 500 feet.

The matrix of the quartzite of the Upper Division of the Witwatersrand System consists mostly of sericitic and chloritic

minerals. Chlorite is abundant in dark-grey quartzite, whereas sericite is predominant in yellow-grey varieties. The distance from a source of higher-grade metamorphism or a source of metasomatism such as a fault or an intrusion, affects the ratio of chloritic to sericitic minerals in the matrix. As an intrusion is approached, the rock at first becomes more intensely yellow, then turns a very dark-grey, the latter colour being due to greater chlorite development. A green tinge is evident in some strata, especially in the siliceous beds. The colour of a quartzite is, therefore, often of doubtful diagnostic value, especially where exposures are limited. On the other hand, abnormal colouration of quartzite is an indication of possible structural complications ahead of the exposure underground. Due to the removal of chloritic and sericitic minerals and the addition of quartz to quartzite in the vicinity of igneous bodies, a dull, argillaceous quartzite sometimes changes into a siliceous one.

Whether the changes in the quartzite is a simple contact-metamorphic effect or whether it is a metasomatic effect involving emanations from solidifying magma is beyond the scope of this treatise. Suffice be it to say that the width of the zone of alteration ranges from a few feet for some intrusions to about 150 feet from the Harmony Sill. The quartzite close to Intrusive "C", south of Merriespruit No. 1 Shaft, and the de Bron fault, west of that shaft, has been altered in this way. Sections 13 and 14 were taken in zone E.L. 1 in the shaft and two feet from the fault respectively. A dyke has intruded into the de Bron fault.

The minerals of the chlorite group range from penninite (low birefringence, anomalous "berlin blue" interference colour, also olive-green next to pyrite and purple in contact with chromite) through optically positive varieties towards prochlorite, by an increase in the aluminium and iron content of the molecule. (Winchell, 1946. p. 278)



Photomicrograph 3.

Chloritoid in quartzite of zone L.F.1.

The hourglass structure is only rarely seen.

Plain light. (X 160)

Section 10.

Sericitic minerals are represented by shreds of sericite, isolated curved shredded plates of pyrophyllite, identified as such by Dr. Liebenberg of the Government Metallurgical Laboratories, and possibly by talc. Beds of argillaceous quartzite are very rich in sericite.

Coloured specks are almost ubiquitous in the quartzite of the Upper Division. In different beds they have a large range in size, variety and concentration. These specks are grains of black chert, yellow silicified sericitic shale, red jasper and other schistose rocks consisting mainly of chlorite, quartz and sericite in varying proportions, their sizes being comparable with the associated quartz grains. Concentrations of chlorite, sericite, chert, rutile and leucoxene also give rise to coloured specks. As these concentrations have indistinct contacts, it is difficult to decide which of these represent altered detrital rock fragments and which are segregations of secondary minerals.

Rutile appears in most of the sediments as yellow, acicular crystals. Genuiculated twins are common. Concentrations of rutile cause bright orange-yellow specks, that are common in some types of quartzite. It appears as if at least some of the rutile is derived from the alteration of ilmenite. The first step in the alteration of ilmenite is leucoxene, which forms dull-yellow specks in the quartzite. In a further stage of alteration, crystals of rutile protrude from a rather indefinite mass of leucoxene, and in still other examples, a mat of rutile crystals contain cloudy whisps of leucoxene.

Chloritoid is confined to particular strata and may therefore constitute a valuable index mineral. The chloritoid-bearing beds are marked on Plate A. It appears that portions of the Lower Footwall beds are chloritoid-bearing whereas the Middle Footwall beds are free from the mineral. The Khaki Shale (E.L. 2, section 22, photomicrograph 3) and Upper Shale Marker (E.S. 1, section 25) are also chloritoid-

TABLE III

Heavy Minerals in Pyritic Stringers

Mineral	Colour		Diagnostic Features	Shape	Abundance*
	Transmitted Light	Reflected Light			
Pyrite	Opaque	Brass-Yellow	Colour	Rounded	"Flood"
Ilmenite	Opaque	Black	Violet translucence on thin edges, alteration to leucoxene	Rounded	Very Common
Leucoxene	Opaque	Pale Yellow	Colour, shape. Alteration from ilmenite or to rutile	Ragged	Very Common
Rutile	Deep Yellow	Yellow	Crystalline, acicular habit, geniculated twins	Crystalline	Very Common
Chromite	Opaque	Black	Brown translucence on thin edges	Rounded	Common
Magnetite	Opaque	Black	Sometimes has a superficial film of red haemetite	Rounded	Scarce
Zircon	Colourless, pink, brown, yellow	Colourless, resinous	High birefringence, strong relief	Crystalline and rounded	Common

\* According to descriptive scale, Milner, H.B., 1952, p.457

Note: The cracks in the broken grains have subsequently been filled in with secondary minerals.



bearing. Two other occurrences of chloritoid in the Upper Footwall and in the V.S. 1 zone are the exception, as adjoining slides in similar strata do not contain chloritoid. (sections 21 and 42 compared with 12,16,40, 41 and 43) It is possible that the bulk composition of the matrix favoured the formation of chloritoid in localised spots which are separated from reaction with the remainder of the matrix during metamorphism by an excess of quartz. It is therefore desirable to examine more than one specimen of any suspected chloritoid-bearing bed before accepting the result.

Tourmaline, which is a rare constituent of argillaceous quartzite, is probably of secondary origin as it is never found as rounded grains, but always as clear crystals of schorlite intimately associated with other minerals forming the groundmass.

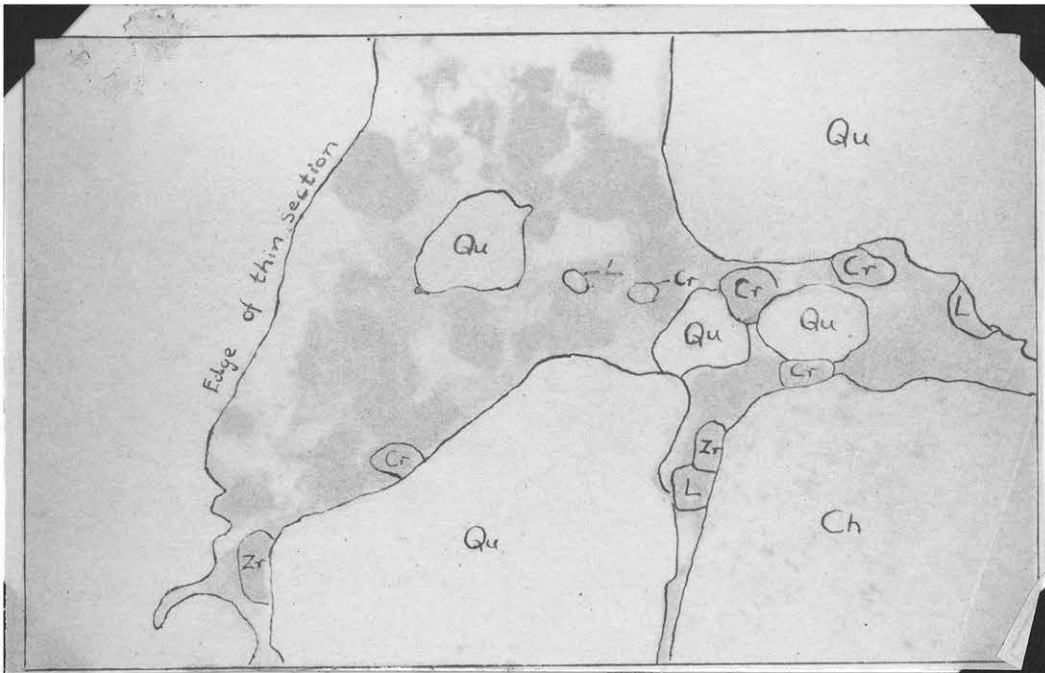
A few grains of a mineral which may be hornblende were encountered. (sections 12 and 30.)

In the quartz grains, inclusions of the following minerals were noticed:- biotite, zircon and tiny acicular inclusions. (section 5).

## 2. Pyrite.

It is not the writer's intention to delve into the origin of the pyrite in the Witwatersrand sediments, but observations on some pyritic stringers indicate strongly that "buckshot" or rounded pyrite is pseudomorphic after minerals such as magnetite, haematite and ilmenite, commonly found in black sands, or that the pyrite is a primary detrital mineral. (See Liebenberg 1955, p. 204). See also table III.

Pyritic stringers are ubiquitous in the sediments of the Upper Division. They never cut across sedimentary layers, although they frequently follow the foreset beds in cross-bedding. The pattern of distribution in the black heavy minerals in unconsolidated sand deposits, is similar to that formed by pyritic stringers in Witwatersrand sediments. (photomicrograph 4.)



Photomicrograph 4.

Typical pyritic stringer in quartzite of zone L.F.1  
Many opaque minerals are rounded and all "heavy"  
minerals occur in the matrix. Some, near the right,  
are crushed, others protrude slightly into quartz  
and chert grains.

Q = quartz  
Ch = chert  
Cr = chromite  
L = leucoxene  
Z = zircon  
Pyrite is not indicated.

Plain light. (X 12)

Section 5.

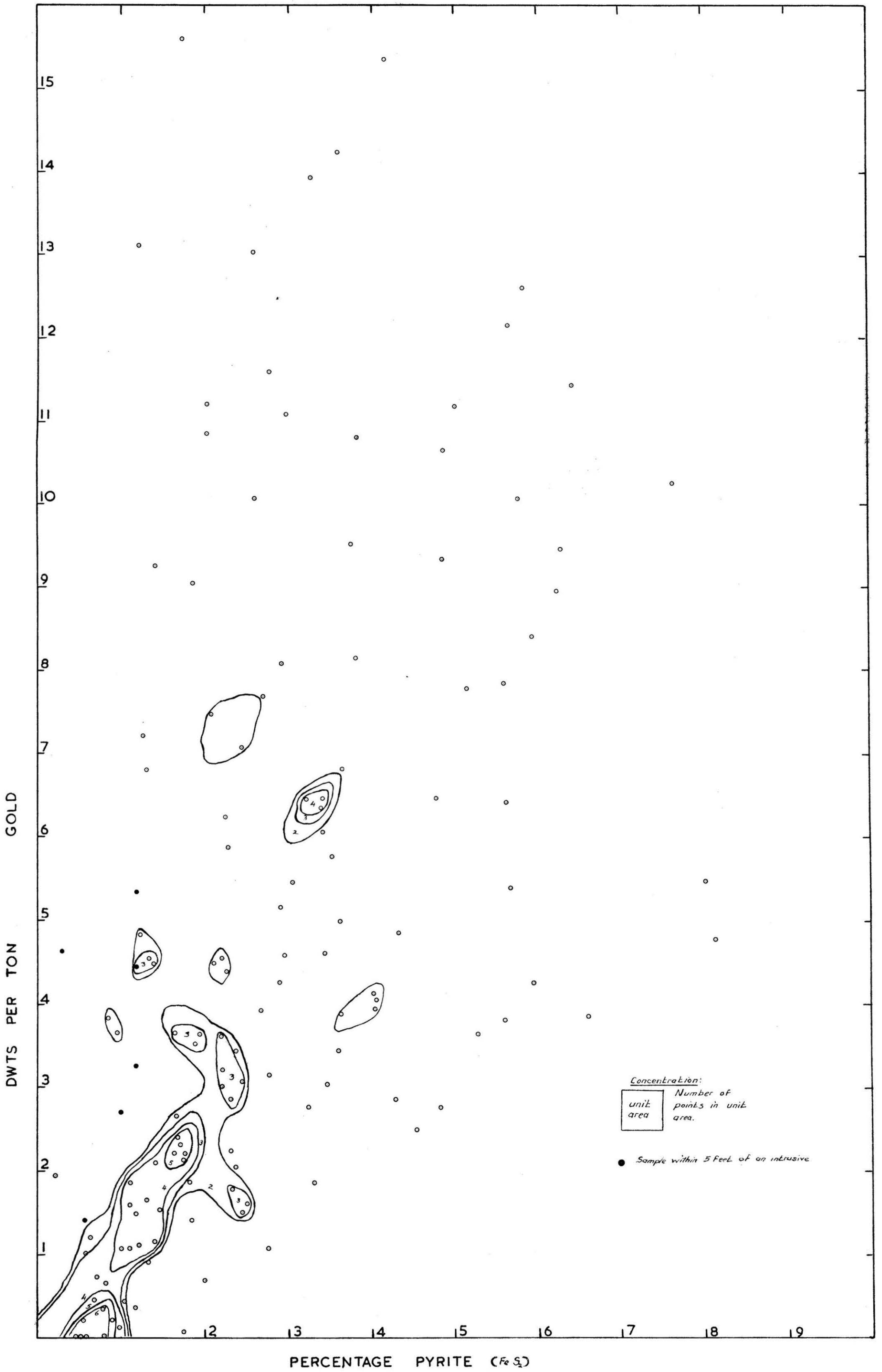


FIG. 2.

Pyrite-gold relationship in Basal Reef.

It is noteworthy that the pyrite of stringers in quartzite far removed from conglomerate is also rounded.

In the basket, the rounded pyrite is generally of a large size. The average size of the pyrite grains are 3 mm. in diameter near the base, and 1 mm. towards the top of the Basal Reef. Rounded pyrite of larger than average size is an indication of high gold values. Grains larger than 3 mm. are locally found in some reefs. They have the shape of water-worn pebbles and granules.

Rounded grains of pyrite less than 0.08 mm. diameter are not found in quartzite. Smaller grains are either crushed grains or secondary pyrite. According to theory, abrasion should be negligible for particles smaller than 1/16 mm. in diameter (0.06 mm) (Twenhofel, 1939, p.199). The evidence is, therefore, strong that the rounded mineral, that is now pyrite has a detrital origin and is not oolitic.

It has often been stated that an increase in the pyrite content in a reef is an indication of high gold values. (Macadam 1935, p.79). A direct comparison between the gold and the pyrite content of the Basal Reef on the Merriespruit mine is now possible because sections sampled at 50 feet intervals are assayed for both gold and pyrite. The results of these assays have been plotted on a graph, fig. 2, and indicates that there is a linear increase of pyrite with increase in the gold tenor of the Basal Reef.

Microscope examination reveals that some of the grains in the pyritic stringers have been fractured and others crushed. Most of the fractures are filled with quartz. Liebenberg has also commented on these fractured grains (1955, p.170).

Grains of rounded pyrite have been pressed into quartz by selective solution of the latter under pressure, (section 7 and others. Note that this effect is best seen in hand specimen against the contacts of the large grains.)

but are always found in the matrix, whereas secondary hackly or crystalline pyrite may partly replace quartz grains.

Whatever the original constitution of rounded pyrite, the grains were already pyritic before silicification occurred. The rarity of magnetite and haematite in the heavy mineral concentrate suggests that the rounded pyrite originally consisted of these minerals and that the pyritic stringers originally were stringers of black sand.

Flaky, ragged and euhedral, crystalline pyrite is commonly found near intrusions, but very close to a dyke the pyrite in a reef is almost completely absent. The shaded circles in fig. 2 represent the composition of samples taken close to intrusions. Note that the percentage of pyrite in these samples are all less than normal. A little further away flakes and concentrations of pyrite occur both in the reef and in the adjacent quartzite. This zone is followed by one enriched in secondary and containing also primary rounded pyrite. Approximately coinciding with this zone is the end of the dark, chloritized quartzite. Further away from the dyke, normal rounded pyrite predominates.

# TABLE IV

SUMMARY OF DETAILED CHARACTERISTICS OF THE DIFFERENT BEDDING UNITS COMPRISING THE  
**UPPER DIVISION OF THE WITWATERSRAND SYSTEM.**

BORE HOLE	ZONE	UNIT	PARTICLE SIZE									COLOUR			SPECKLING					MATRIX AND COMPOSITION				PACKING			ROUNDNESS			PYRITE					REMARKS								
			GRAINS			GRANULES			PEBBLES			YELLOW-BROWN	LIGHT GREY	DARK GREY	GREEN	IN QUARTZITE				GROUNDMASS				QUARTZ	CHERT	SHALE	QUARTZITE	BANDS TASPER	OPALESCENT BLUE QUARTZ	CLOSE	LOOSE	SCATTERED	ANGULAR	SUBANGULAR		SUBROUND	ROUNDED	SIZE		QUANTITY			
			FINE	MEDIUM	COARSE	SMALL	LARGE	SMALL	MEDIUM	LARGE	YELLOW					BLACK	GREEN	MILKY	SILICEOUS	ARGILLACEOUS	ARGILLACEOUS CHALCITIC	SHALY	QUARTZ															CHERT	SHALE	QUARTZITE	BANDS TASPER	OPALESCENT BLUE QUARTZ	SIZE
VZ3	VS1	Type 2	x	x	x	x	x	x											x	x	x			x					x													The two types are interbedded. Pebbles of quartz-porphry rare.	
"	VS1	Type 1	x	x	x	x	x												x	x	x			x					x												" "		
"	VS4/3		x	x															x	x	x			x					x												Dark, shaly zone near centre		
"	VS4		x	x															x	x				x					x												Siliceous, sub-conchoidal fracture		
"	VS5	Conglom	x																x	x	x			x				x													Sharp change in sedimentation at base.		
"	VS5	Quartzite	x																x	x				x					x												Gold Eskates Leader Reef.		
M2	VS5	REL	x																x	x	x			x				x													Small- pebble conglomerate bands in quartzite.		
"	UK1		x	x	x														x	x	x			x				x												Evenly distributed specks.			
"	UK2		x	x	x														x	x	x			x				x													"A" Reef		
"	UK3		x																x	x	x			x				x													Regularly spaced coloured grains. Siliceous quartzite and conglomerate lenses		
"	MK1		x	x	x														x	x	x			x				x												Lenticular large- pebble conglomerate			
"	MK2		x	x	x														x	x	x			x				x													Lenses of rounded quartz- pebble conglomerate		
"	MK3		x	x															x	x	x			x				x													"Big Pebble Reef"		
"	MK4		x	x	x														x	x	x			x				x													Large coloured granules. Oligomictic conglomerate bodies.		
"	LK1		x	x	x														x	x	x			x				x													"Mixed pebble", oligomictic conglomerate.		
"	LK2		x	x	x														x	x	x			x				x													Yellow grey quartzite. Scattered pebbles near top of zone.		
"	LK3	3	x	x	x														x	x	x			x				x												"B" Reef at base			
"	"	1	x	x	x														x	x	x			x				x													Arenaceous shale and argillaceous quartzite		
"	ES1		x	x															x	x	x			x				x													Leader Reef at base.		
"	ES2		x	x	x														x	x	x			x				x													Unstratified		
"	EL1		x	x															x	x	x			x				x													Khaki Shale marker.		
"	EL2		x																x	x				x				x													Basal Reef		
"	EL3		x	x	x														x	x	x			x				x															
"	UF1	3	x	x	x														x	x	x			x				x															
"	"	2	x	x	x														x	x	x			x				x															
"	KA2	1	x	x	x														x	x	x			x				x														Contains dull, yellow, argillaceous quartzite beds.	
"	Upper UF2		x	x	x														x	x	x			x				x													Thin beds of grit make an appearance		
"	Lower UF2	2	x	x	x														x	x	x			x				x														Siliceous quartzite followed by argillaceous, gritty quartzite.	
"	Upper UF3	1	x	x	x														x	x	x			x				x													Thin beds of grit.		
"	Lower UF3	5	x	x	x														x	x	x			x				x													Gritty and slightly argillaceous.		
"	"	4	x	x															x	x				x				x															
"	"	3	x	x	x														x	x	x			x				x															
"	"	2	x	x	x														x	x	x			x				x															
"	"	1	x	x	x														x	x	x			x				x															
"	UF4		x	x	x														x	x	x			x				x															Alternating highly speckled argillaceous and somewhat siliceous quartzite.
"	MF1	2	x	x															x	x				x				x														Layers of grit near top.	
"	"	1	x	x															x	x				x				x															
"	DI	MF2	3	x	x														x	x	x			x				x															
"	"	2	x	x	x														x	x	x			x				x															Streaks of siliceous quartzite.
"	"	1	x	x	x														x	x	x			x				x															
"	MF3	2	x	x															x	x	x			x				x															
"	"	1	x	x															x	x	x			x				x															
"	LF1	7	x	x	x														x	x	x			x				x														Few shale pebbles present. Small, densely packed black specks.	
"	"	6	x	x	x														x	x	x			x				x														Rare granules of quartz-porphry	
"	"	5	x	x	x														x	x	x			x				x													" " " " " , also milk-white chert.		
"	"	4	x	x	x														x	x	x			x				x															
"	"	3	x	x	x														x	x	x			x				x															
"	"	2	x	x	x														x	x	x			x				x															
"	"	1	x																																								

C H A P T E R III.

THE STRATIGRAPHY OF THE MAIN-BIRD SERIES.

The general geological column of the Upper Division of the Witwatersrand System in the Virginia and Merriespruit mining areas, is shown on plate A. Owing to non-deposition of some beds and to disconformities, the complete succession has not been encountered in any single bore-hole, but has been completed after careful study of the cores of all the bore-holes in the area.

In the forthcoming descriptions the local units of division will be used. The relation between the local and regional correlation, and the thicknesses of the strata are also shown on plate A.

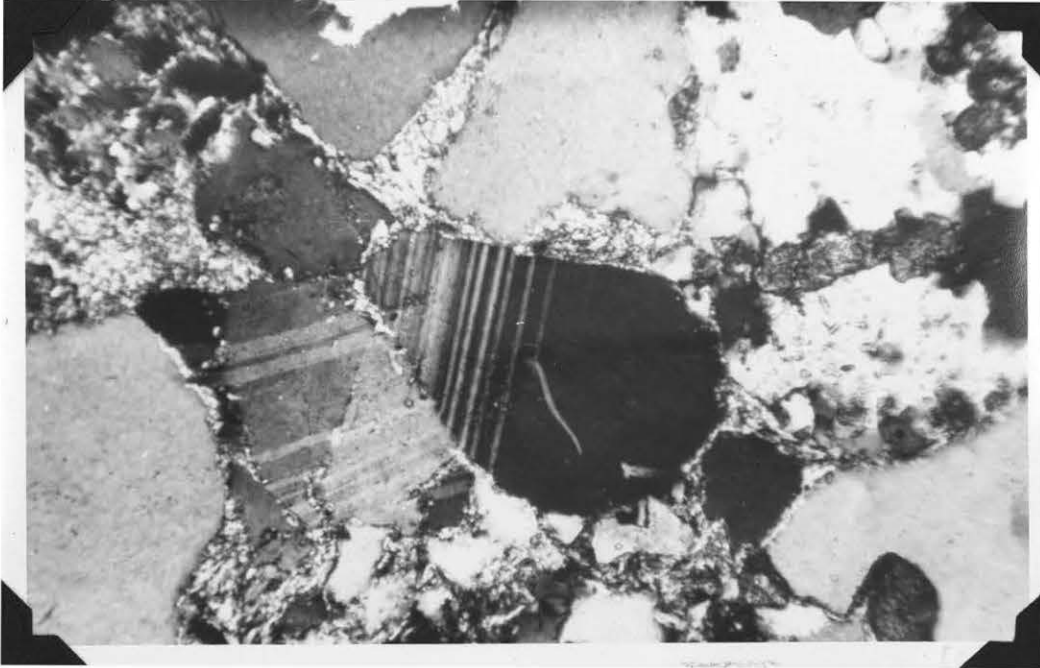
Plate B is a diagrammatical representation of the bore-hole data, drawn with the base of the Elsburg Stage as a reference line, and arranged so that the most complete columns are on the left.

A. FOOTWALL BEDS - ZONE E.F.

The strata underlying the Basal Reef is collectively known as Footwall beds or as the E.F. zone, the latter after the scheme of Borchers and White (1943).

Since drilling was directed to explore the Basal and Leader-Basal Reefs, the number of bore-holes that penetrated some depth into the Footwall beds are limited. The chief characteristic of the Footwall beds is the prevalence of gradational changes between adjacent beds, and the repetition of similar types of quartzite and conglomerate.

In table IV opposite the detailed characteristics of the individual bedding units that comprise the Footwall beds, are given. The units are also numbered in Plate A, so that quick comparison between the stratigraphical column and detailed descriptions is possible.



Photomicrograph 5.

Main Reef Footwall Quartzite. Rounded and cracked grains of plagioclase are surrounded by quartz grains in a matrix consisting mainly of sericite. The inclusion-filled quartz in the upper right hand corner is possibly secondary. The small dark-grey grains near the right hand edge are of epidote.

Crossed nicols. (X 175)

Section 17.



The cores of only three bore-holes were available for the study of the lower 1,400 feet of the Upper Division. They are bore-holes D.1 on the farm Dora 287, included in the Merriespruit Lease Area, W.N.1 on Welgelegen 382, 6 miles south of Merriespruit, and E.X.1 on Excelsior 866, 12 miles south-west of Merriespruit. Descriptions of the cores of bore-holes W.Z.1 and C.B.1, logged by Mr. D.J. Sadie, were available for comparison (See plate B). These two bore-holes are situated east of Merriespruit.

Small changes in facies, the effect of intrusions and of possible faulting increased the difficulty of correlation.

(1) The Main Reef Footwall Quartzite (M.R.F.)

The name applied to this quartzite is that used in the Central and West Rand, as nobody has yet given a specific local name to the quartzite.

The green tinge of this quartzite is characteristic and is most distinct near the Jeppestown shale but becomes very faint towards the top. The change from Jeppestown shale to quartzite is gradational through a zone of alternating layers of quartzite and shale of variable thickness. The top of the transitional zone marks the base of the Upper Division, but this point, in many bore-holes, is somewhat arbitrary.

The lowermost green quartzite is probably the equivalent of the "Red bar" of the Central Rand. In the Free State the rock is of course encountered in the reduced state. The most prominent feature of this quartzite under the microscope (section 17, photomicrograph 5.), is the presence of fresh grains of feldspar. The feldspar is a plagioclase in the range albite-oligoclase, as determined by the Michel-Levy method of measuring maximum extinction angles of albite twins in sections normal to (010). The presence of feldspar is remarkable in that it is the only occurrence in the entire series of slides examined. Borchers (1950, pp. 47, 112) refers to feldspar in the Lower Division, which indicates that this

quartzite shows petrographic affinities with these sediments. The green colour of the quartzite is probably due to the preponderance of chloritic over sericitic minerals. Epidote and ragged grains of pyrite form accessories. The presence of epidote is also unique in the series of slides examined. No rutile occurs in the slide.

Interbedded with the green quartzite are bands of pure, white quartzite of a larger grain-size from about 60 feet, becoming prominent at about 260 feet from the base, where the quartzite forms a fairly consistent, light-coloured zone.

Over the uppermost 160 feet the quartzite gradually changes in composition until it becomes almost identical with the quartzite within the L.F. 1 zone. The colour darkens to gray and the green tinge is very faint. The quartzite is coarser, being medium-grained. Small black chert fragments and yellow sericitic specks appear. Blue opalescent grains of quartz are also common. Interstratified with the quartzite are thin beds of argillaceous quartzite that form the most distinct bedding feature of the quartzite of the Upper Division. They change upwards from green to dark-grey. Current-bedding becomes noticeable and also remains a feature of most of the quartzite of the Upper Division. Narrow pyritic stringers lie in the current-bedded sediments. Sericite is more abundant than at the base and minute needles of rutile occur sporadically and in groups. (section 18.)

Over the upper 60 to 100 feet there are some narrow, mineralised layers of grit.

## (2) The Lower Footwall Beds (Zones L.F.2 and L.F.1)

The Lower Footwall beds are characterised by groups of small-pebble conglomerate and grit alternating with quartzite. There is a striking similarity between these beds and the Commonage-Ada May quartzite and conglomerate beds in the Klerksdorp Area, judging from cores logged by Sadie and Baumbach. (Plate B). For this reason, the correlation of these

beds with the Main Reef Group of conglomerates is fairly certain.

The of zone L.F.2 is formed by the small-pebble conglomerate beds of the Ada May Reef. The conglomerate consists mainly of quartz pebbles and some bands are well-mineralised. Individual bands are, however, less than a foot in thickness and alternate with quartzite. The conglomerate is not sharply demarcated from quartzite. In the Free State this conglomerate is not auriferous. The lower contact of zone L.F.2 is sharp, but there is no change in the characteristics of the quartzite below and between the beds of conglomerate. The even thickness of the Main Reef Footwall quartzite in the central Free State Gold-fields indicate that there is no disconformity at the base of the Ada May Reef. Bore-holes C.B.1 and E.X.1 to the east and south of Merriespruit Mine respectively, have intersected progressively smaller thicknesses of this quartzite. There is, therefore, fairly strong evidence that a disconformity exists near the margin of the basin of deposition at this horizon. This is not, however, accompanied by a change in the character of the Ada May Reef.

At about 25 feet from the base of zone L.F.2 there are small-pebble conglomerates and coarse grits that contain a remarkable amount of silicified quartz-porphyry pebbles. The equivalent horizon in the Klerksdorp Area was not recognised by Sadie, but Baumbach (unpublished logs) described a comparable horizon in bore-hole T.L.6 on Klerksdorp Townlands as containing "igneous" pebbles.

At about 150 feet from the base of zone L.F.2, small-pebble conglomerates and coarse grits again occur, in which pebbles of chert are more abundant than any other pebble constituent. This bed, the Chert Marker, has been used as a key bed both in the Orange Free State and in the Klerksdorp Gold-fields.

A similar cycle of sedimentation to that which produced

the sequence of quartzite and grit up to the Chert Marker has been repeated in the sediments occurring towards the top of this zone.

Zone L.F.1 begins with thin grit and small-pebble conglomerate bands correlated with the Commonage Reef in the Klerksdorp Area. In the cores of the three bore-holes available, the Commonage Reef zone is no more prominent than any of the succeeding coarse members of zone L.F. 1. Pebbles of black chert are conspicuous but although chert is a common pebble constituent, it is subordinate to quartz. These coarse constituents remain fairly similar in composition throughout zone L.F.1 except that a flinty chert becomes prominent high up in the succession (see plate A) and that the quartz pebbles are predominant in the uppermost small-pebble conglomerate beds.

The quartzite, although similar to that in zone L.F.2, is mainly coarse-grained and contains grains of chert in approximately the same proportion as in the grit members.

Grains and pebbles of red jasper occur in the core of bore-hole E.X.1 above the Commonage Reef and persist in the remainder of the Footwall beds.

(3) The Middle Footwall Beds. (Zones M.F.3, M.F.2 and M.F.1)

The Middle Footwall beds are the most difficult to subdivide as they contain thick accumulations of dull, somewhat argillaceous quartzite. Where they change into finer- or coarser-grained beds, the change is gradational. Two beds of very light-grey pure quartzite are the most easily recognizable. They have locally been called the Lower and Upper White bands.

The quartzite of zone M.F.3 is mainly dull and somewhat argillaceous, and terminate with the siliceous quartzite bed of the Lower White band.

The variations in the quartzite in Zone M.F.2 is greater than in zone M.F.3, there being alternations of dull, argillaceous and light, siliceous bands. Narrow lenticular beds of

grit are also present. Grit bands about 175 feet from the base of zone M.F.2 have been correlated by Feringa with the Livingstone-Johnstone reefs. (Feringa 1954, p.14). Examination of detailed bore-hole logs reveals that the grit beds change in facies in an easterly direction to quartzite. (Plate B, bore-holes M.O.2, M.2, M.1 and C.A. 1). It is possible that this change also occurs in a southerly direction, because bore-hole W.N.1 has no grit bands in the relevant position.

The Upper White band forms the base of zone M.F.1 and is succeeded by coarse argillaceous quartzite. In some intersections this contact is sharp, but in many it is gradational. The same can be said of the contact of the argillaceous quartzite with the Intermediate Reefs.

(4) The Upper Footwall Beds (Zones U.F.4 to 1).

The Intermediate Reefs at the base are followed by quartzite containing layers of grit and then by speckled, siliceous quartzite.

The zonal subdivision employed by geologists of the Anglo-American Corporation in the Free State differs from that of Baumbach in that they class the Intermediate Reefs as zone M.F.1 and Baumbach's zone M.F.1 as zone M.F.2, etc. The divisions for the remainder of the Upper Footwall are the same in both schemes.

The Intermediate Reefs comprise narrow grit and small-pebble conglomerate bands intercalated with variable thicknesses of argillaceous, brownish-grey and siliceous, grey quartzite. The pebbles are poorly sorted. They consist, amongst others, of rounded and subangular quartz, subangular and tabular black chert, grey and green chert, irregularly shaped yellow metamorphosed shale and green quartzite. A few pebbles of silicified quartz-porphry, red jasper and blue opalescent quartz have also been noticed. Some of the conglomerate bands contain a fair amount of pyrite. The gold tenor is very low, the concentration rarely exceeding 1 dwt. per ton. The reefs

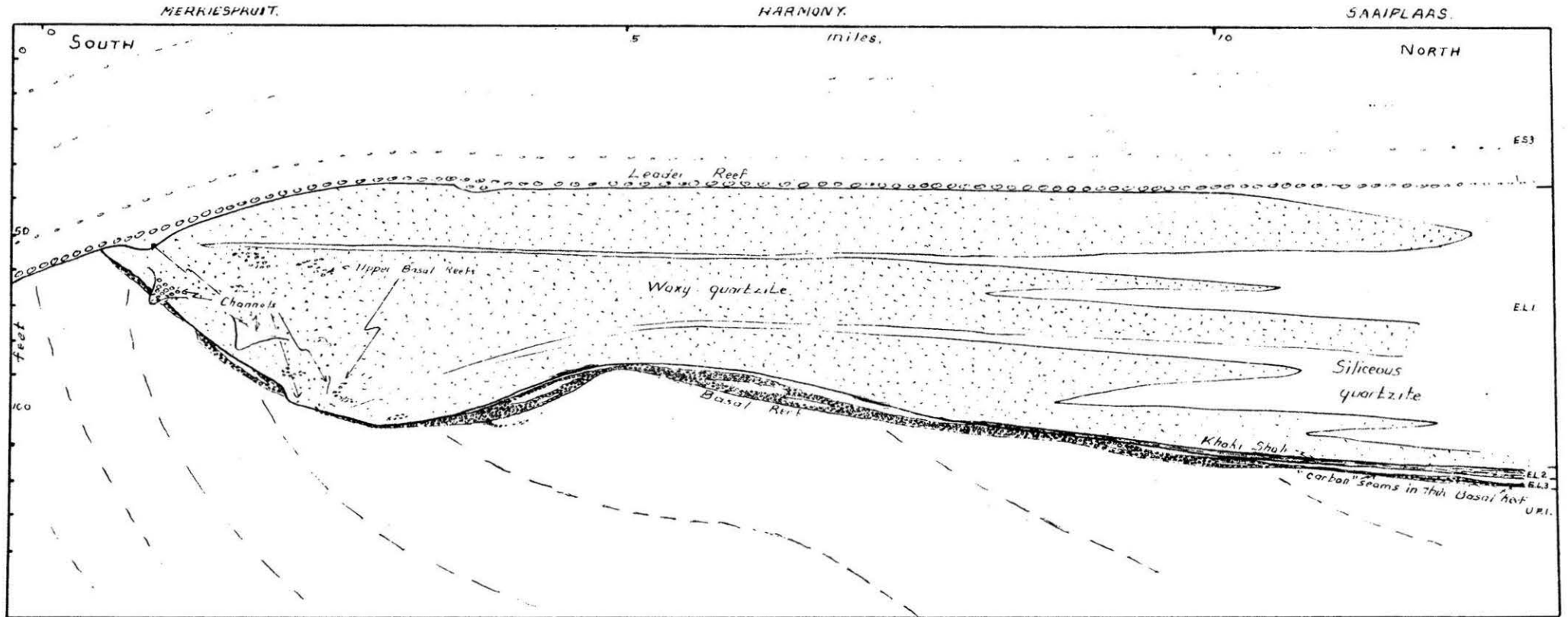


Fig.3.

Diagrammatic profile of Upper Bird Reefs, from Merriespruit to Saaiplaas, O.F.S.

are, however, remarkable for their relatively high content of uranium-bearing minerals.

The quartzite near the top of zone U.F.4 is siliceous, the change upwards being gradational from the argillaceous, brownish-grey, gritty quartzite that predominates toward the base.

The grit beds of zones U.F.1 and U.F.2 are characterised by scattered black, angular granules of chert.

The quartzite of the Upper Footwall beds is variously speckled and siliceous. The details of each bed is presented on plate A and Table IV.

A variable thickness of Footwall Beds have been eroded prior to the deposition of the Basal Reef. In plate B, one can clearly see that the sediments overlies the Footwall beds disconformably.

B. ZONES E.L.3 TO E.L.1 AND E.S.3 TO E.S.2.

(See bore-hole columns in plates C, E and F).

(1) The Basal Reef (Zone E.L.3).

The Basal Reef and the quartzite between the Khaki Shale and the Basal Reef has been given the zone-symbol E.L.3 by Borchers and White (1943, p.143).

In the extreme south of the Orange Free State Gold-field the Basal Reef is a well-developed conglomerate of the type that would be classified by Pettijohn (1949, p.207) as oligomictic. It is characterized in this area by the rarity of carbon seams. From the Harmony Mine northwards the reef decreases in thickness and carbon seams become more prominent. The "carbon seam" type of reef is characteristic of the Saaiplaas mine. (See fig. 3).

The Basal Reef ranges in thickness from zero to more than ten feet. Where its maximum development is attained, the Basal Reef consists of several conglomerate bands separated by lenses of quartzite. The quartzite is similar in appearance and in bedding structures to the footwall quartzite, but the

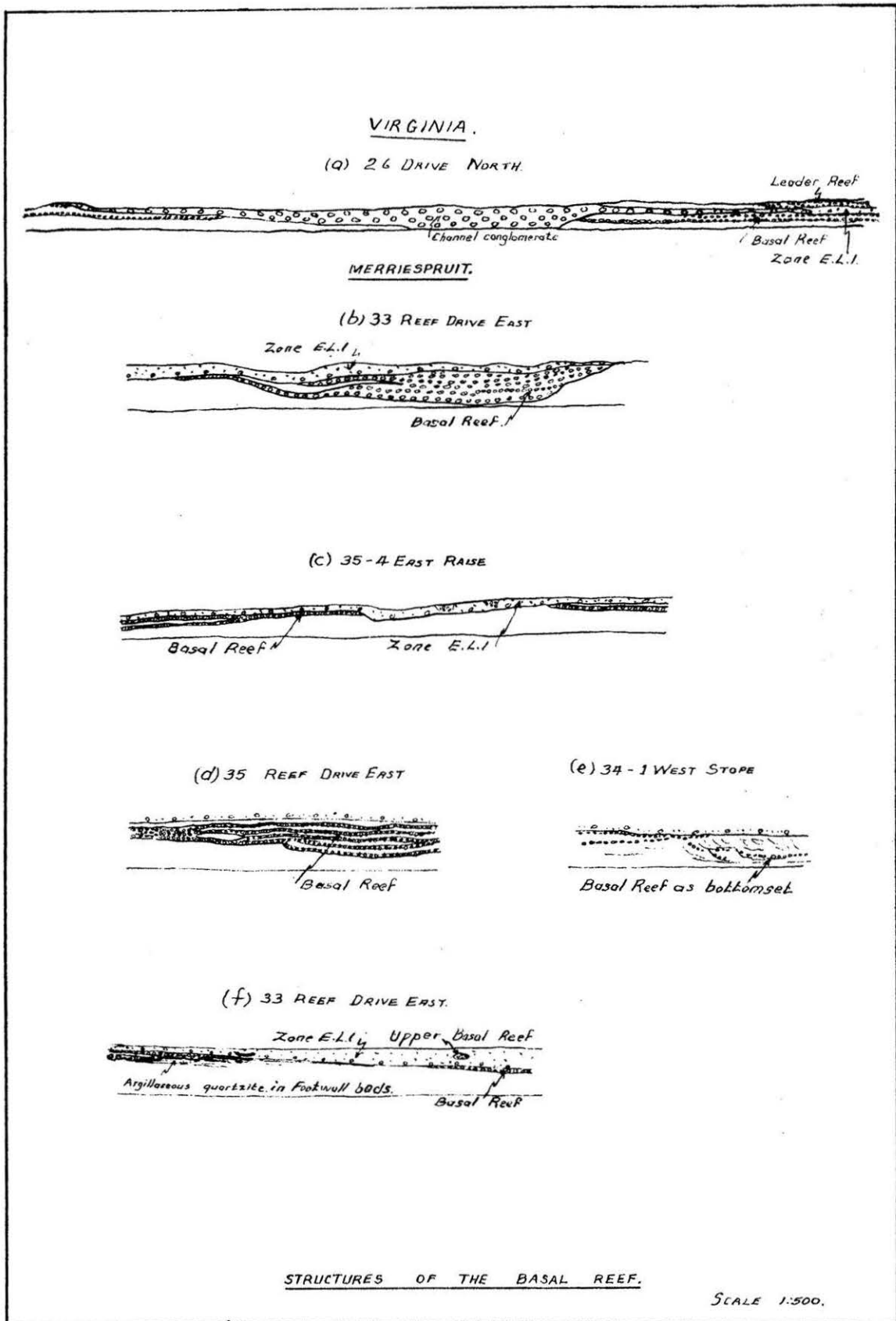


Fig. 4.

Sedimentary structures involving the Basal Reef.



beds with the Main Reef Group of conglomerates is fairly certain.

The of zone L.F.2 is formed by the small-pebble conglomerate beds of the Ada May Reef. The conglomerate consists mainly of quartz pebbles and some bands are well-mineralised. Individual bands are, however, less than a foot in thickness and alternate with quartzite. The conglomerate is not sharply demarcated from quartzite. In the Free State this conglomerate is not auriferous. The lower contact of zone L.F.2 is sharp, but there is no change in the characteristics of the quartzite below and between the beds of conglomerate. The even thickness of the Main Reef Footwall quartzite in the central Free State Gold-fields indicate that there is no disconformity at the base of the Ada May Reef. Bore-holes C.B.1 and E.X.1 to the east and south of Merriespruit Mine respectively, have intersected progressively smaller thicknesses of this quartzite. There is, therefore, fairly strong evidence that a disconformity exists near the margin of the basin of deposition at this horizon. This is not, however, accompanied by a change in the character of the Ada May Reef.

At about 25 feet from the base of zone L.F.2 there are small-pebble conglomerates and coarse grits that contain a remarkable amount of silicified quartz-porphyry pebbles. The equivalent horizon in the Klerksdorp Area was not recognised by Sadie, but Baumbach (unpublished logs) described a comparable horizon in bore-hole T.L.6 on Klerksdorp Townlands as containing "igneous" pebbles.

At about 150 feet from the base of zone L.F.2, small-pebble conglomerates and coarse grits again occur, in which pebbles of chert are more abundant than any other pebble constituent. This bed, the Chert Marker, has been used as a key bed both in the Orange Free State and in the Klerksdorp Gold-fields.

A similar cycle of sedimentation to that which produced

the sequence of quartzite and grit up to the Chert Marker has been repeated in the sediments occurring towards the top of this zone.

Zone L.F.1 begins with thin grit and small-pebble conglomerate bands correlated with the Commonage Reef in the Klerksdorp Area. In the cores of the three bore-holes available, the Commonage Reef zone is no more prominent than any of the succeeding coarse members of zone L.F. 1. Pebbles of black chert are conspicuous but although chert is a common pebble constituent, it is subordinate to quartz. These coarse constituents remain fairly similar in composition throughout zone L.F.1 except that a flinty chert becomes prominent high up in the succession (see plate A) and that the quartz pebbles are predominant in the uppermost small-pebble conglomerate beds.

The quartzite, although similar to that in zone L.F.2, is mainly coarse-grained and contains grains of chert in approximately the same proportion as in the grit members.

Grains and pebbles of red jasper occur in the core of bore-hole E.X.1 above the Commonage Reef and persist in the remainder of the Footwall beds.

(3) The Middle Footwall Beds. (Zones M.F.3, M.F.2 and M.F.1)

The Middle Footwall beds are the most difficult to subdivide as they contain thick accumulations of dull, somewhat argillaceous quartzite. Where they change into finer- or coarser-grained beds, the change is gradational. Two beds of very light-grey pure quartzite are the most easily recognizable. They have locally been called the Lower and Upper White bands.

The quartzite of zone M.F.3 is mainly dull and somewhat argillaceous, and terminate with the siliceous quartzite bed of the Lower White band.

The variations in the quartzite in Zone M.F.2 is greater than in zone M.F.3, there being alternations of dull, argillaceous and light, siliceous bands. Narrow lenticular beds of

grit are also present. Grit bands about 175 feet from the base of zone M.F.2 have been correlated by Feringa with the Livingstone-Johnstone reefs. (Feringa 1954, p.14). Examination of detailed bore-hole logs reveals that the grit beds change in facies in an easterly direction to quartzite. (Plate B, bore-holes M.O.2, M.2, M.1 and C.A. 1). It is possible that this change also occurs in a southerly direction, because bore-hole W.N.1 has no grit bands in the relevant position.

The Upper White band forms the base of zone M.F.1 and is succeeded by coarse argillaceous quartzite. In some intersections this contact is sharp, but in many it is gradational. The same can be said of the contact of the argillaceous quartzite with the Intermediate Reefs.

(4) The Upper Footwall Beds (Zones U.F.4 to 1).

The Intermediate Reefs at the base are followed by quartzite containing layers of grit and then by speckled, siliceous quartzite.

The zonal subdivision employed by geologists of the Anglo-American Corporation in the Free State differs from that of Baumbach in that they class the Intermediate Reefs as zone M.F.1 and Baumbach's zone M.F.1 as zone M.F.2, etc. The divisions for the remainder of the Upper Footwall are the same in both schemes.

The Intermediate Reefs comprise narrow grit and small-pebble conglomerate bands intercalated with variable thicknesses of argillaceous, brownish-grey and siliceous, grey quartzite. The pebbles are poorly sorted. They consist, amongst others, of rounded and subangular quartz, subangular and tabular black chert, grey and green chert, irregularly shaped yellow metamorphosed shale and green quartzite. A few pebbles of silicified quartz-porphyry, red jasper and blue opalescent quartz have also been noticed. Some of the conglomerate bands contain a fair amount of pyrite. The gold tenor is very low, the concentration rarely exceeding 1 dwt. per ton. The reefs

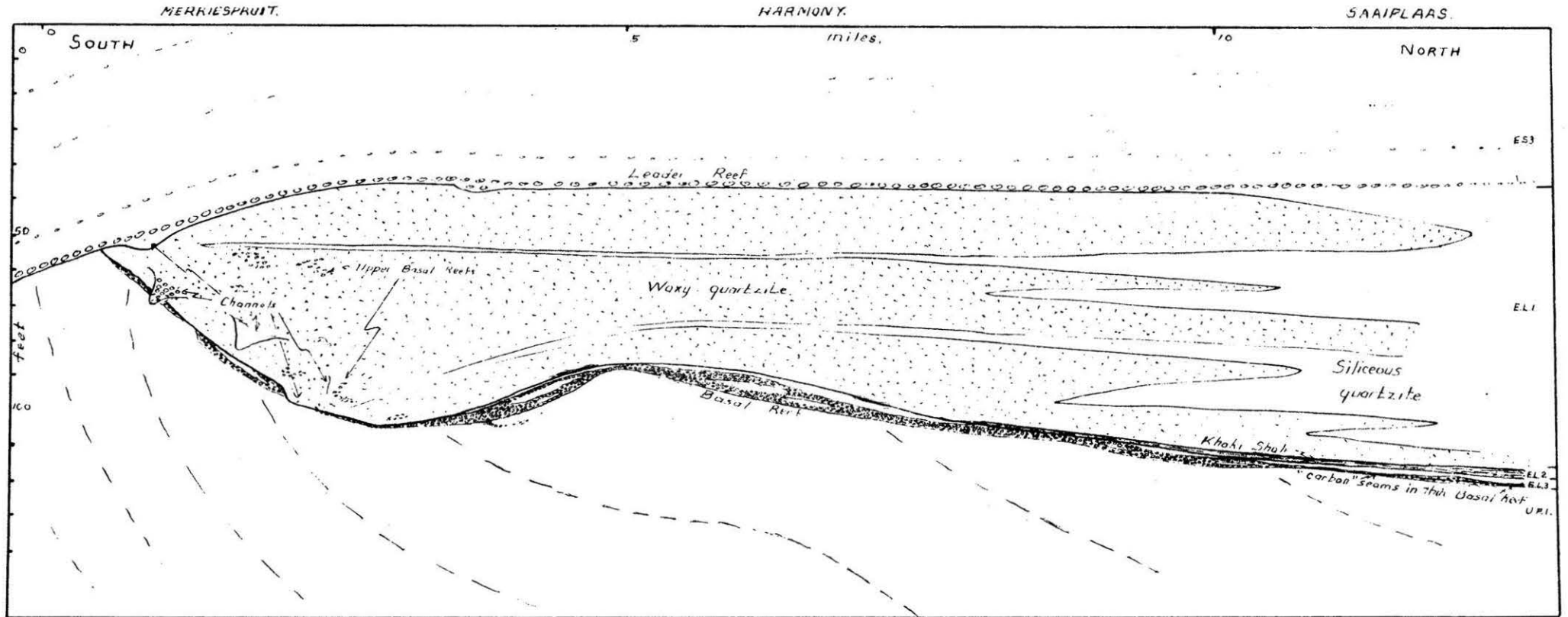


Fig.3.

Diagrammatic profile of Upper Bird Reefs, from Merriespruit to Saaiplaas, O.F.S.

are, however, remarkable for their relatively high content of uranium-bearing minerals.

The quartzite near the top of zone U.F.4 is siliceous, the change upwards being gradational from the argillaceous, brownish-grey, gritty quartzite that predominates toward the base.

The grit beds of zones U.F.1 and U.F.2 are characterised by scattered black, angular granules of chert.

The quartzite of the Upper Footwall beds is variously speckled and siliceous. The details of each bed is presented on plate A and Table IV.

A variable thickness of Footwall Beds have been eroded prior to the deposition of the Basal Reef. In plate B, one can clearly see that the sediments overlies the Footwall beds disconformably.

B. ZONES E.L.3 TO E.L.1 AND E.S.3 TO E.S.2.

(See bore-hole columns in plates C, E and F).

(1) The Basal Reef (Zone E.L.3).

The Basal Reef and the quartzite between the Khaki Shale and the Basal Reef has been given the zone-symbol E.L.3 by Borchers and White (1943, p.143).

In the extreme south of the Orange Free State Gold-field the Basal Reef is a well-developed conglomerate of the type that would be classified by Pettijohn (1949, p.207) as oligomictic. It is characterized in this area by the rarity of carbon seams. From the Harmony Mine northwards the reef decreases in thickness and carbon seams become more prominent. The "carbon seam" type of reef is characteristic of the Saaiplaas mine. (See fig. 3).

The Basal Reef ranges in thickness from zero to more than ten feet. Where its maximum development is attained, the Basal Reef consists of several conglomerate bands separated by lenses of quartzite. The quartzite is similar in appearance and in bedding structures to the footwall quartzite, but the

C H A P T E R IV.

THE STRATIGRAPHY OF THE KIMBERLEY - ELSBURG SERIES.

A. THE KIMBERLEY STAGE.

(See bore-hole columns, plates E, F, and G.)

An impure yellow-grey quartzite, abundance of conglomerate beds and a number of disconformities are general characteristics of this stage.

The general sequence of the strata of this stage is shown in plate A.

Mellor (1915, p.30) chose the lower contact of the Kimberley Shale as the base of the Kimberley - Elsburg Series because he could not find any signs of a disconformity at the upper contact of this shale on the Central and West Rand and because the Kimberley Shale was usually associated with the Kimberley Reefs.

The symbols proposed by Feringa (1954, p.51) have been used as these lend themselves well to application in the southern area of the Free State Gold-field.

Localised lagoonal fluvial and estuarine deposits occur in this stage and will be described in detail.

(1) The Upper Shale Marker (Zone E.S.1).

In the two mines studied, the Upper Shale Marker, as this zone is called in the Orange Free State, has been encountered only in the vicinity of No. 1 Shaft at Virginia Mine. It is the most reliable marker in the Upper Division of the Witwatersrand System and is correlated with the Kimberley Shale of the Central Rand with reasonable certainty. On account of the overlap of the "B" Reef and owing to the fact that coarse sediments were deposited close to the original shore-line, this zone thins out from over 70 feet in the north-western corner of the Harmony mine to about 7 feet at Virginia, No.1 Shaft. Before Virginia No. 2 Shaft is reached, the zone has petered out. The isopach map (fig. 7, Chapter V) indicates the approximate limit of this zone.

The Upper Shale Marker is a phyllitic, highly arenaceous shale alternating with laminae of phyllite and argillaceous quartzite. Slickensided slip-planes parallel to the bedding are common in the phyllite. The predominant minerals are quartz, sericite and some pyrophyllite. Accessory minerals are zircon, rutile, tourmaline and leucoxene. A few small laths of chloritoid cut across the schistosity and in one case shreds of sericite have been pushed out of the way by the force of crystallisation of the chloritoid. Rutile is not so abundant that it may be termed characteristic of this bed. (section No. 25).

Lenticular slickensided quartz veins occur sporadically on the surface between the Upper Shale Marker and the "B" Reef.

(2) The Lower Kimberley Substage (Zones L.K.3 to L.K.1)

This substage, which is the equivalent of zones E.C.3 and E.C.4 of Borchers and White, is divided into three zones, the boundaries of which in some localities, is somewhat arbitrary.

(a) Zone L.K.3.

The "B" Reef lies at the base of this zone, or is separated from the base by a few inches of fairly pure quartzite. The reef is a zone of polymictic conglomerate beds and thin intercalations of quartzite. Closely-packed pebbles form the thickest bands near the base, whereas loosely-packed pebbles occur in the uppermost bands. The pebbles are poorly sorted, many are poorly rounded and have a variety of shapes. Some of the bands contain an abundance of yellow, partly silicified sericitic shale pebbles. Many of these are lath-shaped or discoidal, others are compressed between harder pebbles. The quartzitic matrix is less sericitic than the quartzite overlying the "B" Reef.

The mineralisation is sporadic. Fairly large rounded grains of pyrite (up to 3/16 inch in diameter) and "carbon" specks can be seen in the gold-bearing portions of the reef, these being usually found near the base. It is significant that the mineralised portions of the reef are oligomictic in character.

The meagre evidence obtained from bore-hole cores seems to indicate that the "B" Reef is well-developed in a wide zone running in a north-north-westerly direction from the common boundary point of the three mines bordering on the Sand River. The Reef becomes less robust to the north and south of this zone, and contains a higher proportion of intercalated quartzite. The "B" Reef is probably not developed in the south-western part of the Merriespruit Mine. In bore-hole K.A.3 the Reef is so thin that it could only be distinguished positively by means of its radiometric anomaly, the quartzites above and below being indistinguishable. In bore-holes M.O.2 and M.O.3 the "B" Reef cannot be identified with certainty.

In the south-eastern part of the Merriespruit Mine, the "B" Reef has promising gold values and the disconformity below the reef is more pronounced than elsewhere.

The lenses of small-pebble conglomerate and grit overlying the "B" Reef is similar in composition to the reef itself. The quartzite in which they are found is similar to that of zone E.S.2. The tendency for grains to be orientated is not so strong and the sorting is poorer than that of zone E.S. 2. (sections 15, 26 and 27.)

Up to about 30 feet from the base of the "B" Reef the texture becomes progressively finer. At this elevation in the stratigraphical column a set of lenticular beds of non-auriferous polymictic conglomerate occur.

A light yellow-grey quartzite containing large scattered black and yellow granules rests on this conglomerate. The upper part of this quartzite is characterised by scattered pebbles, consisting mostly of black quartz and chert.

Another set of lenticular polymictic conglomerate beds follows on the pebbly quartzite and marks the end of zone L.K.3.

(b) Zone L.K.2.

This zone is composed of highly sericitic quartzite. The lower boundary of this zone may be either sharp or ill-defined.



It varies from medium-grained to coarse-grained and is yellow-brown. The quartz grains seldom touch each other and the edges of the grains are embayed, owing to replacements by sericitic material. (photomicrograph 1, section 28). Various aggregates of chlorite, sericite, chert and other minerals as described in Chapter II and isolated grains of chert and microcrystalline quartz are encountered in the matrix. Chlorite is only locally present. Small acicular crystals of rutile are common. Coloured grains are inconspicuous in the hand specimen.

Lenses of conglomerate or grit are rare in this zone. In the upper section the quartzite contains isolated rounded pebbles of quartz.

(c) Zone L.K.1.

Lenticular polymictic beds of conglomerate occur at the base of this zone. It is enclosed and succeeded by a yellowish grey, gritty quartzite containing coarse-grained black and yellow granules of chert and shale. (section 29 )

Layers of grit mark the coarsest phases of this quartzite.

(3) The Middle Kimberley Substage (Zones M.K.4 - M.K.1)

The base of this substage is demarcated by the disconformity underlying the "Big Pebble" Reef.

Feringa (1954, p.51) has subdivided this stage into four zones. Correlation of data is very difficult, because the average thickness of this substage intersected by the bore-holes on the Virginia and Merriespruit Mines is only 20 feet and 9 feet respectively, and especially as all the zones are rarely encountered in a single bore-hole. The equivalent of this substage in the scheme of Borchers and White is zone E.C.2.

A feature of this substage is the coarse texture of the quartzite and the oligomictic large-pebble conglomerate beds.

(a) The Big Pebble Reef (Zone M.K.4).

Large, well-rounded pebbles 1 inch to 4 inches in

average diameter, chiefly composed of milky white quartz, but also of flint and dark chert, lie scattered in a matrix of light-grey quartzite with very little argillaceous material. The quartz grains are closely packed and sub-angular. Many are "welded" together, the contacts being sutured. Black, impure grains of chert and some concentrations of sericite and rutile give rise to coloured specks. (section 30.)

There are one or more bands of conglomerate. Quartzite, similar to that occurring in the matrix, may separate the conglomerate locally from the underlying disconformity. The contact between this quartzite and the quartzite of zone L.K.3 is fairly sharp, but the two rock-types cannot easily be split on the plane of the contact.

Pyrite is rare, and occurs in isolated patches at the base and in the reef itself. Gold is associated with the mineralised patches. The only economic concentration of gold was in bore-hole V.Z.3, which assayed 3.25 dwts. over a width of 46.4 inches. The gold content is low, but consistent in the south-eastern part of the Merriespruit area.

The maximum pebble dimensions of the conglomerate beds of the Middle Kimberley substage decreases in a south-westerly direction from approximately 4 inches to 2 inches with the result that the importance of the "Big Pebble Reef" as a marker bed is lost.

The thickness of this zone ranges from zero to 30 feet.

(b) Zone M.K.3.

This zone consists of a sericitic, yellow-grey quartzite. The coloured grains are similar to those in the previous zone. Thin lenses of rounded quartz-pebble conglomerate are present.

(c) Zone M.K.2.

Zone M.K.2 is largely conglomeratic. The matrix is a little more argillaceous than that of zone M.K.4. Well-rounded pebbles averaging 2 inches in diameter occur in this zone. These were first described by Feringa (1954 p.40), who states

that they are the product of the reworking of unconsolidated sediments. They are well-mineralised and contain rounded grains of carbon. This reef can easily be confused with the "A" Reef. Encouraging, but no payable gold values have been obtained from the reef, which must occur in limited areas only, as it is recognised in the core of only a few bore-holes. The best example was intersected in bore-hole Z.V.1, 9000 feet north of Virginia.

(d) Zone M.K.1

A medium-grained grey quartzite which has a very slight yellow tinge forms the main feature of this zone. Grains of black chert and yellow silicified shale form scattered coloured specks in the quartzite. Thin beds of siliceous quartzite and lenses of loosely-packed large-pebble conglomerate are interstratified with the quartzite.

(4) The Upper Kimberley Substage (Zones U.K.3 - 1).

The substage is divided, according to the scheme proposed by Feringa into three zones, as indicated in Table I and Plate A.

They correspond to the Zones T.I and E.C.I in the scheme of Borchers and White.

A disconformity below the "A" Reef has been proved in the Odendaalsrus area of the Orange Free State Gold-fields (Feringa 1954, p.42) and also in the Virginia-Merriespruit area (Feringa 1954, p.54.)

The correlation within this substage, again, must be considered as tentative. The beds are discontinuous and the average thickness, calculated from bore-hole data, is only 6 feet. The short distance between disconformities indicate that shallow-water conditions prevailed when these sediments were being formed.

Over large areas the Upper Kimberley Stage has been eroded away prior to deposition of the Elsburg Stages.

(a) The "A" Reef (Zone U.K.3).

The conglomerate which constitutes this zone is known

as the "A" Reef. It varies in thickness from a single string of pebbles to 2 feet 7 inches and consists of well-rounded pebbles, the average diameter of which is  $\frac{1}{2}$  inch. The pebbles consist of clear, dark, smoky and white quartz, the quartz being exceptionally well-rounded. Some quartz pebbles are dark-rimmed. Black and dark-grey chert pebbles occur in minor amounts. Pebbles about  $\frac{1}{4}$  inch in diameter occur in portions of the conglomerate. The pebbles are compact and well-sorted. The matrix is yellow and sericitic, resembling the quartzite above the conglomerate. In the Virginia No. 1 Shaft, the matrix of the Reef contains abundant sericite and bright orange-yellow specks. The pebbles are coated with sericite and as this coating forms a surface of weakness, the rock tends to break around some of the pebbles in the reef.

As certain bore-holes (e.g. M.1) intersected more than one band of conglomerate in the "A" Reef horizon, it is possible that the reef, in some areas, is multi-banded.

Pyrite is abundant, rounded in shape and less than 1 mm. in size. Disseminated thucolite has discoloured the matrix. The values obtained from the few intersections indicate that the ratio of uraninite to gold will be high. A hand specimen taken adjacent to a sample which had a gold value of 3 dwts. per ton, gave an appreciable count on a Geiger-Muller Counter.

The "A" Reef is confined to the area where the discontinuity at the base of the Elsburg Stage has not cut down appreciably into the underlying sediments. The Reef is poorly developed towards the south-east. It is potentially an economic reef of the patchy type, although so far there are no payable bore-hole intersections of this Reef in the Virginia-Merriespruit area. The nearest payable intersection of the "A" Reef is that of bore-hole Z.V.1.

(b) Zone U.K.2.

The quartzite constituting this zone is light-grey and has a definite yellow tinge, which varies according to the

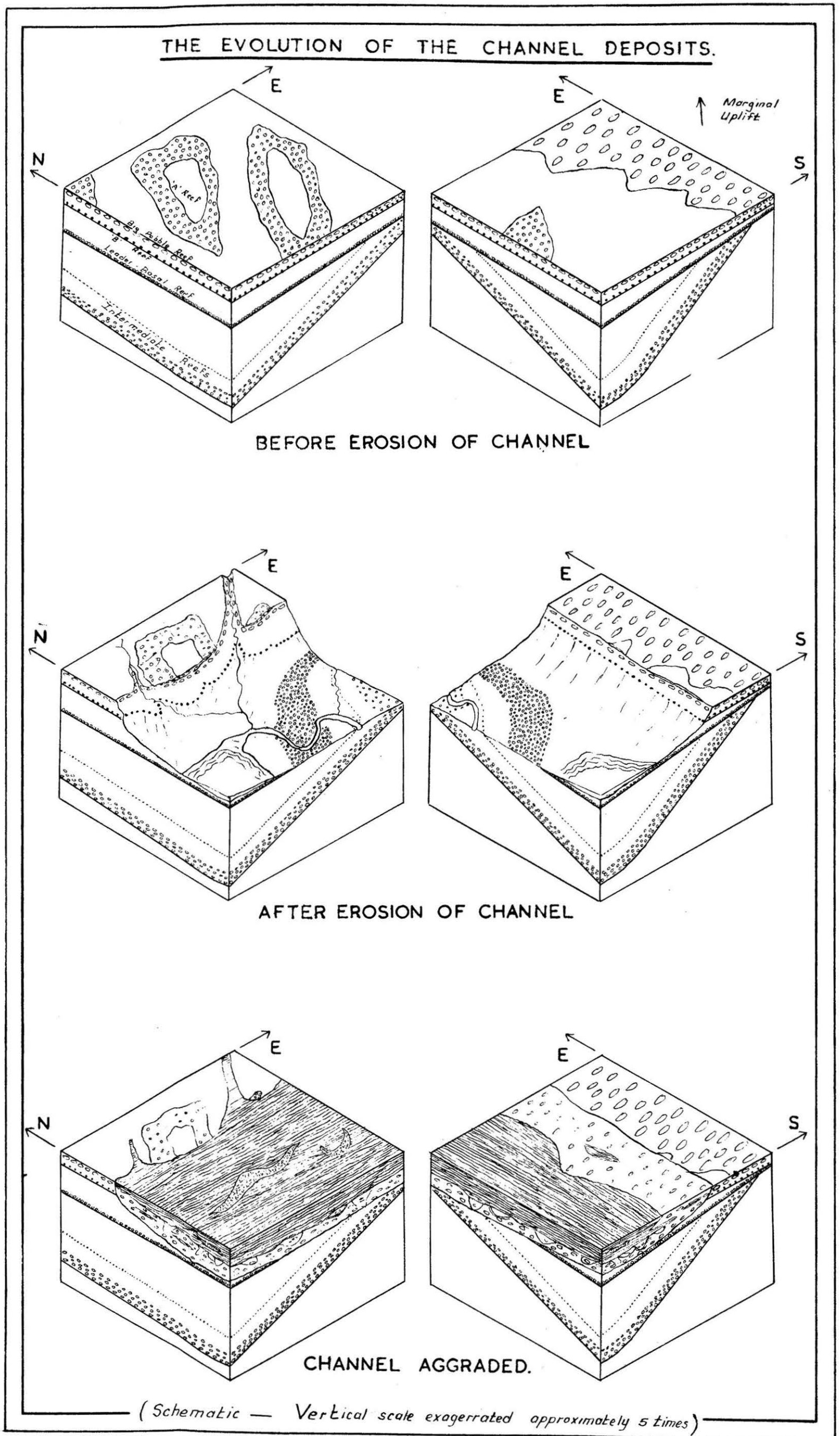


Fig. 5.

amount of sericite in the rock. The grains are packed in such a way that they often touch, but there is space between grains for sericite, chlorite and fine-grained quartz to be present. Concentrations of sericite, chert, acicular yellow rutile and leucoxene give rise to coloured specks which are fairly evenly distributed through the rock. Some of the grains are elongated parallel to the bedding (section 30 ) Large granules are sparsely scattered through the quartzite. Pyritic stringers are present. Strata of argillaceous quartzite less than 5 inches in thickness, lie at intervals of 2 to 3 feet. No current-bedding has been noticed in the bore-hole cores.(section 32.)

(c) Zone U.K.1.

An upper small-pebble conglomerate containing loosely packed pebbles up to  $1\frac{1}{2}$  inches in diameter, has been intersected in bore-hole K.A.2. Feringa 1954 (p.38) has called the correlate of this reef the "A" Reef Leader. The matrix of this conglomerate is of similar composition to the quartzite of Zone U.K.2. The reef is poorly mineralised and the gold content is low.

A stratum of highly argillaceous quartzite, up to 6" thick, appears immediately below the lowest bed of the Elsburg Stage, in bore-holes M.O.1, K.A.2, K.A.3 and S.E.1. This stratum appears to overlie different beds of the Kimberley Stage. Should this bed be continuous, it might represent a fossil soil.

(5) "Channel" Deposits of Kimberley Age.

A wide valley, striking east-west across the central part of the Merriespruit Mine, was eroded into the underlying formations and subsequently filled in with a wide range of sediments. (See fig. 5).

According to a tentative correlation set out in plate G, the earliest sediments formed after the "channel" deposits belong to zone M.K. 1. The correlations within the Middle and

Upper Kimberley Stages are tentative, but one can establish an upper limit to the possible age of the "channel" deposits as pre-V.S.5, by the fact that the deposits underlie the discontinuity at the base of the Elsburg Stage.

In the most easterly intersection of these deposits on the Merriespruit Mine, that of bore-hole M.2, the thickness of the channel deposit, corrected for intrusives, is 245 feet and in No. 1 Shaft, the most westerly intersection, the thickness is 105 feet. An extensive portion of the Leader Basal Reef to the east of Merriespruit No. 2 Shaft has been scoured away (see fig. 5, plates B and I.)

The basal portion of the deposit consists of numerous small channels, partly filled with conglomerate and partly with siliceous, light-grey quartzite. Younger channels have been cut into the first-formed ones with the result that a profile transverse to the general direction of elongation of the channels reveals a cross-bedded structure on a large scale. The small channels trend in the same direction as the main valley. They give the base of the "channel" deposit a scalloped outline.

Lenticular bodies of all grades of particle size from sand to boulder dimensions are represented, reflecting the variable competencies of the stream-currents.

The quartzite is usually siliceous. The pebbles in the conglomerate lenses are rounded. They consist mainly of quartz, chert and a few silicified shale pebbles. Mineralisation is usually very poor, although pyritic stringers appear locally. Occasional concentrations of gold have been found near the base of these deposits. A notable peculiarity of some of the quartzite is the presence of sparsely scattered, rounded, dark pebbles of quartz.

Lenticular shale beds appear high up in the succession, and some of the upper channels are lined with thin beds of shale. Arenaceous shale is common high up in the succession and is predominant in the upper half. Lenticular bodies of poorly mineralised conglomerate, carrying a fair amount of silicified shale

pebbles, were found near the base of the shale in Merriespruit No. 2 Shaft. At this horizon, scattered boulders of quartz lie in the shale or in argillaceous quartzite.

The shale is well-bedded, somewhat graded and arenaceous. The bedding planes part easily, and has smooth, somewhat polished surfaces. Minor slickensiding appears on some of these planes. The shale breaks into slabs varying in thickness from less than an inch to over a foot. Small penecontemporaneous slips, folds and local abnormal inclinations of bedding are features of this shale. Tongues and lenses of fine-grained silty quartzite are irregularly spaced. The arenaceous shale terminates suddenly upward, and forms the upper contact in the majority of the bore-holes that intersect the channel deposits. In bore-hole S.E.2 conglomerate, quartzite and sharply defined tongues and lenses of shale dipping at variable angles indicate a repetition of the quartzite-conglomerate facies of the channel in the upper portion of the deposits. There is a possibility that it is this facies that has been intersected above the shale in bore-holes S.E.1 and K.A.2 (plate G.)

A subsidiary channel has been intersected in bore-hole V.4.

In a thin section of the arenaceous shale (section 31), there are alternating laminae containing particles in the size range of silt and mud. Quartz grains are most common in the coarse-grained, whereas flakes of sericitic material are more abundant in the fine-grained laminae. Large flakes of a sericitic mineral (probably pyrophyllite) are orientated parallel to the bedding planes and are partially altered to chlorite.

#### B. THE ELSBURG STAGE (ZONES V.S.5 - V.S.1).

There is a marked difference between the quartzite of the Elsburg Stage, and that of the underlying Kimberley Stage. The feature that strikes an observer at once is that the yellowish-brown tinge is absent in the quartzite of the Elsburg Stage. Inspection of thin sections reveals that this is so because the sericitic minerals form a smaller proportion in the matrix compared with quartzite of the



Kimberley Stage. (Compare sections 32 and 33, only 1 ft. difference in elevation).

The quartzite is strongly current-bedded and is also ripple-marked on some bedding-planes. Bedding-planes are well-defined and are usually accentuated by thin layers of argillaceous quartzite, which are found at intervals of about two and three feet throughout the quartzite. The current-bedding is exhibited by laminae of varying grain-size and varying amounts of impurities. There are pyritic stringers in some of these laminae.

The Elsburg Stage is divided into five zones as indicated in Table I and Plate A.

(1) Zone V.S.5.

After this zone has been intersected in the No. 2 Shaft of Merriespruit, it was established that two entirely different varieties of conglomerate are developed in it. This intersection may be taken as the type section of zone V.S.5: a compact, well-rounded quartz-pebble conglomerate having an average thickness of 24 inches immediately overlies the "channel" shale. After the deposition of the conglomerate, some of the mud has been squeezed in between the lowermost pebbles. The pebbles are mostly constituted of clear to grey, smoky quartz, some being dark-rimmed, and grey quartzite. A few pebbles of chert and green and yellow sericitic quartzite also occur in this reef. The colour of the quartzitic matrix is grey or dark-grey. The reef is well-mineralised and the pyrite, less than  $\frac{1}{8}$  inch in longest dimension, has a dull lustre. Thucolite forms very small, disseminated, dust-like specks in the matrix. A layer of quartzite, 1 inch thick, splits the reef into two bands along the westerly section of the shaft. The average gold value of the reef in the shaft is 6.8 dwts. per ton, and the uraninite-gold ratio is high.

A bed of quartzite ranging from 9 to 12 inches in thickness separates the lower conglomerate from the upper and there is no parting which could indicate an hiatus between the conglomerate and the quartzite. As this quartzite is essentially similar to

the quartzite of zone V.S.4, the detailed description of the quartzite will not be given here. The upper contact is also conformable, the coarse current-bedded laminae near the top of the quartzite carrying granules and small pebbles typical of the overlying conglomerate. The currents responsible for the current-bedding flowed from west to east.

The upper conglomerate, the one usually known as the V.S.5 Conglomerate, has a thickness of 5 to 7 feet in the shaft intersection. The pebbles are loosely packed, poorly sorted and range from sub-angular to sub-rounded. Numerous milky-white pebbles of quartz contrast with the dark-grey quartzitic matrix, and pebbles of clear and blue opalescent, quartzite, dark-grey chert, pale-yellow silicified shale and quartz-porphry, give this reef its characteristic appearance. Many chert and shale pebbles are tabular and wedge-shaped, and some shale pebbles are compressed between harder pebbles. The matrix of the conglomerate is formed of small pebbles, granules and grains of quartz and chert, and aggregates of chert, chlorite, sericite and rutile in varying proportions. The interstitial material is an aggregate of chlorite, microcrystalline quartz and chert, small shreds of sericite and an opaque black dust. The grains are closely packed. Occasional sub-rounded grains of pyrite and rounded grains of zircon occur in the matrix. Pyrite also occurs in stringers. (sections 33 and 34.)

In bore-hole K.A.2, the pyrite is concentrated locally in a well-sorted section of the V.S.5 Conglomerate. This section occurs away from the contacts of the conglomerate and contains 2.35 dwts. gold over a sampled width of 4 inches.

In all the other intersections of the V.S.5 Conglomerate the gold values are negligible.

In the short interval of 10 feet an oligomictic, auriferous conglomerate and a polymictic non-auriferous conglomerate occur together, the former lying disconformably on "channel" shale. (The disconformity will be discussed in a later chapter.) The

The interesting point about these two conglomerates is that the former has most of the characteristics of a potentially economic gold-bearing reef, whereas the latter is typical of a non-auriferous conglomerate.

The lower conglomerate is lenticular. It was intersected in only 7 out of 18 bore-holes drilled on the Merriespruit Mine, and the reef has not been positively identified in the Virginia Mine, except as a layer of coarse grit in the intersection of No. 1 Shaft. Bore-hole Z.V.1, north of Virginia Mine (fig.9) passed through both these reefs as well as the "A" Reef. In 4 other bore-hole intersections on Merriespruit Mine, the horizon of this conglomerate was recognised as a layer of rounded quartz pebbles. The value obtained in the Merriespruit No. 2 Shaft intersection is the highest encountered in the two mines and in the surrounding area.

The lower conglomerate can be correlated with the "Gold Estates Leader" of the G.F. block. The correlation is based on the following criteria:-

- (a) The appearance of the reef agrees with Feringa's description of the "Gold Estates Leader". (1954, p.56).
- (b) The reef is overlain by the V.S.5 Conglomerate, which Feringa calls the "Elsburg Basal Grit."
- (c) The reef lies directly on the disconformity, which marks the base of the Elsburg Stages, in both the G.F. Block and in the Virginia-Merriespruit area.
- (d) It cannot be the "A" Reef as that reef had been eroded away south of bore-hole G.F.5 before the sediments of the Elsburg Stage were formed. (See the isopach map, fig. 9, in the next chapter.)
- (e) Bore-hole Z.V.1 has intersected the V.S.5 Conglomerate and also both the "Gold Estates Leader" and the "A" Reef.
- (f) The reef lies directly on "channel" shale, both in Merriespruit No. 2 Shaft and in bore-hole V.B.K.1 in the G.F. block. (Feringa 1954, p.58)

Feringa considers the narrow conglomerate underlying the Elsburg Basal Grit, followed by normal Kimberley formations in bore-hole G.F.5, to be the "A" Reef. Considered in the light of the succession revealed in the Merriespruit No. 2 Shaft intersection, the writer is of the opinion that the conglomerate is

not the "A" Reef, but the "Gold Estates Leader". Fortunately, this does not detract from Feringa's arguments concerning the age of the "Gold Estates Leader", and it must be concluded that the "Gold Estates Leader", and not the V.S.5 Conglomerate, forms the basal conglomerate of the Elsburg Stage.

The V.S. Conglomerate varies from a thin grit to a well-developed conglomerate 15 feet in thickness. The conglomerate is the widest and most robust in the western portion of the common boundary of the Virginia and Merriespruit Mines. On moving away from this area, one finds that it becomes thinner, develops more intercalated quartzite lenses and that the average size of the pebbles decreases. Some of the intercalated quartzite lenses are silicious, and resemble the quartzite of zone V.S.4, and others are argillaceous, dark-grey and densely speckled, containing small grains of the same composition as those described in the matrix of the V.S.5 Conglomerate. (section 34).

The lateral variation which this conglomerate reveals is illustrated in bore-hole M.O.3, in which zone V.S.5 was repeatedly intersected due to overfolding and faulting. It is interesting that in one case no conglomerate is developed, but the argillaceous, dark-grey type of quartzite is present.

Beds belonging to zone V.S.5 were not intersected in bore-holes M.2 and M.5, but it is possible that this zone is faulted out or that the core has been ground away as in bore-hole M.3. In bore-holes M.U.2, the V.S.5 Conglomerate is narrow and small-pebbled. North of the G.F. Block, in the Hennenman-Whites area, the V.S.5 exists as a poorly developed grit. It is, therefore, quite feasible that the V.S.5 Conglomerate is not developed in the southern area of the G.F. Block and in the eastern area of the Merriespruit Mine.

## (2) Zone V.S.4.

The quartzite mainly composing this zone is fine-grained, grey and siliceous, the grain-size varying from 0.1 to 0.3 mm. The finest-grained beds are very tough and break with a

subconchoidal fracture. Thin sections (section 2) reveal that the toughness is due to interlocking of the quartz grains except for occasional openings which were subsequently partly filled with a quartz cement.

Loosely packed grit beds occur a few feet above zone V.S.5 in bore-holes M.U.1 and S.M.1. A few inches of quartzite at the base of zone V.S.4 are often a dark-grey, and may be compared with the argillaceous quartzite of zone V.S.5. In fact, this dark quartzite might conceivably be considered as part of zone V.S.5.

The effect of pressure on bedding-planes in the V.S.4 quartzite has resulted in stylolites being developed. The change from zone V.S.4 to the overlying quartzite is gradual, and is especially difficult to establish near intrusives, where the rock is silicified.

(3) Zone V.S.2/3.

In the Welkom area the following subdivisions were recognised:-

Borchers and White, 1943, fig. 1 opp. p.134).

V.S.2 Ventersdorp dark-grey quartzite.

V.S.3 Ventersdorp alternating dark and light-grey quartzite.

V.S.3(a) Ventersdorp small-pebble agglomerate-conglomerate.

As there is no sharp distinction in this area between the various zones mentioned in Borchers' and White's paper, the zones have been grouped together as zone V.S.2/3.

A mineralised grit containing sub-rounded granules of quartz in a dark grey quartzitic matrix was intersected in bore-hole Z.V.1, north of Virginia, at a distance of 42 feet above the base of zone V.S.4. This is the only occurrence in the Virginia-Merriespruit area that can possibly be correlated with zone V.S.3(a).

The quartzite of zone V.S.4 gradually becomes coarser-grained and banded, the coarser bands being dark-grey. The

average grain size of zone V.S.2/3 is 0.3 mm.. A dark-grey, slightly argillaceous quartzite in zone V.S. 2/3 can be distinguished in the northern half of Merriespruit Mine and the western half of Virginia Mine. This zone is no doubt the equivalent of zone V.S.2 in the type area. The quartzite of zone V.S.2/3 grades into the quartzite of zone V.S.1. The thickness of this zone should, therefore, be regarded as approximate.

In the quartzite, sub-angular grains of quartz and isolated grains of chert are fairly tightly packed and are often interlocked. The matrix consists mainly of fine-grained quartz, and small shreds of chlorite and sericite. Segregations of chlorite and chert in the matrix are common, some containing a multitude of acicular rutile. Genuculated twins of the same mineral are also present. (section 35).

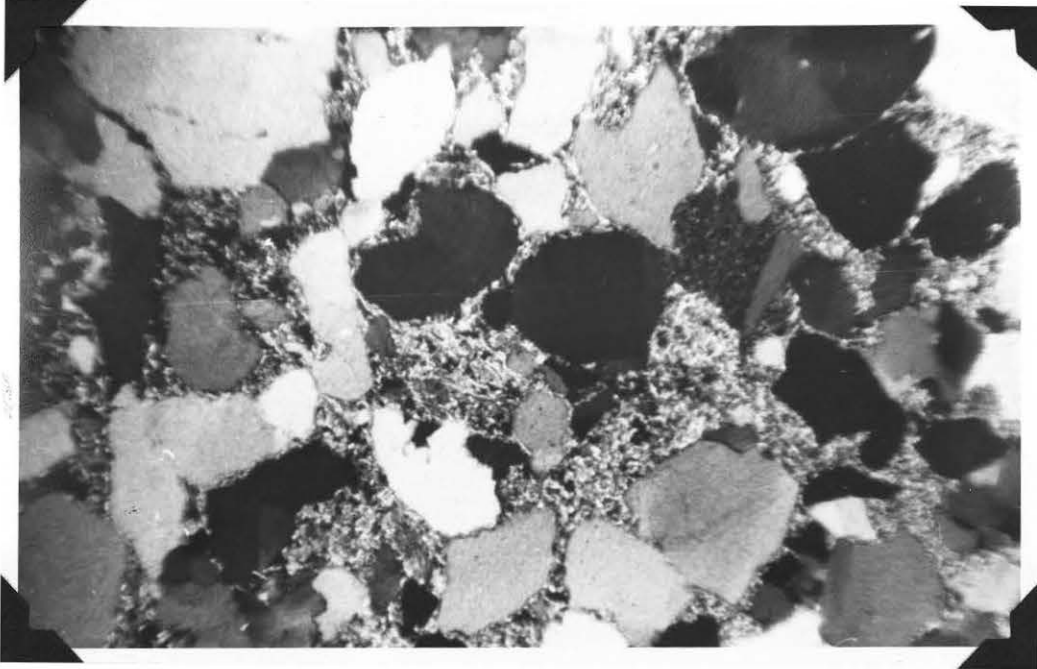
The argillaceous quartzite layers contain a larger amount of sericite and other minerals in the matrix.

A few thin beds of grit appear near the top of zone V.S.2/3.

#### (4) Zone V.S.1.

The base of this zone has been arbitrarily chosen as the lowermost well-developed bed of grit in a zone which is predominantly of a gritty nature. This zone is the equivalent, in the Virginia-Merriespruit area, of the so-called Ventersdorp agglomerate-conglomerate of zone V.S.1 described by Borchers and White (1943, p.137). Beds of grit increase in size and frequency up to about 80 feet from the base of this zone, where coarse grits and scattered small pebbles are encountered. As one proceeds towards the top of the column, several bands of coarse grit are encountered. The 145 feet of quartzite immediately preceding the V.S.1 conglomerate, is, however, not gritty. The zone is terminated by the V.S.1 Conglomerate, which appears at or close to the lower contact of the Ventersdorp Lava.

There are two interbedded varieties of quartzite in zone V.S.1. The first variety is identical with the quartzite of



Photomicrograph 7.

Quartzite, zone V.S.1. The matrix consists of finely divided sericite and chlorite. The dark spot in the matrix on the left is a concentration of chlorite containing very tiny needles of rutile. The sorting and rounding of the grains are much better than that of the subgreywacke in this zone (photomicrograph 2).

Crossed nicols (X 170)

Section 37.

zone V.S.2/3.(section 37, photomicrograph 7) The second variety can be considered as a subgreywacke, as defined by the American geologists (Krumbein and Sloss, 1953, p.132). Poorly sorted, sub-angular grains of quartz, chert and different varieties of silicified shale, hornfels and other metamorphic rocks are loosely packed in a matrix consisting of aggregates of quartz, chloritic and sericitic minerals, and a black dust. The grain-size varies from approximately 0.03 mm. to pebbles of over 2 cm. in longest diameter. Clusters of rutile crystals give rise to yellow specks. (section 36, photomicrograph 2). In hand specimen the quartzite is dark-grey, and contains some blue opalescent quartz grains. Grains of pyrite are angular and have crystal faces. The pyrite, together with leucoxene, is widely scattered throughout the matrix and is concentrated in sinuous stringers consisting of minerals commonly forming the matrix of the quartzite.

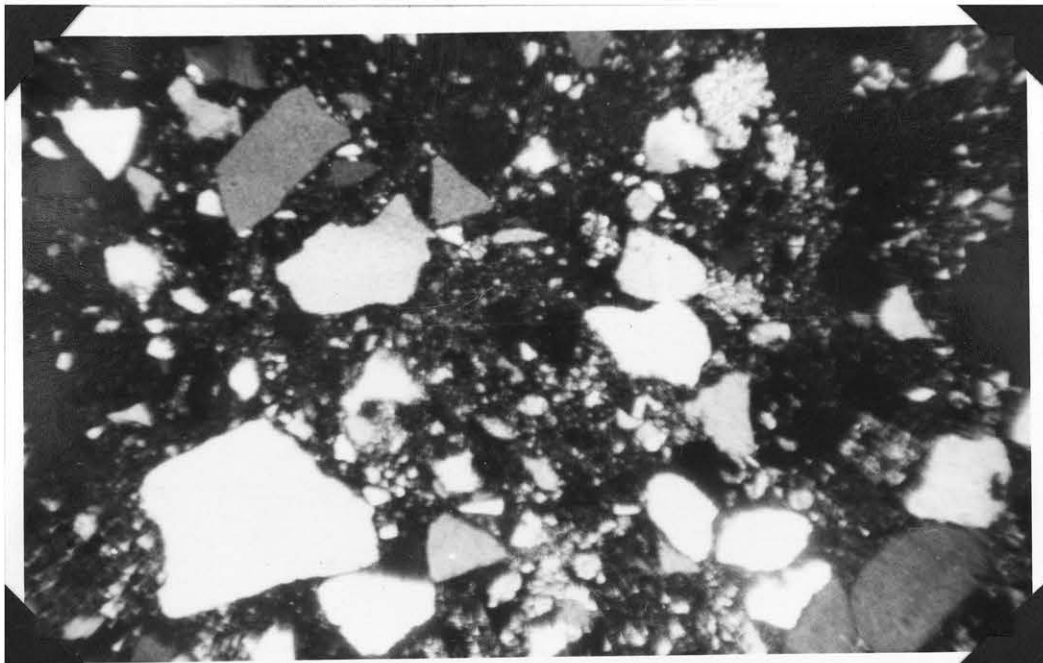
The pebbles in the grit bands are similar to those of zone V.S.5, and are the coarse equivalent of the second variety of quartzite described above. A fair amount of pyrite of average grain-size of 0.07 mm. are often found in the grit. The most robust development of grit and pebble bands occur in the southwestern area of Merriespruit.

The V.S.1 Conglomerate is very poorly sorted, consisting of pebbles up to 3 inches in longest direction. The pebble varieties are similar to that of zone V.S.5, but the pebbles are more angular. The matrix is dark and gritty. Bands of conglomerate are intercalated with a dark, gritty quartzite and grade laterally into grit and quartzite. The conglomerate is not auriferous.

It is possible that this conglomerate is the correlative of the Ventersdorp Contact Reef, in which case it should be considered as the basal conglomerate of the Ventersdorp System.

The quartzite between the conglomerate and the lava has a highly chloritic matrix containing a black dust, similar to the matrix of tuff beds of Ventersdorp age occurring to the west of





Photomicrograph 8.

Subgreywacke, zone V.S.1. Possibly tuffaceous, immediately underlying the Ventersdorp lava. The matrix consists of chlorite and a fine black dust. The grain in the upper right hand corner is completely chloritised.

Crossed nicols

(X 200)

Section 38.

the de Bron fault in the Merriespruit Mine. (section 38, photomicrograph 8)

The extremely coarse development of the sediments in zone V.S. 1, called the "Ventersdorp Basal Conglomerate" by Frost (1946, p.19) and the "agglomerate-conglomerate" by Borchers and White (1943, p.137) is not known from the Virginia-Merriespruit area. The development of grit and small-pebble conglomerate beds in zone V.S.1, however, becomes less robust in a direction away from the St. Helena Mine. The subgreywacke also loses its prominence and merges with the V.S.2/3 type of quartzite in the same direction.

As the composition of the "Ventersdorp Basal Conglomerate" is that of the rudaceous equivalent of a greywacke, the subgreywacke occurring as interfingering beds in the Virginia-Merriespruit area, could be considered as belonging to a facies of the Ventersdorp Basal Conglomerate further removed from the distributive province.

average grain size of zone V.S.2/3 is 0.3 mm.. A dark-grey, slightly argillaceous quartzite in zone V.S. 2/3 can be distinguished in the northern half of Merriespruit Mine and the western half of Virginia Mine. This zone is no doubt the equivalent of zone V.S.2 in the type area. The quartzite of zone V.S.2/3 grades into the quartzite of zone V.S.1. The thickness of this zone should, therefore, be regarded as approximate.

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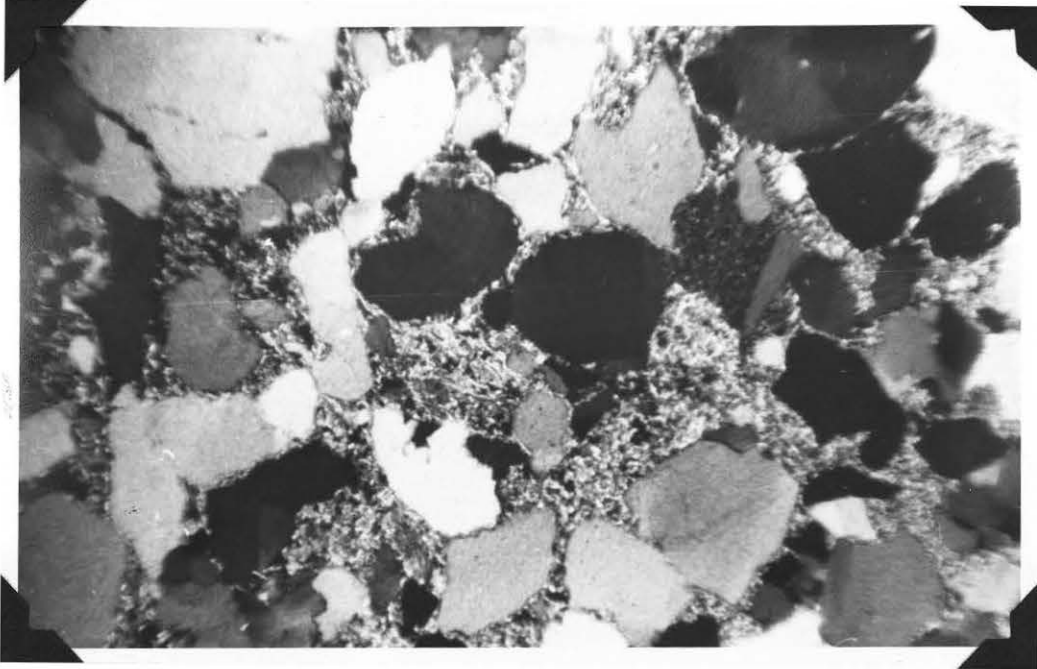
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Crossed nicols (X 170)

Section 37.

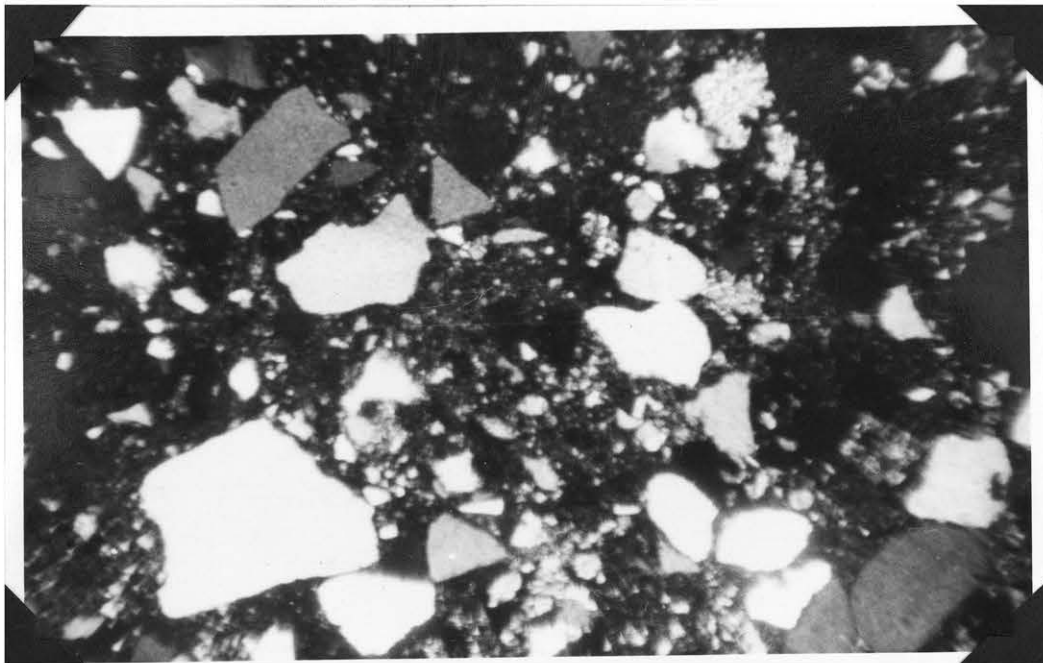
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(X 200)

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## C H A P T E R V

### DISCONFORMITIES.

Geologists soon noticed, as drilling progressed, that disconformities are more prominent in the Virginia-Merriespruit area than in the Welkom area of the Orange Free State Gold-fields. In order to obtain quantitative data on these disconformities, a series of isopach maps have been compiled. (See figs. 6 to 10). These maps give the variations in thickness of the strata between disconformities or between a disconformity and a marker bed.

Dr. Borchers (1950, p.88) is of the opinion that these disconformities are "marginal unconformities" of the Witwatersrand geosynclinal basin. Analysis of these disconformities show that the magnitude of all the breaks in the sedimentation increases towards the south and the east, indicating that shore-lines must have existed in these directions. The curves of the isopachs give us some idea of the shape of the basin during different times.

In general, it will be noticed that the curves of the isopachs conform roughly to the present strike of the Upper Witwatersrand beds. One would expect this to be the case in a geosyncline which was not afterwards subjected to extreme orogeny.

A study of the spacing of the isopachs show that warping took place near the margin of the basin and that the isopach lines which mark the beginning of extensive disconformable relationships, are within a mile or two from each other.

Where the transgression of the overlying conglomerate is regular, the contours of the isopachs are also regular. Irregular isopachs would indicate that there is little transgression, or else it may reveal faulty correlation.

The position of the zero isopach outlines the limits of a marker bed or of the conglomerate associated with the lower disconformity.

The channel deposits are cut so deeply into the footwall



of the Leader-Basal Reef in the eastern part of Merriespruit, partly because of the greater magnitude of the hyatuses towards the east and partly because of the greater depth of the channel.

The disconformities are called after the sedimentary unit which immediately overlies such disconformity.

A summary of the effects of individual disconformities are listed below:-

A. THE BASAL REEF DISCONFORMITY.

The Basal Reef in the Virginia-Merriespruit area lies upon the lower portion of zone U.F.1. Unfortunately, this portion of the succession lacks definite markers, with the result that the amount of transgression is difficult to assess.

According to the information presented in table V below, there is evidence that the relation between the Basal Reef and the Footwall quartzite in this area is disconformable. The greater thickness between the Intermediate Reefs and the Basal Reef in the Welkom area is further proof that the Basal Reef lies disconformably on the Footwall beds.

TABLE V

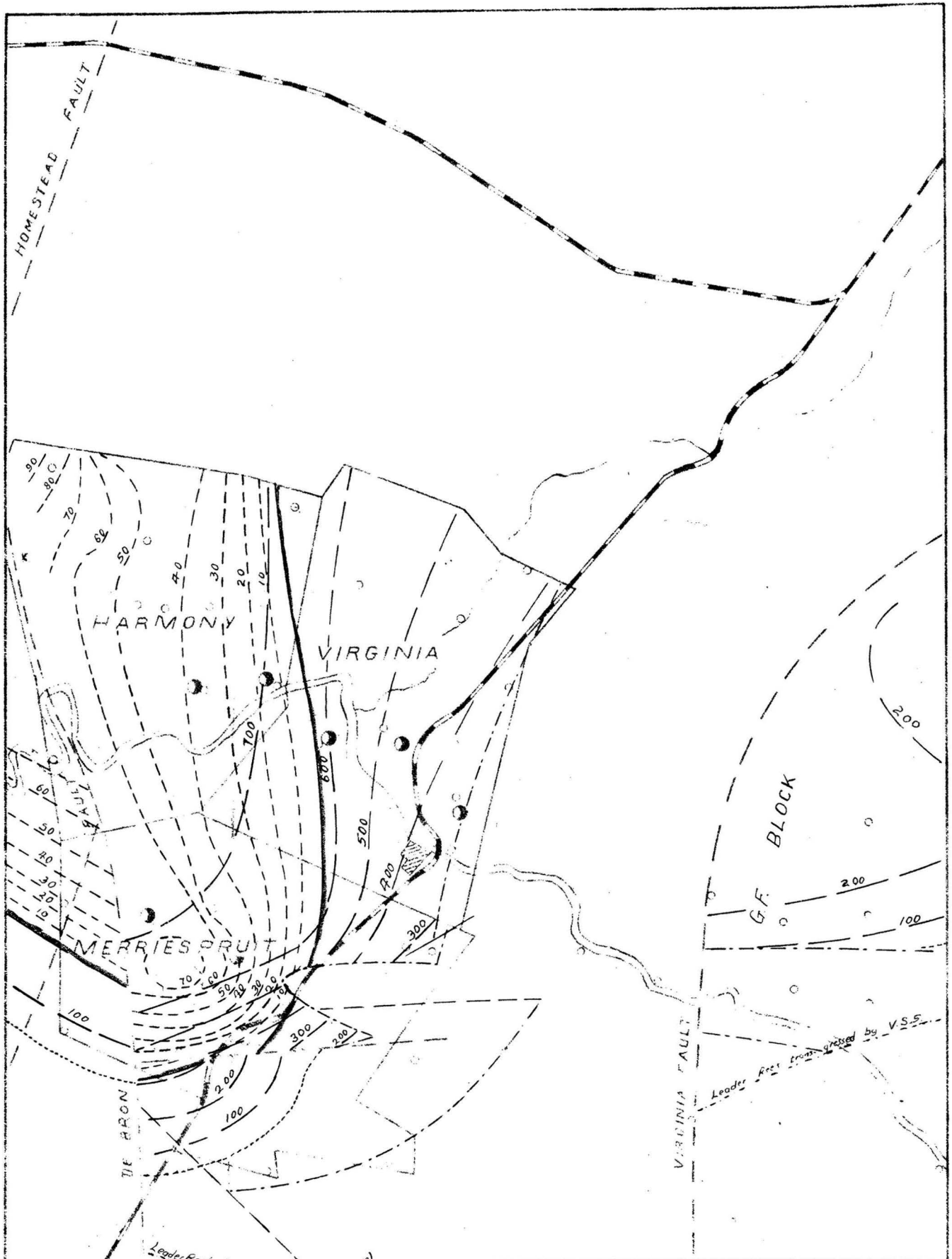
Thickness of Succession between Basal and Intermediate Reefs

BORE-HOLE	THICKNESS	REMARKS
R.U.1*	685	Corrected for intrusives
M.1	613	
K.A.2	600	
S.E.1	500	Corrected for intrusives
WELKOM AREA	875	

\* Bore-hole R.U.1 passed through the Leader-Basal Reef close to the limit of the Basal Reef. The true distances would therefore be slightly greater than that given above.

B. THE E.L.1 DISCONFORMITY.

The disconformable relation of zone E.L.1 to the Basal Reef is indicated by local truncation of the latter



**FIG. 6. ISOPACH MAP.**

**THE LEADER REEF DISCONFORMITY.**

- 100ft Isopachs, Leader Reef to Intermediate Reefs.
- 10ft Isopachs of zone E.L.I.
- Limit of Basal Reef.
- ..... Limit of Intermediate Reefs.
- · - · Sub-outcrop of Leader Reef against Karroo System.

SCALE: - 1:100,000.

and by channels in the plane of the disconformity. The highly irregular patches of Upper Basal Reefs could represent reconcentrated material derived from the erosion of the Basal Reef.

It is not yet known to what extent the Basal Reef has been transgressed in the southern and the south-eastern extremity of the area known to be underlain by quartzite of zone E.L.1. Bore-holes S.E.1 and K.A.3 both passed directly from zone E.L.1 into Footwall quartzite without indications of faulting on the contact. Whether these bore-holes have penetrated isolated area where the E.L.1 quartzite has transgressed the Basal Reef or whether the Basal Reef in that area has been completely overlapped, can only be determined by underground exploration. In the chapter dealing with the geological history it will be seen that the Basal Reef and E.L.1 disconformities form part of a continuous sequence of events that terminates with the E.L.1 disconformity.

C. THE LEADER REEF DISCONFORMITY.

From the isopach map (fig. 6) and the stratigraphy the following features are deduced:-

- (1) Beyond the line of transgression of the Leader Reef over the Basal Reef, towards the margin of the basin in a southerly direction, the angle between the disconformity and the Footwall beds increase to 6 degrees, as calculated from the distances between isopach lines.
- (2) The angle between the disconformity and the Footwall beds in a profile from west to east at the northern boundary of the Virginia Mine is only two degrees, as calculated from the distances between isopach lines.
- (3) The Leader Reef is transgressed by sediments of zone V.S.5 (the "Gold Estates Leader") in the G.F. Block and probably by the "B" Reef south of Merriespruit Mine.

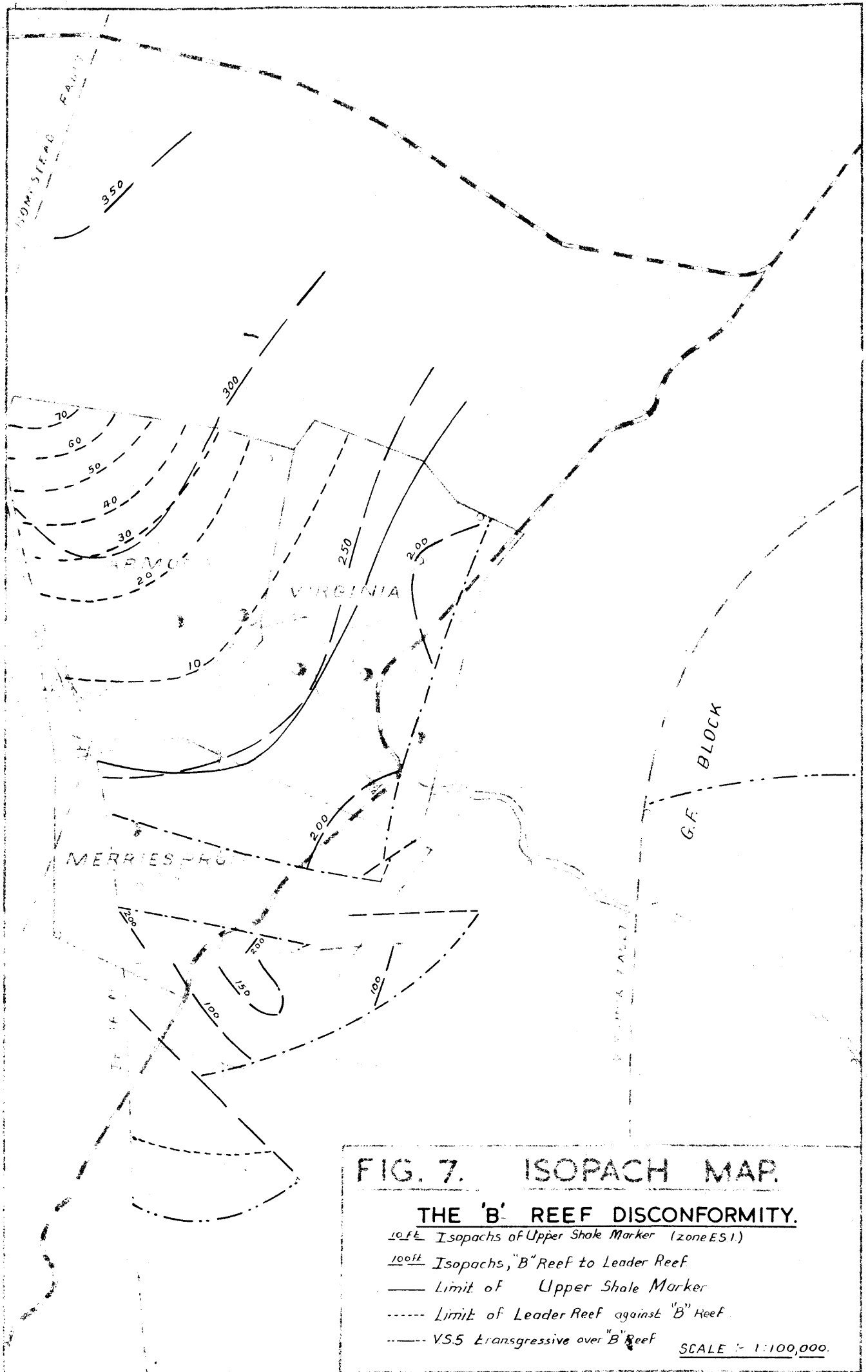


FIG. 7. ISOPACH MAP.

THE 'B' REEF DISCONFORMITY.

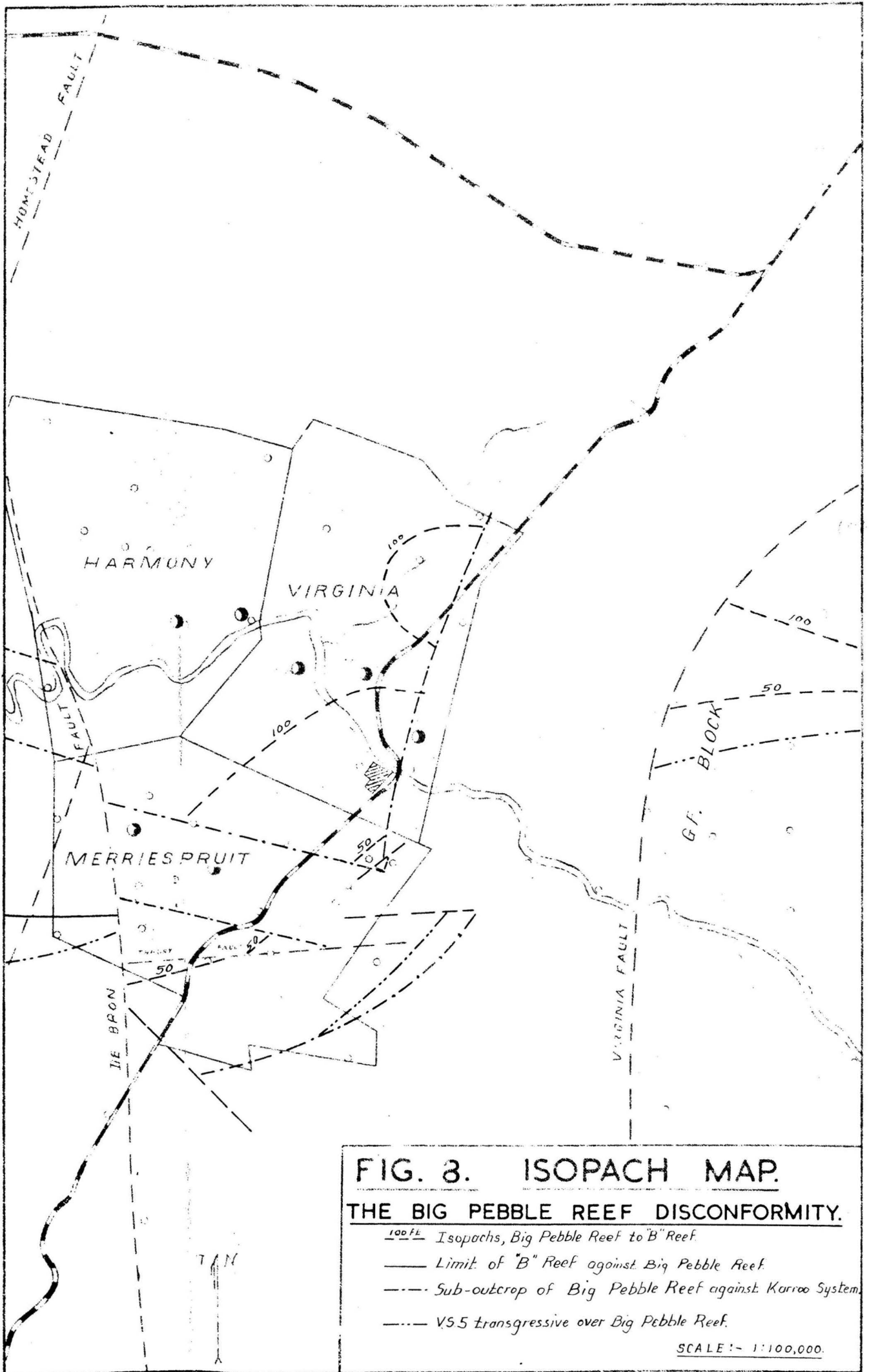
- 10 ft Isopachs of Upper Shale Marker (zone ES1)
  - 100 ft Isopachs, "B" Reef to Leader Reef
  - Limit of Upper Shale Marker
  - - - - Limit of Leader Reef against "B" Reef
  - · - · - VS5 Transgressive over "B" Reef
- SCALE = 1:100,000.

- (4) The displacement of the isopachs on the de Bron fault indicate relative lateral movement of the western fault block towards the north.
- (5) Comparison of the areas of Leader-Basal Reef removed by channels of late Kimberley age, indicates that large lateral movements, such as described by Feringa (1954, p.32) could not have taken place on the Virginia fault. The curvature of the isopachs to the north in the Virginia Mine explains the pronounced relationships in the G.F. Block.
- (6) The displacements of the isopachs on the Merriespruit thrust fault can be explained by overthrusting from the north.
- (7) The lower angle of unconformity on the Virginia Mine has enabled a better sorted conglomerate to be developed on the disconformity on that mine than on the Merriespruit Mine.

D. THE "B" REEF DISCONFORMITY.

From the isopach map (fig. 7) and from the stratigraphy, the following features are deduced:-

- (1) The "B" Reef transgresses the Leader Basal Reef south of the Merriespruit Mine but is overlapped by the "Gold Estates Leader" Reef (V.S.5) before transgressing the Leader Reef in the G.F. Block.
- (2) The "B" Reef transgresses the Upper Shale Marker fairly far from the margin of the basin. This may be the combined effect of erosion and of thinning out or of a change in facies of the Upper Shale Marker.
- (3) Reef in cores of bore-holes west of the de Bron fault in the Virginia-Merriespruit area have not been definitely correlated with the "B" reef and this reef is very poorly represented in bore-hole K.A.3. It is therefore highly probably that the "B" Reef is not developed west of Merriespruit Mine, or that it is



**FIG. 3. ISOPACH MAP.**  
**THE BIG PEBBLE REEF DISCONFORMITY.**

- 100 ft* Isopachs, Big Pebble Reef to "B" Reef.
- Limit of "B" Reef against Big Pebble Reef.
- - - Sub-outcrop of Big Pebble Reef against Karroo System.
- - - V.S. transgressive over Big Pebble Reef.

SCALE: ~ 1:100,000.

transgressed by the Big Pebble Reef.

- (4) Lateral movements on the de Bron fault is proved by the fact that the "B" Reef horizon is scoured away by a channel of later Kimberley age, intersected in bore-hole L.R.1.

E. THE BIG PEBBLE REEF DISCONFORMITY.

From the isopach map (fig. 8) and the stratigraphy, the following features are deduced:-

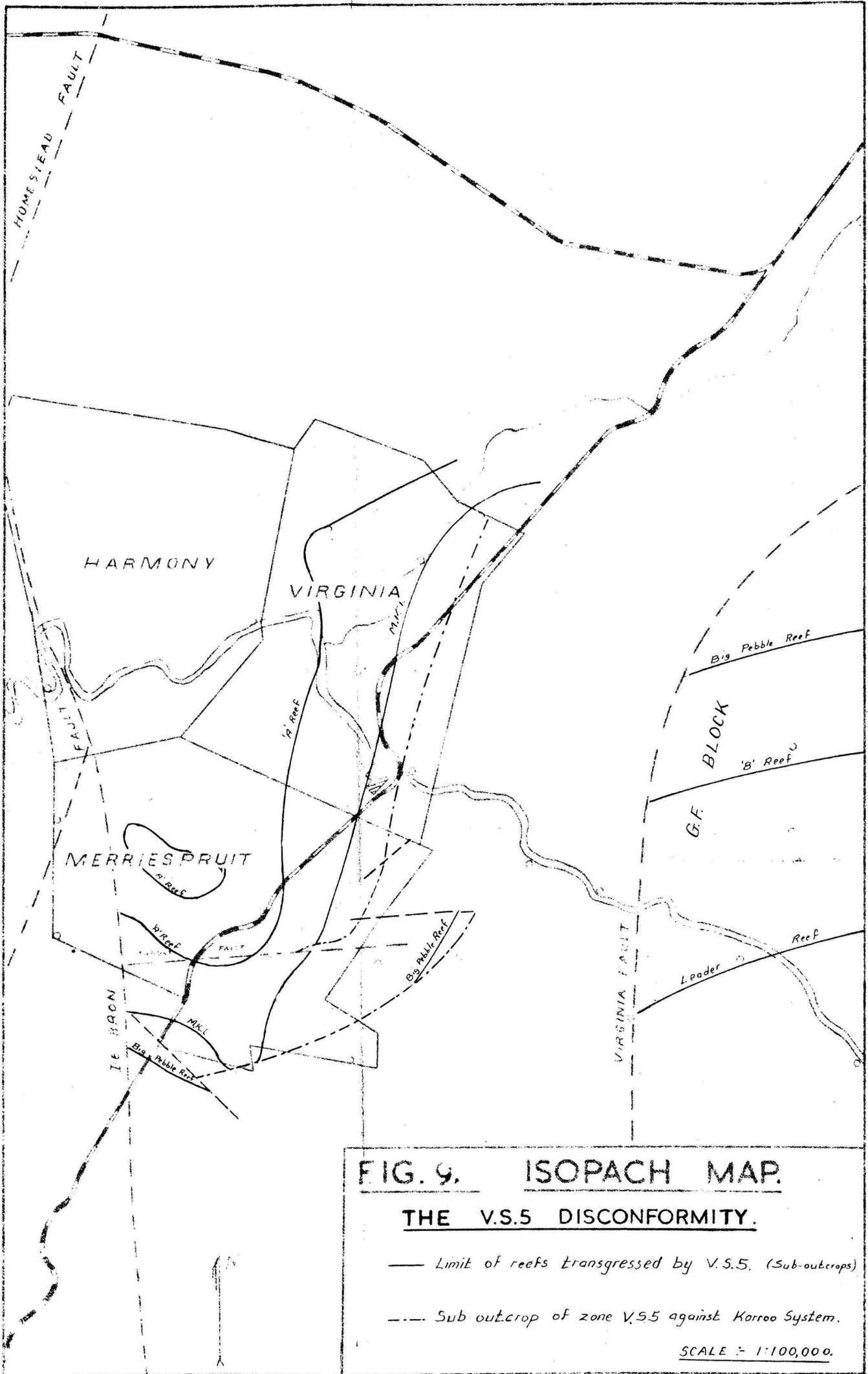
- (1) The irregular curves of the 100 feet isopach indicates that the transgression of the Lower Kimberley beds are so slight that irregularities in the thickness of these beds have a marked effect on the position of this line.
- (2) The large distances between the isopach lines point to a very low angle between the disconformity and the foot-wall beds, and the smooth curve of the 50 ft. isopach indicates that the transgression of the Big Pebble Reef over the Lower Kimberley beds, though slight, is steady. An exposure where the Big Pebble Reef overrides the uppermost bed of conglomerate in zone L.K.1 has been encountered in the No. 2 Shaft area of Virginia Mine. At the shaft, the Big Pebble Reef disconformity is separated from this conglomerate by about 5 feet of quartzite. At approximately 1,200 feet further east, the reef transgresses the underlying conglomerate, enclosing in its lower band pebbles of this totally different variety of conglomerate for some distance east of the line where the transgression of the conglomerate was completed. Coarse material must therefore have moved in the direction of the transgressing shore-line.
- (3) The Big Pebble Reef is overlapped by sediments of zone V.S.5 along a line further into the basin than the line where the former would have overlapped the "B" Reef.

TABLE VI

The Relation between the "A" Reef and its Footwall Beds

BORE-HOLE NUMBER	CORRELATION	DEPTH OF "A" REEF IN BORE-HOLES	GOLD VALUE	REMARKS
M.O.1	"A" on M.K.1	3874	0.75/24	
M.O.3	"A" on M.K.1			
A.D.1(a)	"A" on possible M.K.1	2854	1.8/5.8	Alternative correlation, U.K.1 conglomerate on U.K.2
S.E.1	Possible "A" on possible M.K.1	2067		M.K.1 underlain by "Charnel" deposits
K.A.2	Possible "A" on "Charnel" deposit	2579	0.78/2.4	
S.F.3	Possible "A" on possible M.K.1	1344		M.K.1 underlain by M.K.4
M.O.2	"A" on M.K. 2 or M.K.3			
M.O.4	"A" on M.K.2	3321	1.42/25	"A" Reef underlain by 6 inches of argillaceous quartzite
V.Z.1	Possible "A" on M.K.3	1961		Correlation according to Feringa
V.Z.3	"A" on M.K.3	3343		
M.1	"A" on M.K.4	2465		Correlation according to Feringa
M.U.2	"A" on M.K.4	1580	0.7/12	"A" Reef underlain by 6 inches of quartzite
M.U.3	"A" on remnant of M.K.4	3096		Correlation according to Feringa





**FIG. 9. ISOPACH MAP.**

**THE V.S.5 DISCONFORMITY.**

— Limit of reefs transgressed by V.S.5. (Sub-outcrops)

--- Sub outcrop of zone V.S.5 against Karroo System.

SCALE = 1:100,000.

For that reason, one does not expect to find the Big Pebble Reef directly overlying rocks older than the "B" Reef. West of the de Bron fault, however, the Big Pebble Reef does seem to lie directly on rocks older than the "B" Reef, as revealed in bore-hole M.O.2.

F. THE "A" REEF DISCONFORMITY.

The distance between the "A" Reef and the Big Pebble disconformity is small, and so variable that an isopach map cannot be drawn with the limited number of control points available.

The "A" Reef has not been intersected in all the bore-holes. The reason could be that deposition of the "A" Reef might have been limited to basins in an undulating floor and that local transgression of sediments of zone V.S.5 over beds of the Upper Kimberley Stage has taken place. The "A" Reef has not been found to lie directly upon Lower Kimberley beds. Signs of a disconformable relationship between the "A" Reef and the underlying rocks are difficult to detect. The writer believes that the true relationships between the different beds of the Upper and Middle Kimberley Stages can only be elucidated after careful mapping of underground exposures of the "A" Reef.

Table VI is an attempt to indicate a disconformable relationship between the "A" Reef and its footwall beds.

G. THE V.S.5 DISCONFORMITY.

From the isopach map (fig. 9) and the stratigraphy the following features are deduced:-

- (1) Although the extent of erosion of the sediments underlying the disconformity in the Virginia-Merriespruit area is not very great, a basal conglomerate is sporadically developed in the south-eastern part of the Merriespruit Mine. This basal conglomerate is called the "Gold Estates Leader".

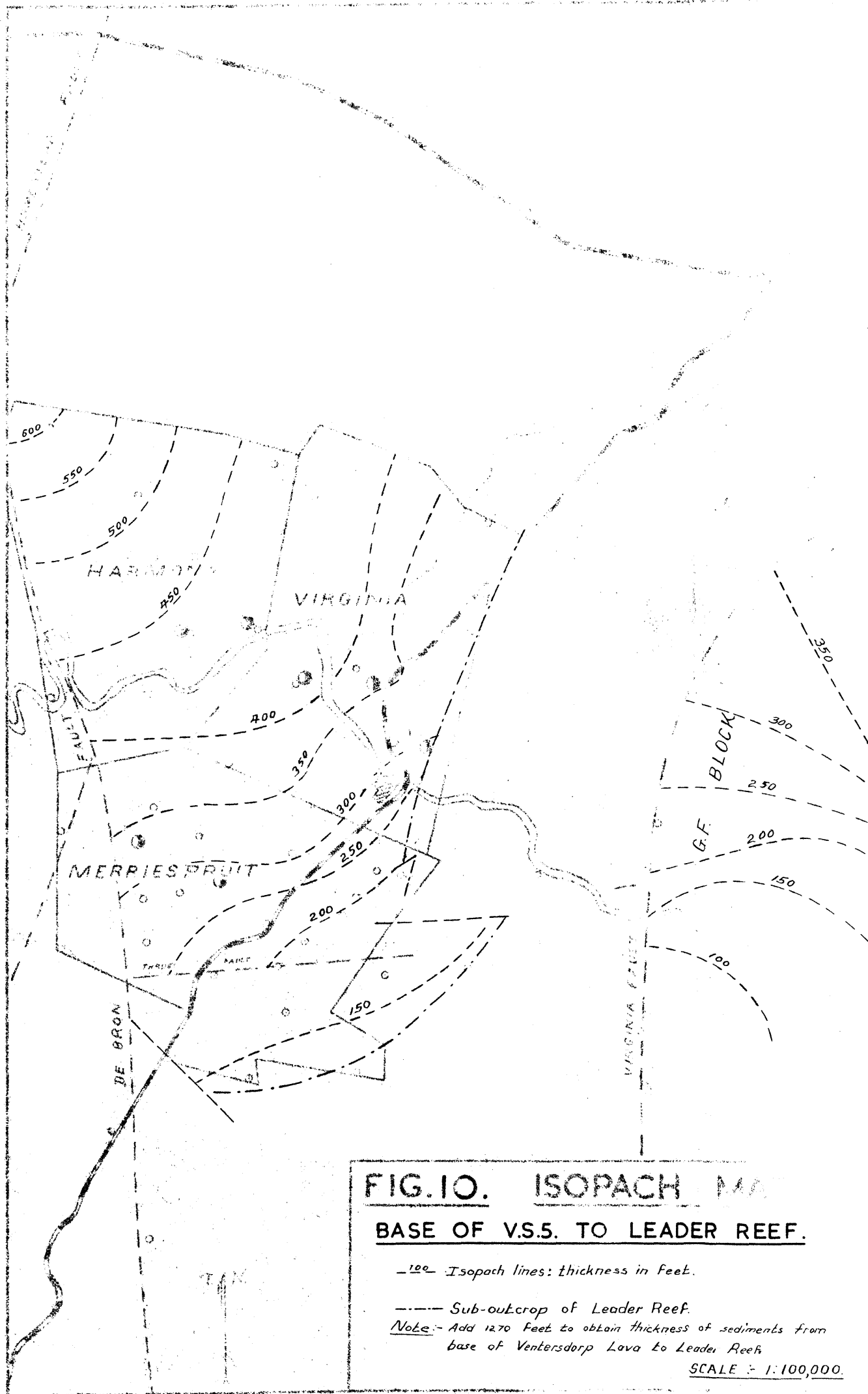
- (2) In the G.F. Block, the sedimentary break represented by this disconformity is extensive: the "Gold Estates Leader" has transgressed the Big Pebble Reef, the "B" Reef and Leader Reef disconformities until, in the far south, "Gold Estates Leader" directly overlies quartzite of the Middle Footwall beds.
- (3) Extensive stretches of "A" Reef have been eroded away prior to deposition of sediments of zone V.S.5.
- (4) The so-called "A" Reef south of bore-hole G.F.5 in the G.F. Block is really the "Gold Estates Leader".

#### H. THE BASE OF THE VENTERSDORP LAVA.

The Ventersdorp lava in the Virginia-Merriespruit area and the Witwatersrand sediments are apparently conformable. In fact, the thickness of the Elsburg Stage remains remarkably constant over the area. The average thickness of the Elsburg Stage in the Welkom area, 12 miles north of the Sand river, is 1400 feet (Borchers and White, 1943, p.44) in the Virginia-Merriespruit area 1270 feet, and on the farm Monstari 1798, 10 miles south of the Sand river, it is 1100 feet. The diminution of the thickness of the Elsburg Stage towards the edge of its basin of deposition can be explained as a thinning out of the sediments. The V.S.1 conglomerate occurs directly below the lava along the whole of the distance from Welkom to the Monstari bore-hole.

#### I. SUMMARY.

A calculation of the differences in thickness of the Upper Division from the most northerly to the most southerly point on the Merriespruit Mine reveals that about a thousand feet of sediments, a fifth of the total thickness, is missing at the southernmost point. The thousand feet represent the increase in the magnitude of the breaks in the sedimentation across the mine area. It is clear that the greatest portion of this increase in the magnitude of



the break took place in the southern portion of the Mine, the lowest disconformity being at the Basal Reef and the uppermost at the base of zone V.S.5. We must therefore conclude that erosion took place periodically in the marginal area of the basin prior to the deposition of zone V.S.5.

The isopachs between the base of zone V.S.5 and the Leader Reef has been given separately in figure 10. This map is useful in the drawing of profiles and also shows that the combined effect of the several disconformities enclosed between these strata is to shorten the stratigraphical column of the Upper Division of the Witwatersrand system in directions opposite to the general dip of the strata.

Finally, the isopach maps prove that disconformities, and not changes of facies, were responsible for the large differences in the footwall quartzite of the Leader -Basal Reef in bore-holes drilled in the south-eastern portion of the Merriespruit Mine.

## CHAPTER VI

### CORRELATION BY METHODS OTHER THAN PURELY STRATIGRAPHICAL

#### A. HEAVY MINERAL ANALYSIS.

A heavy mineral investigation of the quartzite in zones E.S. 3 and U.F.4 was carried out in order to find confirmation for the correlation of controversial bore-hole intersections of the Leader-Basal Reef and of the Intermediate Reefs in the south-eastern portion of the Merriespruit Mines. Concentrates from zones E.L.1 and U.F.1 were also prepared as a control.

The heavy mineral concentrates are characterised by a flood of pyrite, abundant zircon, and smaller amounts of opaque detrital minerals. These opaque minerals include ilmenite, chromite, magnetite, iridosmine, uraninite and thucolite in approximate order of abundance. Accurate quantitative identification of these minerals, mounted on glass slides, is extremely difficult. Rare tourmaline occurs only in splinters and is probably authigenic. No garnet appears in the suites.

As ilmenite is prone to alteration and obliteration, the ratio of opaque minerals to zircon cannot be relied upon. Therefore the only hope of finding sufficient differences in the concentrates lie in a quantitative study of the varieties of zircon.

Considerable basic research in this direction is necessary before any results of correlative value will be available.

#### B. RADIOMETRIC LOGGING.

In a series of papers Dr. D.J. Simpson has shown that radiometric logs can be utilized to solve problems of correlation in the Witwatersrand System (1950, 1951 and 1952).

In his paper: "Some results of radiometric logging in the bore-holes of the Orange Free State Goldfields and

neighbouring Areas", 1951, (pp. 121 to 128), he discussed the correlation of reefs in some abnormal bore-hole intersections in the area south of the Sand river. He came to the conclusion that the reef horizon correlated as the Intermediate Reefs by local geologists, was a modification of the Leader-Basal Reef. The correlation according to local geologists can, however, be justified without violating the principles on which Dr. Simpson's correlation was based. His deductions were based on a composite radioactivity log (1951, plate XXII, fig. 6), which was derived from bore-holes M.O. 4 and W.N.1, neither of which intersected the Intermediate Reefs (see plate B) with the result that a wrong impression of the radioactivity anomaly was obtained.

When the radiometric log of bore-hole K.A.2 became available in July, 1953, this gap could be closed since this bore-hole intersected both the Leader Reef and the Intermediate Reefs horizon. The sequence between these horizons compare well with that in the core of bore-hole M.1; therefore one can safely assume that the log was derived from a succession unaffected by faulting.

The new composite radiometric log is compared with the old composite log of Dr. Simpson in plate H, and the radiometric and geological logs of the controversial bore-holes are added, giving the revised correlation.

It is clear that the correlation of the reefs in bore-holes M.5 and S.E.2 with the Intermediate Reefs is in accordance with the anomalies to be expected at that horizon.

In table VII, the statements on the correlation of the southern area of the Free State Gold-fields proposed by Dr. Simpson (1952, p. 121), are compared with the correlation suggested on plate H.

TABLE VII

Dr. Simpson's Correlation (quoted from page 121)	Comments
<p>(1) Radiometric logging suggests that the true Intermediate Reef zone as developed in the central area does not exist in the far south area, and that the "Intermediate Reef" in this area is actually the upper cycle R.5</p>	<p>(1) As can be seen in the radiometric log of bore-hole K.A.2, a distinct Intermediate Reefs anomaly (R.7) does exist, and it is the R.5 anomaly that is poorly developed.</p>
<p>(2) The Leader-Basal Reef (R.3.C sub-cycle) is sometimes logged as Intermediate Reef due to facies changes.</p>	<p>(2) Only the Leader-Basal Reef in bore-hole M.U.3 was originally logged as Intermediate Reefs zone. The characteristic gold values and the gold-uranium ratio proves that this happened</p> <p style="padding-left: 40px;">It is also to be expected, from the isopach map (fig. 6), that the Leader-Basal Reef would overlies the Intermediate Reefs. The anomaly in bore-hole M.5 compares very well with the R.7 cycle.</p>
<p>(3) The Leader-Basal Reef zone is sometimes missed in bore-holes due to de-generation of the Leader</p>	<p>(3) This happened in the case of bore-hole M.U.3 only. Dr. Simpson's correlation of the Intermediate Reefs</p>



<p>conglomerate into grits, and the lack of gold values. Radiometric logs show this horizon to be present in the so-called "Footwall beds".</p> <p>(4) No R.3.A.1 inner cycle (V.S.5 conglomerate) exists in the Virginia area, and the conglomerate logged as V.S.5 is in reality the upper zone at the "A" Reef cycle developed locally.</p>	<p>in bore-holes M.2, M.5 and S.E.3 have been disputed by different methods, and the radioactivity anomalies fit in very well with the R.7 cycle.</p> <p>(4) This anomaly evidently originates from the "Gold Estates Leader", the reef lying at the base of the Elsburg stage and between the V.S.5 conglomerate and the "A" Reef.</p>
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C. GOLD.

As the cores of most of the sediments of the Upper Division of the Witwatersrand System was assayed, it was possible to draw a graph of the variation of the gold content with depth. This "log" supplies one with an additional criterion on which to base correlation.

From a study of plate H, it became apparent that the Basal Reef, the Leader Reef and the Intermediate Reefs each have a different average Gold : Uranium ratio.

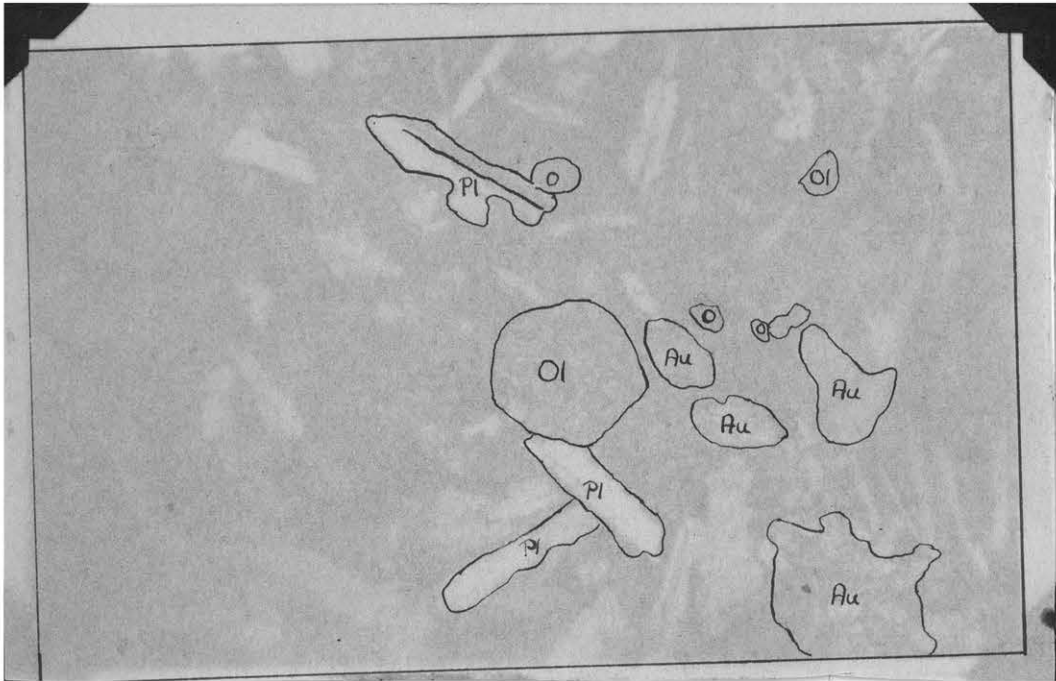
A characteristic graph of this ratio can be obtained for each reef by plotting gold values against uranium values. The assay results of a reef of doubtful correlation can then be plotted on the graph and its identity revealed. This method of correlation would fail in the case of a reef which has derived material from an underlying reef by erosion.

C H A P T E R VIIINTRUSIVE ROCKS

Up to the time of writing, quartz-rich intrusive rocks have not been encountered in the Virginia-Merriespruit area. The original minerals of most of the mafic rocks have been altered by metamorphism to minerals that are stable in conditions of low grade regional metamorphism, thus rendering detailed classification as igneous rocks impossible. Much importance is therefore attributed to textures and to the degree of alteration of the constituent minerals. Although these two criteria may vary on approaching a chilled zone and in areas where an igneous body has been locally subjected to shearing stress or prophyllitisation, such variation can be kept to a minimum by careful selection of specimens, and it has been found that individual intrusions can be correlated over considerable distances by means of the microscope.

Besides the petrographical characteristics, the following features are taken into account to aid in the correlation of individual intrusive bodies over different sections of the mines : the shape of the intrusive, the nature of the contacts with the host rock, the nature of the chill zone, the degree of contact metamorphism of the host rock, the granularity of the igneous rock, the spacing and mineral composition of veinlets, the presence of xenoliths, phenocrysts and amygdales, mottling, shearing, flow structure, the nature of displacements of the host rock and the relative age with respect to faults and other intrusives.

The amount of shearing on the contacts and in the body of an intrusive determines its water-bearing potentialities. It is therefore of great practical importance to be able to recognise intrusives which may cause dangerous inflows of water in one intersection although bone-dry in an adjoining intersection. Some of the most prominent intrusives discussed are shown on the structure contour map (plate 1).



Photomicrograph 9.

Olivine dolerite, bore-hole K.A.2.

The olivine is partly altered to antigorite.

pl = plagioclase                      au = augite

ol = olivine                              o = ore

Crossed nicols                      (X 150)                      Section 44.

The intrusives are discussed in the abnormal order from the youngest to the oldest, because we know the age of the youngest as being post Karroo, whereas the oldest are of doubtful age.

A. DOLERITE.

Although dolerite abounds in the Karroo System, and is in fact the only type of igneous rock intruded into that System within this area, the occurrences of dolerite in the Witwatersrand System encountered in bore-holes drilled from the surface are confined to Witwatersrand sediments directly underlying the Karroo System. In bore-holes K.A.1, K.A.2 and K.A.3 thin sills are found in zone V.S.1.

The dolerite is a very dark-grey medium-grained, porphyritic rock (section 44 photomicrograph 9 from a specimen taken near the centre of a sill in bore-hole K.A.2).

TABLE VIII

Optical Properties of Dolerite from Sill  
in Bore-hole K.A.2 (section 44)

MINERAL	2V <sub>v</sub>	$\delta \wedge C$	COMPOSITION	ZONING
olivine	96°		Fa <sub>29</sub>	slightly zoned
augite	48°	40°		zoned
pigeonite				strongly zoned
bytownite			An 78-82	zoned
labradorite			An 52-68	zoned

The presence of approximately 8% by volume of olivine, altered largely to bowlingite, indicates that the intrusive is an olivine dolerite. The sub-ophitic relationship between augite and labradorite is not as clear in the case of pigeonite. Zonal augite is common and is evidenced by a decrease in the optic axial angle towards the margin. The zoning in the pigeonite is such that the optic axial angle increases from zero at the core to an angle of approximately 20° at the margin. The pigeonite is therefore the

the ferriferous brown variety, described by Walker and Poldervaart (1949, p. 639). Twinning on the composition plane (100) is common in the pyroxene.

There are two generations of plagioclase: the older more calcium-rich bytownite occurs as glomeroporphyritic aggregates and started its crystallisation before the mafic minerals, and the younger labradorite occurs as laths producing a sub-ophitic texture with pyroxene.

Both generations of feldspar are zoned. Twinning according to the albite and carlsbad laws are most common. The crystals of bytownite are tabular and the labradorite lath-shaped, the average length of the laths being 0.4 m.m. Superficial saussuritisation of the plagioclase occur mostly in the bytownite. Magnetite is an accessory mineral. This dolerite is an example of the Blaauwkrans type of Walker and Poldervaart (1949, p. 616).

The dolerite between 1748 and 1755 feet in bore-hole S.M.1 is the basaltic contact phase of the above type. The texture is intersertal, the ground mass being rich in grains of an opaque ore (section 45).

The average length of the plagioclase laths is 0.25 m.m. The following optical constants compare well with the previous example:-

TABLE IX

Optical Properties of Dolerite from Bore-hole S.M.1  
(section 45)

MINERAL	2V <sub>x</sub>	$\chi^{\wedge} / C$	COMPOSITION	ZONING
olivine	94-96°	41°	Fa <sub>24-29</sub>	slightly zoned
augite	49-51°			zoned
pigeonite	0-20°			strongly zoned
bytownite			An 69-88	zoned
labradorite			An 58-68	zoned

The majority of the dolerites occurring in the Karroo System in the Virginia-Merriespruit area belong to the Blaauwkrans type, but a near-surface sill on the farm Merriespruit 219 is of the Perdekloof type. Both types contain some olivine.

There is little doubt that the dolerite that occurs in the Upper Division of the Witwatersrand System is of late-Karroo age.

B. EPIDIORITE.

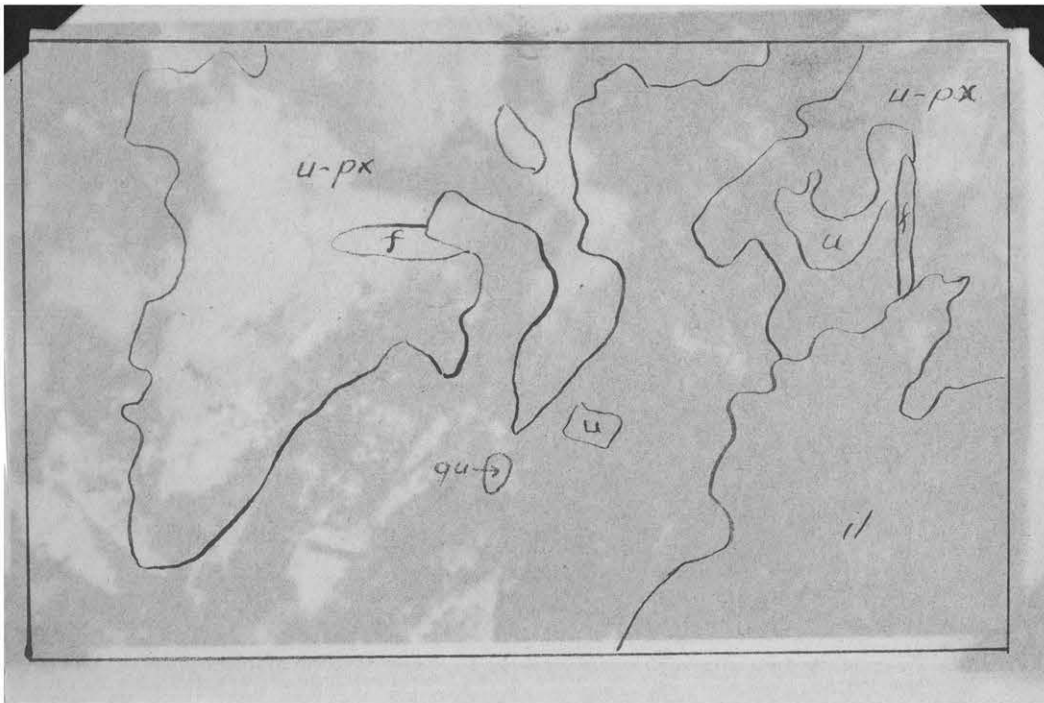
Although epidiorite is known in the Central Witwatersrand, only one occurrence has so far been encountered in the Virginia-Merriespruit area. Usually the feldspars of the intrusives older than the dolerites are also altered and for that reason the rocks are not classified as epidiorite. (Compare McDonald, 1911, p. 92).

The one occurrence is an intersection in bore-hole C.A.1 between 3336 feet and 3345 feet of an intrusive dipping approximately  $25^{\circ}$  in a direction coinciding with the dip of the strata.

TABLE X

Epidiorite from Bore-hole C.A.1.  
(section 46, photomicrograph 10)

PRIMARY MINERALS	SECONDARY MINERALS
augite	{ uralite, chlorite (
pigeonite	
plagioclase	saussurite, a carbonate mineral, quartz, chlorite
ilmenite	leucoxene
pyrite	



Photomicrograph 11.

Uralite diabase, Harmony sill, bore-hole K.A.2.  
Large crystals of uralitised pyroxene lie in a  
groundmass consisting mainly of chlorite, quartz  
and some ankerite.

qu = quartz

u-px = uralitised pyroxene

il = ilmenite

f = saussuritised feld-

u = uralite

spar.

Crossed nicols

(X 44)

Section 53.

C. URALITE DIABASE.

The outstanding example of this type of intrusive is the Harmony Sill. It is a domical sheet and has an average thickness of 110 feet. In Harmony Mine it is present in the Ventersdorp Lower Lava and in the Ventersdorp Upper Sediments, and it cuts through the economic horizon in Virginia and Merriespruit Mines. It is also known from bore-holes on Saaiplaas Mine (Verbal communication, A. Kriek). The structure contour map indicates its intersection with the Basal and Leader-Basal Reefs (plate I). The block diagram of the Virginia Mine also features this sheet (plate J).

The origin of this sheet is assumed to be similar to that of the Marievale type of intrusion on the Far East Rand (Ellis 1940, 1944). The displacement of the surrounding strata is always equal to the thickness of the sill. It therefore obeys the law of minimum lateral thrust (Blignaut and Furter, 1940, p. 48) and the sediments underlying the sheet have subsided, similar to the "bell-jar" dolerite intrusions in the Eastern Karroo (Walker and Poldervaart, 1949, p. 610). Steeply inclined sections of this intrusion are not common, although they have been encountered in 21 Level Haulage North on the Virginia Mine. The the West of No. 1 Shaft in Merriespruit Mine, the Harmony Sill cuts through the de Bron fault into the Ventersdorp Upper Sediments without being displaced. It is therefore younger than both these sediments and the fault.

Thin sections of this intrusion in bore-hole K.A.2 were made of specimens taken at approximately ten feet intervals (sections 44-60, photomicrograph 11). There are no indications of magmatic differentiation. The rock is greyish-green, ranging from fine-to medium-grained and has an intergranular texture. White feldspar

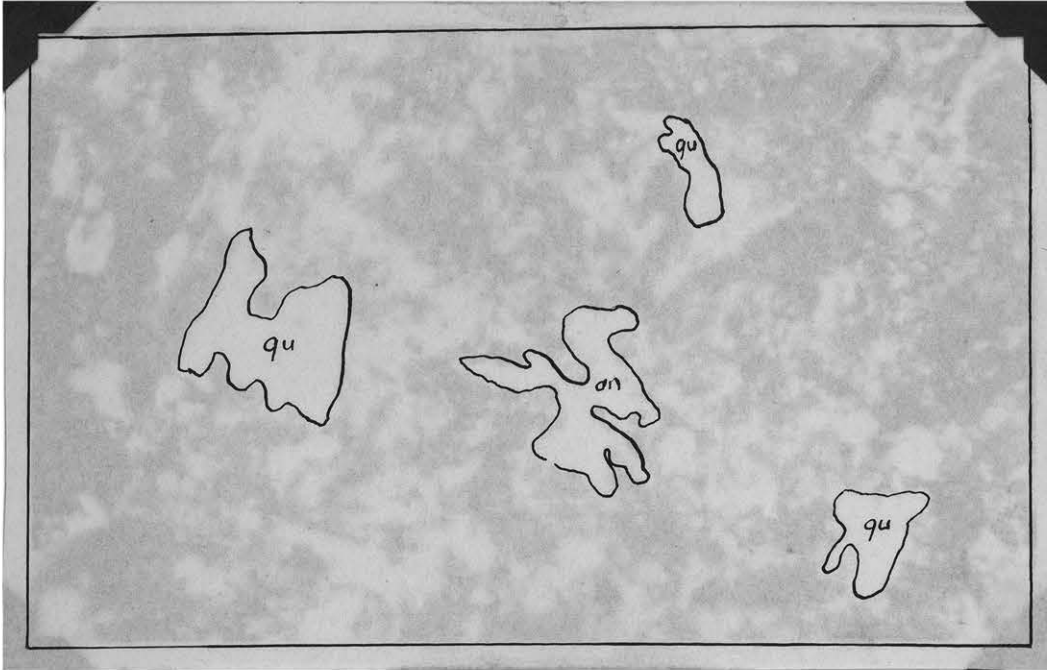


laths, usually clustered around indistinct centres, can be seen in the hand-specimen. A pseudo-stratification is caused by the segregation of mafic and felsic minerals into narrow bands. A lineation, parallel to a set of steep joints, is also visible in some portions of the sheet. Thin veinlets, the majority having the same attitude as the contacts of the intrusive, are composed of the following secondary minerals, quartz, carbonate, epidote, chlorite, chalcopyrite, pyrite and galena. The contacts with the host rock are "frozen", that is, not affected by subsequent shearing. The chill zone is 3 feet thick and is followed by a fine-grained zone 9 feet thick.

The original minerals have, to a large extent, been converted to secondary ones. The pyroxene or its alteration product is partly penetrated by laths of saussuritised feldspar, proving that the original texture was sub-ophitic. A few fresh grains of pyroxene possess the optical features of augite ( $2V_{\gamma} = 42^{\circ} - 43^{\circ}$ ,  $\gamma \wedge C = 35^{\circ}$ , twinning on (100)). The first stage of alteration of the augite is hornblende. ( $\gamma \wedge C = 15^{\circ} - 17^{\circ}$ , pleochroism: x = yellow, y = brown, z = green, absorption: Y>X, characteristic amphibole cleavage). The hornblende in turn has been converted to a pale green chloritic mineral with a weak birefringence giving grey and white interference colours. It has a small, variable optic axial angle with negative sign.

The alteration products of feldspar are quartz, chlorite, carbonate, zoisite, and sericite, and perhaps other minerals, forming an aggregate usually known as saussurite.

Quartz forms 3% of the rock by volume. The variable size, the shape and the inclusions of secondary minerals all indicate that the quartz is secondary, and one of the last minerals to have formed.



Photomicrograph 12.

Uralite diabase, Intrusive "C", Merriespruit No.1 Shaft.  
Most original minerals are altered beyond recognition.  
Small shreds of pyroxene show up as white specks. Some  
shreds are altered to uralite. The dark groundmass is  
mainly chlorite. Quartz and ankerite are prominent  
secondary minerals.

Crossed nicols. (X 190) Section 61.

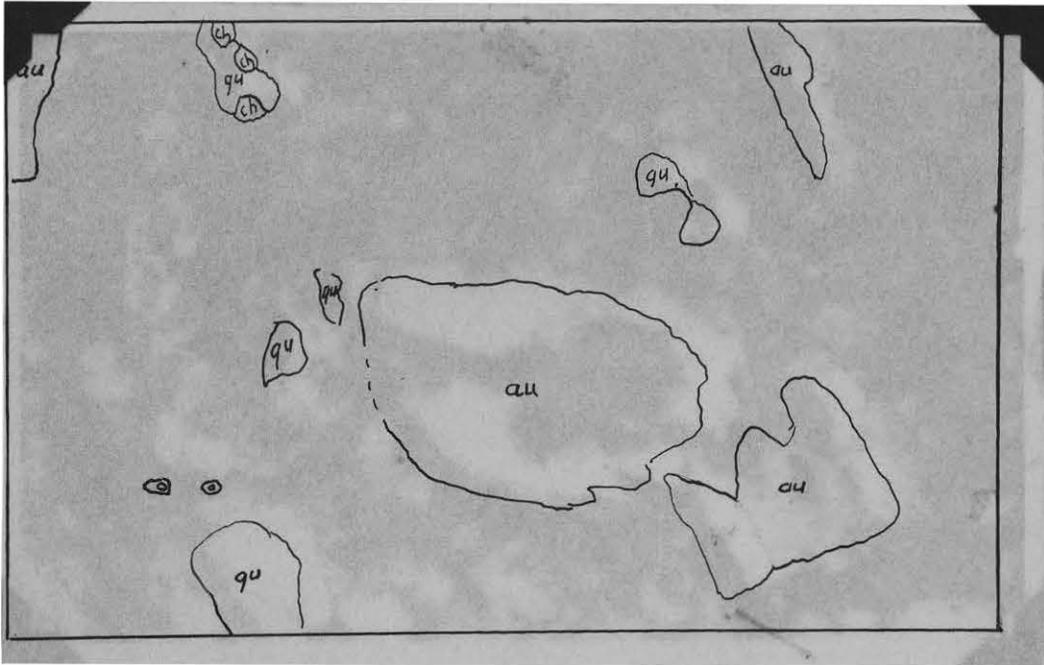
Epidote has been found in appreciable amounts in some of the thin sections.

Ilmenite, approximately 4% by volume, is present as large skeletal crystals. It is partly altered to leucoxene.

Although quartz and ilmenite are conspicuous they are not so abundant that they warrant the prefixes quartz and ilmeno to be applied to the name of the rock-type.

The chill zone is highly altered. Chlorite, carbonate quartz, epidote and leucoxene are the principle minerals. A faint, felty, relict igneous texture is visible in ordinary light, proving that each rock-forming mineral has given rise to a characteristic aggregate of metamorphic minerals. The thin section was taken at a distance of one foot from the lower contact.

A finer-grained intrusion of uralite-diorite which could possibly be older than the Harmony Sill has been encountered in Merriespruit Mine and has been called intrusive "C" (section 61, photomicrograph 12). This intrusive has an intergranular texture. The rock is transitional to the pyroxene diorite described below. The pyroxene still occurs as shreds and cores in the chloritic alteration product and a few crystals of secondary hornblende are present. Secondary quartz and a microperthitic intergrowth of quartz and chlorite is prominent. Epidote is fairly common. The contact with the host rock is unshattered. It exhibits a dense, grey, chill phase approximately  $\frac{1}{2}$  inch in thickness. The structure of the intrusive is similar to the Marievale dykesills, as steeply transgressive dyke-like sections alternate with concordant sections. It is chilled against intrusive "D" (see below), but is displaced by a strike-slip fault in 35 Haulage East. Its thickness in the transgressive portions is approximately 25 feet. The concordant portions are nowhere completely exposed.



Photomicrograph 13.

Pyroxene diabase, bore-hole D.1.

Partly altered pyroxene ( augite and pigeonite) occur  
in a groundmass of secondary quartz, chlorite and  
a grey, semi-opaque dust.

au = augite

ch = chlorite

qu = quartz

o = ore, probably ilmenite

Crossed nicols. (X 50)

Section 63.

C. PYROXENE DIABASE.

The medium-grained diabase which appeared in bore-hole D.1 at a depth of 4797 feet and in which this hole was stopped at 4887 feet, is typical of the relatively thick intrusions of diabase, probably sills, occurring in or close to the Jeppestown Series in this area (section 63, photomicrograph 13).

Augite and pigeonite are the only minerals not completely metamorphosed. The crystals occur in tabular subhedral form and as long slender euhedral laths. One of the laths measured 2 mm. by 0.3 mm.

Most of the augite ( $2V_{\gamma} = 49^{\circ} \pm 1^{\circ}$ ,  $\gamma \wedge C = 42^{\circ}$ , twinning on (100) common) is altered to chloritic minerals. Uralite is rarely encountered.

The feldspars have been completely saussuritised. Secondary quartz and carbonate are beginning to segregate from the saussurite.

Ilmenite, partly altered to leucoxene, occurs as small, ragged crystals.

An intrusive, intersected in the same bore-hole at a depth of 3517 to 3631 feet, has a similar composition to the one described above, but the pyroxene is not lath-shaped (section 64).

A further intrusive of this group (section 65) has been intersected between 1630 feet and 1751 feet in bore-hole S.E.2. The fresh pyroxene in this specimen is probably pigeonite, on account of its small positive optic axial angle. Alteration to uralite has only taken place at the margins of the pyroxene. Pale-grey mottling in the hand specimen, which differentiates this intrusive from others of this kind, are revealed in thin sections as patches of opaque dust, pale-yellow in reflected light. Small rods of leucoxene occur in these patches. The absence of large

crystals of leucoxene suggests that the dust consists of leucoxene. A thin veinlet of zoisite is also present in the slide.

E. CHLORITE DIABASE.

These fine-grained and medium-grained diabasic intrusions are characterised by the complete alteration of both the mafic and the felsic minerals to quartz, biotite, epidote and a carbonate mineral although they retain the intergranular texture. It is proposed to call them chlorite diabase by analogy to the uralite diabase and pyroxene diabase in the previous groups and to distinguish them from the group of intrusives known as Ventersdorp diabase.

It has not yet been ascertained whether some of the rocks have been completely altered because of the small granularity or whether they are all older and in a more advanced metamorphosed state, than other types. The similarity between the chill and fine-grained phases of the Harmony Sill and some of these intrusions indicate that fine-grained intrusions are more apt to be completely reconstituted than ones with a coarse granularity. Unfortunately, the age-relation between the latter type of diabase and the Harmony Sill is not yet known.

TABLE XI

Examples of Chlorite Diabase Intrusives

BORE-HOLE NUMBER	DEPTHS IN FEET BELOW SURFACE	THIN SECTION NUMBER	REMARKS
S.E. 2	1807-1847	66	
S.E. 3	1974-2026	67	
M.5	1636-1756	68	Ilmenite abundant
V.Z. 2	3537-3555	69	

F. VENTERSDORP DIABASE.

These intrusives numerically comprise the most important series of dykes. They are dense, green-grey and superficially resemble the Ventersdorp andesitic lava. Veins consisting of quartz, chalcedony, carbonate, chlorite and pyrite are more common than in the other types of intrusive, indicating that percolating solutions had a great influence in producing the mineralogical changes. Veins occupying joints parallel to the contacts of the intrusive are numerous.

In the unravelling of the structure of intrusive "D" south of Merriespruit No. 1 Shaft, for instance, the fact that most of the veinlets trend parallel to the contacts of the intrusive was used to predict where the intrusive became transgressive, even when no contacts were exposed. Chlorite is very abundant in shear fractures.

Shearing and brecciation is common both in the body of the intrusive and on the contacts, the intrusive forming a zone of weakness on which adjustments of stress could take place. In general, the oldest intrusives have been the most intensely deformed. Water is almost invariably stored in the shear fractures. In places where the contacts are solid against the adjoining rock there is a thin, grey, chill zone. Many intrusives are mottled close to the contacts due to spherical patches of pale-green material rich in a carbonate mineral.

In thin section, the rock is a crystalloblastic aggregate of chloritic minerals, a carbonate mineral and quartz, and has leucoxene and pyrite as accessories. Minerals of the epidote group are not present in these highly altered intrusives.

There appears to be several varieties of chlorite. A pale-green chlorite has the anomalous "berlin blue"

interference colour characteristic of penninite (Winchell II, 1946, p. 282). Another variety, closely resembling penninite, has an olive-green anomalous interference colour. This variety has been found in the "Iron Curtain" intrusive dyke (section 70) and in intrusive "C" (section 61), and it also surrounds grains of pyrite in pyritic stringers (section 5 and 7). Other chlorites with higher birefringences than the penninite have been noticed.

The carbonate mineral occurs as aggregates or, more rarely, as euhedral crystals. It is the first mineral to form independently of the boundaries of the original igneous minerals. In a slide of an intrusive in bore-hole M.2 (section 71) which underwent weathering prior to the formation of the Karroo System, the carbonate mineral is reddish-brown indicating that the molecule contained ferrous iron which had become oxidised. A specimen of an intrusive intersected immediately below the base of the Karroo System in bore-hole O.W.1 was sent to the Union Geological Survey for identification. Their report mentioned ankerite as being a prominent constituent. It is possible therefore that the carbonate mineral in all the intrusives is ankerite.

The variety of quartz present is mainly chalcedony. In many of these intrusives it is impure, containing very small grains of chlorite and opaque minerals. Some of the quartz is coarse-grained and clear.

The Ventersdorp intrusives can be subdivided into three groups:-

(a) Palimpsest Igneous Texture Visible.

The original feldspar crystals are altered to chalcedony containing finely disseminated leucoxene.

The latter also occurs as rods and angular crystals.

In some intrusives, chlorite is intergrown with



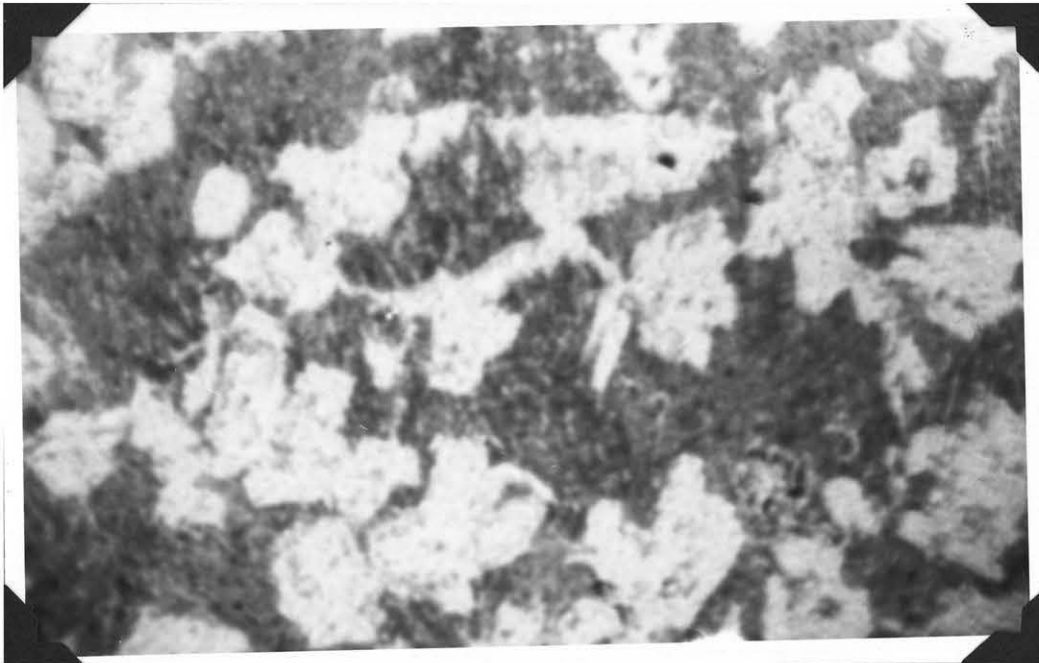
TABLE XII

Examples of Ventersdorp intrusives with palimpsest igneous texture.

Local Designation	Locality	Thick-ness	Slide	Characteristic Features	Form of Intrusion	Age Relationship
1. Ilmenite Diabase	Virginia No.1 Shaft area (north-east) (Plate I)	15 feet	72	Mafic minerals altered to a dirty brown chloritic aggregate. Abundant ragged and rod-shaped aggregate of leucoxene apparently pseudomorphous after ilmenite, similar to "ilmenite-diabase" described by Ellis (1940).	Dyke system: contacts with jagged outlines and locally slickensided; dip for each dyke constant, but different in adjacent dykes	Intruded by Harmony Sill, but cuts through sill of other Ventersdorp diabase (group F(b)) seemingly without disturbance (intersection not exposed). Less altered than other Ventersdorp intrusives and probably younger than lower Ventersdorp lava.
2. 25 Level Station Dyke	Virginia No.1 Shaft area, at 25 Level Station	1 - 2 feet	73	Mafic minerals altered to dirty brown chloritic aggregate. Leucoxene rod-like and angular, after ilmenite.	Dyke  P.T.O.	Unknown

TABLE XII (Contd.)

Local Designation	Locality	Thick-ness	Slide	Characteristic Features	Form of Intrusion	Age Relationship
3. 27 Level Strike Dyke.	Virginia No.1 Shaft area on 27 Level, reef intersection.	5 feet	74	Mafic minerals altered to dirty brown chloritic aggregate. Leucoxene rod-like and angular, after ilmenite. Contains amygdales of carbonate, quartz and chlorite, and inclusions of quartzite.	Dyke, intruded into brecciated quartzite. "Frozen" chill contacts. Parallel to strike of Basal Reef; dips 80° west. Downthrow to west on dyke is 4 feet.	Unknown.
4. Intrusive "D".	Merriespruit No.1 Shaft area, south of shaft.	2, feet	75 photo- micro- graph 40	The light-grey palimpsest mineral aggregate lies in subophitic relationship to the dark-grey palimpsest mineral aggregate. Leucoxene very finely divided.	Compound intrusion of the Mariévale type (Ellis, 1944)	Intruded by a uralitediabase, intrusive "C".



Photomicrograph 14.

Ventersdorp intrusive, type a, Intrusive "D", 31 Reef Drive East, Merriespruit Mine.

Composed chiefly of chlorite and quartz; ore dust in the dark portions. It exhibits a relict igneous texture that is not visible under crossed nicols.

Plain light. (X 195)

Section 75.

chalcedony and forms a feathery texture resembling feldspar microlites in an aphanitic rock. In most of the thin sections, this feathery texture is orientated in such a way that the microlite "feathers" trend in the same direction. A very faint pattern of plagioclase was visible on an X-ray film of these microlites.

Examples of this group are given in table XII.

Intrusives belonging to this group have been intersected in the following bore-holes:-

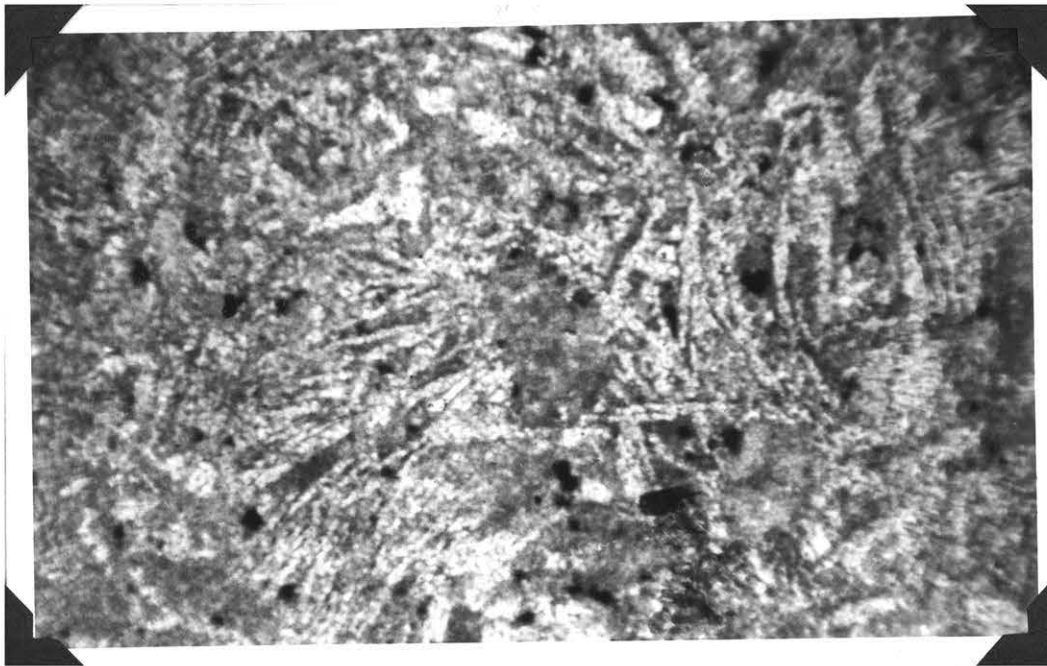
TABLE XIII

BORE-HOLE NO.	DEPTH IN FEET	SECTION NUMBER	REMARKS
A.D.1(a)	2633-2664	76	Correlated with the dyke north of the "Iron Curtain" dyke.
M.2	1365-1429	77	
K.A.1	1668-1736	78	Contains numerous veinlets
K.A.2	5095-5138	79	

(b) All Igneous Textures Destroyed.

The only texture visible in thin sections is the feathery texture mentioned in the previous section. It is accentuated in some intrusives by the irregular distribution of dust and small crystals of leucoxene. In some thin sections, careful inspection will reveal a very faint relict igneous texture, implying that there is a gradational relationship, as far as degree of alteration is concerned, between intrusives of groups F (a) and F (b).

The most notorious dyke in the Virginia Mine is,



Photomicrograph 15.

Ventersdorp intrusive, type b, "Iron Curtain Dyke",  
Virginia No.1 Shaft.

Chlorite, quartz and ore are intimately intergrown  
The feathery texture resembles feldspar microlites.

Plain light. (X 165) Section 70.

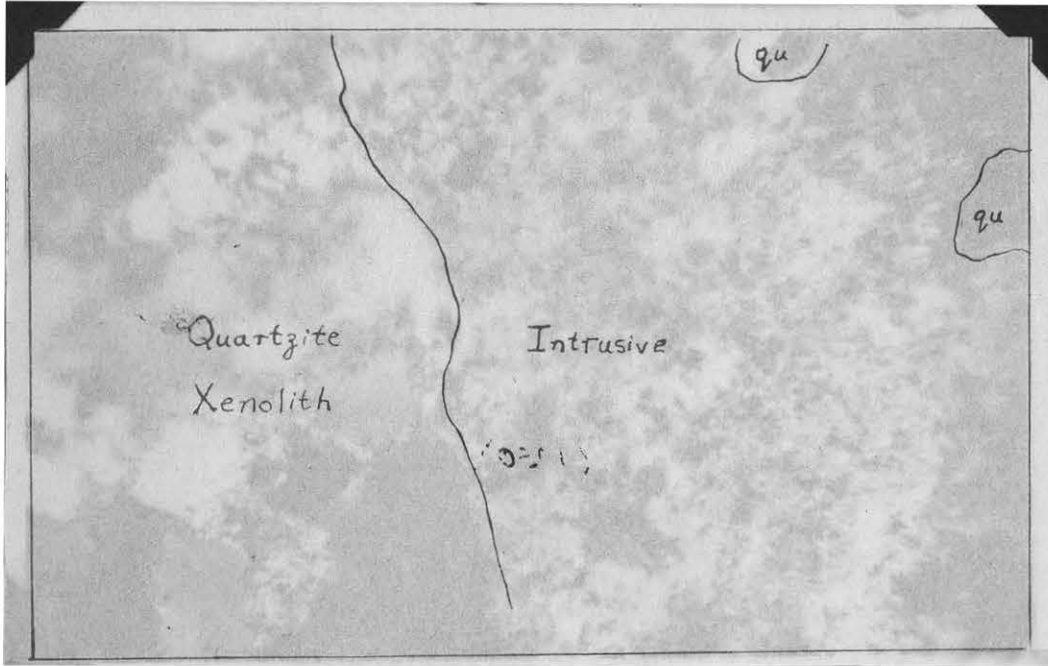
no doubt, the "Iron Curtain" dyke, (plate I, photomicrograph 15), which has delayed the initial development of the mine because of the considerable quantities of water stored up against its sheared contacts and in shear-planes in the body of the intrusive. In plan it is a fairly straight dyke striking east-west, but where it traverses the much faulted ground around No. 2 Shaft, it is broken up into a series of en echelon dykes.

A sill of this group having an average thickness of 35 feet overlies the reef in the area around the No. 1 Shaft of Virginia Mine. The sill does not remain on the same horizon, however, but transgresses the strata in a highly irregular way, in places cutting through the reef and recrossing the reef a little further on. Irregular tongues protrude from the main body into the adjacent quartzite. The sill has been traced as far as the No. 2 Shaft area. The magma appears to have been intruded into the Upper Division of the Witwatersrand System not long after a main period of tectonic activity, releasing unbalanced stresses by the injection of magma into planes that were locally under diminished pressure.

An intrusive belonging to this group has been intersected in bore-hole M.2 between 1231 feet and 1238 feet (section 71) and in bore-hole M.U.1 at 1455 feet (section 80).

(c) Dykes Associated with Faults.

The fault east of Virginia No. 2 Shaft, the de Bron fault and the Merriespruit thrust fault are all occupied by such dykes. These dykes are dense, green-grey and badly sheared. They have peculiar elongated zones of lighter-coloured intrusive material rich in carbonate



Photomicrograph 16.

Contact of Ventersdorp intrusive of type with a xenolith of quartzite. The chilled zone is absent and relict grains of quartz appear in the intrusive. Bore-hole C.A.1 at 2581 feet.

Crossed nicols. (X 150) Section' 82.

which resembles a flow structure. Many dykes of this type have been described as mylonites by field geologists. In thin section they are similar to the Ventersdorp intrusives (section 81).

The intrusions of group F is regarded to be of Ventersdorp age by the majority of geologists who have studied the intrusive rocks in the Witwatersrand System, as these intrusives closely resemble the Ventersdorp lava petrographically. Among these are Horwood (1910) Ellis (1946) and Pegg (1950).

Pegg believes that some of these may have been feeders to the Bird Amygdaloid, but as this lava flow is not present in the Orange Free State, this probability is remote.

#### G. CONTACT PHENOMENA.

A Ventersdorp intrusion of type (a) immediately underlying the Leader-Basal Reef in bore-hole C.A.1 at a depth of 2577 to 2590 feet, has assimilated portions of the surrounding quartzite. In the slides (sections 82 and 83, photomicrograph 16) of the contact between the intrusive and a partly resorbed xenolith of quartzite, there is no sign of a chill contact. Calcitic and chloritic materials derived from the intrusion have migrated into the quartzite, replacing all but the large grains of quartz. The rim of the quartzite xenolith is more chloritic and calcitic than the core, indicating hydrothermal solutions rich in magnesium, aluminium, iron and calcium have permeated the quartzite in contact with the igneous rock. Some more resistant xenoliths of sedimentary material within the igneous rock have been altered to coarsely crystalline calcite containing some quartz, sericite and a few shreds of biotite. It is possible that the "amygdales" found in the "27 Level Strike Dyke" are reconstituted xenoliths. No examples of rheomorphism and syntexis have so far been encountered.



## H. AGE RELATIONS.

The various groups of intrusive rock have been discussed, as far as the writer was able to determine, in the order proceeding from the youngest to the oldest rocks. Their age relations still require a great deal of study. It is probable for instance, that the Harmony Sill is much younger than intrusive "C" although they are both uralite diabase, because, in the hand-specimen, the Harmony Sill seems less altered. On the other hand, representatives of the pyroxene and chlorite diabase group may be of the same age as intrusive "C", but only more intensely metamorphosed. Some of the Ventersdorp diabase intrusives may originally have been very fine-grained, with the result that their alteration was completed at an earlier stage than the coarser intrusives, or with the result that their alteration gave rise to that particular type. Also the dykes occupying fault-zones of diabase could have been completely reconstituted much more rapidly than the others as a result of shearing stress.

It is the writer's experience that individual intrusives can be recognised by minor textural details. Polished or shellac-coated planes on hand-specimens are often useful in revealing details of texture, and individual intrusives can often be correlated in this way before thin sections are made.

## I. COMPARISON WITH PUBLISHED LITERATURE.

In table XIV information from various publications are compared.

The importance of quartz in many of these intrusives seems to have been over-emphasised. The presence of approximately 3 per cent of quartz in uralite diabase may be considered by some geologists as ample justification to use a term such as quartz diabase, as long as the silica

TABLE XIV

Comparison of Intrusives as described by various authors

Mc Donald, D.P. 1911	Nel, L.T. 1935	Ellis, J 1940 - 1944	Pegg, C.W. 1950	O.F.S. Virginia-Merriespruit Area	General Physical Characteristics
Dolerite (1) Olivine-bearing (2) Olivine-free Karoo		Dolerite Karoo	Dolerite Karoo	Olivine-bearing dolerite Karoo	Rock-forming minerals mainly fresh. Contacts not sheared
	Basic sheets Transvaal	Quartz dolerite Bushveld		Uralite diabase Post-Ventersdorp	Domical sheets, en echelon dykes, Maryvale types. Contacts locally sheared.
Granophyre Bushveld		Granophyre, syntectic, Bushveld			
Tonalite Bushveld	Feldspar porphyry and Quartz porphyry	Syenite dykes Bushveld	Quartz porphyry Bushveld		
Epidiorite Ventersdorp				Epidiorite	Unknown, possibly thick sills
	Basic sheets Transvaal	Ilmenite diabase Post-Transvaal	Ilmeno-dolerite Karoo?	Ventersdorp diabase, Pyroxene-diabase Chlorite-diabase	En echelon dykes, ragged, sheared contacts, sheets

TABLE XIV contd

Mc Donald, D.P. 1911	Nel, L.T. 1935	Ellis, J 1940-1944	Pegg, C.W. 1950	O.F.S. Virginia-Merriespruit Area	General Physical Characteristics
Completely metamorphosed intrusives, and intrusives showing relict igneous texture. Ventersdorp Ventersdorp	Aphanitic intrusives connected with Ventersdorp lavas Pre-Transvaal	Ventersdorp diabase Ventersdorp		Ventersdorp diabase Ventersdorp?	Sills, dykes, Maryvale-type compound intrusions irregularly-shaped intrusions sheared contacts.
			Chloritoid-bearing dykes (1) Ventersdorp (2) Bird Amygdaloid		
	Xenolithic diabase Pre-Transvaal?		Amygdaloidal diabase Pre-Transvaal	Xenolithic diabase also amygdaloidal?	Dykes, contacts not sheared

is of primary origin. (Shand S.J., Eruptive Rocks, 1947, p. 226). As it is most likely that the quartz is of secondary origin, the writer prefers not to use the prefix.

The writer also finds that sericite in these intrusives are rare and surmises that calcite in fine-grained form could easily have been confused with sericite.

No chloritoid appeared in any of the slides examined.

## C H A P T E R VIII.

### STRUCTURE

#### A. GEOPHYSICAL PROSPECTING.

The original drilling program was already far advanced when an aeromagnetic survey was carried out. The survey was designed to provide structural information which could be used in conjunction with the information obtained from completed bore-holes. It was hoped that bore-holes could then be located to the best advantage.

Except for a well-defined linear anomaly striking west from the old Kaalvallei Diamond Mine and indicating the position of a Kimberlite "fissure", the variations in the magnetic intensity gave only the broadest outline of the structure by indicating on a regional scale where beds of the Lower Division of the Witwatersrand System lie close to the base of the Karroo System.

A gravimetric survey was carried out after the drilling program had been completed. The purpose of this survey was to trace the strike of faults, which were intersected in bore-holes and to determine whether faults, which were not intersected in bore-holes could be traced by this means.

Unfortunately, the results of the gravimetric survey did not come to expectations. There were too many variable factors that could cause gravimetric anomalies or obscure them. Firstly, there is the variable depth of the covering Karroo System, for which corrections had to be made. (The depth of the Karroo system on the Virginia and Merriespruit mines ranges from approximately 700 feet to over 2,000 feet. See Cousins, 1950, plate XXXVII). Secondly, near-surface sheets of dolerite that have a thickness approximating 100 feet caused anomalies which could have been interpreted as being the result of faulting in the Witwatersrand System. The variable proportion of dolerite in the Karroo System is another difficulty that had to be accounted for. In

addition the anomaly due to increase in the thickness of Ventersdorp lava on one side of a fault tends to be compensated by shallower heavier rocks of the Lower Witwatersrand System. Even the presence of the de Bron fault was obscured by the occurrence of Ventersdorp Upper Sediments in the western block. These sediments are comparable in density with the quartzite of the Upper Division of the Witwatersrand System, with the result that the expected high density anomaly usually characteristic of the Ventersdorp System did not exist over the western block. On the other hand, the strike of a fault east of No. 2 Shaft on the Virginia Mine was correctly predicted after having first been intersected in a bore-hole drilled horizontally in the direction in which the crosscut was advancing.

B. STRUCTURAL INTERPRETATION.

On the average, only one bore-hole per square mile was drilled on the Virginia and Merriespruit mines. Only generalised structural maps could, therefore, be drawn from bore-hole information alone, yet these had to be as accurate as possible so that the positions of shafts could be planned to the best advantage. Structure contour maps were revised and kept up to date as underground development exposed greater detail. Plate I is the latest structure contour map of the Basal and Leader-Basal Reefs.

In order to obtain very reliable structural information from bore-hole drilled from the surface, the more recent bore-holes were surveyed by an Eastman directional survey instrument for deviation from the vertical. Radiometric logging was also done by the Union Geological Survey soon after completion of each of the recent bore-holes.

In the case of bore-hole K.A.2 an attempt was made to determine the dip and strike of the Basal Reef by means of two deflections, each of which were accurately surveyed by the Eastman directional survey instrument. The deduced strike

is almost at right angles to the average strike of the Basal Reef in the drive nearest to the bore-hole (see plate I). The reason for this discrepancy presumably is that the points of intersection of the Basal Reef are too close together, the largest distance between points being less than 12 feet, coupled with the fact that the margin of error in measuring the depth of the reef intersections is too great.

It is a well-known fact that bore-holes penetrating low-dipping strata tend to deviate in such a way as to penetrate the strata perpendicularly. (Garrett W.S., 1952, p.p. 510-513.)

Other mechanical factors also influence the deviation of a hole. The direction of deviation can, therefore, be used only as a guide to the strike and dip in the vicinity of a bore-hole, when other more precise information is lacking. In steeply dipping holes, the hole seems to deviate parallel to the bedding.

The dips of the strata can be measured on the core and should then be corrected for the deviation of the hole. Dips measured on cores of quartzite differ somewhat from the true dip because false dips in current-bedded strata cannot always be distinguished from true bedding-planes.

The structure contour map (plate I) and the block diagram of Virginia Mine (plate J), show that faulting in this part of the Orange Free State Gold-field is much less intense than in the Odendaalsrus area. Large, relatively unfaulted blocks are bounded by a few faults of considerable throw. Adjustments in the fault blocks are achieved by folding and by minor faults with displacements of only a few feet.

The change in strike of the Upper Witwatersrand sediments in the Merriespruit Mine takes place on the nose of a large north-plunging syncline.

Because of the vast thickness of competent brittle quartzite involved in the folding, the fold is open, and the dip of its limbs seldom exceed 20 degrees. The western limb

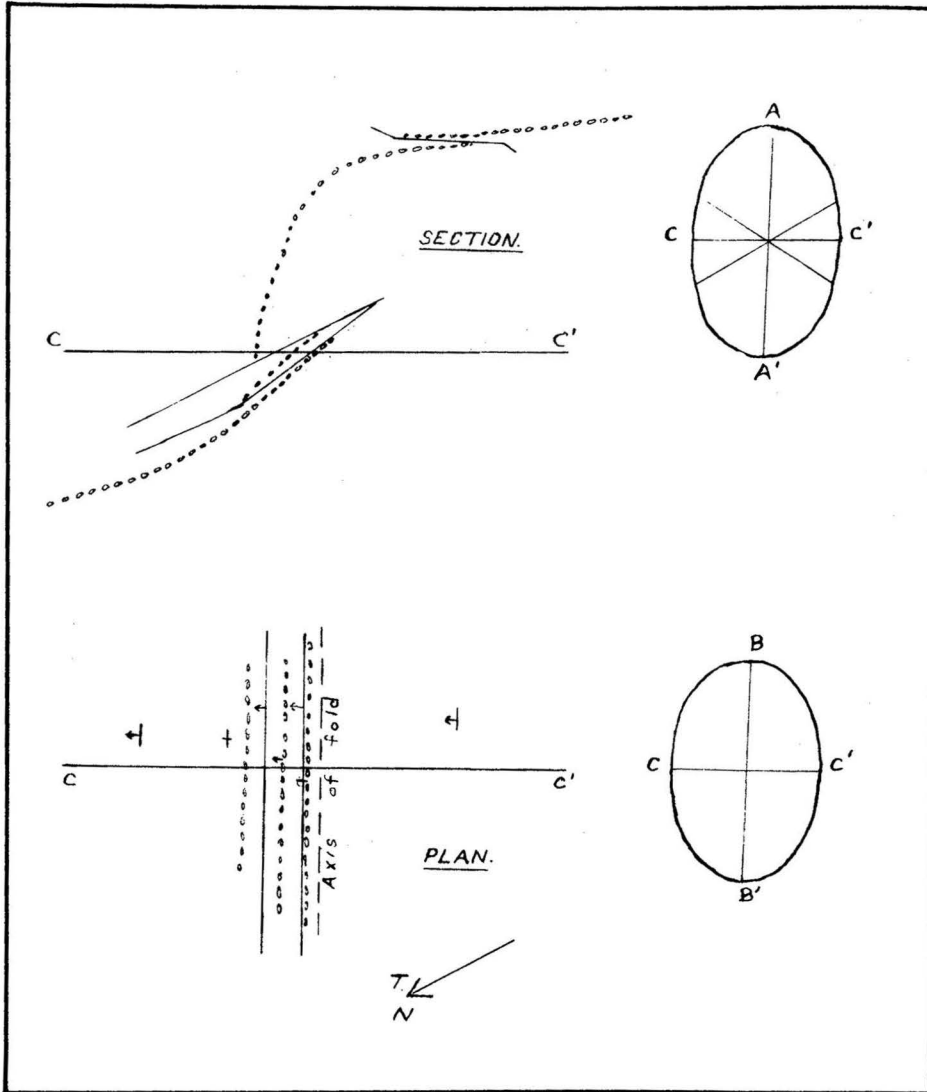


Fig. 11.

Faulted monoclinal fold in 33-3E Raise,  
Merriespruit.



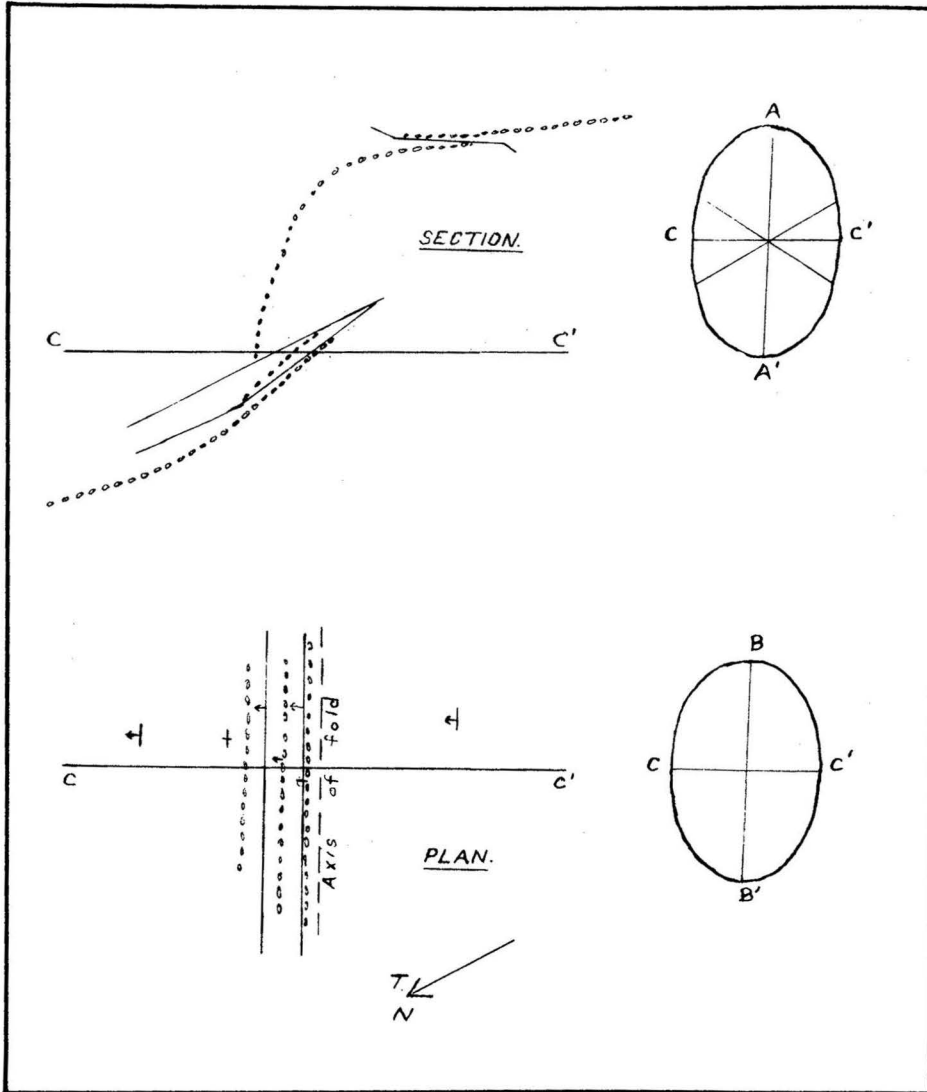


Fig. 11.

Faulted monoclinal fold in 33-3E Raise,  
Merriespruit.

in bore-hole M.O.2 indicates that the dip in the western block is either reversed, or that further intense faulting complicates the downthrow block. The latter possibility has been assumed in plate I.

A detailed structural and stratigraphical analysis of the core of bore-hole M.O.3 shows that this bore-hole has penetrated a steep, faulted monoclinial structure (plate I, section A.-A.) As the depth of the Basal Reef in bore-holes to the west of the Merriespruit Mine agree more closely with the upper intersection of the reef and as the hole followed the dip of the strata for a considerable extent, the faulted monocline can be considered as the other wall of a trough or graben. The faulted monocline is considered to meet the de Bron fault at an oblique angle north of the Merriespruit Mine, with the result that bore-hole L.R.I is situated on the shallow side of this structure. The faulted monocline parallels the Homestead fault and may represent the southerly extension of this fault after trailing the de Bron fault for some six miles.

In bore-holes S.E.3 and M.U.I., duplication of strata indicates the presence of a reverse or thrust fault, which has a throw of approximately 2,000 feet in the vicinity of these bore-holes. The difference in the type of quartzite forming the footwall of the two intersections of Leader-Basal Reef in bore-hole S.E.3, shown in plate F, indicate that considerable compression took place perpendicular to the strike of the fault, which favours the belief that this is a thrust fault. (Billings M.P, 1942, p.172). For the sake of conservatism, the dip of this fault in the structure contour map has been taken at  $45^{\circ}$ , although the dip may in reality be much smaller.

Local steepening of the beds occurs on the limbs of the syncline and forms minor monoclinial folds, some of which are associated with thrust and other faults. (See fig.11) These are prominent in the Merriespruit Mine around the nose

of the syncline, but does not seem to be related to that feature. The orientation of the ellipsoid of deformation is similar to that of the Merriespruit thrust fault and it may be assumed that they are of the same age.

A normal fault with a down-throw of approximately 350 feet towards the west has been encountered in the course of underground development between No. 2 and No. 3 Shafts of the Virginia Mine. The strike of this fault is parallel to that of the large Virginia or Railway fault, to the east of which the so-called G.F. Block of Upper Witwatersrand sediments has been thrown down. To the west of the fault near No. 2 Shaft, there is local folding and intense minor faulting. The folds trend north-east towards the south-west the faults decrease in intensity.

Some of the intrusions followed fault-planes. Most of these are Ventersdorp type intrusions which exhibit a structure similar to the flow-structure of viscous lava.

Fault-planes along which the tensional movement has been up or down commonly dip at angles between  $55^{\circ}$  and  $70^{\circ}$  and these along which horizontal movement predominated are usually steeper than  $80^{\circ}$ . The latter have a mullion structure pitching at low angles.

The low-angle thrust faults associated with minor folds have variable, curved strikes.

The thrust faults are displaced by most of the other types. The age relation between the strike-slip faults and the tensional faults is less certain. Small, water-bearing strike-slip faults south of Merriespruit No. 1 Shaft appears to have been subjected to a later vertical movement, which has partly shattered the mullion structure, leaving openings up to 6 inches in thickness in which water has accumulated.

The displacement of the de Bron fault took place during the deposition of the Upper Ventersdorp sediments. A great thickness of agglomerate, tuff and quartzite accumulated in the trough that developed to the west of this fault. The age relation between this fault and the others is not known.

## C H A P T E R IX.

### STRATIGRAPHICAL ANALYSIS AND ENVIRONMENTAL RECONSTRUCTION.

#### A. INTRODUCTION.

The study of sedimentary rocks should always be directed towards the unravelling of the environmental conditions under which the sediments were deposited. The alteration of strata representing a succession of lithotopes or areas of uniform sedimentary environment provides the key to the geological history or conditions prevailing during deposition of the sediments. A careful study has, therefore, been made of the characteristics and variations of each sedimentary unit for the purpose of determining the environmental pattern of that unit.

Sharpe (1949, p.266-279) has shown that the concept of cyclical sedimentation can be applied to sediments of the Witwatersrand System. The study of sedimentary tectonics in sedimentary analysis is being increasingly realised as of major importance and it is felt that diastrophism is a major factor in sedimentation. The theory of a geosynclinal origin of the Witwatersrand System is now generally accepted. B.B. Brock ("A view of faulting in the Orange Free State"), has given a vivid picture of the main stages in the growth of the geosyncline.

A number of features, which Pettijohn has mentioned as being typical of the geosynclinal facies are also characteristic of the Witwatersrand Beds: (Pettijohn, 1949, p.444-446).

- (1) The great thickness of the Witwatersrand is comparable with thicknesses of sediments in geosynclinal basins.
- (2) Arenaceous and argillaceous materials are intimately mingled.
- (3) The coarseness of grain and the abundance of sand increases upwards.
- (4) Rhythmic and graded bedding is common in the Lower Witwatersrand System.

- (5) Carbonate rocks are absent or very rare and other chemical sediments are rare, but bedded chert is common near the base.

It must be borne in mind that the proximal facies of a geosyncline is the one most often found in outcrops, so that the following features of Pettijohn must be added: (See also Krumbein and Sloss, p.22).

- (6) The rocks are very thick, coarse-grained and polymictic in composition.
- (7) They contain material of earlier deposited strata of the margins of the same geosyncline.

In the chapter on disconformities, we have come to the conclusion that a considerable thickness of sediment had been removed from the marginal areas subsequent to deposition. If the Witwatersrand System was formed in a geosynclinal basin, where else could these sediments have gone to but further into the basin, where the depth of water was below the base-level of erosion. It must be stressed that the area covered by this treatise is not the proximal facies of the geosyncline, but is presumably near one of the extremities of its axis, with the result that the environment bears many of the characteristics of an unstable shelf. The tectonic framework of the Far East Rand, on the other extremity, resembles that of this area.

## B. GEOLOGICAL HISTORY.

During the closing phases of deposition of the Lower Division of the Witwatersrand System, coarse sediments began to preponderate, as the surface of deposition approached the base-level and also as a result of isostatic adjustment whereby the distributive province was elevated. It must be assumed that the great thickness of material comprising the sediments of the Lower Division must have definitely disturbed the balance of load on the substratum. In the Free State, submergence kept pace with the influx of detritus although the presence of pebble bands in the Lower Footwall beds indicate that the base-level was approached and perhaps actually reached for short intervals. On the Central Rand,

the base level was not only reached, but erosion of newly-formed sediments occurred and a strand line was present with its concomitant environments of beach, lagoon, estuary and dune. Transgressive seas over newly-formed sediments of these environments left auriferous conglomerate beds as their basal deposit.

Throughout the time preceding the deposition of the Basal Reef, normal marine (neritic) sedimentation is postulated to have taken place in the Orange Free State area. Owing to isostatic adjustments the sedimentary basin was periodically depressed and the distributive province elevated, resulting in periodical rejuvenation which in turn affected the composition, volume and coarseness of the sediments being deposited. The resulting sedimentation was cyclical, the sands ranging from argillaceous to pebbly. The conglomeratic units in the Lower Footwall beds and the Intermediate Reefs represent culminations in diastrophism or crests in the cycles of sedimentation (Sharpe, 1949, p.270.)

Dr. D.J. Simpson has noticed that the uranium content of the sediments also increase and decrease rhythmically as the coarseness of the sediments increases or decreases. (1951, p.106).

During the interval of time immediately prior to the deposition of the Basal Reef, there was no coarsening of the sediments deposited, not even in other parts of the Orange Free State. The sedimentation during that interval must have taken place in a shallow-water environment where currents could have been strong enough to form current-bedding and ripple-marks. Extensive drilling has proved that the Lower Footwall beds exist far beyond the limits of the Basal Reef. The sedimentary basin, after the formation of the Basal Reef, was, therefore, much smaller than previously. The tectonical zone between the area of subsidence and the positive area, or the zone of uplift, must, therefore, have moved towards the axis of the geosyncline during that time.

Let us review some of the facts concerning the Basal Reef. In the Welkom area, marker beds occurring in the Upper Footwall beds are progressively overlapped by the Basal Reef in directions radiating from the Welkom Mine. In the Virginia-Merriespruit area, the Basal Reef directly overlies quartzite that is some 200 feet below the reef in the Welkom area. One would, therefore, expect that the Basal Reef would lie on a sharply demarcated plane, a disconformity. This is not the case. We have seen that the sediments of zone E.L.1 is separated from the Basal Reef by a disconformity and that the lenticular quartzite intercalated with the conglomerate of the Basal Reef is almost impossible to distinguish from the quartzite immediately underlying the reef.

One can attempt to explain these facts by assuming a sudden influx of coarse sediments from a rejuvenated distributive province. Such an event would have been heralded by a somewhat progressive increase in coarseness of the detritus, for which there is no evidence. In fact, the gradation from large to small pebbles in the Basal Reef is upward.

Should one assume that the coarse sediments had been eroded prior to the emplacement of the Basal Reef, one would also have to assume the elevation of almost the entire Orange Free State section of the geosynclinal basin above the base level. The assumption is contrary to the tectonic framework of sedimentation in a subsiding geosynclinal basin.

The sequence of events to be described below seems to explain the facts most satisfactorily. Prior to the deposition of the Basal Reef, sedimentation took place in shallow water where currents and waves could wash away the finer-grained clayey material and leave a fairly pure sandy deposit. The subsidence of the basin was so slow that the base level was eventually reached, with the result that most of the incoming detritus of sand-dimensions were swept deeper into the basin. The surface then became covered with the coarse materials

which the waters were not competent to carry away. "These would be a part of the underlying unit and would be the last sediments deposited before the beginning of the new cycle". (W.H. Twenhofel, 1939, p.27, see also p.30). The Basal Reef is, therefore, petrologically not a basal conglomerate, but a marginal or terminal conglomerate.

Coupled with the slow subsidence of the basin at the time of the deposition the Basal Reef, was an uplift at the margin. This took place at such a rate that wave action and currents were able to preserve the base level by removing the sand elevated above this level and transporting it to areas further into the basin, where the bottom of the sea was below the base level. Throughout this interval, which was long enough to have eroded about 300 feet of sediment from near the margin, heavy minerals and material of pebble dimensions were concentrated on the base level. At the same time, material from the distributive province was also received and sorted. The pebbles of soft material were ground away and the hard pebbles were rounded and comminuted. The majority of pebbles remained close to the shore-line, forming a thicker body of conglomerate than deeper into the basin.

The mapping of the Basal Reef on the Merriespruit Mine revealed that it contained elongated lenticular patches where the reef is of uniform appearance. (plate D.) Their longest axes lie in a north-easterly direction. Krumbein and Sloss, (1953, p.194) has called such individual patches lithotopes. Together they form the environmental pattern of the Basal Reef. We have shown previously that the distribution of gold in the reef is closely related to the sedimentary features and that "pay shoots" exist in lithotopes where the reef is well-developed. A knowledge of the environmental pattern of the Basal Reef may, therefore, assist in predicting the distribution of "pay shoots".

The writer tentatively submits the following explanation for the environmental pattern encountered in the



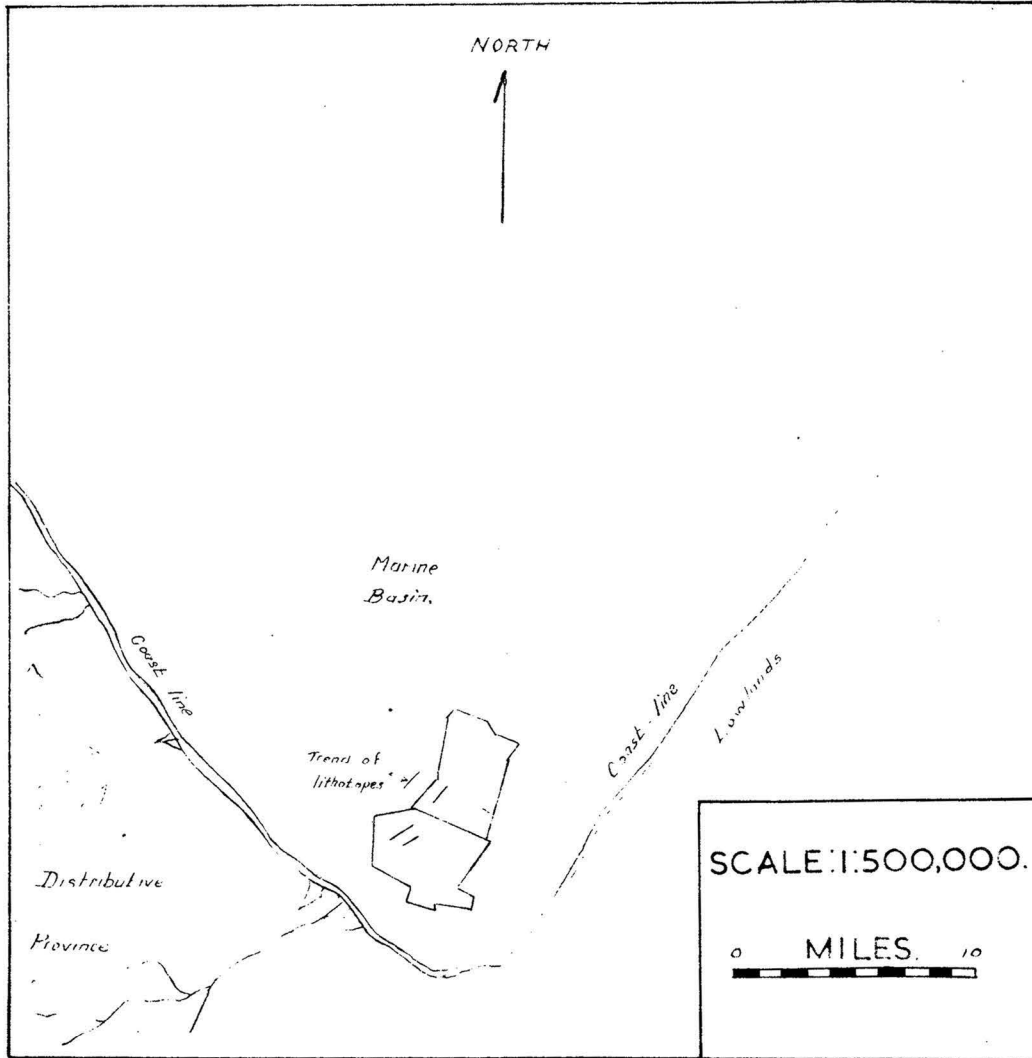


Fig. 12.

Paleogeographic map of the Basal Reef.

Virginia-Merriespruit area.

It is common knowledge that there are areas on any beach where the undertow is stronger than elsewhere. These areas are depressed relative to the rest of the shore-line. The elevated areas are the so-called beach cusps, and may be as much as 3 feet higher than the surroundings. The undertow results in the formation of off-shore currents. It is reasonable to assume that sediments subjected to the additional energy of these off-shore currents would be coarser and better sorted than those in bordering areas.

The presence of long-shore currents would modify the lithotope thus formed if the strength of the current at the bottom of the sea is comparable with that of the off-shore currents. At this stage, we do not yet have sufficient information to state definitely whether these currents had a marked effect on the environmental pattern of the Basal Reef.

The direction of elongation of lithotopes in the Basal Reef, as well as the direction of flow of currents displayed in the Footwall beds are north-east. From the paleogeographic map, fig. 12, it is not clear whether off-shore currents or long-shore currents played the longest roll in the formation of pay-shoots, as the coast-line curves from south-east to north-west near the Merriespruit Mine, but the writer considers that the portion of the coast-line opposite the distributive province had been the most effective in determining the shapes of the lithotopes.

Only a slight amount of marginal uplift would have been necessary for the high-lying portions of the Basal Reef to have become exposed to erosion. With the environmental pattern as shown in plate D, the portions where the Basal Reef were removed would be elongated in a north-easterly direction. The material of the Basal Reef that was removed, was washed into the initial sediments that formed during the ensuing period of subsidence. The basin must then have

subsided rapidly by about 70 feet, accompanied by further marginal uplift. The resulting deposit was unstratified, and contained numerous small channels and pot-holes that were filled up with pure, well-washed sand and pebble detritus originating from the higher-lying portions of the Basal Reef. The environment was probably deltaic or littoral. The erratic well-rounded pebbles and the poor sorting of the sand and clay detritus which gave rise to the "waxy" appearance of the quartzite point to rapid deposition in water, as if the detritus was dumped into the basin and covered up before stratification could have been imposed on it by the agency of sea currents. The surface of the delta or deltae might have been above sea-level, as numerous rapidly aggrading distributaries left their imprints in the deposit.

Some of the large streams actually scoured their channels through the Basal Reef. These channels were filled with coarse detritus mainly from the distributive province, as the varied pebble assemblage and the lack of economic concentration of gold and uraninite would attest.

During severe storms, spring tide or perhaps after dust storms, thin layers of pure sand either washed clean of clayey material by water, or sorted by aeolian agencies, were left on the surface of the deposit. As a result of marginal uplift, coarse material of the Basal Reef that had been deposited there in the previous cycle of sedimentation was removed and this material was re-deposited in the distributaries of the deltaic deposit, together with fresh material from the distributive province. This hypothesis would explain the existence of lenses of auriferous and uraniferous conglomerate as much as 40 feet above the base of the E.L.1 sediments. Such conglomerates were intersected in bore-holes K.A.2 and K.A.3 south of No.1 Shaft on the Merriespruit Mine. It appears as if these isolated conglomerate bodies were concentrated near the margins of the basin as it existed during E.L.1 times and that only the southern area was

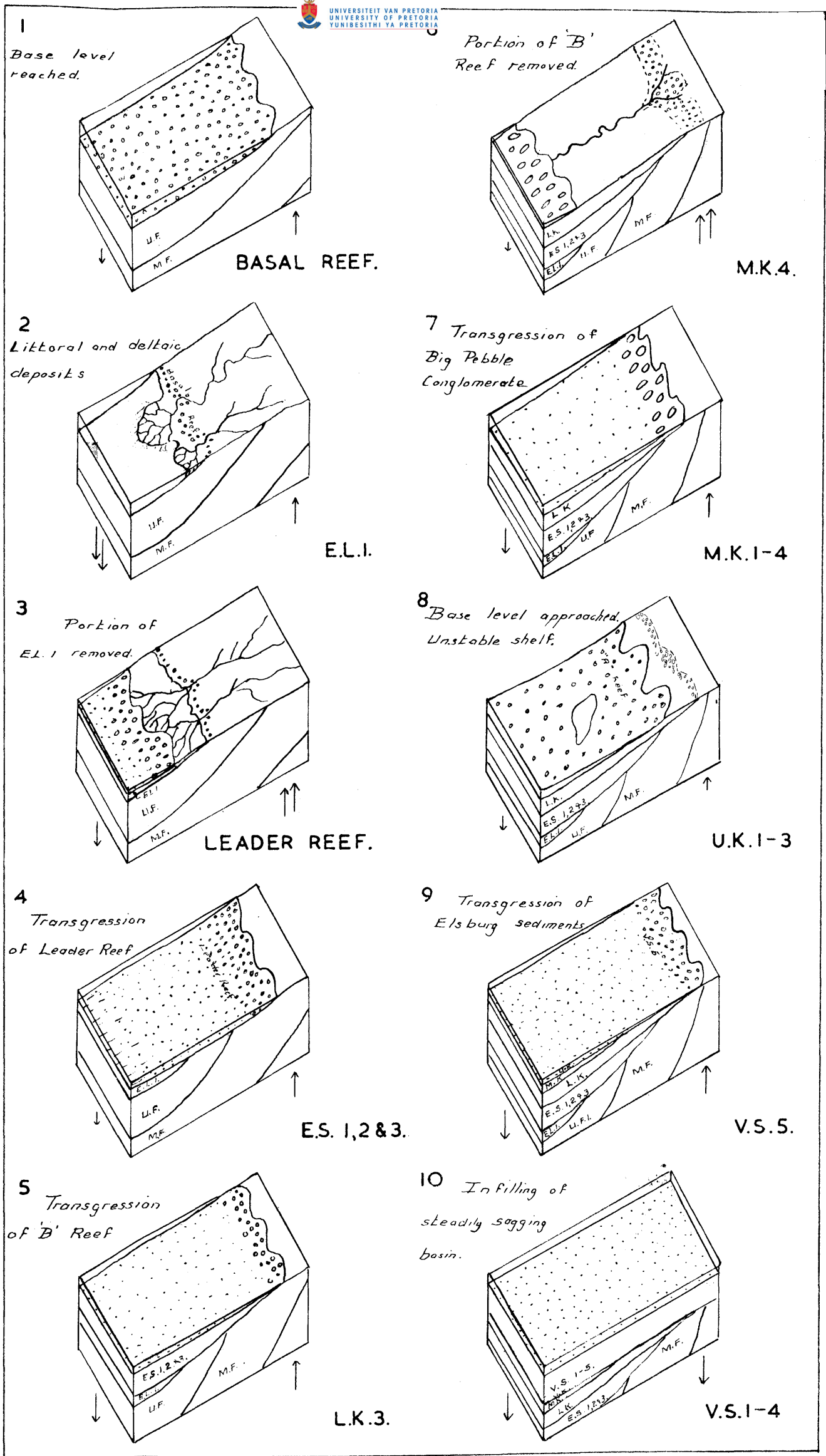


Fig. 13. Stages in the evolution of the Upper Division of the Witwatersrand System in the Virginia-Merriespruit area. ---- Schematic.

subsequently preserved from denudation.

The suspension load of the distributaries, consisting mainly of very small particles of clay, slowly settled beyond the confines of the delta and formed a bed of shale, the well-known Khaki Shale. As the deltae extended, the bottomset beds were covered with deltaic material. The deltaic facies of zone E.L.1 interfingers with stratified quartzite of neritic environment further into the basin and consists almost entirely of the neritic facies towards the Odendaalsrus area. (fig.3).

Current ripple-marks, formed on the upper surface of an outlier of the Khaki Shale, possess a wave-length averaging 3 inches and an amplitude of  $\frac{1}{4}$  inch. This gives a ripple index of 12, which is close to the range of 4 to 10 given by Twenhofel (1939, p.521) for aqueous wave ripple-marks. As aeolian ripples have indices ranging from 20 to 50 one can be fairly certain that these ripple-marks were not formed by wind. The schematic block diagrams in fig. 13 depict stages in the evolution of the Upper Division of the Witwatersrand System from the time that the Basal Reef started to form until the end of the Witwatersrand period. The arrows below the blocks indicate the relative movements which took place and the length and number of arrows the intensity of diastrophism.

The Leader Reef, with its different assemblage of pebbles to that the Basal Reef and zone E.L.1, has probably received a great amount of its material from the distributive province. The coarse basal beds of zone E.S.3 were subject to wave and current action and an environmental pattern probably similar to that of the Basal Reef was evolved. The direction of elongation of the lithotopes have not yet been firmly established, but the meagre evidence available indicates an elongation in a similar direction to that of the Basal Reef. Distributaries on the surface of the delta were filled with material of sand and pebble dimensions.

The Leader Reef, transgressing the E.L.1 quartzite, merged with the Basal Reef and a zone was formed in which the constituents of both reefs were mixed. This brought about a definite enrichment in the mineral content of the reef, which was, therefore, called the Leader-Basal Reef. As the transgression of the Leader-Basal Reef proceeded towards the edge of the basin, and progressively onto older sediments, sand was simultaneously being deposited off-shore on top of the newly-formed conglomerate. The coarseness of the sediments diminished somewhat progressively away from the shore-line with the result that fairly argillaceous sediments of zone E.S.1 formed deeper in the basin at the time that beds of pebble dimensions were being formed near the shore.

The Leader Reef, according to its method of formation, is petrologically a basal conglomerate. It rests upon a disconformity, the base level, and the overlying sediments diminish somewhat progressively in coarseness as one proceeds upwards in the column. We also find, that, whereas the material of the Basal Reef had been subjected to wave and current action for a long time over a considerable area, sorting and concentration of the Leader Reef took place over a narrow zone that advanced into the land with the shore-line. The Basal Reef was, therefore, more nearly contemporaneously developed over the whole area and subjected to a much longer period of sorting and concentration than the Leader Reef.

A similar cycle to the previous one was repeated with the "B" Reef as the basal conglomerate, but this cycle had hardly begun when a fresh upheaval of the source area brought on the very coarse sediments of the Big Pebble Reef.

The lenticular conglomerates, minor disconformities and diastems frequently found in the Upper Kimberley Stage indicate that sedimentation took place close to the base level. The high sphericity of the pebbles and the oligomictic character of the conglomerate bodies indicate that they had repeatedly or for a considerable time been subjected to wave

and current action.

It was during this period that a large river, flowing either eastwards or westwards, scoured its valley out of the semi-compacted sediments. Soundings at river mouths have shown that rivers scour out their channels for considerable distances from the shoreline. It is, therefore, not even necessary to assume that sub-aerial erosion of the adjacent sediments had taken place, as indicated in fig. 5.

The evolution of a valley formed seawards of the shoreline would differ from the diagrams only in that tributaries would be absent, and that the sea-level would be higher than shown.

The period of marginal uplift in the Virginia-Merrie-spruit area ended with the transgression of the Elsburg sediments. The "Gold Estates Leader", which formed in restricted favourable areas on the disconformity has a wider distribution in the marginal area where the newly-formed Upper Kimberley conglomerate beds supplied the coarse material. The contention that the "Gold Estates Leader" has derived its material from the re-working of underlying sediments (Feringa, 1954, p.58) seems logical when one remembers how closely this reef resembles the "A" Reef and how completely different the other Elsburg conglomerate beds are from Kimberley conglomerates.

The V.S.5 conglomerate is a widespread bed of poorly rounded and sorted pebbles of a variety totally different from the underlying conglomerate and typical of the Elsburg Stage. This conglomerate was derived from the coarse constituents of the distributive province and was formed while wave and current action was still strong. The basin was very large at that time. Bore-holes as far south as Monstari 1798, 10 miles south of the Sand River, drilled through as much as 1100 feet of the Elsburg Stage. It is possible that the distributive province also moved further away from the axis of the geosyncline, thus accounting for the different composition of the sediments discharged into the basin. Sedimentation more or less kept pace with subsidence in the basin throughout the

Elsburg Age. In the final stages there was an influx of coarse material, which formed the polymictic fanglomerate against fault - scarps in the St. Helena area. Coarse material was even spread out as far as the Virginia-Merriespruit area. According to Brock, (1954, p.8) the basin west of St. Helena ruptured as a result of an overload of accumulated sediments. The elevated block west of the fault supplied the coarse material that was dumped into the basin east of the scarp.

A bed of conglomerate immediately preceding the first flow of lava resembles other Elsburg conglomerates and is apparently conformable with the Elsburg sediments. Its position with respect to the lava, however, indicates that the conglomerate is the correlate of the Ventersdorp Contact Reef, which is the basal conglomerate of the Ventersdorp System. In the Virginia-Merriespruit area, therefore, the Ventersdorp System follows upon the Witwatersrand System apparently without a break in the sedimentation.



## C H A P T E R X

### THE RELATION BETWEEN THE ORIGIN OF THE BANKET AND ITS MINERAL CONTENT.

---

In the course of the petrographical investigation, it became clear that the conglomerate beds that possess a particular set of characteristics are more likely to contain gold and uraninite in economic concentration than others. These characteristics are, as previously mentioned, a high proportion of resistant pebbles, a high co-efficient of sorting and degree of roundness and sphericity, close packing, and a minimum of intercalations of quartzite. These characteristics are caused by the action of aqueous currents and waves. The fact that the majority of gold-bearing conglomerates are connected with disconformities suggest that the selective action of waves and currents took place on a profile of equilibrium. The sedimentary environments in which the bankets of the Witwatersrand System originated favoured concentration of heavy minerals with the coarse light constituents. The gold and uraninite in the bankets can therefore be explained as concentrations of heavy minerals in ancient placer deposits.

The theory of post-depositional infiltration of mineralising solutions can hardly account for the high concentrations of gold and uraninite in isolated bodies of conglomerate lying in zone E.L.1. Neither can it account for the barren channel conglomerate that locally replace the mineralised Basal Reef.

It may be argued that either gold or uraninite or both of these minerals have replaced other heavy minerals, or that these minerals were precipitated by certain heavy minerals. If that were the case, the distribution of gold and uraninite would be controlled by the distribution of these heavy minerals. Environmental conditions that would concentrate heavy minerals would still control the distribution of

gold and uraninite.

The writer finds that in this area, at least, a terminal conglomerate is likely to be of greater economic importance than a basal conglomerate.

## C H A P T E R XI

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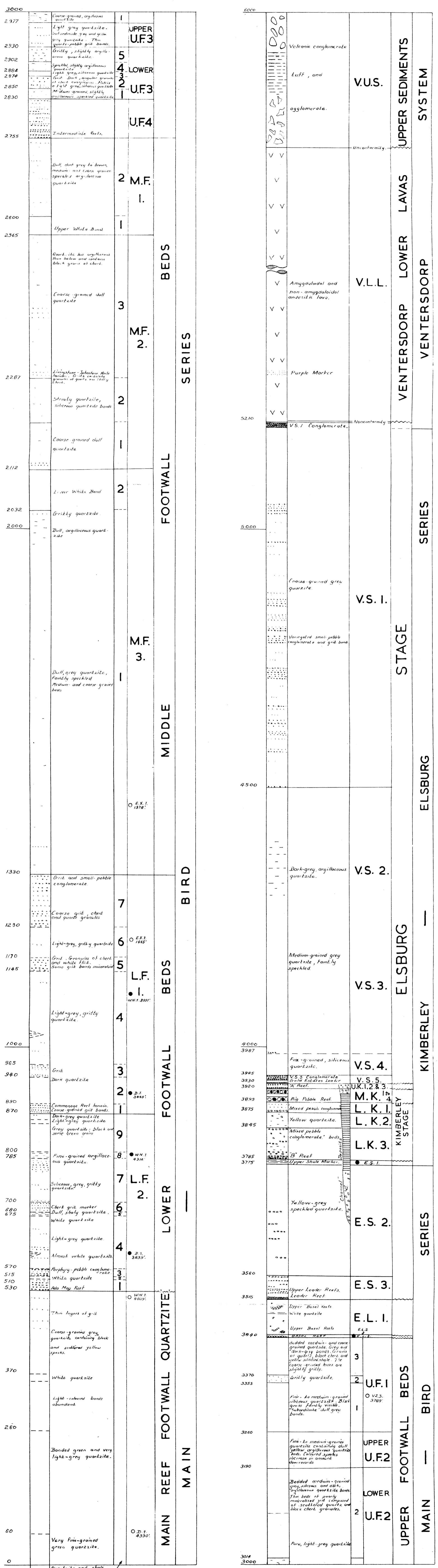
A.

# GENERALISED GEOLOGICAL COLUMN

OF

## VIRGINIA AND MERRIESPRUIT MINES

ORANGE FREE STATE.



SCALE 1:1000 FT.



LIST SUBDIVISION OF FOOTWALL BEDS FOR COMPARISON WITH TABLE IX.

- Chloritoid-bearing sedimentary rock
  - Thin section locality - no chloritoid. (Footwall beds only)
- (None of the hole and depth given)

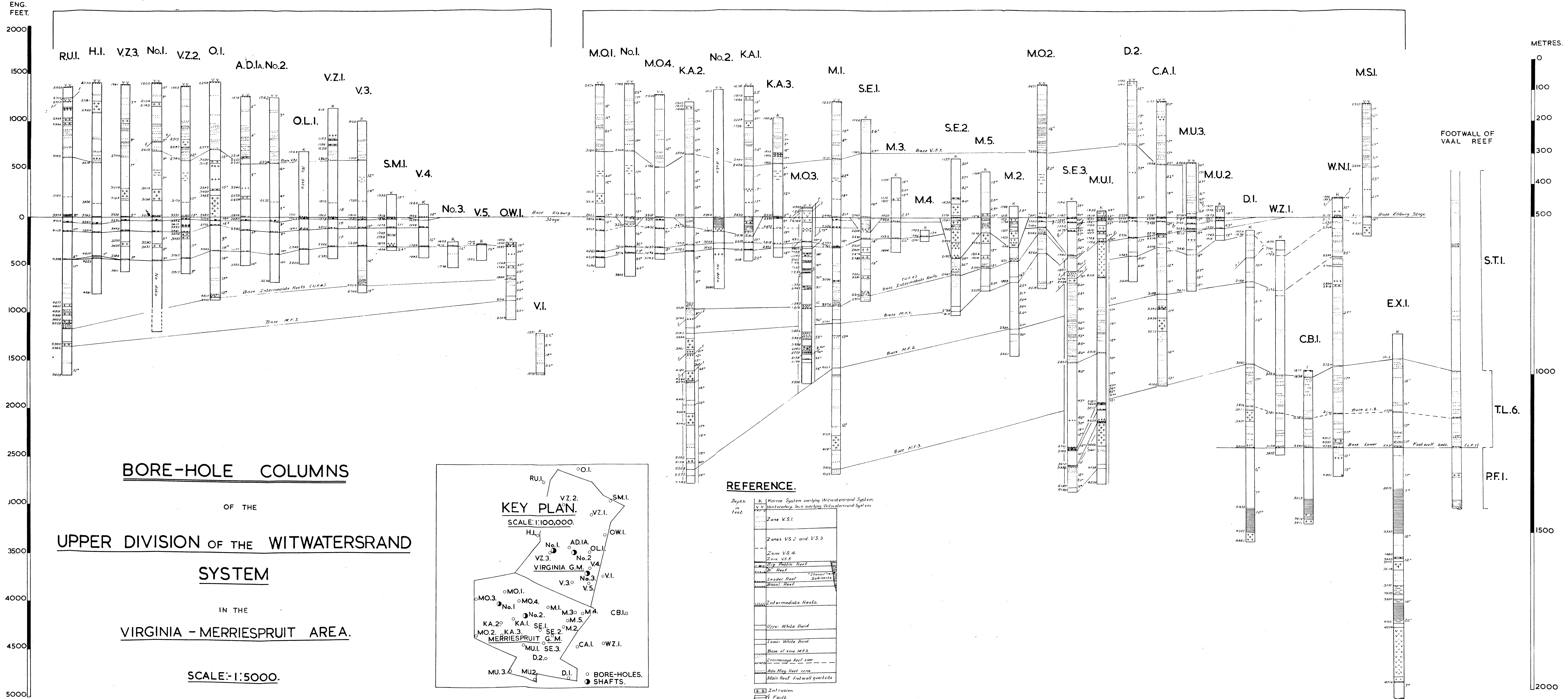


B.

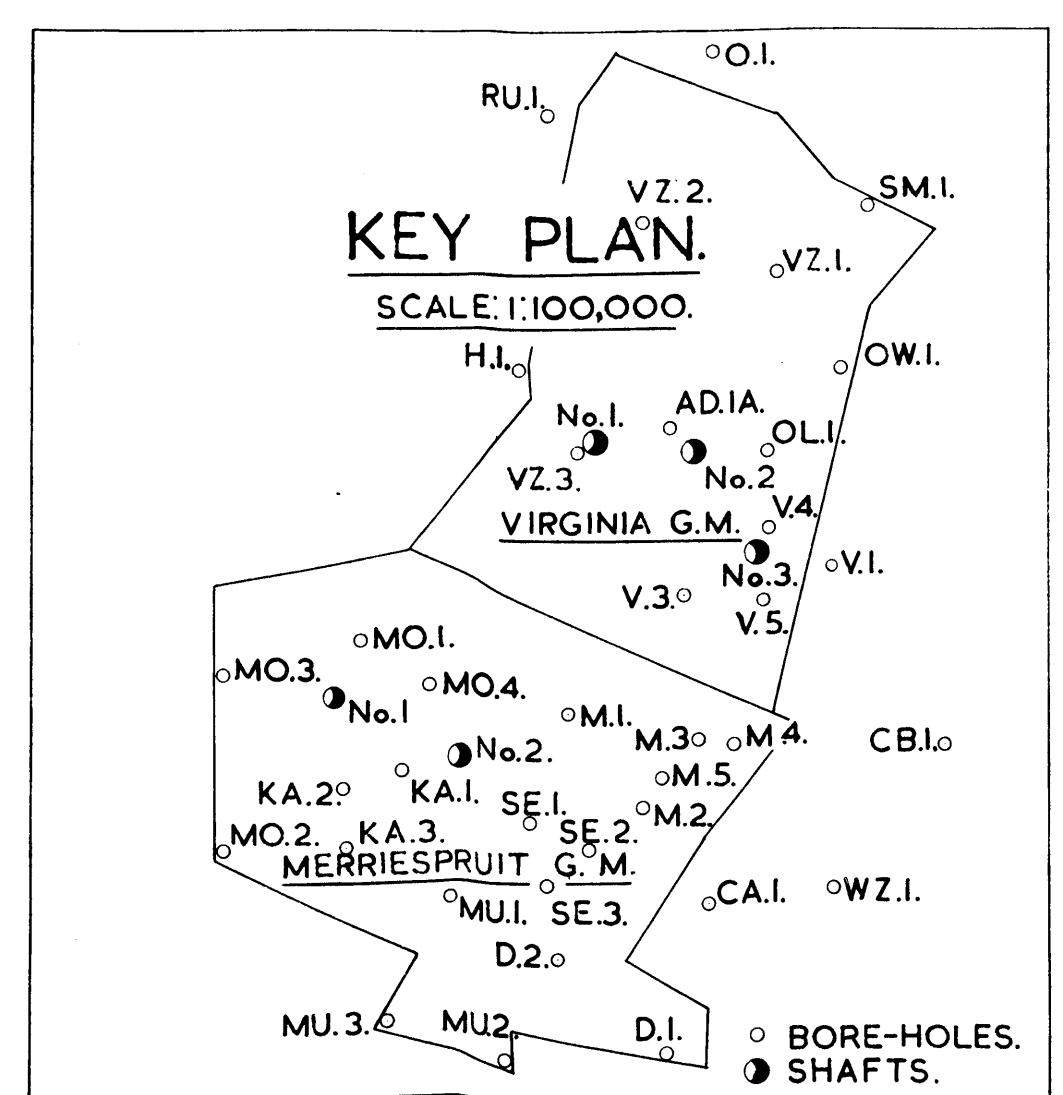
VIRGINIA GOLD MINE AND SURROUNDINGS.

MERRIESPRUIT GOLD MINE AND SURROUNDINGS.

KLERKSDORP.



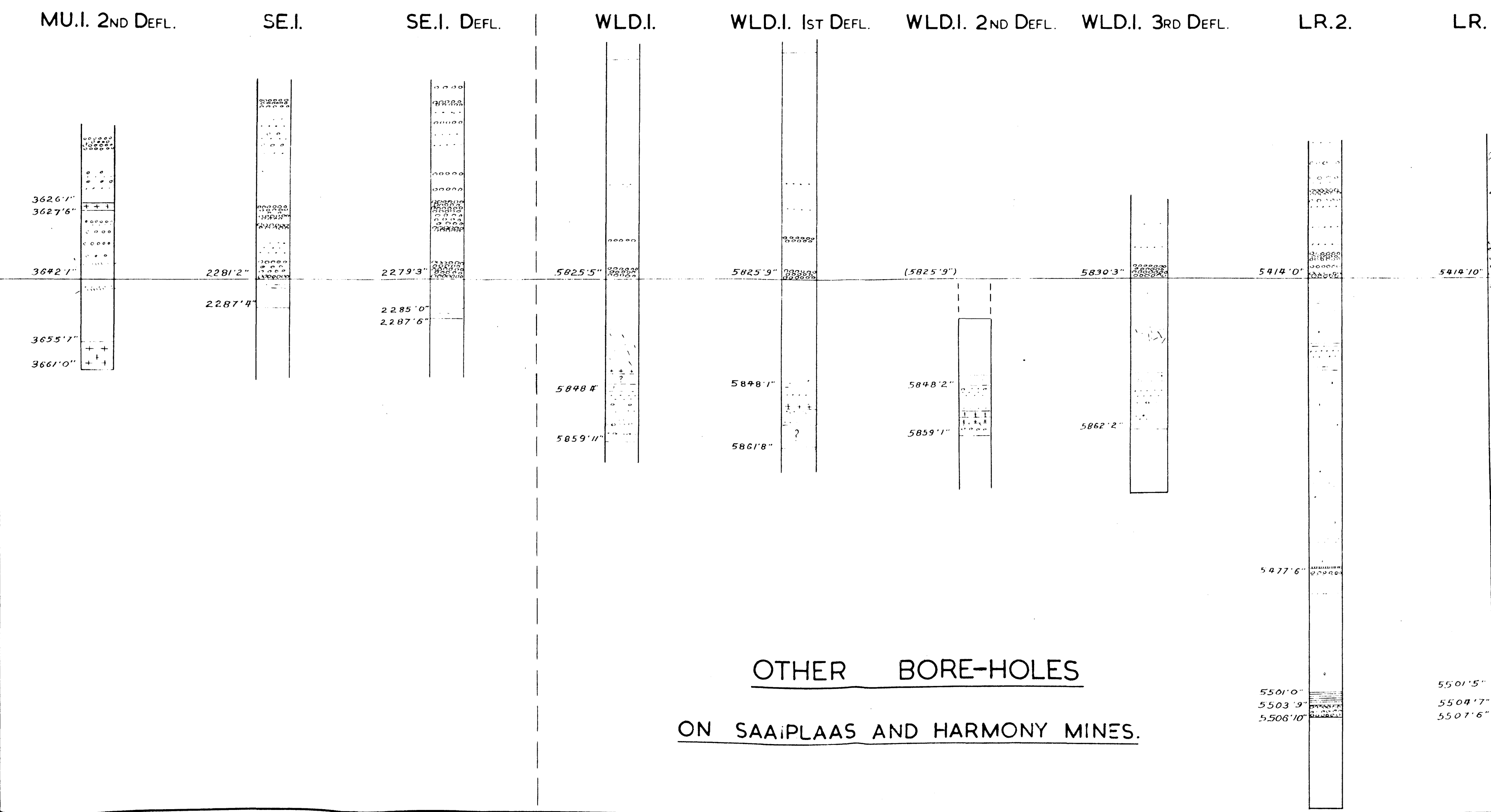
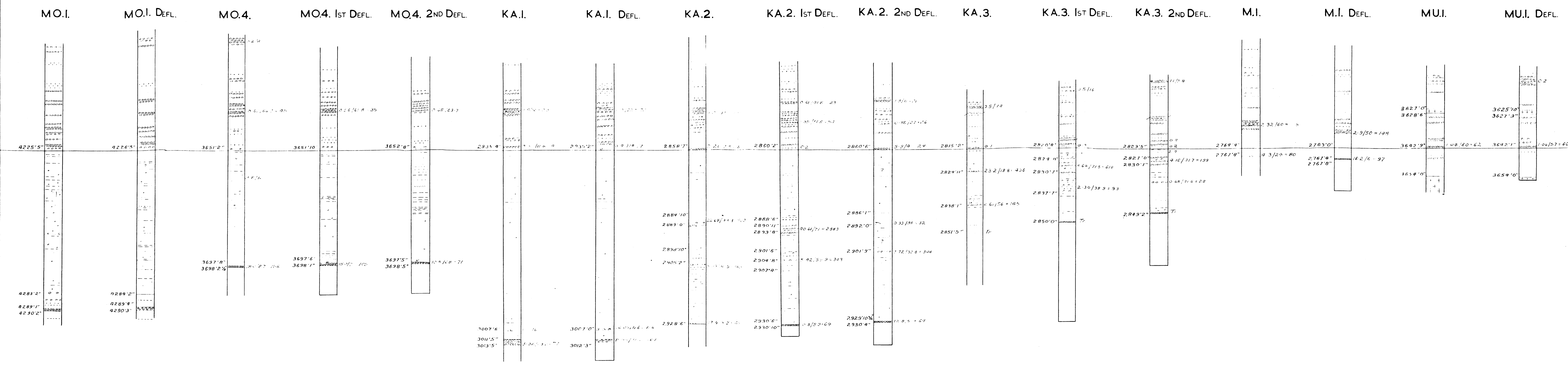
**BORE-HOLE COLUMNS**  
OF THE  
**UPPER DIVISION OF THE WITWATERSRAND**  
SYSTEM  
IN THE  
**VIRGINIA - MERRIESPRUIT AREA.**  
SCALE:- 1:5000.



**REFERENCE.**

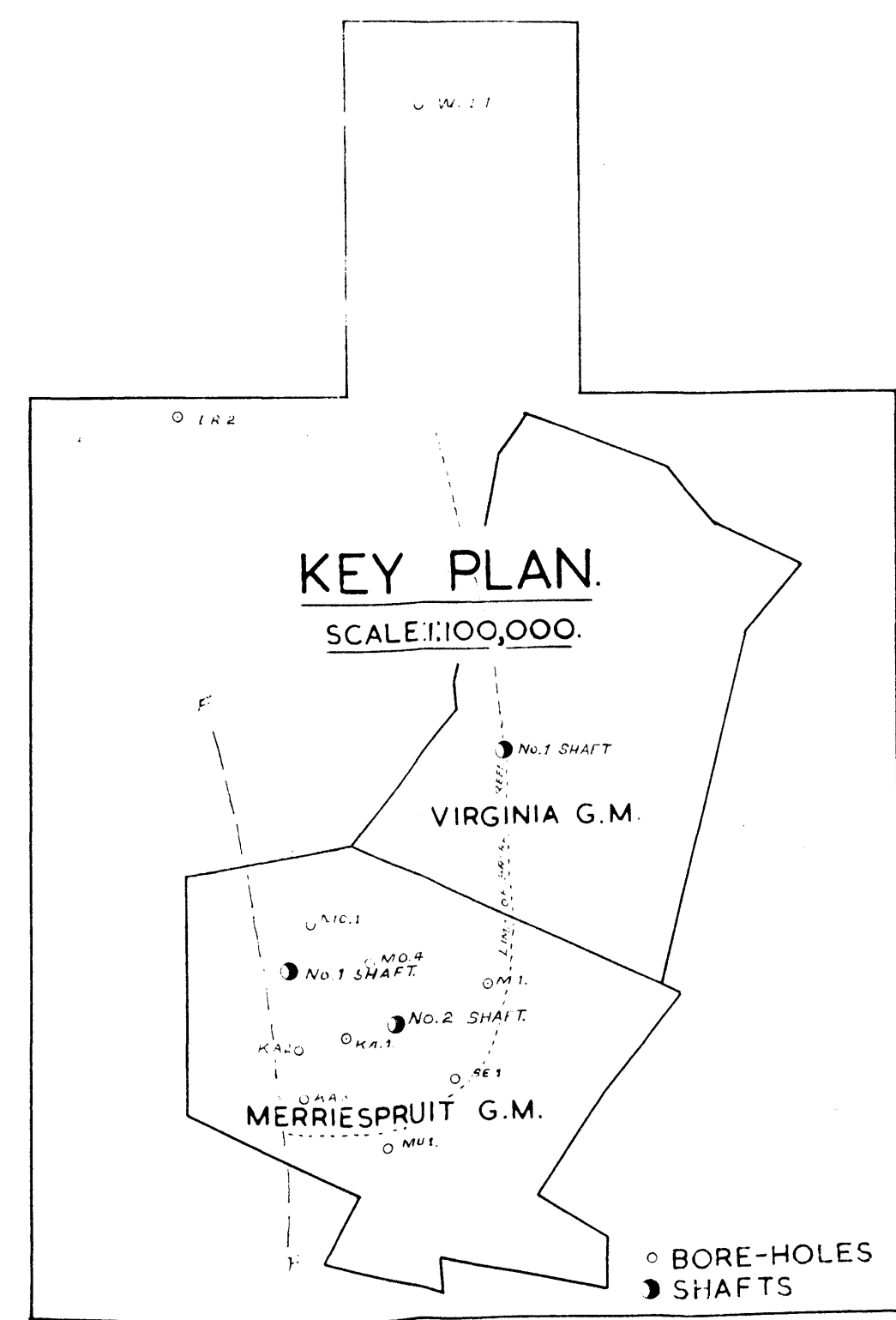
Depth in feet	Description
K	Karoo System overlying Witwatersrand System.
V.V.	Venterburg lava overlying Witwatersrand System.
Zone V.S.1	Zone V.S.1
Zones V.S.2 and V.S.3	Zones V.S.2 and V.S.3
Zone V.S.4	Zone V.S.4
Zone V.S.5	Zone V.S.5
Big Public Reef	Big Public Reef
B Reef	B Reef
Leader Reef	Leader Reef
Basal Reef	Basal Reef
Intermediate Reefs	Intermediate Reefs
Upper White Band	Upper White Band
Lower White Band	Lower White Band
Base of zone M.F.3	Base of zone M.F.3
Commonage Reef zone	Commonage Reef zone
Red May Reef zone	Red May Reef zone
Main Reef	Main Reef
Footwall quartzite	Footwall quartzite
Intrusion	Intrusion
Fault	Fault

12° Apparent dip measured on core.



REFERENCE.

ZONE	Description
E.S.3	Upper Leader Reef
	Leader Reef
E.L.1	Thin brown, waxy quartzite
	Siliceous quartzite (lenticular)
E.L.2	Upper Basal Reef (lenticular)
E.L.3	Basal Reef
U.F.1	Upper Foot wall quartzite



MERRIESPRUIT (O.F.S.) G.M. Co., LTD.

**BOREHOLE COLUMNS**  
SHOWING SPATIAL DISTRIBUTION AND DEVELOPMENT OF  
**UPPER BIRD REEFS**  
[ZONES E.S.3 (LEADER REEF) E.L.1 & BASAL REEF.]  
COMPARED WITH THEIR  
**GOLD CONTENT.**  
SCALE: 1:200.

GEOLOGY:  
DRAWN:  
DATE:  
REFERENCE:

OTHER BORE-HOLES  
ON SAAIPLAAS AND HARMONY MINES.

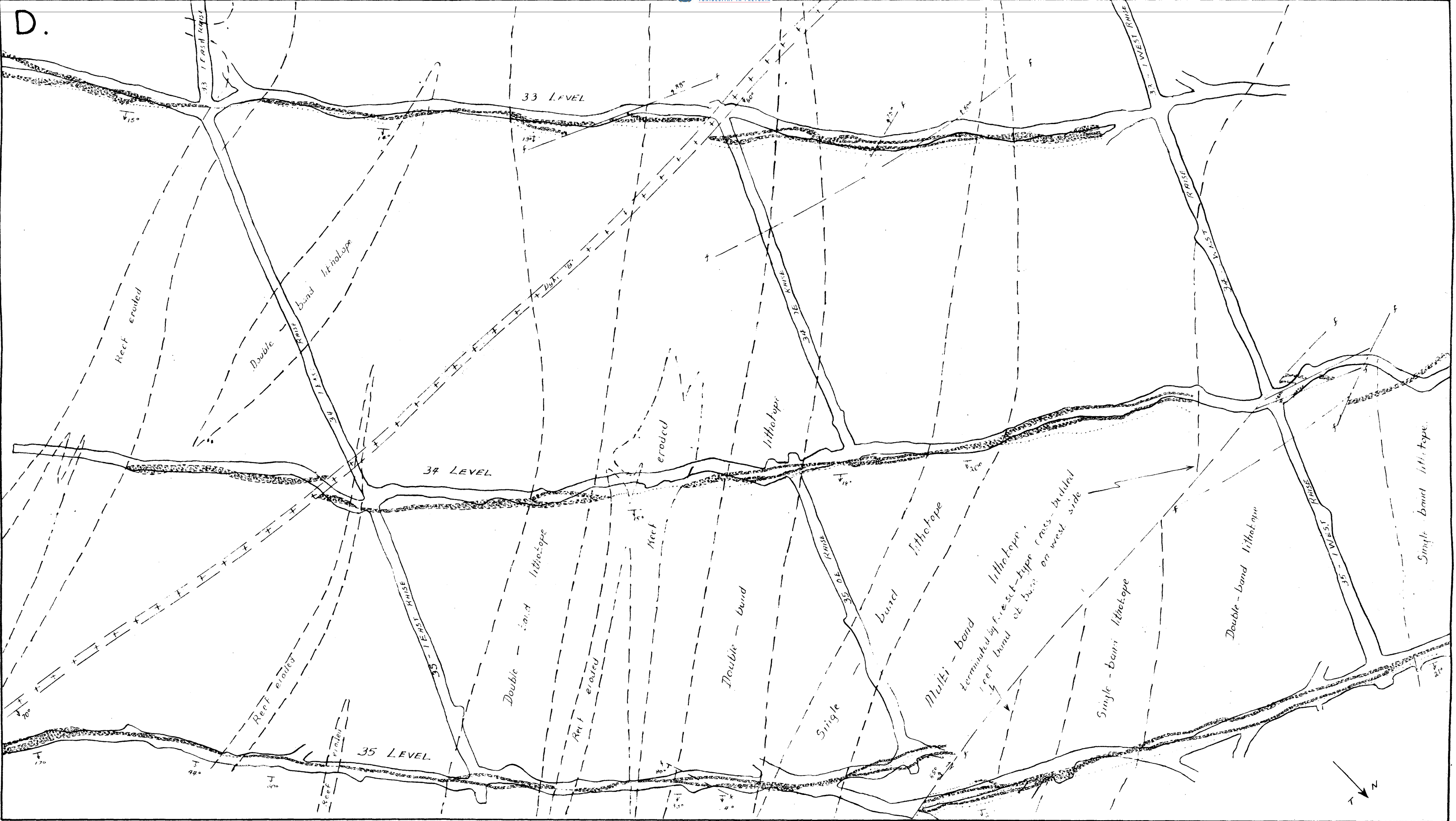
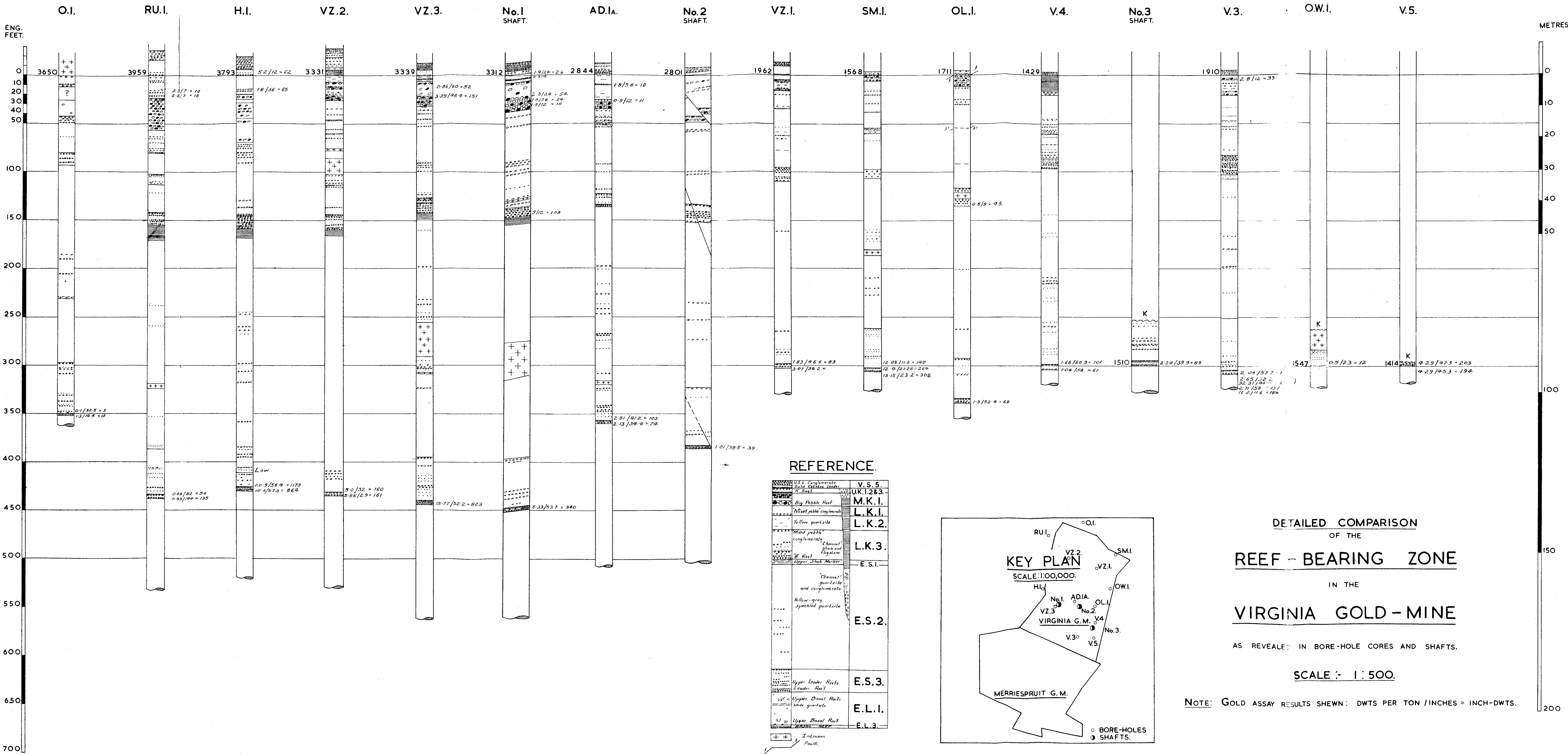


PLATE D. LITHOTOPE MAP OF BASAL REEF ON PORTION OF MERRIESPRUIT MINE.

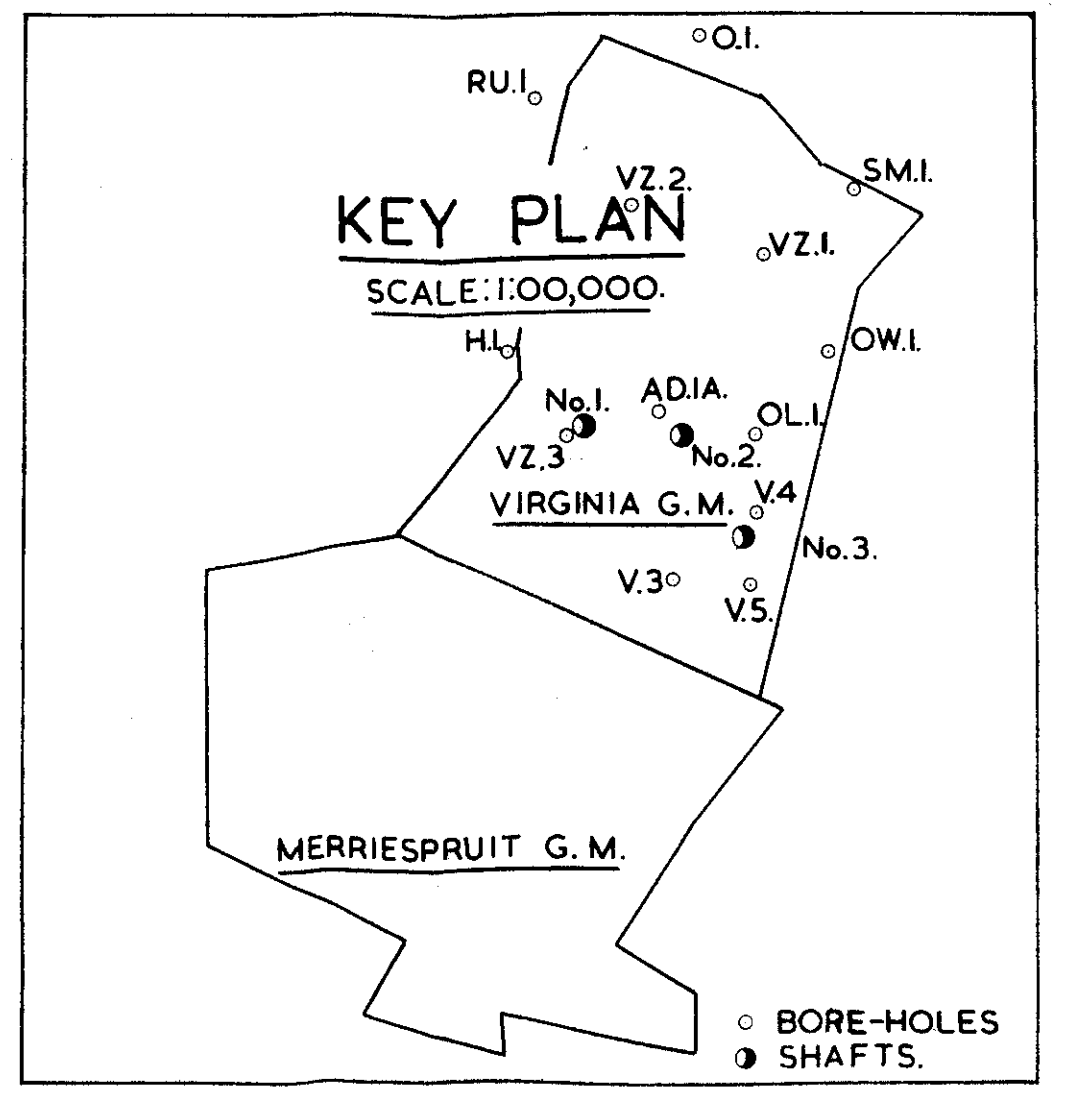


E.



REFERENCE.

V.S. Conglomerate	V.S.5
Sandstone	UK.1,2&3
Big Pebble Reef	M.K.I.
Mixed pebble conglomerate	L.K.I.
Yellow quartzite	L.K.2.
Mixed pebble conglomerate	L.K.3.
Channel shale and flagstone	E.S.I.
Upper Shale Marker	E.S.2.
Channel quartzite and conglomerate	E.S.3.
Yellow-grey speckled quartzite	E.L.I.
Upper Leader Rocks	E.L.3.
Leader Reef	
Upper Basal Reef	
White quartzite	
Upper Basal Reef	
Basal Reef	
Inclusion	
Fault	



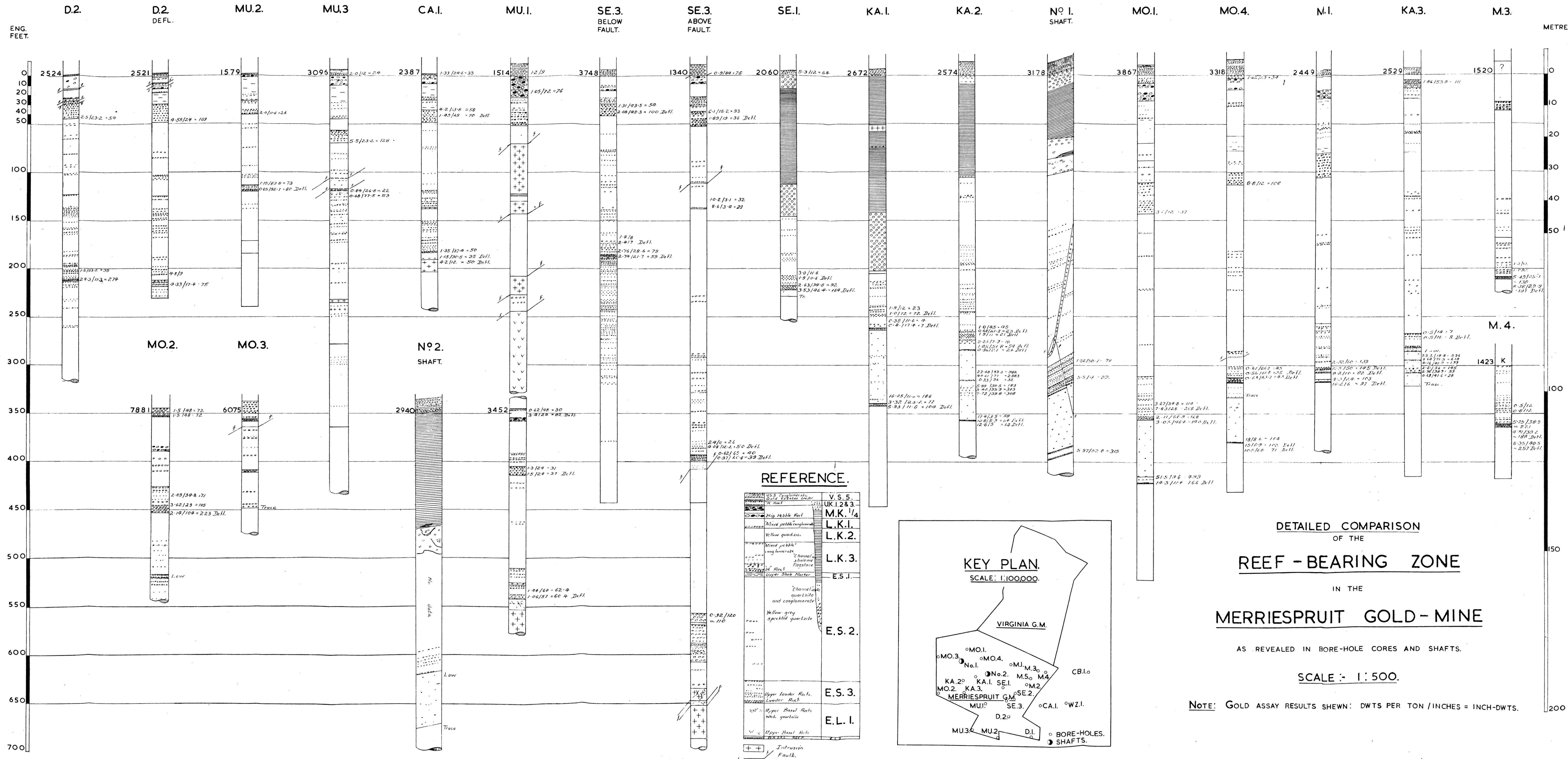
DETAILED COMPARISON  
OF THE  
REEF-BEARING ZONE  
IN THE  
VIRGINIA GOLD-MINE

AS REVEALED IN BORE-HOLE CORES AND SHAFTS.

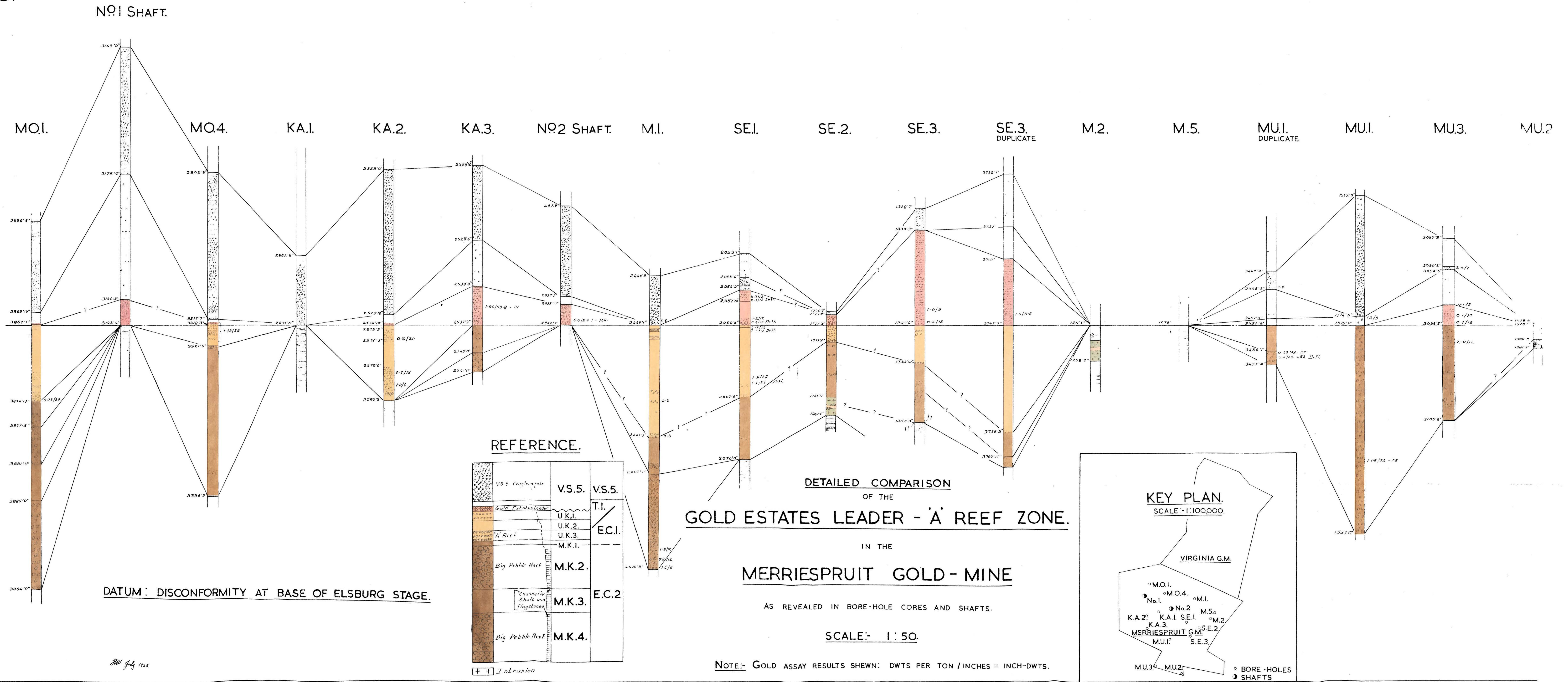
SCALE: 1:500.

NOTE: GOLD ASSAY RESULTS SHOWN: DWTS PER TON / INCHES = INCH-DWTS.

F.



G.

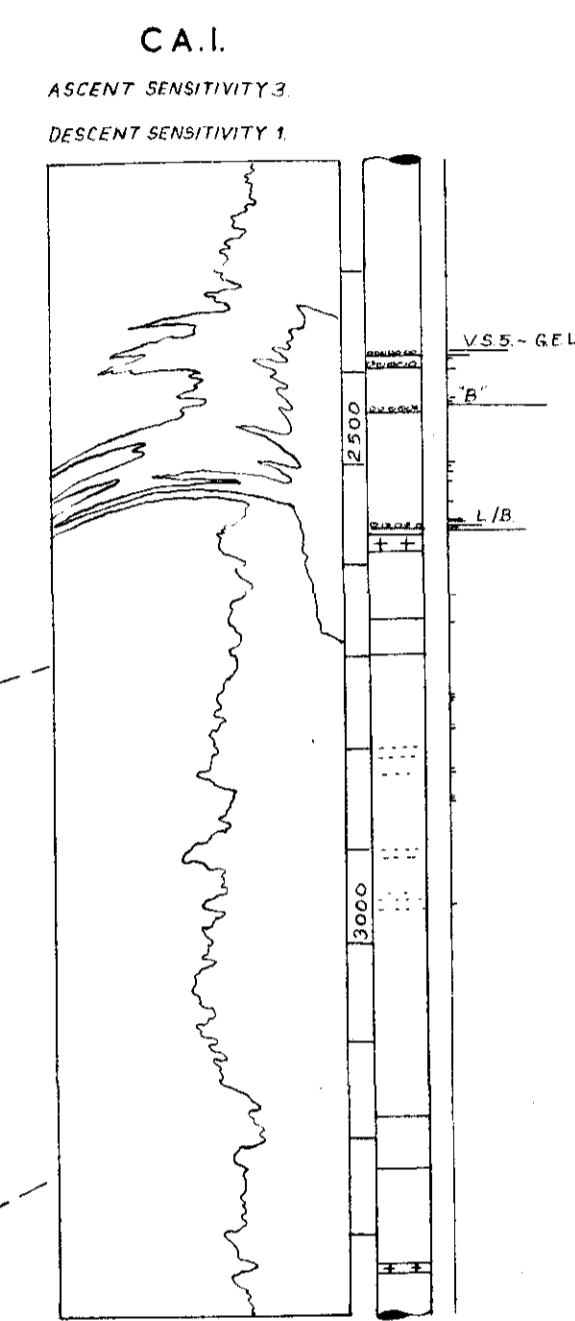
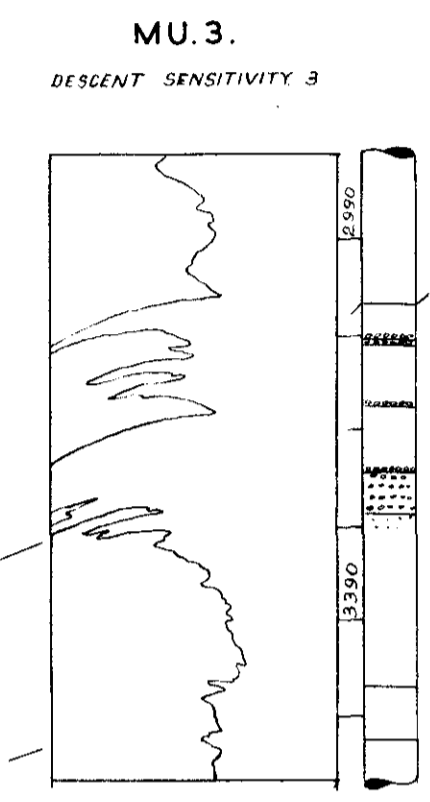
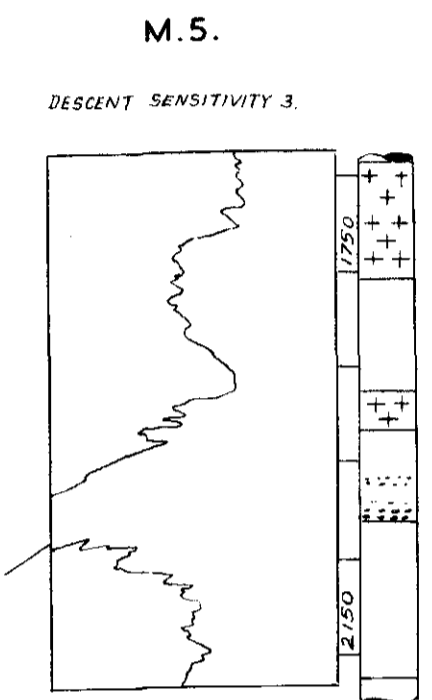
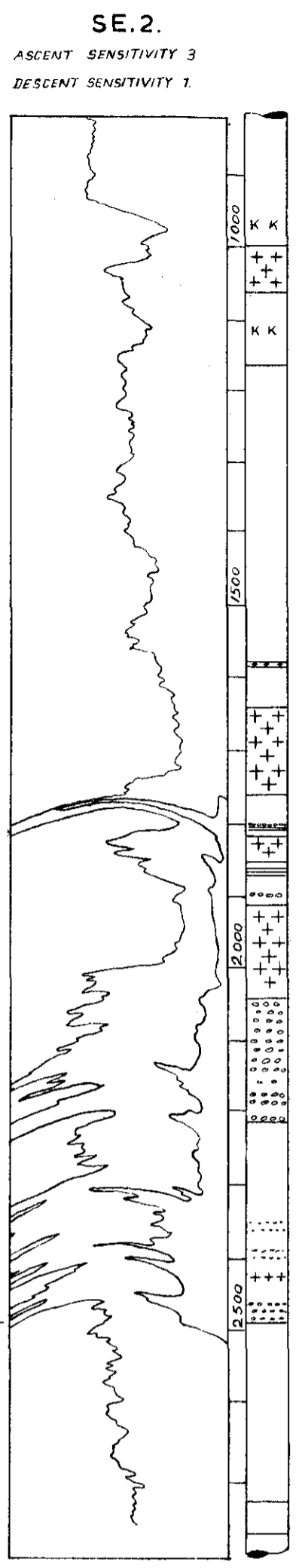
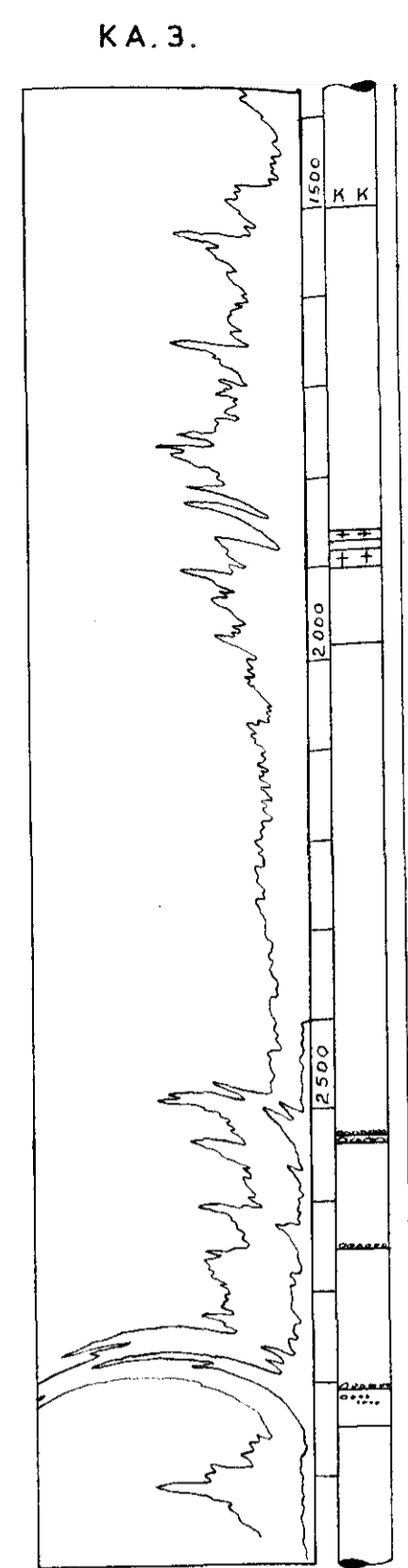
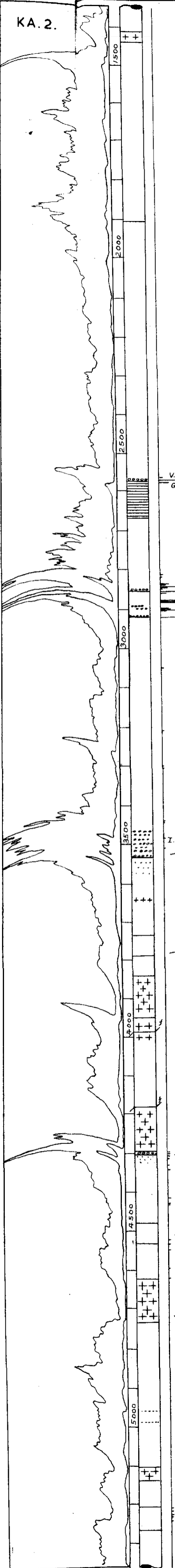
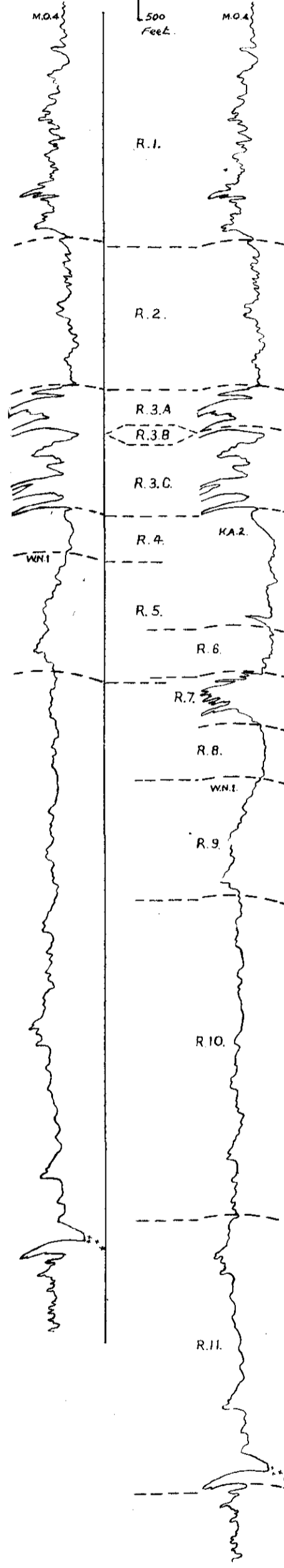
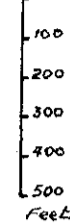


COMPOSITE LOGS

DR. SIMPSON.  
(1952)  
(PLATE XXII  
FIG. 6.)

REVISED.

SCALE

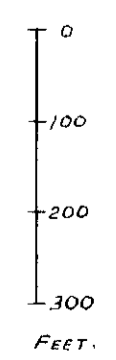


RADIOMETRIC LOGS AND GOLD CONCENTRATIONS.

COMPARED WITH DESCRIPTIVE COLUMNS OF SELECTED BORE-HOLES

IN THE  
MERRIESPRUIT MINE.

VERTICAL SCALE.



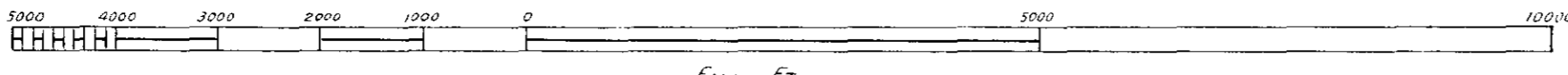
R1, R2, etc.: Radiometric Subdivisions.

ABBREVIATIONS.

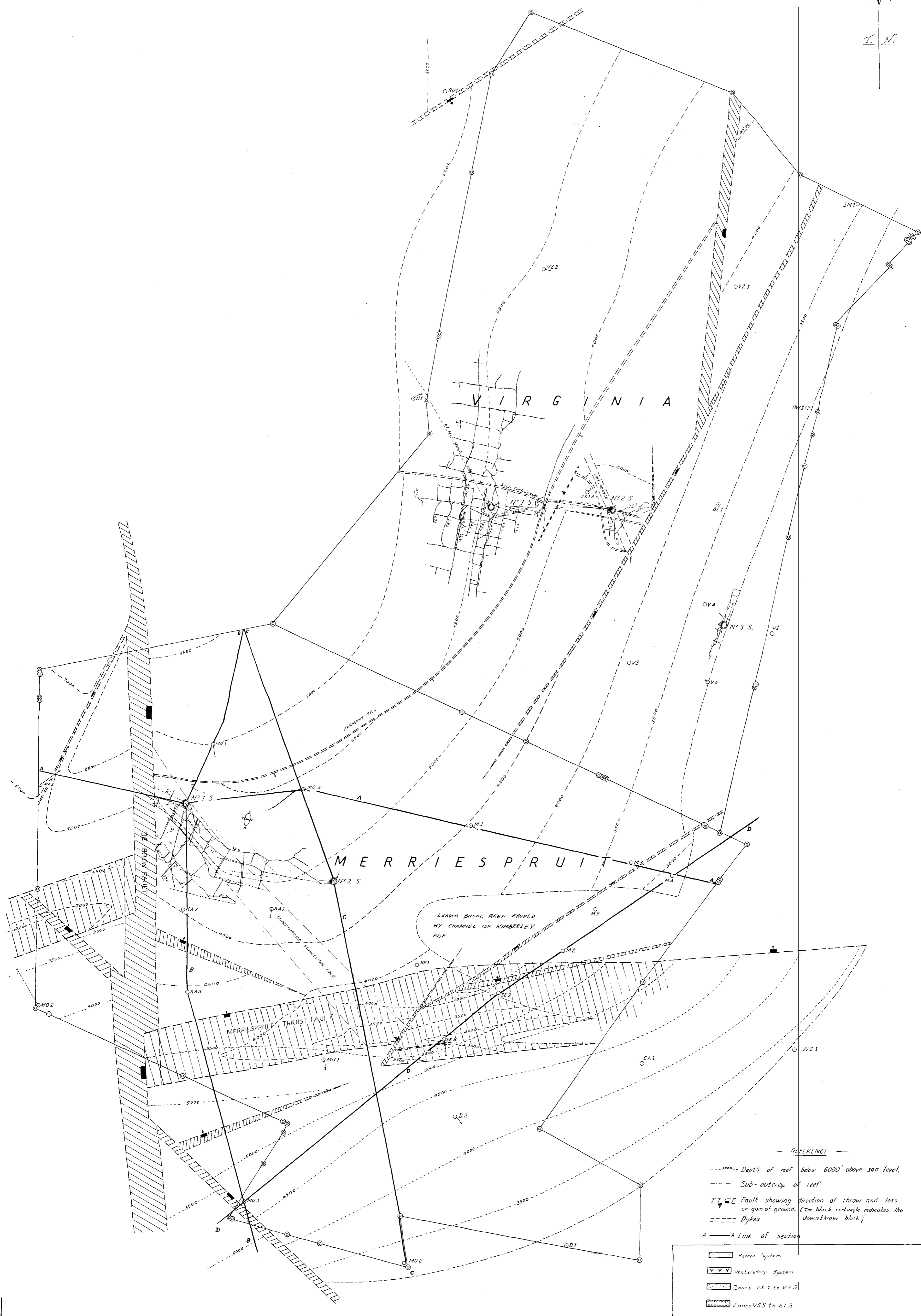
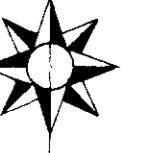
V.S.S.	V.S.S. Conglomerate
G.E.L.	Gold Estolite Leader.
"B"	"B" Reef.
L.R.	Leader Reef.
U.B.R.	Upper Basal Reefs.
B.R.	Basal Reef.
L/B.	Leader-Basal Reef.
I.R.	Intermediate Reefs.



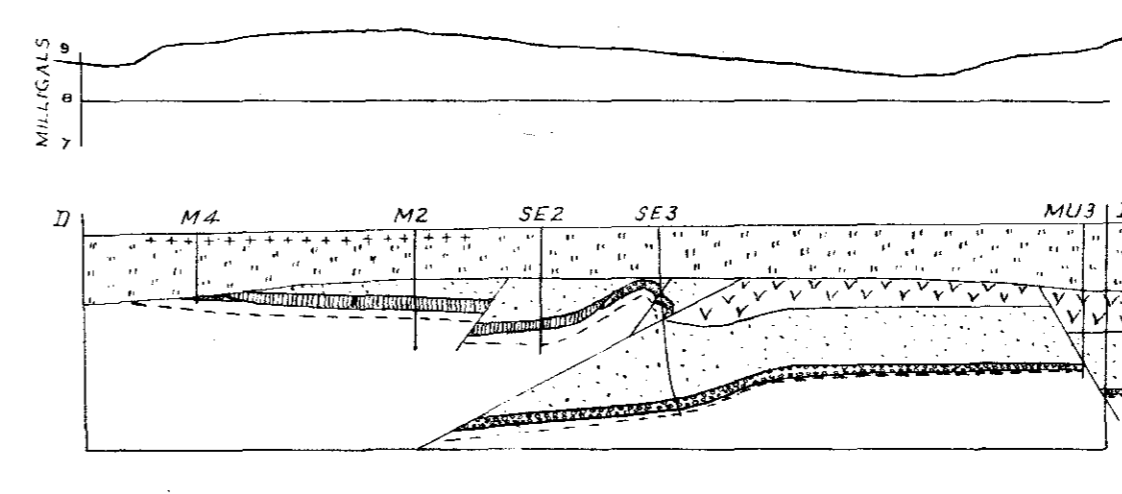
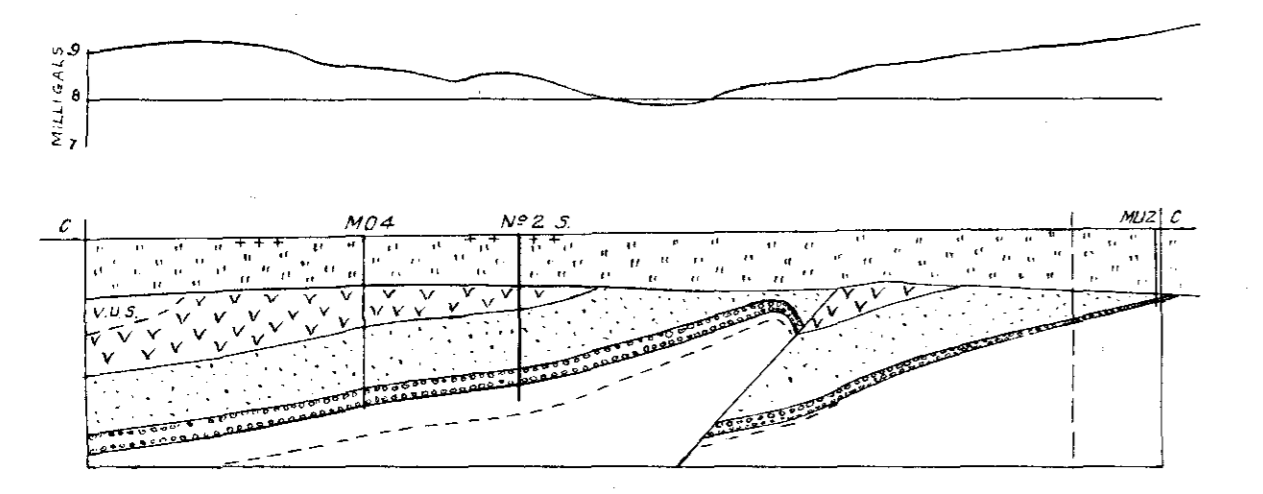
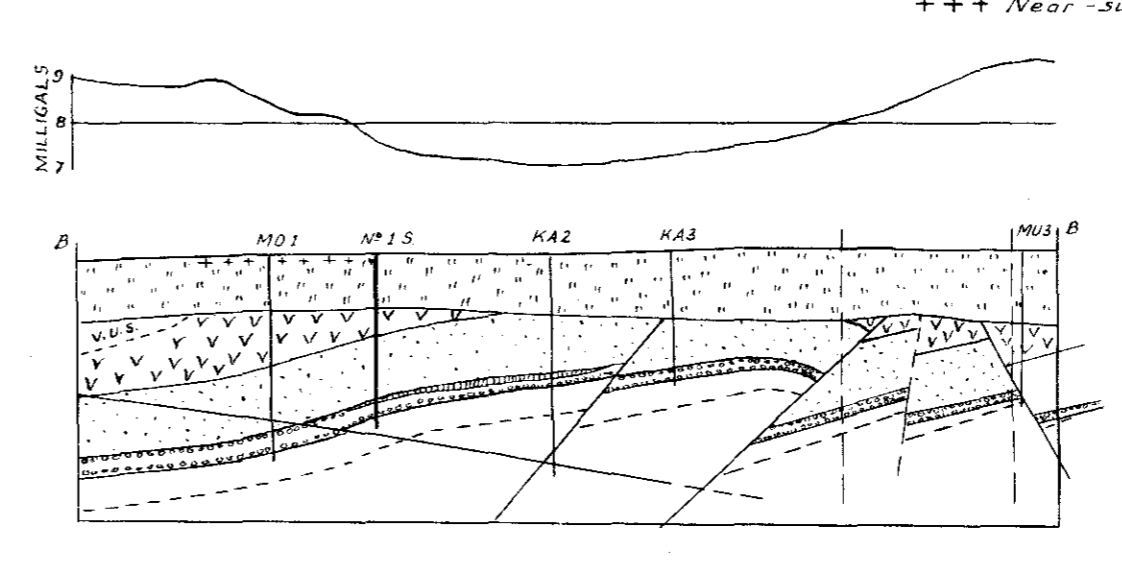
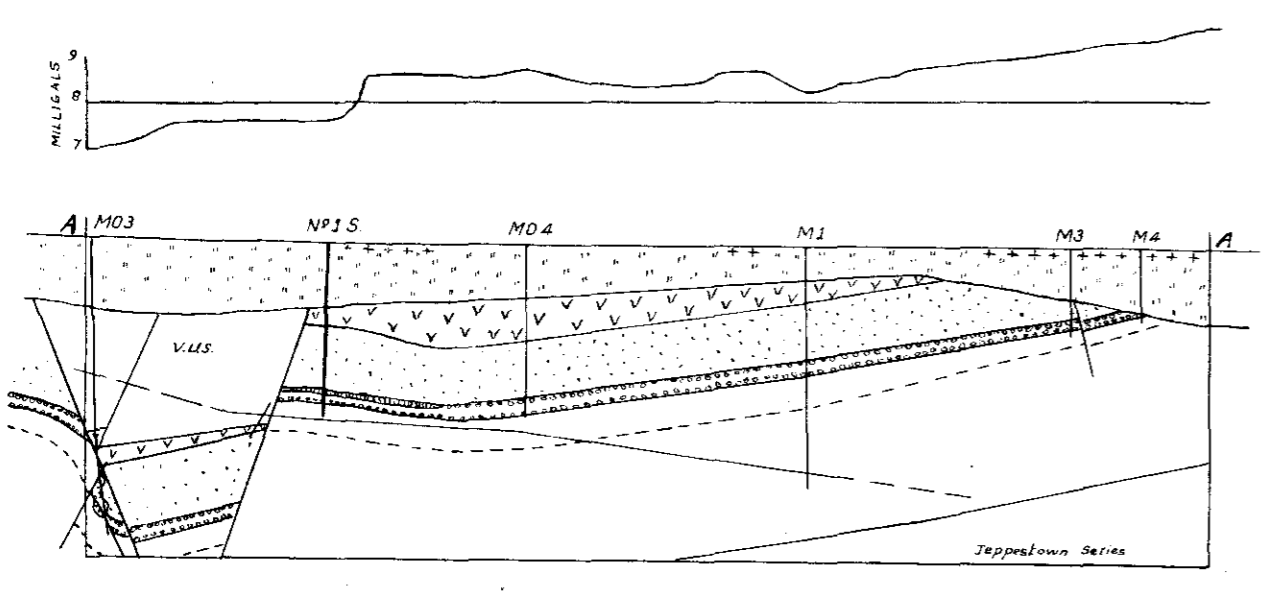
VIRGINIA AND MERRIESPRUIT MINES.



SCALE: 1:20,000.



- REFERENCE
- Depth of reef below 6000' above sea level.
  - - - Sub-outcrop of reef
  - Fault showing direction of throw and loss or gain of ground. (The black rectangle indicates the downthrow block.)
  - Dykes
  - A --- A Line of section
  - [Pattern] Karoo System
  - [Pattern] Ventersdorp System
  - [Pattern] Zones V.S. 1 to V.S. 5
  - [Pattern] Zones V.S. 5 to E.L. 3.
  - [Pattern] Footwall beds
  - [Pattern] Channel deposits
  - Base Intermediate Reefs
  - +++ Near-surface dolerite sheets

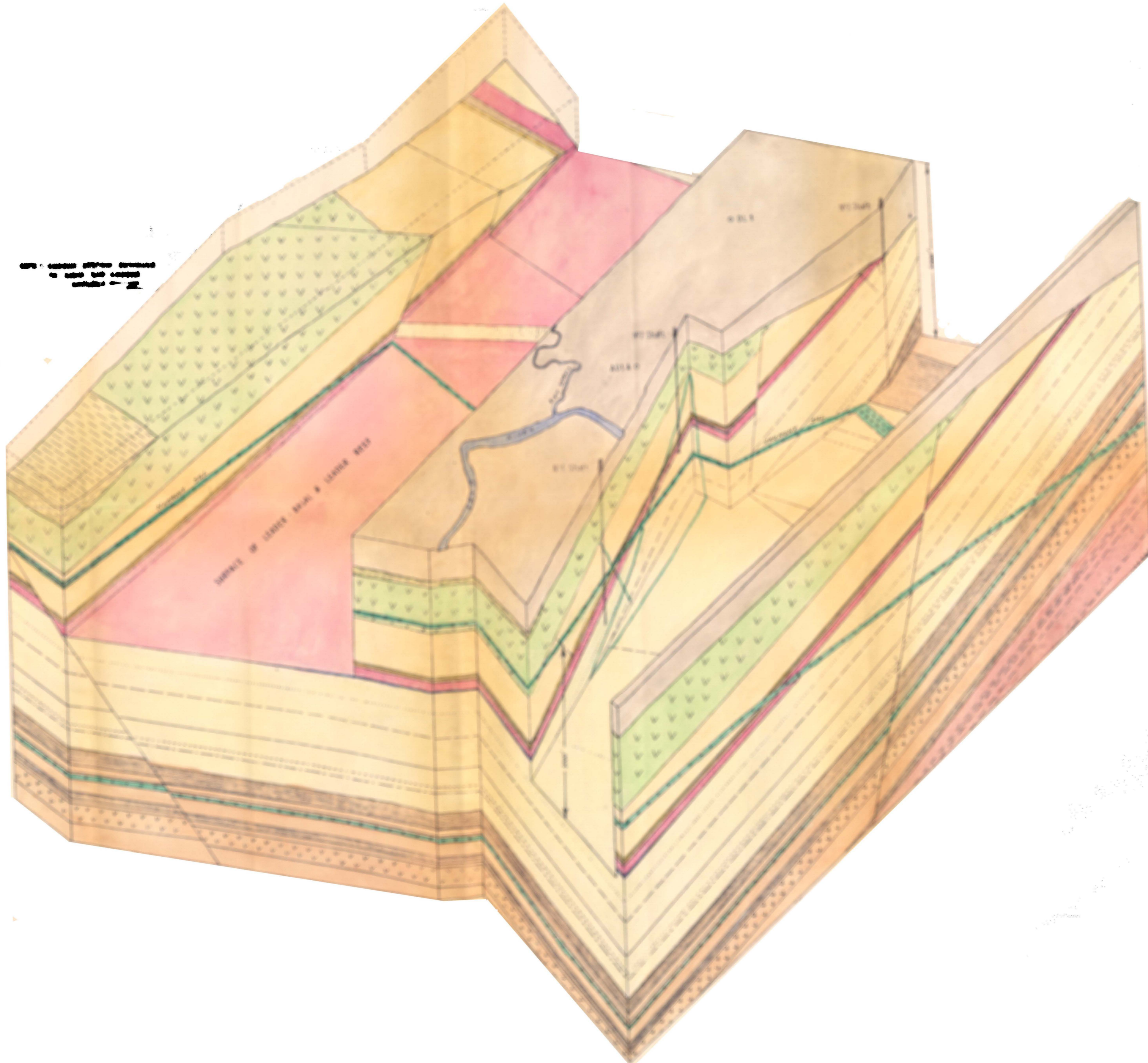


SCALE: 1:50,000.

J



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NOTE: SANDSTONE STRATA CONTAINED  
IN THIS BLOCK DIAGRAM  
WAS CALCULATED FROM THE  
SECTION OF LAMBE BASIN & LAMBE HILLS

**REFERENCE**

